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Water Allocation in the Klamath Reclamation Project, 2001:

An Assessment of Natural Resource, Economic, Social, and Institutional Issues with a Focus on the Upper Klamath Basin

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Introduction

William S. Braunworth, Jr. and Emery Castle

In April 2001, the water status quo in the Upper Klamath Basin was turned on its head. Decisions intended to conserve endangered and threatened fish, combined with a severe drought, resulted in curtailment of 2001 irrigation water deliveries to much of the Klamath Reclamation Project. One decision required a minimum water level for Upper Klamath Lake. Another required a minimum discharge into the lower Klamath River. The decisions stemmed from years of concern about water quality, habitat loss, and declining populations of three species of fish—Lost River and shortnose suckers in Upper Klamath Lake and coho salmon in the lower Klamath River.

The story is partly one of shifting costs from one segment of society to another. As a species declines, there often are costs to people who previously benefited from abundant populations of that species. In the Klamath Basin, for example, Native American tribes and fishing communities have experienced economic, social, and cultural costs from the decline of fishery resources. Over the course of the past century, these costs have been chronic and cumulative.

Listing of a species as endangered or threatened under the Endangered Species Act is intended to result in steps leading to species recovery. The costs of species recovery may be borne by other segments of society. In the Klamath Basin, these costs include direct costs of improving fish habitat and indirect costs incurred when irrigation water is denied to farmers. In 2001, costs were immediate and measurable.

Clearly, the way water is allocated in the Basin has great significance for the ecological, economic, and social future of the area. Thus, it is no surprise that the events of 2001 generated great controversy. Sharp differences of opinion exist among people residing in the area, as well as among others who have an interest in the Basin. These differences of opinion include debates over historical interpretations, scientific data, and legal standards. For example, was the year 2001 unique, or are similar conditions likely to arise in 1, 2, or 3 years in 10? What is the relation of water quantity to water quality in fish survival? How will the rights of Native Americans to use Klamath Basin waters be quantified?

In other cases, the questions address fundamental differences in values. Some believe that irrigated agriculture is compatible with ecological sustainability, while others disagree. There are debates about water rights priorities and who should bear the costs of decisions intended to benefit the public good. The questions are many, and there are no easy answers.

The need for reliable information

Where there is controversy, there usually is uncertainty. Thus, generally speaking, the greater the controversy, the more valuable reliable information becomes.

The events of 2001 in the Upper Klamath Basin were filled with both controversy and uncertainty. During the spring and summer, Oregon State University and University of California faculty held and attended meetings throughout the region. Many of the participants at those meetings expressed concern about the accuracy and completeness of information reported in the media and used in public debate. This report is a response to their expressed desire for more complete and reliable information, presented in one place with extensive references.

The nature of this report

The intent of this report is to provide a discussion of a number of the ecological, economic, social, and policy issues in the Klamath Basin (primarily the Upper Basin) relevant to the 2001 water allocation controversy. It is our hope to contribute to greater understanding about these interrelated issues. Such information is unlikely to eliminate controversy, but it should make debate and negotiation more productive.

Our intent is to illuminate various aspects of these issues. We do not intend to defend or criticize the values of any of the interested parties in the Basin. Due to the contentious nature of these issues, some readers likely will see this report as supportive or critical of various positions, especially if a particular point is not considered within the full context of related topics. We appeal to readers to use caution when reaching conclusions.

Many difficult water-related decisions face the Klamath Basin, with the potential for significant ecological, economic, and social consequences. We hope this report will prove useful to those involved in these decisions, including policy makers, citizens, administrators, journalists, and others.

We believe this report:

- Increases understanding of what is known, and what is not known, about the interactions among natural resources, people, economics, and institutions
- Provides a reference on a wide range of subjects related to Klamath Basin water allocation
- Assesses some of the potential (and, where possible, documented) consequences of the decision to curtail irrigation water deliveries in 2001
- Identifies management alternatives and lessons that can be learned from the Klamath experience
- Provides a base for additional efforts in research, education, and problem-solving
- Proposes future actions to address particular information needs and reduce remaining uncertainties

This report is only one of many addressing water-related questions in the Klamath Basin. Authors have taken advantage of additional information as it has become available from a variety of other sources.

Nonetheless, there are characteristics of this report that distinguish it from others. The principal difference is a multidisciplinary approach. In this report, we consider the Upper Klamath Basin to be a system made up of many parts—economies, public policies, communities, and natural resources—and we look at how they fit together. It quickly becomes clear that changes in one part of the system can have consequences throughout the system.

Scope of the report

The broad consequences of water allocation decisions in the Upper Klamath Basin—both geographically and through time—posed special challenges in the preparation of this report. The effects of the 2001 decisions were felt most directly in the area served by the Klamath

Reclamation Project. Yet, clearly there are broader geographic implications. Any action that affects the quantity and quality of water leaving the Upper Basin has economic, ecological, and social consequences all the way to the ocean. Likewise, the costs of species decline and recovery extend over a period of decades or longer. Thus, a comprehensive analysis and search for solutions to water allocation issues in the Klamath Basin must include the Lower Basin, upstream activities, and an analysis of costs over an extended period of time.

This report, however, is not a full assessment of past or future costs or benefits of water allocation alternatives. Most of the focus is on the Upper Basin, and especially on the immediate consequences of the irrigation curtailment in 2001.

We chose to limit our focus for the following reasons.

- At community meetings in the Upper Basin, community leaders asked us to help develop reliable data on the consequences of the 2001 decisions for local economies, communities, and natural systems. In the emotionally charged atmosphere following the announcement of the irrigation curtailment, there was a great deal of confusion and disagreement about the nature and extent of the costs, partly because it is impossible to assess longer term economic and other impacts in a short period of time.
- The Endangered Species Act does not require consideration of economic and social impacts from species management decisions (as would be required for a decision made under the National Environmental Policy Act). Thus, we saw a need for an assessment of the effects of these decisions on the most immediately affected communities.
- We saw the opportunity to present and build a solid base of knowledge that could provide guidance in the design of a more comprehensive study.
- We were constrained by the limited budget of the two universities, faculty teaching and research responsibilities, and the community's need for timely information.

By narrowing our focus, we do not mean to imply that other parts of the system are less important. Indeed, many chapters do present historical background to set the events of 2001 within a larger context. Others look to the future and suggest new approaches to addressing water-related questions in the Basin.

How the report was developed

The decision to prepare this report was made in July 2001 by a group of scientists and administrators from Oregon State University (OSU) and the University of California (UC), together with university Extension and research personnel working in the Upper Klamath Basin. The group had participated in a field trip in the area and had heard from many community members. Several of the faculty had previously conducted research or educational activities in the Basin, and all were familiar with natural resource issues in the West.

The group agreed to prepare the report quickly, with a final version to be made available early in 2002. The process of developing the report included limited research to develop new information, but the majority of the effort involved synthesis and interpretation of existing data and reports.

Authors were asked to generate a draft for public review by December 14, 2001. This draft was made available through a Web site at OSU and at various public locations in the Upper Basin. On December 19, it was presented at a public meeting at the OSU Extension office in Klamath Falls. This meeting was intended to invite public comment and discussion as well as to highlight the availability of the draft report for public use.

In addition to the discussion on December 19, the public was invited to comment in writing at the meeting, by mail, and by e-mail. The public comment period ended on January 25, 2002, and authors had until February 22 to develop a final draft. We intended to release the report by the end of March 2002, but by delaying the release until later in the year, we were able to obtain and analyze more complete economic data, which became available in the summer of 2002. The drafts were edited and compiled into the final report by December 18, 2002.

Peer review

Prior to release of the first draft, authors obtained external peer review of their work to the extent time permitted. Additional peer review was obtained during the public comment period from December 14, 2001 through January 25, 2002. Most of the material did not represent new research; thus, some peer review was not as extensive as it is for scientific journal articles. Nonetheless, authors took seriously their responsibility for obtaining peer review.

Authors also reviewed each other's work on many occasions, providing a valuable within-discipline and cross-discipline review. Although each author brought considerable expertise on a specific set of topics, all of us were challenged by the complexity of the connections between these issues. Given the interrelationships among chapters, we found the rigorous internal cross-discipline review as helpful as reviews from within a given discipline. The experience led us to step outside our professional areas of expertise and grapple with an extremely multifaceted problem.

Those preparing this report did not always agree, and it could not have been otherwise. Unlike many educational publications, this report addresses a very complex, contentious issue. When the ecological, economic, and social issues of the Klamath Basin are considered, there is no single, correct answer to questions such as "What constitutes relevant data?" "How should data be interpreted?" and "How important are certain variables?" Furthermore, scientific knowledge is constantly developing, and new discoveries may change previously held views. There rarely is enough data to fully answer our questions, and, as a result, uncertainty often abounds. Our experience in wrestling with these issues certainly illustrates the difficulty of finding comprehensive solutions to such complex problems.

Public review

Public review and comment are unusual for an educational document, but in this case they were essential. Reviewers identified issues that needed more detailed treatment, provided multiple perspectives, and shared rich local knowledge. Their input greatly enhanced the report. Authors took the comments seriously and incorporated them as much as possible into the final document. In cases where they were not able to address every suggestion, the comments often highlighted additional areas of needed research, which are identified in the report.

In retrospect, it would have been desirable to expand the time frame for public review and to provide an opportunity for public comment on a second draft. However, the dynamic nature of events in the Klamath Basin and the need for timely completion of the report made this impractical.

Where do we go from here?

Water use has long been a controversial subject in the West, and this reality is unlikely to change in the immediate future. The controversy in the Upper Klamath Basin highlights the continuing inability of existing institutions to resolve conflicting claims for scarce resources in a way that meets the needs and claims of all stakeholders. This report makes clear the need for change if places such as the Klamath Basin are to enjoy an ecologically, economically, and socially sustainable future.

Times of controversy and uncertainty can be times of opportunity, as those involved may become open to solutions that otherwise would not be considered. We have tried to contribute to a greater understanding of the possibilities created by the events of 2001. Among these possibilities are opportunities for more effective relations among the jurisdictions and interests in the Basin. Several chapters in this report identify other approaches and potential solutions. Note particularly Chapter 18 ("Policy"), Chapter 19 ('Water Allocation Alternatives'), Chapter 20 ("Synthesis"), Chapter 12 ("Crop Revenue"), and Chapter 6 ("Coho Salmon").

Water quality is one component of a comprehensive consideration of questions related to water allocation and fish habitat in the Upper Klamath Basin. A detailed discussion of water quality in the Basin, and especially in Upper Klamath Lake, will be the topic of a future chapter of this report. Because of the complexity of these issues, a broad team of scientists will be involved in preparing and reviewing that chapter, and it will be available at a later date.

The preparation of this report has afforded the Land Grant university system in two states the opportunity to be engaged in issues of great public significance, and it represents our commitment to contribute in a positive manner to the understanding of natural resource issues. The report has provided a learning environment for university faculty to be constructively engaged in natural resource management issues in general and in the Klamath Basin in particular. We expect to continue to be involved in this and other natural resource issues in the future.

Key Lessons learned

The 2000–2001 drought was neither the Klamath Basin's first nor its last. Likewise, similar natural resource conflicts face communities across the country. If sustainable and equitable methods of resource allocation are not found, the conflicts of 2001 are destined to be repeated in the Basin and elsewhere.

No single individual, group, law, agency, or natural event bears sole responsibility for natural resource conflicts. Nonetheless, human-created agencies, laws, and groups are imperfect, and their interactions usually do not yield optimal results. Thus, improvements might produce better results in the future. We offer several lessons from the Klamath Basin in the hope that they may aid in the search for solutions there and elsewhere.

Roots of the conflict

- Assorted state and federal laws and treaties, established at various times under various circumstances, have laid the legal basis for conflicting claims to the Klamath Basin's limited water, mainly by three interests—irrigators, Native Americans, and at-risk species. *(Chapters 1, 3, 18, 20)*
- As society's priorities change, the relative influence of various agencies, laws, and groups also changes. In the Klamath Basin, tribal rights and species protection have become more influential than in the past, thus altering the ways in which resource-use conflicts are resolved. *(Chapter 18)*
- Many of the early symptoms of trouble in the Klamath Basin (collapse of fisheries, algal blooms, overcommitment of water, etc.) were observed more than a decade ago. Yet, the absence of timely and effective collaboration among diverse interests, and between upstream and downstream communities, has so far prevented development of solutions. *(Chapters 1, 5, 6, 18)*
- The incomplete status of water rights adjudication in the Oregon portion of the Klamath Basin—establishing who has what rights to how much water—limits water users' ability to plan for and respond effectively to drought. *(Chapters 3, 19, 20)*
- Government agencies have different missions. When those missions conflict, the cumulative actions of many individuals working to achieve the mission of their particular agency can have unintended or undesirable consequences. *(Chapters 18, 20)*
- Natural systems often lack definitive data about the potential risks and benefits of any particular action (or inaction). In the Klamath Basin, for

example, uncertainty exists about precise relationships between fish survival and water level or stream flow. Decision-makers, thus, nearly always must act based on their best professional judgment and interpretation of incomplete and imperfect data. *(Chapters 4, 5, 6)*

- Resource managers typically can control only some of the actions that affect ecosystems. Irrigation on the Klamath Reclamation Project, although important, is only one of many land uses that affect the quality and quantity of water in the Klamath Basin. Other important variables are much more difficult to control. *(Chapters 5, 6, 18)*
- The eleventh-hour nature of the decision to curtail irrigation allocations and the absence of compensation programs at the time of the decision contributed to its social and economic costs. *(Chapters 9, 19)*

Consequences of the 2001 irrigation curtailment

- The story of 2001 in the Klamath Basin is partly one of shifting costs from one segment of society to another. Over the past century, Native American tribes and fishing communities have experienced economic, social, and cultural costs from the decline of fishery resources. In 2001, farming communities—at least initially—bore much of the cost of species recovery. *(Chapters 3, 9, 13, 14, 18, 19, 20)*
- The events of 2001 polarized many Upper Basin communities and created conflicts between government workers, tribal members, farmers, conservationists, businesses, farmworkers, and fishers. *(Chapter 9)*
- Both the agricultural sector and the regional economy fared better than most observers expected in 2001. Government responses such as groundwater pumping and emergency payments helped to shift the local economic impact of the irrigation curtailment to the larger public. Through these government actions, the larger public shared in the cost of species protection. *(Chapters 8, 13, 14)*
- Dollar measures of loss are inadequate to capture the full experiences of those affected by economic change. Disruption of personal relationships, the stress of uncertainty, and community discord are difficult to measure, but were large in many Basin communities in 2001. *(Chapter 9)*
- Regional economic measures mask the highly uneven experiences of individuals. Some firms, individuals, and agricultural producers experienced losses as a result of the irrigation curtailment, while others may have gained. *(Chapters 9, 13, 14)*
- Uneven eligibility for public emergency programs meant that some groups did not receive compensation for their losses. These groups—including farmworkers, tenant farmers, sharecroppers, and agricultural input suppliers—may have suffered the most as a result of the irrigation curtailment. *(Chapters 9, 13, 14)*

- This report focuses on short-term impacts of the 2001 irrigation curtailment on communities in the Upper Klamath Basin. Other potential consequences—benefits to at-risk species or downstream fishers, for example—are difficult to measure and were not addressed, but are no less important. *(Chapters 5, 6, 18)*

Looking for solutions

- Regardless of one's view about the relative merits of various claims to the Klamath Basin's water, more cooperation, more flexibility, and greater certainty would be desirable traits of any future water allocation system. *(Chapters 12, 18, 19, 20)*
- Greater flexibility in water allocation would have lowered the costs of the irrigation curtailment considerably. Transfers of irrigation water between non-Project and Project users, for example via water banks or water markets, could have reduced the overall cost to agriculture by 80 percent. *(Chapter 19)*
- Had there been prior agreement about how water would be shared in years of scarcity and what compensation could be expected by those who did not receive water, uncertainty and conflict could have been reduced. *(Chapters 9, 12, 18, 19)*
- Completion of the Oregon water rights adjudication process is crucial to any long-term solution. Clarity with respect to water rights—including quantity of water—is needed before any water transfer and allocation system can function well. *(Chapters 19, 20)*
- Continued scientific research is needed to provide decision-makers with more complete data on which to base natural resource management decisions. *(Chapters 5, 6, 15, 16, 17)*
- Solutions to water allocation questions in the Klamath Basin must consider the legitimate interests of Native Americans, irrigators, fishers, and at-risk species. *(Chapters 18, 20)*

  Key components of success include:

  - Sufficient commitment of federal effort and resources to overcome the disparate directions of federal agencies and to mediate among competing interests
  - A governing principle that the effects of scarcity will be shared in drought years
  - A successful framework for water management might include: (1) a council of federal, state, and tribal governments to deal with broad policy and jurisdictional issues, (2) a subordinate mechanism for coordination among agencies, and (3) a forum for negotiation and cooperation among agricultural, tribal, environmental, urban, and other water interests

Summary

This report discusses a variety of ecological, economic, social, and policy issues related to water allocation in the Klamath Basin (primarily the Upper Basin). We believe it:

- Increases understanding of what is known, and what is not known, about the interactions among natural resources, people, economies, and institutions
- Provides a reference on a wide range of subjects related to Klamath Basin water allocation
- Assesses some of the potential (and, where possible, documented) consequences of the decision to curtail irrigation water deliveries in 2001
- Identifies management alternatives and lessons that can be learned from the Klamath experience
- Provides a base for additional efforts in research, education, and problem-solving
- Proposes future actions to address particular information needs and reduce remaining uncertainties

The story of the 2001 irrigation curtailment is partly one of shifting costs from one segment of society to another. Over the course of the past century, Native American tribes and fishing communities in the Klamath Basin have experienced economic, social, and cultural costs from the decline of fishery resources. In 2001, the costs of actions intended to lead to species recovery were immediate and measurable for farmers and communities.

A search for solutions to water allocation issues in the Klamath Basin must include the Lower Basin, upstream activities, and an analysis of costs and benefits over an extended period of time. This report, however, is not a full assessment of past or future costs or benefits of water allocation alternatives. Most of the focus is on the Upper Basin, and especially on the immediate consequences of the irrigation curtailment in 2001. By narrowing our focus, we do not mean to imply that other parts of the system are less important.

Chapter 1—Background

Ron Hathaway and Teresa Welch

Water resources in the Upper Klamath Basin depend on annual recharge of groundwater and stream flows by melting snow, most of which falls in the mountains. The area around Upper Klamath Lake averages only about 14 inches of rain per year, and drought years have occurred several times during the past century.

Prior to European-American settlement and agricultural development, the Upper Basin contained large complexes of wetlands associated with streams and lakes. The Klamath Indians have hunted, fished, and foraged in the Upper Basin for many generations, and fishery and other natural resources provide religious, cultural, subsistence, and commercial support for the Tribes. The decline of these fisheries has had broad cultural, economic, and social consequences for the Tribes.

Through a series of dikes, dams, and channel modifications, the Klamath Reclamation Project converted many of the lakes and marshes of the Upper Klamath Basin to agricultural lands and waterfowl refuges. The Project currently delivers irrigation water through a network of canals to approximately 200,000 acres.

The Upper Klamath Basin is home to five national wildlife refuges and annually hosts the largest concentration of migratory waterfowl in North America. A variety of other animals, birds, and fish inhabit the area, including the largest wintering population of bald eagles in the United States outside of Alaska.

In April 2001, decisions intended to conserve endangered and threatened fish, combined with a severe drought, resulted in curtailment of irrigation water deliveries to much of the Klamath Reclamation Project. One decision required a minimum water level for Upper Klamath Lake. Another required a minimum discharge into the lower Klamath River. The decisions stemmed from years of concern about water quality, habitat loss, and declining populations of three species of fish—Lost River and shortnose suckers in Upper Klamath Lake and coho salmon in the lower Klamath River.

Ultimately, the combined effects of a low water supply, minimum lake level, and minimum river flows prevented the diversion of water from Upper Klamath Lake for Project irrigation or national wildlife refuges. About 1,200 farms, or 85 percent of normally irrigated Project lands, were affected.

Chapter 2—The Klamath Reclamation Project

Kenneth A. Rykbost and Rodney Todd

The Klamath Reclamation Project supplies water to agricultural irrigators and wildlife refuges through a system of reservoirs, diversion dams, and canals. Two main sources supply water for the Project. One consists of Upper Klamath Lake and the Klamath River, and the other consists of Clear Lake Reservoir, Gerber Reservoir, and the Lost River.

In 2001, agriculture received 22 percent of the average annual Upper Klamath Lake diversion for 1991–2000. The 2001 Project operations plan provided about 70,000 acre-feet to the Horsefly and Langell Valley irrigation districts from Clear Lake and Gerber reservoirs. Water from private wells and minor quantities from the Lost River, derived from purchased groundwater, maintained limited supplies for up to about 75,000 acres within the Project. A small release in late July from Upper Klamath Lake (75,000 acre-feet) provided significant late-season relief to pastures and hay crops. Remaining fields in the Project were not irrigated through the summer.

Operation of the Project with the minimum lake elevation and river flow requirements that existed prior to 2001 would have supplied additional water for irrigation and the refuges in the following manner:

- 160,000 acre-feet of water by allowing Upper Klamath Lake to fall to 4,137 feet elevation in a critically dry year, as permitted by the U.S. Fish and Wildlife Service 1992 lake-level Biological Opinion for suckers (instead of holding lake elevation at 4,139.5 feet as was done in 2001)
- 109,000 acre-feet by setting May-through-September flows over Iron Gate Dam at the minimum established by the Federal Energy Regulatory Commission as a condition for dam licensing

Thus, Upper Klamath Lake could have provided 269,000 additional acre-feet for irrigation and refuges in the absence of Endangered Species Act requirements. When the 75,000 acre-feet midseason release is added, the total represents almost the amount of the average annual 1991–2000 diversions to the A-Canal, North Canal, and ADY Canal.

In addition to the reduction in irrigated acreage in 2001, the irrigation curtailment had the following effects.

- The lack of irrigation water reduced groundwater recharge from percolation of applied irrigation water and water in canals. Failures of several domestic and livestock/yard wells were reported by late July 2001.
- A flurry of well-development activities was initiated in an effort to replace surface irrigation water. Private efforts and funding from the states of California and Oregon resulted in the development of several new wells. The ability of groundwater aquifers to sustain season-long or long-term irrigation use has not been determined, however. Several irrigation wells are reported to have lowered water levels in nearby wells in 2001.

Chapter 3—Legal Aspects of Upper Klamath Basin Water Allocation

Reed Marbut

Two legal issues are key to understanding water allocation questions in the Upper Klamath Basin: (1) Oregon water rights and Oregon water right adjudication, and (2) federal interests in water, including Indian water rights.

Water rights adjudication. In Oregon, any use of water that began before 1909, and water rights established under federal law (reserved rights), are subject to quantification in state adjudication proceedings. During adjudication, water rights are verified, quantified, and documented. The right holder then receives a decreed right for a specific amount of water with a specific priority date.

The Klamath Basin Adjudication (KBA) began in 1975, and it covers much of the Oregon portion of the Upper Klamath Basin. Approximately 700 claims were filed in the KBA, including about 300 private claims and 400 claims by various agencies of the U.S. government and the Klamath Tribes. Approximately 5,600 contests were filed to oppose claims. All of the contests have been referred to the state Central Hearing Panel, and proceedings on several groups of contests are ongoing.

Federal reserved water rights. When the federal government sets aside land from the public domain, an implied reserved water right is created. In the Klamath Basin, there are a number of federal reservations with reserved water rights (e.g., national forests, wildlife refuges, Crater Lake National Park, wilderness areas, wild and scenic rivers, and, in the past, the Klamath Indian Reservation).

Indian water rights. In 1864, the Klamath and Modoc tribes entered into a treaty with the United States whereby they relinquished aboriginal claim to some 12 million acres in exchange for a reservation of approximately 800,000 acres in the Upper Klamath Basin. In 1954, Congress enacted the Klamath Termination Act, under which federal recognition of the Klamath Tribes ended, and most of the Reservation lands eventually were transferred to the U.S. Fish and Wildlife Service and the U.S. Forest Service.

A 1983 ruling by the federal District Court in Portland *(U.S. v. Adair)* found that:

- The 1864 treaty granted the Indians an implied reserved water right to as much water on the Reservation as was necessary to preserve their hunting and fishing rights.
- The Tribes' water rights survived the Klamath Termination Act.
- Individual Indians who were allotted lands within the former Reservation are entitled to water for their agricultural needs with a priority date of 1864.

- Non-Indian successors to Indian allottees have an 1864 water right for actual acreage under irrigation when the non-Indian obtained title from the Indian and to additional acreage developed with reasonable diligence.
- Quantification of the tribal water rights is to be left to the State of Oregon adjudication proceeding.

Additional clarification was provided in February 2002 in a follow-up case, *Adair III.* Judge Panner declared that "... the Klamath Tribe's water rights include a water right to support resources the Tribes gather, in addition to the resources they hunt, fish, and trap." He also declared that "... [I]n no event shall the [KBA] adjudicator quantify or reduce the Tribal water right to a level below that which is necessary to support productive habitat.

Chapter 4—Understanding Science

A. John Arnfield, a geographer and climatologist at Ohio State University, describes several characteristics of science and environmental issues that often are misunderstood or forgotten during times of controversy.
For example:

- Science cannot make statements that are certain. The conclusions of science possess a greater probability of being true than ideas discovered by other means, but they are not "true" in the sense that they are beyond doubt.
- Scientific consensus is more important than scientific disagreements. When we begin to study a system, such as suckers in Upper Klamath Lake, it takes years to move from the frontiers to consensus on all issues.
- We have incomplete knowledge about the functioning of systems on this planet. In part, this is because of data limitations. Estimates are based on scientifically defensible procedures and are subject to constant revision and recalculation based on new knowledge.
- Environmental data collection is, minimally, representative and, ideally, random. Random is not haphazard. Rather, randomization is the only way to avoid bias.
- The complexity of what we do know about natural systems means it is always possible for a proponent or opponent of a particular course of action to point to alternative data or interpretations that support his or her point of view.
- We must deal with a dynamic blend of science, values, and beliefs. We all are governed by particular sets of values by which we live our lives. Given the uncertainty of our knowledge and the complexity of natural systems, such values tend to intrude into scientific discussions.
- The profound relevance of environmental issues to future generations of humans and other species makes these issues controversial.
- Simple solutions to environmental problems are rare.

Chapter 5—Sucker Biology and Management of Upper Klamath Lake

Douglas F. Markle and Michael S. Cooperman

Historically, Lost River suckers (LRS) and shortnose suckers (SNS) were abundant in Upper Klamath Lake and were utilized as a subsistence and sport fishery. The sport fishery was closed in 1986, and both species were federally listed as endangered in 1988.

In 1992, when the first Biological Opinion (BiOp) for the Bureau of Reclamation's Klamath Project was issued, biologists assumed that adult sucker populations were low and that low numbers of fish were surviving until adulthood, but that a major source of adult mortality, the fishery, had been controlled. Because both species are long lived and produce large numbers of eggs, it was thought that occasional years of poor production would not adversely affect healthy populations.

Data from the early 1990s seemed to indicate rebounding adult populations. However, a series of fish kills in the mid-1990s caused a significant loss of adult fish. Thus, by the time of the 2001 BiOp, the population was assumed to be about the same as in 1992, but a source of adult mortality, fish kills, clearly was not under control. Furthermore, because older females produce the most eggs, the loss of older adults during the fish kills resulted in reduced reproductive potential.

The 2001 BiOp raised the minimum lake elevation from 4,139 to 4,140 feet above sea level. It is not our intent to defend or critique the 1992 or 2001 Biological Opinions. Rather, we attempt to explain them within the context in which they were written. Managers acknowledged that lake elevation alone could not guarantee survival of juveniles and healthy adults, but argued that lower elevations increased risks to the species. Increased lake elevation was intended to reduce the risk of winter kill, increase the amount of available habitat for spawning and early juvenile development, improve water quality, and provide access to areas of better water quality at times when overall quality of the lake is poor.

Factors behind the 2001 Biological Opinion were: (1) a Congressional mandate to err on the side of the species of concern in the face of uncertainty, (2) the Bureau of Reclamation's failure to implement certain requirements of prior BiOps, (3) increased imperilment of the species since 1992, and (4) an increased concern for the effects of poor water quality.

Chapter 6—Coho Salmon

Guillermo Giannico and Christopher Heider

Coho salmon stocks in the Klamath River Basin have been greatly reduced and now consist largely of hatchery fish. Only small runs of wild coho salmon remain in the Basin, and the species was listed as threatened under the Endangered Species Act in 1997.

The Klamath Basin has a long history of human activities that have altered fish habitat and fish abundance—commercial harvesting of timber, fishing, mining, cultivation of crops, ranching, water diversion for agriculture, and hydroelectric dams.

Hatcheries were begun in response to declining fish stocks. In retrospect, it has become clear that they have created a number of unintended biological problems, resulting from their goal of increasing run sizes and from the poor integration of genetic, evolutionary, and ecological principles into hatchery planning and operation.

There are several water quality issues in the Klamath Basin. The combined effects of high temperatures, high nutrient concentrations, changes in pH, and low dissolved oxygen levels during the summer months can create stressful conditions for coho salmon and other salmonids in the lower Klamath River.

In response to the Bureau of Reclamation's proposed operation of the Klamath Reclamation Project for 2001, the National Marine Fisheries Service presented in its Biological Opinion on coho salmon a Reasonable and Prudent Alternative (RPA), which established minimum flows at Iron Gate Dam (IGD). Aiming to maintain between 40 and 65 percent of the mainstem channel's salmonid habitat during various months, the RPA established April–September minimum water releases at IGD. Higher flows during the spring were intended to benefit coho smolts migrating to the ocean. The assumption was that higher flows would shorten the duration of the trip to the estuary and, therefore, increase the survival rate of smolts. Although there was no guarantee that the "additional" release of water would work as intended, the assumption is supported by some studies on smolt migration and survival.

The BiOp RPA also recommended lower, albeit constant, flows for the mid-June through early-September period. This recommendation balanced the need for higher flows in the spring with the need for regulating flows in a manner that ensured the limited available water supply would last until fall. Although the water-release schedule was designed to protect coho salmon, other nonlisted species such as steelhead, chinook salmon, and Pacific lamprey are likely to have benefited the most from higher flows in the mainstem of the Klamath River.

Management decisions related to salmon habitat often have ignored the fact that upstream land-use activities affect water quantity, quality, and habitats downstream. Management decisions should be made within the context of the entire Basin and should aim to conserve and enhance the processes that connect its many components (e.g., headwaters, hill slopes, mountain streams, riparian forests, lakes, valleys, wetlands, groundwater reservoirs, tributaries, mainstem channel, floodplains, estuary, etc.). Development of an effective integrated basin management plan will require the cooperation of all of the Basin's stakeholders.

Chapter 7—Soil Resources

Harry L. Carlson, Donald R. Clark, Kerry Locke, and Rodney Todd

The U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) defines soil capability classes that indicate, in a general way, the suitability of soils for most kinds of field crops. Soils are placed in capability classes represented by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use. Soils falling in soil capability classes I through III usually are designated Prime Farmland. When irrigated, or drained and irrigated, most of the agricultural soils in the Klamath Reclamation Project can be considered Prime Farmland.

The decision to deny water deliveries to most of the Project in 2001 threatened to transform the productive Project area into a major dust bowl. About 30,000 acres had been tilled in the fall of 2000 in preparation for spring planting. With this bare soil exposed to spring winds, serious soil erosion was a certainty.

In response, the Klamath Soil and Water Conservation District (KSWCD) implemented the largest single soil conservation effort in the Northwest. The KSWCD, with resources from the NRCS, was able to institute a cover crop program for farmers to cover bare soil on their farms. Growers were offered cost sharing to plant a small cereal grain crop to protect exposed soil. Growers provided a 25 percent match and received a 75 percent cost-share payment. This effort resulted in the planting of cover crops on more than 37,500 acres in the Project. The cost of the program was $1.7 million, and the amount paid to participants was nearly $1.3 million.

With some limitations, the program was able to conserve topsoil in the Project area. It is estimated that 95 percent of the seeded cover crops did emerge, resulting in a significant reduction in soil erosion.

Chapter 8—Effects on Crop Production

Harry L. Carlson and Rodney Todd

Agriculture is the predominant land use within the boundaries of the Klamath Reclamation Project. The principal crops in terms of acreage are alfalfa hay, pasture (for beef cattle), and barley, followed by other hay, potatoes, and wheat.

The 2001 curtailment of irrigation water supplies to the Project had major effects on the Basin's agricultural landscape, including the following.

- The number of idle acres was greatly increased.
- Acreage of spring-seeded, high-value row crops such as potatoes and onions was greatly reduced.
- Barley acreage was increased in California due to plantings intended to prevent soil erosion. However, much of the barley went unharvested or was harvested for hay because of concern about poor grain yields.

- Per-acre yields of cereals harvested for grain and alfalfa were greatly reduced.
- Weed control generally was not practiced in fallow fields or in dryland fields planted to grain, alfalfa, or peppermint. Major increases in weed seeds in the soil are likely to result in increased weed problems in the future.
- The farm-gate value of agricultural production in the Project was greatly diminished. In the Tulelake Irrigation District, crop production value fell from a 3-year average of $38.7 million to $17.3 million. In Klamath County, crop production value fell from a 3-year average of $58.6 million to $31.5 million (preliminary data).

Chapter 9—Effects on Project-area Communities

Denise Lach, Leslie Richards, Corinne Corson, and Patty Case

The communities affected by the curtailment of irrigation water during the 2001 growing season took a social hit, the consequences of which are likely to be fully realized only in the months and years ahead. Several key themes emerged from focus groups and interviews with community members, each reflecting the contradictions and conflicts we heard.

- **Community support and community polarization**. Almost all participants described how the water situation had drawn the community together in many ways. Yet, they also described incidents of polarization around issues related to the water situation. These experiences ranged from tension in long-term relationships to highly confrontational incidents between farmers and conservationists, farmers and state and federal agencies, farmers and tribal members, and/or farmers and farmworkers.
- **Uncertainty about the future and long-term planning**. All of our participants described the situation as intolerably uncertain and increasingly frustrating. Yet, we also heard from farmers and others that this "crisis" was unexpected *only* in its appearance in 2001. Many already had been planning and working to shift reliance from irrigated fields and the agricultural economy to alternative crops and new business sectors.
- **The role of information**. While all participants agreed that information was needed, there was little agreement about just what constituted "good" information that could help move conversations and decisions forward. There was almost unanimous disapproval of the way the media had handled the situation, although some claimed the media were too biased toward the farmers, and others claimed the farmers weren't getting a fair shake. Others were highly critical of the media for sensationalizing the situation and causing more polarization.
- **Getting help**. All participants expressed concern about helping the farming community and others affected by the situation. Participants generally relied most strongly on their personal networks, and support

came primarily from family and friends. Assistance for other members of the community was limited, and social service providers were concerned that increased needs resulting from the water situation would limit their ability to provide services to the neediest members of the community.

- **Needed: visionary leadership**. It was clear to many of our participants that the visionary leadership needed to craft workable solutions did not exist. However, it is not clear from our interviews what participants would like from leadership beyond bringing people together. Farmers would like leaders to "make sure that agriculture stays whole to protect our society." Others look for someone to initiate a broad discussion, provide concise national policy from the top, promote education about the situation, see the big picture, and bring people together.

Chapter 10—Preface to Economics

William K. Jaeger and Bruce Weber

In the economics chapters of this report, two principal types of monetary measures are used to quantify economic changes:

- Measures that reflect the scale of economic activity (e.g., gross output, exports, gross revenue, and regional gross sales)
- Measures that reflect net financial changes for individuals and regions (e.g., net revenue, economic loss, and income)

It is important that these two measures not be confused. The following example is offered as clarification.

Consider a homebuilder in Klamath Falls with a contract to build a $500,000 home. If the contract is cancelled, how should we quantify the economic effects? Did the homebuilder lose a $500,000 sale? Yes. Is the homebuilder's income reduced by $500,000? No. Let's assume the home would cost $400,000 to build (materials, hired labor, subcontracts, etc.). Thus, we can say that losing the contract involves a reduction in "net revenue" or "income" of $100,000 for the builder. It is important to remember that changes in "gross revenues" or "gross sales" caused by an event are not a good measure of the gains or losses to individuals. Changes in net revenue or income better reflect economic gains or losses.

We also present two kinds of information about regional economic changes—impact estimates and reported outcomes. Impact estimates attempt to predict how a particular event, such as the 2001 irrigation curtailment, would affect gross output, income, and employment (holding everything constant other than the change identified with the particular event). Reported outcomes document how an economy changed over a period of time. Reported outcomes will differ from impact estimates due to public and private responses to the event (e.g., well drilling and government emergency payments) that are not accounted for in the impact estimate, as well as unrelated factors (e.g., price changes).

To the extent that we can distinguish between the effects of unrelated factors and those attributable to the event being studied, we can more accurately estimate the impact of the event. In Chapter 14, Jaeger combines information on estimated impacts, reported outcomes, and unrelated changes to produce a set of "inferred impacts."

Aggregate changes in an economy frequently mask the distribution of gains and losses. Gains in one part of the economy (or by one individual) may be offset by losses elsewhere. Measured changes in net revenue or income in 2001, moreover, likely do not reflect all of the benefits and costs of the 2001 irrigation curtailment. Some impacts on costs of production, asset values, employment, and income may take longer than 1 year to become evident. There also may be positive or negative impacts on other groups and sectors, including tribal and environmental interests, commercial and sports fisheries, recreation, and tourism.

Chapter 11—Upper Klamath Basin Economy

Bruce Weber and Bruce Sorte

The Upper Klamath Basin (Klamath County, Oregon, and Modoc and Siskiyou counties in California) is home to about 120,000 people. The Basin economy produced $4 billion worth of sales in 1998 and provided almost 60,000 jobs. The sectors with the largest shares of sales were wood products, agriculture, construction, and health care/social assistance. The sectors with the largest shares of employment were retail trade, agriculture, educational services, and health care/social assistance.

Agriculture was responsible for 7.9 percent of sales, 7.3 percent of value added, and 10 percent of employment in the Upper Basin in 1998. The regional value of agricultural production in 1997 was estimated to be $239 million. Klamath Reclamation Project lands produced about $109 million of this total. There were 2,239 farms in the Upper Basin in 1997 (defined as producing $1,000 or more of agricultural products annually). Of the 1,744 irrigated farms in the Upper Basin, 1,400 were part of the Project.

Chapter 12—Effects on Crop Revenue

Susan Burke

An analysis of the effect of the 2001 Biological Opinions and drought on gross farm crop sales in the Klamath Reclamation Project shows that with the 2001 requirements for both in-stream flow and lake elevation, our economic model estimates a loss of $74.2 million in gross farm crop sales. Comparing model results to reported crop production data from the Tulelake Irrigation District indicates that the model may overestimate the loss by about 20 percent. If so, the loss would be about $59.3 million. With no minimum in-stream flow requirement below Iron Gate Dam, however, there would have been no loss in gross farm crop sales, regardless of whether lake elevation was held at the 1992 or 2001 minimum.

In 2001, the combination of drought and Biological Opinions led the Bureau of Reclamation (BOR) to forgo irrigation deliveries to all Project irrigators who normally receive water from Upper Klamath Lake. In future years, however, the BOR may have to determine how to allocate water to Project lands when irrigation diversions are less than a full supply but greater than zero.

Water allocation to irrigators currently is based on a system of contract priorities. "A users" have the most senior contract type, followed by "B users," and finally "C users." Seniority of contract type means that, when water is allocated among users, the A users receive all of the water they can beneficially use before either the B or C users receive any water. Once the A users receive all of the water they can beneficially use, deliveries begin to B users. Once the B users receive all of the water they can put to beneficial use, C users receive their allocation.

Not all land is equally productive in terms of the value of crops it can produce. In the event of a water shortage, allocating water by priority use forces the highest quality B land completely out of production while the lowest quality A lands are still in production.

By changing the way in which water is allocated, the economic effects of a water shortfall can be reduced. For example, reducing deliveries to all users by an equal proportion, instead of by using the existing A,B,C priority method, could save as much as 10 percent of total gross farm crop sales, depending on the percent of full irrigation diversions available.

Chapter 13—Impact on the Regional Economy

Bruce Weber, Jim Cornelius, Bruce Sorte, and William Boggess

Based on economic models, we estimate that the 2001 Klamath Project Operations Plan (KPOP) would have reduced agricultural exports (production) in the Upper Klamath Basin by $82 million in 2001 if there had been no public and private efforts to mitigate its effect. With the release of some water, the drilling of wells, and the public sector loans, grants, and purchases that occurred during the summer of 2001, our estimates suggest that the short-term impact of the 2001 KPOP on agricultural exports is likely to have been cut by more than half—to $38 million.

The impact of a reduction in agricultural sales is felt in other sectors of the Basin economy because of the economic interrelationships among sectors. We estimate that the 2001 KPOP would have reduced total personal income (employment compensation, proprietor income, and other property income) by 3.4 percent ($80 million) in the three-county region without any offsetting public and private responses.

We estimate that the KPOP would have reduced regional employment by 3.3 percent (almost 2,000 jobs) and total regional gross sales by 2.7 percent ($115 million) during the first year, had there been no mitigating responses.

Four sets of responses reduced the negative impacts of the KPOP: (1) additional irrigation water, which made possible additional agricultural production and exports, (2) public emergency assistance payments to farmers, (3) public expenditures on services and infrastructure, and (4) expenditures on new wells financed by farm borrowing.

The first three responses (which do not involve any future financial obligations for individuals or businesses in the region) brought almost $80 million into the region. In the aggregate, these responses nearly offset both the direct and indirect income losses that would have occurred under KPOP 2001.

The added water and public emergency payments and expenditures also substantially reduced the estimated negative impacts on regional employment and output. With these responses, the KPOP is estimated to have reduced employment by almost 700 jobs (1.1 percent) and output by $29 million, or 0.7 percent.

Farm borrowing to finance wells added an additional $3 million to regional income. It also added almost 250 jobs and $6 million in output to the regional economy.

It is essential to remember, however, that these regional economic aggregates mask the considerable unevenness in impacts among and between various sets of stakeholders.

Chapter 14—Estimated Impacts and Reported Outcomes

William K. Jaeger

Our understanding of the economic consequences of the irrigation curtailment is based on an appraisal of recent economic data and revised impact estimates from models in Chapters 12, 13, and 19. Although we cannot fully separate the changes due to the irrigation curtailment from those due to unrelated events, the available information enables us to identify a set of "inferred impacts" from the irrigation curtailment.

Our analysis suggests that agricultural outcomes were better than predicted by the initial model estimates. The main reasons for this were the additional private and publicly funded groundwater pumping, about $45 million in emergency payments and other public appropriations, and higher prices for livestock and potatoes.

Based on our assessment of available information and model estimates, we have identified the following outcomes and inferred impacts of the irrigation curtailment.

- Irrigated acreage in the Project was reduced by 53 percent.
- Net crop revenue on the Project was reduced by $27 to $46 million. With emergency payments of between $35 and $37 million, the overall change in net farm revenue was between –$11 and +$10 million.
- Total regional agricultural sales were reduced by 13 to 17 percent.

Other reported economic outcomes in 2001 include the following.

- Gross agricultural production value in Klamath County was only 2.1 percent lower in 2001 compared to the average for the previous 5 years. Continued high livestock prices helped offset the severe decline in Project crop revenues.

- There was a 2.3 percent decline in total employment in the three-county region compared to the previous year.

These results suggest that other events and responses mitigated and offset many of the financial effects of the irrigation curtailment. Principal offsetting factors were additional private and publicly funded groundwater pumping, emergency payments and other public appropriations, and higher prices for livestock and potatoes.

It is essential, however, to recognize that measures of aggregate or total changes in income and net revenues mask the highly uneven distribution of the net losses or gains among farms, farmworkers, and other individuals across different sectors of the economy.

Chapter 15—Bald Eagles

Jeff Manning and W. Daniel Edge

The Upper Klamath Basin supports the largest population of wintering bald eagles outside of Alaska, ranging from 200 to 1,100 eagles during a single survey day. The primary food for wintering bald eagles in the Basin is waterfowl. Because the bald eagle is a federally listed threatened species, the Bureau of Reclamation (BOR) and the U.S. Fish and Wildlife Service (USFWS) must assess effects of Project operations on bald eagles.

Based on the BOR's 2001 Project operations plan, which included no provision for specific water deliveries to the Lower Klamath National Wildlife Refuge, the USFWS concluded that nesting eagles might suffer hunger and other adverse effects from the loss of waterfowl habitat. Nonetheless, because the number of nesting pairs in the Upper Klamath Basin represents a small percentage of the total in the seven-state Pacific Recovery Region, those effects would not substantially alter the bald eagle recovery goals in the region.

Regarding wintering bald eagles, the USFWS estimated: (1) the number of waterfowl needed to sustain an estimated population of bald eagles, and (2) the amount of water needed for that number of waterfowl. The Biological Opinion required the BOR to supply sufficient water to the refuges to meet this need, but only if water was available after meeting the lake elevation and river flow requirements for suckers and coho salmon, respectively.

Based on our alternative analyses of the data used by the USFWS, it is likely that the Biological Opinion underestimated the wintering population of bald eagles in the Basin. Thus, a larger, but unknown, number of eagles might be affected by water allocation decisions. There also is uncertainty surrounding the relationship between bald eagle numbers and waterfowl populations.

Nonetheless, the changes in water distribution within the Upper Klamath Basin in 2001 did not result in changes in bald eagle populations. For example:

- The number of nesting pairs increased slightly in 2001, and nest success was 66 percent, both consistent with results over the previous several years.
- January bald eagle counts were within the normal range of variation in previous years' counts.

Chapter 16—Effects on Waterfowl

Robert L. Jarvis

Because of its location on the Pacific Flyway, its mild climate, and extensive wetlands, the Upper Klamath Basin is a major staging area for waterfowl migrating to and from wintering areas farther south in California and Mexico. Current fall migrant populations peak at about 1 to 2 million, with about half that many during spring migration. Partial counts and anecdotal accounts leave little doubt that waterfowl were much more abundant early in the 20th century.

Agricultural development in the region resulted in the draining of more than half the Basin's wetlands. These changes have meant much less wetland habitat for waterfowl, but abundant food for species adapted to field feeding on small grains. Most of the remnant wetlands are in public ownership. The two key waterfowl habitat areas are Tule Lake and Lower Klamath national wildlife refuges (NWR). Some refuge lands are leased to farmers for grain production, and many harvested fields are flooded in the fall so waterfowl can feed on the remaining grain.

The 2001 drought and irrigation curtailment resulted in several changes that affected waterfowl. Key results were as follows.

- Production of young at Lower Klamath NWR probably was essentially zero, as water deliveries began too late in the fall to benefit nesting waterfowl. Production probably was minimally affected at Tule Lake NWR because of the requirement to keep water levels normal on part of the refuge to maintain habitat for suckers.
- The lack of irrigation adversely affected crop production at Tule Lake NWR, and 640 acres of experimental wetlands were left dry.
- Lower Klamath NWR was the most severely affected area. The Bureau of Reclamation's Project operations plan did not include any specific provision for water delivery to the refuge. The U.S. Fish and Wildlife Service Biological Opinion required a minimum amount of water delivery, but only if water was left over after the lake level and stream flow minimums were met for suckers and coho salmon, respectively. As a result, the acreage of wetlands at Lower Klamath NWR in 2001 was far below normal. Crops on the refuge normally are not irrigated, so grain production was minimally affected; however, the harvested fields were not flooded, making them much less attractive to waterfowl.
- Peak populations during the fall 2001 migration were about 20 percent below the average peak in the 1990s.
- Early-winter precipitation and availability of irrigation water recharged most waterfowl habitat by January 2002. January waterfowl counts were within the normal range of variation in previous years' counts.

Chapter 17—Mule Deer

Jeff Manning and W. Daniel Edge

The drought and water allocation decisions in the Klamath Reclamation Project area in 2001 had the potential for direct and indirect influences on mule deer. For example:

- The reduced water availability likely would result in a reduction in the quantity and quality of natural vegetation and the quantity of irrigated crops available as forage. Thus, individuals might move to areas where higher quality forage was available. They also might experience poorer nutritional condition, decreased fat reserves, and reduced survival rates, especially during the winter.
- Big game damage might increase on farms that did receive water because of the limited availability of green vegetation.
- It is not clear whether reduced water availability and forage would affect males more than females because of their lower winter fat reserves. If so, increased losses of adult males could affect sex ratios.
- Females might delay the onset of reproduction, and adult females might produce fewer fawns.
- Poor nutritional condition might result in low birth weights and higher fawn mortality.

Data collected in big game counts are based on broad geographic areas that encompass a variety of natural and human-modified habitats, weather conditions, and water sources. Consequently, if there are changes in mule deer populations, it probably will not be possible to determine whether the changes are based on habitat conditions, loss of habitat, weather conditions, availability of water, or size of the wildlife population. Therefore, it is unlikely that changes can be attributed to changes in water distribution in the Project area.

Chapter 18—Policy Assessment

George Woodward and Jeff Romm

The 2001 curtailment of Klamath Reclamation Project irrigation water was consistent with previous judicial interpretation of the Endangered Species Act (ESA). Nonetheless, the immediate and real, as contrasted with speculative, losses to farmers, farmworkers, and communities stretched the envelope of consequences that have resulted from previous applications of the ESA. Thus, the events of 2001 raise several questions, including:

- The legitimate extent of private burden for a public purpose
- The appropriate balance between scientific uncertainty and socioeconomic burden

- The reasonable stress between required procedures and the natural and social processes in which they are used
- The acceptable tension between absolute water claims and dynamic natural and social systems
- The relationship between tribal treaty rights, state systems of water rights, and federal laws that control water allocation in certain circumstances

The losses seen in 2001 were not unprecedented in the Klamath Basin, although prior crises have not been associated with the ESA. Native American tribes, for example, have suffered drastic, enduring losses of resources under other federal laws. A pendulum of catastrophe in the Basin has imposed massive losses on different parties at different times.

This history of recurring losses raises the question of whether the events of 2001 were due to application of the ESA or to the relationship between federal law and Basin capacities to shape its application for favorable outcomes. In these terms, the Klamath Basin is unusual relative to other basins in the West. With its social and institutional fragmentation, it displays few of the capacities that other basins use to assert a shared vision and to coordinate and implement advantageous actions. The consequence is a default of local and regional power to clear federal law. Thus, while other basins have absorbed ESA applications in largely beneficial ways, the Klamath once again was hit with the full force of externally defined choices without internal buffers against the pendulum of either/or outcomes.

Several strategic needs become apparent from this analysis:

- Sufficient commitment of federal authority and resources to overcome the disparate directions of federal agencies and to mediate among the interests of Oregon, California, and the tribes
- Acknowledgment, respect, and support for tribal treaty-based rights and treatment of tribes as sovereigns as well as water claimants
- A governing principle of adaptive water allocation in times of scarcity
- A framework for Basin governance that includes:
  - A council of federal, state, and tribal governments to deal with broad policy and jurisdictional issues
  - A subordinate mechanism for coordination among agencies
  - A forum for negotiation, exchange, and cooperation among agricultural, tribal, environmental, urban, and other water interests

The events of 2001 have contributed to the possibility of meeting these needs by stimulating the formation of Basinwide coalitions of interests that may serve as resources for cooperation and problem solving.

Chapter 19—Water Allocation Alternatives

William K. Jaeger

The value of irrigation water varies greatly across the Upper Klamath Basin, depending primarily on differences in soil productivity. Costs of a shortage of irrigation water could be minimized by flexible mechanisms that allow scarce irrigation water to be transferred among growers so that it finds its way to the highest value uses through voluntary exchange.

Our analysis suggests that more than 80 percent of the costs of the 2001 water shortfall could have been avoided had water markets or other transfer mechanisms been available. Given the high value of agriculture within the Project, and the presence of large areas of significantly lower value agriculture in other parts of Klamath County, a cost-minimizing approach to reducing irrigated acreage would involve full irrigation for the Project and curtailed irrigation in other, less productive areas.

This analysis suggests that the absence of water transfer mechanisms, such as water markets or water banks, magnified the costs of drought and Endangered Species Act determinations fourfold. The cost of future water shortages could be reduced if mechanisms for transferring water rights were put in place. If water rights can be transferred, it will be possible for irrigation water to be allocated with the greatest certainty to those users with the most to lose from not getting their water. The development of such mechanisms requires that water rights adjudication in Oregon be completed.

Chapter 20—A Synthesis: Policy Analysis and Public Institutions

Emery Castle

This report documents numerous inconsistencies and unintended consequences stemming from government programs in the Upper Klamath Basin in 2001. These outcomes do not necessarily mean that particular programs have failed. Rather, they may indicate that government activity, taken as a whole, is not performing effectively. Three alternative, highly preliminary, views are sketched here of how institutional change might occur.

Alternative I proposes minimal institutional change, but suggests improvements in operating procedures. One suggestion is for water users to collectively formulate contingency plans to be used when water is in short supply. Additionally, Chapter 18 suggests that the court decision in *Tulare v. United States* might be tested to determine whether compensation must be paid when the cost of a "taking of water rights" falls heavily on a particular group.

Alternative II is moderate institutional modification. The assumption here is that certain institutions—for example, the Endangered Species Act, Reclamation legislation, Native American rights, and California and Oregon state water laws—are more basic than others. Less basic institutions are modified to make the basic institutions perform better or to remove inconsistencies. This strategy aims to create a more flexible system for managing water. Water markets, for example, are one means of minimizing the costs of water shortages (Chapter 19).

Alternative III considers significant change in basic water institutions. For example, some might believe that significant acreage of irrigated agriculture is not compatible with ecological integrity in some parts of the Klamath Basin. Others maintain that the Endangered Species Act does not provide the flexibility needed to reconcile conflicting interests in natural resources.

In examining each alternative from a local, state, and federal perspective, it becomes clear that institutional modification should be considered at every level of government.

- Federal—The 2001 decisions were at least partly the result of conflicting missions of federal agencies and inconsistent application of some government programs. Chapter 18 calls attention to the unusually severe consequences of the Endangered Species Act in the Upper Klamath Basin in contrast to its application elsewhere.
- State—A clarification of water rights in the Oregon portion of the Klamath Basin clearly is required if effective water management institutions are to be developed.
- Local—The most basic decision facing regional communities is whether they wish to continue the divisiveness that characterizes the current situation.

It should now be clear that the Endangered Species Act trumps other claims to water when the survival of a species is in question. It also is clear that tribal claims to water have a legal standing. Irrigators and other out-of-stream water users need to recognize these realities. It is important to note that these realities are not necessarily inconsistent with both in-stream and out-of-stream water uses.

Any lasting solution to conflicts surrounding water allocation requires that the needs of **all** interested parties be addressed. In the Basin, the legitimate interests of Native Americans, irrigators, and endangered species all must be recognized and considered.

Part 1. Setting the Stage

Background

Ron Hathaway and Teresa Welch

In 2001, water allocation decisions intended to benefit fish protected under the Endangered Species Act, along with a severe drought, resulted in curtailment of irrigation deliveries on the Klamath Reclamation Project. The events that followed made headlines across the country.

The situation did not develop overnight, however. Like most areas in the United States, various parts of the Klamath Basin have been affected over the past 150 years by crop production, grazing, timber harvest, mining, wildlife management, fishing, industry, hydroelectric power production, introduction of nonnative species, and urbanization. It is against this historical backdrop that we must consider the events of 2001.

The controversy brought to the stage a bewildering cast of characters—federal and state agencies, farmers, environmental groups, Native American tribes, farmworkers, power companies, lawyers, scientists, three species of fish, bald eagles, waterfowl, and other wildlife. Discussions revolved around acronyms such as BiOps, BAs, KPOPs, and RPAs. To those not directly involved, it can be difficult to make sense of the debate.

This chapter is intended to help you sort it all out. Here we set the stage by introducing many of the key players and factors that led up to the situation in 2001. We hope this background will help you understand the discussions in the chapters that follow.

Overview of the Klamath Basin

The Klamath River watershed begins in the mountains of Oregon and California east of the Cascade Range. Crater Lake National Park sits at the top of the watershed. From Upper Klamath Lake, the river flows generally southwesterly, entering the Pacific Ocean south of Crescent City, California (Figure 1).

For practical purposes, the Basin can be described as consisting of an upper and a lower section separated by a river reach with a series of hydroelectric dams. Except for Chapter 6 (“Coho Salmon”) and Chapter 18 (“Policy”), most of this report deals with the Upper Basin.

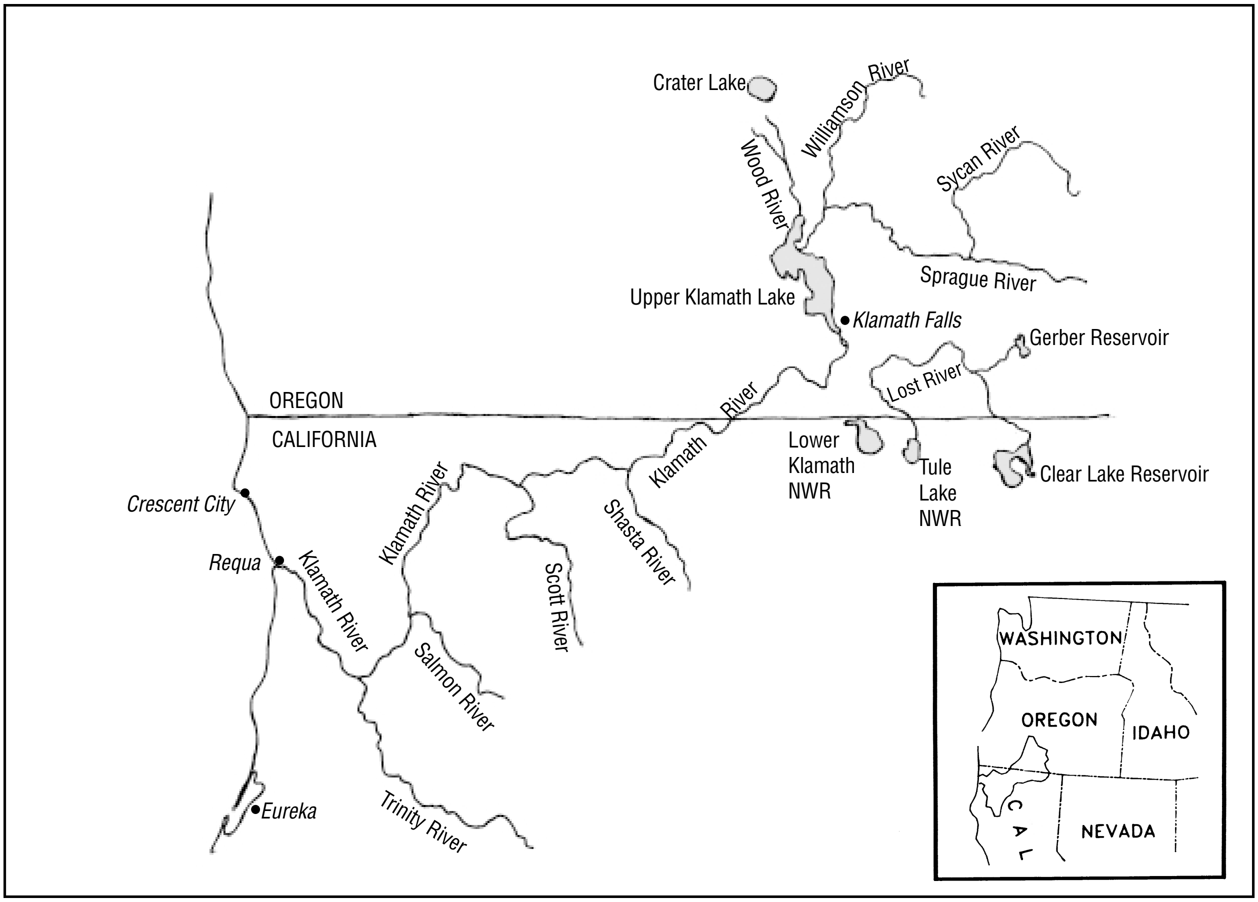


Figure 1. The Klamath Basin from its headwaters near Crater Lake, Oregon, to its mouth at Requa, California.

Upper Basin

The Upper Basin is considered to be the area upstream of Iron Gate Dam or from the Oregon–California border (the dam is only a few river miles downstream from the state line). The Upper Basin is cut roughly in half by the Oregon–California state line (Figure 2).

The primary body of water in the Upper Basin is Upper Klamath Lake, a large but very shallow natural lake on the Oregon side of the border. The lake is fed by the Williamson and Wood rivers, as well as by several springs. Water leaves the lake via the Link River, which empties into Lake Ewauna and then flows down the Klamath River to the Pacific Ocean.

There are six dams on the Klamath River from Upper Klamath Lake to Iron Gate Dam. Dam development over the past several decades has affected river flows and the ability of fish to return to their natal stream to spawn.

The California part of the Upper Basin contains parts of the Lost River system, which includes Tule Lake and Clear Lake (now a reservoir). This system is connected to the Klamath River via human-made structures of the Klamath Reclamation Project.

The Upper Basin is a high-elevation, short-growing-season area. The Cascade Mountains to the west trap most of the coastal moisture, leaving the east side of the mountains cool and dry. Forest lands cover about two-thirds of the Basin, and most of the remaining third is arable land. The eastern and southern sides of the Basin are formed by sagebrush- and juniper-covered fault blocks and ridges.

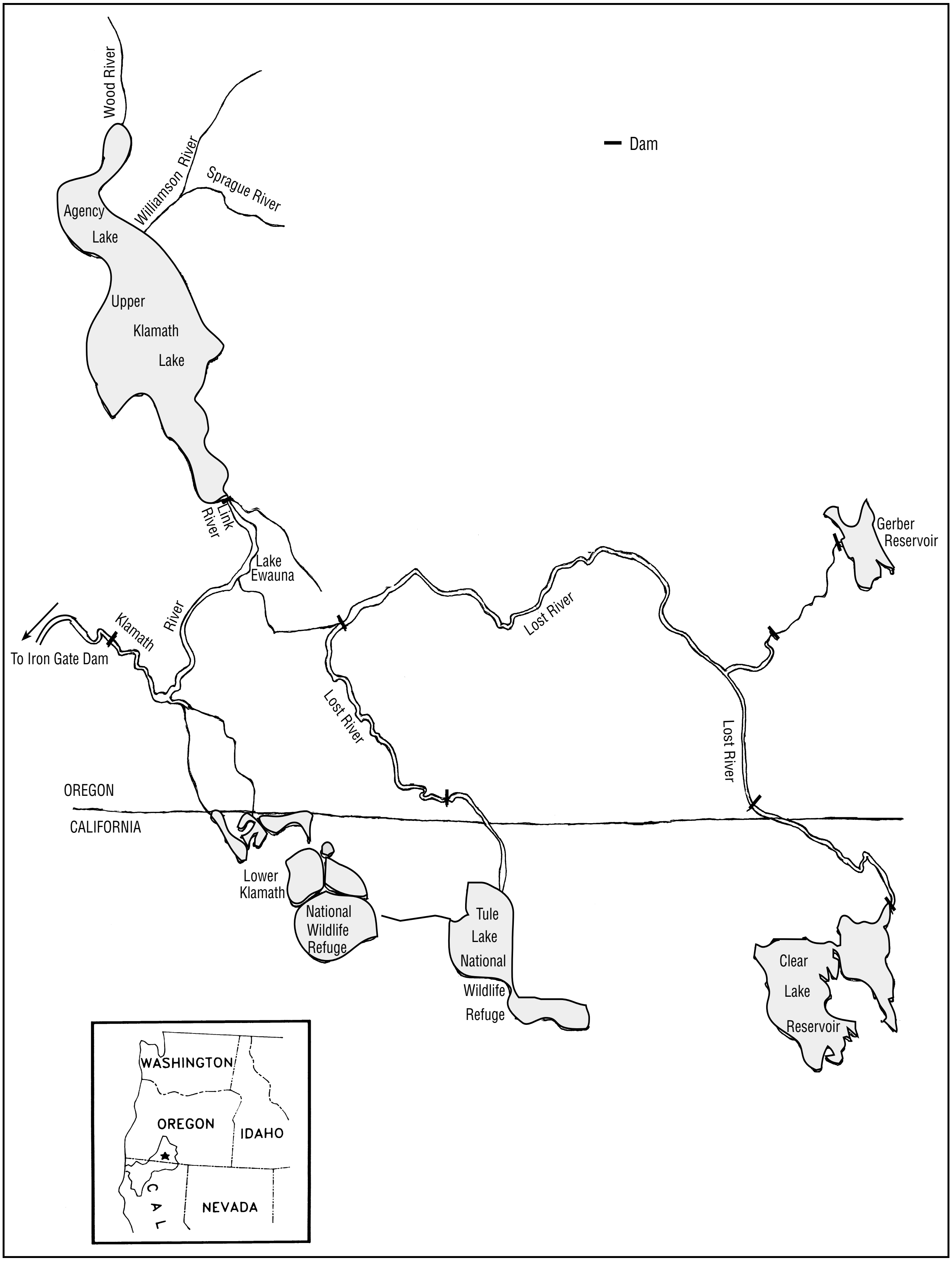


Figure 2. The Upper Klamath Basin.

The area around Upper Klamath Lake averages only about 14 inches of rain per year. Water resources in the Basin depend on annual recharge of groundwater and stream flows by melting snow, most of which falls at the higher elevations. Drought is not unprecedented in the Basin. Multiple years of low precipitation were experienced several times during the 20th century. Prior to 2000–2001, the most recent critically dry years were 1992 and 1994.

Lower Basin

The Lower Klamath Basin—the area downstream from Iron Gate Dam—is made up of the middle and lower sections of the Klamath River and the tributary subbasins of the Shasta, Scott, Salmon, and Trinity rivers. All of these tributary systems have been highly altered by irrigation dams and/or diversion of water for irrigation except the Salmon, which was extensively dredged for gold.

The lower part of the watershed near the Pacific Ocean is a temperate rainforest. Much of the lower Klamath River is included in the federal Wild and Scenic River system.

The Upper Klamath Basin before agricultural development

Land and water

Prior to European-American settlement and agricultural development, the Upper Basin contained large complexes of wetlands associated with streams and lakes. A large portion of Upper Klamath Lake was surrounded by wetlands.

In the southeastern portion of the Basin, the Lost River followed a circuitous route from Clear Lake to Tule Lake, a large, marsh-fringed lake. High water during normal spring runoff annually recharged wetlands throughout much of the course of the Lost River. The river got its name because it had no outlet to the sea and ended 6 miles from its source.

In the southwestern portion of the Basin, marshy Lower Klamath Lake was fed by high flows from the Klamath River during the wet season via the Klamath Straits.

Native Americans

The Klamath Indians have hunted, fished, and foraged in the Upper Klamath Basin for many generations. There currently are about 3,300 tribal members.

Fishery and other natural resources provide religious, cultural, subsistence, and commercial support for the Tribes. The decline of these resources has had broad cultural, economic, and social consequences for the Tribes.

The United States has a treaty responsibility to protect tribal trust resources. In general, the United States is required to protect tribal fishing, gathering, hunting, and water rights. Tribal fishing rights require that sufficient water be retained in waterways to support fishery resources. Indian water rights are considered to date from "time immemorial," meaning they predate, and have priority over, any other water rights. These rights have been upheld and clarified by court rulings, but they have yet to be quantified through the adjudication process.

The Klamath Reclamation Project

The Klamath Reclamation Project was one of the first federal reclamation projects developed under provisions of the Reclamation Act of 1902. The Project was designed to convert many of the lakes and marshes of the Upper Klamath Basin to agricultural lands and waterfowl refuges.

Project development

As the Project developed, the area began to change from a shallow lake-marsh system to an agricultural and waterfowl refuge system. Much of Tule Lake was converted to agricultural land and a wildlife refuge by preventing the annual recharge of wetlands by the Lost River. Part of the Lost River drainage was diverted to the Klamath River, and Clear Lake was expanded for water storage. Tule Lake now consists of two small areas known as sumps.

A railroad grade was constructed, which blocked the flow from the Klamath River to Lower Klamath Lake, thus converting much of the land in the Lower Klamath Lake area to agricultural land and a wildlife refuge.

In the northern portion of the Basin, about 40,000 acres of wetlands surrounding Upper Klamath Lake were diked off, drained, and converted to agricultural use.

Dams were built throughout the Basin to control the flow of water and divert it as needed, and canals were constructed to convey irrigation water from Upper Klamath Lake, the Klamath River, and the Lost River system to the newly converted agricultural lands and wildlife refuges.

Under authority of the Reclamation Act, the Bureau of Reclamation (BOR) entered into contracts with various irrigation districts. These contracts provided for the repayment of Project costs, the granting of rights to use Project water, and delivery of water. The contracts are all written in perpetuity. Irrigators are assessed annual operation and maintenance charges by the districts.

Homestead Project lands

Under provisions of the 1902 Reclamation Act, the newly reclaimed agricultural lands were opened for homesteading. Homesteaders were assessed construction charges to repay Project costs. The first public lands became available to homesteaders in March 1917, and the Tule Lake area was open from 1922 to 1948. World War I veterans were eligible for the early homesteads, and the last homesteads were open to World War II veterans. Many of today's Project farmers are descendants of homesteaders.

Current Project operations

In 2001, the Project included 240,000 acres of irrigable land plus 86,000 acres of national wildlife refuge lands (Figure 3). The Project generally provides water to about 200,000 acres of agricultural lands, including about 130,000 acres in Oregon and 70,000 acres in California. Overall, the Project is operated by the U.S. Bureau of Reclamation, although many of the individual structures and canals are operated by irrigation districts.

Water is diverted from the Klamath River and Lost River systems for irrigation and refuge use. The primary storage facility in the Klamath River system is Upper Klamath Lake. Gerber Reservoir and Clear Lake store water for the Lost River system (Figure 3). Water is delivered through a network of canals to lands throughout the Project area.

The Project is noted for high irrigation efficiencies, which are achieved through Project-wide water reuse. Applied irrigation water that is not used by crops (known as return flows) is captured in drains and pumped to lateral canals so that it can be reused by other irrigators.

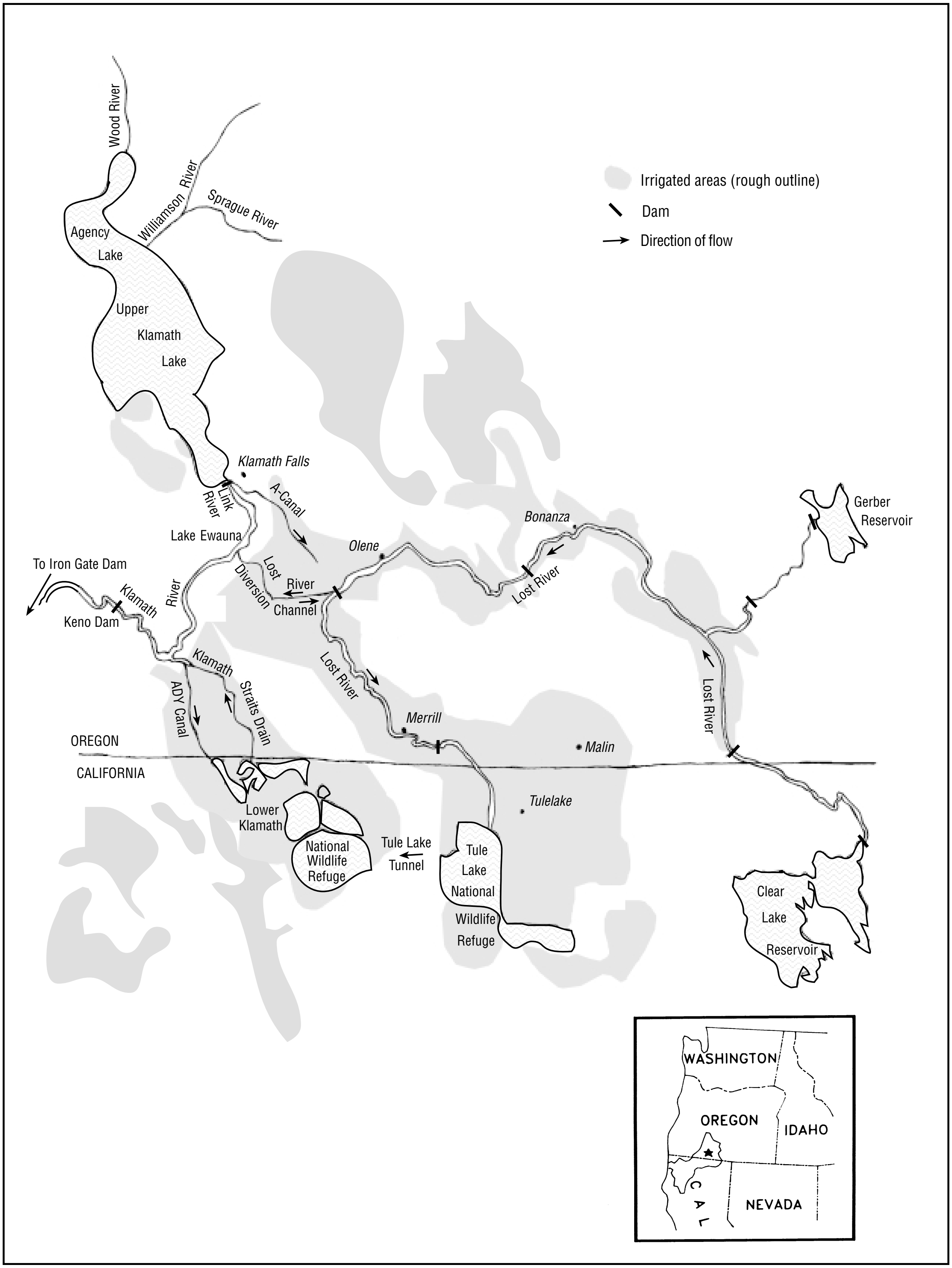


Figure 3. The Upper Klamath Basin, showing irrigated areas and key features of the Klamath Reclamation Project. (A more detailed map of the Project is found in Chapter 2, "Klamath Reclamation Project").

The Upper Klamath Basin economy

The Upper Klamath Basin is home to about 120,000 people. The Basin economy produced $4 billion worth of output in 1998 and provided almost 60,000 jobs. In 1998, the sectors with the largest shares of output were wood products, agriculture, construction, and health care/social assistance. The sectors with the largest shares of employment were retail trade, agriculture, educational services, and health care/social assistance.

Agriculture in the economy

The regional value of agricultural production in 1997 was estimated to be $239 million. Project lands produced about $109 million of this total. There were 2,239 farms in the Upper Basin in 1997 (defined as producing $1,000 or more of agricultural products annually). The principal crops in terms of acreage are alfalfa hay, pasture (for beef cattle), and barley, followed by other hay, potatoes, and wheat. Other crops of importance include oats, onions, peppermint, and horseradish.

Wildlife refuges in the Upper Basin

A strategic junction in the routes of the Pacific Flyway, the Upper Klamath Basin annually hosts the largest concentration of migratory waterfowl in North America. A variety of other animals, birds, and fish inhabit the area, including the largest wintering population of bald eagles in the United States outside of Alaska. The two principal national wildlife refuges (NWR) in the Basin are Tule Lake NWR and Lower Klamath NWR (Figure 3).

Tule Lake NWR consists of two large marsh sumps (remnants of the former Tule Lake) surrounded by cropland, which is managed in part to provide grain for migrant waterfowl. Some refuge lands are leased to private farmers. The refuge is fed by the Lost River and return flows from agricultural irrigation.

Lower Klamath NWR consists of permanent marshes and seasonal wetlands, as well as uplands and croplands managed for migrant and breeding waterfowl and associated wildlife. The seasonal marshes are flooded in fall and allowed to dry during spring and summer. The refuge receives water from Tule Lake NWR via the Tule Lake Tunnel and from the Klamath River via the ADY Canal.

The Bureau of Reclamation has an obligation to ensure that the refuges receive adequate water to fulfill their purposes, as long as water is available. Because the refuges were created after authorization of the Project, the refuge water rights are junior to those of the Project.

Water rights adjudication in the Upper Basin

Since 1909, the right to use surface water in Oregon has been governed by a permitting process that establishes how much water may be used and for what purposes. Any use of water that began before that time is subject to quantification in an adjudication proceeding. During adjudication, pre-1909 water rights are verified, documented, and quantified. The right holder then receives a decreed right for a specific amount of water with a specific priority date.

The Klamath Basin Adjudication (KBA) process began in 1975. It covers much of the Oregon portion of the Upper Klamath Basin. The Lost River, North and South Forks of the Sprague River, and portions of the Wood River are not included, as they already have been adjudicated.

Approximately 700 claims were filed in the KBA, including about 300 private claims and 400 claims by various agencies of the U.S. government and the Klamath Tribes. As part of the adjudication process, the claims were made available for public inspection. Approximately 5,600 contests were filed to oppose claims. All of the contests have been referred to the state Central Hearing Panel, and proceedings on several groups of contests are ongoing.

Since 1997, a voluntary Alternative Dispute Resolution process has been underway to provide a forum to address adjudication claims and related matters. The ADR process is intended to provide a way to resolve KBA contests as well as a forum for addressing broader water issues in the Basin.

The Klamath River Basin Compact

The Klamath River Basin Compact was ratified by Congress on September 11, 1957. The purpose of the Compact is to deal with water resources in the Klamath River Basin—"to facilitate and promote orderly development, use, conservation and control thereof." Additional purposes are to further cooperation among state and federal agencies, to establish preferential uses of water, and to prescribe relationships between beneficial uses of water.

Article III of the Compact established the following order of use for water: (1) domestic use, (2) irrigation use, (3) recreational use, including use for fish and wildlife, (4) industrial use, (5) generation of hydroelectric power, and (6) such other uses as are recognized under laws of the state involved.

Article IX created a three-member commission to administer the Compact. The commission includes one member from the California Department of Water Resources, one from the Oregon State Water Resources Board, and one federal representative appointed by the President.

Article X states that nothing in the Compact shall be deemed to: (1) adversely affect the rights of Indian tribes to use the waters of the Klamath River Basin for irrigation, (2) deprive Indian tribe(s) of rights afforded under federal treaty, or (3) affect the obligations of the United States to the Indian tribes.

Downstream fisheries

Lower Basin fisheries historically supported Indian and non-Indian communities along the Klamath River and on the coast. In addition to coho salmon, other important fish species in the river include chinook salmon, steelhead trout, Pacific lamprey, green sturgeon, eulachon (candlefish), and coastal cutthroat trout. Populations of all of these species have dwindled.

Like the Klamath Tribes in the Upper Basin, the Yurok, Karuk, and Hoopa Valley tribes in the Lower Basin have experienced cultural, economic, and social stresses as a result of the decline of fishery resources. Court rulings have established that the Yurok Tribe has a federally reserved fishing right that requires in-stream flows sufficient to maintain fisheries needed to support their lifestyle.

The Endangered Species Act

The Endangered Species Act (ESA) was passed by Congress in 1973. Its purposes are to: (1) conserve endangered and threatened species, (2) conserve the ecosystems upon which these species depend, and (3) aid in species recovery so that protected status no longer is necessary.

Coho salmon in the Klamath River below Iron Gate Dam and shortnose and Lost River suckers in Upper Klamath Lake are protected under the ESA. Protection of these native species was a major factor in the 2001 water allocation decisions for the Klamath Reclamation Project.

Species decline and listing under the ESA

Suckers

Large populations of suckers in Upper Klamath Lake were utilized historically by Native Americans and later by a popular sports fishery. Between 1966 and 1985, however, the annual harvest dropped from about 12,500 fish to less than 700. The State of Oregon closed the sucker fishery in 1986. The Lost River and shortnose suckers were listed as endangered by the U.S. Fish and Wildlife Service (USFWS) in 1988.

Sucker populations seemed to be increasing from 1988 to 1995, but those gains were diminished in a series of massive fish kills in 1995–1997, which were caused by a bacterial infection associated with changes in water quality.

Coho salmon

Historically, the Klamath River Basin sustained relatively large coho salmon populations. Over time, coho salmon stocks have been greatly reduced and now consist largely of hatchery fish. Only small runs of wild coho salmon remain in the Basin.

Southern Oregon and California wild coho salmon were listed as threatened under the ESA in 1997. Because coho salmon are anadromous fish (they spawn in freshwater and mature in the ocean), they were listed by the National Marine Fisheries Service (NMFS).

The ESA consultation process

The ESA requires all federal agencies to ensure that their actions are not likely to jeopardize the continued existence of any endangered or threatened species or to result in the adverse modification of such species' habitat. When any listed species might be affected by an agency action, Section 7 of the ESA requires the agency to consult with the agency responsible for listing the species.

In the case of the Klamath Reclamation Project, the Bureau of Reclamation must consult with the USFWS regarding possible effects of its annual Project Operations Plans on suckers and bald eagles, and with the NMFS regarding possible effects on coho salmon.

The BOR first prepares a Project Operations Plan, which lays out planned water management for the year and contains a Biological Assessment (BA) of likely effects on suckers, coho salmon, and bald eagles. The USFWS then determines whether the proposed operations are likely to jeopardize suckers or bald eagles, and the NMFS does the same for coho salmon. If jeopardy to any of these species is found to be likely, the appropriate agency (USFWS or NMFS) prepares a proposed alternative for Project operations, known as a Reasonable and Prudent Alternative (RPA). Each agency then issues a final Biological Opinion (BiOp), containing its assessment and RPAs. The BOR then must decide whether to adopt the RPAs.

Biological Opinions prior to 2001

Suckers

Beginning in 1989, after the Lost River and shortnose suckers were listed as endangered under the ESA, the BOR has been required to consult with the USFWS on the likely effects of Project operations on suckers. The question in this case is the effect of water withdrawals from Upper Klamath Lake on fish habitat.

The USFWS issued its first BiOp on suckers in 1992. The BiOp determined that the proposed operation of the Project was likely to have serious effects on sucker survival. This BiOp set the minimum summer lake elevation for Upper Klamath Lake at 4,139 feet above mean sea level. The summer elevation was allowed to drop to 4,137 feet in critically dry years—but no more than 4 times during a 10-year period or 2 consecutive years. The BiOp also included other measures designed to improve water quality and sucker habitat.

Coho salmon

Considerations for lower Klamath River coho salmon relate to water releases at Iron Gate Dam (IGD) to maintain flows in the lower Klamath River. Prior to 1999, IGD minimum flows were based on provisions of PacifiCorp's license for its power-generating dams (licensed by the Federal Energy Regulatory Commission, or FERC). These flows were subject to water availability and senior water rights, however, and they were not always met.

In 1999, a wet year, the BOR held its first formal consultation with the NMFS regarding effects of Project operations on coho salmon. After the BOR proposed operating the Project in 1999 to meet minimum Iron Gate Dam flows higher than those set by FERC, the NMFS issued a BiOp stating that Project operations were not likely to jeopardize coho salmon.

The events of 2001

Drought

Snowpack surveys in the winter of 2001 indicated the lowest expected inflow on record to Upper Klamath Lake. Total precipitation recorded at Klamath Falls from October 1, 2000 through April 1, 2001 was 3.01 inches, about 32 percent of normal.

Biological Opinions

Because the previous BiOps for both suckers and coho salmon had expired, the BOR was required to reinitiate consultations with the USFWS and the NMFS for operation of the Project in 2001.

Suckers

On February 13, 2001, the BOR provided the USFWS its Biological Assessment of the effects of Project operation on shortnose and Lost River suckers and requested reinitiation of formal consultation. The proposed Operations Plan would have resulted in dropping the elevation of Upper Klamath Lake to 4,136.8 feet in late summer. On March 13, 2001, the USFWS issued a draft BiOp, which concluded that operation of the Project as proposed by the BOR was likely to jeopardize suckers.

On April 5, 2001, the USFWS released its final BiOp, which included Reasonable and Prudent Alternatives for minimum lake elevations. The minimum elevation was set at 4,140 feet. Because of the anticipated water shortfall, subsequent coordination among affected agencies and interested parties led to some reductions in the minimum elevation for 2001.

Thus, the 2001 BiOp differed from the 1992 BiOp in two key respects: (1) the 4-in-10 year lower elevation of 4,137 feet was eliminated, and (2) the long-term minimum elevation was raised from 4,139 to 4,140 feet (Table 1).

Coho salmon

On January 22, 2001, the BOR forwarded its Biological Assessment of effects of Project operation on coho salmon to the NMFS. Based on its proposed operation of the Project, flows at Iron Gate Dam were expected to be as low as 398 cfs in late summer during critically dry years (such as 2001). On March 19, 2001, the NMFS completed its draft BiOp, which found that the proposed operation would jeopardize coho salmon.

On April 6, 2001, the NMFS released its final BiOp and RPA, which established April-through-September 2001 IGD flows ranging from 1,000 to 2,100 cfs (Table 2). These

Table 1. Upper Klamath Lake elevation under the 1992 Biological Opinion, the BOR 2001 proposed Operations Plan, and the 2001 Biological Opinion.

	Surface elevation above mean sea level (feet)		
	USFWS 1992 BiOp	2001 BOR proposal	USFWS 2001 BiOp
Minimum summer elevation (except in critically dry years)	4,139	4,137.6–4,138.9[a]	4,140
Minimum summer elevation in critically dry years	4,137[b]	4,136.8	—[c]

[a]Lower elevation in dry water years; higher elevation in above-average water years

[b]Permitted in no more than 2 consecutive years and no more than 4 out of 10 years

[c]To be coordinated among the BOR, USFWS, NMFS, and other agencies, tribes, and affected parties

Table 2. Flows at Iron Gate Dam under FERC minimums, the 1999 Project Operations Plan, the BOR 2001 proposed Operations Plan, and the 2001 Biological Opinion.

	Minimum flows at Iron Gate Dam (cfs)			
	FERC	1999	Expected during critically dry years based on BOR proposal	NMFS final 2001 Biological Opinion
April	1,300	3,310	569–574[a]	1,700
May	1,000	3,060	501–525[a]	1,700
June	710	2,250	476–536[a]	1,700–2,100[a]
July	710	1,710	427–429[a]	1,000
August	1,000	1,350	398	1,000
September	1,300	1,400	538	1,000

[a]Depending on the time of the month

flows were higher than the FERC minimums; however, in response to the critically dry year, they were lower than the 1999 flows. In its final Operations Plan, the BOR adopted the RPAs in the Biological Opinion.

Curtailment of irrigation diversions from Upper Klamath Lake

On April 6, 2001, the Bureau of Reclamation Klamath Project Area Office mailed a notice to Project water users below Upper Klamath Lake who receive water primarily from the lake, notifying them that "Project water would not be available for use until such time as the 2001 Operations Plan or other such written notification is completed." Following are excerpts from the letter:

> "Current conditions indicate a potential for shortage of water in the upper basin and, if precipitation does not increase significantly over the next few months, severe water shortages are likely during the upcoming 2001 irrigation season. Therefore, you are notified that Project water is not available for use until such time as the 2001 Operations Plan or other such written notification is completed.
>
> Reclamation is in the process of developing the 2001 Annual Operations Plan. Biological opinions resulting from current consultations will be a critical part of the plan's formulation. While it is possible that there may be drastic reductions in Project agriculture and refuge deliveries in 2001, Reclamation is working diligently to avoid such an outcome. However, until Reclamation completes the consultation process, no diversion of Project water may occur that would result in a violation of Section 7(d) of the ESA which prohibits '…any irreversible or irretrievable commitment of resources…' pending completion of consultation. To date, Reclamation has not made a determination as to whether and to what extent Project water could be delivered in advance of completed consultations. Thus, until such a determination is made or the consultations are completed, no Project water may be diverted or used unless expressly authorized by Reclamation…."

Ultimately, the combined effects of a low water supply, minimum lake elevation, and minimum Iron Gate Dam flows prevented the diversion of water from Upper Klamath Lake for Project irrigation or for the Tule Lake and Lower Klamath national wildlife refuges. About 1,200 farms, or 85 percent of normally irrigated Project lands, were affected.

Deliveries in the Lost River portion of the Project above Harpold Dam from Clear Lake and Gerber reservoirs were made on a regular schedule for the 2001 season. Farmers in the affected portions of the Project did utilize supplemental irrigation water from wells, exchanges, and purchased sources. In addition, in July and August, the Department of the Interior was able to release about 40,000 acre-feet of water from Upper Klamath Lake for irrigation deliveries due to unanticipated increases in net inflow.

The Lower Klamath National Wildlife Refuge received approximately 23,900 acre-feet of water from January 10 to October 30, 2001, approximately 30 percent of normal. In November, additional water was delivered by fall precipitation, water removal from Sump 1A, and continued delivery through the ADY Canal. An additional 12,000 acre-feet were released for refuge use in December.

Key water-related events in the Upper Klamath Basin

1864—United States and Klamath and Modoc tribes enter into a treaty establishing the Klamath Reservation.

1902—Reclamation Act passed by Congress.

1905—Klamath Reclamation Project authorized and construction begins with the aim of converting much of the marshy Klamath Lake and Lost River systems to agricultural land and wildlife refuges.

1908—Lower Klamath National Wildlife Refuge established.

1917—First Project lands opened to homesteaders.

1928—Tule Lake and Upper Klamath Lake national wildlife refuges established.

1948—Final homestead lands distributed.

1957—Klamath River Basin Compact established by Congress to deal with water resource issues in the Basin.

1973—United States eliminates the Klamath Reservation, after having purchased much of the land for national forests and wildlife refuges.

1975—Klamath Basin Adjudication begins the process of quantifying pre-1909 water rights.

1986—Sport fishery on suckers closed by the State of Oregon.

1988—Lost River and shortnose suckers listed as endangered under the Endangered Species Act.

1992—U.S. Fish and Wildlife Service issues first Biological Opinion on effects of Project operation on suckers, resulting in establishment of minimum elevations for Upper Klamath Lake.

1997—Alternative Dispute Resolution process established to resolve claims under the Klamath Basin Adjudication process.

—Southern Oregon and California wild coho salmon listed as threatened under the Endangered Species Act.

1999—National Marine Fisheries Service issues first Biological Opinion on effects of Project operations on coho salmon, finding no jeopardy to the species, contingent upon specific minimum Klamath River flows.

2000—Low precipitation and snowpack lead to predictions of the lowest inflow on record to Upper Klamath Lake for 2001.

2001—U.S. Fish and Wildlife Service issues new Biological Opinion on suckers, resulting in a higher minimum lake elevation than that established by the 1992 Biological Opinion.

—National Marine Fisheries Service issues new Biological Opinion on coho salmon, resulting in minimum flow requirements in the Klamath River at Iron Gate Dam higher than the pre-1999 minimums but lower than the 1999 flows.

—Bureau of Reclamation informs Project irrigators that no water from Upper Klamath Lake will be available for irrigation deliveries or wildlife refuges during the 2001 growing season.

—In July, Department of the Interior releases 40,000 acre-feet of water from Upper Klamath Lake for irrigation deliveries. (Later releases of 26,000 acre-feet benefited the refuges.)

2

Klamath Reclamation Project

An Overview of the Klamath Reclamation Project and Related Upper Klamath Basin Hydrology

Kenneth A. Rykbost and Rodney Todd

This chapter briefly discusses the most important structures of the Klamath Reclamation Project, as well as related geographical, climatic, and hydrologic aspects of the Upper Klamath Basin. We look primarily at the Project and how it interacts with Basin hydrology. Thus, the focus of this chapter is on the use of water for irrigation. Other uses of water, such as for fish and wildlife, are an important part of basinwide water needs and are covered in other chapters.

In this chapter, we define the Upper Klamath Basin as the area above Iron Gate Dam. We include all of the areas that drain into the Klamath River above Iron Gate Dam, including those parts of the Klamath Reclamation Project that lie on the California side of the state line (for example, Tule Lake and Lower Klamath national wildlife refuges and Clear Lake Reservoir).

Factual data on the Bureau of Reclamation (BOR) Klamath Reclamation Project, including a map of the Project, are found in the Appendices to this chapter. While much greater detail is needed to completely and accurately define the Project and its components, the Appendix will be a useful point of reference throughout this report.

The Biological/Conference Opinion Regarding the Effects of Operation of Reclamation's Klamath Project on the Endangered Lost River Sucker, Endangered Shortnose Sucker, Threatened Bald Eagle and Proposed Critical Habitat for the Lost River/Shortnose Suckers (USFWS Biological Opinion 2001), prepared by the Klamath Falls office of the U.S. Fish and Wildlife Service (USFWS) in April 2001, provides an exhaustive description of the Project. Much of the descriptive material in this chapter has been taken from this report, with the written permission of Steven Lewis, USFWS. All material taken directly from the Biological Opinion is presented as indented quotations. Notes within brackets have been added for clarification.

Table 1 summarizes Project hydrology for the 10-year period from 1991 through 2001 based on BOR data. Several sections in this chapter will refer to the data shown in Table 1.

Water quality is a key component of questions related to water allocation and fish habitat in the Upper Klamath Basin. A detailed discussion of water quality in the Basin, and especially in Upper Klamath Lake, will be the topic of a future chapter of this report. Because of the complexity of these issues, a broad team of scientists will be involved in preparing and reviewing that chapter, and it will be available at a later date.

Table 1. Hydrologic data for the Upper Klamath Basin, 1991–2001.

Year	Total annual precip. (in)	UKL releases[a] Link River	UKL releases[a] A-Canal	Klamath River diversions North Canal	Klamath River diversions ADY Canal	Releases Gerber Reserv.	Releases Clear Lake	Discharge Straits Drain	Klamath River flow Keno Dam	Klamath River flow Iron Gate Dam
		(1,000 acre-feet)								
1991	9.29	427	264	38	108	12	34	75	340	601
1992	11.34	400	227	28	71	1	8	31	271	469
1993	14.96	1,118	223	43	91	31	28	94	1,200	1,468
1994	7.72	480	226	28	81	37	8	61	361	556
1995	19.06	893	232	49	88	30	29	87	955	1,278
1996	19.54	1,468	252	36	71	52	32	132	1,719	2,159
1997	14.29	1,366	255	40	86	60	45	100	1,521	1,884
1998	19.51	1,418	236	28	78	53	101	128	1,896	2,218
1999	11.54	1,355	282	36	91	94	118	111	1,759	2,052
2000	11.51	1,047	273	41	93	37	57	78	1,123	1,438
Mean	**13.88**	**997**	**247**	**37**	**86**	**41**	**46**	**81**	**1,115**	**1,412**
2001	10.03	714	40	16	42	35	65	18	720	1,015

[a]Releases from Upper Klamath Lake

Data are presented on a calendar-year basis. Although hydrology data for the Project usually are presented on a water-year basis (October 1 to September 30), in some respects it is easier to visualize diversions for agricultural use on a calendar-year basis.

The Project includes other key points of diversion, which are more difficult to define and are not shown here. For example, the Lost River Diversion Channel is a major component of the system, but data sets do not indicate the direction of flows through the channel. (The channel is designed so that water can flow in either direction depending on operational requirements. See the section on the Lost River Diversion Channel, below, for additional explanation.)

Sources: Precipitation data are from the Klamath Experiment Station, and flow data are from the Bureau of Reclamation Klamath Project office.

Climate conditions and weather records

Limited Klamath Falls weather records date back to 1884. The U.S. Weather Bureau monitored precipitation at Klamath Falls until an official National Oceanic and Atmospheric Administration (NOAA) station was established at the Kingsley Field Air Force Base in 1949. A weather station at the Klamath Experiment Station (KES) has been maintained since 1984. The KES station, located approximately 0.5 mile west of Kingsley Field, became the official NOAA station for Klamath Falls in 1997, when the Kingsley Field station was formally abandoned. In *Climatological Data Oregon*, the KES station is identified as Klamath Falls Ag Sta.

A third weather station for Klamath Falls is reported as station Klamath Falls 2 SSW. This station is operated by Pacific Power and Light and is located near the Klamath River.

Since 1999, the BOR has established four Agricultural Meteorological (AgriMet) stations in the region. Stations are located at KES, Agency Lake Ranch, Lower Klamath Lake area, and in the Langell Valley.

U.S. Weather Bureau annual precipitation records are complete from 1884 through 1948 except for the years 1890–1901 and 1903 (Rykbost and Charlton 2001). More detailed weather records from 1949 to the present are available from NOAA and from KES annual research reports for 1987 through 2000. Precipitation data for the KES weather station from 1991 to 2001 are shown in Table 1.

The long-term average annual precipitation at Klamath Falls is about 13 inches, with a range from less than 8 inches to more than 20 inches. When data are averaged by decade, a fairly consistent range of about 12 to 14 inches is observed.

High-elevation areas in the upper watershed receive much more precipitation. Crater Lake receives on average more than 500 inches of snowfall (a water-equivalent of more than 40 inches) and has a long-term average annual precipitation of approximately 65 inches (*Climatological Data Oregon*). The eastern flank of the Cascade Mountains is a major source of recharge for Upper Klamath Lake.

The majority of the region's precipitation occurs from November through March. Over the past 16 years, Klamath Falls has experienced on average about 5.5 inches of precipitation from April through October, out of a total annual average of 13 inches (Rykbost and Charlton 2001).

The drought of 2000–2001 started in March 2000. Total precipitation recorded at KES from March 1, 2000 through October 31, 2001 was 10.5 inches, about 55 percent of normal. The drought followed a 4-year period (1995–1998) of the highest precipitation recorded at Klamath Falls since records began. Unfortunately, limited water storage capacity did not allow the surplus water to be stored for later use.

The 2000–2001 drought, while serious, is not unprecedented. Multiple years of low precipitation were experienced in 1914–1921, 1928–1935, 1951–1956, 1965–1968, 1970–1978, and 1991–1994. During the period of full development of the Project (since 1960), 1992 and 1994 produced the most serious water supply deficiencies. Several areas within the Project experienced reduced water deliveries in 1992 and 1994, including Tule Lake and Lower Klamath national wildlife refuges.

The Upper Klamath Basin watershed

Upper Klamath Lake/Agency Lake

> "UKL [Upper Klamath Lake] (including Agency Lake), with a surface area ranging from 60,000 to 90,000 acres depending on lake levels, is currently the largest water body in the Klamath Basin. [The BOR area capacity table cites a surface area of 77,593 acres at a surface elevation of 4,143.3 feet above sea level and 44,200 acres at 4,136 feet.] Historically (before diking and drainage of properties adjacent to UKL), the lake had a surface area of about 105,000 acres (Rosborough 1917, cited by Gearheart et al. 1995).
>
> Mean summer depth is about 7 feet. Hydraulic residence time [mean time between inflow and discharge] is approximately 0.5 years. Its waters are generally well mixed because of shallowness.
>
> The major sources for UKL are the Williamson/Sprague (46% of total inflow) and Wood (15%) rivers, and various large springs (17%) which provide about 78% of the annual inflow (Miller and Tash 1967).
>
> Regulation of water levels in UKL began in 1919, with completion of the Link River Dam. By 1921, the reef at the entrance to Link River was lowered. [The reef is a natural bedrock constriction at the head of Link River; it was cut to a lower elevation with dynamite.] Prior to construction of the dam, the lake level

varied from about 4,139.9 to 4,143.1 ft, with a mean annual variation of about 2 ft (USBR [Bureau of Reclamation] data). However, the range may have been even greater, from 4,139.9 to 4,145 (USBR 2000). Since 1921, water levels have varied from 4,136.8 to 4,143.3 ft, a range of about 6.5 ft (USBR data).

Water level regulation has also changed the seasonal timing of high and low elevation by making the highest and lowest elevations occur earlier in the season as well as prolonging the period of low water. This has had profound effects on the ecology of the lake…" (USFWS Biological Opinion 2001).

A surface elevation of 4,136 feet above sea level is as low as the lake can go. Known as "dead storage," this is the level of the bottom of the Link River Dam. At lake levels above 4,136 feet, storage capacity is available for other uses, including irrigation (Table 2). Storage capacity at maximum allowed elevation of 4,143.3 feet is approximately 486,828 acre-feet. Storage capacities at 4,140 and 4,139 feet are approximately 241,000 and 174,000 acre-feet, respectively. In 1994, lake elevation declined to 4,136.8 feet, with storage capacity at 39,201 acre-feet (BOR data). Management of lake elevations at 4,140 or 4,139 feet, versus allowing the elevation to decline to dead storage at 4,136 feet, represents a reduction in available water for other uses of 241,000 or 174,000 acre-feet, respectively.

Table 2. Relationship between Upper Klamath Lake elevation and lake storage capacity.

Lake elevation (feet above sea level)	Storage capacity (acre-feet)
4,143.3	486,828
4,140.0	241,000
4,139.0	174,000
4,136.8	39,201
4,136.0	0

Source: U.S. Bureau of Reclamation

Modeling of the hydrology of Upper Klamath Lake by BOR (2001) is based on the period from 1961 through 1998. The BOR water-routing model (KPOPSIM) classifies water year-types based on April-through-September net inflows (outflow plus or minus change in storage). The average (arithmetic mean) April-through-September net inflow for the 38-year period was calculated as 500,000 acre-feet per year. Water years are classified as:

- Above average—greater than 500,000 acre-feet
- Below average—312,000 to 500,000 acre-feet
- Dry—185,000 to 312,000 acre-feet
- Critical—less than 185,000 acre-feet

The 1961–1998 era included 20 above-average, 11 below-average, 5 dry, and 2 critical year-types. The 1990s included the greatest extremes of water supply since the Project was established in 1905. In 1992 and 1994, inflows were 155,000 and 179,000 acre-feet, respectively, making them critical years. In contrast, 1995 through 1998 were above-average years.

The BOR bases its recommendations for Project operations plans on these hydrologic year-types and on estimates of potential inflow from April 1 snowpack surveys at key locations in the upper watershed. The snowpack survey for 2001 indicated a critical year-type and the lowest inflow on record. Actual net inflow to Upper Klamath Lake from April through September 2001 was about 200,000 acre-feet, thus exceeding April-through-September inflow in 1992 and 1994 and surpassing the April 1, 2001 snowpack survey estimate.

For a discussion of the 2001 BiOp's minimum lake elevation requirements, see Chapter 5 ("Suckers").

Tributaries and inflow sources for Upper Klamath Lake

Inflow contributions to Upper Klamath Lake vary with year-type hydrologic conditions. For example, in short-term drought years, springs and spring-fed streams contribute a greater portion of total inflow. In years with high rainfall and heavy snowpacks, the Williamson River system contributes a greater percentage.

Two studies have contributed to our understanding of inflows into Upper Klamath Lake. Miller and Tash (1967) used water-budget estimates based on a 14-month, relatively dry period. Hubbard (1970) estimated inflows over a 3-year period from 1965 to 1967.

Williamson River

The single largest source of inflow to Upper Klamath Lake is the Williamson River, which discharges into the northeastern part of the lake. Miller and Tash (1967) estimated the Williamson River contribution to Upper Klamath Lake inflows at 46 percent. Hubbard (1970) attributed 49 percent of inflows to the Williamson River.

The major tributaries to the Williamson River are the Sprague River (which includes the Sycan River) and Spring Creek. The headwaters of the Sprague are in the Gearheart Mountains to the east. Spring Creek dominates late-summer flows below its confluence with the Williamson River above Chiloquin, Oregon. Significant agricultural diversions out of the Williamson, Sprague, and Sycan rivers occurred even before development of the Klamath Reclamation Project.

Major wetlands in the Williamson River watershed include a combined total of more than 60,000 acres in the Williamson River (at the Klamath Marsh National Wildlife Refuge) and in the Sycan River (at Sycan Marsh, currently managed by The Nature Conservancy).

Several wetlands have been developed recently or are planned on properties adjacent to Upper Klamath Lake that were recently retired from agricultural production. These wetlands are being developed to provide wildlife habitat and improve water quality in Upper Klamath Lake. (For example, they may filter out excess nutrients that otherwise would enter the lake.) To date, about 15,000 acres of these properties have been taken out of agricultural use for conversion to water storage or wetlands. Not all of these properties have been reconnected to the lake.

Wetlands are likely to require more water than did previous agricultural production, although water use in wetlands varies, depending on climatic conditions, vegetation, extent of open-water surface area, and other factors. Kann (2001) estimates evaporation losses from open-water surfaces at 39 inches per year and from wetlands at 27 to 32 inches per year. (This is the depth of water evaporated from the water surface. A tub of water 39 inches deep would all be evaporated in an average year if no water were added.) Bidlake (1997) reported evapotranspiration (ET) loss from May through October at Wocus Bay and Sagebrush Point wetland sites in 1996 of 26 and 27 inches, respectively. Bidlake and Payne (1998) reported ET from wetland sites at Wocus Bay and Klamath Marsh National Wildlife Refuge (NWR) for May through October 1997 of 35 and 27 inches, respectively. These rates exceed water use for cereals and row crops (about 21 inches).

While these studies suggest that ET rates for wetlands are less than rates for open-water surfaces, some studies have reached different conclusions. Abtew and Obeysekera (1995) compared the ratio of ET rates for several wetland macrophyte species (large nonwoody plants) in various locations to free-water evaporation reported in several published papers. Water lily ET was reported to be 86 percent of free-water evaporation in Michigan. Two species of cattails ranged from 115 to 188 percent of free-water evaporation at Logan, Utah, and Ann Arbor Michigan, respectively. In 10 other species, ET ranged from 100 percent to more than 300 percent of free-water evaporation.

Cost–benefit analyses of the conversion of agricultural land to wetlands must consider both potential benefits to water quality and species habitat and potential effects on the water supply for other beneficial uses in the watershed. There are early reports of habitat use and benefits for endangered species from recent wetlands established at the Williamson River Delta Preserve (Bienz 2002). Yet, if wetlands were reestablished on all of the 35,000 acres adjacent to Upper Klamath Lake that were diked and drained for agricultural production, the result would be a reduction in water supply in the remainder of the watershed. If dikes were breached and direct contact with Upper Klamath Lake were reestablished, subsidence in these properties due to loss of organic soil would result in deeper water on these properties than historical levels.

Wood River

The Wood River originates as springs at Kimball Park and enters Agency Lake at its northeast corner. When Crooked Creek is included, it accounts for 18 percent of total inflow to Agency Lake (Miller and Tash 1967). Hubbard's estimate for the 1965–1967 period was 16 percent (Hubbard 1970). The Wood River includes flows from streams originating within Crater Lake National Park (Annie and Sun creeks), as well Fort Creek and Crooked Creek, which are formed by springs on the east side of the Wood River Valley.

Other inflow to Upper Klamath Lake

Sevenmile Creek and Sevenmile Canal combine flows from several springs on the west side of the Wood River Valley with return flows from irrigation diversions. The 7,200-acre Agency Lake Ranch diverted water out of the Sevenmile Canal for livestock production until the property was purchased for water storage in the late 1990s. Miller and Tash (1967) estimated that Sevenmile Canal, Fourmile Canal, Central Canal, and several small creeks contributed approximately 9 percent of Upper Klamath Lake inflow. Hubbard's estimate for these canals and creeks was 10 percent (Hubbard 1970).

Precipitation and pumped drainage from agricultural properties adjacent to the lake were estimated at 4.4 and 5.1 percent of inflow, respectively, by Miller and Tash (1967). Hubbard (1970) estimated drainage from agricultural properties adjacent to Upper Klamath Lake at 4 percent of inflow.

The remaining 17.4 percent of lake inflows was estimated by Miller and Tash (1967) to come from springs discharging directly to the lake. Hubbard (1970) attributed remaining inflow to springs and seeps (14 percent) and precipitation falling directly on the lake (7 percent). Both studies estimated inflow from springs and seeps as the residual from the hydrologic budget after all other inflows, outflows, and changes in storage had been accounted for.

Discharges from Upper Klamath Lake

Miller and Tash (1967) estimated that 20.4 percent of the water that leaves Upper Klamath Lake is lost to evaporation. Discharges to the Link River and A-Canal account for 78 percent, and 1.5 percent is used for pumping and direct diversions to agriculture on properties adjacent to the lake.

Link River/Lake Ewauna/Klamath River

Discharges from Upper Klamath Lake over the Link River Dam traverse about 1 mile in Link River, before entering Lake Ewauna and then the Klamath River. They later flow over Keno Dam (21 miles below the Link River) and leave the Upper Basin at Iron Gate Dam.

Elevations in the Klamath River above Keno can vary by as much as 3 feet, but they are maintained within a range of about 6 inches most of the time. Flows at Link River Dam are managed to meet required flow targets at Iron Gate Dam. Upper Klamath Lake releases to the Link River, as well as flows at Keno Dam and Iron Gate Dam, for the period from 1991 through 2001 are shown in Table 1.

In addition to Klamath Lake discharges, the Klamath River above Keno receives inflow from the Lost River Diversion Channel and the Klamath Straits Drain (usually during periods of high flow in winter and spring), from the Klamath Falls and South Suburban sewage treatment plants and storm runoff, and from the Collins Products and Columbia Plywood mills.

Irrigation diversions out of the river include the Lost River Diversion Channel, ADY Canal, North Canal, Keno Irrigation District diversion, and numerous small irrigation diversions to individual farms and ranches. Data for the ADY Canal and the North Canal are shown in Table 1.

Between Keno Dam and Iron Gate Dam, accretions from springs and minor tributaries add about 300,000 acre-feet annually or about 400 cfs averaged over the year (BOR data). During the April-to-September irrigation season, accretions below Keno usually are in the range of 250 to 350 cfs. In the drought years of 1992 and 1994, annual accretions were about 200,000 acre-feet, or about 280 cfs when averaged over the year.

Entrainment, or passage, of endangered suckers into Lake Ewauna is a potential problem for which there currently is no resolution. Poor water quality in Lake Ewauna and the Klamath River above Keno is well recognized.

Major elements of the Klamath Reclamation Project

A-Canal

> "The A-Canal (Main), constructed in 1905, was the first irrigation facility completed on the Klamath Project. The canal supplies irrigation water, either directly or indirectly through return flows [applied irrigation water that is not used by crops and is captured primarily in drains and pumped to lateral canals], to the majority of the Project.
>
> The headworks for the canal are located on Upper Klamath Lake west of the city of Klamath Falls and are operated by the Klamath Irrigation District (KID). The earth channel with lined sections is 60 ft wide x 8 ft deep x 9 miles long. Maximum flow is 1,150 cfs.
>
> The canal is operated on a demand basis. Generally, the canal is charged with water in March or April. Flows average 500 cfs for the charge-up period. Orders for water are placed by irrigators with the watermaster [an employee of KID, not the state watermaster] who then schedules the flow in the canal. At the end of the irrigation season, generally during October, the canal is drained into the Lost River and the Lost River Diversion Channel" (USFWS Biological Opinion 2001).

Typical diversion through the A-Canal includes extended periods of flows on the order of 1,000 cfs. During the 1990s, total annual diversions through the canal ranged from about 220,000 to 280,000 acre-feet. During the drought years of 1992 and 1994, the A-Canal diversions were 227,000 and 226,000 acre-feet, respectively (Table 1).

Entrainment of endangered suckers into the A-Canal is a major concern for future operations of the Project. For several years, the BOR and the USFWS have been recovering entrained fish during the draining of the canal in October and returning them to Upper Klamath Lake.

The BOR, KID, and other interested parties have been working since 1995 to develop a screening system to prevent fish from getting into the canal. Because the canal intake is near the lake's outlet at the Link River Dam, currents around the intake are complex and are influenced by lake elevation and flows to either structure. Preliminary screen designs have been evaluated but have not proven satisfactory. The bid for the final design of screens for the A-Canal was let in September 2001. A-Canal screening should be in place in 2003.

Clear Lake Dam and Reservoir

> "Clear Lake Dam is located in California on the Lost River about 39 miles southeast of Klamath Falls, Oregon, and provides storage for irrigation and reduced flow into the reclaimed portion of Tule Lake and the restricted Tule Lake Sumps in Tule Lake National Wildlife Refuge. [Water is held in Clear Lake Reservoir to reduce downstream flows to former wetlands that have been converted to agricultural use and a wildlife refuge.]
>
> The dam is an earth and rock fill structure with a crest length of 840 ft and a height

of 36 ft above the streambed. The crest of the dam is at elevation 4,552.0 ft and is 20 ft wide. At the normal maximum water surface elevation of 4,543 ft, the dam will impound a total of 527,000 acre-ft in Clear Lake Reservoir.

Clear Lake Dam was constructed in 1910 to increase the storage capacity of the pre-existing lake, and to control releases of water for irrigation and flood control. It was also designed to increase evaporation rates by creating a large lake with shallow depths in order to reduce downstream flows to reclaimed wetlands near Tule Lake; thus it is not an efficient water storage facility. Seepage losses are also high. Annual evaporation and seepage losses account for over half of the average inflow of water, 128,120 acre-ft, at higher elevations.

At maximum storage capacity of 4,543 ft above mean sea level, the reservoir has a surface area of 25,760 acres and a maximum depth of about 30 ft. However, Clear Lake elevations have only surpassed 4,540 ft in four years since 1910 and have never reached maximum storage (U.S. Fish and Wildlife Service 1992); recently Reclamation has had to control lake levels because of dam safety issues.

Approximately 8,000 acres of irrigated land in the Langell Valley depend on water from Clear Lake. These irrigation projects operated by Langell Valley and Horsefly irrigation districts divert approximately 36,000 acre-ft of water each year from Clear Lake (U.S. Fish and Wildlife Service 1994). [Langell Valley and Horsefly irrigation districts include a total of 26,000 irrigated acres.]

Prior to construction of the dam a natural lake and marsh/meadow existed. During most years the Lost River below the present dam would run dry from June through October.

Since construction, Clear Lake has been lower than the October 1992 elevation [the1992 Biological Opinion minimum lake elevation of 4,519.29 feet] in only 4 years, all during the prolonged drought of the 1930s. In 1934, the water surface elevation was the lowest on record, reaching 4,514.0 ft. Contour maps provided by Reclamation indicate the lowest lake bed elevation is 4,513.09 ft. Pre-impoundment elevation records for Clear Lake only exist for a few years (1904–1910), but 4,522 ft is the lowest elevation recorded for the natural lake. Inflow to Clear Lake averages 128,120 acre-ft but has varied from 18,380 acre-ft in 1933–1934 to 368,550 acre-ft in 1955–1956 (U.S. Fish and Wildlife Service 1994).

The outlet at Clear Lake is opened in the spring, usually around April 15, to provide irrigation water to the Langell Valley Irrigation District (LVID), Horsefly Irrigation District (HID) and private "Warren Act" contract lands. [Warren Act contracts provide for a water supply at a certain point, with responsibility of the contractor to construct, operate and maintain all necessary conveyance facilities.] In most years the outlets are shut off around October 1. No other releases are made from the dam unless an emergency condition dictates otherwise. Since the reservoir has a storage limitation of 350,000 acre-ft from October 1 through March 1, summer drawdown releases are occasionally necessary" (USFWS Biological Opinion 2001).

During the high precipitation years from 1995 through 1998, Clear Lake was allowed to fill to only approximately 400,000 acre-feet because of concern for the integrity of the earthen dam. Construction began on a new structure immediately below the existing dam in

September 2001 at an estimated cost of $6 million (Cook 2001).

Although raising the dam at Clear Lake has been suggested as an opportunity for storage augmentation, the failure to fill the reservoir in its 90-year history indicates this is not likely to increase water supply. The new structure will simply allow storage to return to its original design capacity.

The BOR's Biological Assessment proposed a minimum elevation in Clear Lake of 4,519.29 feet. The 2001 Biological Opinion required a minimum elevation of 4,521 feet on September 30. The difference in storage between these two levels is about 17,000 acre-feet.

Releases from Clear Lake from 1991 to 2000 averaged 46,000 acre-feet on a calendar-year basis (Table 1). The range was from 8,000 acre-feet in both 1992 and 1994 to 118,000 acre-feet in 1999. Net recharge of the reservoir (releases plus or minus the change in storage) was –36,000, –33,000, and –60,000 acre-feet in 1991, 1992, and 1994, respectively, and +187,000 acre-feet in 1995. In 2000, the reservoir experienced a net recharge of –500 acre-feet. Long-term average inflow to Clear Lake is reported to be 117,000 acre-feet (BOR data).

Gerber Dam and Reservoir

> "Gerber Dam is located on Miller Creek about 14 miles east of Bonanza, Oregon. Gerber Reservoir has a surface area of 3,830 acres and an active capacity of 94,270 acre-ft at the spillway crest, elevation 4,835.4 ft. In an average year, Gerber Dam, the source of water for Miller Diversion Dam, releases about 40,000 acre-ft of irrigation water.
>
> Construction of Gerber Dam was completed in May of 1925. The reservoir is used to store seasonal runoff to meet irrigation needs (17,000 acres) of the Project, primarily for the Langell Valley Irrigation District (LVID), and to limit runoff into Tule Lake. Prior to construction of the dam, no reservoir existed and Miller Creek would run dry from June to October in most years" (USFWS Biological Opinion 2001).

Proposals have been made to raise Gerber Dam by 3 to 5 feet. This is projected to increase storage capacity by up to 20,000 acre-feet at a cost of approximately $3 million (Cook 2001, personal communication). However, in most years, Gerber Reservoir does not receive sufficient inflow to fill current capacity.

The BOR proposed a minimum elevation of 4,796.52 feet for Gerber Reservoir for 2001. The Biological Opinion required a minimum elevation of 4,802 feet on September 30. The difference in storage at these elevations is less than 4,000 acre-feet (BOR data).

The average release from Gerber Reservoir for calendar years 1991–2000 was 41,000 acre-feet per year (Table 1). Releases ranged from 1,000 acre-feet in 1992 to 94,000 acre-feet in 1999. Net recharge, as defined above, has ranged from –100 acre-feet in 1994 to +84,000 acre-feet in 1995. Average inflow is 55,000 acre-feet (BOR data).

The 2001 Biological Opinion allowed for diversion of a combined volume of 70,000 acre-feet from Clear Lake and Gerber Reservoir for irrigation in the Langell Valley and Horsefly irrigation districts and for maintaining a minimum lake level in Tule Lake. As of late September, the 2001 combined releases from these reservoirs were about 100,000 acre-feet (Table 1).

Lost River

The Lost River traverses approximately 100 miles from Clear Lake Reservoir to Tule Lake. Before implementation of the Klamath Reclamation Project, it was a closed system (i.e., it had no outlet to the ocean).

The decision to drain and reclaim Tule Lake and Lower Klamath Lake for agricultural production required changes in and management of the Lost River. Today, throughout most of its length, the river is highly channelized and managed and includes several impoundments (water storage areas). It has lost all resemblance to a natural river system. BOR documents refer to the Lost River as the Lost River Improved Channel. The Lost River system is now connected to the Klamath River watershed via the Lost River Diversion Channel and the Klamath Straits Drain.

Two important structures include the Lost River Diversion Dam (Wilson Dam), which allows discharge of up to 3,000 cfs to the Lost River Diversion Channel, and the Anderson-Rose Dam, which facilitates diversion to the J-Canal for irrigation of land within the Tulelake Irrigation District (TID). The J-Canal has a capacity of 800 cfs and typically diverts about 135,000 acre-feet per year to TID.

Lost River Diversion Channel

> "The Diversion Channel, operated by Reclamation, begins at Wilson Diversion Dam [Lost River Diversion Dam] and travels in a westerly direction, terminating at the Klamath River. It was constructed originally in 1912 and enlarged in 1948. It is an earthen channel 8 miles long. The channel is capable of carrying 3,000 cfs to the Klamath River from the Lost River system during periods of high flow. The channel is designed so that water can flow in either direction depending on operational requirements. During the irrigation season the predominant direction of flow is from the Klamath River. Miller Hill Pumping Plant is located on the channel along with the Station 48 drop to the Lost River system.
>
> During the fall, winter, and spring, the channel is operated so that all of the water that enters from the Lost River is bypassed to the Klamath River. During periods that the flow is in excess of 3,000 cfs, water is bypassed into the Lost River. [Actually, when Lost River flow from Gerber and Clear Lake discharges exceeds 3,000 cfs, any excess over 3,000 cfs must remain in the Lost River.] During the spring of most years it is necessary to import water from the Klamath River to the Lost River for early irrigation in the Tulelake area. During the summer months the channel is operated as if it were a forebay for the Miller Hill Pumping Plants and the Station 48 turnout. Depending on the needs of these two irrigation diversions, water that is not able to come from the Lost River must come from the Klamath River" (USFWS Biological Opinion 2001).

Tule Lake Sumps

> "Historically, Tule Lake covered a maximum area of about 95,000 acres (Abney 1964), making it about the same size as UKL, before diking and draining reduced its surface area. Tule Lake is the terminus of Lost River, but historically, flood flows from the Klamath River would also enter Tule Lake by way of the Lost River Slough. Lost River got its name from the fact that it did not directly connect to the sea.
>
> In the 1880s, white settlers built a dike across the Lost River Slough in a first attempt to reclaim [drain and convert to productive farmland] Lower Klamath and Tule Lakes. Reclamation began actively reclaiming historic Tule Lake with the construction of Clear Lake Dam in 1910 and the Lost River Diversion Dam [Wilson Dam] in 1912 (USBR 1953). [Both dams reduced inflow into Tule Lake from the Lost River.]
>
> In 1932, a dike system was constructed to confine the drainage waters entering Tule Lake to a central sump [depression for storage of drainage water] of about 10,600 acres. In 1937, maintaining the dike system became difficult as heavy inflows required an additional 3,400 acres of surrounding lands to be flooded. In 1938, the sump was increased to 21,000 acres. During the winter of 1939–40, heavy flows entered the sump again and dikes broke, flooding an additional 2,400 acres and damaging

crops. Thus it became necessary to control the level of Tule Lake by installing a pumping station.

In 1942, a 6,600 ft long tunnel through Sheepy Ridge and Pumping Plant D were completed, allowing water to be pumped from Tule Lake into Lower Klamath Lake (USBR 1941). This pumping station provides flood control for Tule Lake and is now the primary source of water for Lower Klamath NWR.

The present Tule Lake is highly modified and consists of two shallow sumps, 1A and 1B connected by a broad channel, the 'English Channel.' The two sumps have a surface area of 13,000 acres and a maximum depth of 3.6 ft. Water entering Tule Lake comes from three sources: (1) direct rainfall, (2) agricultural return water, and (3) the Lost River.

In winter, most of the Lost River flows are diverted at the Lost River Diversion Dam to the Klamath River via the Lost River Diversion Channel. In the irrigation season, this channel is also used to supply water from the Klamath River by reverse flow for lands in the Tule Lake area. Therefore, most of the water entering Tule Lake during the irrigation season originates from UKL, via the Klamath River in the Lake Ewauna area. The total mean annual inflow into Tule Lake is about 90,000 acre-ft (Kaffka, Lu, and Carlson 1995).

Water level elevations in Tule Lake sumps have been managed according to criteria set in the 1992 BO. From April 1st to September 30, a minimum elevation of 4,034.6 ft was set to provide access to spawning sites below Anderson-Rose Dam for dispersal of [sucker] larvae and to provide rearing habitat. For the rest of the year, October 1 to March 31st, a minimum elevation of 4,034.0 ft is set to provide adequate winter depths for cover and to reduce the likelihood of fish kills owing to low DO [dissolved oxygen] levels below ice cover" (USFWS Biological Opinion 2001).

Klamath Straits Drain

In addition to the previously discussed Lost River Diversion Channel, the Lost River watershed has a second altered feature connecting it to the Klamath River—the Klamath Straits Drain.

> "The Klamath Straits Drain, constructed in 1941 and operated by Reclamation, begins at the Oregon/California border and proceeds north to the Klamath River. It is a 60 ft wide x 4.6 ft deep x 8.5 mile earth channel with relift pumping stations. The water is lifted twice by pumps and is then discharged to the Klamath River.
>
> The Straits Drain is in the Lower Klamath National Wildlife refuge, which in turn receives drainage water from the Tule Lake National Wildlife Refuge. The Straits Drain was enlarged in 1976 to provide additional capacity to drain problem areas within the refuge. Maximum flow is 600 cfs.
>
> The Klamath Straits Drain is operated at levels that will provide adequate drainage to both private lands and refuge lands. The pumps are operated to meet flow conditions within the drain. Water quality conditions are monitored continuously near the outlet of the channel to the Klamath River" (USFWS Biological Opinion 2001).

In its historical, unaltered state, the Lost River drainage was connected to the Klamath River not as a source, but as a sink, for excess water during years of high water supply. A portion of the Klamath River flows during high-water years moved through the Lost River Slough to Tule Lake, where the water evaporated or seeped into groundwater aquifers. Excess flows in the Lost River watershed had no way to reach the Klamath River under natural conditions.

In contrast to these historical conditions, drainage from the Lost River watershed now is carried by the Straits Drain to the Klamath River (Table 1), where it contributes to flows in the river. Average annual discharge of drainage water to the Klamath River from the Straits Drain for the period 1991 to 2000 was approximately 81,000 acre-feet, with peak flows occurring in late winter. During the drought years of 1992 and 1994, discharge was 31,000 and 61,000 acre-feet, respectively (Table 1). During the other years of this 10-year period, discharge ranged from 75,000 to 132,000 acre-feet.

It should be noted that diversions from the Lost River watershed to the Klamath River typically occur at times of high water supply during winter or spring. They generally are not available during periods of low flows or in years of limited water supply.

An analysis of water quality conditions in the Lost River subbasin, for purposes of establishing Total Maximum Daily Load (TMDL) targets, identified the Klamath Straits Drain as a potential contributor of pollution (nutrients from agricultural activities) to the Klamath River. Water quality concerns include pH, dissolved oxygen (DO), temperature, nutrients, bacteria, and chlorophyll-a.

Recirculation of Straits Drain water through agricultural land and/or the Lower Klamath National Wildlife Refuge during at least portions of the year has been suggested as a possible solution for discharges. Construction of wetlands to filter the water prior to discharge to the river also has been investigated.

Lower Klamath Lake

Prior to development of the Project, a reef at Keno, Oregon backed up the Klamath River, forming Lower Klamath Lake. This lake ranged in size depending on watershed conditions, with a maximum of 75,000 acres. In 1907, a dike was constructed to isolate Lower Klamath Lake from the Klamath River and to serve as a bed for a railroad connecting Klamath Falls with points south. Construction of the railroad was completed in 1909. This was the beginning of efforts to drain Lower Klamath Lake and convert the region to agricultural land and a wildlife refuge.

Construction of this dike resulted in increasing flows in the Klamath River during periods of high flows by eliminating the river's access to the Lower Klamath Lake area. With less water reaching the Lower Klamath Lake area, evaporative losses were reduced, but there also may have been a reduction of late-season seepage back into the Klamath River.

ADY Canal

> "The [headworks] structure, a concrete box culvert with slide gates and stoplogs, was constructed in 1912 by the Southern Pacific Railroad in cooperation with Reclamation to control the water flow into the Lower Klamath Lake area through the Klamath Straits Channel. It is operated by Reclamation. At the present time these gates are left open to allow irrigation water into the Lower Klamath area in a controlled manner. Water flow is controlled by the Klamath Drainage District using automatic gates located downstream from this facility. Irrigation flow is 250 cfs" (USFWS Biological Opinion 2001).

The ADY Canal diverts water from the Klamath River to the Lower Klamath Lake area. Average annual diversion through the canal was 86,000 acre-feet from 1991 to 2000 (Table 1). Diversions to the ADY Canal have been quite consistent from year to year, ranging from 71,000 to 108,000 acre-feet from 1991 to 2000. In 1999 and 2000, total diversions from April through October were about 60,000 and 50,000 acre-feet, respectively (BOR data). A portion of this water is used to irrigate about 6,000 acres of crops or pastures in Lower Klamath NWR lease lands in Area K and about 10,000 acres in the Klamath Drainage District

(KDD). The remainder returns to the Klamath River through the Straits Drain.

Off-season diversions are used to flood habitat in the Lower Klamath National Wildlife Refuge.

The intake for the ADY Canal and the final pumping station for the Straits Drain are located immediately adjacent to each other and could easily be modified to divert Straits Drain drainage water into the ADY Canal for recirculation through agricultural lands or the refuge. While this could result in a potential buildup of salts, it might be an alternative that would prevent discharge of contaminants to the Klamath River at critical times of the year. An additional alternative would be to divert water from the Straits Drain to the intake for the North Canal, replacing river diversion for irrigation of agricultural land in the KDD.

North Canal

The North Canal diverts water from the Klamath River to approximately 20,000 acres of private agricultural lands in the KDD of the Lower Klamath Lake area. The diversion has a capacity of approximately 300 cfs.

The 10-year average diversion to the North Canal is 37,000 acre-feet. Total annual diversions through the North Canal have ranged from a low of 28,000 acre-feet in 1992, 1994, and 1998, to a high of 49,000 acre-feet in 1995 (Table 1). In 1999 and 2000, the total April-through-October inflow was about 35,000 acre-feet (BOR data).

Some of this water returns to the Klamath River through the Straits Drain after flood irrigation during winter months. Winter flooding of agricultural fields provides control of rodents (drowning and/or exposure to raptor predation), weeds, and plant diseases, in addition to providing waterfowl habitat.

As in the ADY Canal, gates to the Klamath River are left open, and the canal holds water year-round at the elevation maintained in the Klamath River.

Other Project features

Additional features of the Project are not described here in detail, but are important to the overall functioning of the Project. It is beyond the scope of this chapter to describe all diversion dams, lateral canals, drains, pumping stations, and sumps that are used to direct flows, recover return flows, and facilitate distribution of water within the Project and discharge of water to the lower Klamath River.

It is noteworthy that minor laterals, which divert 95 percent of water deliveries to farms, include 680 miles of channels. A total of 728 miles of drain ditches range in depth from a few feet to 10 feet, with discharge capacities of up to 600 cfs (Straits Drain) (USFWS Biological Opinion 2001).

Most drains retain water throughout the year and are important sources of recharge for shallow domestic wells, as are main canals and laterals during the irrigation season. This fact was clearly demonstrated during the 2000–2001 drought, as many wells became inoperable by late summer 2001. Several of these wells came back on-line within days after canals were charged in late July and early August. These canals and drains also provide several thousand acres of habitat for birds, amphibians, reptiles, and mammals.

Tule Lake and Lower Klamath national wildlife refuges

The wildlife refuges within the Project were established in 1908, 3 years after the Project was authorized. As a result, the refuges have a junior water priority in relation to the majority of lands within the Project.

The material quoted in this section is taken from the *National Wildlife Refuges 2001 Water Requirements* (USFWS 2001), which is based on management planning assuming full water delivery. It does not reflect the BOR's proposed Project Operations Plan, the 2001 BiOp, or actual water deliveries in 2001.

Tule Lake National Wildlife Refuge

The Tule Lake NWR receives water from the Lost River and drainage from the Tulelake Irrigation District (TID). Lost River supplies can originate from Clear Lake and Gerber reservoirs or from Upper Klamath Lake via the Lost River Diversion Channel. The estimated water use in the refuge indicates an average consumptive use of 3.25 acre-feet per acre for the Tule Lake sumps.

> "The 2001 Habitat Management Plan for the Tule Lake NWR calls for Sump 1A to be permanently maintained and Sump 1B to be drawn down in May and flooded again in September or October or later as supply permits. [Operating Sump 1B as a seasonal wetland was intended to increase its usefulness for waterfowl; see Chapter 16, "Waterfowl."]
>
> Evaporation losses for Sump 1A, assuming an area of 9,500 acres, is estimated to be 36,400 acre-ft. Sump 1B is about 3,500 acres and will require an estimated 7,000 acre-ft of water to re-flood.
>
> Additionally, there will be 400 acres of flood fallow lots and 885 acres of seasonal wetlands on Tule Lake NWR outside of Sump 1A and Sump 1B. The flood fallow lots will be permanently flooded and will require approximately 1,200 acre-ft of water to meet ET losses throughout the year. The water requirement for the seasonal wetlands would be an estimated 1,800 acre-ft. Seasonally flooded areas will be drawn down in May and flooded again in September or October or later as supply permits. The seasonal areas include the Headquarters fields (85 acres), Covey Point (200 acres), and 600 acres of new seasonal lands in Sump 3. The total water requirement for Tule Lake NWR is 46,400 acre-ft. This does not include any irrigation needs for farmed areas on the lease lands" (USFWS-Klamath Basin National Wildlife Refuges 2001).

Lower Klamath National Wildlife Refuge

> "The 2001 Habitat Management Plan for Lower Klamath NWR calls for a total of 11,163 acres of permanently flooded wetlands, 11,379 acres of seasonally flooded wetlands, 4,476 acres of grain fields, and 4,561 acres of flooded upland areas. Of the total seasonal acreage, 8,161 acres will be flooded from September 1 to October 31. The remaining seasonal acreage as well as all grain and upland areas will be flooded after October 31.
>
> Water requirements were estimated using the ref_for982.xls model for Lower Klamath NWR, assuming median precipitation and the 20% exceedance ET rate for the permanent wetlands. The total water requirement for the period May 1–October 31 is 50,660 acre-ft. Of the 50,660 acre-ft, 26,110 acre-ft is for permanent wetlands and 24,540 acre-ft is for seasonal wetlands to be filled before October 31.
>
> After October 31, additional water will be needed to fill the remaining 3,236 acres of seasonal wetlands (9,090 acre-ft), the 4,476 acres of grain fields (11,190 acre-ft), and the roughly 300 acres of upland area that will be flooded with ADY water this year (about 1,000 acre-ft). In addition, the permanent wetlands will require freshening flows of up to 5,480 acre-ft at some point during the winter. The total demand for the period November 1–April 30 is 26,760 acre-ft. This brings the total water requirement for the refuge in 2001 to 77,420 acre-ft. This does not include any lease land irrigation needs" (USFWS-Klamath Basin National Wildlife Refuges 2001).

Water for the Lower Klamath NWR is provided by drainage pumped from the Tule Lake NWR (Sump 1A) through Sheepy Ridge and by diversions from the Klamath River

Table 3. Estimated water use in Lower Klamath National Wildlife Refuge by month for permanent marsh, seasonal marsh, and grain units, 1998–2000.

		Water use (acre-feet)												
	Acres	J	F	M	A	M	J	J	A	S	O	N	D	Total
1998														
Permanent	7,417	560	1,090	2,070	3,100	3,940	4,930	5,590	4,770	3,570	2,290	720	520	33,150
Seasonal	15,670	8,810	2,190	3,710	1,710	0	0	0	0	11,290	10,880	3,600	2,160	44,320
Grain	3,530	7,150	0	0	0	0	0	3,530	0	0	0	0	0	10,680
Total	26,617	16,520	3,280	5,780	4,810	3,940	4,930	9,120	4,770	14,860	13,170	4,320	2,680	88,150
1999														
Permanent	9,060	690	1,340	2,530	3,790	4,810	6,020	6,820	5,830	4,360	2,790	880	630	40,490
Seasonal	12,710	8,590	1,440	2,280	480	0	0	0	0	11,290	5,550	2,760	1,950	34,340
Grain	4,460	9,020	0	0	0	0	0	4,460	0	0	0	0	0	13,480
Total	26,230	18,300	2,780	4,810	4,270	4,810	6,020	11,280	5,830	15,650	8,340	3,640	2,580	88,310
2000														
Permanent	7,720	590	1,140	2,150	3,230	4,100	5,130	5,810	4,960	3,710	2,380	750	540	34,490
Seasonal	14,420	1,090	1,350	2,110	220	0	0	0	0	13,070	8,620	4,260	4,170	34,890
Grain	3,630	7,360	0	0	0	0	0	3,630	0	0	0	0	0	10,990
Total	25,770	9,040	2,490	4,260	3,450	4,100	5,130	9,440	4,960	16,780	11,000	5,010	4,710	80,370

Source: U.S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuges. 2001. *National Wildlife Refuges 2001 Water Requirements* (Tulelake, CA).

through the ADY Canal. More than 50 percent of this refuge is devoted to seasonal flooding or grain production.

Data on water use within the Lower Klamath NWR for 1998, 1999, and 2000, provided by the USFWS, are presented in Table 3. Total usage was about 88,000 acre-feet in 1998 and 1999 and 80,000 acre-feet in 2000. Reduced use in 2000 occurred because of the need to meet target lake elevations and Iron Gate Dam flows required by the 2000 Operations Plan.

Lower Klamath NWR consumptive use averages 2.45 acre-feet per acre. In contrast, per-acre crop consumptive use ranges from about 1.75 acre-feet for grain to about 2 acre-feet for potatoes and onions, and 2.5 acre-feet for alfalfa and pastures. Data for these crops for 1999 and 2000 are available on the BOR AgriMet Web site (http://mac1.pn.usbr.gov/agrimet/index.html).

For additional discussion of the refuges, see Chapter 15 ("Bald Eagles") and Chapter 16 ("Waterfowl").

Flow requirements at Iron Gate Dam

As noted above, the reduction in available water for agriculture and refuge use resulting from maintaining Upper Klamath Lake at a minimum elevation of 4,139 feet in a critical year-type is about 174,000 acre-feet compared to available water if the elevation were allowed to go to 4,136 feet (dead storage). The flows at Iron Gate Dam (IGD) required by the National Marine Fisheries Service (NMFS) 2001 Biological Opinion for coho salmon have a potentially greater effect on water supply in the Upper Basin.

In its 2001 Biological Assessment (BA), the BOR proposed a flow regime at IGD for April 1 through September 30 of about 180,000 acre-feet. The final NMFS BiOp requirement for that period for 2001 was about 500,000 acre-feet. (This was a compromise from the draft Biological Opinion, which had called for more than

Table 4. Iron Gate Dam monthly flows under various proposals and actual 2001 flows.

	FERC	INSE	Trihey	Bureau of Reclamation: Above average	Bureau of Reclamation: Below average	Bureau of Reclamation: Dry	Bureau of Reclamation: Critical	Actual 2001
	(1,000 acre-feet per month)							
January	79.9	90.8	73.8	69.3	82.0	54.6	62.2	81.5
February	72.2	100.4	89.3	50.5	85.9	41.5	29.2	74.0
March	79.9	128.0	92.2	124.8	98.3	44.6	31.4	81.3
April	77.4	148.9	92.2	101.5	82.1	44.1	34.0	98.2
May	61.5	167.1	83.3	84.1	61.9	51.9	31.5	108.5
June	42.2	189.0	92.2	44.7	42.4	39.4	30.1	113.8
July	43.7	196.8	119.0	42.6	42.7	33.5	26.4	63.0
August	61.5	187.9	153.7	62.2	43.1	39.8	24.5	62.7
September	77.4	133.8	101.2	61.6	43.1	44.6	32.0	60.8
October	79.9	105.4	61.5	81.7	80.4	52.4	55.6	80.3
November	74.4	82.8	61.5	79.6	78.8	51.9	54.1	78.3
December	79.9	83.0	59.5	85.3	88.2	54.7	56.2	81.2
April–Sept.	363.7	1,023.5	641.6	396.7	315.3	253.3	178.5	507.0
Total	829.9	1,613.9	1,079.4	887.9	828.9	553.0	467.2	983.6

FERC = Set by the Federal Energy Regulatory Commission as a condition of PacifiCorp's license for power-generating dams

INSE = Hardy, Thomas B. 1999. *Evaluation of Instream Flow Needs in the Klamath River, Phase I Final Report* (Institute for Natural Systems Engineering, Utah Water Research Laboratory, Utah State University, Logan). The INSE flows were the basis for the draft NMFS 2001 BiOp.

Trihey = Trihey and Associates, Inc. 1996. *Instream Flow Requirements for Tribal Trust Species in the Klamath River* (prepared on behalf of the Yurok Tribe, Eureka, CA)

Bureau of Reclamation = U.S. Fish and Wildlife Service–Klamath Falls Fish and Wildlife Office. 2001. *Biological/Conference Opinion Regarding the Effects of Operation of the Bureau of Reclamation's Klamath Project* (U.S. Department of the Interior, Sacramento, CA)

Actual 2001 = Bureau of Reclamation data. Actual discharge in 2001 closely followed the final 2001 BiOp.

1,000,000 acre-feet during the April–September period.) For comparison, during the droughts in 1992 and 1994, total flows from April 1 through September 30 were about 150,000 acre-feet and 250,000 acre-feet, respectively.

The difference between the BOR's BA proposal (180,000 acre-feet) and the NMFS requirement (500,000 acre-feet) is 320,000 acre-feet, or about equal to the 10-year average diversion for the A-Canal, North Canal, and ADY Canal less the return to the Klamath River at Straits Drain.

Table 4 illustrates what flows past Iron Gate Dam would be under the following scenarios:

- The Federal Energy Regulatory Commission license conditions for Pacificorp's power-generating dams
- The January 2001 draft Biological Opinion (based on recommendations by the Institute for Natural Systems Engineering, or INSE, in Hardy 1999)
- The Trihey and Associates (1996) report prepared for the Yurok Tribe
- The 2001 BOR Biological Assessment (which proposed various flows under four hydrologic year-types)

Actual 2001 flows were quite close to the flows required by the final 2001 NMFS BiOp. They are shown in the final column of Table 4.

The BOR's proposed flows were based on the hydrology of the Project since 1961 and took into account use of water for irrigation and refuges. The INSE (Hardy 1999) and Trihey (1996) models do not allow flexibility to adjust for hydrologic conditions in any given year.

With accretions below Keno Dam accounting for about 300,000 acre-feet in an average year, and inflow to Upper Klamath Lake averaging 1,300,000 acre-feet, the INSE Iron Gate flow requires all average available Upper Klamath Lake water.

The flow requirements suggested by INSE (in Hardy 1999), in Hardy and Addley 2001, and in the 2001 draft NMFS Biological Opinion were based on historical estimates made by Balance Hydrologics, Inc. (Hecht and Kamman 1996). These estimates were based on an analysis of flows at Keno, Oregon, during the period from 1905 to 1912.

The U.S. Weather Bureau records indicate precipitation at Klamath Falls was about 20 percent above normal during this period. Weather records indicated precipitation was 22 percent above normal for Yreka, California during these years (Balance Hydrologics, Inc. 1996). BOR data indicated inflow to Upper Klamath Lake was 34 percent above normal for the period. Thus, the 4 percent adjustment applied by Balance Hydrologics, Inc. to account for flow conditions during this period results in greatly exaggerated in-stream flow expectations.

An analysis of the hydrology of the Project from 1961 through 1997 compared INSE proposed flows with discharges from Upper Klamath Lake. None of the years during this period produced total flows greater than 1,000,000 acre-feet (the INSE target). The analysis showed that flows could not have met INSE annual flow targets in 13 out of 37 years even if no water had been diverted for irrigation or the refuges. In only 15 of 37 years was sufficient water available to meet the flow targets and historical use for irrigation and refuges.

The above analysis did not take minimum lake elevations into consideration. Holding lake elevation at a minimum of 4,139 feet or higher would increase the number of years not meeting flow targets.

The flows suggested in the Trihey (1996) report would have left no water from Upper Klamath Lake for irrigation or refuges in 1992 and 1994 and less than current use quantities in an additional 6 of 37 years. The final 2001 BiOp would have resulted in no water for agriculture or refuges in 1992 and less than current use in 5 additional years from 1961 to 1997. Clearly, the adoption of a long-term operations plan based on Iron Gate Dam flows within the range of values between the INSE and Trihey targets would result in significant shortfalls in surface water supply for the Project.

An alternative analysis is to consider only the April-through-September period, which is the critical period for fish habitat and includes the critical low flow months of July, August, and September. Total flows during this period using the Trihey targets are approximately 640,000 acre-feet. Actual operations provided this quantity or more at Iron Gate Dam in 9 of 37 years while meeting agricultural and refuge use requirements. The 2001 flows at Iron Gate Dam (507,000 acre-feet) were met or exceeded in 20 of 37 years.

INSE flows would not have been achieved in 20 of 37 years for the April-through-September period even if there were no diversions of Upper Klamath Lake water for irrigation and the refuges.

For additional discussion of Klamath River flows at Iron Gate Dam, see Chapter 6 ("Coho Salmon").

Economics of irrigation water in the Project

Users of Project irrigation water pay operation and maintenance (O&M) fees to the irrigation districts delivering water. Fees range from $12 per acre for the Van Brimmer Ditch Co. to $70 per acre for the pressurized Shasta View

Irrigation District (Smith and Rykbost 2001). The fees are due regardless of water delivery. There is no charge for the water.

Project irrigators enjoy reduced electricity prices for irrigation pumps through a 50-year contract that expires in 2006. The rates range from \$0.003 to \$0.006/kwh. The negotiations for contract renewal have begun, but it is anticipated that the very favorable rates will not be renewed. Any increase approaching standard charges will significantly affect irrigation costs, particularly for wells with lifts greater than a few feet.

For a perspective on potential effects of increased electricity prices, Pumping Plant D, which pumps drainage from Tule Lake NWR Sump 1A to the Lower Klamath NWR, typically costs \$50,000 per year to operate at rates of \$0.003/kwh during nonpeak periods or \$0.005/kwh during peak demand periods. At current commercial rates, about 10 times higher, the annual electrical cost for this pumping station would increase to about \$500,000. This would increase O&M fees for Tulelake Irrigation District members by about \$7 per acre, a 25 percent increase.

Effects of water management in 2001

The change in water allocation implemented in 2001 is illustrated in Figures 1 and 2. Data provided by the BOR show the relative allocation of water from Upper Klamath Lake to Iron Gate Dam flows, to Tule Lake and Lower Klamath national wildlife refuges, and to agricultural lands in the Project. Data do not include water supplied by the Lost River system or from groundwater wells.

In 2001, agriculture received 22 percent of the average Upper Klamath Lake diversion for 1991–2000. Iron Gate Dam flows were 68 percent of the 1991–2000 mean. Refuge use was 71 percent of the 1991–2000 mean.

Figure 2 compares Upper Klamath Lake water allocation during the drought years of 1991, 1992, 1994, and 2001. Total water availability from the lake in 2001 was greater than in 1992 and 1994 and similar to the supply in 1991.

This section looks at effects of the 2001 water allocation decisions on water use for Project irrigation, on groundwater resources, and on the refuges. Effects on fish and wildlife species are examined in other chapters.

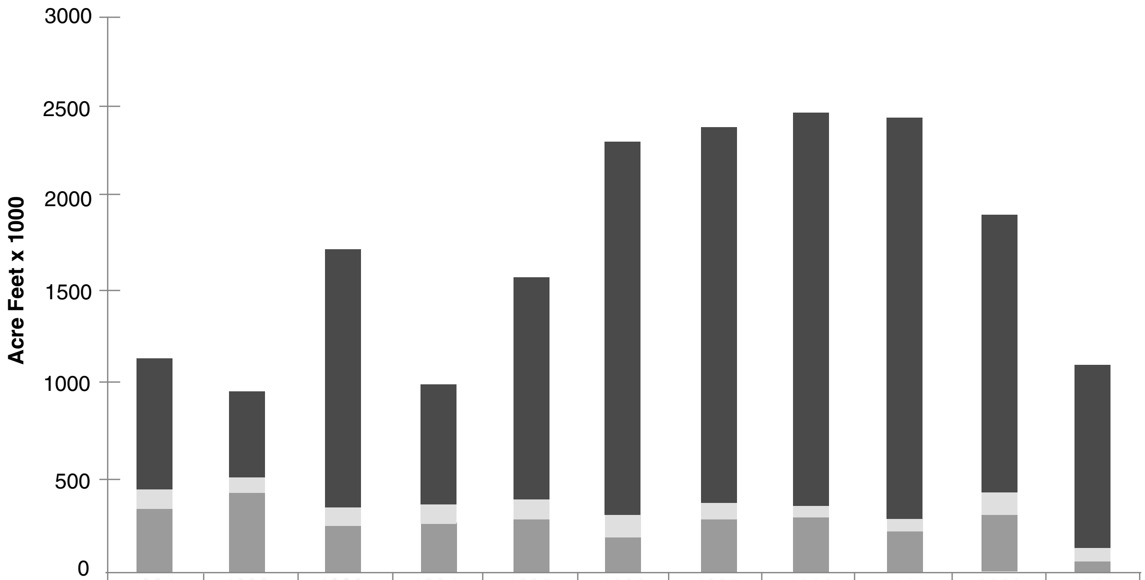
Chapter 12 (“Crop Revenue”) contains additional discussion of how the interaction between hydrologic year-types and Biological Opinions affects irrigation diversions.

Effects on the Klamath Reclamation Project

The Project Operations Plan for 2001 provided about 70,000 acre-feet to the Horsefly and Langell Valley irrigation districts from Clear Lake and Gerber reservoirs. Water from private wells and minor quantities from the Lost River, derived from purchased groundwater, maintained limited supplies for up to about 75,000 acres within the Project. A small release in late July and August from Upper Klamath Lake (40,000 acre-feet) provided significant late-season relief to pastures and hay crops. Remaining fields in the Project were not irrigated through the summer.

The Klamath County Tax Assessor estimates that about 85,000 acres in Klamath County, 67 percent of Project lands in the county, received no water in 2001. The acreage that received only the late delivery in July–August was also considered to have received no water for tax assessment purposes. The late release from Upper Klamath Lake was inefficiently used because of difficulty in moving it through canals clogged with weeds. Fields normally irrigated with return flows from drains were unable to be served from this release.

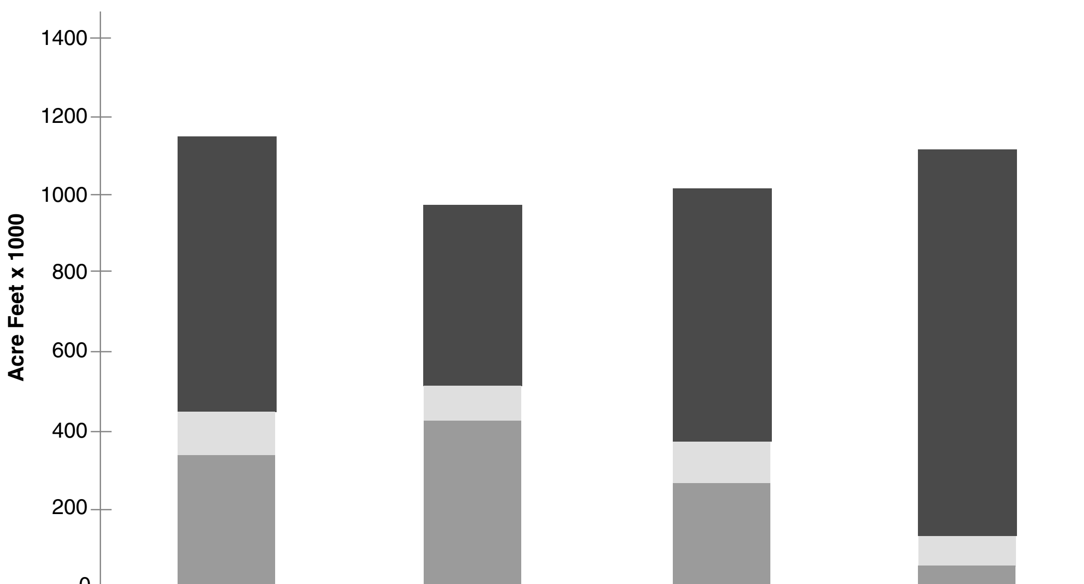
Water made unavailable for irrigation and the refuges by minimum elevations for Upper Klamath Lake established in the USFWS 2001 Biological Opinion for suckers (compared to the 1992 BiOp) included 4,000 acre-feet in Gerber Reservoir, 17,000 acre-feet in Clear Lake Reservoir, and 160,000 acre-feet in Upper Klamath Lake. This quantity of water would have been sufficient to irrigate more than 100,000 acres of cereal or potato crops, using about 1.75 acre-feet per acre, or 72,000 acres of alfalfa or pasture using 2.5 acre-feet per acre.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Iron Gate Flow	701	464	1394	652	1211	2031	2028	2115	2157	1515	988
Refuges	103	83	111	99	101	91	86	58	75	120	66
Agriculture	344	429	241	268	295	204	292	303	219	305	63

Acre Feet x 1000

Figure 1. Klamath Lake water allocation for Iron Gate Dam flows, refuges, and agriculture, 1991–2001. Source: Bureau of Reclamation data



	1991	1992	1994	2001
Iron Gate Flow	701	464	652	988
Refuges	103	83	99	66
Agriculture	344	429	268	63

Acre Feet x 1000

Figure 2. Klamath Lake water allocation for Iron Gate Dam flows, refuges, and agriculture in drought years of 1991, 1992, 1994, and 2001. Source: Bureau of Reclamation data

The increased water allocation to flows at Iron Gate Dam required by the NMFS 2001 Biological Opinion can be determined by comparing the required flows to flow regimes prior to the listing of coho salmon under the ESA. Before that time, the standard flow requirements for Iron Gate Dam were based on minimum flows established by the Federal Energy Regulatory Commission (FERC) at the time Iron Gate Dam was licensed. These minimums were 1,000 cfs for May, 710 cfs for June and July, 1,000 cfs for August, and 1,300 cfs for September. (Because the FERC minimums were subject to water availability and senior water rights, they were not always met.)

Using the period from May through September, actual 2001 flows at Iron Gate Dam were about 409,000 acre-feet. FERC minimum flows would have been about 300,000 acre-feet. The difference would have provided adequate irrigation water for about 60,000 acres of cereals or potatoes or 44,000 acres of alfalfa or pasture.

In summary, operation of the Project with the 1992 USFWS Biological Opinion for minimum lake elevation and FERC minimum flow requirements at Iron Gate Dam would have supplied water for irrigation and the refuges in the following manner:

- 160,000 acre-feet of water by allowing Upper Klamath Lake to fall to 4,137 feet elevation in a critically dry year, as permitted by the USFWS 1992 lake-level BiOp for suckers (instead of holding lake elevation at 4,139.5 feet as was done in 2001)
- 75,000 acre-feet of water from the late-season release that did occur in 2001
- 109,000 acre-feet by setting May-through-September flows over Iron Gate Dam at the FERC minimum

Thus, Upper Klamath Lake could have provided 344,000 additional acre-feet for irrigation and refuges in the absence of ESA requirements. This represents almost the amount of the average 1991–2000 diversions to the A-Canal, North Canal, and ADY Canal (370,000 acre-feet).

As a final note, failure to charge the Project canals also resulted in elimination of habitat for numerous species in thousands of acres of canals and drain ditches.

Effects on groundwater resources

Existing wells

The lack of irrigation water on much of the Project in 2001 reduced groundwater recharge from percolation of applied irrigation water and water in canals. Failures of 17 domestic wells and 10 livestock/yard wells in the Henley and Merrill areas, and of 5 domestic wells in the Tulelake area, were reported by late July 2001. A listing of 114 problem wells within the Klamath County portion of the Project was compiled by a local resident (Barbara Hall). More wells also failed on the California side of the Project late in the season. All of the failed wells in the Henley and Merrill areas were shallow wells that receive recharge from canal and surface application seepage (Gates 2001, personal communication).

In some cases, well failures might be resolved by lowering pump bowls or replacing shallow well pumps with deeper submersible pumps. Others will need to be extended deeper into the aquifer.

Well development

With the 2001 decision to withhold surface water from most of the Project, a flurry of well-development activities was initiated in an effort to replace surface irrigation water. Private individuals developed several wells in the Project in late spring. Funding from the California and Oregon legislatures to assist irrigation districts with well development is expected to result in as many as 20 new large irrigation wells. By July 2001, the Oregon Water Resources Department (OWRD) had approved 89 of 92 applications for drought/supplemental-use wells in the region, sufficient for 20,500 acres of irrigated land (Gates 2001, personal communication).

The Tulelake Irrigation District (TID) brought 6 new wells into production by August, with maximum production approaching

12,000 gallons per minute (gpm) for the largest producing well. Pump test yields on 9 TID wells have ranged from 4,000 to 12,000 gpm, with 6 of 9 wells exceeding 9,000 gpm. (For conversion to other measures, approximately 450 gpm = 1 cfs = 2 acre-feet per day.) See Chapter 12 ("Crop Revenue") for additional data on Tulelake well development.

Optimistic projections of well production are for 150 to 175 cfs from a $5-million well-development fund in California and 50 to 75 cfs from the $2-million fund in Oregon. This represents about 15 to 20 percent of typical surface-water diversions for agriculture and refuge use.

Depths to aquifers suitable for irrigation wells vary from 150 feet in southern portions of the Project in Copic Bay to more than 2,000 feet in other areas. The upper surface of water-bearing basalt bedrock ranges in depth to more than 1,000 feet. Several wells developed in 2001 are more than 2,000 feet deep. Depths of the 9 completed wells in the TID range from 571 to 2,380 feet. All but two of the wells are more than 1,400 feet deep. An unsuccessful well in the Henley area stopped at 2,146 feet without finding a productive aquifer. Fortunately, the water level in most of these wells rises to within 50 feet or less of the surface.

The ability of groundwater aquifers to sustain season-long or long-term use has not been determined. Several of the high-producing wells developed in 2001 were pumped for only a few weeks in 2001. Extensive monitoring of wells and examination of logs from newly developed wells is underway by hydrologists from the California Water Resources Department, OWRD, and U.S. Geological Survey. A 6-year USGS study will be completed in 2004. It will be several years before the local groundwater hydrology is well defined. Full-season pumping will be required before there is any assurance of the extent to which wells can replace surface irrigation supplies on a season-long basis.

Several irrigation wells in the TID (some existing and some new) are reported to have lowered water levels in nearby wells considerably. The level in one well in Malin, Oregon, declined by more than 20 feet in 2001.

The economic consequences of replacing surface water with wells are significant. Energy requirements vary with well depth, water levels, capacity, and source of power, but in any case are considerably greater than costs for pressurizing surface water. Installation costs for newly developed wells currently range from $50,000 to $600,000, with several of these wells producing in the range of 5,000 to 10,000 gpm. Three attempts at well drilling in 2001 resulted in dry holes at costs of about $60,000, $70,000, and $100,000. Other unsuccessful drilling also has been reported.

The latest projection for well development on the TID with the $5 million in state funding indicates possible production of 75,000 gpm. This equates to about 170 cfs, or 340 acre-feet per day. Assuming 100 days of pumping and 2 acre-feet per acre of crop, this volume would serve about 17,000 acres, or 34,000 acre-feet. Based on an initial investment of $5 million, the cost of replacing surface water with groundwater would be about $300/acre.

Pumps and pumping costs are in addition to well development costs. As an example, the pump and installation costs for one of the largest wells on the TID were about $65,000, and monthly electrical costs for continuous use are estimated at $800 (at current low rates). At 10,000 gpm, this well could service about 2,000 acres using the assumptions above.

The replacement of surface water with well sources offers little operation and maintenance savings for delivery systems and irrigation districts. Conveyance structures still are required to move water to individual properties. The newly developed TID wells are pumping directly into existing canals.

In Oregon, permanent water rights for new wells may be difficult to acquire. Most of the wells developed in the early 1990s within the Project are permitted only for declared droughts or supplemental use. When new wells interfere with previously permitted wells, permitted wells must be "fully developed" before the offending well is shut off. In other words, the existing affected well must be deepened through the bearing aquifer (Ned Gates 2001, personal communication).

California has fewer regulations for well development, but both Modoc and Siskiyou counties have ordinances against exporting groundwater out of the county. Waivers could be obtained, provided all water needs within the county are being met.

Substitution of groundwater for surface supplies for agricultural and refuge use also raises water quality concerns. Discharge of nutrient-rich, warm water from Klamath Lake to the Lower Klamath River may put salmonids at risk below Iron Gate Dam (National Research Council 2002). If Klamath Lake water were used for irrigation and the refuges, and cool, high-quality groundwater were discharged to the river, benefits for fish might be realized. This issue may receive more attention in the future.

Payments for foregone irrigation water and groundwater deliveries

Even before the shortage in water supply became apparent, the BOR had planned a pilot program to offer Project users an opportunity to submit bids for foregoing surface water in 2001. In view of the supply shortfall, participation in the program was greater than would have been expected. Bids were submitted for nearly 25 percent of the Project acreage, with a range from $55 to $4,000 per acre.

The BOR accepted bids on about 150 parcels at up to $300 per acre. A total of 16,525 acres were accepted for the program at a total cost of about $2,760,000, or an average of $167 per acre.

The BOR also invited bids from Project users or others who could deliver groundwater from wells to Project delivery systems. This program accepted bids for about 67,000 acre-feet of groundwater at an average price of about $33 per acre-foot and a total cost of about $2,208,000. Accepted bids for groundwater ranged from $25 to $52 per acre-foot (BOR data).

Effects on national wildlife refuges

The 2001 Biological Opinion called for maintenance of a minimum surface elevation of 4,034.6 feet in Sump 1A at Tule Lake for suckers. The irrigation curtailment caused by the requirements for Upper Klamath Lake elevation and IGD flows reduced grain production on the refuge, however, thus eliminating a source of waterfowl food.

The BOR's BA did not state a plan to provide water delivery at any mimimum level to Lower Klamath National Wildlife Refuge. The USFWS, in preparing its Biological Opinion, estimated minimum acreages of wetlands needed at the refuge, based on a calculation of the population of waterfowl required to support the area's population of threatened bald eagles. (See Chapter 15, "Bald Eagles," for a detailed discussion.) The 2001 BiOp stated that the BOR should provide water necessary to meet these minimums *if* water was available after lake level and river flow requirements were met for suckers and coho, respectively.

At midsummer 2001, it was expected that only 1,000 acres of permanent wetlands could be maintained in the Lower Klamath NWR (Hainline 2001, personal communication). In normal years, about 7,000 to 9,000 acres are kept in wetlands (Table 3). In late summer, arrangements were made by interested parties to augment the water supply from several sources, including newly developed wells in California, discharges from Clear Lake and Gerber reservoirs, and depletion of storage behind dams on the Klamath River. About 14,000 acre-feet were released for refuge use in July–August and an additional 12,000 acre-feet in December. In all, Lower Klamath National Wildlife Refuge received about 30 percent of normal water deliveries between January and October 2001.

Effects of the water allocation decision on waterfowl, bald eagles, and mule deer are discussed in detail in Chapters 15–17.

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Appendix A. Facts about the Klamath Reclamation Project

This information is reprinted from the Bureau of Reclamation's "Factual Data on the Klamath Project" published by the U.S. Government Printing Office, 1998.

Irrigation plan

The Klamath Project on the Oregon–California border in Oregon's Klamath County and California's Siskiyou and Modoc counties was one of the earliest Federal reclamation projects. In early 1905, Oregon and California State Legislatures ceded title in Lower Klamath and Tule Lakes to the United States for project development under provisions of the Reclamation Act of 1902. Construction was authorized by the Secretary of the Interior on May 15, 1905, for project works to drain and reclaim lakebed lands of the Lower Klamath and Tule Lakes, to store waters of the Klamath and Lost Rivers, to divert irrigation supplies, and to control flooding of the reclaimed lands. Under provisions of the Reclamation Act, project costs were to be repaid through the sale of water rights to homesteaders on the reclaimed project lands.

Water supply

Two main sources supply the water for the Klamath Project. One consists of Upper Klamath Lake and the Klamath River, and the other consists of Clear Lake Reservoir, Gerber Reservoir, and Lost River, which are located in a closed basin. The total drainage area which includes the Lost River and Klamath River watershed above Keno is approximately 5,700 mi^2 (1470 x 10^3 ha).

Features of the Project plan

Link River Dam on Link River at the head of the Klamath River and just west of Klamath Falls, Oregon, regulates flow from Upper Klamath Lake Reservoir. This reservoir is a principal source of water supply for the project. The dam is a reinforced concrete slab structure, with a height of 22 ft (7 m) and a crest length of 435 ft (133 m). The reservoir has a capacity of 735,000 acre-feet (907 x 10^6 m^3) and is operated by the Pacific Power and Light Company, subject to Klamath Project rights.

Gerber Dam and Reservoir on Miller Creek, 14 mi (23 km) east of Bonanza, Oregon, provides storage for irrigation and reduces flow into the reclaimed portions of Tule Lake and the restricted sump areas in the Tule Lake National Wildlife Refuge. The dam is a concrete arch structure, with a height of 84.5 ft (25.8 m) and a crest length of 478 ft (146 m). The reservoir has a capacity of 94,000 acre-ft (116 x 10^6 m^3).

Clear Lake Dam and Reservoir on Lost River in California, about 19 mi (31 km) southeast of Malin, Oregon, provides storage for irrigation and reduces flow into the reclaimed portion of Tule Lake and the restricted sump areas in Tule Lake National Wildlife Refuge. The dam is an earth and rock fill structure, with a height of 42 ft (13 m) and crest length of 840 ft (256 m). The reservoir has a capacity of 527,000 acre-ft (650 x 10^6 m^3).

Malone Diversion Dam on Lost River, about 11 mi (18 km) downstream from Clear Lake Dam, diverts water to serve lands in Langell Valley. The dam, an earth embankment with a concrete gate structure, has a height of 32 ft (10 m) and a crest length of 515 ft (157 m).

Lost River Diversion Dam on Lost River, about 4 mi (6 km) below Olene, Oregon, diverts excess water to the Klamath River through the Lost River Diversion Channel and thereby controls downstream flow in Lost River to control or restrict flooding of the reclaimed portions of the Tule Lake bed and to regulate sumps of the Tule Lake National Wildlife Refuge. It is a horseshoe-shaped, multiple-arch concrete structure with earth embankment wings. The structure height is 42 ft (13 m) and the crest length is 675 ft (206 m).

Lost River Diversion Channel extends from the Lost River Diversion Dam to the Klamath River, a distance of nearly 8 mi (13 km). The channel carries excess water to the Klamath River and also supplies additional irrigation water from the Klamath River by reverse flow for the reclaimed lakebed lands of Tule Lake.

Anderson-Rose Dam on the Lost River, about 3 mi (5 km) southeast of Merrill, Oregon, diverts water to serve the lands reclaimed from the bed of Tule Lake. The dam is a reinforced concrete slab and buttress structure with a height of 23 ft (7 m) and a crest length of 324 ft (99 m).

Miller Diversion Dam on Miller Creek, 8 mi (13 km) below Gerber Dam, diverts water to serve lands in Langell Valley. The dam is a concrete weir, removable crest, and earth embankment wing structure, with a height of 32 ft (10 m) and crest length of 290 ft (88 m).

Pumping plants. There are 5 major pumping plants with power input ranging from 450 to 3,650 hp (336 to 2722 kW) and capacities from 60 to 300 ft^3/s (1.7 to 8.5 m^3/s), and 40 pumping plants of less than 1,000 hp (746 kW).

Canals, laterals, and drains. There are 18 canals with a total length of 185 mi (298 km) and diversion capacities ranging from 35 to 1,150 ft^3/s (1 to 33 m^3/s). Laterals total 516 mi (830 km) and drains 728 mi (1172 total km).

Tule Lake Tunnel. A concrete-lined tunnel, 6,600 ft (2000 m) in length and with a capacity of 300 ft^3/s (8 m^3/s) conveys drainage water from Tule Lake restricted sumps to Lower Klamath Lake.

Klamath Straits Drain. The enlarged 600 ft^3/s (17 m^3/s) drain conveys drainage water from Lower Klamath National Wildlife Refuge and irrigated land which has been reclaimed from Lower Klamath Lake. The drain, which extends from the State Line Road northwesterly to Klamath River, removes the excess winter flows and the drainage from the lower basin, a closed basin, to the Klamath River.

Irrigable acres

The project area includes 233,625 acres (94,545 ha) of irrigable lands of which 204,492 acres (82,758 ha) were irrigated by the project in 1979.

Soils

Soil varies from sandy loam to peaty and clay loams throughout the irrigable areas.

Irrigation season

The average irrigation season extends from April through September. The growing season varies considerably from year to year, but averages approximately 120 days from about May 15 to September 15.

Precipitation and temperature

The annual precipitation over the project area averages about 14 in (356 mm). At Klamath Falls temperatures have ranged between recorded extremes of 105°F (41°C) and –24°F (–31°C). Temperatures average about 67°F (19°C) during July and August, 29°F (–2°C) during the coldest winter month and about 48°F (9°C) for the year.

Principal products and markets

The principal crops grown in this area are cereal grains, alfalfa hay, irrigated pastures for beef cattle, onions, potatoes, and grass seed. The area is noted for the production of malting barley. With excellent rail connections to San Francisco and Portland, both within a distance of 400 mi (644 km) from the project area, the principal markets for agricultural products are in Oregon and California, and adjoining states.

Basin geography

The Upper Klamath River Basin encompasses an area of about 9,500 mi^2 (2460 x 10^3 ha), including the Klamath Project service area. The terrain varies from rugged, heavily timbered mountain slopes to rolling sagebrush benches and broad flat valleys. Most of the valleys of the basin are high and comparatively flat; the elevation above sea level ranging from 2,600 ft (792 m) in Scott Valley to 5,000 ft (1524 m) in the Sycan Marsh. The highest of the mountains is Mt. Shasta, 14,161 feet (4316 m) above sea level. Forest lands total about two-thirds of the basin area and most of the remaining third is arable land.

Homestead lands

Oregon and California legislation which relinquished state title to project lands, and congressional action which directed the project undertaking, provided for disposition of the reclaimed lands in accordance with the 1902 Reclamation Act. Under provisions of the act, the reclaimed public lands were to be opened for homesteading, subject to water right charges designed to repay project costs. The first public lands were opened for homestead in March 1917, for Unit 3 of the Main Division which included 3,250 acres (1315 ha) of private lands and 2,700 acres (1093 ha) of public lands. The 1917 land opening notice announced a construction charge of $39 per irrigable acre for land already in private ownership and $46 per irrigable acre for unentered public land. Reclaimed lands in the Tule Lake Division were opened for homestead entry under 10 different public notices the first in 1922 and the last in 1948. In total, about 44,000 acres (18 x 10^3 ha) making up 614 farm units were homesteaded in the Tule Lake Division. The 1922 homestead notice, later recalled, included a construction charge of $90 per irrigable acre. Subsequent land openings in the Tule Lake Division included a construction charge of $88.35 per acre contingent on the landowners forming an irrigation district to assume joint liability for construction costs.

Public lease lands

As Tule Lake receded, reclaimed lands were leased for farming before opening to homestead. The practice of leasing served to develop and improve the land during the construction of irrigation and drainage facilities to serve farm units and permit homestead entry. To protect developed homestead lands from flooding, areas at lower elevations were designated as sump areas and reserved for flood control and drainage. Some of the marginal sump acreage subject to less frequent flooding was made available for leasing, but retained in Federal ownership. In addition to providing flood control, the reserved sump areas also preserved existing marsh habitat which has subsequently been included within the basin's national wildlife refuge areas.

National wildlife refuges

A strategic junction in the routes of the Pacific Flyway, the Klamath Basin annually receives the largest concentration of migratory waterfowl in North America. During migration, the area provides feeding and resting grounds for more than 5 million ducks and geese. By Executive Order in 1908, President Theodore Roosevelt established the Lower Klamath Lake area as the first Federal wildlife refuge for waterfowl in the Nation. Today the Klamath Basin is the site of five national wildlife refuges: the Lower Klamath, Tule Lake, Clear Lake, and Upper Klamath refuges within the Klamath Project service area, and the Klamath Forest National Wildlife Refuge north of the project area. In addition to wildlife conservation, a key function of the refuge areas is to decrease crop depredation in California's Central and Imperial Valleys. Refuge areas attract and delay the migrating birds during harvest of rice and other valley crops. Provisions for waterfowl management purposes are included in Public Lease Land agreements to provide for the growing of grain and cereal crops for waterfowl forage. The bulk of waterfowl food is gleaned by the birds from the lease lands after harvest. Additional acreage in the refuge areas is farmed by the Fish and Wildlife Service specifically for waterfowl food, nesting habitat, and cover.

Recreation, fish, and wildlife

While migrating waterfowl are the most widely recognized wildlife feature of the basin, a variety of other animals, birds, and fish inhabit the area. Game resources include deer, elk, antelope, bear, and cougar. Furbearers include muskrat, beaver, and mink. Upland game birds include 10 species, most notably doves, pheasant, grouse, and quail. Rainbow trout is the most important game fish, found in relatively large numbers and most sought by fishermen. Basin fishery also includes three other major species of trout, two species of landlocked salmon, and eight species of warmwater game fish. Recreation and tourism, the fastest growing industry, ranks third as a contributor to the basin's economy, following agriculture and timber. Sport hunting of waterfowl at refuge public shooting grounds brings into commercial channels substantial sums of money each year. The spectacular sight of millions of ducks and geese, and thousands of other water and marsh birds on the Federal refuges is a prime tourist attraction. Klamath Project reservoirs join other federally administered parks and forest areas as major recreation sites, providing opportunities for fishing, swimming, boating, skiing, camping, and picnicking.

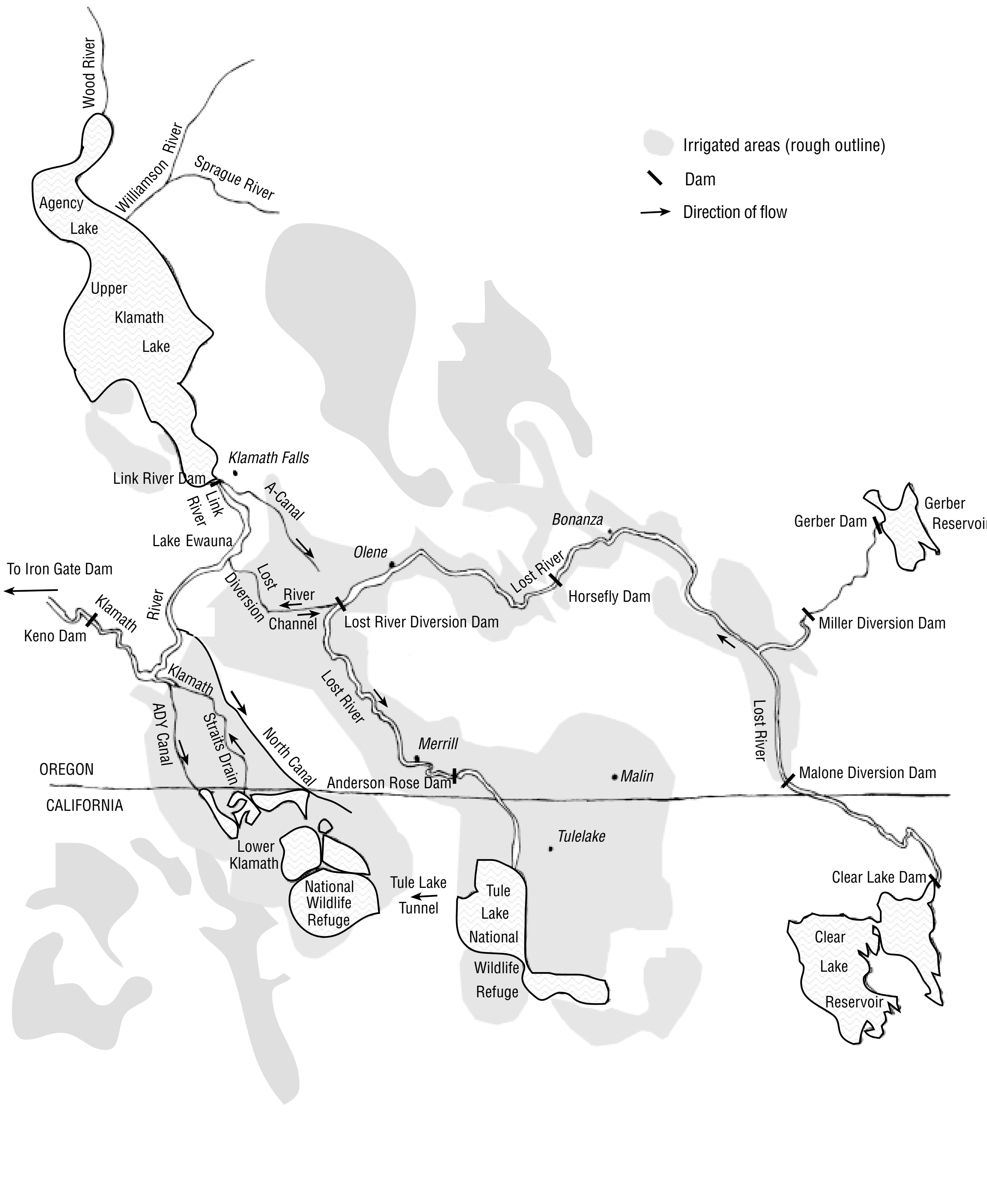
Hydroelectric power

By contract executed in 1917, the United States authorized California-Oregon Power Company [now PacifiCorp] to construct Link River Dam. The dam, deeded to the United States, is operated and maintained by the power company in accordance with project needs. Under the contract, all irrigation rights and requirements are protected and water users of the Klamath Project are provided for as preference power customers. The original contract was amended in 1956 and extended for a 50-year period.

Operating agencies

Clear Lake Dam, Gerber Dam, and Lost River Diversion Dam are operated by the Bureau of Reclamation; Link River Dam is operated by Pacific Power and Light Company [PacifiCorp]; Anderson-Rose Dam is operated by Tulelake Irrigation District; and Malone and Miller Diversion Dams are operated by Langell Valley Irrigation District. Project canals and pumping plants are operated by the various irrigation districts. Recreational facilities at Lower Klamath Lake, Tule Lake, and Upper Klamath Lake are administered by the Fish and Wildlife Service. The Bureau of Land Management administers Gerber Reservoir recreation facilities. Recreation facilities at Malone and Wilson Reservoirs are administered by the Bureau of Reclamation. National wildlife refuges in the Klamath Basin are administered by the Fish and Wildlife Service as part of the national wildlife refuge system.

Appendix B. Map of the Klamath Reclamation Project area



Legal Aspects
of Upper Klamath Basin Water Allocation

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This chapter provides background on Oregon water law, the Klamath Reclamation Project's relationship to the Endangered Species Act, Indian water rights, and several court cases related to water allocation in the Upper Klamath Basin (defined here as the area above Iron Gate Dam). It does not address issues related to water rights in the Lower Klamath Basin.

Oregon water law

As in most western states, Oregon law provides that all water within the state belongs to the public.[1] All such water is subject to appropriation for beneficial use. Except for certain defined exempt uses and uses that were vested prior to enactment of the state's water code, any person intending to acquire a water right must apply to the Oregon Water Resources Department (OWRD).[2]

Once appropriated under the provisions of the state's water code, the right to use the water continues in the owner, so long as the water is applied to a beneficial use in accordance with the terms of the certificate of water right. Water rights are subject to loss only by nonuse.[3]

In addition to state water right systems, certain authority to use and control water arises under federal law. This authority gives the federal government the power to do the following:

- Set aside (reserve) land from public domain for particular purposes (e.g., national forests, national parks, Indian reservations, military bases, etc.)
- Develop federal irrigation, flood-control, and hydroelectric projects
- Manage rivers and lakes for protection of threatened or endangered aquatic species
- Protect navigation

Water law statutes

Notwithstanding the very modest riparian-like rule concerning use of water from a spring under ORS 537.800, Oregon water law is governed by the doctrine of prior appropriation. Oregon's appropriation procedure is set out in Oregon Revised Statutes (ORS) Chapters 536 through 541. Other ORS chapters address matters related to water resource surveys,

[1]ORS 537.110
[2]ORS 537.130(1)
[3]ORS 537.250(3)

river-basin project development, interstate compacts,[4] hydroelectric power projects,[5] water use organizations,[6] and weather modification.[7] The basic statutory provisions of Oregon's appropriation doctrine are:

- Water resource administration—ORS 536
- Appropriation—ORS 537
- Withdrawal of waters from appropriation—ORS 538
- Determination of pre-1909 vested and federal reserved water rights—ORS 539
- Distribution and transfer of rights—ORS 540
- Miscellaneous provisions—ORS 541

Water use policy is set by the legislature and is implemented by a seven-member Water Resources Commission appointed by the Governor. Certain administrative responsibilities are delegated both by statute and by regulation to the Director of OWRD.

The Oregon legislature has articulated several policy standards concerning beneficial uses of water and public-interest criteria associated with water use. In addition, the legislature has created programs for statewide coordination of water development and use, identification of minimum stream flows, stream basin planning, drought management, and enforcement of water use. Pursuant to its stream basin planning authority, the Commission may restrict or prohibit certain uses of water within a basin or, in cases of extreme overappropriation, completely withdraw a stream or river from further appropriation.

Water right appropriation under Oregon's water code

Pursuant to ORS 537.130(1), an individual must apply for a permit before initiating a water use development. The application must describe all elements of the proposed water use. A map prepared by an Oregon certified water right examiner (CWRE) must accompany the application. (Any Oregon professional engineer or land surveyor may become certified as a CWRE upon successful completion of the certifying examination.) A fee must be submitted with the water right application and map.[8]

The United States, the State, or any person has the power to secure a right-of-way across any public or private land as necessary for construction, maintenance, repair, and use of such right-of-way for the purpose of conveying water for beneficial purposes. Such right-of-way may be acquired by condemnation in the manner provided by law for the taking of private property for public use.[9] In addition, any person may enter upon any land for the purpose of locating a point of diversion or a proposed canal, ditch, or other conveyance.[10]

Groundwater appropriation

Groundwater is declared to be part of the public waters of the state and, except in limited circumstances, must be appropriated through the application/permit/certificate process.[11] Uses of groundwater for (1) stock watering, (2) watering any lawn or noncommercial garden not exceeding 0.5 acre in size, (3) certain school grounds and fields, (4) single or group domestic uses not exceeding 15,000 gallons per day, (5) down-hole head exchanges, and (6) single industrial or commercial uses not exceeding 5,000 gallons per day are exempt and do not need to secure a water use permit.[12] The Water Resources Commission is authorized to designate limited and/or critical

[4]ORS 542
[5]ORS 543
[6]ORS 545–555
[7]ORS 558
[8]ORS 536.050(1)
[9]ORS 772.305
[10]ORS 537.320
[11]ORS 537.505–537.720
[12]ORS 537.545

groundwater areas where evidence of declining water levels or patterns of substantial interference between wells is found.[13] Well construction is regulated by the OWRD.[14]

The Oregon Groundwater Code (ORS 537.505 to 537.793 and 537.992) preempts all local ordinances relating to well location, well construction, groundwater allocation, and flow testing of wells.[15]

Pre-1909 water rights and adjudication

Since February 24, 1909, the right to appropriate water in Oregon has been governed by the provisions of ORS 537.110 through 537.270. Any use of water that began prior to February 24, 1909, is deemed to be a vested water right subject to quantification in an adjudication proceeding.[16] Pre-1909 and federal reserved water rights[17] are verified, quantified, and documented through adjudication proceedings in the circuit court of the county in which the water use is located. This adjudication procedure is set out in ORS 539.010 through 539.240. Pre-1909 vested water rights have been adjudicated in approximately two-thirds of the river basins in Oregon.

In order to expedite collection of pre-1909 claims in the remaining river basins, the 1987 Oregon legislature amended ORS Chapter 539 to require all property owners claiming a pre-1909 vested right to file a registration statement on or before December 31, 1994.[18] Federal reserved water right claimants, including federally recognized Indian tribes, are not required to file surface water registration statements; however, federal and Indian claimants can be required to participate in all general stream adjudications in Oregon in accordance with the McCarran Amendment.[19]

Any person claiming an interest in the stream subject to the determination is made a party to and is bound by the adjudication. The court then reviews the Director's determination and any exceptions that are filed, affirms or modifies the order, and enters a final judgment in the form of a stream decree.

The Oregon adjudication process

Each river basin adjudication is initiated by notice of the OWRD Director. Persons claiming a vested, unadjudicated right must file a "proof of claim" with the OWRD. The Director reviews the claims; examines each water use development; provides opportunities for affected parties

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[13]ORS 537.730

[14]ORS 537.747–537.780

[15]See *Ashland Drilling, Inc. v. Jackson County*, 4 P.3d 748 (Or.App.2000).

[16]Pre-1909 vested water rights are verified and documented in the adjudication process described in this chapter. During the adjudication process, the right holder has the opportunity to prove the quantity of water that he/she has vested by beneficial use. Once quantified by the court, the right holder receives a decreed right for that amount.

[17]Federal reserved water rights, sometimes referred to as "Winters" rights, are water rights created under federal law. (See *Winters v. United States*, 28 S.Ct. 207 (1908).) These water rights are created, usually by implication, when the federal government sets aside land from the public domain. The clearest articulation of the federal reserved water right concept is set out in the United States Supreme Court's opinion in *Cappaert v. United States*, 96 S.Ct. 2062 (1976). "When the federal government withdraws land from the public domain and reserves it for a federal purpose, the government, by implication, reserves associated water then unappropriated to the extent needed to accomplish the purpose of the reservation" *(Cappaert*, at 2069). "The implied-reservation-of-water-rights doctrine, however, reserves only that amount of water necessary to fulfill the purpose of the reservation, no more" *(Cappaert*, at 2071). The priority date of a water right associated with a federal reservation is the date the reservation was created. In the case of an Indian reservation, the date generally is the date of the treaty or executive order creating the reservation.

[18]ORS 539.230–539.240. The Klamath Basin adjudication (see description of the KBA, below) is the last adjudication conducted under the pre-1987 version of the Code. Klamath Basin claimants were not required to file registration statements under ORS 539.240.

[19]43 U.S.C. § 666. See description of the McCarran Amendment below in the discussion of the *United States v. Oregon* case.

to submit contests of claims; schedules appropriate hearings; and, finally, prepares a “finding of fact and order of determination” to be filed in the circuit court in the county where the stream or river is located. The specific process is as follows.

1. OWRD Director initiates an adjudication with notice to basin property owners and the United States Attorney General.
2. Individuals who believe they have a pre-1909 water right, as well as the United States government (federal reserved water right), may file a “notice of intent” to claim a right.
3. Before the 1987 amendments to ORS 539, the OWRD prepared maps of water use, which located all irrigation uses by quarter-quarter section. Under the 1987 amendments, individuals must supply a map with each statement and proof of claim.
4. Notice is sent to individuals who filed “notice of intent” to file a “statement and proof of claim” during a specified claiming period.
5. Claimants file statements and proofs of claim. Claimants who agree that OWRD’s maps correctly delineate their water use may check a box accepting the Department’s map. Claimants who disagree with the Department’s map must submit a map prepared by a certified water right examiner (CWRE).
6. Claims are reviewed by the Director (Adjudicator) for completeness. Supplemental information and/or documentation may be requested.
7. A preliminary evaluation of each claim is prepared.
8. Open inspection is held. Notice of the open inspection must be given at least 10 days before the beginning of the open inspection period.
9. The contest period begins immediately following the open inspection period. Any person owning any irrigation works or claiming any interest in the stream involved in the adjudication may file a contest(s) opposing any claim or the Director’s preliminary evaluation of a claim(s). The contest period must run at least 15 days and may be extended up to an additional 20 days at the discretion of the Director (Adjudicator).
10. Contests are referred to hearing. Contests may be settled by negotiation (stipulation).
11. The hearing officers submit preliminary orders and/or stipulations to the Director (Adjudicator).
12. The Director (Adjudicator) submits findings of fact and order of determination to the circuit court in the county where the adjudication basin is located.
13. The Director provides notice to all parties that the findings and order have been submitted to the court. Any party may file exceptions to the findings and order. If no exceptions are filed, the court must enter a judgment affirming the Director’s findings and order. If exceptions are filed, the court may hear the case or remand to the Director or a referee for further findings.
14. Appeal of the court’s final judgment is to the Oregon Court of Appeals and the Oregon Supreme Court if necessary. If there is a federal question in the adjudication, a petition for certiorari (asking for review of the Oregon Supreme Court holding) may be filed with the United States Supreme Court.

Klamath Basin adjudication

The Klamath Basin adjudication (KBA)[20] is the seventh subbasin[21] adjudication in the Klamath Basin.[22] All persons claiming a right to water, the use of which began before February 24, 1909, were required to file proofs of claim with the Department during the 1990–1991 private-right claiming period. The United States and Klamath Tribes were required to file claims during the 1996–1997 federal-right claiming period.

Approximately 700 claims were filed in the KBA, including approximately 400 claims filed by various agencies of the United States Government and the Klamath Tribes (Appendix A). The KBA is the first Oregon general stream adjudication in which large, complex federal claims have been filed.

OWRD staff conducted a preliminary evaluation of each claim. The claims and the Department's preliminary evaluation were made available for inspection. Following the open inspection period, approximately 5,600 contests were filed during the contest period. All of the contests have been referred to the state Central Hearing Panel, and proceedings on several groups of contests are ongoing.

Alternative dispute resolution

Given the magnitude of the claims and the complex adjudication of these claims, the Department believes that some form of alternative dispute resolution (ADR) could be used to resolve many of the issues surrounding the adjudication. In addition, resolution of the adjudication issues likely will involve a number of related matters such as the balance between water supply and demand, connected surface water/groundwater administration, water quality, endangered species, interstate water administration, and state/federal coordination in water management. Therefore, OWRD has initiated a voluntary ADR process to provide a forum to address adjudication claim issues and these related matters.

The ADR process is intended to provide a way to resolve KBA contests as well as a forum for evaluating the full range of water allocation and management issues in the Basin. It is a forum for claimants, other water right holders, and interested parties to meet and discuss opportunities for resolution of the Basin's water issues. The Director of the OWRD is the ADR process leader. The Department has held regular ADR monthly meetings since September 1997.

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[20]The State Engineer (Director) initiated the current Klamath Basin Adjudication in 1975 and notified almost 30,000 property owners that if they intended to file a claim in the adjudication, they must file a "Notice of Intent." Approximately 1,200 notices of intent were submitted to the Department, including filings by a number of irrigation districts on behalf of their district members. Upon receipt of the notices of intent, the Department conducted water use surveys of the adjudication area. Individual water uses in 108 townships were mapped. On September 7, 1991, the Director mailed notice to all individuals who had filed notices of intent to file statements and proofs of claim. The claiming period for federal and tribal claims was delayed by the *U.S. v. Oregon* case. Upon final resolution of the *U.S. v. Oregon* case in August 1996, the Director provided notice to the United States, the Klamath Tribes, and the Klamath Reclamation Project irrigation districts to file statements and proofs of claim.

[21]The KBA is confined to the area of the former Klamath Indian Reservation, along with that portion of the Basin between Upper Klamath Lake and the Oregon–California state line (roughly the area receiving water from Upper Klamath Lake, Link River, Lake Ewauna, and the Klamath River). The Lost River; Cherry, Sevenmile, and Annie creeks; the North and South forks of the Sprague River; and portions of the Wood River have been adjudicated. All of these adjudications were conducted before adoption of the McCarran Amendment.

[22]The KBA court is the Klamath County Circuit Court. The KBA Court's jurisdiction is limited to water used or diverted in Oregon. The Klamath River and its tributaries in California are under the jurisdiction of the California Water Resources Control Board (CWRCB) and the California courts. The State of California has completed four adjudications of Klamath River tributaries in California (Shasta River in 1932, Scott River in 1980, Willow Creek in 1972, and Cold Creek in 1978). In addition, in 1959, the CWRCB issued Permit Order No. 124 for transbasin diversion of Trinity River water to the Sacramento River for use in the Central Valley Project. There are no ongoing or planned adjudications of the Klamath River Basin in California.

Klamath Reclamation Project (U.S. Bureau of Reclamation)

Pursuant to the Reclamation Act of 1902, on May 19, 1905, the U.S Reclamation Service filed a notice in the office of the State Engineer stating that the United States intended to utilize "all of the waters of the Klamath Basin in Oregon, constituting the entire drainage basins of the Klamath River and Lost River, and all of the lakes, streams and rivers supplying water thereto or receiving water therefrom..." to furnish water to the Klamath Reclamation Project in Oregon and California. Following the filing of this notice in 1905, the Bureau of Reclamation filed plans and authorized necessary construction in compliance with the Reclamation Act.[23]

The Act of February 9, 1905 authorized the Secretary "...to dispose of any lands ... under the terms and conditions of the Reclamation Act of 1902." Since much of the area to be served by the Project consisted of submersed lands, Congress authorized the Secretary of the Interior to raise or lower the level of Lower Klamath Lake and Tule Lake.[24]

Because the title to these submersed lands had passed to the states of Oregon and California at the time of admission to the Union, it was necessary for each state to cede title back to the United States. In 1905, Oregon "...ceded to the United States all right, title, and interest ... to any land uncovered by the lowering of water levels or by drainage of any or all of said lakes."[25] Likewise, California ceded its "... right, title, interest, or claim..." to the lands uncovered by lowering said water levels.[26]

The Project was approved by the President on January 5, 1911 in accordance with the Act of June 25, 1910.[27] The total irrigable area of the Project was estimated at approximately 240,000 acres, of which approximately 110,000 acres was public land and 130,000 acres was in private ownership. About 90,000 acres of the Project were located in California and 150,000 acres in Oregon. The cost of the Project was estimated at approximately $4.5 million. Major project facilities include Link River Dam (completed in 1921), Clear Lake Dam (completed in 1910), and Gerber Dam (completed in 1925).

It should be noted that there was significant irrigation development in the vicinity of Klamath Falls before initiation of the Klamath Reclamation Project in 1905. The Klamath Canal Company, Van Brimmer Ditch Company, the Little Klamath Water Ditch Company, and the Big Water Ditch Company were in operation for many years before initiation of the federal project. The irrigation companies, along with a number of other private water users, were incorporated into the Project and ultimately served by the Project facilities.

The Project currently delivers irrigation water to approximately 130,000 acres in Oregon and 70,000 acres in California. During a normal year, the net water use on the Project is approximately 2 acre-feet per acre, including water used by the U.S. Fish and Wildlife Service in the Tule Lake and Lower Klamath national wildlife refuges.[28]

The Reclamation Act of 1902 and authorizing legislation for the Project authorized the U.S. Reclamation Service (later the U.S. Bureau of Reclamation) to enter into contracts with individuals and duly formed irrigation districts for the delivery of water within the Project. These

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[23]The Project was authorized by the Secretary of the Interior on May 1, 1905 in accordance with the Reclamation Act of June 17, 1902 (43 U.S.C. §372 et seq., 32 Stat. 388).

[24]Act of February 9, 1905, ch. 567, 33 Stat. 714. The lands formerly inundated by Tule Lake and Lower Klamath Lake were dewatered and were homesteaded by farmers as late as 1949.

[25]General Laws of Oregon, 1905, p. 63, January 20, 1905

[26]Cal. Stats. 1905, p. 4, February 3, 1905

[27]36 Stat. 835

[28]The Lower Klamath National Wildlife Refuge was established in 1908, and the Upper Klamath Lake and Tule Lake national wildlife refuges were established in 1928.

contracts include repayment contracts (commonly referred to as "A" contracts),[29] Warren Act contracts (commonly referred to as "B" contracts),[30] and annual surplus water contracts (commonly referred to as "C" contracts). Historically, only about 4,000 acres in the Project receive water under temporary annual surplus water contracts.

Project operations plans and the Endangered Species Act

Since 1995, the U.S. Bureau of Reclamation (BOR) has operated the Klamath Project according to annual operations plans. The annual operations plans have been developed to assist the BOR in operating the Project consistent with its federal statutory obligations and responsibilities, including obligations under the Reclamation Act, the Endangered Species Act (ESA), and in accordance with the U.S. Department of the Interior's tribal trust responsibilities. In addition to the BOR's contractual obligations to deliver water to Project irrigators and its responsibilities under the ESA, each operations plan must be able to address varying annual hydrological conditions, changes in agricultural cropping patterns, and changes in national wildlife refuge operations.

Prior to 1994, operation of the Project was primarily dictated by the BOR's contractual obligations for delivery of irrigation water and for downstream river flows made in coordination with PacifiCorp. Deference was given to PacifiCorp's Klamath River Federal Power Act license (FERC license). However, in 1988, with the listing of the Lost River and shortnose suckers as endangered under the ESA, Project operational considerations began to change. In 1989, the BOR began consultation with the U.S. Fish and Wildlife Service (USFWS) under Section 7 of the ESA.[31]

The USFWS issued its first Biological Opinion (BiOp) for recovery of suckers in 1992. This BiOp set the minimum lake elevation for Upper Klamath Lake at 4,141 feet above sea level by May 31 and 4,139 feet from June 1 through the end of February. In addition, the 1992 BiOp allowed the lake elevation to drop to 4,137 from June 1 through September 30 in no more than 2 consecutive years and in no more than 4 years in a 10-year period. Since there were adequate supplies of water for most of the years between 1992 and 2001, the minimum lake elevations in these years did not deprive the Project of regular supplies.

In 1997, the water-budget picture was further complicated by the listing of southern Oregon/northern California coho salmon as threatened under the ESA. In 1998, the BOR initiated consultation with the National Marine Fisheries Service (NMFS) under Section 7 of the ESA. Considerations for lower Klamath River coho relate to flows over Iron Gate Dam to maintain in-stream flows in the lower Klamath. The first BiOp on the coho was issued in 1999. Again, adequate water years in 1999 and 2000 allowed for regular deliveries to Project irrigators during those seasons.

However, in 2001, the water needs of the listed species (suckers in Upper Klamath Lake and coho salmon in the lower Klamath River),[32] along with the reduced water supplies caused by

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[29]Repayment contracts are entered into by the U.S. Bureau of Reclamation pursuant to Article 9(d) of the Reclamation Act of 1939 to provide for repayment of Project costs. The contracts specify an acreage to be covered. In most cases, these contracts do not specify an amount of water, relying instead on beneficial use as the limit of water used. Klamath Reclamation Project repayment contracts are all written in perpetuity.

[30]Act of February 21, 1911, ch. 141, 36 Stat. 925. These contracts provide for a water supply at a certain point, with responsibility of the contractor to construct, operate, and maintain all necessary conveyance facilities.

[31]Section 7 of the ESA requires federal agencies who intend to take an action that would be likely to jeopardize the existence of a listed endangered species to consult with the federal agency responsible for the listing and recovery of that species. Because operation of the Project is deemed to be an "action" under the ESA, the BOR must consult on each of its annual operation plans with both USFWS and NMFS. These agencies then issue Biological Opinions on the likely effects of the Project operations plan on suckers (USFWS) and coho salmon (NMFS).

[32]New BiOps on both suckers and coho salmon were issued in early 2001.

the severe drought of 2000–2001, resulted in an April announcement that there would be no irrigation deliveries during the 2001 season from Upper Klamath Lake.[33]

On February 25, 2002, the BOR issued its Biological Assessment (BA) for the 2002 Klamath Project Operations Plan.[34] Unlike the 2001 BA or BiOp, the 2002 BA contains several paragraphs of legal analysis concerning authorization of the Project and associated water rights.

The following excerpts are examples of such language:

> "[W]ater can only be stored and delivered by the Project for authorized purposes for which Reclamation has asserted or obtained a water right in accordance with Section 8 of the Reclamation Act of 1902 and applicable federal law. Reclamation must operate the Project in a manner that does not impair senior or prior water rights. Reclamation has an obligation to deliver water to the Project water users in accordance with the Project water rights and contracts between Reclamation and the water users (which may be through a water district). Water lawfully stored in Project's reservoirs can be used for Project purposes to the extent the water is applied to beneficial use within the Project.
>
> The beneficial interest in the Project water right is in the water users who put the water to beneficial use.
>
> Federal law concerning Reclamation projects, which is consistent with Oregon law, also provides that the use of water acquired under the Act 'shall be appurtenant to the land irrigated, and beneficial use shall be the basis, measure, and the limit of the right.'
>
> Reclamation has no general authority to reallocate Project water. As to the Klamath Project, Reclamation, in certain circumstances, may be unable to deliver water for Project purposes."

With respect to the BOR's proposed action for the period covered by the BA (2002–2012), including the 2002 irrigation season, the BOR proposes "... to continue operation of the features and facilities of the Klamath Project consistent with the historic operation of the Project from water year 1990 through water year 1999." Apparently, for the 2002 irrigation season, the BOR proposes full deliveries to Project water users.

Chapter 5.0 of the 2002 BA sets out the "Effects of the Proposed Action." In analyzing the operation's effects, the BOR described, and apparently relied upon, the findings of the National Academy of Science (NAS).[35] The NAS findings conclude that there was no substantial scientific support for the recommendations in the 2001 USFWS and NMFS BiOps concerning minimum water levels in Upper Klamath Lake (for suckers) or increased minimum flows in the Klamath River mainstem (for coho salmon). Therefore, it seems that the BOR is proposing that, if operations conform to the general pattern followed between 1990 and 1999, future operation of the Project will not be likely to jeopardize suckers or coho.

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[33]Project irrigation supplies were curtailed in 2001 only for deliveries from Upper Klamath Lake. Deliveries in the Lost River portion of the Project from Clear Lake and Gerber Reservoir were made on a regular schedule for the 2001 season. In addition, on July 24, 2001, the Department of the Interior was able to release approximately 75,000 acre-feet of water from Upper Klamath Lake for irrigation deliveries.

[34]In fact, the BA describes the BOR's proposed operations of the Project from April 1, 2002 through March 31, 2012. This is the BOR's first attempt to develop an operations plan covering more than 1 year.

[35]The National Academy of Sciences formed a Committee on Endangered and Threatened Fishes in the Klamath River Basin to conduct an independent peer review of the science concerning suckers and coho salmon. The report was issued in early February 2002.

Klamath Indian Reservation

The Klamath Indians have hunted, fished, and foraged in the Upper Klamath River Basin for many generations. In 1864, the Klamath and Modoc tribes entered into a treaty with the United States whereby they relinquished aboriginal claim to some 12 million acres in exchange for a reservation of approximately 800,000 acres in the Upper Basin.

The Tribes held the land in communal ownership until Congress passed the General Allotment Act of 1887. Pursuant to the Allotment Act, parcels of tribal land were granted to individual Indians in fee. Approximately 25 percent of the original Klamath Indian Reservation passed from tribal ownership to individual Indians. Over time, many of these allotments passed into non-Indian ownership.

In 1954, Congress enacted the Klamath Termination Act,[36] under which tribal members could give up their interest in tribal property for cash. A large majority of the tribal members chose to sell. In 1958, the federal government purchased 15,000 acres of the Klamath Marsh to create the Klamath Forest Wildlife Refuge. In 1961, and again in 1975, the United States purchased large forested portions of the former reservation to become part of the Winema National Forest. In 1973, the United States condemned most of the rest of the tribal land and essentially extinguished the original Klamath Reservation. The United States now holds title to approximately 70 percent of the former reservation land.

United States v. Adair[37]

In September 1975, the United States filed suit in federal District Court in Portland for a declaration of water rights within an area whose boundaries roughly coincide with the former Klamath Indian Reservation. The suit named as defendants some 600 individual owners of land within the former reservation. The Klamath Tribes and the State of Oregon intervened in the case.[38]

The United States and the Tribes argued that the Tribes and individual Indians retained an implied reserved water right for agricultural purposes and to protect their traditional hunting and fishing lifestyles, notwithstanding the Klamath Termination Act. The State moved for dismissal of the federal court action under the Colorado River "abstention doctrine," arguing that the rights of the claimants should be decided in a state adjudication proceeding, not in a federal court action.[39]

The federal District Court (Judge Solomon) denied the motion for dismissal and issued a pretrial order setting out the issues to be decided:

- Whether water rights had been reserved for the use of the Klamath Reservation by the 1864 treaty with the Klamath and Modoc tribes
- Whether such rights passed to the federal government and to private persons who took title to such lands
- What priority dates should be accorded to each of the present owners
- Whether quantification of the rights should be left to the state court proceeding under the provisions of the McCarran Amendment

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[36]25 U.S.C. §§ 564-564w

[37]723 F.2d 1394 (9th Cir. 1983)

[38]The Klamath Tribes, arguing that they and their members had interests in the water within the former reservation, and thus in the potential outcome of the case, intervened as a plaintiff. The State of Oregon, arguing that landowners hold their water rights through the State, intervened as a defendant.

[39]See *Colorado River Water Conservation District v. United States*, 424 U.S. 800 (1976). The United States Supreme Court in the *Colorado River Conservation District* case indicated that where a state adjudication proceeding was in progress, the policy evinced in the McCarran Amendment to avoid piecemeal adjudication of water rights counseled abstention.

Judge Solomon held:

- The 1864 treaty with the Klamath and Modoc Indians granted the Indians an implied reserved water right to as much water on the reservation as was necessary to preserve their hunting and fishing rights.
- The Klamath Termination Act did not abrogate such water rights.
- Individual Indians who were allotted lands within the former reservation are entitled to water essential to their agricultural needs with a priority date of 1864.
- Non-Indian successors to Indian allottees have an 1864 water right for actual acreage under irrigation when the non-Indian obtained title from the Indian and to additional acreage developed with reasonable diligence.
- The United States Forest Service acquired reserved water rights for timber production and conservation of water flows.
- Quantification of the tribal water rights is to be left to the State of Oregon under the McCarran Amendment.

The United States, Tribes, and Oregon all appealed the District Court decision to the 9th Circuit Court of Appeals. The 9th Circuit generally affirmed Judge Solomon, while providing more specific detail as to the various reserved water rights within the former reservation.

The priority date of the Tribes' reserved water right to support its hunting and fishing lifestyle is time immemorial. This right is a nonconsumptive, in-stream water right not based on the doctrine of prior appropriation. It is a right to prevent depletion below a protected level; however, it is not a wilderness servitude.[40] The water is protected to support hunting and fishing as currently exercised to maintain the livelihood of Tribe members, not as these rights once were exercised by the Tribe in 1864.

The priority date of the individual Indians holding allotted lands is 1864. This right is to be determined by the "practicably irrigable acreage" (PIA) standard as set out in *Arizona v. California,*[41] and it is not forfeitable. Non-Indian successors (Walton Rights) have a priority date of 1864 for acreage under irrigation on the date title passes from his/her Indian predecessor, with additional acreage developed with reasonable diligence. This right can be forfeited for nonuse under state law.

Finally, the 9th Circuit Court held that the federal agencies that took over control of the land within the former reservation did not receive an "Indian" reserved water right with a time immemorial or 1864 priority date. However, these agencies (the United States Forest Service and USFWS) will be able to claim reserved water rights for forest and wildlife purposes in the state adjudication.

Adair III CV No. 75-914 (Opinion and Order February 27, 2002)

The United States and the Klamath Tribes filed a "Motion for Exercise of This Court's Continuing Jurisdiction" in Federal District Court in Portland on January 16, 2001. The United States' motion asks the court "... to construe certain legal issues regarding the

[40]The Court, in describing the nature of the Tribes' water right to support its treaty hunting and fishing rights, stated that the right "... retains a priority date of first or immemorial use. This does not mean, however ... that the former Klamath Reservation will be subject to a 'wilderness servitude' in favor of the Tribe."

[41]83 S.Ct. 1468, 1497-98 (1963). When the United States government sets aside land for an Indian reservation, the courts have held that there is created an implied reserved water right for enough water to satisfy the purpose of the reservation. (See discussion of federal reserved water rights above at n.17.) In *Arizona v. California*, at 1498, the United States Supreme Court stated that "... water was intended to satisfy the future as well as the present needs of the Indian Reservations ... that enough water was reserved to irrigate all practicably irrigable acreage on the Reservations." The determination of "practicable irrigable acreage" (PIA) in the adjudication of a reservation is fact-specific as to each parcel on the reservation. Factors such as soil conditions, topography, and access to water are considered in the determination of whether any particular acre is irrigable.

priority date and scope of the Klamath Tribes' water rights that were previously decided in this action and thereby provide the necessary direction to certain parties to this case who are also parties to the State of Oregon's Klamath Basin Adjudication."

The United States posed two questions to the Court:

- "[D]o the Klamath Tribes have water rights to support plants from which the Tribes gather food and other items under Art. 1 of the 1864 Treaty?"
- "[W]hat is the proper measure of the tribal water rights to support their treaty, hunting, fishing, trapping, and gathering rights?"

The second question includes the following three related issues:

- What is the role of the "moderate living" doctrine in quantifying the Tribes' water rights?
- What is the role of the phrase "as currently exercised" in quantifying the Tribes' water rights?
- Is the measurement of the Tribes' water rights the "*minimum* amount of water" necessary to meet the needs of the Klamath Tribes' treaty resources?

The State of Oregon moved for dismissal under the Colorado River abstention doctrine. Judge Panner denied the State's motion and reopened the *Adair* case.

On February 27, 2002, Judge Panner issued his Opinion and Order in *Adair* III. The Order declares that "... the Klamath Tribe's water rights include a water right to support resources the Tribes gather, in addition to the resources they hunt, fish, and trap." The Order also declares that the moderate living standard has limited application in this case, and, finally, "... [I]n no event shall the [KBA] adjudicator quantify or reduce the Tribal water right to a level below that which is necessary to support productive habitat."

United States v. Oregon[42]

On December 20, 1990, the United States filed suit in Federal District Court in Portland seeking a temporary restraining order (TRO) and a permanent injunction to prohibit Oregon from requiring the federal government to file claims in the Klamath adjudication. (Oregon law states that if a party to an adjudication fails to file a statement and proof of claim within the time specified in the notice, all rights are forfeited, and such party may not later claim a water right.) This suit was filed on behalf of various federal agencies that manage federal land in the Basin, including the Bureau of Reclamation as operator the Klamath Reclamation Project. The Klamath Tribes and the individual Klamath Indian allottees filed for intervention in the suit.[43]

The Federal District Court granted the TRO and injunction to allow the case to be argued on the merits. The United States and Oregon entered a stipulated agreement to not require the federal government to file claims until 60 days after the suit was concluded.

The underlying issue of the case is whether the United States is immune from suit in state court. In general, the United States is immune unless Congress expressly waives its immunity. However, in 1952, the McCarran Amendment was enacted, which waived federal sovereign immunity in state general stream adjudications.[44] The United States argued that, notwithstanding the McCarran Amendment, it had not waived its sovereign immunity in the Klamath adjudication, and, therefore, it need not file claims. In

[42]44 F.3d 758 (9th Cir. 1996).

[43]The Klamath Tribes and members of the Tribes holding allotments within the former reservation argued to be allowed to intervene in the case to protect their rights to the water of the reservation as determined in the *Adair* case. (See discussion of *United States v. Adair* above.)

[44]43 U.S.C. §666(a). "Consent is hereby given to join the United States as a defendant in any suit ... for the adjudication of rights to the use of water of a river system or other source.... The United States, when a party to such suit, shall (1) be deemed to have waived any right to plead that the State laws are inapplicable or that the United States is not amenable thereto by reason of sovereignty...."

addition, the Tribes argued that they would be deprived of due process because the state had a history of hostility to the Tribes' treaty rights, including the claims to water rights.

The United States' argument that sovereign immunity had not been waived was based upon a strict reading of the language in the McCarran Amendment. Their point was that Oregon's adjudication system was not a "suit" for the determination of water rights. In addition, the U.S. argued that the OWRD's adjudication procedure was administrative, not judicial, and that the adjudication was not comprehensive in that it did not include all water users and did not include groundwater uses.

The Federal District Court held that the United States must file claims in the Klamath adjudication and must pay the state adjudication fees. In addition, the Tribes must file claims, but are not required to pay fees. The allottees' motion to intervene was denied.

The United States and Tribes filed an appeal to the 9th Circuit Court of Appeals. The 9th Circuit affirmed the District Court except for the fees, holding that, under the McCarran Amendment, the United States cannot be required to pay state fees. The Klamath Tribes petitioned the United States Supreme Court for certiorari. The United States opposed this petition. The Supreme Court denied the Tribes' petition and did not take the case. The allottees eventually settled with the state and filed claims in the adjudication.

Appendix A. Summary of federal agency claims in the Klamath Basin adjudication

U.S. Forest Service

214 claim forms claiming 416 water rights

17	Claims for consumptive uses
117	Claims for in-stream flows for timber production, channel maintenance (favorable conditions of stream flow), fish, wildlife, and recreation
13	Claims for in-stream rights for lakes
62	Claims for in-stream rights for springs
5	Claims for wilderness water rights

U.S. Bureau of Land Management

52 claims for water on BLM land

51	Claims for waterholes (Public Reserve No. 107)
1	Claim for the Klamath Wild and Scenic River

National Park Service

21 claims for Crater Lake National Park

10	Claims for in-stream water rights
11	Claims for 44 consumptive uses

U.S. Fish and Wildlife Service

22 claims for water rights in four wildlife refuges

9	Claims for irrigation of approximately 63,000 acres
12	Claims for approximately 200,000 acre-feet of water per year for wildlife refuge uses
1	Claim for approximately 80 cfs for stockwater

U.S. Bureau of Indian Affairs

393 claims on behalf of the Klamath Tribes

5	Claims for consumptive uses
52	Claims for in-stream flows in, above, and below the former reservation
1	Claim for minimum water level in Upper Klamath Lake
1	Claim for minimum water level in the Klamath Marsh
334	Claims for wildlife seeps and springs within the former reservation

Klamath Tribes

5 claim forms incorporating all of the claims filed by the Bureau of Indian Affairs (in effect duplicate claims to the BIA filing)

U.S. Bureau of Reclamation

7 consolidated claims for the Klamath Project

Diversion of 3,505 cfs for irrigation of 218,654 acres

486,830 acre-feet of storage in Upper Klamath Lake

92,300 acre-feet of storage in Gerber Reservoir

481,300 acre-feet of storage in Clear Lake

Appendix B. Court cases related to water allocation in the Upper Klamath Basin

Kimball v. Callahan, 493 F.2d 564 (9th Cir. 1974) (Kimball I)

The 1864 Treaty with the Klamath Tribes gave the Tribes the exclusive right to hunt, fish, and gather on their reservation.

Kimball v. Callahan, 590 F.2d 768 (9th Cir. 1979) (Kimball II)

The Treaty rights survived the Klamath Termination Act.

U.S. v. Adair, 723 F.2d 1394 (9th Cir. 1983)

See discussion above.

Adair III CV No. 75-914
See discussion above.

U.S. v. Oregon, 44 F.3d 758 (9th Cir. 1996)

See discussion above.

Bennett v. Spear, 117 S.Ct. 1154 (1997)

Lost River irrigators have standing to bring judicial challenge to the U.S. Fish and Wildlife Service Biological Opinion, which made a jeopardy finding on the Lost River and shortnose suckers and identified minimum water levels in Clear Lake and Gerber Reservoir as reasonable and prudent alternatives. Irrigators had standing to challenge the Biological Opinion based on injury in fact from reduced water delivery, which was traceable to the Biological Opinion.

Bennett v. Spear, 5 F.Supp. 882 (D.Or. 1998)

On remand, District Court held that the record did not support the U.S. Fish and Wildlife Service determination that retaining minimum lake levels in Clear Lake and Gerber Reservoir would help avoid jeopardy.

Klamath Water User's Association v. Patterson, 204 F.3d 1206 (9th Cir. 1999)

Klamath Water Users Association brought a contract action in the federal District Court in Oregon against the Bureau of Reclamation and PacifiCorp, challenging the operation of Link River Dam (which controls the level of Upper Klamath Lake). The court held that the irrigators are not third-party beneficiaries under the contract between the BOR and PacifiCorp for operation of the dam. In addition, the court pointed out that the BOR "... has authority to direct operation of the Dam to comply with the ESA [and] with Tribal trust requirements." However, it should be noted that the issues related to water rights, the ESA, and tribal interests were not briefed or argued in the case; therefore, the court's discussion of these matters likely will be treated as dictum and, thus, not binding as precedent in future cases.

Langell Valley Irrigation District v. Babbitt, Case No. 00-6265-HO (D.Or. 2000)

The LVID challenges BOR releases from Clear Lake, in the Lost River side of the Klamath Basin, for delivery to various uses on the Klamath side. Request for the injunction was denied, and the case was dismissed without prejudice.

Water for Life v. State of Oregon, Case No. 00-1260CV (Klamath County Circuit Court, August 2000)

Water for Life sought an injunction to delay the KBA on procedural grounds. Water for Life argued that certain notice procedures in the KBA were deficient and that the adjudication should be suspended while the notice defects were corrected. Circuit Court dismissed the action on the ground that plaintiffs can raise procedural arguments when the Adjudicator's Findings and Order of Determination reach circuit court.

In the Matter of Lost River, Case No. 1918-001 (2000) (Klamath County Circuit Court, May 12, 2000)

Lost River irrigators sought modification of the 1918 Oregon decree adjudicating the waters of the Lost River. The decree "recognized," without determining, the United States water rights for the Klamath Reclamation Project. The Bureau of Reclamation moved to dismiss the modification request on the ground that: (1) the 1918 decree was not valid as to the United States because the decree predates the McCarran Amendment, and (2) the decree cannot be modified without the participation of the Bureau, which is an indispensable party. The court agreed and dismissed the action.

Dept. of the Interior v. Klamath Water Users Protective Assoc., 121 S.Ct. 1060 (2001)

Documents relating to claims filed in the adjudication by the Bureau of Indian Affairs on behalf of the Klamath Tribes are not exempt from disclosure under the Freedom of Information Act as interagency or intraagency memoranda or letters.

Pacific Coast Federation of Fishermen's Assoc. v. U.S. Bureau of Reclamation, 138 F.Supp. 1228 (D. N. Cal., April 3, 2001)

The Bureau is enjoined from sending irrigation deliveries to the Project at any time when required downstream flows are not met, until the Bureau completes a plan to guide operations during the new water year and consultation on that plan is completed.

Kandra v. U.S., 145 F.Supp.2d 1192 (D. Oregon, April 30, 2001)

Irrigators in the Project sought preliminary injunction against the BOR's 2001 Operating Plan, under which no irrigation water deliveries would be made to the majority of land within the Klamath Project because of extreme low-water conditions, ESA obligations, and tribal trust obligations. The preliminary injunction was denied, and the case was dismissed without prejudice.

U.S. v. Adair, CV No. 75-914-PA (D. Oregon, August 9, 2001)

See discussion above.

Tulare Lake Basin Water Storage District v. United States, U.S. Cl. Ct., No. 98-101 L (April 30, 2001)

The Water Storage District claimed that their contractually conferred right to use water was taken from them when the federal government imposed water use restrictions under the Endangered Species Act. Plaintiffs seek compensation under the Fifth Amendment of the United States Constitution. The court held that by limiting plaintiffs' ability to use an amount of water, the government essentially substituted itself as the beneficiary of the contracted rights, totally displacing the contract holder. By preventing plaintiffs from using water to which they would otherwise have been entitled, they have rendered the right valueless, and thus have effected a physical taking. The Klamath Irrigation District has filed claims for damages based upon a taking of property rights (water rights) in the United States Court of Federal Claims.

Alsea Valley Alliance v. Evans and NMFS, U.S. D. Ct. Or., Case No. 99-6265 (Sept. 10, 2001)

Plaintiffs challenge the 1998 listing of the Oregon Coast coho salmon evolutionary significant unit (ESU). In its final rule listing the coho ESU as threatened, NMFS only listed the "naturally spawned" coho. Plaintiffs sought to invalidate the 1998 listing decision because the distinction between "naturally spawned" and "hatchery spawned" coho salmon is arbitrary and capricious and thus unlawful under the federal Administrative Procedures Act. The Court agreed and held that the 1998 NMFS listing decision is unlawful and should be set aside as arbitrary and capricious. The case currently is on appeal to the U.S. 9th Circuit Court of Appeals.

Methow Valley situation

A number of private irrigation ditches divert water from tributaries of the Methow River in north-central Washington. Several species of fish found in the Methow River and its tributaries have been listed as either threatened or endangered under the ESA (some by the NMFS and some by the USFWS). Some of the points of diversion of the irrigation ditches, along with portions of the ditches themselves, are located within the United States Forest Service's (USFS) Okanogan National Forest. The owners of these ditches were issued Special Use Permits (SUP) by the USFS to allow use of the National Forest lands for diversion and conveyance of water. As a result of the ESA listings, the USFS was required to enter into consultation with the NMFS and the USFWS to ensure that diversion of water within the Forest was not "likely to affect" the listed species. The consultation resulted in reduced irrigation deliveries. Those ditches diverting water from the tributaries of the Methow not located within the Forest are subject to provisions of the ESA that prohibit "take" of a listed species. To date no actions have been initiated.

4

Science

Understanding Science

Douglas F. Markle

A. John Arnfield, a geographer and climatologist at Ohio State University, describes several characteristics of science and environmental issues that often are misunderstood or forgotten during times of controversy. We have paraphrased his explanations below.

- Science cannot *prove* anything—it can only *disprove* ideas. Advances occur through controversy by discarding ideas that do not stand accepted testing.
- Science cannot make statements that are certain. The conclusions of science possess a greater probability of being true than ideas discovered by other means, but they are not "true" in the sense that they are beyond doubt. As a result, we cannot wait until we have complete certainty about environmental issues because such certainty will never exist. Neither should we expect certainty; as individuals we routinely act on the basis of incomplete knowledge. If farmers required certainty about weather and prices, for example, they never would plant a crop.
- *Scientific consensus* is more important than scientific disagreements, although news media often make it difficult to believe there ever is consensus. News often focuses on "breakthroughs," which often are controversial, as they have not been widely tested and accepted among the scientific community—so-called *frontier science*. After further testing, some of this science eventually becomes incorporated into *consensus science*—data, theories, and laws that are widely accepted in the scientific community. Consensus science is very reliable, but rarely newsworthy. When we begin to study a system, such as suckers in Upper Klamath Lake, it takes years to move from the frontiers to consensus on all issues.
- *Theory*, with a capital "T," as used in science, is not speculative or untested. In science, "Theory" implies a well-tested and widely accepted idea or principle that explains many facts that previously seemed to be unrelated. Relativity Theory, Evolutionary Theory, the Theory of Plate Tectonics, and Quantum Theory are as reliable as human ideas get.
- *Theory*, with a small "t," is a term that means working theory or hypothesis. Because science cannot prove things, theories are tested as *null hypotheses*. We can, for example, test whether different estimates of fish abundance in two habitats are due to chance by disproving the hypothesis that the two populations are the same.
- Working theories help scientists develop *models*—simplified representations or simulations of a natural system used to

generate predictions. Although models are simplified with respect to nature, they can be some of the most complex creations of the human mind.

- We have incomplete knowledge about the functioning of systems on this planet. In part, this is because of data limitations. For example, there is no way to measure the number of tons of carbon dioxide added to the atmosphere by fossil fuel combustion. Nor can we measure the number of suckers in Upper Klamath Lake. Such numbers are *estimates*, but they are not *guesses*. For many basic quantities about the environment, estimates are all we have and all we ever will have. Estimates are based on scientifically defensible procedures and are subject to constant revision and recalculation based on new knowledge. We know they are in error, but such error may run in either direction; the "true" value might be bigger or smaller than our estimate.

- Environmental data collection is, minimally, representative and, ideally, random. *Random* is not haphazard. Rather, randomization is the only way to avoid bias. For this reason, it is the basis for public opinion polling. The *errors* associated with environmental estimates often can be reduced through increased sampling, but the added costs often are prohibitive.

- The complexity of what we do know about natural systems means it is always possible for a proponent or opponent of a particular course of action to point to alternative data or interpretations that support his or her point of view. The result can be public confusion and the desire to fully understand a system before we act—an impossibility given the inherent limitations of science and the complexity of most environmental issues.

- We must deal with a dynamic blend of science, values, and beliefs. We all are governed by particular sets of values by which we live our lives. Given the uncertainty of our knowledge and the complexity of natural systems, such values tend to intrude into scientific discussions. Reasonable people with the same scientific data can reach different conclusions about the amount of risk (a value judgment) that is acceptable. If two people have the same information about the stock market, and one chooses to take more risk, it does not mean that the cautious person has based the decision on "junk science." It is important to understand that public agencies are highly risk-averse.

- The profound relevance of environmental issues to future generations of humans and other species makes these issues *controversial*. As a result, debate in this area tends to degenerate into finger-pointing, name-calling, and other "cheap shots"—modes of discourse that are counterproductive.

- *Peer review* is a process that seeks to refine and improve data collection, analysis, and interpretation. Authors of scientific publications may or may not incorporate, acknowledge, or respond to peer review, although editors typically demand responses or rebuttals to substantive criticisms. Science in public policy and management arenas also typically includes responses or rebuttals, but standards differ depending on applicable laws.

- Finally, simple solutions to environmental problems are rare. Most solutions require us to wrestle with, and perhaps abandon, cherished values. Knee-jerk reactions and sloppy thinking that exacerbate problems can be countered only by critical thinking.

Adapted with permission from Arnfield, A.J. 2002. Geography 210, "Science, Uncertainty, Controversy, and Environmental Issues" (http://thoth.sbs.ohio-state.edu/classdocs/210/scene/science.htm). Accessed January 11, 2002.

Part 2. Suckers and Coho Salmon

5

Suckers

Relationships between
Lost River and Shortnose Sucker Biology
and Management of Upper Klamath Lake

Douglas F. Markle and Michael S. Cooperman

This chapter presents information about several aspects of sucker biology that are relevant to Biological Opinions on the effects of Klamath Reclamation Project operations on Lost River and shortnose suckers. It is not our intent to defend or critique the 1992 or 2001 Biological Opinions. Rather, we attempt to explain them within the context in which they were written.

Lost River suckers (LRS) and shortnose suckers (SNS) became federally listed endangered species in 1988, but concern for their declining abundance had been raised by Oregon State University professor Carl Bond and others in the 1960s. Specific concerns, then and now, were water quality, loss of spawning populations, large fish kills, fluctuating abundance, variable or no recruitment of juveniles into the adult population, simplification of the age/size structure through loss of older fish, and the success of nonnative fish.

The U.S. Bureau of Reclamation (BOR) manages the release of water from the habitat of these endangered species (Upper Klamath Lake). Section 7 of the Endangered Species Act requires the BOR to consult with the U.S. Fish and Wildlife Service (USFWS) to ensure that BOR operation of the Klamath Reclamation Project does not jeopardize the continued existence of these species. In 1992, a USFWS Biological Opinion (USFWS 1992 BiOp) stated that the endangered suckers were adversely affected by the Project, signaling the beginning of irrigation curtailment in the Project area. During the droughts of 1992 and 1994, some Project acreage with low-priority water contracts did not receive water. In April 2001, a new BiOp for 2001 allocated water during a drought in a way that greatly reduced irrigation water deliveries from Upper Klamath Lake.

This chapter describes how this happened. The story requires an understanding of sucker biology, human interactions with suckers, human interactions with sucker habitat, natural resource science, and management decisions.

The amount of water in Upper Klamath Lake (as measured by surface lake elevation above sea level) is a particularly important variable in this story because it is manageable. It often is not the most important variable, but other variables often are weather related or less manageable for other reasons.

Upper Klamath Lake is complex, and its elevation is highly autocorrelated. In other words, the elevation on a particular date can be predicted with a high degree of certainty by knowing the elevation on an earlier date in the same year. For example, because of lake management and seasonal hydrological cycles, August elevations are highly autocorrelated with elevations on earlier dates in the same year.

Lake elevation also is cross-correlated with other variables of interest such as temperature and other important water quality variables. Because these variables, like lake elevation, are highly correlated with dates, the result is a series of complex cross-correlations, or interdependencies. Thus, simple relationships between suckers and lake elevation may not tell the whole story.

It also is important to understand that natural resource science in general, and Upper Klamath Lake biological science in particular, are not based on "common garden experiments," in which one variable, such as fertilizer, is applied at different rates to several identical plots, and a response is measured. This type of controlled experiment is not possible in Upper Klamath Lake because there is only one lake. Instead, each year of observation gives one sample with a "response" (for example, whether or not there was a fish kill) and many possible "predictors" (for example, air temperature in August or lake elevation in June).

To date, the biological information has been analyzed by looking at the "fit" of data to fairly simplistic hypotheses about how the system works, so-called *frontier science* (see Chapter 4, "Science"). As is often the case when a system is first studied, there are contradictory data. Over time, other, sometimes more complex, hypotheses can be expected to better explain the system and resolve such conflicts, leading to *consensus science*.

We are just entering a period when it now is possible to revise, or improve, hypotheses about how the Upper Klamath Lake system functions, because there are about 10 years of high-quality physical and biological data available. This revisionary process is ongoing and will lead to more consensus, but it is not the subject of this chapter. Instead, it is our intent to explain the 1992 and 2001 Biological Opinions in the context in which they were written.

Sucker biology

LRS and SNS are long lived. LRS can live as long as 43 years, and SNS up to 33 years. In both species, females are mature by 7 to 9 years of age. The two species are endemic to the region.

Reproduction

Suckers are iteroparous (an individual spawns in many years). The advantage of a long-lived, iteroparous strategy is that an individual's progeny production is spread over many years, increasing the likelihood of spawning when environmental conditions are favorable for progeny survival. This strategy reduces the impact of environmental variation on lifetime reproductive success (Leaman and Beamish 1984; Goodman 1984; Schultz 1989). Such a strategy also benefits from a broad distribution of spawning age classes because there is greater reproduction from older fish. In addition, different-aged fish tend to spawn at different times during the season. Thus, the annual spawning season is extended within a year, again spreading risk over time.

Females produce 70,000 to 200,000+ eggs per spawning season, although they may not spawn every year. They might, for example, skip years if energy reserves are low, if they have been significantly stressed, or if environmental conditions are not appropriate, but this behavior is difficult to document.

Beuttner and Scoppettone (1990) and Perkins et al. (2000a) found evidence that larger suckers produce more gametes (eggs and sperm), but it is not known whether gametes improve in quality as adult size increases, a pattern common in other fish species (Sinclair 1988).

While longevity compensates for varying environmental conditions, it also makes fish more susceptible to overexploitation. The removal of larger fish through fishing can be detrimental to long-lived species, especially when the fishery targets large, spawning fish. Individuals risk mortality every year they spawn, and the probability of reaching old age is reduced. The result is lowered egg production and fewer old spawners—the individuals with potentially higher reproductive potential (Borisov 1978; Beverton 1986; Leaman and Beamish 1984).

Spawning behavior

Upper Klamath Lake suckers spawn in lakeshore springs and in the Williamson and Sprague rivers. At this time, genetic and size distribution data are inconclusive as to whether in-lake and river spawning groups are reproductively isolated or broadly mixing (panmictic). In other words, do in-lake spawners ever spawn in the rivers, and vice versa?

Different sizes of spawners in the two groups might indicate that spawning groups are not randomly drawn from the whole population but are reproductively isolated. Perkins et al. (2000a) found larger LRS at lake springs relative to other individuals of the same species in the Williamson and Sprague rivers, except in 1998. USGS (2001) suggests that median size differences between river- and lake-spawning suckers are minimal. Genetic data collected to date cannot discriminate between lake and river spawners (unpublished data).

Tagging studies suggest that river and lakeshore spawners seldom move between these spawning sites. Perkins et al. (2000a) and USGS (2001) have reported recapture of 446 suckers at lakeshore springs, and only 1 originally had been tagged in an area away from the springs. USGS (2001) reports recapture of 119 Lost River suckers at lakeshore springs; 118 had been tagged at the springs and 1 in the Williamson River. The same effort recaptured four previously tagged shortnose suckers, all of which were recaptured at the original tagging location.

Fish movement among eastern lakeshore springs has been observed. USGS (2001) reports that a total of 69 suckers (63 Lost River suckers and 6 shortnose suckers) were captured at least twice in 2000 at shoreline spawning areas. Of the 63 Lost River suckers, 48 percent were recaptured at springs other than where they were first captured, and 5 out of 7 shortnose suckers were captured at sites other than where they were tagged. However, it has not been documented that suckers spawn at multiple locations. Capture at different springs demonstrates movement and is suggestive of, but does not conclusively prove, lack of reproductive isolation between spawners at different lakeshore springs.

It also is not known whether progeny display fidelity to natal sites (i.e., are imprinted and have homing ability). Therefore, it is not clear whether spawning groups are self-maintaining or part of a panmictic population created by intergenerational mixing. In other words, are river progeny ever recruited to lakeshore springs, or vice versa?

The presence or absence of spawning-site fidelity is an important question because high fidelity effectively limits natural recolonization of suitable sites. If a site's spawners are lost, other individuals will not move in to take their place. Also, multiple spawning sites may offer greater protection from chance events than a single site of comparable size. Thus, in species exhibiting high fidelity to spawning sites, loss of a spawning group could lower total production beyond the simple loss of adult numbers and could reduce the "buffer" provided by multiple sites.

Larval survival

The larval stage lasts approximately 40 to 50 days. The strategy of producing large numbers of small eggs means there usually is high mortality in the early life of most fishes. Average patterns of freshwater fish mortality suggest 95 percent do not reach the juvenile stage (Houde 1994). Field work done in 1989 indicates apparent larval mortality rates for suckers within the Williamson River of 93 percent per day (Dunsmoor 2001, personal communication).

Cooperman and Markle (1999 and unpublished data) documented that larval sucker movement through the Williamson River can take as little as 1 day, and that more than 99 percent of larvae exit the Williamson before completing flexion (caudal fin formation). This suggests that the 93 percent mortality level calculated by Dunsmoor occurs during the first days of the larval life history stage.

Simon and Markle (2001) showed that annual October population estimates of juveniles (1995–2000) ranged from 0 to 108,000 for LRS and about 1,500 to 74,000 for SNS. They also suggested that winter mortality (winter kill) might routinely reduce young-of-the-year abundance an additional 90 percent by the following spring. (Young-of-the-year, or "age-0" fish, refer to fish after hatching and before completion of their first winter.)

Because mortality rates are high for a relatively long time, very small changes in mortality rates or in the length of time individuals spend in a particular life history stage can lead to dramatically different outcomes (Houde 1987). Fisheries scientists seldom are able to measure these rates with the precision needed to detect small changes. Thus, they have difficulty determining causes of subtle differences in year-class production. Generally, they rely on long-term studies to unravel major patterns in recruitment (entry into the adult population). Small-scale, site-specific studies are used to test particular hypotheses.

Habitat use

Distribution and habitat use change throughout the sucker life cycle.

- Eggs are deposited in unconsolidated gravel/cobble bottoms in areas of groundwater upwelling (lakeshore springs) or in portions of rivers 2 to 6 feet deep with moderate current.
- Larval suckers are most abundant in near-shore areas of northeast Upper Klamath Lake and the lower Williamson River. Larvae are associated with macrophytes (large nonwoody plants), particularly emergent macrophytes (those partly above the water surface).
- During summer, the daytime habitat of young-of-the-year juveniles shifts to near-shore clean, rocky substrates (sand, gravel, or small boulders), but not fine, silty bottoms (Simon et al. 2000). The center of abundance of young-of-the-year juveniles moves southward in the lake.
- By fall, juveniles no longer are associated with near-shore habitats. They either move offshore to deeper waters, where all substrates are fine silts, or leave the lake via the A-Canal or the Link River (Gutermuth et al. 2000).
- Older juveniles and adult suckers are found throughout Upper Klamath Lake, but they are concentrated in the northern third of the lake (Reiser et al. 2001).

Population estimates and age structure

Several attempts have been made to estimate the size and age structure of sucker populations in Upper Klamath Lake (Bienz and Ziller 1987; USFWS 2001). Confidence intervals (the errors associated with the mean estimate) are large, methodologies differ, and interpretation of these numbers should be cautious.

Population estimates

All of the estimates suggest that between 1984 and 1997 adult populations were in the low thousands to low 100 thousands. (With the data we have, it is not possible to estimate the population more closely.) The populations that sustained the fishery in the 1960s and earlier almost certainly were larger. Because there are no reliable long-term adult abundance data, managers have relied on indices, which show relative changes from year to year.

In the 1980s, the sucker populations in Upper Klamath Lake seemed limited by lack of juvenile recruitment, and they were heavily skewed to older fish, those 19 to 28 years old (Buettner and Scoppettone 1990; Scoppettone and Vinyard 1991). In the late 1990s, successful recruitment from the 1991 and 1993 year classes brought in some younger fish (Cunningham and Shively 2000; USFWS 2001). However, many older fish seem to have died prematurely, probably because of the fish kills in 1995, 1996, and 1997, which were caused by low oxygen levels exacerbated by bacterial infection.

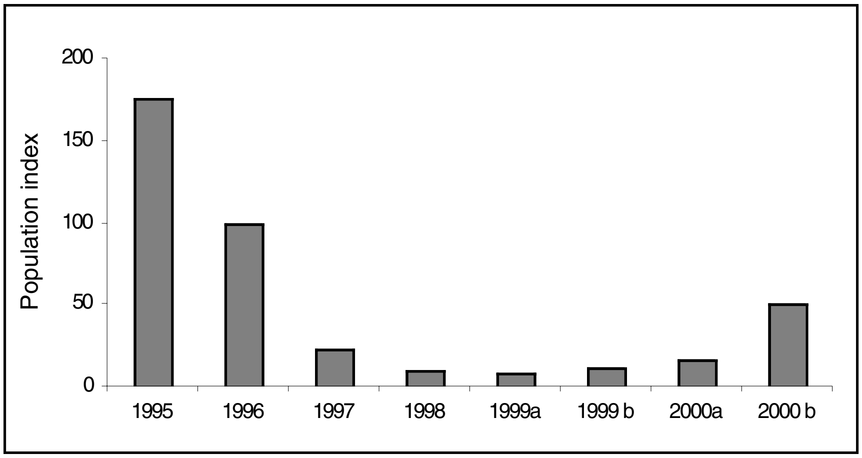

Figure 1. Population index trends in Williamson River shortnose sucker spawning runs, 1995–2000 (USGS 2001). Index values do not indicate estimated population numbers, but rather a relative comparison across years. They are based on the sum of mean daily catch per net during spawnings runs. The "a" and "b" designations of 1999 and 2000 refer to estimates based on different calculation methods.

A Williamson River spawning abundance index declined dramatically during and after the fish kill years (Figure 1). This decline was especially disturbing because it coincided with the time when the relatively strong 1991 and 1993 year classes would have been expected to begin spawning.

The number of fish killed during the 1995–1997 fish kills is uncertain, but the numbers of carcasses collected give some idea of the magnitude of these events. The numbers of dead suckers collected during each fish kill event were 472 (1995), 4,453 (1996), and 2,335 (1997) (Perkins et al. 2000b). Collections were not systematic and involved different levels of effort, making comparisons among years difficult. Investigators report that only a small percentage of sucker carcasses was recovered (Perkins et al. 2000b).

If the numbers collected are considered minimum estimates, they suggest that the fish kills were at least of the same order of magnitude as the snag fishery in the early 1980s and probably much larger than earlier snag fisheries. It is probable that the number of suckers killed during the 1996 and 1997 mass mortality events greatly exceeded the number of suckers harvested during any year of the snag fishery (see "The sucker fishery," following page).

The lack of long-term adult abundance data and quantifiable fish kill data is a major data gap.

Age structure

Spawner ages were estimated based on lengths of suckers entering the Williamson River in 2000 (Cunningham and Shively 2001) and from a size/age relationship (Buettner and Scoppettone 1990). LRS spawners were 5 to 35 years old, and SNS spawners were 4 to 27 years old, with median ages of about 12 years for LRS and 9 years for SNS. The ranges and median ages suggest that most of the fish were produced after closure of the fishery in 1987.

Coupled with the apparent declining adult abundance, the shift in age structure to younger fish means that reproductive potential declined. The loss of large, old fish during the fish kills means that even if the adult populations in 1992 and 2001 were the same size, the reproductive potential would have been lower in 2001.

Nonnative species

The fish community of the Upper Klamath Basin has changed in the past century, with unknown consequences. Scoppettone and Vinyard (1991) reported that 84.5 percent of the fish biomass in Upper Klamath Lake is exotic species. Logan and Markle (1993) reported that exotic fishes were 58 percent of the fish captured in trap nets in Agency Lake and the northern portion of Upper Klamath Lake, and they were 92 percent of the beach seine fish.

One exotic species, the fathead minnow, represented 59 percent of the fish in trap net samples in Agency Lake and 27 percent in Upper Klamath Lake in 1992 (Simon and Markle

1997). They also reported that declines in fathead minnow abundance from 1991 to 1995 were associated with an increase in some native fishes.

Since 1995, patterns have been more complex. In 1998, the year following the 1995–1997 fish kills, beach seine catch rates dropped for age-0 native fishes (suckers, blue chub, and tui chub), but were unchanged for fathead minnows and rose for age-0 yellow perch, another exotic species (Simon and Markle, 2001).

Fathead minnows prey on larval suckers in a laboratory setting (L. Dunsmoor, Klamath Tribes, unpublished report), and young yellow perch are known to be opportunistic fish eaters (Hubbs and Lagler 1974). The impacts of exotic species on sucker larvae are unknown, but it is possible that management actions enhancing habitat availability or water quality for the benefit of suckers might also have positive effects for exotic species.

The sucker fishery

Historically, Lost River and shortnose suckers were abundant in Upper Klamath Lake and were utilized as a subsistence fishery by the Klamath and Modoc tribes. Early settlers also used the suckers, constructing a cannery on the Lost River and using the abundant fish for fertilizer and oil. As early as the 1880s, some settlers tried to pass laws to prevent the tribes from fishing (Klamath Falls *Herald and News*, April 10, 2001).

In the 1900s, the suckers, known locally as "mullet," also were subjected to a sport snag fishery on spawning adults. Anglers used treble hooks weighted with spark plugs to snag large, spawning fish. The first reference to sport fishing of "mullet" seems to be a 1909 reference to sportsmen snagging "mullet" in the Link River at Klamath Falls (*Klamath Republican,* October 14, 1909).

Regulation of the sport fishery began in 1959, when Klamath suckers became "game species" under Oregon statute. The fishery on Klamath suckers was extremely popular (Figures 2 and 3). In the 1960s, the Klamath Falls office of the Oregon Department of Fish and Wildlife (ODFW) maintained a mailing list of mullet fishers from Seattle to Los Angeles, who were sent a postcard informing them of the timing of sucker runs. Fishers harvested an estimated 100,000 lb in 1966 (about 12,500 fish), according to ODFW's Art Gerlach (*The Register-Guard*, Eugene, Oregon, May 7, 1967).

In 1969, ODFW instituted a bag limit of 10 suckers. From 1966 through 1978, ODFW data files show a decline in the average number of suckers harvested per fisher. Before the 1969 bag limit, the average was 3.5 to 5.6 suckers per fisher; it fell to 1.5 to 3 suckers per fisher afterward. From 1966 to 1974, average lengths declined from 25.7 to 21.3 inches, average weight declined from 7.54 to 4.9 lb, and the number of fish caught per hour declined from 1.19 to 0.87.

Because suckers were poorly understood, the initial cause of concern was declining catches in the popular seasonal fishery and elimination of some of those fisheries (Andreasen 1975). In 1983, the Klamath Tribes, ODFW, and the USFWS jointly initiated a series of studies of Klamath suckers (Bienz and Ziller 1987). These studies discovered populations made up mainly of older fish. (Ninety-five percent of LRS were more than 19 years old.) These findings prompted the Klamath Tribes to curtail sucker fishing in 1985 (Scoppettone and Vinyard 1991) and close it in 1986.

Bienz and Ziller (1987) estimated the harvest had dropped to 1,262 fish in 1984 and 687 fish in 1985. LRS made up 92 percent of the 1985 catch. Thus, in 19 years, the catch had dropped about 95 percent, from about 12,500 fish to 687. This decline may be understated, because ODFW files indicate that undersized fish often were discarded and not counted in the 1960s and 1970s. The decline in catch rate continued through 1986 (Figure 4), and the State of Oregon closed the fishery in 1987 (Scoppettone and Vinyard 1991).

*Figure 2. A 1967 "mulleteer," Ken Mills, showing catch with spark plug/treble hook snagging gear (*The Register-Guard, *Eugene, Oregon, May 7, 1967).*

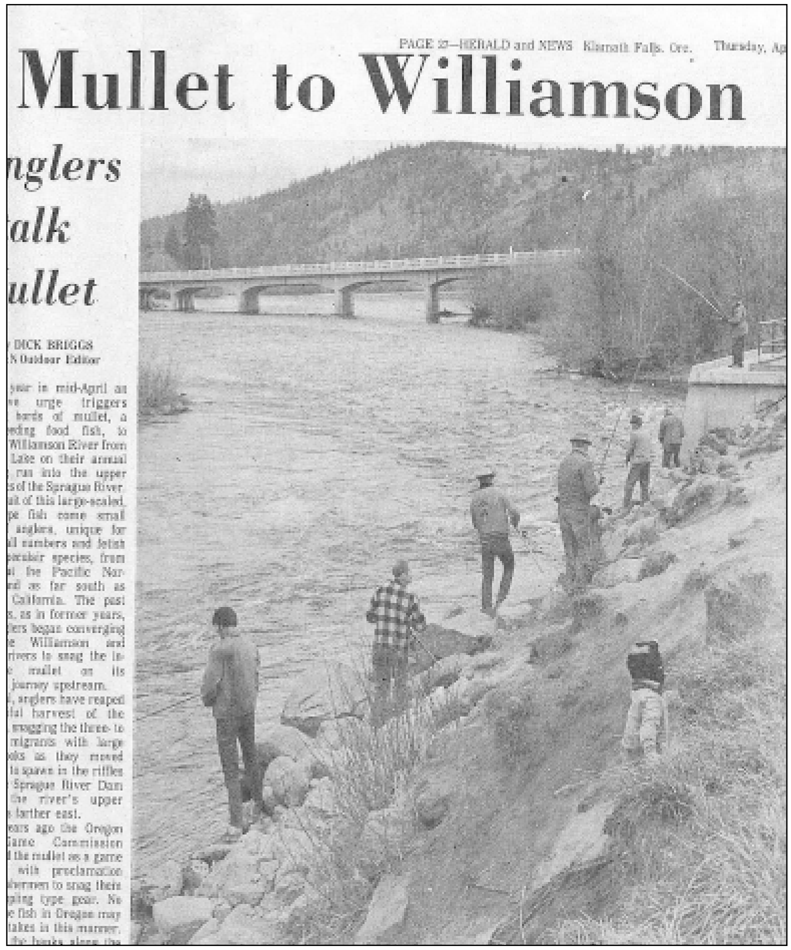

*Figure 3. Sucker fishers below the Highway 97 bridge on the Williamson River (*Herald and News, *Klamath Falls, Oregon, April 23, 1970).*

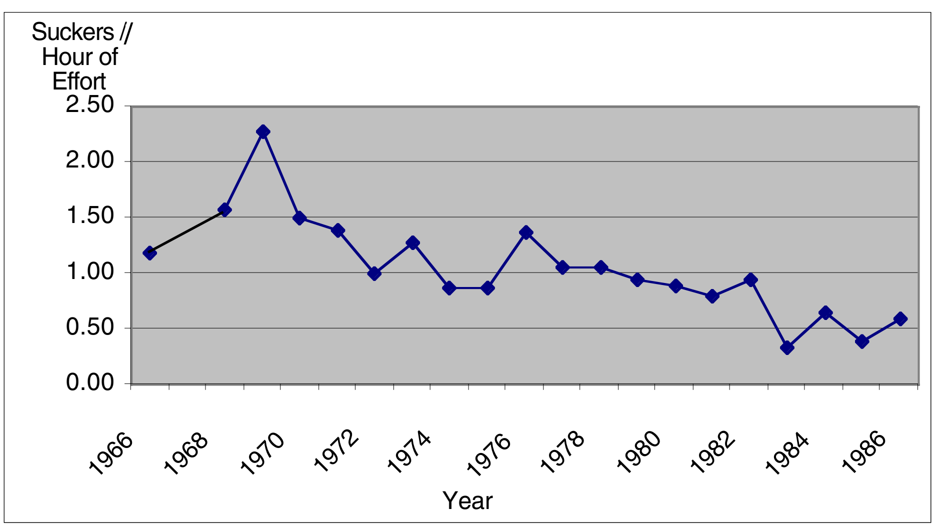

Figure 4. Relationship between sucker catch rate and year. Source: Oregon Department of Fish and Wildlife, Klamath Falls office data files (data before 1974 also reproduced in Andreasen 1975)

The impact of the closure of the fishery seems to be reflected in the age-class distribution of suckers killed during the 1997 fish kill (Figure 5). Those data show that most of the population susceptible to fish kills in 1997 was born after the fishery closed. The fact that the population during the mid-1990s contained very few fish born in the 1970s and 1980s reinforces the fisheries data (above) that indicated low adult populations in the 1980s. The data from the fish kills also demonstrate that low numbers of highly fecund fish can produce large numbers of recruits (juveniles entering the adult population).

Loss of spawning groups

There is direct and indirect evidence that the fishery may have contributed to elimination of several spawning groups. During the record-low lake elevations of 1994, Oregon State University researchers mapped shoreline substrates, including the distribution of spark plugs and treble hooks. Many sites with spark plugs, such as Ouxy and Sucker springs, are known sucker spawning sites. At least four other areas on the eastern shore between Modoc Point and Sucker Springs had treble hooks and spark plugs, as well as flowing springs, suggesting historical sucker spawning (authors' unpublished data). There currently is no known spawning at these sites.

Numerous other locations are thought to have lost sucker spawning groups in the past 20 to 30 years. For example:

- The last spawning fish at Harriman Springs, on the west side of the lake, were seen in 1974 (Andreasen 1975).
- No spawning has been observed at Barkley Springs on the southeast side of the lake since the late 1970s (Perkins et al. 2000a). Extensive habitat modifications, which limited access to the spring, are thought to have eliminated the Barkley Springs spawning group.
- More than 90 springs were mapped on Bare Island in 1994, many with water too hot (>30°C, 86°F) for spawning, but spawning suckers were reported at a Bare Island spring in the early 1990s, an observation unconfirmed based on surveys in 1997 (Perkins et al. 2000a) and 2001 (R. Shively, USGS, personal communication).

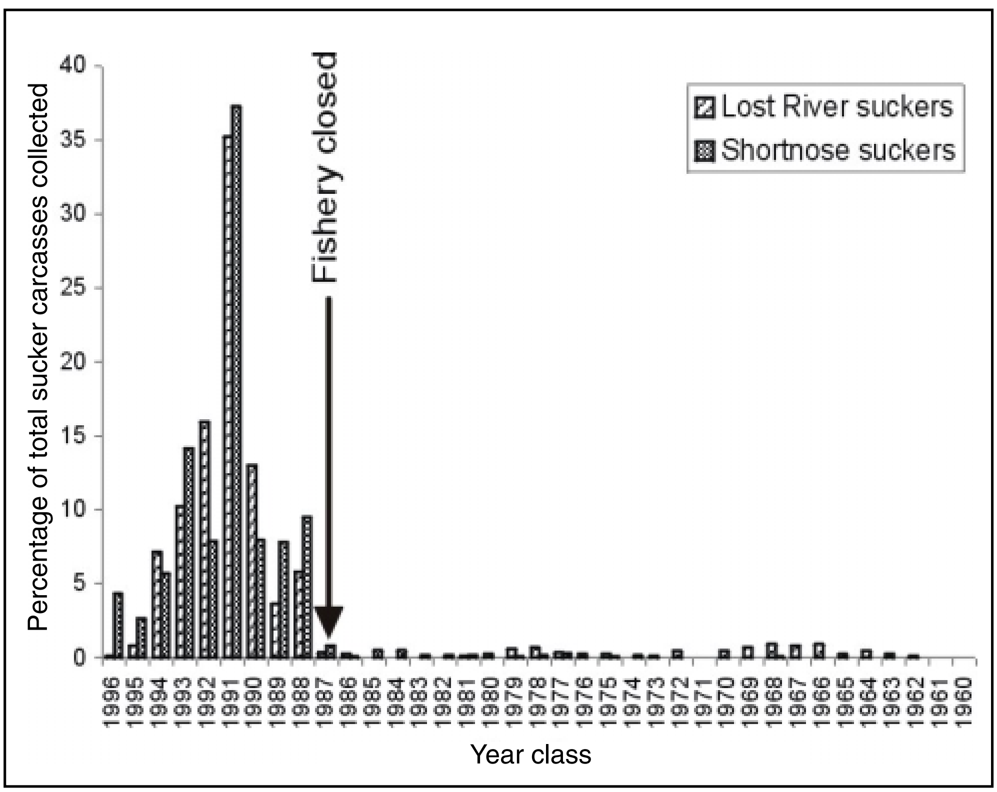

Figure 5. Estimated age distribution (by year class) of Lost River suckers and shortnose suckers collected from 1997 fish kill in Upper Klamath Lake. ODFW closed the snag fishery on spawning adults in 1987. Source: U.S. Geological Survey, unpublished data, reproduced with permission of R. Shively.

- In the Agency Lake subbasin, sucker spawning in Crooked Creek was last documented in 1987 (Smith 2001, personal observation) and in Fort Creek, Sevenmile Creek, Fourmile Creek, Crystal Creek, and Odessa Springs in the late 1980s and early 1990s. The Wood River may have the last spawning suckers in this subbasin, based on recent captures of a few adult SNS and on capture of larvae in 1992 (Markle and Simon 1993; Simon and Markle 1997). In addition, annual monitoring of larval and juvenile suckers in Agency Lake has shown a long-term decline in the 1990s, with only two juveniles caught in 2000 and one juvenile caught in 2001 (Simon and Markle 2001).

The 2001 Biological Opinion lake elevation criteria

The 2001 Biological Opinion (USFWS, BiOp, Section III, Part 2, pages 143–145) provides date-specific minimum elevations for Upper Klamath Lake and justification for these minimums (Table 1). Five justification criteria are presented:

- Reduced potential of winter kill
- Lakeshore spawning habitat
- Young-of-year habitat
- Water quality
- Access to water-quality refugia

Each criterion is discussed in this section.

Table 1. Date-specific minimum levels for Upper Klamath Lake and justifications.

Date	Minimum elevation (feet above sea level)	Justification criteria
January 1	4,141.0	Reduce potential of winter kill Water depth for lakeshore spawning
February 15	4,141.5	Water depth for lakeshore spawning Reduce potential of winter kill
March 15	4,142.0	Water depth for lakeshore spawning Reduce potential of winter kill
April 15	4,142.5	Water depth for lakeshore spawning Inundated emergent vegetation for young fish
June 1	4,142.5	Inundated emergent vegetation for young fish Moderated water quality
July 15	4,141.5	Inundated emergent vegetation for young fish Moderated water quality Access to refugia
August 15	4,141.0	Inundated emergent vegetation for young fish Moderated water quality Access to refugia
September 15	4,140.5	Moderated water quality Access to refugia
October 15	4,140.0	Moderated water quality Access to refugia Reduce potential of winter kill Carry-over water to reduce drought effect next year

Source: U.S. Fish and Wildlife Service (USFWS). 2001. *Biological/Conference Opinion Regarding the Effects of Operation of the Bureau of Reclamation's Klamath Project on the Endangered Lost River Sucker* (Deltistes luxatus), *Endangered Shortnose Sucker* (Chasmistes brevirostris), *Threatened Bald Eagle* (Haliaeetus leucocephalus) *and the Proposed Critical Habitat for the Lost River/Shortnose Suckers* (Department of the Interior, Klamath Falls, OR).

Winter kill

"Winter kill" is mass mortality of fishes during winter, usually associated with low dissolved oxygen levels caused by ice cover, which prevents wind-generated reoxygenation of water.

When the lake is covered with ice, additional oxygen comes only from photosynthesis, which also is low in winter. Snow on top of ice may exacerbate conditions by further reducing light penetration and photosynthesis.

The rate at which oxygen is removed from water is a function of two things: biological oxygen demand and chemical oxygen demand. Biological oxygen demand results from respiration of living organisms such as bacteria, plants, and fish. Chemical oxygen demand is caused by the reaction of chemicals with oxygen. In Upper Klamath Lake, biological oxygen demand is thought to be notably greater than chemical oxygen demand, and bacterial decomposition typically is the greatest biological oxygen demand component.

Fish vulnerability to winter kill depends on many factors, including species, life stage, physiological condition, and severity of the winter. Winter kill is difficult to document and has not been documented in Upper Klamath Lake suckers. Simon and Markle (2001) hypothesized that winter kill may occur in Upper Klamath Lake since populations of several species, including juvenile suckers, decline by about 90 percent between late fall and early spring.

Role of lake elevation

The total amount of dissolved oxygen (DO) is a function of volume and temperature. Higher lake elevations should equate to more available oxygen. The 2001 BiOp (page 192) addresses the potential interaction between lake elevation and winter kill.

> "There is a higher probability of low DO at lower elevations. Welch and Burke (2001) estimated that DO levels would be adverse to suckers after 60 days of ice cover or less. To reduce the risk of catastrophic winter fish kills, they recommended that UKL end of season levels should not go below 4,140 ft and be brought up quickly."

Lakeshore spawning

Because there is evidence of loss of in-lake spawning groups, maintaining viable lakeshore spawning is a primary management concern. Lakeshore spawning typically extends from late February to May, with greatest activity in March and April (USGS 2001).

Role of lake elevation

Surveys of Sucker Springs found more than 60 percent of spawning was in water greater than 2 feet deep. Thus, Reiser et al. (2001) suggested that the minimum acceptable water depth during spawning season should be 2 feet above lakeshore springs.

Both the number of sites and total surface area for lakeshore spawning are directly related to lake elevation. At two important eastern-shore springs, between 13 and 45 percent of the spawning substrates would be more than 2 feet deep during March and April if the 2001 BiOp elevations are met (Table 2). These elevations equal the pre-Link River dam (1921) elevations for February and March, but are 0.44 feet higher than pre-1921 April elevation (Figure 6). The BOR's 2001 Biological Assessment (BA) requested lower elevations (Figure 7).

Table 2. Relationship between 2001 BiOp minimum lake elevation and percent of spawning habitat at two important eastern-shore springs.

	Lake elevation (feet above mean sea level)	Percent of potential habitat more than 2 feet deep	
		Sucker Springs	Ouxy Springs
February 15	4,141.5	5	0
March 15	4,142.0	27	13
April 15	4,142.5	45	33

Source: Reiser, D.W., M. Loftus, D. Chapin, E. Jeanes, and K. Oliver. 2001. *Effects of Water Quality and Lake Level on the Biology and Habitat of Selected Fish Species in Upper Klamath Lake* (R2 Resource Consultants, Inc., Redmond, WA)

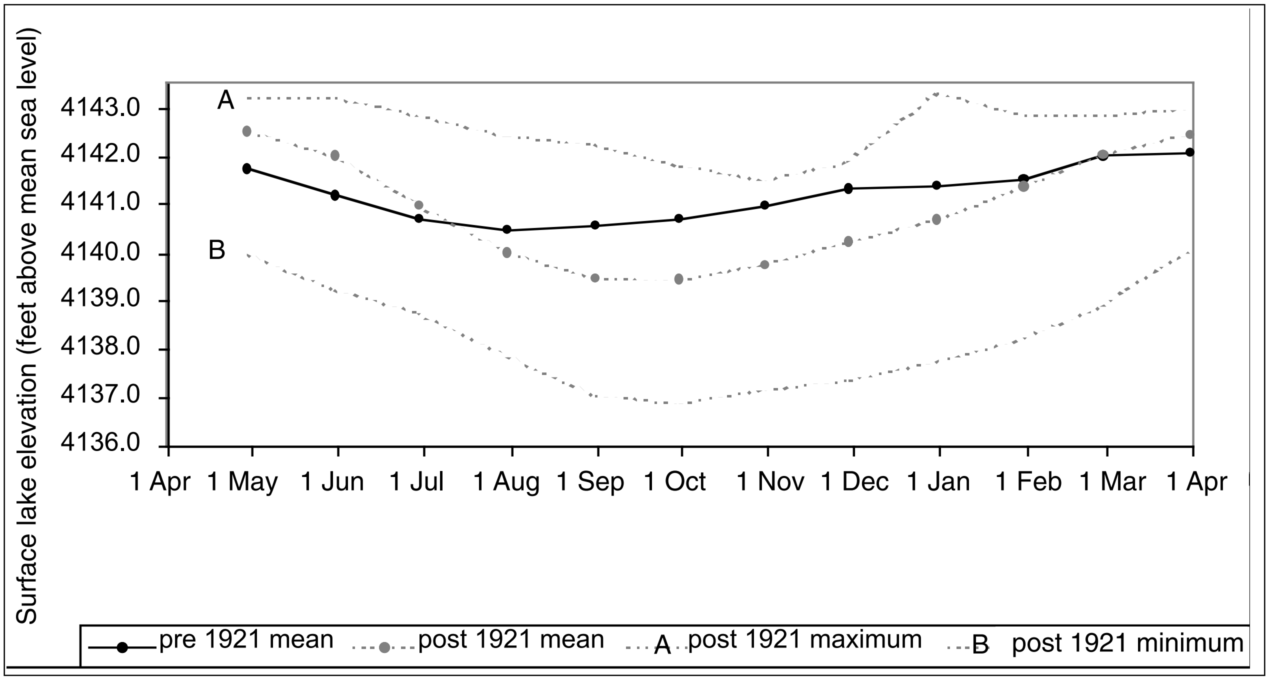

Figure 6. Relationship between lake elevation and month before 1921 and after 1921. Outer dotted lines show the total range of variation since 1921.

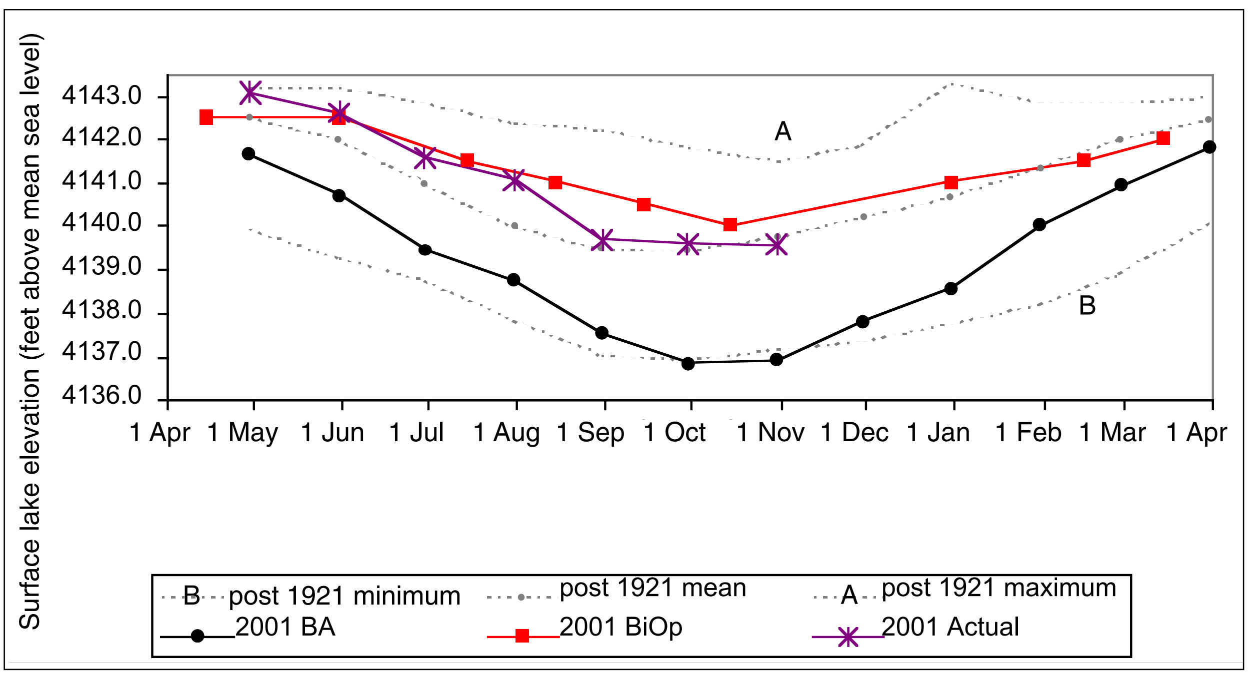

Figure 7. Lake elevations as suggested by the 2001 Biological Assessment (BA), 2001 Biological Opinion, and actual 2001 elevations as permitted with the coho salmon amendment. (Minimum lake elevations in 2001 were reduced from those in the draft 2001 BiOp in order to meet requirements for Klamath River flows for coho salmon.) Dashed lines show mean, minimum, and maximum monthly elevations since 1921 as in Figure 6.

Young-of-the-year habitat

Young-of-the-year suckers typically range from 10 to 75 mm (0.4 to 3 inches), although LRS may reach 100 mm (4 inches) in years with good growth rates. Young-of-the-year suckers are subdivided into larval and juvenile stages.

Larval suckers typically are in the Williamson River–Upper Klamath Lake system from March through June, and juveniles any time after April. Larval suckers are most abundant in near-shore areas of northeast Upper Klamath Lake and the lower Williamson River. The mouth of the Williamson River and Goose Bay are two critical rearing grounds known to have high concentrations of larval and juvenile suckers.

Larvae are associated with macrophytes (large nonwoody plants), particularly emergent macrophytes (those partly above the water surface). Examples include *Scirpus acutus* (hardstem bullrush), *Sparganium eurycarpum* (river burr reed), and *Polygonum coccineum* (water smartweed). Cooperman and Markle (1999) found that larvae use emergent vegetation at the mouth of the Williamson for several weeks and other emergent-vegetated areas in the lake for an additional several weeks. Because spawning is protracted, these habitats are important for considerably longer than the 1 or 2 months required for use by any individual.

During summer, the daytime habitat of young-of-the-year juveniles shifts to near-shore clean, rocky substrates (sand, gravel, or small boulders), but not fine, silty bottoms (Simon et al. 2001). The center of abundance of young-of-the-year juveniles moves southward in the lake, perhaps associated with the distribution of preferred gravel substrates. Juvenile shortnose suckers seem more dependent on shallow water than Lost River suckers, since they dominate beach seine collections (Simon et al. 2000). Juveniles also may use other habitats not sampled by cast nets (such as offshore areas or emergent macrophytes), and they may have other habitat preferences at night.

Larval and juvenile shortnose suckers also are found all summer on open, submersed beaches during daytime sampling (Simon et al. 2001), and they apparently survived well there during the low-water year of 1991. In other systems with little shoreline emergent vegetation, young suckers have varying success. They apparently do well in Clear Lake (2001 BiOp) but poorly in J.C. Boyle and Copco reservoirs (Desjardins and Markle 2000). Most juveniles are not found on mud or silt but on clean, rocky substrates such as gravels, a rare substrate in Upper Klamath Lake (Simon et al. 2000).

Role of lake elevation—larval habitat

The amount of emergent macrophyte habitat potentially available to young suckers is a function of lake elevation. Table 3 shows this relationship.

During the time frame when young-of-the-year suckers are present, the lake levels required by the 2001 BiOp result in emergent macrophyte availability ranging from about 70 percent near the mouth of the Williamson River to about 5 percent in the mainstem Williamson River and Goose Bay.

Role of lake elevation—juvenile production and recruitment

Relationships between lake elevation and juvenile production have been the subject of much debate. Part of the uncertainty stems from different uses of the term recruitment. Most fisheries biologists use the term to mean entry into the adult spawning population. Larval fish

Table 3. Relationship between lake elevation and potential availability of emergent macrophyte habitat.

Lake elevation (feet above mean sea level)	Percent of lakeshore emergent macrophytes under 1 foot of water
4,140	<10
4,141	10–25
4,142	40–60
4,143	85–100

Source: Reiser, D.W., M. Loftus, D. Chapin, E. Jeanes, and K. Oliver. 2001. *Effects of Water Quality and Lake Level on the Biology and Habitat of Selected Fish Species in Upper Klamath Lake* (R2 Resource Consultants, Inc., Redmond, WA) biologists, on the other hand, often use it to refer to estimated juvenile abundance in late summer.

It is important to understand the purpose of estimating recruitment. If the purpose is to evaluate effects of lake elevation and summer Project operations, then recruitment should be measured when summer operations are the primary effective variable. In this case, the proper measure of recruitment is the estimate of juvenile abundance in late summer (the term "recruitment" as often used by larval fish biologists).

Recruitment to the adult spawning population (the more traditional use of the term) incorporates additional mortality over the next 5 to 7 years. Thus, it is less likely to show a meaningful relationship to natal year conditions.

Data for adults are available only for years through 1993, as later year classes have not yet reached spawning age.

The minimum elevation set for July 15, 2001 (target—4,141.5 feet, actual 4,141.43 feet) was the fourth lowest since 1991. In 2 of the 3 years when elevations were lower, juvenile production was poor. In 1992, zero juvenile suckers were caught per cast net in 335 samples (Table 4). In 1994, 0.04 SNS and 0.01 LRS were caught per cast net in 300 samples (Simon et al. 2000). The low juvenile production estimates in 1992 and 1994 were corroborated by A-Canal salvage data. (Most fish salvaged in 1992 and 1994 were 1-year-olds from the 1991 and 1993 year classes, respectively, rather than young-of-the-year.) However, in the other low-water year, 1991 (a July 15 elevation of 4,140.81 feet), 0.43 SNS and 0.39 LRS were caught per cast net in 44 samples (a density at least 10 times greater than in 1994).

The low 1992 production estimates have been challenged based on fish kill data showing that 1992 fish have entered the adult population. There can, of course, be errors associated with age estimates. It also is important to understand that a juvenile production estimate of zero does not state with certainty that zero fish were produced. It simply means that the method used cannot distinguish between zero and the real production, which may or may not be zero. In other words, no juveniles were caught in cast nets in 1992, but there may have been some in the lake.

Regarding late-summer estimates of juvenile year-class strength, the the 2001 Biological Opinion states on page 41:

> "Simon et al. (2000b) monitored the status of juvenile suckers in UKL since 1991 and reported that annual abundance (based on "catch per unit of effort" of beach seines) for age 0+ suckers at the end of summer were [sic] relatively high in 1991, 1993, 1995, 1996, and 1999, but were very low in the drought years of 1992 and 1994, and in 1997 and 1998 during and following the fish kills." (See Table 4, footnote (f) regarding "late-season" sampling. The BiOp clearly is referring to "mixed data," not just beach seines. For example, the 1997 data refer to October cast net/trawl abundance, while the 1991 data refer to fixed cast net samples. Note also that high beach seine numbers in 1997 reflected conditions before the fish kill and stand in contrast to October data, which were collected after the fish kill and are the basis of the statement quoted above from the BiOp.)

Because 1993, 1995, and 1999—years of relative abundance—were among the four highest lake elevations since 1990 (when measured April through August), the implication is that high lake elevations are good for juvenile production. It is clear, however, that the relationship is neither simple nor linear, and additional analyses and observations are needed to better understand the relationship.

Water quality

Some water quality parameters (temperature, pH, dissolved oxygen, and un-ionized ammonia) frequently reach levels stressful to suckers in Upper Klamath Lake (Loftus 2000). Lethal effects of water quality on suckers have been examined in multiple laboratory tolerance studies (Falter and Cech 1991; Castleberry and Cech 1992; Monda and Saiki 1993; Bellerud and

Table 4. Upper Klamath Lake elevation, fish kills, juvenile sucker production, and A-Canal entrainment, 1991–2001. Years are in order by lake elevation on September 15 (highest elevation first).[a]

Lake elevation (feet above sea level on Sept. 15)	Year	Mass sucker mortality[b]	Larval trawl CPUE[c]	Age-0 juvenile sampling: Summer beach seine CPUE[d]	% SNS[e]	Late-season fixed cast net SNS CPUE[f]	LRS CPUE[f]	Total estimated juvenile abundance (October) SNS[g]	LRS[g]	A-Canal juvenile entrainment[h]
4140.50	1999	No	23.25	53.40	93	—	—	68,795	108,399	—
4140.22	1998	No	3.95	6.90	85	—	—	11,626	5,082	246,524
4140.14	1995	Yes	11.65	29.02	91	0.29	0.05	9,129	38,313	—
4140.13	1997	Yes	15.73	19.19[i]	85	—	—	1,483	0	46,708
4139.83	1993	No	—	21.66	94	0.64	0.78	—	—	—
4139.56	2001	No	8.80	8.45	19	—	—	5,007	13,077	—
4139.47	2000	No	5.20	54.17	82	—	—	25,698	33,323	—
4139.15	1996	Yes	20.05	87.08	88	—	—	74,383	11,288	—
4138.49	1991	No	—	4.94	95	0.43	0.39	—	—	—
4137.54	1992	No	—	—	—	0.00	0.00	—	—	—
4136.98	1994	No	—	0.17	88	0.04	0.01	—	—	—

[a]Dashes signify no data. CPUE = catch per unit of effort.

[b]Small, localized mortalities of fish, such as sculpins, occur in many years, but large, lakewide mortalities of thousands of adult suckers are the "large fish kills" (Perkins et al. 2000b), or mass mortalities, of concern to management.

[c]Larval trawl CPUE = mean number of larvae per trawl (per unit of effort). Based on sampling every third week, April through July. Sampled at 10 fixed near-shore locations in Upper Klamath Lake. A matched pair of larval trawls is done at each location, one in an unvegetated area and one in nearby vegetation if available.

[d]Beach seine CPUE = mean number of age-0 juvenile suckers per seine (per unit of effort). Based on sampling every third week, late June through early August. Sampled at same 10 locations as larval trawl sampling. Two samples are collected per location.

[e]% SNS = percentage of beach seine CPUE that are SNS, based on vertebral counts. The remainder are LRS. (A small percentage of SNS, less than 1 percent, may be Klamath largescale suckers.)

[f]Late-season fixed cast net CPUE = mean number of age-0 juvenile suckers collected per cast net (per unit of effort). Based on multiple cast net samples at 10 to 17 fixed near-shore locations in Upper Klamath Lake. Variably sampled once per month from August through October or September through October. This was the only relatively consistent "late-season" sampling prior to 1995.

[g]October total estimated juvenile abundance = end-of-growing-season estimate of the total number of age-0 juvenile suckers in Upper Klamath Lake. Based on stratified random near-shore cast net and offshore otter trawl sampling. Weighted-density estimates of suckers on different substrates were extrapolated to the total shoreline area (within 10 meters of shore) for cast nets and to the total offshore area for trawls. Extrapolations assume that densities on a substrate are uniform within 10 meters of shore for cast nets and lakewide for trawls.

[h]A-Canal juvenile entrainment = estimated total entrainment (entry) of juvenile and subadult suckers. A-Canal entrainment was estimated to equal 75 percent of total out-of-lake transport of suckers, with other entrainment at Link River canals (Gutermuth et al. 2000).

[i]Juvenile numbers were relatively high during summer beach seine sampling in 1997, but fell sharply during and following the fish kill. (Note the low total estimated juvenile abundance in October.)

Source: Larval and juvenile data from Simon, D.C. and D.F. Markle. 2001. *Annual Survey of Abundance and Distribution of Age 0 Shortnose and Lost River Suckers in Upper Klamath Lake* (annual report to the U.S. Bureau of Reclamation, Klamath Falls office, Klamath Falls, OR) and previous annual reports, updated for 2001 samples.

Saiki 1995; Saiki et al. 1999). All studies report similar findings.

Saiki et al. (1999) found concentrations required to kill at least 50 percent of larvae or juveniles in 96-hour tests were:

- Temperatures of 30.3 to 31.8°C (87 to 88°F)
- Ammonia concentration of 0.5–1.1 mg/l
- pH of 10.3 to 10.4
- Dissolved oxygen level of 1.3–2.1 mg/l

Meyer et al. (2000) examined 14- and 30-day chronic effects and found mortality thresholds at:

- Ammonia concentration of 0.37 to 0.69 mg/l
- pH greater than 10
- Dissolved oxygen level of 1.5 to 2 mg/l

In support of the lab studies, daytime field collections of juveniles seldom have been associated with these conditions (Simon and Markle 2001 and earlier reports).

Poor water quality also might exert indirect effects. Adult fish kills in 1995, 1996, and 1997 were caused by low oxygen, which may have been exacerbated by *Flavobacterium columnare*, a type of opportunistic bacteria that always is present, but may contribute to death when fish are stressed by low oxygen, high pH, warm temperatures, and/or high levels of un-ionized ammonia.

In contrast, Terwilliger et al. (in review) could find no indirect effects of poor water quality on juvenile growth, even during a year of excessively high un-ionized ammonia levels (1997). They suggest that surviving juveniles may have found water quality refugia (localized areas of higher quality water).

The cause of the Upper Klamath Lake water quality problem is excessive nutrients, especially nitrogen and phosphorus. The nutrients come from natural inputs, external sources, and internal loading.

Upper Klamath Lake was historically eutrophic (containing high levels of nutrients), and the bitter, foul water was described in early accounts (Williamson and Abbot 1857). However, the nutrient budget of the lake has changed dramatically in the past 50 to 100 years (Eilers et al. 2001). Sediment cores show recent increases in sediment accumulation rate and concentrations of nitrogen and phosphorus, as well as a shift toward dominance of a single species of blue-green alga, *Aphanizomenon flos-aquae* (Eilers et al. 2001).

Although a full accounting of water quality and productivity of Upper Klamath Lake is beyond the scope of this chapter, we provide the following brief discussion to assist in generating a common vocabulary and to introduce basic concepts.

"Natural input" is synonymous with "background" concentrations that existed before post-1900 human activity. For example, the Upper Klamath Basin has extensive upwelling of groundwater containing nitrogen and phosphorus.

"External" sources of nutrients are those that originate upstream from Upper Klamath Lake, in excess of nutrients associated with natural inputs. Externally derived nutrients enter the lake via surface water runoff or groundwater upwelling. Many human activities contribute nutrients to the lake, including cattle grazing, agricultural fertilization, drainage of wetlands, and, to a lesser extent, soil erosion and domestic sewerage (Bortleson and Fretwell 1993; Snyder and Morace 1997; Risley and Laenen 1999).

Wetland soils of the Upper Klamath Basin have a high percentage of organic matter, normally maintained in the soil as refractory material (undecomposed remains of plants). The nutrients in this organic matter are unavailable for plant use. Drainage of wetlands dries the soil, allowing oxygenation that promotes decomposition of refractory material by aerobic bacteria, thus making the nutrients available. The resulting bioavailable nutrients can enter Upper Klamath Lake either via groundwater discharge or during seasonal pumping of drainage water.

The production and export of external nutrient loads to Upper Klamath Lake is exacerbated by the loss of the filtering effects of wetlands and streamside riparian vegetation. These habitats filter and immobilize nutrients by capturing particulate matter suspended in surface runoff and by uptake of nutrients transported in groundwater (Gregory et al. 1991; Kauffman et al. 1997; Naiman and Décamps 1997).

"Internal loading" is the liberation of nutrients from the lakebed into the water column. Nutrients bound to sediments or held in the pores of the lakebed are not biologically available until released into the water column. It is estimated that up to 61 percent of the annual phosphorus budget of Upper Klamath Lake comes from internal loading (Kann and Walker 1999). A primary contributor to the annual budget of internally loaded nutrients is the decayed remains of previous years' algae.

Internal loading is particularly troublesome in Upper Klamath Lake because it happens in summer when water quality already may be stressful to fish. High pH, which can stress fish, also initiates internal loading, which triggers or maintains algal blooms, further exacerbating the situation.

Role of lake elevation

Although the relationships between nutrient load, water quality, and lake elevation are complex and nonlinear, one working hypothesis advanced by Kann, Loftus, and Reiser is that higher lake levels promote better water quality (Kann 1995; Loftus 2000; Reiser et al. 2001). Specific mechanisms by which lake elevation influences water quality in a positive or negative way include, but are not limited to:

- Dilution of nutrients and algae
- Delayed onset of algal blooms
- Lower water temperatures via a greater resistance to heating
- Higher dissolved oxygen availability and resupply rate
- Reduced internal loading of nutrients

Fish kills and poor water quality are thought to be set up in late spring by conditions conducive to large algal blooms. Later in summer, large algal blooms interact with climatic conditions, such as high temperature and low wind speed, to create lethal conditions for fish. Although wind is not manageable, the working hypothesis in the 2001 BiOp is that higher lake elevations could ameliorate the negative consequences of low summer winds. The BiOp states:

> "Low lake levels per se do not cause fish kills; they can however, contribute to conditions that cause fish kills. Low lake levels can contribute to conditions that promote *AFA* [algal] blooms chiefly by increasing average light intensities in the water column and aiding internal nutrient loading, and can also worsen water quality conditions through a number of mechanisms, but chiefly by reducing lake volume/surface area ratios which reduce DO levels and increasing pH and ammonia concentrations, as discussed in detail below" (2001 BiOP, Section 3, Part 2, page 71).

Among examples to illustrate this point, the BiOp describes differences between shallower Agency Lake and Upper Klamath Lake proper. At a certain concentration of chlorophyll-a (a surrogate for algal biomass density), there is an 18 percent probability of exceeding pH 9.5 in Upper Klamath Lake proper and a 40 percent probability in Agency Lake. Agency Lake has a mean depth about 1.6 feet shallower (about 30 percent) than Upper Klamath Lake, suggesting support for the hypothesis that low lake elevations can contribute to conditions that promote algal blooms (2001 BiOP, Section 3, Part 2, page 74).

Although many people agree that a long-term goal is to reduce the magnitude and intensity of algal blooms, there are significant obstacles, such as the challenge of reducing nutrient loading, that make this goal difficult to achieve. Thus, it may be necessary to continue to search for short-term solutions.

Access to refugia

Water quality refugia are areas of higher quality water where fish can take refuge during times of general low water quality. In Upper Klamath Lake, water quality refugia are most important when low dissolved oxygen, high temperature, high pH, and un-ionized ammonia create stressful conditions for suckers in late summer and early fall. These conditions typically occur when blue-green algae concentrations are highest or when the algae have begun to die off. Groundwater springs and the mouths of inflowing tributary streams are sites of better water quality (Buettner and Scoppettone 1990) and may serve as refugia from the stressful conditions of the main lake body (Vincent 1968).

Role of lake elevation

Use of water quality refugia by adults seems to be limited by water depth. Daytime radio tracking of adult suckers indicates a preference for depths of 6 to 9 feet and avoidance of water less than 3 feet deep (Buettner 2000; Reiser et al. 2001).

It is unclear whether suckers will choose poor, deep water over good, shallow water since both behaviors have been observed. Bienz and Ziller (1987) report finding between 100 and 200 adult suckers in shallow Pelican Bay on August 27, 1986, a period when the main body of Upper Klamath Lake had poor water quality. Reiser et al. (2001) also report limited evidence that suckers utilize Pelican Bay during episodes of poor water quality. However, these authors and others suggest that the observed suckers were lethargic and potentially in poor health. Large numbers of dead suckers were collected from Pelican Bay and other "clear-water" areas of the lake during the fish kills of the mid-1990s. Conversely, at lake elevations below 4,137 feet, suckers have been found to relocate away from the northeast shore of Upper Klamath Lake to the west, where deeper water is available, but quality is more stressful (Reiser et al. 2001).

The 2001 minimum elevation for Upper Klamath Lake on July 15 was 4,141.5 feet, and on September 15, 4,140.5 feet. These levels were specified, in part, to ensure adequate water depths in areas of groundwater and tributary inflows so that adult suckers could access high-quality water without the presumed stress of shallow water. Table 5 shows how much of the lake is at the preferred depth of 6 to 9 feet given various lake elevations.

Because refugia tend to exist around the periphery of the lake, it is likely that the loss of refugia at preferred depths is greater than for the lakewide values given above.

Table 5. Relationship between lake elevation and availability of 6- to 9-foot-deep water.

Lake elevation (feet above mean sea level)	Percent of lake at 6- to 9-foot-depth
4,139	18
4,140	27
4,141	38–40

Source: Reiser, D.W., M. Loftus, D. Chapin, E. Jeanes, and K. Oliver. 2001. *Effects of Water Quality and Lake Level on the Biology and Habitat of Selected Fish Species in Upper Klamath Lake* (R2 Resource Consultants, Inc., Redmond, WA)

The 2001 Biological Opinion—other factors

Although closure of the snag fishery occurred before federal listing of LRS and SNS under the ESA, it was a critical management decision that allowed the remaining older fish the opportunity to reproduce and the populations to begin recovery (Figure 5). All subsequent actions have helped promote recruitment or ensure that some proportion of females live long lives (20 to 30 years or more).

Prior to the April 2001 BiOp, the Project had operated under a 1992 BiOp and subsequent amendments (except in 1997, when the Project operated without a BiOp—Larson 2002, personal communication). The 2001 BiOp is notably more "conservative" in protecting the aquatic system, requiring higher water levels to be maintained in Upper Klamath Lake than the 1992 BiOp. The movement of the USFWS to a more conservative stance seems to be linked to four factors:

- A benefit-of-the-doubt instruction
- Failure of the BOR to implement requirements and recommendations specified in the 1992 Biological Opinion
- A perception of greater imperilment of the sucker species since 1992
- A greater emphasis on water quality issues since 1992

Benefit-of-the-doubt

The most influential factor seems to be that "Congress instructed the Service to provide the 'benefit of the doubt' to the species of concern when formulating its biological opinion" (H.R. Conf. Rep. No. 697, supra, at 12; page 124 of 2001 BiOp; page numbers are those for Section III, Part 2). This factor is value-laden, as there always is uncertainty or doubt in science. In any complex ecosystem such as Upper Klamath Lake, this instruction suggests that the USFWS must evaluate acceptable risk. Because reasonable people with the same information can reach different conclusions about acceptable risk, this instruction is not easily carried out. As discussed below, the USFWS apparently perceived the risk to suckers to be greater in 2001 than in 1992.

The authors of the 2001 BiOp clearly considered the risk to the species high. The difference between the 1992 and 2001 BiOps seems to be a more optimistic view in 1992 that managing lake elevations near the post-1921 average, closing the fishery, salvaging suckers from irrigation canals, and enhancing spawning sites could lead to recovery. The large fish kills of the 1990s cast doubt on this optimistic view.

Failure to implement 1992 BiOp requirements

Failure of the BOR to implement specific recommendations and requirements in the 1992 BiOp was identified as another factor in the more conservative approach of the 2001 BiOp. Specific issues included installation of a fish-screening device to limit entrainment (entry) of suckers to the A-Canal, rehabilitation of Barkley Springs, assessment of ways to improve sucker passage over the Sprague River Dam in Chiloquin, and identification of ways to reduce the Project's demand for water and to augment supply.

In the Reasonable and Prudent Alternative (RPA) section of the 1992 BiOp, the USFWS wrote, "Reclamation shall implement a method to reduce entrainment of larval, juvenile, and adult Lost River and shortnose suckers into the A-Canal within five years of issuance of this biological opinion." On page 126 of the 2001 BiOp, the USFWS wrote:

> "Reclamation has not complied with installation of a screen facility requirement on the A-Canal, as directed by an amendment to an RPA in the 1992 BiOp, and has at this time committed to no additional screening at any of its facilities. The fact that adequate screening has not been provided anywhere within the Klamath Project after nearly a century of operation is considered by the Service to be a major factor imperiling and retarding the recovery of the two endangered suckers."

Entrainment of suckers to the A-Canal is significant (Gutermuth et al. 2000). Salvage operations aim to rescue suckers that are stranded in the A-Canal at the end of the irrigation season, but the efficiency of salvage is unclear; the percentage of fish returned in a viable condition to Upper Klamath Lake is unknown, and salvage does not rescue larval or smaller juvenile suckers.

It is unclear how failure to screen the A-Canal influenced the USFWS decision process for 2001. Because low water elevations allowed for in the 1992 BiOp are now considered to jeopardize suckers, it seems reasonable to conclude that lake elevation requirements would not have been more "relaxed" had the A-Canal been screened in compliance with the 1992 BiOp.

Three additional recommendations in the 1992 BiOp had not been resolved by 2001: the restoration of Barkley Springs, improving fish passage around the Sprague River Dam, and reducing the demand for water by the irrigation community. Point 8 of "possible mitigation measures" of the 1992 BiOp states:

> "Historically Barkley Springs was the site of prolific spawning activity. Thirty years ago Hagelstein Park was developed by Klamath County in the immediate vicinity of the springs. Construction of the park included diking, ponding, and the rerouting of water. This caused spawning to essentially cease, although it has been reported that as late as 1973 great numbers of suckers attempted to reach this traditional spawning ground. This work would be completed in time for the sucker spawning runs in March of 1993."

In 1993, the BOR added spawning substrate at two locations at the spring, and in 1995 a water-control device was installed to attempt to ensure that spawning areas were kept at adequate depth throughout the spawning season. Despite these efforts, no sucker spawning has been observed at Barkley Springs in the past decade (Buettner 2001, personal communication).

The Sprague Basin above the Sprague River Dam has been extensively modified from its predam condition, including loss of riparian zones and establishment of exotic fish species. Point 9 of the 1992 BiOp states, "Assess Methods to Improve Passage in the Sprague River. If a feasible plan is determined before March 1993, Reclamation will attempt to implement it before spawning in 1993." Between 1992 and 2001, however, no changes were made to the Sprague River Dam.

It is unclear whether suckers hatched in the Sprague River would survive in sufficient numbers due to water quality problems and exotic fishes. It also is unclear whether there would be significant downstream impacts from the release of sediments accumulating behind the dam, although a BOR study in 1997 documented little sediment deposition behind the dam (Buettner 2001, personal communication). Both of these issues seem to have contributed to uncertainty about the wisdom of removing or modifying Sprague River Dam.

It is not clear whether implementation of the actions called for in the 1992 BiOp would have changed the 2001 BiOp. Presumably, if screening had been done and suckers reestablished at Barkley Springs and the Sprague River, and these actions could be linked to increased recruitment of juveniles, the USFWS might have concluded that a lower lake elevation was reasonable and prudent. However, concerns about water quality and increased imperilment of suckers suggest that, in the short term at least, the decision would not have been changed by these factors.

Increased imperilment of suckers

The third factor influencing the shift to a more conservative approach was the belief among USFWS scientists that Upper Klamath Lake suckers are more imperiled now than they were in 1992. "However, the RPAs have not been fully implemented and evidence now indicates that the two endangered sucker species are more imperiled than when previous opinions were issued" (2001 BiOp, page 156).

Increased imperilment is not well documented because it has been difficult to get rigorous estimates of the annual adult population. Instead, the USFWS noted estimated losses from fish kills in 1995, 1996, and 1997 and declines in spawning run indices (Figure 1). Populations seem to have been increasing from 1988 to 1995, but those gains were lost in the 1995–1997 fish kills. Because of uncertainty about adult populations, it is possible that the authors of the 1992 and 2001 BiOps presumed population estimates of about the same order of magnitude.

Even if the USFWS agreed that population abundances were similar in 1992 and 2001, however, there are differences in reproductive potential between the two populations. The older fish present in 1992 would have had much greater reproductive potential than the younger fish in 2001.

Water quality concerns

Water quantity and quality are considered key elements in sucker recovery (USFWS 1993, 2001). High nutrient loads (phosphorus and nitrogen) and associated blooms of blue-green algae (*Aphanizomenon flos-aquae*), high pH, and low dissolved oxygen have been recognized as problems for more than 30 years (Vincent 1968). See the section above on "Water quality" for a discussion of these issues.

Water quality concerns recently have expanded to include other anthropogenic (human-caused) changes in the Upper Klamath Basin, including water diversions and the loss of floodplain, wetland, and riparian habitats. These increased concerns about the role of water quality in sucker survival were another factor behind the 2001 USFWS Biological Opinion.

Differences between the 1992 and 2001 Biological Opinions

The 2001 BiOp used new information to show that two aspects of the 1992 opinion required revision. The first was the minimum lake elevation of 4,139 feet. The second was the 4-in-10-year permitted lower elevation of 4,137 feet.

The first aspect of the 1992 BiOp that was revised was the minimum elevation of 4,139 feet. In 2001, the USFWS concluded that this elevation would jeopardize suckers. The BiOp does not show that this elevation is a threat, but states that, given certain climate outcomes, it might be a threat.

The 2001 BiOp presents an argument for raising the minimum elevation 1 foot to 4,140 feet. The argument is based primarily on a potential indirect benefit to ensure against low wind speeds. "Since winds cannot be managed, summer and early fall lake levels in Upper Klamath Lake need to be managed near the higher pre-Project levels to reduce risk of catastrophic fish kills" (2001 BiOp, page 86). The amount of insurance provided by 1 foot of lake elevation is not described.

The empirical data suggest uncertainty regarding the size of the benefit of higher lake elevations. The 2001 BiOp recognizes that other factors, primarily algal bloom dynamics and disease, complicate this relationship. It considers higher lake levels a means to reduce the probability of negative consequences of these unmanageable factors. This and other hypotheses can be tested and refined only if long-term data sets are maintained, and modeling and empirical analyses continue. This type of hypothesis is normal in science and has some support, as documented in the 2001 BiOp. It created controversy, however, because it is complex and was applied to a difficult management decision.

The second aspect of the 1992 BiOp that was revised was the compromised (lower) lake elevation of 4,137 feet, permitted in critically dry years, but in no more than 4 of 10 years or 2 consecutive years. By 2001, the USFWS had concluded that the acceptance of compromised lake elevations in 4 of 10 years would jeopardize suckers. They based this conclusion on relationships between lake elevation, water quality, and sucker recruitment and survival.

The 1992 BiOp recognized that periodic recruitment failure could be tolerated in long-lived species, and it allowed 4 in 10 years of compromised lake elevation. More recently, the 1995–1997 fish kills caused adult mortality rates greater than the annual historical snag fishery. As a result, there was increased uncertainty about previous assumptions. In other words, in the face of uncertainty about massive fish kills, it was believed that 4 out of 10 years of lower lake levels were too risky. As a result, recent actions have attempted to increase the probability of recruitment and reduce the probability of fish kills.

The 2001 BiOp makes a case that the 4-in-10-year compromised elevation of

4,137 feet might create jeopardy. The empirical data from the 2 lowest lake elevation years (1992 and 1994) show little juvenile production but no fish kills (Table 4). The USFWS believed that lake elevation was only part of a complex of factors creating fish kills and that fish kills may have been avoided during the 2 very low water years because of climatic conditions (2001 BiOp).

In summary, the 2001 BiOp makes a case for revising the conditions of the 1992 BiOp. Essentially, the experience since 1992 demonstrated uncertainty about the previous choice of a minimum lake elevation. The 2001 BiOp suggested that lowered lake levels no longer were reasonable because of concerns for water quality, population size, age structure, and recruitment.

Decision-making in the face of uncertainty

The Biological Opinion was developed by a risk-averse federal agency for an ecosystem in which consensus science is just emerging. The data on which the management of Upper Klamath Lake elevation is based vary in completeness. Some weather and lake elevation data predate the Project, while most relevant biological and hydrological data are available only since about 1990 or later.

Faced with this situation, the management decision process would seem to have two possible courses of action. One is to take a probability approach to assessing risk. This is the approach taken by the 2001 BiOp, which considered the past decade as providing insight into probabilities of certain risks at particular lake elevations. For example, page 106 of the Biological Opinion states:

> "The Service acknowledges that meeting prescribed lake elevations does not ensure year-class success or prevent sucker die-offs. Other factors can all lead to year-class failure and sucker die-offs independent of lake level. However, both Reclamation and the Service recognize that high lake elevations can enhance the *probability* of year-class survival and reduce the frequency and magnitude of major sucker die-offs, and is the only short-term way to offset some of the threat to sucker populations in UKL" (emphasis added).

The second approach is empirical and is simply to answer the question, "What is the lowest lake elevation at which recruitment was good and adult fish kills were not detected?" Based on the data of the past decade, the elevations of 1991 meet these criteria and could be assumed to establish an empirical minimum. In 1991, the July 15 lake elevation was 4,140.81 feet, about 7 inches lower than the 2001 elevation of 4,141.43 feet.

The 1992 BiOp seems to have used a probability approach for most years and an empirical approach for critically dry years. The difference between the 1992 and 2001 BiOps reflects a difference in willingness to accept negative consequences. The minimum elevations for critically dry years in the 1992 BiOp were assumed to have negative consequences, but those consequences were considered acceptable in 4 out of 10 years. The 2001 BiOp, on the other hand, does not seem willing to accept negative consequences and uses lake elevation to try to reduce risk.

Ultimately, the 2001 BiOp had to evaluate both science and risks, the latter a human perception that differs from one person to the next. One might hope that peer review could lead to consensus on both. Although there was no requirement for peer review, the 2001 BiOp was sent to peer reviewers as a rough draft (dated February 5, 2001) and as a final document (dated April 5, 2001). The rough draft was reviewed by researchers actively working in the Basin, and the final draft was reviewed, or is under review, by additional groups (University of California–Davis, the Governor's Independent Multidisciplinary Science Team (Oregon), and the National Research Council). The results of those reviews indicate that consensus on both the science and the risks has not been reached.

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Coho Salmon
and Water Management in the Klamath Basin

Guillermo Giannico and Christopher Heider

The purpose of this chapter is to assist the broadest possible readership in understanding the ongoing controversy regarding the stipulation of minimum flows in the lower Klamath River between April and September 2001 to protect threatened coho salmon. It is not intended to be an evaluation of the National Marine Fisheries Service's (NMFS) Biological Opinion (BiOp) on Klamath Basin coho salmon. Instead, it aims to provide a synthesis of the most relevant hypotheses (or theories with a small "t" as defined in Chapter 4, "Science"), data, and conclusions from available reports and studies on coho salmon in the Klamath Basin. The topics covered are:

- Main tributaries of the lower Klamath River
- Coho salmon habitat requirements
- The status of coho salmon in the Pacific Northwest and in the Klamath Basin
- Effects of hatchery supplementation on wild coho salmon
- Human activities that affect salmonids and their habitat in the Klamath Basin
- Methods for establishing minimum flows
- Various flow recommendations for the lower Klamath River
- Water quality issues related to coho salmon
- The most salient aspects of the 2001 water allocation recommendations
- Potential effects of the 2001 decisions on coho salmon
- A suggested basinwide approach to planning

Background

The Klamath River Basin, from its headwaters in south-central Oregon to its estuary by Requa, California, covers approximately 15,600 square miles (USDI 1985). For practical purposes, the Klamath Basin can be described as consisting of an upper and a lower section separated by a river reach with a series of six dams (two water diversion dams and four hydroelectric dams) (see map in Chapter 1, "Background"). In this chapter, we consider the Upper Klamath Basin to be the area upstream from Keno Dam, including the subbasins of the Williamson, Wood, Sprague, and Lost rivers; Upper Klamath Lake; Agency Lake; Tule Lake; Clear Lake; and Gerber Reservoir. We consider the Lower Klamath Basin to be the area downstream from Iron Gate Dam (IGD). It includes the tributary subbasins of the Shasta, Scott, Salmon, and Trinity rivers, in addition to the middle and lower sections of the Klamath River.

This report focuses primarily on the Lower Klamath Basin because, in this basin, the distribution of anadromous salmonids (those that spawn and rear in freshwater, but complete their growth and maturation at sea) is restricted to the lower section by hydroelectric dams.

The upper and lower parts of the basin have different geologies. The Upper Klamath Basin is characterized by a complex series of northwest/southeast-oriented valleys dominated by alluvial fans and lake clay sediments. These valleys are separated by ridges of volcanic origin, which are underlain by thick, very porous basalt flows. The great extension and thickness of these highly permeable basalt flow units give the Upper Basin a high water-storage capacity. Snowmelt recharges the groundwater reservoirs of the Upper Basin on an annual cycle. Before dam construction, these aquifers, in combination with Upper Klamath Lake, Lower Klamath Lake, and a vast network of wetlands in the Upper Basin, may have maintained relatively high and constant flows in the lower Klamath River during late summer and early fall (Boyle 1976; Hecht and Kamman 1996).

In contrast, the geologic setting of the Lower Basin is more diverse due to multiple fold systems and faults that have created a mosaic of deposits of various origins: volcanic (e.g., basalts), granitic (e.g., granite), intrusive (e.g., diorite, pyroxenite), metamorphic (e.g., marble), and sedimentary (e.g., shale, sandstone, limestone) (USDI 1985; KRBFTF 1991).

The following species of anadromous fish are found in the Klamath Basin: coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarkii*), green sturgeon (*Acipenser medirostris*), eulachon (*Thaleichthys pacificus*), and Pacific lamprey (*Lampetra tridentata*).

Historically, chinook salmon (both fall and spring types) and steelhead trout entered Klamath Lake. From Upper Klamath Lake, it is likely that they moved farther upstream into the uppermost tributaries of the Basin (USDI 1985; KRBFTF 1991). Coho salmon capture data from the 1920s at the Klamathon Racks indicate that this species probably reached the lower portion of the Upper Basin (Snyder 1931).

Many studies indicate that fisheries resources in the Klamath Basin have been negatively affected by the cumulative effects of more than a century of human activities. However, during the past decade, the effects of water diversion and hydroelectric projects on fish populations have been the primary focus of investigation and debate. Although the reduction in fish stocks has been caused by a variety of interactive factors, dams and water diversion projects have attracted attention for two reasons. First, they clearly block fish access to hundreds of miles of habitat. Second, according to several hydrological studies, they have changed the lower Klamath River's annual hydrograph (the graphical representation of water discharge over time) (USGS 1995; Hecht and Kamman 1996; USFWS 1999; Hardy 1999).

Although all species of anadromous fish in the Klamath River are in serious decline, two salmonid species in particular—coho salmon and steelhead trout—have undergone status review by the NMFS under the Endangered Species Act (ESA). As a result, coho salmon have been listed as threatened.

A formal ESA Section 7 consultation process was initiated on January 22, 2001, between the Bureau of Reclamation (BOR) and the NMFS. As a result, the NMFS issued a BiOp that found "jeopardy and adverse modifications" of critical salmon habitat in the lower Klamath River by the BOR's proposed operation of the Klamath Reclamation Project in response to the critically dry conditions anticipated in the summer of 2001. The BiOp provided what is known as a Reasonable and Prudent Alternative (RPA), which established an interim spring-through-fall Iron Gate Dam water release schedule aimed at preventing further decline of the listed fish and adverse modifications to its habitat.

Main tributaries of the lower Klamath River

In addition to the lower Klamath River mainstem, salmonids are known to utilize spawning and nursery habitats in its many tributaries. The largest tributary systems, such as the Shasta, Scott, Salmon, and Trinity subbasins, may influence the lower Klamath River mainstem's water volume and quality and, therefore, its salmonid carrying capacity (KRBFTF 1991).

The confluence of the Shasta River with the lower Klamath River is located approximately 14 miles downstream from IGD, at mile 176 of the river's mainstem. The Shasta River subbasin covers an area of approximately 340 square miles. It contains an estimated 50,000 acres of agricultural land under active irrigation, which in 1988, as an example, used 150,500 acre-feet of water (KRBFTF 1991; Siskiyou County Farm Bureau 2001).

Like the upper part of the Klamath Basin, the Shasta Valley receives very little rainfall (between 11 and 17 inches per year), and groundwater within this system is recharged via melting snow, which is stored in porous volcanic rocks. Stream flows and agricultural uses within the Shasta River subbasin depend on inputs from springs and subsurface flows.

In 1928, Dwinnell Dam was built on the upper Shasta River to hold irrigation water for the Montague Water Conservation District. This dam eliminated anadromous salmonid habitat above the dam and created Lake Shastina, with a maximum water-storage capacity of 41,300 acre-feet (KRBFTF 1991).

Little water (up to 3 cfs) is released from this reservoir into the Shasta River during the summer. The release was established to meet water rights in the reach below, where diversion points had been displaced by dam construction. This water is immediately withdrawn from the river, and it does not make much of a contribution to flows in downstream reaches. The limited summer flow of the upper Shasta River (below the dam) is maintained by springs. The water released by these springs has low dissolved oxygen, which creates some localized water quality problems during summer (Deas, personal communication).

The Scott River enters the lower Klamath River at mile 143, or 47 miles downstream of IGD. The Scott River Resource Conservation District (RCD) is 1,176,160 acres in size, with 294,160 privately owned acres and 882,000 acres of public land (CARCD 2000). In this region, flat, fertile valleys have been used since the early 1900s for crop production, grazing, and urban development.

Estimates of water use within the Scott River Valley in 1988 show that 96,400 acre-feet of water were delivered via 200 diversions along 240 miles of ditches and pipelines to 34,100 acres of crop and pasture lands. The amount of irrigated land in the valley was reported to have changed very little between 1958 and 1991 (Siskiyou County Farm Bureau 2001).

Although large, permanent dams were never built on the Scott River, summer nursery habitat for salmonids has been affected by other human activities. As early as 1974, fish habitat-related problems were documented in many reaches of this river, which were either totally dry or running in an intermittent manner during July, August, and part of September (CDFG 1974).

The Salmon River subbasin, which drains into the lower Klamath River near mile 68, is the only major subbasin within the Lower Klamath Basin that is not affected by water diversion projects. A large portion of this catchment area is under National Wilderness designation and is covered by forests. Therefore, fire, road construction, and timber harvest have been the main types of disturbances that have affected the system during the past century (USFWS 1994). In 1977, fires burned 56,000 acres of forest in this subbasin, and some 450 million board-feet of wood were reported salvaged during the following 5 years. Another 78,128 acres of forest burned in 1987 (KRBFTF 1991).

Numerous landslides and high sediment loads have negatively affected spawning gravel and invertebrate production in the Salmon River. USFWS (1994) assessments of habitat attributes, however, indicate that the relatively low quality of spawning habitat may have only minor negative implications for salmon production in this subbasin. The main limiting factor is the elevated summer water temperature, which is high enough to reduce the survival of juvenile salmonids (USFWS 1994).

The Trinity River subbasin is the largest and most complex of all Klamath River subbasins and joins the lower Klamath River at mile 43. Until the middle of the 20th century, the Trinity River was characterized by a dynamic and meandering channel that moved back and forth across its relatively broad floodplain over time (USFWS 1999). This subbasin sustained large runs of chinook salmon, coho salmon, and steelhead until the construction of the Trinity and Lewiston dams (a.k.a. Central Valley Project's Trinity River Division or TRD) in the early 1960s.

The TRD Project not only prevented fish access to 109 miles of spawning and nursery habitat above Lewiston, California, but it diverted between 74 and 90 percent of the annual flow of the upper portion of the Trinity River into the Sacramento River Basin. This resulted in drastic changes in the flows of the Trinity River, which affected its channel morphology, its substrate composition, and the characteristics of both its floodplain and riparian areas. The original channel structure included an alternating sequence of gravel-rich riffles and deep pools that provided good salmonid habitat. In the absence of high flow events after dam construction and operation, the channel structure changed to a continuous and uniform "run" or glide type of habitat that became confined, over time, by riparian berms (KRBFTF 1991; USFWS 1999; USDI 2000).

The changes in the Trinity River had a strong negative effect on the subpopulations of salmonids that relied upon it. Despite hatchery supplementation, fish abundance in the Trinity River has been reduced between 53 percent (steelhead) and 96 percent (coho salmon) after the construction and operation of the TRD Project began (USFWS 1999; USDI 2000).

After a lengthy review and decision-making process, the Department of the Interior in 2000 ordered the TRD Project to put into practice a "preferred alternative" that included the augmentation of variable annual in-stream flow releases from Lewiston Dam, a plan to introduce gravel to the stream, the construction and rehabilitation of 47 stream channels, and the implementation of adaptive management and watershed restoration programs (USDI 2000). It is estimated that transbasin water exports from the Trinity into the Sacramento River will be curtailed to an average of 52 percent of the water flowing into the river above Lewiston (Ahern 2000; USDI 2000).

In addition to the four subbasins described above, smaller scale water diversion projects for irrigation have been built in several minor direct tributaries of the lower Klamath River. The affected creeks are Grider Creek, Cottonwood Creek, Horse Creek, Bogus Creek, Little Bogus Creek, and Willow Creek (KRBFTF 1991).

Coho salmon habitat requirements

Habitat can be defined simply as the place where an organism lives and the range of environmental conditions (both physical and biological) it requires to live, grow, and reproduce (Odum 1971). The abundance and distribution pattern of animals is determined by the availability of resources and their spatial distribution (Milinski and Parker 1991). The uneven distribution of resources, in both space and time, creates patches of better or poorer habitat among which individual organisms distribute themselves.

The scale of an organism's habitat is not fixed; rather, it is determined by the home range of that organism. Thus, the habitat of a large or relatively mobile organism (e.g., a bird) is large and contains within its physical boundaries the smaller scale habitats of smaller, or less mobile, organisms. This kind of organization implies a hierarchy of habitats that are nested in space.

A river represents a particularly good system to illustrate this point. The entire watershed makes up an environment of smaller scale subsystems, such as stream sections, which in turn constitute the environment of habitat systems at even smaller scales, such as stream reaches. Each stream reach is made up of smaller components, such as pools and riffles, and these habitats contain patches or microhabitats of different types (Frissell et al. 1986).

All of these habitat components are connected by flowing water and receive the cumulative effects of upstream human activities and natural landscape processes. Such cumulative effects may reduce or eliminate fish habitat in large river channels, small stream reaches, marshes, and even estuaries (Henderson 1991; Turner and Meyer 1993; Williams 1993).

To understand how land-use activities such as agriculture, dam construction, mining, logging, or urban development might affect fish production, it is necessary to know the habitat requirements of the different species and to identify the general environmental changes brought about by human activities in each watershed. Because juveniles of different salmonid species have specific nursery habitat requirements and different lengths of freshwater residence, they are not equally susceptible to all development activities. In British Columbia, for example, human activities have harmed some sockeye salmon (*O. nerka*) stocks at two different stages of their life cycle. During the egg incubation phase, they are negatively affected by the silt deposition and gravel displacement that some land uses may cause. During the juvenile migration period, they are prevented from entering lake nursery habitat by newly built dams (Nehlsen et al. 1991).

Coho salmon are anadromous salmonids that typically exhibit a 3-year life cycle, almost equally divided between the freshwater and sea phases. Their relatively long period of residence in freshwater makes this species particularly vulnerable to habitat alterations (Hicks et al. 1991; Henderson 1991).

Coho spawning and nursery habitat

Small coastal streams and the tributaries of large rivers offer the type of spawning and nursery habitat that coho salmon prefer (Sandercock 1991). Shortly after emergence from the gravel, coho salmon fry establish feeding territories, which they defend from other salmonids. They tend to be more territorial in stream reaches with fast-flowing waters than in slow-flowing areas, where it is common to find them forming loose aggregates and cruising for food (Mundie 1969). Although, coho salmon fry are predominantly stream dwellers, they also have been observed in the littoral zone of lakes (near the shore) (Mason 1974).

Individuals that "take residence" normally occupy a small area of slow-moving water, from which they make short excursions to feed or to chase away intruders. Subordinate fish, which are not able to establish a territory, tend to be less aggressive than dominant individuals and have a reduced growth rate due to their lack of access to good feeding areas (Chapman 1962).

In general, the young of this species prefer zones with reduced water velocity. They favor pools over other types of habitat and use in-stream structures as protection from fast currents. In this manner, they may minimize their energy expenditures to maintain position while feeding on drifting prey (Mundie 1969; Everest and Chapman 1972; Fausch 1993). Coho are visual predators and seldom feed from the bottom. They prefer to capture invertebrates that drift in the water column or on the surface (Nielsen 1992).

In addition to providing prey items and shelter from water velocity, in-stream and riparian cover provides other benefits. Low-hanging overhead cover such as undercut banks and root wads may decrease the amount of light reaching the water surface, thereby making fish less visible to potential predators and minimizing stream temperature extremes (Murphy and Hall 1981). In-stream cover also can provide refuge from predators and increase visual isolation among competitors. Visual isolation may reduce aggressive interactions among competitors and, therefore, could lead to an increase in the number of fish occupying a given area (Dolloff 1986; Fausch 1993; Giannico 2000).

The amount of spawning habitat in a stream is regulated by flows. D.H. Fry (cited in Bjornn and Reiser 1991, page 89) explains:

> "… as flow increases, more and more gravel is covered and becomes available for spawning. As flows continue to increase, velocities in some places become too high for spawning, thus canceling out the benefit of increases in usable spawning area near the edges of the stream. Eventually, as flows peak, the losses begin to outweigh the gains, and the actual spawning capacity of the stream starts to decrease. If spawning area is plotted against stream flow, the curve usually shows a rise to a relatively wide plateau followed by a gradual decline."

Egg incubation is affected by the amount and velocity of the water circulating among the gravel particles and eggs. This, in turn, may increase or decrease with the depth and quantity of the surface water (Wickett 1954). An additional problem associated with increases in peak water flows is possible redd (nest) scouring and gravel displacement that can cause the mortality of eggs and alevins (recently hatched fish that have not yet absorbed their entire yolk sac) (Chamberlin et al. 1991).

Seeding rate (abundance of spawners) is the primary factor regulating the abundance of juvenile salmonids present in a stream. Because numbers of anadromous spawners are determined in part by their ocean survival, their numbers do not necessarily show a direct relationship with in-stream flows in their natal streams. That said, it is worth noting that Smoker (1955), in 21 western Washington basins, found a correlation between the commercial catch of coho salmon and annual runoff, summer flow, and lowest monthly flow 2 years earlier. Smoker's data were for the 1935–1954 period, but in the last decades of the 20th century, hatchery production of coho salmon smolts increased to the point that such comparisons no longer are possible in most systems. (Smolts are juvenile salmonids that are undergoing the physiological changes needed to survive in saltwater.) However, Mathews and Olson (1980) analyzed data from Washington for the 1952–1977 period and found that summer in-stream flows still had an important positive influence on total coho salmon production in streams in the Puget Sound area.

Although coho salmon show a strong preference for small streams over mainstem river habitat, some fry may end up being displaced into mainstem and even estuarine habitat if fish densities are too high or stream habitat is somehow limited (Sandercock 1991). In the spring, shortly after emerging from the gravel, coho fry distribute themselves throughout their natal stream reach and establish feeding territories that are aggressively defended from intruders. As late-emerging fry try to establish their own feeding "posts," they find that most of the nearby good nursery habitat already has been claimed by the early-emerging individuals. Because they can start feeding earlier, the early-emerging fry grow bigger and become successful at defending their territories. This forces other fry to move in search of vacant nursery habitat (Chapman 1962). Although some fry move upstream, the vast majority move downstream. Thus, many individuals end up in the river's mainstem and even in the estuary, where they are less likely to survive (Sandercock 1991).

A 1997 USFWS report and the 2001 mainstem trap records (USFWS unpublished data) show that young-of-the-year coho salmon emigrate from the Shasta and Scott rivers, where they probably were spawned, into the mainstem of the lower Klamath River between March and July. Considering that there are very low densities of coho salmon fry in all Klamath subbasins, it is unlikely that these fish were displaced downstream because of competitive interactions with other juveniles of their own species. Possible hypotheses to explain their summer movement are: (1) the declining quantity and quality of water in these tributaries (USFWS records indicate that the Shasta and Scott rivers were warmer than the mainstem Klamath during the summer of 2001), or (2) interspecific competition with steelhead (see Harvey and Nakamoto 1996).

Coho temperature tolerance

Juvenile coho salmon's temperature tolerance and their use of cool-water areas in the Klamath River have received a lot of attention recently. Unfortunately, this is a complex issue that can be addressed adequately only with field studies and experimental manipulations in the Lower Klamath Basin.

A number of studies have shown a rather consistent pattern of temperature preference. Like other salmonids, coho salmon prefer cool, well-oxygenated waters. Brett (1952) observed that coho prefer a temperature range of 12 to 14°C (53.6 to 57.2°F), which is close to the optimum temperature for maximum growth efficiency reported by other authors (see Sandercock 1991). Although fish may survive at temperatures near the extremes of the tolerance range (1.7 to 28.8°C, 35.1 to 83.8°F) (Bjornn and Reiser 1991), growth is reduced at both low and high temperatures.

Regarding the maximum temperature that juvenile coho salmon can withstand, several studies have reported different results, depending on a variety of factors. For example, Eaton et al. (1995), using an extensive database of primarily large stream and river data, estimated that the maximum temperature that juvenile coho salmon tolerate is 23.4°C (74.1°F). Brett (1952) found that exposure to temperatures in excess of 25°C (77.8°F), or a quick rise in temperature from less than 20 to 25°C (68 to 77°F), resulted in high mortality rates. Becker and Genoway (1979) reported a lethal temperature limit of 28.8°C (83.8°F) when they gradually exposed fish to increasingly warmer waters. Bisson et al. (1988) found neither evidence of mortality nor lethargic behavior in juvenile coho salmon when stream temperatures exceeded 24.5°C (76.1°F) during extended periods, and even when they peaked at 29.5°C (85.1°F) for 3 consecutive days in two Mount St. Helens streams (Washington). Relatively similar high tolerance limits were reported by Konecki et al. (1995), who tested the critical maximum temperature for wild juvenile coho salmon from three streams in Washington. They found consistently high thermal tolerance levels that ranged from mean maximum temperatures of 28.21°C (82.8°F) for one population to 29.23°C (84.6°F) for another.

These results suggest that juvenile coho salmon are able to tolerate different critical maximum temperatures, depending on stream channel size, acclimation period, food abundance, competition, predation, body size, and condition. Longer acclimation periods, higher prey availability, and lower numbers of competitors seem to increase the upper temperature limit these fish can endure.

Behavioral responses, such as migration, utilization of cool-water refugia, feeding rate, and activity level are some of the mechanisms fish use to survive adverse temperatures. A recent study by Welsh et al. (2001) on the summer distribution of juvenile coho salmon among tributaries of the Mattole River, in northern California, found fish only in creeks with maximum weekly temperatures below 18.1°C (64.6°F). These results corroborate that fish distribution is affected by water temperatures and that coho salmon seek relatively cool-water areas as summer refugia. Such thermal refugia are found in spring-fed tributaries, in main river channels below the confluence of tributaries, and around groundwater seepage areas.

A 1996 snorkeling survey of the lower Klamath River mainstem located 32 cool-water areas between IGD and Seiad Creek (60.27 miles below IGD). Twenty-eight of these were associated with tributary confluences, and four with springs (Belchik 1997). During the course of this study (July and August), the temperature of the Klamath River mainstem ranged from 21.3 to 26.2°C (70.3 to 79.2°F), whereas cool-water areas ranged from 10.2 to 22.8°C (50.4 to 73°F). Seven tributary confluences did not offer cool-water areas because the tributaries were either dry (two creeks) or were warmer than the river (including the Shasta River). Juvenile salmonids were observed in 19 of the 32 cold-water refugia; most of them were chinook salmon and steelhead. Coho salmon were observed in only two of these areas (Belchik 1997).

During the summer of 2001, the USFWS counted thousands of juvenile salmonids in the mainstem of the lower Klamath River. Sampling was restricted to the mainstem and specifically to tributary confluence areas. For most locations, it was repeated several times between June and September. Mainstem Klamath temperatures ranged from 16.7 to 26.2°C (62.1 to 79.2°F) during this period and generally were warmer than both the tributaries (which ranged from 12.8 to 24.5°C, 55 to 76.1°F) and the cool-water areas these tributaries created in the mainstem. Although the vast majority of fish observed during this survey were juvenile chinook salmon and steelhead, a few coho salmon were seen in some mainstem cool-water refugia (86 individuals) and in several of the creeks (395 individuals) near their confluence with the river.

During some July and August days, water temperature in a small number of tributaries (Beaver, Grider, and Pecwan creeks and the Salmon River) was either the same or higher than in the main river, and many young fish were observed in these warmer waters. Later, on the afternoon of September 13, 240 juvenile steelhead, 233 juvenile chinook salmon, and 15 juvenile coho salmon were observed near the confluence of Pecwan Creek in 24.6°C (76.3°F) waters, while the mainstem Klamath was at 20.5°C (68.9°F). Only the Shasta and the Scott were warmer than the mainstem Klamath during the 3 days of the survey. In fact, these tributaries on average were warmer than the mainstem Klamath throughout July and August. The average July–August daily temperature for the Shasta was 22.9°C, or 73.2°F; for the Scott, it was 22.8°C, or 73.0°F. Nevertheless, these tributaries' area of thermal influence in the Klamath occasionally seemed to attract small numbers of juvenile salmonids.

These observations support the notion that juvenile salmonids are able to respond in a flexible manner to temperatures around the mid-20s°C (70s°F). As discussed earlier, their tolerance to high temperatures seems to be determined by factors such as food abundance, competition and predation pressures, time to acclimate, fish condition, etc. (see Bisson et al. 1988; Konecki et al. 1995; Harvey and Nakamoto 1996; and Welsh et al. 2001).

In autumn, as water temperatures decline and flows increase, juvenile coho salmon redistribute into deeper pools, smaller tributaries, or lateral channels. In these areas, abundant cover from fallen logs or root wads provides shelter from winter conditions (Bustard and Narver 1975; Cederholm and Scarlett 1982; McMahon and Hartman 1989; Nickelson et al. 1992). Winter habitat availability tends to be one of the most important factors affecting the survival of juvenile coho salmon in streams (Moyle 2002).

Coho requirements for water quality and quantity

The quality and quantity of water determine whether fish can live in a particular aquatic habitat, what species of fish can use it, and how many individuals can occupy it. Water quality requirements for salmon have been well established by a large number of studies (see Bjornn and Reiser 1991; Groot and Margolis 1991). Salmonids can live only in water with chemical characteristics (e.g., oxygen concentration and pH) and physical characteristics (e.g., temperature) that are within their relatively narrow range of tolerance.

Quantity requirements, particularly for stream-dwelling fish, have been more difficult to determine. Some of the most common tests of flow/fish relationships consist of analyses of correlations between fish abundance and flow, as well as physical and chemical characteristics affected by the flow regime (Binns and Eiserman 1979). Measures of density (number of fish per unit of area) are one way to measure abundance.

Despite regional and watershed-specific differences, several studies have identified the same set of variables as very important in controlling salmonid abundance. These variables are water velocity, minimum water-column depth, in-stream cover, substrate composition, water temperature, dissolved oxygen, alkalinity, and turbidity (Gosse and Helm 1981; Shirvell and Dungey 1983). The fact that almost all of these variables are directly or indirectly influenced by in-stream flows explains why water flows can have such a strong controlling effect on fish numbers.

Water velocity and water-column depth affect upstream fish migration. Under increasingly fast water velocities, it becomes harder for fish to migrate upstream (although fish may be assisted in their upriver migration by turbulent flows and eddies). As the water column in a channel becomes deeper, fish seek to save energy by migrating closer to the river bottom through slower and relatively colder waters. For information on a series of techniques to estimate stream discharges that provide suitable depths and velocities for upstream passage of adult salmonids, see Thompson (1972).

The amount of suitable stream habitat to be occupied by salmonids is a function of in-stream flows, channel morphology, gradient, and in some cases in-stream or riparian cover availability. Suitable habitat for each salmonid life stage requires water of sufficient depth and quality to be flowing at appropriate velocities.

Diversions of water from streams and/or impoundments alter water discharge and reduce or eliminate flow variation over time, thus changing the stream's carrying capacity for salmonids. The relationship between flow and carrying capacity varies with channel geometry and valley form. (For example, it differs between a channel dominated by riffle habitat within a narrow canyon and a channel with many pools in a broad valley.)

In general, the relationship must start at the origin (no flow, no fish), increase (not necessarily in a uniform manner) with flow increases up to a point, and then level off or even decline if flows become excessive. The existence of this relationship has been demonstrated empirically (see Kraft 1972; Stalnaker 1979; White et al. 1981) and is not in dispute. What remains to be defined is the nature of the relationship (or the shape of the curve representing the relationship) between flow levels and fish abundance. Because the relationship is not linear, and it varies with channel structure and the fish species under consideration, its theoretical formulation has been the goal of many models.

Status of coho salmon in the Pacific Northwest

Each salmonid species is made up of local populations, referred to as stocks, which are adapted to the specific environmental conditions of their watershed of origin (Ricker 1972). In the case of anadromous salmonid populations, the strong tendency to spawn in their natal streams (homing behavior) maintains a high level of reproductive isolation among populations and makes them highly susceptible to local extinctions.

This type of reproductive isolation allows for the development of watershed-specific adaptations (e.g., thermal tolerance, migration timing, etc.) at the population level and increases the genetic variability of the species as a whole (Thorpe et al. 1981). A high level of genetic variation among the populations of a species provides the basis for future evolution and an "insurance" of adaptation to environmental changes (White and Nekola 1992). Consequently, the genetic diversity within each species must be maintained by protecting local breeding populations and their habitats. To consider only the overall abundance of salmonids at a regional level is not a reasonable long-term resource management approach (NRC 1996).

Many wild populations of anadromous salmonids (*Oncorhynchus* spp.) in western North America are at risk of becoming extinct, while others have declined between 50 to 85 percent from their average historical abundance (Nehlsen et al. 1991; Northcote and Burwash 1991; Slaney et al. 1996). A review by Weitkamp et al. (1995) of coho salmon status in California, Oregon, and Washington identified six population groups (Evolutionary Significant Units, or ESUs) and indicated that wild populations in all ESUs are significantly below historical levels. In southern Oregon, Nehlsen et al. (1991) considered all but one coho salmon population to be at "high risk of extinction." In northern California, coho salmon populations, including hatchery fish, might be at 6 percent of their abundance during the 1940s. They have been eliminated in many streams, and in some watersheds, adults are observed only 1 year in 3 (CDFG 1994). In other words, two of the three spawner lines have been lost.

It is obvious that the anadromous salmonid populations of the Klamath Basin are not the only ones in the Pacific Northwest that face a bleak future. Such widespread declines cannot be attributed to one single land-development project, nor even to one natural factor.

Several hypotheses have been advanced to explain these declines (e.g., overfishing, freshwater habitat loss, interactions with hatchery fish, and ocean habitat changes). It is worth noting, however, that freshwater habitat loss has been associated with the decline of every one of the 214 salmonid stocks that Nehlsen et al. (1991) identified as either facing high to moderate risk of extinction or being of special concern. These researchers recognized several factors that had a negative effect on wild stocks, but concluded that freshwater habitat degradation and loss were among the leading causes of their decline.

Although some stocks may be affected primarily by a single factor, it is reasonable to conclude that a combination of the above-mentioned factors, with their relative importance varying from year to year and location to location, is behind the widespread decline in salmonid abundance.

Commercial fishing has been one factor contributing to the decline of salmon abundance throughout the Pacific Northwest. However, salmon mortality caused by the combined effects of other human development activities and natural factors usually exceeds the mortality caused by fishing. This chapter focuses on human activities that are particularly important in the case of Klamath Basin coho salmon. Because retention of naturally produced coho salmon has been prohibited in marine fisheries south of Cape Falcon, Oregon since 1994, the commercial fishery currently is not a significant barrier to recovery of the wild population.

Status of coho salmon in the Klamath Basin

According to the 2001 BiOp (NMFS 2001), the Southern Oregon/Northern California Coast coho salmon Evolutionary Significant Unit (SONCC ESU) "was listed as threatened under the ESA on May 6, 1997. This ESU includes coho salmon populations between Cape Blanco, Oregon, and Punta Gorda, California." The listing of these stocks was the response of the NMFS to abrupt declines in their abundance, in particular during the past decade. The designation of "critical habitat" within this ESU (waterways, stream bottoms, and riparian zones below impassible natural barriers) followed in May 1999.

Historically, the Klamath River Basin was well known for its large runs of chinook salmon. Its coho salmon populations were relatively large, but never as abundant as in some of the larger basins north of Cape Blanco, such as the Columbia River or the Fraser River (Weitkamp et al. 1995). Over time, however, coho salmon stocks have been greatly reduced and now consist largely of hatchery fish. Only small runs of wild coho salmon remain in the Basin (CDFG 1994).

Out of a total of 396 streams within this ESU that once had coho salmon runs, Brown et al. (1994) found survey information for 115 (30 percent) of them. Seventy-three (64 percent) of these streams still supported coho salmon, while 42 (36 percent) did not. The streams identified as lacking coho salmon were all tributaries of the Klamath or Eel rivers (Brown et al. 1994; Weitkamp 1995).

Estimates from 1994 showed an average spawning coho salmon population in the Klamath Basin of 7,080 wild fish and 17,156 hatchery fish. Combined with Rogue River data, spawning adult coho salmon were estimated to be 10,000 wild fish and 20,000 hatchery fish (PFMC 1999).

Coho salmon enter the Klamath River from the Pacific Ocean between mid-September and late December. Spawning typically takes place in tributaries between early November and mid-February (USDI 1985). Some limited spawning also occurs in the mainstem, where USFWS biologists have recorded coho spawning in the Klamath River between Iron Gate Dam and the confluence of the Shasta River (Shaw 2001).

Because fish sampling in the Klamath River traditionally has focused on fall chinook salmon, and coho salmon runs peak later in the season, data on wild coho spawners have not been collected consistently. Fish-counting weirs are removed from the river after the fall chinook salmon migration is over and before flows reach very high levels. The migration of adult coho salmon typically coincides with periods of high water discharge, which make the use of counting weirs impractical and often dangerous. Unfortunately, trapping efforts for juveniles in the Basin also have focused on chinook salmon smolts and have provided relatively poor estimates of coho salmon smolt output.

Notwithstanding these technical difficulties, the California Department of Fish and Game has estimated that total coho salmon runs are less than 6 percent of what they were in the 1940s (CDFG 1994). This is within the range estimated by Nehlsen et al. (1991).

Fish-counting weir data from the Shasta River and carcass counts from the Scott River show similar declines in the abundance of coho salmon spawners during the past 30 years. Shasta River fish counts, during years when trapping started and ended at equivalent times, show an average of 217 spawners in the 1970s and only 7 in the 1990s. Between 1991 and 2000, coho salmon counts ranged from 0 to 24 fish, with 1 or 0 fish counted during 4 of these years (CDFG, unpublished data).

Counting weirs in the Scott River indicated a similar trend, with an annual average count of 25 coho salmon (range = 5 to 37) between 1982 and 1986, and an average of 4 fish (range = 0 to 24) between 1991 and 1999. Again, within the past decade, a single year accounted for most of the fish observed, whereas no coho salmon were counted during 4 of those years (CDFG unpublished data). These data emphasize the importance that 1 year's spawning success can have on the survival of these coho salmon stocks.

Smolt data also suggest that Klamath Basin coho salmon stocks are in trouble. Juvenile traps, operated on the river's mainstem, were used to estimate smolt production. Based on counts from these traps between 1991 and 2000, the annual average number of wild coho salmon smolts was estimated at only 548 individuals (range = 137 to 1,268 individuals) (USFWS 2000). For the same period, an average output of 2,975 wild coho salmon smolts (range = 565 to 5,084 individuals) was estimated for Willow Creek within the Trinity River subbasin (USFWS, unpublished data).

The incomplete trapping record provides limited information on trends, but remains a useful indicator of the extremely small size of coho salmon populations in the Klamath Basin. Furthermore, the presence of coho salmon fry in these smolt traps helps to shed some light on how the young fish are distributed within the system during their period of freshwater residence.

Effects of hatchery supplementation on wild coho salmon

A comprehensive review of the effects of hatchery operations warrants an entire chapter. Unfortunately, such an evaluation is beyond the scope of this report. Instead, we will present a brief summary of the main hatchery-related issues as they relate to Klamath Basin coho salmon.

The idea to use hatcheries to offset habitat destruction and overfishing is not new. In the Klamath Basin, a series of attempts began as early as 1889 with small facilities that were operated for only a few years. To compensate for the habitat lost to Copco Dam, Fall Creek Hatchery was built in 1920. This facility, which was operated by the California Department of Fish and Game, released an annual average of 3,400,000 chinook and 600,000 steelhead fingerlings between 1920 and 1948 (KRBFTF 1991).

The two large-scale hatcheries that currently operate in the Klamath River Basin are the Iron Gate and Trinity River hatcheries. The fish produced in these hatcheries are derived from a combination of Klamath Basin and Columbia Basin coho. The hatcheries were built in the 1960s to mitigate for habitat lost to Iron Gate Dam on the mainstem of the Klamath River and to the Lewiston and Trinity dams on the upper Trinity River (KRBFTF 1991). Currently, coho salmon stocking goals have been reduced to 75,000 yearlings for Iron Gate Hatchery and 500,000 yearlings for Trinity River Hatchery (Rushton 2001).

The intended goal of most hatcheries was to mitigate or reduce the negative effects of human activities on salmonid stocks. In retrospect, it has become clear that they have created a number of unintended biological problems. These problems derive from the hatcheries' goal of increasing run sizes and the poor integration of genetic, evolutionary, and ecological principles into hatchery planning and operation. The problems associated with past and most current hatchery practices listed by the National Research Council (NRC) (1996) include:

- Demographic risks (e.g., overfishing in mixed-population fisheries, which tends to drive the smaller wild stock to extinction)
- Genetic and evolutionary risks (e.g., loss of genetic diversity, inbreeding, domestication)
- Differences in behavior (e.g., size-related competitive displacement of smaller wild fish, inadequate response to predators by hatchery fish)
- Physiological state (e.g., higher susceptibility to disease and lower proportion of individuals that smolt among hatchery fish)
- Ecological effects (e.g., reduction of number of carcasses in streams, overload carrying capacity of rivers)

In the case of Klamath River wild coho salmon, competition with the more abundant hatchery fish for limited resources (e.g., food, space, and spawning beds) is likely to result in reduced survival for both hatchery and wild fish (Stempel 1988; Steward and Bjornn 1990). Despite their lower ability to survive, hatchery salmon greatly outnumber their wild counterparts and impose unnatural pressure on their populations and on the resources they require (NRC 1996). As the interim report by the NRC (2002) states, hatchery production of coho salmon has strong negative effects on the wild populations of the species in the Basin, and it does not represent the solution to the current wild coho salmon crisis.

Human activities and fish habitat

Fish habitat degradation and loss are side effects of various types of human activities. Changes to the aquatic parts of a watershed begin when humans alter its terrestrial components. Mining and logging have historically preceded a number of other land-use activities in coastal watersheds of the Pacific Northwest. These operations indirectly affected stream channel shape and water movement by modifying the soil and its vegetation cover. In the past, they also directly altered stream channels and their substrates through practices such as moving heavy machinery, skidding logs across channels, and building (and subsequently blasting) "splash dams" to float and transport logs downstream.

The expansion of agriculture into some river valleys and the encroachment of grazing into some riparian zones have altered the connectivity of stream channels with their floodplains. In some cases, government assistance was provided for straightening and moving stream channels. In California and Oregon, hydroelectric projects are common. Dams created impassible barriers to fish migration, and the regulation of flows altered the structure of channels and the hydrology of rivers. More recently, urban sprawl has begun to cover ever-larger portions of coastal watersheds (Gregory and Bisson 1997).

Land use activities in the Klamath Basin

The Klamath Basin has a long history of human activities that have altered its hydrology and, as a result, the availability and quality of fish habitat in the system. Commercial harvesting of timber in the Lower Klamath Basin started in the late 1800s, concurrent with the development of a commercial fishery in the river estuary and surrounding coastal waters (KRBFTF 1991). Mining, primarily for gold, was a very common activity, particularly in the middle reaches of the Klamath River. The cultivation of crops and the raising of cattle began in the 1850s. The hydrology of most of the Klamath Basin was altered drastically by the development of many water diversion projects. Although mining was the first activity that diverted water from the river, irrigation diversions for agriculture have been, and still are, common practice, not only in the Upper Basin, but also in some lower tributaries to the Klamath River such as the Shasta, Scott, and Trinity rivers.

Mining

In the 1800s, gold mining was carried out primarily by means of suction dredging and placer mining—two methods that disrupt stream substrates and negatively affect fish spawning beds, food production, and nursery habitats (Bjornn et al. 1977; Hassler et al. 1986). Other types of mining, such as tunnel mining for gold, copper, and chromite, have been intermittent in different parts of the Basin during the past 100 years. In-stream gravel mining has been a more sporadic activity (KRBFTF 1991).

Forestry

Forestry represents a very important industry in the Klamath Basin. High timber demand began with gold-mining activities, and this demand made possible the establishment of many lumber mills in the central part of the Klamath Basin (Wells 1881). Timber harvest increased with the arrival of the railroad to Yreka, California in 1887, and it experienced extraordinary growth after World War II. As a result, log rafting, road construction, skid-trail construction, earth removal, and other related practices increased to the point of presenting a threat to fish life in the Klamath River.

"Corrective actions" were ordered by the California legislature in 1957 (KRBFTF 1991). Although an increasing number of regulations have been implemented since that time to minimize the negative effects of timber harvest practices on fish habitat, many questions regarding their effectiveness remain unanswered.

Agriculture

While forestry has been the predominant type of land use in the Lower Basin, crop production and ranching have flourished in the fertile valleys and hillside grasslands of the Upper Klamath Basin, as well as in the floodplains of tributaries such as the Shasta and Scott rivers. Land clearing to provide cropland and ranchland modified the vegetation of entire valleys, with native trees and perennial grasses being replaced by crops, junipers, brushes, and forbs (USSCS 1983; KRBFTF 1991).

As farmland became more valuable, flood-control measures became increasingly common. As a result, riparian vegetation was removed from entire river reaches, stream channels were straightened, and dikes were built along stream banks. Flooding was not the only problem, however. By the mid-1900s, pressure to conserve soil and water resources prompted farmers and ranchers in various valleys to organize soil conservation districts (KRBFTF 1991).

Water diversions

The U.S. Bureau of Reclamation began construction of the Klamath Reclamation Project, near Klamath Falls, Oregon, in 1905. Marshes, Lower Klamath Lake, and most of Tule Lake were drained, and a complex network of levees, dikes, pumping stations, and channels was developed to divert water from Upper Klamath Lake and the Klamath and Lost rivers to irrigate about 220,000 acres of agricultural land and wildlife refuges. The main water diversion facilities that were built on the Klamath River immediately downstream from Upper Klamath Lake include the A-Canal (1905–1907), the Link River Dam (1921), and Keno Dam (1967). (See Chapter 2, "Klamath Reclamation Project," for a detailed description of the water diversion system in the Upper Klamath Basin.) The network of irrigation channels was designed to reroute water from the lake and river through farmland and national wildlife refuges and return unused water back to the upper river above IGD.

The combined effects of Project water requirements and the dams that were built on the Klamath River for electricity production reduce summer flows, increase nutrient load, and alter water temperature in the river. These changes seem to affect the quantity and quality of fish habitat downstream from IGD during summer and early fall, especially during dry years (KRBFTF 1991; USGS 1995; Deas and Orlob 1999).

Hydroelectric projects

During the late 1800s, small, water-impounding dams supplied the water needed for mining and farming operations. However, these small projects did not represent a permanent barrier to fish migration because they often were washed out during floods. It was not until 1892 that the first large dam was built; it was part of a hydroelectric power plant project on the Shasta River. After that time, the California Oregon Power Company (COPCO) identified numerous potential dam sites on the Klamath River. Because the proposed projects were not always feasible based on hydroelectric power production alone, the company tried to develop irrigation supply benefits as well whenever possible (Boyle 1976; KRBFTF 1991).

The KRBFTF (1991) report shows that COPCO's Klamath River flow records started in May 1910, before the construction of any of the dams. These flows were measured on a daily basis at Ward's Bridge and ranged from 1,450 cfs to 4,500 cfs. Boyle (1976) and the USGS (1995) have attributed the relative uniformity in the river's flow to the moderating influence of the large, shallow Upper and Lower Klamath lakes.

Over time, these records revealed a change in the river flow regime from a relatively uniform flow to one with higher flows in early spring and lower flows in the summer. This hydrological change, which was primarily caused by construction of four hydroelectric dams (KRBFTF 1991), apparently became accentuated by the concurrent development of the Bureau of Reclamation's irrigation projects (Boyle 1976).

The first large hydroelectric dam on the mainstem of the Klamath River was Copco 1, which was completed in 1917 in the Ward's Canyon area, northeast of the town of Yreka, California. Copco 1 created a reservoir with a holding capacity of 58,800 acre-feet of water. This hydroelectric project created the first impassible barrier to the migration of anadromous salmonids to the Upper Klamath Basin (Snyder 1931). In 1925, Copco 2 was completed immediately downstream from Copco 1 (Boyle 1976).

Because no minimum flows were required for the operation of these dams, their water releases fluctuated from 200 cfs to 3,200 cfs in response to peak power demands and regulatory capacity. Such changes in flow often made the water level in the river rise or drop several feet within a 20-minute period (Jones and Stokes

1976; KRBFTF 1991). These extreme and frequent changes in flow had very negative effects on fish habitat and fish production in the Lower Klamath Basin (Snyder 1931; Jones and Stokes 1976).

In 1947, the proposed "solution" to this problem was the construction of a reregulating dam below Copco 2 that would eliminate the daily peaks of water discharge. It took 13 years for construction of this dam to begin. Water users in the Upper Basin were concerned about the allocation of water and opposed COPCO's plans for more dams.

It was not until the Federal Power Commission (FPC) approved COPCO's Big Bend hydropower project, and commanded the extension of its contract with the Bureau of Reclamation, that Upper Basin water rights were dealt with in a manner that allowed construction of a flow-regulating dam (KRBFTF 1991). In 1958, the FPC granted approval for the construction of Big Bend Dam and power plant (now known as J.C. Boyle) upstream of Copco 1 on the Oregon side of the state line. By then, COPCO had reached an agreement with the California Department of Fish and Game regarding flow-release regimes and thus had obtained the state water rights and the license from the FPC to build the recommended flow-stabilizing dam downstream from Copco 2 (Jones and Stokes 1976).

The construction of the flow-regulating Iron Gate Dam began in 1960 and was completed by 1962. IGD is located 7 miles below Copco 2, and its reservoir has a capacity of 46,850 acre-feet of water. It now marks the limit to upstream fish migration in the Klamath River.

Methods for establishing recommended minimum flows

The complex dynamics of river systems, combined with salmonids' diverse repertoire of adaptive behaviors, limit the predictive capability of any model. Methods for establishing minimum flow requirements are no exception. Nevertheless, such methodologies constitute broadly applicable and useful tools to establish the minimum flows needed in a stream channel to ensure that a specified proportion of habitat remains available to fish during low-flow periods. Because predetermined in-stream flows are not compatible with the emerging emphasis on ecosystem-based management, these methodologies are more effective at protecting aquatic resources if used within the context of watershed-scale management programs.

In-stream flow quantification methodologies are classified into two general categories: standard-setting and incremental methodologies. Standard-setting methodologies are techniques used to determine the minimum flow needed to protect certain habitat types of interest for the benefit of fish and other aquatic life. The application of these methods usually results in a minimum flow value for a specified stream reach, below which water may not be withdrawn. The minimum or "threshold" flow almost always is less than the historical level and, therefore, reduces the amount of available habitat. Nevertheless, these methods are used in many states.

Standard-setting methods can be further divided into nonfield types (e.g., the Tennant Method) and field types (e.g., R2CROSS) (Espegren 1998). The Tennant Method is a nonfield technique used for setting "target" percentages of mean annual discharge that are expected to "protect" specified amounts of aquatic habitat (Tennant 1976). This method was developed for fish-bearing stream sections and has become popular because it is quick, cheap, easy, objective, and can be readily applied to both recorded flows and estimated mean annual discharges. The Tennant Method has been commonly used in the U.S. since 1976 and is second in popularity only to the In-stream Flow Incremental Methodology (IFIM).

Many regulatory agencies still consider the Tennant method a useful, albeit coarse, tool that can be used to set in-stream flow targets over a large number of streams in a short period of time and at a relatively low cost. However, because it is a nonfield method, many managers and scientists believe it should not be used as the sole basis for developing in-stream flow recommendations (Castleberry et al. 1996). In fact, Tennant (1976) indicated that field verification of this method is necessary to establish appropriate "target" flow levels.

Incremental methodologies, such as IFIM, combine hydraulic data with biological information on selected aquatic organisms to assess habitat alteration relative to incremental changes in flow. They help evaluate potential effects of alternative development scenarios on aquatic species (Stalnaker 1993). These methods were developed from habitat-versus-flow functions that take into consideration specific needs of target species at various life stages (e.g., migration, spawning, and rearing).

Incremental methodologies simulate the quantity and quality of potential habitat resulting from proposed water development, illustrated for a series of alternative flow regimes (Trihey and Stalnaker 1985). These methodologies are field-based techniques often used to evaluate the impacts of hydroelectric projects and to develop conditions for water licenses and permits on very controversial stream segments with high potential for water development. Their downside, from the perspective of the stream ecosystem, is that they do not define flow targets in terms of the natural variability of the hydrograph. In other words, they pay little attention to the importance of flow changes in maintaining the river ecosystem structure and function. They also focus only on the most "valued" species and the most vulnerable life stages of those species, thus requiring a subjective value judgment. This is a particularly important issue if we are to begin thinking of stream-flow management as part of a larger program of ecosystem management.

Lower Klamath River in-stream flows

All of the Klamath River Basin hydrological studies that we could obtain (USGS 1995; Hecht and Kamman 1996; Hardy 1999) conclude that human activities have altered flows in the lower Klamath River. However, the nature of these changes and their precise magnitude is somewhat ambiguous; thus, their effects on salmonid habitat availability and fish abundance remain contentious, to say the least. In this section, we limit ourselves to summarizing those studies and their main conclusions. Review of their data and critical analysis of their conclusions are beyond the scope of this chapter. Additional discussion of in-stream flows is found in Chapter 2 ("Klamath Reclamation Project").

Some individuals have raised concerns about the conclusions of those studies and have proposed alternative hypotheses regarding the effects of human activities on river flows. Although we consider that those hypotheses should be examined, we do not discuss them in this section because we were not able to find any hydrological studies that addressed them. The only study of Klamath River hydrology of which we are aware that is not included in our synthesis is INSE 2002 (Institute for Natural Systems Engineering, Utah State University). Its release coincided with the completion of this chapter.

It is important to note that looking at historical flows does not imply that we can go back in time and match historical conditions. Rather, these analyses are intended to help us understand patterns of change and to provide guidance toward selecting appropriate flow regimes for the future.

A 1995 USGS study characterized the baseline flow regime for the Klamath River Basin. Baseline flows in this case meant historical flow conditions that provide a basis for comparison of past flow conditions to contemporary and possible future alternative water management scenarios. This study did not identify any significant changes in annual water discharge at Keno Dam (a water diversion dam on the Klamath River, upstream from the hydroelectric dams) between 1914 and 1960 that could be attributed to human intervention in the flow regime.

However, the analysis of monthly flows showed a discernible seasonal change in water discharge both below IGD and in the Scott River after 1960. Lower Klamath River flows below IGD have become higher in February and lower between June and September than in previous decades. Evaluations of seasonal trends in flow for the Scott River near Fort Jones also show a reduction in flow between July and August after 1960. Such changes in flow were attributed by the USGS (1995) to changes in crop patterns and irrigation techniques, as well as water availability and demand due to changes in weather patterns.

The analysis of daily flow fluctuations in the lower Klamath River presented in the USGS study confirmed that the operation of IGD created a steady flow and eliminated abrupt changes in water discharge of up to 2,000 cfs. The biggest single change in the USGS gauge records was reduced flow during dry years. This led the authors of the study to conclude that human water use during years of drought drastically reduces the already limited flows of the lower Klamath River.

In 1996, Hecht and Kamman (Balance Hydrologics, Inc.) were commissioned by the Yurok Tribe to quantitatively estimate the historical flow patterns in the Klamath River. Although agricultural diversions were in place in 1905 above Upper Klamath Lake (on the Williamson and Sprague rivers), water diversions were at a minimum until the construction of the Lost River Diversion Dam in 1912 (Hecht and Kamman 1996). Thus, USGS gauge data from 1905 through 1912 at Keno were used to estimate "natural flows" in the river.

The years 1905 through 1912 were identified to be above average for precipitation and runoff in much of the Upper Klamath Basin. To counter this, stream flow and rainfall data were normalized to a period of average rainfall using annual precipitation indices. Hecht and Kamman (1996) divided the average flow/annual precipitation during the 1905–1912 period by the average flow/annual precipitation value over a long-term period (1905–1994). They reported that:

> "… indices derived from precipitation records suggested that conditions during the 1905–1912 period were wetter in northern California at Yreka (index 1.21) than in southern Oregon at Klamath Falls (index 1.04); i.e., the higher the index above 1.0, the wetter the 1905–1912 period relative to the long-term average. If this trend of decreasing relative wetness to the north and east is extrapolated up into the upper Klamath basin, we could surmise that much of the upper basin experienced normal conditions (index of 1.0) during the 1905–1912 period. The index derived from the Bureau of Reclamation's inflow record was 1.34 for this period, suggesting much wetter conditions than either of the rainfall records would suggest. However, this index is probably inflated for the following reason: inflow to Upper Klamath Lake has continuously decreased during the 20th century due to upstream diversions and withdrawals from the Sprague and Williamson River systems. This artificially reduces the long-term inflow average which, as the denominator in the index calculation, leads to an inflated index" (Hecht and Kamman 1996, page 14).

To estimate pre-Project flows at IGD, Hecht and Kamman (1996) added historical flow accretions between Keno and IGD to the Keno flow record. These accretions were estimated in a separate study by CH2M Hill using USGS flow records, because no gauge data existed for IGD until 1960. After adding the estimated accretions to the pre-Project flows at Keno, Hecht and Kamman (1996) concluded that the average annual flow in the lower Klamath River at IGD was about 1.8 million acre-feet per year prior to the completion of the Klamath Reclamation Project.

A second phase of Hecht's and Kamman's study (1996) involved analysis of changes in flow at a gauging station over time. Stations with long flow records were selected, and similar pre- and post-Project water year-types were identified. They chose and matched water year-types that had similar short-term and long-term

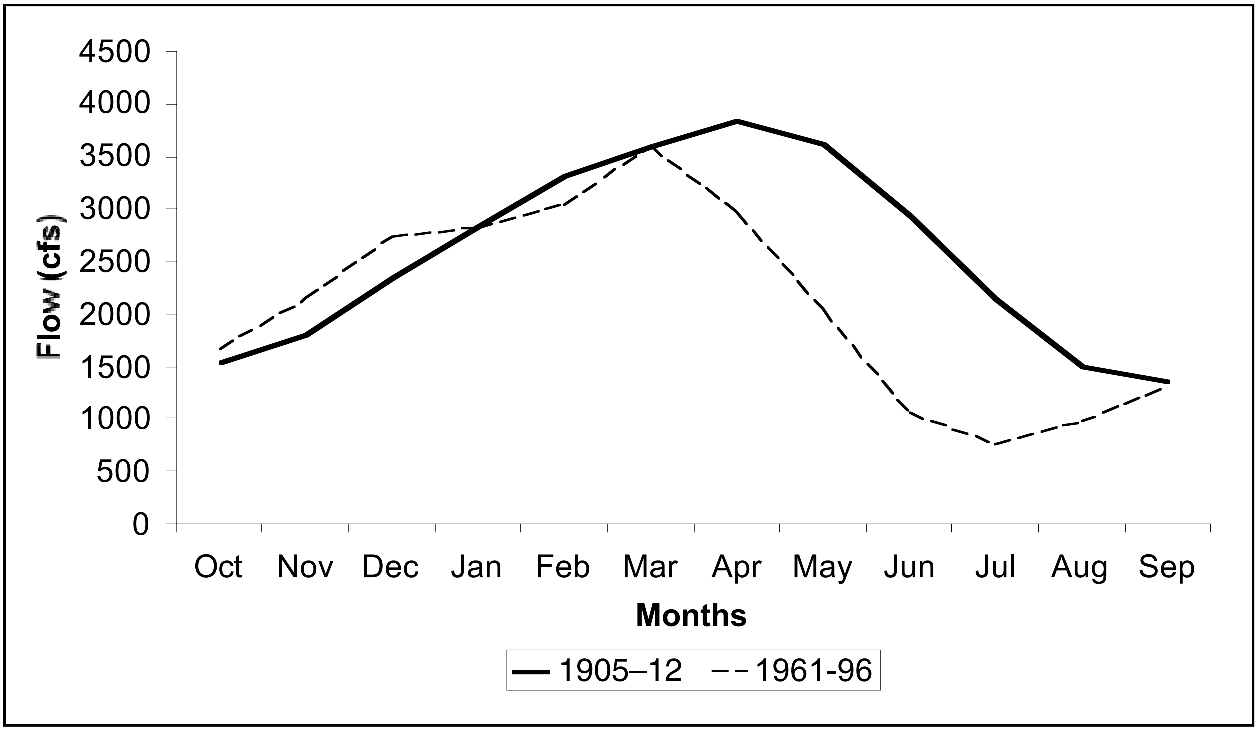

Figure 1. Mean monthly flows at Iron Gate Dam. Source: Data from Hecht, B. and G.R. Kamman. 1996. Initial Assessment of Pre- and Post-Klamath Project Hydrology on the Klamath River and Impacts of the Project on Instream Flows and Fishery Habitat *(Balance Hydrologics, Inc., Berkeley, CA).*

conditions, such as 1916/1985 and 1918/1987. For example, both 1916 and 1985 experienced above-normal runoff and precipitation and were preceded by 4 years of high water availability. Thus, the 1916/1985 year pair represents historical vs. current flow conditions for relatively wet periods. The 1918/1987 pair corresponds to flow conditions during relatively dry periods.

Based on their analyses, Hecht and Kamman (1996) concluded that flows in the lower Klamath River have been reduced from historical levels by water diversion projects in the Upper Klamath Basin and the Shasta, Scott, and Trinity subbasins. They also indicated that the Project changed the seasonal distribution of flows, usually increasing water discharge very slightly during fall and early winter and markedly reducing spring and summer flows. This shift in flow regimes between pre-Project times and the mean monthly 1961–1996 flows is shown in Figure 1 (based on Hecht's and Kamman's data). A graph of annual average pre-Project flows (hydrograph) indicates that higher flows were available in the river channel before all diversions and dams were built.

According to Hecht and Kamman (1996), the Upper Klamath Basin in July–August of 1911–1913 (pre-Project wet period) contributed between 30 and 35 percent of the river flow at its mouth. During July–August of 1983–1985 (a comparably wet post-Project period), this flow contribution was reduced to 10 to 15 percent of the flow at the river's mouth. Their study estimated that, during droughts, the post-Project flow contributions of the Upper Basin to the flow recorded at the mouth of the river become even lower, approximately 5 percent.

Although the reports by the USGS (1995), Hecht and Kamman (1996), and the Institute for Natural Systems Engineering of Utah State University (INSE, in Hardy 1999) differ in their objectives, analytical techniques, and underlying assumptions, they all describe a common scenario of flow changes in the river that are related to human activities in the Upper Basin and in the main subbasins of the Lower Basin. Both the

USGS (1995) study and Hecht's and Kamman's (1996) report arrive independently at the conclusion that water management practices have increased late-winter and early-spring flows in the lower Klamath River, while reducing summer flows compared to estimated pre-Project flows.

Hecht's and Kamman's (1996) "pre-Project" flow estimate at IGD was used by Trihey and Associates (1996) to develop minimum in-stream flow recommendations. Trihey and Associates applied the Tennant Method based on 60 percent of the mean annual discharge estimated by Hecht and Kamman. The recommended minimum in-stream flows are included in Table 1, along with those originally established by the Federal Energy Regulatory Commission (FERC), those requested by the Yurok Tribe in response to the draft 2001 BiOp by the NMFS, and those recommended by INSE.

In 1999, a study was initiated by INSE to quantify the minimum monthly flows for the Klamath River below IGD needed to maintain and restore the aquatic resources of the river, with special emphasis on salmonids. These researchers elaborated interim minimum in-stream flow recommendations using a battery of hydrology-based methods. Such recommendations were intended to be of temporary application (Phase I) until field-based methods, incorporating site-specific information, tributary flows, and water quality, could be used to validate and refine the minimum recommended flows (i.e., Phase II of the INSE report, which was recently made public and was not reviewed in this chapter).

The minimum in-stream flow recommendations described by INSE (Hardy 1999) were calculated on the premise that suitable salmonid habitat is directly related to flow regimes. They focused on four basic flow components: fish habitat flows, channel maintenance flows, riparian flows, and valley maintenance flows.

For purposes of determining interim minimum in-stream flows for the Klamath River, INSE (Hardy 1999) used five different minimum

Table 1. Estimated pre-Project mean monthly flows, mean monthly flows between 1961 and 1996, and various recommended minimum monthly flows at Iron Gate Dam.

	Mean monthly flows 1905–1912 (pre-Project)	Mean monthly flows 1961–1996	FERC	Trihey & Associates (Tennant method)	Yurok Tribe	INSE 1999 (mean, various methods)
	(cfs)					
October	1,536	1,664	1,300	1,200	1,300	1,476
November	1,809	2,142	1,300	1,500	1,500	1,688
December	2,358	2,744	1,300	1,500	1,500	2,082
January	2,827	2,825	1,300	1,500	1,500	2,421
February	3,331	3,047	1,300	1,500	1,500	3,008
March	3,604	3,601	1,300	1,500	1,500	3,073
April	3,857	2,970	1,300	2,000	2,100	3,307
May	3,627	2,046	1,000	2,500	2,100	3,056
June	2,930	1,050	710	1,700	1,700	2,249
July	2,147	758	710	1,000	1,000	1,714
August	1,503	970	1,000	1,000	1,000	1,346
September	1,370	1,303	1,300	1,000	1,300	1,395

Source: Data from Hardy, Thomas B. 1999. Evaluation of Interim Instream Flow Needs in the Klamath River, Phase I, Final Report *(prepared for the Department of the Interior by the Institute for Natural Systems Engineering (INSE), Utah Water Research Laboratory, Utah State University, Logan).*

in-stream flow-setting methods (Hoppe, New England Flow Recommendations Policy, Northern Great Plains Resource Program, Tennant, and Washington Baseflow). They then took the average monthly flow across the five estimated values to calculate the "best estimate."

This study has been criticized by a consulting firm (see Miller 2001) in a review for the BOR. Miller argued that INSE made independent corroboration of its analyses and conclusions difficult by not providing supporting data, using "outdated" methods when "newer," more biologically based, methods were available, and modifying the methods without clear justification. It is our understanding that Phase II of the INSE report addresses these issues.

Water quality issues

Although water quality often is mentioned as a "problem" in the Klamath Basin, very little attention is given to it in reports. There are several water quality issues related to coho salmon. For example, the metabolic activity of algae in the lower Klamath River mainstem causes a marked daily cycle in pH, with maximum readings of 9. Also, during the summer, water temperature can exceed 25°C (77°F) (Deas, personal communication). The combined effects of high temperatures, high nutrient concentrations, changes in pH, and low dissolved oxygen levels during the summer can create extremely stressful conditions for coho salmon and other salmonids in the lower Klamath River. High nutrient concentrations (especially nitrogen and phosphorus) typically promote the growth of algae and aquatic plants, which contribute to increased water temperatures, reduce water velocities, and lower the levels of dissolved oxygen at night.

Temperatures in the mainstem of the lower Klamath River regularly exceed 20°C (68°F) between mid-July and late September. This was particularly evident during the drought of 1994 (Kier and Associates 1997). In June 2000, temperatures reached critical levels in the Klamath River and resulted in an estimated kill of more than 1,000 salmonids per mile for about 10 miles (CDFG 2000).

Although in-stream flows between July 1 and September 1, 2001, were higher than during previous dry years, maximum daily temperatures below IGD ranged from 19.6 to 22.5°C (67.3 to 72.5°F), and minimum daily temperatures from 18.6 to 20.6°C (65.5 to 69.1°F) for the 90 days of record (USGS 2001).

Because increased flows provide a lower stream surface-to-volume ratio, they were recommended by INSE (Hardy 1999) as a way to buffer day–night fluctuations in stream temperatures and dissolved oxygen levels. This assumption is supported by the reservoir and river models developed by Deas and Orlob (1999), which indicate that increased flows in late spring, summer, and early fall moderate the daily temperature range, provide modest thermal benefits in downstream reaches, and reduce transit time in the IGD–Seiad Valley river reach.

The 2001 Biological Opinion and its implications for coho salmon

The first formal Section 7 consultation regarding effects of Project operations on coho salmon was held in 1999. For operating year 1999, the BOR proposed operating the Project in a way that would meet the FERC minimum flows at IGD (Table 2). The FERC minimum flows were established as a condition for dam licensing, but they are subject to water availability and senior water rights; thus, they have not always been met. Considering that 1999 was an above-average hydrologic year, and adequate water was available for irrigation, in-stream flows, and maintenance of Upper Klamath Lake elevation, the NMFS recommended higher flows. The BOR then proposed IGD releases similar to those recommended by INSE (Hardy 1999, see Table 1). Based on those flows, the NMFS found that Project operations would not cause jeopardy to coho salmon.

The 1999 Biological Opinion expired in March 2000, but the BOR did not request formal Section 7 consultations with the NMFS in 2000.

As a result, in May 2000, various conservation and fishing interests filed a lawsuit challenging the BOR's 2000 Project operations plan (*Pacific Coast Federation of Fishermen's Assoc. v. U.S. Bureau of Reclamation*). They argued that the BOR violated the ESA by releasing water for irrigation and water flows in the Klamath River prior to consultation with the NMFS regarding the Project's effects on threatened coho salmon. (See Chapter 18, "Policy," for additional discussion.)

On January 22, 2001, the BOR requested initiation of formal ESA Section 7 consultations with regard to the ongoing operation of the Klamath Project. The request letter included a Biological Assessment of the effects of Project operations on coho salmon in the SONCC ESU. The BOR proposed critically dry year minimum flows at IGD as low as 398 cfs (Table 2).

In April 2001, Judge Sandra Brown Armstrong ruled in the *Pacific Coast Federation of Fishermen's* case and enjoined the BOR from sending irrigation deliveries to the Project at any time when IGD flows drop below the minimum flows recommended by INSE (Hardy 1999), until the Bureau completed a plan to guide operations during 2001 and consultation on that plan was completed.

As part of the 2001 consultation, the NMFS reviewed the status of SONCC coho salmon, the environmental conditions in the area, the potential effects of the proposed ongoing operation of the Project, and its cumulative effects. The NMFS concluded that the BOR's proposed operation of the Project in 2001 was "likely to jeopardize the continued existence of SONCC coho salmon" and adversely alter critical coho salmon habitat.

Subsequently and as part of the BiOp, the NMFS presented its Reasonable and Prudent Alternative (RPA) to the operations proposed by the BOR (Table 2). The RPA was based on the premises that: (1) the operation of the Project substantially affects flows, fish habitat, and water quality in the lower Klamath River, and (2) the Project is not the only human activity that has a negative effect on salmonid habitat and anadromous salmonid populations in the Klamath Basin.

Table 2. Minimum monthly flows (April–September) at Iron Gate Dam (FERC, the BOR Operations Plan, and the NMFS draft and final Biological Opinion), and actual flows, 2001.

	FERC minimum	BOR proposed dry year minimum	BOR proposed critically dry year minimum	NMFS Draft 2001 Biological Opinion	NMFS Final 2001 Biological Opinion	Actual flows, 2001
	(cfs)					
April 1–15	1,300	728	569	1,700	1,700	1,528
April 16–30	1,300	754	574	2,100	1,700	1,667
May 1–15	1,000	761	525	2,100	1,700	1,749
May 16–31	1,000	924	501	2,100	1,700	1,704
June 1–15	710	712	476	1,800	2,100	2,099
June 16–30	710	612	536	1,400	1,700	1,695
July 1–15	710	547	429	1,000	1,000	1,008
July 16–31	710	542	427	1,000	1,000	1,016
August	1,000	647	398	1,000	1,000	1,026
September	1,300	749	538	1,300	1,000	1,025

A similar table is contained in Chapter 1 ("Background"), with flows measured in acre-feet.

Source: FERC, BOR, and NMFS flows are from National Marine Fisheries Service. 2001. *Biological Opinion. Ongoing Klamath Project Operations* (Southwest Region, April 6); actual flows are from U.S. Geological Survey. 2001. Water gauge database (Water Resources of California, http://water.usgs.gov/ca/nwis).

According to the NMFS (2001), the proposed RPA aimed to prevent further decline of the listed species that the NMFS concluded was likely to be jeopardized by the ongoing operation of the Project. The agency indicated that it was in the process of collecting additional information and analyzing the relationship between IGD releases and fish habitat availability with the intent to develop a comprehensive BiOp addressing all water year-types by June 7, 2001. In the meantime, the April 6, 2001 BiOp was a subset of the more comprehensive report being developed and was intended to specify minimum in-stream flows only for the April–September period of 2001.

Recommended IGD releases

During summer months in dry years, water releases at IGD contribute significantly to in-stream flows in the Klamath River. Because of the hydrology of the system, the climate of the region, and the number of tributaries present, the influence of IGD water releases is greatest near the dam and diminishes as one moves downstream, according to a flow study conducted by the U.S. Geological Survey (1995).

Therefore, the IGD-to-Shasta-River reach is the one that relies the most upon IGD water. Based on USGS gauge data, the NMFS (2001) estimates that, on average, between July and October, from 1962 to 1991, water releases at IGD contributed approximately 60 to 85 percent of the river flows measured at Seiad Valley and 50 to 65 percent of the river flows measured at Orleans. These data also indicate that the importance of IGD water releases increases during dry years, when 90 percent of the summer flow at Seiad Valley is directly attributable to IGD water releases (NMFS 2001).

Considering both the contributions of IGD releases to the lower Klamath River flow and the preliminary field data provided by INSE (from its Phase II flow study, then in preparation), the NMFS presented an RPA in response to the BOR's 2001 water-release plan for a critically dry year. The RPA stated that under IGD releases of 1,700 cfs for April and May, coho salmon fry would have access to approximately 50 percent of the maximum available habitat, and chinook salmon fry would have access to close to 65 percent of their nursery habitat.

Aiming to maintain between 40 and 65 percent of the mainstem channel's salmonid habitat during various months, the RPA established April–September minimum water releases at IGD. Such releases (both from the draft and final versions of the BiOp) are summarized in Table 2, along with FERC's minimum flows and the flows proposed by the BOR for dry and critically dry years (e.g., 2001). The table also includes the actual flows that were measured at IGD between April and September, 2001.

Although the RPA flows recommended in the final version of the BiOp (NMFS 2001) stand out as relatively high when compared to those recommended by either FERC or the BOR, they are much lower than the minimum in-stream flows recommended for the restoration and maintenance of aquatic resources by the INSE Phase I study, the basis for the 1999 flows (Hardy 1999, see Table 1). In fact, the RPA flows (NMFS 2001) are closer to the minimum in-stream flows recommended by Trihey and Associates (1996) and the Yurok Tribe (2001).

Notice, however, that the shape of the graphics (hydrographs) generated by these various flow regimes is somewhat different (Figure 2). The main difference between the in-stream flows recommended by FERC for a critically dry year, such as 2001, and the ones requested by the BiOp (NMFS 2001), Trihey and Associates (1996), or the Yurok Tribe (2001) occurs during spring and early summer.

Those who recommend higher flows during this time of the year argue that coho smolts (which have been rearing in the system for 12 to 14 months and are ready to enter coastal waters) migrate to the ocean in the spring and are likely to benefit from relatively higher flows. The assumption behind the request for higher flows is that the higher the flow, the shorter the duration of the trip to the estuary and, therefore, the higher the survival rate of coho smolts. Although there is no guarantee that the "additional" release of water will work as intended and make a difference in the number of fish that survive their seabound migration, the assumption finds support in some studies on smolt migration and survival (see Sandercock 1991).

The BiOp's RPA clearly states the importance of balancing the need for higher flows in the spring with the need for regulating flows in a manner that could ensure that, after one of the driest winters in recent decades, the limited available water supply would last until fall. This balancing act may explain why the water release at IGD (1,700 cfs) requested in the RPA for the spring period, although higher than the one approved by FERC, is lower than the water releases asked for by Trihey and Associates (2,500 cfs) or the Yurok Tribe (2,100 cfs).

The in-stream flows requested for the first 2 weeks of June by the RPA show a peak (2,100 cfs) in water discharge to assist the last coho salmon smolts leaving the system. Beginning in July, and continuing through September, the flows requested in the RPA remain constant at 1,000 cfs. Such flows are slightly more than those established by FERC for July during critically dry years, but they match the August flow levels established by FERC and recommended by Trihey and Associates (1996) and the Yurok Tribe (2001) (Table 1).

Contrary to what might be expected, the September flows requested in the RPA only match those suggested by Trihey and Associates (1996) and are lower than those established by FERC or asked for by the Yurok Tribe (2001). The slight increase in September's water discharge has been proposed to assist upstream migrating fall chinook salmon. This type of action is supported by a study on fall chinook passage in the lower Klamath River by Vogel and Marine (1994), but only for late September and October. Based on the arguments presented in the RPA, the recommended in-stream flows for September seem to be another balancing act between what is needed for the maintenance of

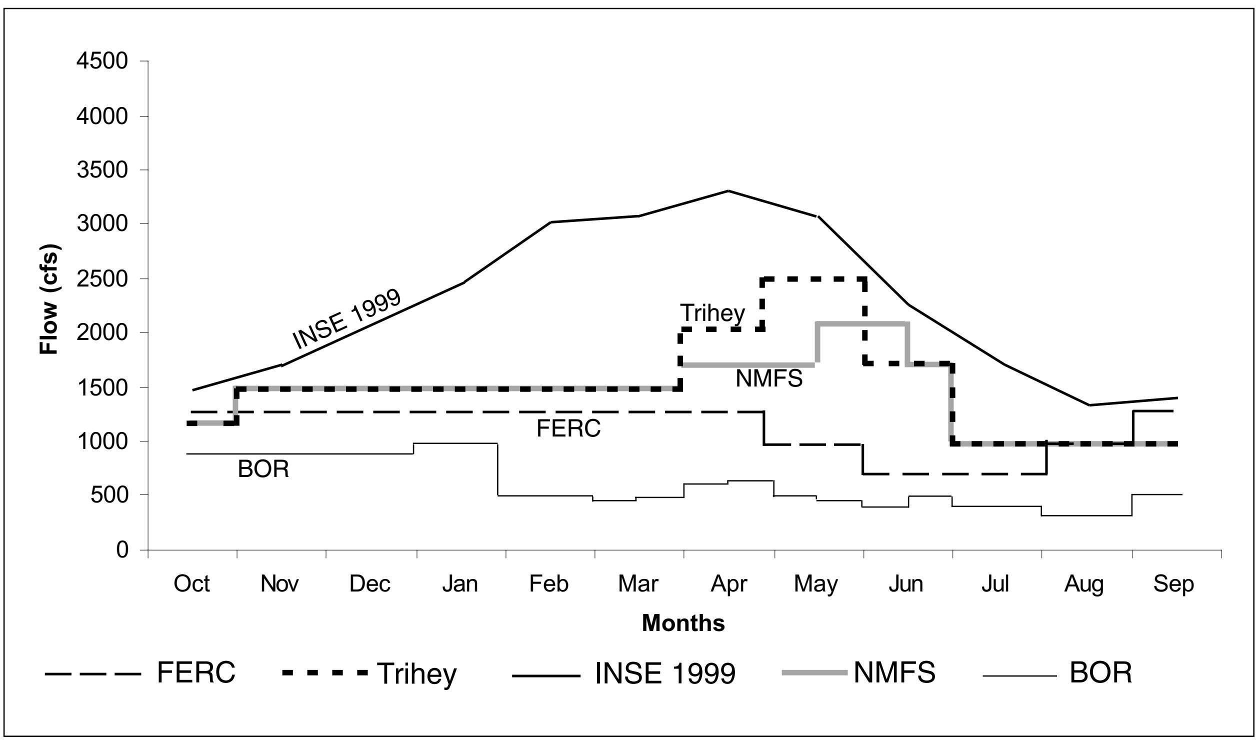

Figure 2. Minimum monthly flows at Iron Gate Dam under various proposals. Source: Data from Hardy, Thomas B. 1999. Evaluation of Interim Instream Flow Needs in the Klamath River, Phase I, Final Report *(prepared for the Department of the Interior by the Institute for Natural Systems Engineering (INSE), Utah Water Research Laboratory, Utah State University, Logan) and from National Marine Fisheries Service (NMFS). 2001.* Biological Opinion. Ongoing Klamath Project Operations *(Southwest Region, April 6).*

fish habitat in the short term and what can be released from IGD without risking insufficient water availability later on.

The NRC (2002) interim report draws attention to the potential usefulness for management purposes of models that relate indicators of coho salmon year class strength (abundance of spawners from one particular year) to specific flow conditions during their emergence and migration as smolts. Unfortunately, as that same report acknowledges, "the small size and scattered nature of the present native coho population [make] collection of such data difficult."

Given the limited information available on Klamath Basin wild coho salmon, it is not surprising that it has been impossible to determine whether relatively strong year classes have emerged from wet years in the recent past. However, better data are available for Klamath Basin fall chinook salmon. Notwithstanding the confounding effect of hatchery production on any attempt to establish a correlation between flow and spawner abundance, the chinook data do show a relationship between river flows during emergence and smolt migration and spawner abundance of that year class 3 and 4 years later (USFWS, unpublished data on spawner escapement and age composition).

Although the BiOp's water release schedule was designed to protect coho salmon, other nonlisted species may have benefited more than coho. Steelhead, chinook salmon, and Pacific lamprey are likely to have gained the most from higher flows in the mainstem of the Klamath River.

The reduced water-release plan proposed by the BOR's BA (Table 2 and Figure 2) could have been detrimental to coho salmon and to other anadromous fish species in the mainstem Klamath. According to the NRC (2002) interim report, stranding of fish and increased fish vulnerability to predation would have been two of the consequences of the progressive summer reduction of river flows proposed by the BA. Neither flow increases beyond those of the past decade nor the reduced IGD releases proposed by the BOR (the plan responsible for triggering the "jeopardy" BiOp from the NMFS) were justifiable based on available scientific evidence, according to the NRC.

In the absence of an integrated basin management plan, and facing the uncertain effects of the BOR's proposed water release schedule on listed coho salmon, it is not surprising that the NMFS, which is responsible for the management of fisheries resources, opted for a risk-averse approach, rather than waiting to have complete certainty, because such certainty will never exist about natural resources (see Chapter 4, "Science"). In fact, such a precautionary approach is dictated by Congressional mandate, and it is difficult to imagine a regulatory agency ignoring such a directive. (See Chapter 5, "Suckers," for a discussion of the U.S. Fish and Wildlife Service's approach to biological uncertainty in the case of suckers.)

Potential effects of the 2001 BiOp on water temperature

The lower Klamath River has been listed as water quality impaired by both Oregon and California under Section 303(d) of the Federal Clean Water Act. Excessively high water temperatures, elevated nutrient concentrations, and the associated low dissolved oxygen levels have been identified as important limiting factors for salmonids. The recently released NRC (2002) interim report considers that "water temperature is a major concern for the welfare of the Klamath Basin coho salmon. Summer temperatures appear to be especially critical.… High temperatures are the result of reduced flow in the main stem and in tributaries as a result of diversions, warming of water in lakes prior to its flow to the main stem, and loss of shading. Climate variability, although probably responsible for some interannual thermal variation, is unlikely to be an important factor by comparison with changes in flow and loss of riparian vegetation."

Data collected by M. Deas on Klamath mainstem summer temperatures show that water at IGD and Seiad Valley exceeded 20°C (68°F) for 24 hours a day between early July and August 2000; by early August, the mean daily water temperature exceeded 22°C (71.6°F) at IGD and 25°C (77°F) at Seiad Valley. However, some intermediate locations closer to IGD experienced daily minimum temperatures below 20°C (68°F), even as low as about 18°C (64.4°F) (Deas, personal communication).

Despite such elevated temperatures, juvenile coho salmon and other salmonids are present in the river (USFWS, unpublished data). As discussed earlier (see "Spawning and nursery habitat"), various studies indicate that juvenile coho salmon, although considerably stressed, are able to survive water temperatures in the mid-20s°C (70s°F), depending on a variety of other factors (food, competition, predation, acclimation process, body size, etc.). In a system such as the Klamath River, salmonids (and juvenile coho salmon in particular) are expected to rely on the mainstem cool-water areas derived from spring-fed tributaries (NRC 2002). This strategy of seeking cool-water refugia may explain the distribution of juvenile coho salmon that the USFWS survey crews observed during the summer of 2001 (USFWS, unpublished data).

The water-release schedule requested in the BiOp's RPA was intended to alleviate the effects of low in-stream flows on salmonid habitat by increasing the volume of water present in the channel. According to flow models (Deas and Orlob 1999), it was expected that the minimum in-stream flows requested in the RPA would moderate the daily fluctuations in water temperature, provide modest cooling in downstream reaches, and reduce the water-transit time between IGD and the Seiad Valley. However, the effectiveness of this practice is uncertain and deserves close examination.

The NRC (2002) interim report cast doubts that any significant degree of cooling could be accomplished in this way. In fact, the report suggests that higher flows may work to the disadvantage of coho salmon if the source water is warmer than the river below. However, this is only a hypothesis, and one that deserves rigorous testing. During the summer of 2001, no cooler groundwater was detected seeping into the river between IGD and the Salmon River confluence. Despite warm water and extremely reduced tributary flows in this river segment, juvenile coho salmon were observed, and no fish kills occurred (USFWS, unpublished data).

Looking ahead—a basinwide approach

As in many other places, natural resources in the Klamath Basin have been managed in a fragmented manner—as if the flow of water did not connect one part of the Basin with another. Effects of upstream land-use activities on water quantity, quality, and aquatic habitats downstream often have been ignored, and most studies and monitoring programs in the Klamath Basin have reflected an isolationist view and a narrow subbasin focus.

Within this context, the situation existing in the Klamath Basin in 2001 developed over a long period of time. Many of the early symptoms (collapse of fisheries, fish kills, algal blooms, overallocation of water in many subbasins, etc.) were observed more than a decade ago. Unfortunately, these early warning signals did not lead to the development and implementation of an integrated basin management plan.

The events of 2001 affected all basin stakeholders in a negative manner. Although some faced greater losses or more difficult circumstances than others, nobody emerged unscarred. However, as often is the case when trouble strikes, the events of 2001 offered a clear indication of the need to move away from the current development path, which clearly is not sustainable. An integrated basinwide management plan that balances the needs of all stakeholders is necessary to end the systematic and gradual erosion of natural resources in the Klamath Basin and provide for the needs of all users of the Basin's water.

The need to renew the licenses of Klamath River dams before they expire in 2006 may represent an opportunity for all of the Basin's stakeholders to heed the warnings of 2001 and move toward development and implementation of a basinwide management plan. The relicensing of these dams is likely to differ markedly from the process that gave the green light to their construction and operation several decades ago. Current environmental standards and a broader spectrum of interested parties likely will slow down the process and involve upper management from the regulatory agencies. Increased stakeholder engagement should help identify issues and problems more effectively and lead to better coordination of land management decisions as well as fish and wildlife management recommendations. It would be desirable for this process to be open and collaborative.

A basinwide management plan can be developed and implemented only with a great deal of local support and cooperation. Furthermore, collaboration among different government agencies and interest groups is needed for the evaluation of appropriate management practices for this basin.

Of the several phases in the elaboration of such a plan, the first, and most fundamental, is the development of a "watershed health card/map" that integrates hydrologic and geologic information, the classification and location of environmentally sensitive areas, and the status of biological resources in the system. Much of this information already is available, but it is scattered among various agencies. Some of it may be of questionable quality for some stakeholder groups. In these cases, the information should be independently evaluated and, if necessary, collected or produced again.

The second phase involves developing a management plan that takes into account social needs and desires. This step involves deciding what is important and then choosing management options to meet the desired objectives. For example, it might be determined that integrity of the Klamath River and conservation of salmonid resources are important. If so, planners would need to choose options for protecting, rehabilitating, or further modifying the system's hydrology and the river's channel characteristics. It would be necessary to consider a minimum guaranteed summer flow as well as an adequate winter flow regime that enhances the connection between the river and its valley and increases the availability of fish habitat. Management decisions regarding biological components of the basin also would be needed (e.g., restoration of riparian vegetation, reduction of nutrient concentrations to control the abundance of algae, etc.).

Several alternatives for improving fish habitat could be considered as part of this process. Examples include:

- Flow restoration in tributaries
- Flow augmentation in the mainstem through higher dam bypass flows (Although habitat in tributaries is important to the long-term maintenance of wild coho salmon, mainstem habitat cannot be written off without negatively affecting the Klamath Basin populations.)
- Alteration of ramping rates (change in rate of water release)
- Purchase and retirement of water rights
- Creation of mitigation funds to purchase water rights
- Riparian and in-stream habitat restoration
- Wetland restoration
- Water quality improvement
- Spawning gravel enhancement
- Large wood placement
- Dam removal or retirement

These examples illustrate the breadth of options available to planners. By taking a basinwide approach and choosing a variety of restoration activities, all stakeholders could become part of the solution, and no one group would bear all of the burden.

Based on the flow and biological options selected, land-use management decisions could then be made. These decisions would control human-induced damage to the physical and biological parts of the system.

The last, but not least important, part of any plan is the financial compensation scheme and the nondevelopment alternative. Compensation usually is necessary when the costs of implementing a basin management plan are particularly burdensome for some stakeholders.

The implementation of an integrated basin management plan will not be possible without improvements in the functioning of the institutions involved (see Chapter 18, "Policy," and Chapter 20, "Synthesis"). Examples of needed changes include a redefinition of the terms of cooperation among government agencies, the design of effective regulatory instruments (taxes, trusts, water markets, mitigation funds, etc.), and an improved public consultation system. These factors represent important "political" obstacles that must be overcome for any management plan to achieve the desired effects. Technical problems, although very important in many circumstances, tend to be less of an obstacle.

Continued improvement in our understanding of ecological systems is another key component to basinwide management planning. Several issues require rigorous study before the effects of future water management decisions on fisheries resources of the Klamath Basin are adequately understood. Examples include:

- The structure and dynamics of fish populations (Although initial efforts should focus on listed species, it is important to consider other species in the system when taking an ecosystem management approach and in order to avoid future listings.)
- Fish habitat distribution and utilization
- Fish migration patterns (both juveniles and adults)
- Water temperature regimes and their effects on fish
- Effects of increased water releases from reservoirs on downstream fish habitat
- Effects of early water spills on the seasonal release temperatures at Iron Gate Reservoir

In conclusion, development of an effective integrated basin management plan will require the cooperation of all of the Basin's stakeholders (including government agencies), as well as continued analysis of the many components of the system and how they relate to each other. Success will be more likely if the following principles are kept in mind:

- Management decisions should be made within the context of the entire Basin.
- The integrity of the entire Basin should be protected by conserving and enhancing the processes that connect its many components (e.g., headwaters, hill slopes, mountain streams, riparian forests, lakes, valleys, wetlands, groundwater reservoirs, tributaries, mainstem channel, floodplains, estuary, etc.).
- Long-term monitoring and research should be conducted to evaluate the effectiveness of management practices and to determine whether environmental changes are naturally caused or human induced.
- Contingency plans should be developed in case monitoring reveals that the implemented management actions interfere with processes that maintain the connectivity of the system.
- Management plans should be flexible enough to respond to new scientific knowledge and the development of new techniques.

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Part 3. Agriculture

Soil Resources
in the Klamath Reclamation Project

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The focus of this chapter is on soils within the Klamath Reclamation Project, which encompasses 233,625 acres of irrigable lands in Klamath County, Oregon, and Modoc and Siskiyou counties in California. The map in Chapter 2 ("Klamath Reclamation Project") illustrates the region.

A brief general introduction to the geography and geologic development of the region provides some perspective on the following discussion of area soils as they influence productivity and land values. The Project lies within a high-elevation, short-growing-season area created from volcanic and sedimentary events. Regional geology reflects repeated volcanic activity, erosion, and sedimentary rock deposition, combined with episodes of landscape faulting and folding.

The region is an area where the high desert and the Cascade Mountains meet. This union provides the two dominant geophysical features that influence the climate and drainage of the Upper Klamath Basin (the area above Iron Gate Dam that is drained by the connected Klamath River–Lost River watersheds). The first important feature is the large range in elevation—from 4,000 feet in the southern end of the Basin to 8,700 feet at Crater Lake in the northern end. This variation in elevation causes wide temperature ranges. Frost is possible any day of the year. Second, the Cascade Mountain range to the west traps most of the moisture moving in from the coast, leaving the east side of the mountains cooler and drier and exposing the Basin to a rain-shadow effect. Sagebrush- and juniper-covered fault blocks and ridges form the eastern and southern sides of the Basin (Powers 1999).

Most of the precipitation in the Project area occurs from October to March and is sufficient to moisten the soil to a depth of up to 5 feet. Evaporation greatly exceeds precipitation during the growing season.

Upper Klamath Lake is the largest lake in Oregon and serves as the main storage reservoir for the Project. It is 60,000 to 90,000 acres in size, with a mean summer depth of 7 feet. The lakebed fills a graben (a sunken area of the earth's crust bound by faults) many thousands of meters deep, mainly with volcanic debris and sediments. Sedimentation continues today, producing a large, shallow lake.

Soil formation

In this chapter, we define soils as dimensioned segments of landscape capable of supporting higher plants such as trees, shrubs, grasses, and agricultural crops. Soils are formed through the interaction of five major factors: climate, parent material, relief (topography), plant and animal life, and time. Parent material and relief cause most of the differences in soils of this area. Human actions also influence soil formation.

Parent material

Parent material is the unconsolidated mineral or organic matter in which soils form. Many distinctive kinds of parent material have influenced the formation and properties of area soils. The influence of parent material in soil formation can be profound where materials are very different and other soil-forming factors are weak. The soil properties most affected by differences in parent material in the Upper Klamath Basin are bulk density (weight per unit volume), available water-holding capacity, fertility, and availability of nutrients.

Soils generally are described as ranging from organic to mineral, depending on their origin. In the irrigable areas of fertile farmland within the Project, soils range from peat to sandy loam and clay loam.

Soils in Klamath, Siskiyou, and Modoc counties generally can be divided into two broad categories—muck and mineral. Highly organic muck soils are found in drained lakebeds, while mineral soils, ranging from sands to loams, are found in upland areas. The muck soils are characterized by high fertility and water-holding capacities. The mineral soils tend to vary more, and they depend more on textural differences in regard to water-holding and fertility status.

Most of the agriculturally significant soils in the Project area formed in lacustrine (lakebed) or alluvial (waterborne) sediment weathered mainly from diatomite, tuff, and basalt. Soils on lake terraces commonly are underlain by diatomite, or diatomite stratified with lacustrine sandstone. Some soils formed partly in sediment that washed off the lake terraces and partly in alluvium transported from other areas. Soils that formed in lacustrine and alluvial sediment have somewhat lower bulk density and somewhat higher available water-holding capacity than soils of similar texture and other mineral origin.

Fibrous organic material covers the floor of much of Upper Klamath Lake as well as the bays and other large areas around the lake, which have been diked and drained for irrigated cropland. The organic soils formed in this material have low bulk density, high available water-holding capacity, critical plant and animal nutrient deficiencies (including copper and selenium), and low thermal conductivity. When farmed, this soil is subject to continuing subsidence (lowering of the soil surface) due to oxidation of organic material.

Relief

Relief and landforms have been important factors both in soil formation and in determining the distribution of soils in the Project area. Relief also determines the location of lakes, streams, and marshes, as well as where soils are subject to flooding, have high alkali, or have perched water tables.

Human influences

Humans have influenced soils by draining large areas of marsh and by cutting and filling the land to level it for irrigation. By removing soil from parts of the landscape and creating new areas of soil, humans have had an extensive, though recent, influence on soil properties.

It is estimated that more than 100,000 acres in the Project area have been leveled and smoothed for irrigation. Deep ripping to break up hardpans, intensive fertilization, and irrigation have changed the reaction of the upper part of some soils from alkaline or neutral to slightly acid or strongly acid. Irrigation and drainage also have redistributed carbonates in the soils, decreased their salt and sodium contents, and lowered the depth of water tables. Tile drainage systems have been installed in many fields to facilitate the lowering of perched water tables.

The Klamath Reclamation Project

As Project development began in 1905, the area began to change from a natural, shallow lake–marsh system to an agricultural and waterfowl refuge system. The first Project feature constructed was the main A-Canal out of Upper Klamath Lake. In 1908, the height of the Keno Reef in the Klamath River below Keno was lowered with dynamite. By allowing more water to leave the lake, this action lowered the lake level and began turning parts of its former area into agricultural land and a wildlife refuge. Tule Lake also was converted to agricultural use and a wildlife refuge with the diversion of part of the Lost River drainage to the Klamath River and establishment of an evaporation basin by expansion of Clear Lake.

Other major elements of the Project today include the Lost River Diversion Channel, which can control flooding in the Tulelake area by diverting water from the Lost River to the Klamath River, the Tule Lake Tunnel, which conveys drainage water from the Tule Lake sumps to the Lower Klamath National Wildlife Refuge, and the Klamath Straits Drain, which conveys water back to the Klamath River. The Diversion Channel also can augment irrigation supplies to the Project from the Klamath River.

Soil capability classes and crop yield potential

The U.S. Department of Agriculture Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) defines soil capability classes that indicate, in a general way, the suitability of soils for most kinds of field crops. Soils are classified according to their limitations for field crops, the risks of damage from cultivation, and their response to treatment. Classifications do not consider: (1) major and generally expensive land forming that would change slope, depth, or other characteristics of the soils, (2) possible, but unlikely, major reclamation, and (3) suitability for horticultural or other crops that require special management.

Soils are placed in capability classes represented by Roman numerals I to VIII. The numerals indicate progressively greater limitations and narrower choices for practical use. These classes are defined as follows (Soil Conservation Service 1985).

- Class I soils have few limitations that restrict their use.
- Class II soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
- Class III soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.
- Class IV soils have very severe limitations that reduce the choice of plants, require very careful management, or both.
- Class V soils are not likely to erode but have other limitations, impractical to remove, that limit their use.
- Class VI soils have severe limitations that make them generally unsuitable for cultivation.
- Class VII soils have very severe limitations that make them unsuitable for cultivation.
- Class VIII soils and miscellaneous areas have limitations that nearly preclude their use for commercial crop production.

Limitations for soils in the Project area include the following (Soil Conservation Service 1985):

- Erosion—soils susceptible to erosion
- Water—poor soil drainage, wetness, high water table, or overflow
- Soil limitations—shallow or stony rooting zone, low water-holding capability, low fertility, salinity, or sodium
- Climatic limitations—frost risk or lack of moisture

Because of the high-altitude-induced short growing season and nearly constant possibility of frost, there are no designated Class I soils in the Project. Soils have essentially been downrated one class as a result of this limitation.

USDA soil surveys include tables of estimated crop yields for various soil types. For frost-tolerant crops normally grown in the Project, the soil surveys generally underestimate current crop production potential. Irrigation, drainage, and advances in crop varieties, crop-protection strategies, and agronomic systems have created production capabilities greater than the basic soil survey ratings.

Higher crop yields in test-plot experiments and on-farm field trials are documented in annual reports of the Oregon State University (OSU) and University of California (UC) experiment stations. Yields in excess of original soil survey estimates also are documented in annual crop reports prepared by the Agricultural Commissioners of Modoc and Siskiyou counties, the Tulelake Irrigation District, the OSU Extension Service-Klamath County, and the U.S. Bureau of Reclamation.

Several examples are seen with a Poe fine sandy loam soil found at the OSU Klamath Experiment Station (KES) in Klamath Falls.

- The Klamath County Soil Survey estimates expected alfalfa yields of 5 tons per acre. However, in a 28-variety trial conducted from 1997 to 2000, the average yield was 6.5 tons per acre.
- The soil survey shows expected wheat yields of 5,100 lb per acre. In the 2000 Western Regional Spring Wheat Nursery at KES, average wheat yield across 39 varieties was 6,150 lb per acre.
- For barley, soil survey yield estimates are 4,560 lb per acre. In the 2000 Western Regional Spring Barley Nursery at KES, average barley yield across 36 varieties was 5,730 lb per acre.
- The soil survey estimates potato yields of 330 cwt per acre. In the 2000 Western Regional Potato Trial, average yield across 16 varieties was 550 cwt per acre.

Prime Farmland

Soils falling in soil Capability Classes I through III usually are designated Prime Farmland. Prime Farmland is of strategic importance in meeting the nation's short- and long-range needs for food and fiber. State and local land-use planning laws are designed to protect and preserve Prime Farmland.

When irrigated, or drained and irrigated, most of the agricultural soils in the Project can be considered Prime Farmland as defined and recognized by the United States Department of Agriculture. The cutoff of irrigation water to many Project lands during the 2001 crop season resulted in a temporary loss of many thousands of acres of Prime Farmland by preventing the production of economic crop yields.

Specific soil series data

We have analyzed specific soil series properties within the southern Klamath County and California portions of the Project. Data for Oregon were obtained from the *Soil Survey of Klamath County, Oregon, Southern Part*, issued April 1985. Data for the California portion of the analysis were obtained from the *Soil Survey of Butte Valley–Tule Lake Area, California, Parts of Siskiyou and Modoc Counties*, issued February 1994.

The Oregon portion of this analysis includes a very diverse set of soils. Seventy-five series, complexes, and associations of soils are considered fit for irrigated crops or pastures. Of these, 22 are considered Prime Farmland. These 22 series are found on more than 133,000 acres in Klamath County.

Less diversity of soils is apparent in the California part of the Project. Most of the soils there are found on the drained lakebeds of Lower Klamath Lake and Tule Lake. The soils analyzed in California include those found in the Project and in the Tule Lake and Lower Klamath national wildlife refuges. Most of these soils are mucky silt loams, which, due to climate, high water tables, and sodium content, fall into Capability Class III.

Nonetheless, high-organic-matter soils common in this region produce some of the highest yielding crops in the Project. The installation of tile drainage systems and the use of overhead irrigation systems for frost protection have overcome most of the limitations of these soils. Some of the sandier, alkali-affected areas near the Oregon–California border south of Malin fall into Capability Class IV.

Table 1. Textural class, slope, area, depth to hardpan, depth to water table, and available water for the Prime Farmland soils of southern Klamath County, Oregon, and the Klamath Reclamation Project portion of Modoc and Siskiyou counties in California.

State	Soil series name	Soil textural class	Slope (%)	Acres	Percent of total acres (%)	Depth to hardpan (in)	Depth to water table (in)	Avail. water (in/ft)	Total avail. water in profile (in)
OR	Calimus	fine sandy loam	0–2	3,022	1.1	>60	>60	1.9	9.5
OR	Calimus	loam	0–2	10,543	3.7	>60	>60	2.0	9.9
OR	Calimus	fine sandy loam	2–5	5,653	2.0	>60	>60	1.9	9.5
OR	Calimus	loam	2–5	9,427	3.4	>60	>60	2.0	9.9
CA	Capjac	silt loam	0–1	43,700	15.5	>60	>60	5.6	28.2
CA	Capjac	silt loam ponded	0–1	4,240	1.5	>60	>60	5.6	28.2
OR	Capona	loam	0–2	843	0.3	20–40	>60	2.1	4.4
OR	Capona	loam	2–5	2,550	0.9	20–40	>60	2.1	4.4
CA	Dehill	fine sandy loam	0–5	6,350	2.3	>60	>60	1.4	7.2
OR	Deter	clay loam	0–2	3,503	1.2	>60	30–72	2.0	9.9
OR	Deter	clay loam	2–7	915	0.3	>60	>60	2.0	9.9
OR	Dodes	loam	2–15	4,693	1.7	20–40	>60	2.1	3.9
CA	Dotta	sandy loam	0–5	4,630	1.6	>60	>60	1.4	7.0
CA	Eastable	loam	0–5	6,250	2.2	>60	>60	1.9	9.8
OR	Fordney	loamy fine sand	0–2	29,592	10.5	>60	24–72	1.4	6.9
CA	Fordney	loamy fine sand	0–2	7,760	2.8	>60	>60	1.4	6.9
OR	Fordney	loamy fine sand terrace	0–3	1,006	0.4	>60	>60	1.4	6.9
OR	Fordney	loamy fine sand	2–20	8,964	3.2	>60	>60	1.4	6.9
OR	Harriman	loamy fine sand	0–2	1,930	0.7	40–60	30–72	2.0	6.9
OR	Harriman	loam	0–2	4,210	1.5	40–60	30–72	2.3	9.0
OR	Harriman	loam	2–5	2,990	1.1	40–60	>60	2.2	8.8
CA	Klamath	silt loam	0–1	11,720	4.2	>60	>60	2.6	12.8
OR	Lakeview	silty clay loam	0	2,957	1.1	>60	30–60	2.1	10.7
CA	Laki	fine sandy loam	0–2	9,570	3.4	>60	>60	2.8	14.2
OR	Modoc	fine sandy loam	0–2	7,645	2.7	20–40	>60	1.7	4.4
OR	Modoc	fine sandy loam	2–5	2,438	0.9	20–40	>60	1.7	4.4
OR	Poe	loamy fine sand	0	6,100	2.2	20–40	24–48	1.4	3.5
OR	Poe	fine sandy loam	0	1,526	0.5	20–40	24–48	1.4	3.5
CA	Truax	fine sandy loam	0–5	4,520	1.6	>60	>60	1.5	7.5
OR	Tulana	silt loam	0	16,671	5.9	>60	24–60	5.0	38.2
OR	Tulana	silt loam sandy substratum	0	5,904	2.1	>60	24–60	5.1	25.6
CA	Tulana	silt loam	0–1	7,930	2.8	>60	>60	5.1	25.4
CA	TuleBasin	mucky silty clay loam	0–1	41,560	14.8	>60	>60	4.8	24.0
Total			—	**281,312**	—	—	—	—	—

Sources: Soil Conservation Service. 1985. *Soil Survey of Klamath County, Oregon, Southern Part* (U.S. Department of Agriculture); Soil Conservation Service. 1994. *Soil Survey of Butte Valley–Tule Lake Area, California, Parts of Siskiyou and Modoc Counties* (U.S. Department of Agriculture)

Overall, 10 soil series were analyzed, accounting for more than 148,000 acres. For these Prime Farmland soils, depth to hardpan, depth to the water table, and available water-holding capacity were determined. Data are shown in Table 1.

Hardpans (some of which could be ripped by deep chisels) or bedrock at depths of less than 60 inches were indicated for 12.4 percent of the soils. These layers, if not mechanically altered, limit water-holding capacities and rooting depth.

During some portion of the year, 25.7 percent of the soils are expected to be affected by shallow water tables less than 60 inches below the soil surface. Drainage tiles help these soils, and such systems are used extensively in the Project.

Water-holding capacity varies widely among these soils. Water-holding capacity is a function of both the inherent ability of a soil to hold water and the depth of the soil. Water-holding capacity is a key factor in irrigation scheduling, as it is a principal determinant of the maximum allowable time between irrigations. Categorizing the soils in Table 1 by their relative water-holding capacities reveals the following:

- Soils that hold less than 3 inches of water per foot of soil—57.3 percent
- Soils that hold between 3 and 5 inches of water per foot of soil—14.8 percent
- Soils that hold between 5 and 6 inches of water per foot of soil—27.9 percent

When soil depth is combined with water-holding capacities, the amount of water held in the total depth of the soil (down to 60 inches) is:

- Less than 10 inches—48.8 percent
- Between 10 and 20 inches—8.6 percent
- Between 20 and 30 inches—36.8 percent
- Between 30 and 40 inches—5.9 percent

Klamath County Tax Assessor data

In Klamath County, recent map-digitizing efforts have allowed NRCS soil capability classes to be assigned to soils for tax-assessment purposes. The Klamath County Tax Assessor divides the Klamath County portion of the Project into six irrigated areas: Midland/Henley/Olene; Poe Valley; Merrill/Malin; Lower Klamath Lake; Shasta View/Malin; and Malin Irrigation District. Table 2 indicates the capability classes for the soils on privately owned land in these areas.

Overall, more than 140,000 acres of land are found in the six areas. Of this land, 76 percent is classed as suitable for crops. No Class I soils are present (due to climatic limitations), and very limited amounts of Class V soils are present. The 24 percent in classes V to VIII are found mainly on hills and mountains that limit their use for crops.

Table 3 shows the percentages of each of the soil capability classes that did not receive full irrigation in 2001. Overall, about 108,000 acres are considered cropland in Klamath County, 78 percent of which did not receive full irrigation.

For the Midland/Henley/Olene area, mainly serviced by the Klamath Irrigation District, more than 88 percent of the agricultural land did not receive full-season irrigation, the highest percent of any area. In contrast, only about 63 percent of the Poe Valley agricultural land did not receive full-season irrigation. More irrigation wells operate in this area, and land serviced by the Horsefly Irrigation District did receive irrigation water during the 2001 growing season from Gerber Reservoir and Clear Lake.

Klamath County has decided to alter the tax liability for property for the 2001 growing season, depending on whether the land received full irrigation or not. Full irrigation was defined by Klamath County Assessor Reg LeQuieu as irrigation that was available for cropland throughout the growing season (LeQuieu 2001, personal communication). A land-based survey

Table 2. Capability classes of privately owned land in six irrigated areas of Klamath County.

Area[a]	Total acres	Cropland and pastureland: Class II	Class III	Class IV	Total	Noncrop total	Grand total
		Percent of land					
1	50,700	15.0	36.6	23.5	75.1	24.9	100.0
2	36,260	13.6	18.1	20.2	52.0	48.0	100.0
3	25,362	8.0	55.1	24.5	87.5	12.5	100.0
4	20,630	1.4	90.3	6.1	97.7	2.3	100.0
5	5,345	18.7	58.0	20.6	97.3	2.7	100.0
6	3,525	8.5	82.4	3.4	94.3	5.7	100.0
Total	141,822	11.4	44.9	19.7	76.0	24.0	100.0

[a]Klamath County Tax Assessor irrigated areas:
1 = Midland/Henley/Olene
2 = Poe Valley
3 = Merrill/Malin
4 = Lower Klamath Lake
5 = Shasta View/Malin
6 = Malin Irrigation District

Table 3. Percentage of acres in each capability class that did not receive full irrigation in the 2001 growing season (privately owned land in six irrigated areas of Klamath County).

Area[a]	Total acres	Cropland and pastureland: Class II	Class III	Class IV	Total	Noncrop	Grand total
		Percent of land not receiving full irrigation					
1	50,700	84.4	88.1	91.3	88.4	100.0	91.3
2	36,260	59.1	68.5	59.9	62.7	100.0	80.6
3	25,362	78.0	81.8	83.3	81.9	100.0	84.1
4	20,630	89.6	70.8	76.9	71.4	100.0	72.1
5	5,345	61.0	76.0	88.4	75.7	100.0	76.4
6	3,525	28.7	82.0	96.7	77.7	100.0	79.0
Total	141,822	73.5	78.8	80.5	78.4	100.0	83.6

[a]Klamath County Tax Assessor irrigated areas:
1 = Midland/Henley/Olene
2 = Poe Valley
3 = Merrill/Malin
4 = Lower Klamath Lake
5 = Shasta View/Malin
6 = Malin Irrigation District

was completed on August 3 to verify the land area that did not receive full irrigation. The special assessed value for lands not receiving full irrigation is $28.41 per acre.

Land values

Another aspect of the loss of irrigation water in the Project that must be considered is the effect on land values. Data provided by Reg LeQuieu, Klamath County Tax Assessor, for the years 1998 to 2000 indicate the magnitude of this effect. More than 6,000 irrigated acres were sold in Klamath County during this period at an average price of $1,687 per acre. For the same time period, close to 1,300 dryland acres were sold at an average price of $783 per acre. Thus, dryland acres returned $904 less per acre than irrigated land (LeQuieu 2001, personal communication). This land value analysis is not complete, but it was the best available at the time of the communication.

Soil erosion

The wearing away of land by water, wind, ice, or other geologic processes occurs naturally. It can be accelerated by human activities or catastrophes such as fires and floods.

Erosion by wind

Wind erosion is the major cause of soil loss in the Project area, especially in the spring during field preparation. Several thousand acres of Project soils are rated as Highly Erodible Lands (HEL) by the NRCS. Several thousand additional acres of deep, organic soils escape the HEL designation due to their great depth and high tolerance for incremental soil loss under the Universal Soil Loss Equation (USLE) used by the agency to determine soil loss tolerance. Nonetheless, these light, organic soils are highly subject to wind erosion when dry, and they present air-quality and public-safety hazards beyond their modest erodibility ratings.

The decision to deny Project water deliveries to most of the Project threatened to transform the productive Project area into a major dust bowl (Woodley 2001, personal communication). About 30,000 acres had been tilled in the fall of 2000 in preparation for spring planting. With this bare soil exposed to spring winds, serious soil erosion was a certainty.

In response, the Klamath Soil and Water Conservation District (KSWCD) implemented the largest single soil conservation effort in the Northwest (Woodley 2001, personal communication). The KSWCD, with resources from the USDA Natural Resources Conservation Service, was able to institute a cover crop program for farmers to cover bare soil on their farms. Growers were offered cost sharing to plant a small cereal grain crop to protect exposed soil. Growers provided a 25 percent match and received a 75 percent cost-share payment. They were reimbursed after they were determined to be eligible and their cover crop planting was certified to be complete. Some growers who reacted quickly to the situation and planted a cover crop before the program started were not eligible for the cost-share payment.

This effort resulted in the planting of cover crops on more than 37,500 acres in the Project. The cost of the program was $1,725,000. The amount paid to participants was nearly $1,293,750.

With some limitations, the program was able to conserve topsoil in the Project area. It is estimated that 95 percent of the seeded cover crops did emerge, resulting in a significant reduction in soil erosion (Woodley 2001, personal communication).

For health and safety reasons, the Oregon Department of Environmental Quality monitors air quality for particulates during the firewood-burning season. Air-quality data are not available for the early spring of 2001, but residents greatly appreciated the cover crop program for reducing dust in the air, and farmers benefited by saving tons of soil from loss to wind erosion.

Erosion by water

Water moving across the soil surface picks up and carries away soil particles that later are deposited in irrigation drainage ditches or in drainage water impoundments (e.g., refuge sump areas). Since flow rates in the Project and return flows to the Klamath River are relatively small, very little of this sediment mass returns to the Klamath River via the Straits Drain. Nonetheless, this water-caused loss of topsoil results in reduced farm productivity, siltation in the sumps (which reduces their water-holding depth), and expense to the irrigation districts for maintenance of the irrigation system.

Adoption of efficient sprinkler irrigation systems limits soil erosion caused by water transport of soil particles. Most of the farmland in the Project is under sprinkler irrigation (80 percent). The remaining 20 percent represents cereal crops and pastures that are surface irrigated (U.S. Bureau of Reclamation, Annual Crop Reports).

Crop rotations

Crop rotations are essential for sustainable, long-term farming operations. In general, productive rotations for the Project area include alfalfa, grain crops, and row crops (e.g., potatoes and onions). Row crops are grown no more than twice in an 8- or 9-year cycle, with alternating alfalfa and grain crops between the row-crop years. Rotations in which potatoes are grown 3 or more years apart increase yields and reduce quality losses due to soilborne diseases and insect pests.

Most of the Basin's mineral soils are low in soil organic matter. The alternating use of alfalfa and grain crops, along with residue management, can help build organic matter. Organic soils also benefit from crop rotations through reduced insect and disease problems and improved soil tilth (structural integrity and organic matter). There is interest in including "green manure" crops of sudangrass, white mustard, and rape for their capability to reduce nematode populations and generally improve the soil. (Green manure crops are tilled into the soil for soil improvement.)

Economics and physical management considerations often override long-term soil-management goals, but short-term cropping strategies (for example, planting high-value row crops in consecutive years) are not sustainable from a soil-building perspective. Appropriate rotations that include a diversity of both row and field crops are critical for improving soil tilth, while avoiding or reducing pest problems.

The loss of a dependable water source for agriculture has disrupted normal cropping rotations and added another difficult consideration for choice of crop. Without a dependable water source, high-value, input-intensive row-crop farming is not possible. Thus, crop rotations are limited to a less diverse mix of crops that can survive if water is restricted. These crops, for example, alfalfa, cereal grains, and pastures, generally are of lower value than row crops.

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8

Crop Production

Effects of the 2001 Water Allocation Decisions on the Agricultural Landscape and Crop Production in the Klamath Reclamation Project

Harry L. Carlson and Rodney Todd

This chapter addresses the effects of the 2001 water allocation decisions on crop production and other components of the agricultural landscape in the Klamath Reclamation Project.

Agriculture is the predominant land use within the boundaries of the Project. The Project was fully developed by the 1960s, and since that time Project irrigation water has been applied to approximately 210,000 acres of cropland annually. There were 2,239 farms in the Upper Klamath Basin in 1997, and the regional value of agricultural production was estimated to be $239 million. Project lands produced about $109 million of this total.

The principal crops in terms of acreage are alfalfa, pasture, and barley, followed by other hay, potatoes, and wheat (Figure 1). Other crops of importance include oats, sugarbeets, onions, peppermint, and horseradish. Crop acreage and average yield for crop years 1998–2000 are presented in Table 1. Crop values are shown in Table 2.

A major effect of the change in water allocations in 2001 was the tremendous reduction in irrigation water available to agriculture and the resulting changes in crop vegetation in the Project area. With the prospect of no irrigation water, much of the annual crop ground went unplanted, at least initially. There was immediate concern over the likelihood of severe wind erosion of soil from fields, particularly in fields that were tilled the previous fall in preparation for spring planting. Many of these fields eventually were seeded in the spring with cover crops—generally barley—to help hold the soil, with little grower anticipation of harvesting a crop.

Immediately after the U.S. Bureau of Reclamation (BOR) announced its decision to severely limit irrigation water, growers scrambled to secure water from all available sources, including transfers of water from the Lost River system, development of private wells, and the purchase of groundwater from neighbors. Much of this limited, procured water was applied to onion or potato production in an attempt to protect existing markets and future contracts. All of these activities resulted in a very atypical array of field plantings and vegetative growth in the agricultural landscape.

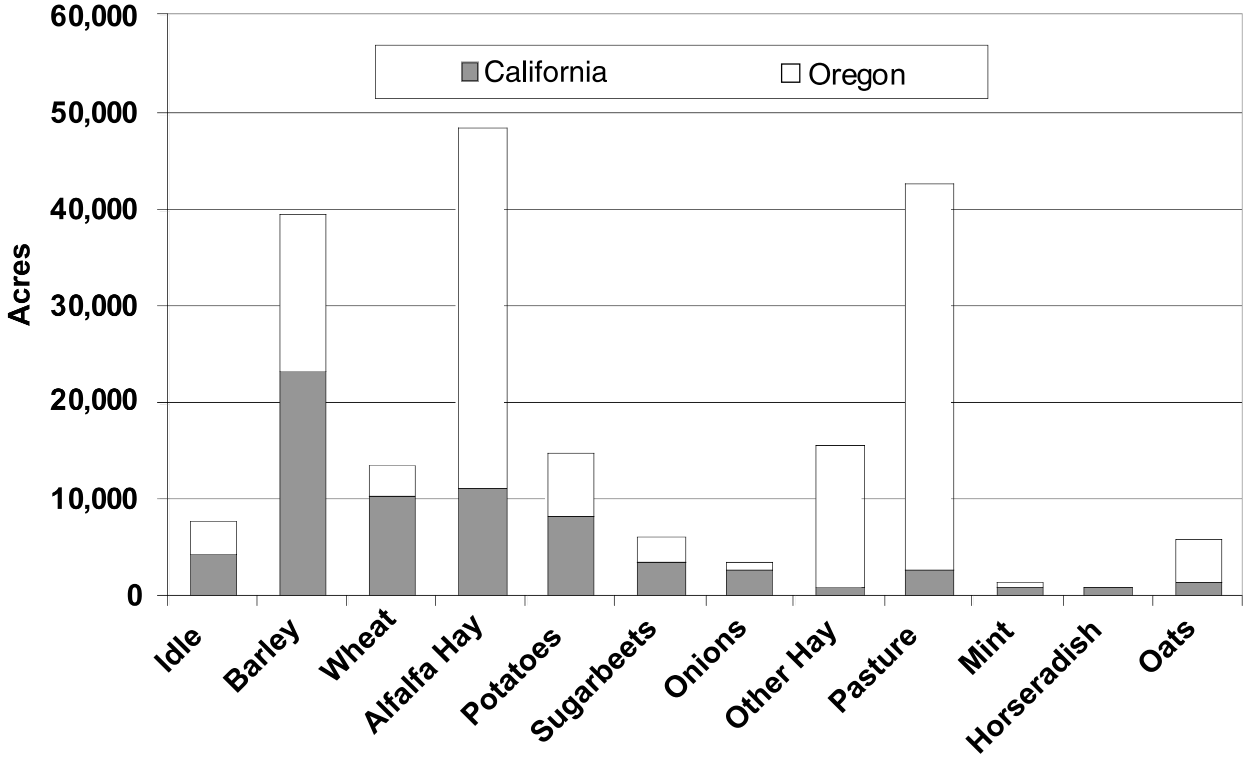

Figure 1. Crop acreage on the Klamath Reclamation Project, 3-year average, 1998–2000. Source: U.S. Bureau of Reclamation Annual Crop Reports

Table 1. Crop acreage and yield on the Klamath Reclamation Project, 1998–2000.

	Acreage				Yield (unit/acre)				
California	**1998**	**1999**	**2000**	**3-year average**	**1998**	**1999**	**2000**	**Average**	**Unit**
Barley	25,560	21,591	22,375	23,175	89	89	104	94	bu
Oats	1,348	1,689	1,677	1,571	131	131	158	140	bu
Wheat	7,299	13,974	10,067	10,447	106	106	86	99	bu
Other cereals	313	63	139	172	36	36	86	53	bu
Alfalfa	10,452	11,530	12,202	11,395	6	6	6	6	ton
Other hay	1,189	851	1,021	1,020	4	4	3	4	ton
Irrigated pasture	2,811	2,766	2,734	2,770	5	5	4	5	aum[a]
Peppermint	299	956	1,880	1,045	60	60	65	62	lb (oil)
Sugarbeets	4,336	4,486	2,393	3,738	21	21	21	21	ton
Misc. crops	779	806	975	853	—	—	—	—	—
Onions	2,339	3,175	2,834	2,783	423	423	520	455	cwt
Potatoes	9,556	7,797	7,427	8,260	400	400	500	433	cwt
Pea seed	—	—	168	168	—	—	14	14	cwt
Idle acres	5,747	5,182	1,965	4,298	—	—	—	—	—
Total California	**72,028**	**74,866**	**67,857**	**71,696**					
Oregon	**1998**	**1999**	**2000**	**3-year average**	**1998**	**1999**	**2000**	**Average**	**Units**
Barley	16,692	16,507	15,497	16,232	88	92	118	100	bu
Oats	5,306	3,705	3,416	4,142	145	151	158	151	bu
Wheat	1,954	3,741	3,421	3,039	96	99	86	94	bu
Other cereals	660	547	264	490	40	54	86	60	bu
Alfalfa	35,416	36,556	39,110	37,027	5	5	6	5	ton
Other hay	15,087	13,324	14,997	14,469	3	4	3	3	ton
Irrigated pasture	40,827	40,345	38,987	40,053	4	4	4	4	aum[a]
Silage/ensilage	305	390	1,123	606	7	7	7	7	ton
Other forage	—	—	60	60	—	—	3	3	ton
Peppermint	24	545	505	358	70	60	65	65	lb (oil)
Sugarbeets	2,731	3,067	1,479	2,426	21	22	19	21	ton
Horseradish	—	20	21	21	—	—	2	2	ton
Onions	1,082	744	422	749	400	400	500	433	cwt
Potatoes	7,141	7,029	5,339	6,503	385	400	500	428	cwt
Pea seed	—	—	60	60	—	—	14	14	cwt
Potato seed	—	—	50	50	—	—	200	200	cwt
Misc. crops	260	595	227	361	—	—	—	—	—
Idle acres	2,918	3,617	3,699	3,411	—	—	—	—	—
Total Oregon	**130,403**	**130,732**	**128,676**	**130,057**					
Project total	**202,431**	**205,598**	**196,533**	**201,753**					

[a]Animal Unit Month

Note: Values in this table may differ slightly from those in other chapters because of differences in data sources and crop category definitions.

Source: U.S. Bureau of Reclamation Annual Crop Reports

Table 2. Crop production value within the Klamath Reclamation Project, 1998–2000.

	Value ($/acre)				Value of crop production ($)			
California	**1998[1]**	**1999[1]**	**2000**	**3-year average**	**1998**	**1999**	**2000**	**3-year average**
Barley	169.50	169.50	218.00	185.70	4,333,000	3,660,000	4,878,000	4,290,000
Oats	170.50	170.50	212.50	184.50	230,000	288,000	356,000	291,000
Wheat	311.60	311.60	253.50	292.20	2,274,000	4,354,000	2,552,000	3,060,000
Other cereals	72.00	72.00	171.50	105.20	23,000	5,000	24,000	17,000
Alfalfa	575.00	575.00	575.00	575.00	6,010,000	6,630,000	7,016,000	6,552,000
Other hay	300.00	300.00	225.00	275.00	357,000	255,000	230,000	281,000
Irrigated pasture	150.00	150.00	120.00	140.00	422,000	415,000	328,000	388,000
Peppermint	840.00	840.00	910.00	863.30	251,000	803,000	1,711,000	922,000
Sugarbeets	777.00	777.00	724.50	759.50	3,369,000	3,486,000	1,734,000	2,863,000
Misc. crops	4,500.00	4,500.00	1,500.00	3,500.00	3,506,000	3,627,000	1,463,000	2,865,000
Onions	1,903.50	1,903.50	2,600.00	2,135.70	4,452,000	6,044,000	7,368,000	5,955,000
Potatoes	2,320.00	2,320.00	2,062.50	2,234.20	22,170,000	18,089,000	15,317,000	18,525,000
Pea seed	—	—	140.00	140.00	—	—	24,000	24,000
Total California					**47,396,000**	**47,655,000**	**43,000,000**	**46,033,000**
Oregon	**1998**	**1999**	**2000**	**3-year average**	**1998**	**1999**	**2000**	**3-year average**
Barley	178.50	175.40	229.30	194.40	2,980,000	2,893,000	3,553,000	3,142,000
Oats	195.50	196.50	212.50	201.50	1,037,000	728,000	726,000	830,000
Wheat	325.80	291.00	253.50	290.10	637,000	1,089,000	867,000	864,000
Other cereals	79.20	108.00	171.50	119.60	52,000	59,000	45,000	52,000
Alfalfa	450.00	450.00	522.50	474.20	15,937,000	16,450,000	20,435,000	17,608,000
Other hay	225.00	262.50	225.00	237.50	3,395,000	3,498,000	3,374,000	3,422,000
Irrigated pasture	120.00	120.00	120.00	120.00	4,899,000	4,841,000	4,678,000	4,806,000
Silage/ensilage	420.00	420.00	420.00	420.00	128,000	164,000	471,000	254,000
Other forage	180.00	180.00	—	180.00	11,000	11,000	—	11,000
Peppermint	980.00	840.00	910.00	910.00	24,000	458,000	459,000	314,000
Sugarbeets	924.00	814.00	655.50	797.80	2,523,000	2,497,000	969,000	1,996,000
Horseradish	—	—	330.00	330.00	—	—	6,000	6,000
Onions	1,800.00	1,800.00	2,500.00	2,033.30	1,948,000	1,339,000	1,055,000	1,447,000
Potatoes	2,233.00	2,320.00	2,062.50	2,205.20	15,946,000	16,307,000	11,011,000	14,421,000
Pea seed	—	—	140.00	140.00	—	—	8,000	8,000
Potato seed	—	—	400.00	400.00	—	—	20,000	20,000
Misc. crops	260.00	595.00	227.00	361	468,000	6,030,000	1,434,000	2,644,000
Total Oregon					**49,973,000**	**56,352,000**	**49,125,000**	**51,847,000**
Project total					**97,369,000**	**104,007,000**	**92,125,000**	**97,879,000**

[1]The Bureau of Reclamation's crop reports for California use the same price and yield estimates for 1998 and 1999; thus, calculated per-acre values for these years are the same.

Note: Values in this table may differ slightly from those in other chapters because of differences in data sources and crop category definitions.

Source: U.S. Bureau of Reclamation Annual Crop Reports

Major changes in Project agriculture in 2001

- The number of idle acres was greatly increased.
- Acreage of spring-seeded, high-value row crops such as potatoes and onions was greatly reduced.
- Per-acre yields of potatoes and onions were near normal because these crops were planted where full-season irrigation was available.
- Acreage of sugarbeets was reduced to zero. (This was not because of the water shortage, but because of the closure of two northern California sugar refineries.)
- Barley acreage was increased in California due to cover crop plantings. However, much of the barley went unharvested or was harvested for hay because of concern about poor grain yields. Harvested acreage of barley in Klamath County was down significantly.
- Per-acre yields of cereals harvested for grain were greatly reduced because of the high percentage of dryland grain. Oat yields on lower lake dryland muck soils were less affected.
- Per-acre alfalfa yields were reduced, but crop value increased slightly in response to high prices. The improved price also resulted in some new alfalfa fields being planted where water was available.
- Few new plantings were made in peppermint. Surviving mint plantings were about 200 acres in Klamath County, compared to more than 400 acres the previous year.
- Grain fields harvested in 2000 were left as stubble fields in 2001 (except for fields that were tilled in the fall of 2000 in preparation for planting in 2001).
- Weed control generally was not practiced in fallow fields or in dryland fields planted to grain, alfalfa, or peppermint.
- Major increases in weed seed soil banks are certain.
- The farm-gate value of agricultural production in the Project was greatly diminished.

The best available information to track changes in cropping patterns within the Project area is the *Annual Crops Report* prepared by the BOR. Tables 1 and 2 summarize the crop acreage figures compiled by the BOR for the years 1998, 1999, and 2000, along with crop yields and average production values. Unfortunately, figures for the 2001 season were unavailable from the BOR at the time of this writing.

Without figures for the entire Project, data from the Tulelake Irrigation District (TID) were evaluated to gain a sense of the magnitude of the vegetation changes that occurred during the 2001 season. Preliminary acreage and crop value figures for Klamath County also were evaluated.

Table 3. Crop acreage within the Tulelake Irrigation District, 1998–2001.

	Acres				
	1998	1999	2000	3-year average	2001
Barley	21,219	16,468	18,798	18,828	12,916
Wheat	7,157	13,478	10,215	10,283	825
Oats	1,475	965	1,067	1,169	525
Peas	37	280	158	158	605
Sugarbeets	4,038	4,203	2,379	3,540	0
Alfalfa hay	9,723	10,862	11,659	10,748	12,416
Other hay	1,092	253	869	738	5,761
Pasture	1,752	1,707	1,700	1,720	1,288
Potatoes	9,527	7,912	7,572	8,337	1,162
Onions	2,292	2,963	2,703	2,653	779
Mint	299	940	1,775	1,005	1,151
Rye	28	28	139	65	31
Horseradish	766	781	979	842	830
Idle acres	2,500	998	1,652	1,717	23,140
Total	**59,405**	**60,840**	**60,013**	**61,803**	**61,429**

Source: Tulelake Irrigation District Annual Reports

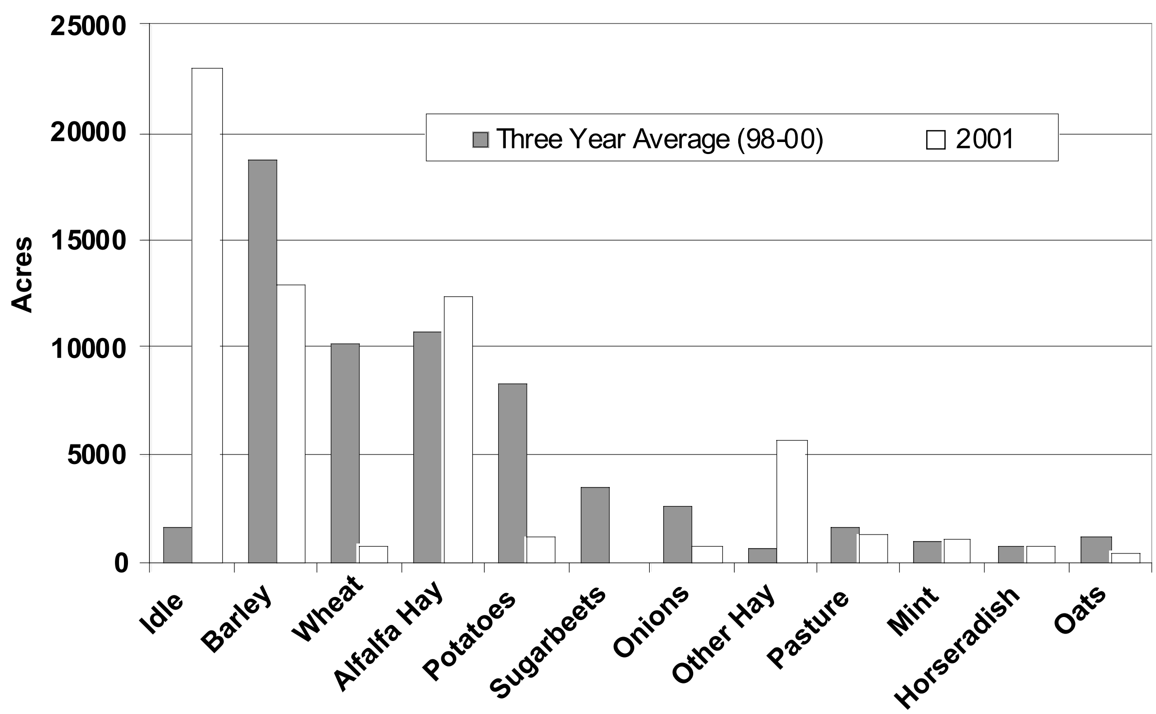

Figure 2. Comparison of 2001 crop acreages with previous 3-year average, Tulelake Irrigation District. Source: Tulelake Irrigation District Annual Reports

Acreage and yield

Crop acreage figures for 1998 through 2001 within the TID are presented in Table 3. Based on a 3-year average, barley was produced on the greatest acreage in the district, followed by alfalfa, wheat, and potatoes. Other important crops in terms of acreage included sugarbeets, onions, pasture, oats, mint, horseradish, and hay other than alfalfa (mostly grass hay). Minor plantings were made of rye and peas.

There were several notable shifts in crop acreage in 2001 (Table 3 and Figure 2). The number of idled acres jumped dramatically from about 1,700 acres on average to 23,000 acres in 2001. Onion acreage was reduced to 30 percent of normal. Potato acreage was reduced to less than 14 percent of the previous 3-year average. Wheat acreage was 12 percent of normal. Sugarbeet acreage was reduced to zero, reflecting the closure of two northern California sugar refineries. While the sugarbeet change was in no way related to the water situation, in a normal water year the loss of sugarbeets probably would have led to an increase in acreage of other row crops.

Barley grown for grain was reduced from the previous years' acreage, but represented a similar percentage of the total planted acreage in 2001 as in previous years (about 30 percent). However, the reported barley acreage does not include barley that was cut for hay because of insufficient soil moisture to make a grain crop. For this reason, the "other hay" crop category jumped to 5,700 acres in 2001 from an average of fewer than 1,000 acres previously. Peppermint, a relatively new crop to the district, had been expanding in acreage over the past 3 years. In 2001, several mint fields were abandoned, and no new fields were established. In addition, a few acres of horseradish were abandoned.

Crop acreages for Klamath County for the years 1998, 1999, and 2000 appear in Table 4, along with preliminary figures for crop acreage in 2001. Alfalfa is a much more important crop in the Oregon part of the Basin. On average (1998–2000), alfalfa and other hay made up 58 percent of the crop acreage in Klamath County. Cereal grains, principally barley, made up the bulk of the remaining acreage. Potato crops made up only 5 percent of the acreage, but contributed more than 21 percent of the overall value of crop production in Klamath County.

The reduced water allocation in 2001 resulted in significant shifts and reductions in Klamath County acreage. Compared to the

Table 4. Klamath County crop acreage, 1998–2001.

	Acres				
	1998	1999	2000	3-year average	2001[a]
Barley	31,600	37,200	36,700	35,167	12,000
Wheat	6,000	6,400	6,400	6,267	2,100
Alfalfa hay	49,000	50,000	49,400	49,467	44,000
Potatoes	7,800	6,900	5,900	6,867	2,600
Sugarbeets	4,000	4,100	2,100	3,400	0
Oats	3,000	4,100	5,500	4,200	2,000
Other hay	26,300	30,000	31,500	29,267	20,000
Mint	250	440	400	363	200
Total	**127,950**	**139,140**	**137,900**	**134,997**	**82,900**

[a]Preliminary

Source: Oregon State University, Klamath County Annual Crop Reports previous 3 years, acreage reduction occurred in all crops (Table 4 and Figure 3). The reduction was much less in hay than in other crops. Barley and potato acreages were reduced by more than half, while the combined acreage of alfalfa and other hay was reduced by less than 20 percent.

Water management and yield

Following the decision to curtail irrigation in the Project, there was general concern about the prospect of serious soil erosion on unplanted ground. Growers made a dedicated effort to seed the fields with a cover crop, with assistance from a cost-share program offered by the USDA Natural Resources Conservation Service (see Chapter 7, “Soil Resources”). Barley generally was selected as the cover crop of choice, given its potential to rapidly cover the ground under cool temperatures and limited moisture conditions. Most of these fields went unirrigated.

Many of these fields produced sufficient top growth to harvest as cereal hay. Other fields did mature and produced grain for harvest, but at yields well below the typical yield of irrigated fields. Many barley fields did not produce a harvestable yield of hay or grain.

Harvestable dryland grain crops were almost entirely limited to fields with muck soil types and very high soil-moisture-holding capacities. Stored soil moisture in the lighter soil types was not sufficient to produce a crop.

Several factors combined to determine the relative per-acre yield of individual barley fields. Better yields were attained in barley that followed irrigated row crops, primarily due to the presence of residual soil moisture from the previous crop. Yields also were improved by early planting and, in some cases, by receipt of well-timed, locally heavy rainfall. The midseason allocation of water by the BOR did not help grain crops, as the crops had fully matured by that time.

Production of potatoes and onions was possible only where growers could locate dependable sources of water sufficient to produce full-season crops. This water was

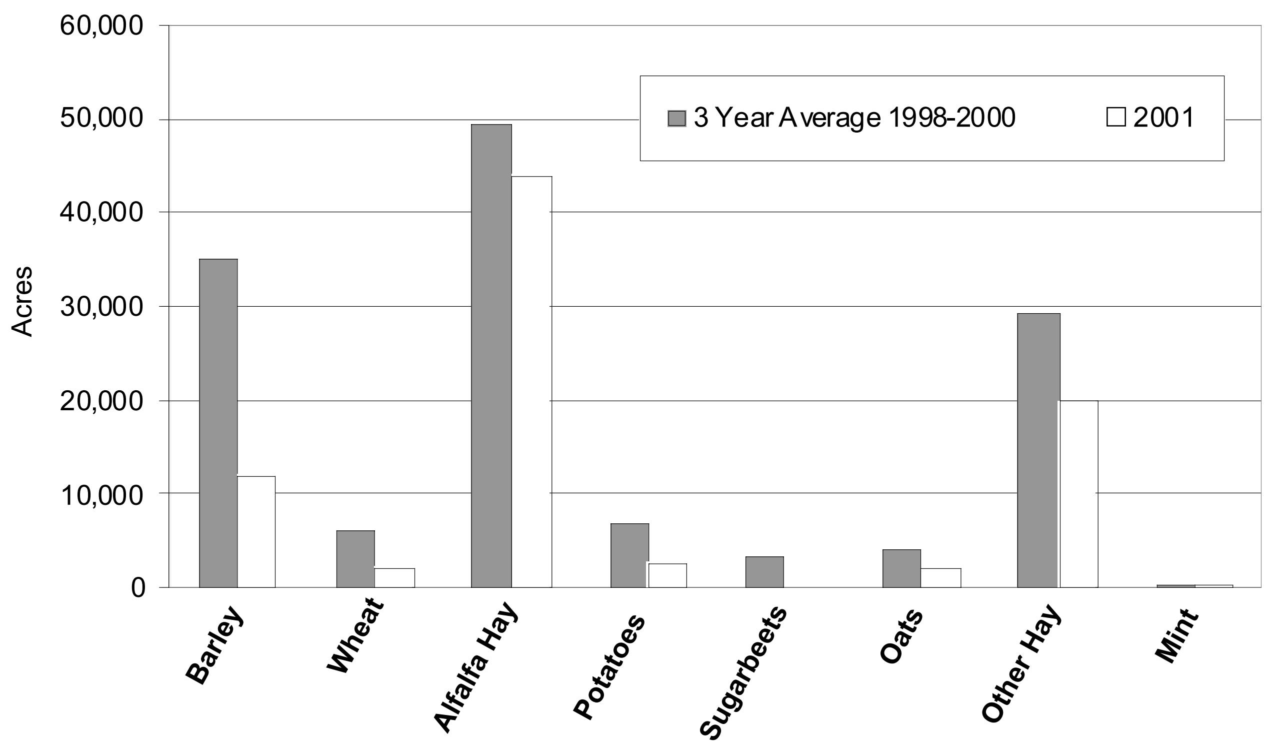

Figure 3. Comparison of 2001 Klamath County crop acreages with previous 3-year average. Source: Oregon State University, Klamath County Annual Crop Reports

available from existing and newly developed wells, purchases from other landowners, and transfers from other irrigation districts. Potato and onion growers went to great lengths and expense to secure at least some land with water to protect their potato markets and future onion contracts.

Where water was available all season, water management generally did not affect per-acre potato and onion yields (Table 5). However, some yield loss in potatoes and onions was attributed to production in less-than-desirable fields, which were selected only because they had a source of irrigation. Problems in some of these fields were attributed to poor soil tillage, less productive soil types, or less-than-desirable crop rotations.

Alfalfa is a deep-rooted crop. Most fields in the TID have high soil-moisture-holding abilities and relatively high perched water tables. Thus, first-cutting per-acre yields of alfalfa in the TID were near normal. However, second cuttings generally were poor or nonexistent. Many alfalfa growers were able to take advantage of the Department of the Interior's midseason release of 40,000 acre-feet of Upper Klamath Lake water to irrigators in the Project. The resulting midseason irrigation on alfalfa significantly improved third-cutting yields and reduced the risk of stand losses throughout the Project. Yield of dryland alfalfa was poor on the light soils common in Klamath County, and a significant loss of plant stands may become evident in many dryland fields in the spring of 2002.

Other perennial crops also were favorably affected by the midseason allocation of irrigation water. Irrigated pastures responded to the added water. For the most part, however, livestock had been removed from the pastures by that time, so little significant increase in revenue occurred. The midseason irrigation did stimulate pasture growth and improved pasture condition, possibly preventing stand losses in the winter of 2001–2002.

Table 5. Crop yield within the Tulelake Irrigation District, 1998–2001.

	Yield (unit/acre)					
	1998	1999	2000	3-year average	2001	Unit
Barley	43.0	62.0	56.5	53.8	35.0	cwt
Wheat	62.3	66.4	60.8	63.2	47.5	cwt
Oats	42.0	50.0	55.0	49.0	38.0	cwt
Peas	25.0	25.0	25.0	25.0	12.5	cwt
Sugarbeets	23.0	20.0	21.0	21.3	—	ton
Alfalfa hay	5.8	5.8	5.7	5.8	4.5	ton
Other hay	4.0	3.8	4.0	3.9	2.3	ton
Pasture	4.0	4.0	4.0	4.0	0.3	aum[a]
Potatoes	400.0	450.0	500.0	450.0	430.0	cwt
Onions	423.0	423.0	470.0	438.7	420.0	cwt
Mint	70.0	40.0	90.0	66.7	65.6	lb
Rye	20.0	30.0	30.0	26.7	20.0	cwt
Horseradish	2.5	2.5	2.5	2.5	2.2	ton

[a]Animal Unit Month

Source: Tulelake Irrigation District Annual Reports

Some peppermint stands may have been saved by the midseason water application. However, as with pasture, the midseason application of water (the only application to most peppermint) generally did not result in increased crop harvest. As with alfalfa, significant stand loss will become evident in the spring of 2002 in many peppermint fields and perhaps in some pastures. The risk is greatest in fields with lighter soil types that did not receive supplemental water.

The midseason allocation of water also provided some economic relief to growers who were purchasing groundwater or relying on other water transfers.

Weeds

A direct consequence of the reduced water allocation was the tremendous increase in weedy fields. Weed control generally was not practiced on fallow fields. The resulting weed growth in fallow fields ranged from moderate to severe. The large difference in weed growth from field to field was due to:

- Differences in weed seed populations in the soil
- Distinct differences in the ability of individual weed species to germinate and grow under dry soil conditions
- Tillage practices the previous fall
- Soil moisture retention from the previous crop

Solid, shoulder-high weed growth was observed in many fields. Predominant weeds included those common in local agricultural production (e.g., mustards, pigweed, lambsquarters, and kochia) as well as species rarely seen in production fields (principally prickly lettuce).

Most of the fields that were in grain in 2000 were left as stubble fields in 2001, except for those fields that were tilled in the fall of 2000 in preparation for planting in 2001. The untilled stubble generally was effective in reducing soil erosion. Weed growth on grain stubble fields ranged from very slight to heavy, depending mostly on weed populations in the field and the effectiveness of limited rainfall in stimulating weed seed germination.

A major concern for the 2002 crop year and beyond is the increase in soil weed seed populations that will certainly result from weed growth on fallow and stubble fields. The accumulation of tremendous weed seed banks in the soil will cause major difficulties in controlling weeds in future crop cycles. Extensive weed growth in dewatered canals and drain ditches also will serve as a long-term source of weed seed and may create serious debris problems when ditches are rewatered.

Herbicide use generally was curtailed in dryland grain and alfalfa because of the reduced prospect for yield increases in the absence of irrigation water. Uncontrolled weeds undoubtedly contributed to reduced yields and quality in these crops.

Economic consequences

The production value in the TID (farm-gate sales) averaged $38,678,000 per year from 1998 to 2000. The estimated value fell to $17,288,000 in 2001 (Table 6). Changes in production values for specific crops are shown in Figure 4. The loss in farm-gate value was moderated to some extent by the midseason allocation of water to alfalfa and horseradish producers and by improved prices for potatoes and alfalfa (Table 7).

Table 6. Crop production value within the Tulelake Irrigation District, 1998–2001.

	Production value ($)				
	1998	1999	2000	3-year average	2001
Barley	3,714,000	4,135,000	4,493,000	4,114,000	1,912,000
Wheat	2,416,000	4,716,000	2,885,000	3,339,000	178,000
Oats	279,000	193,000	249,000	240,000	91,000
Peas	11,000	84,000	47,000	47,000	106,000
Sugarbeets	4,179,000	3,615,000	2,048,000	3,281,000	0
Alfalfa hay	5,075,000	5,621,000	6,369,000	5,688,000	6,146,000
Other hay	284,000	62,000	243,000	196,000	1,102,000
Pasture	70,000	68,000	68,000	69,000	3,000
Potatoes	15,396,000	15,808,000	10,525,000	13,910,000	4,376,000
Onions	4,848,000	6,267,000	6,352,000	5,822,000	1,554,000
Mint	293,000	526,000	1,917,000	912,000	906,000
Rye	2,000	3,000	14,000	6,000	2,000
Horseradish	958,000	977,000	1,224,000	1,053,000	913,000
Total	**37,525,000**	**42,075,000**	**36,434,000**	**38,678,000**	**17,288,000**

Note: Values in this table may differ slightly from those in other chapters because of differences in data sources and crop category definitions.

Source: Tulelake Irrigation District Annual Reports

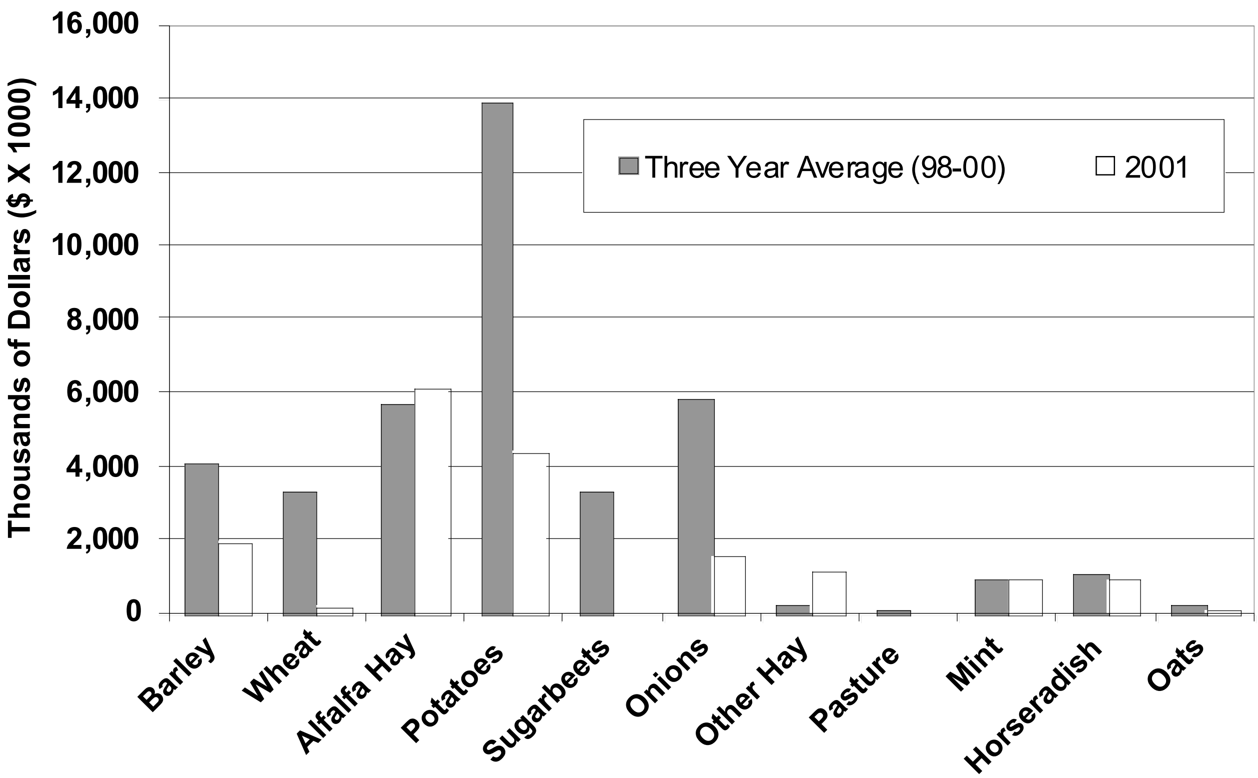

Figure 4. Comparison of 2001 crop values with previous 3-year average, Tulelake Irrigation District. Source: Tulelake Irrigation District Annual Reports

Table 7. Prices for crops within the Tulelake Irrigation District, 1998–2001.

	Unit value ($/unit)					
	1998	1999	2000	3-year average	2001	Unit
Barley	4.07	4.05	4.23	4.12	4.23	cwt
Wheat	5.42	5.27	4.65	5.11	4.54	cwt
Oats	4.50	4.00	4.25	4.25	6.50	cwt
Peas	12.00	12.00	12.00	12.00	14.00	cwt
Sugarbeets	45.00	43.00	41.00	43.00	—	ton
Alfalfa hay	90.00	90.00	95.00	91.67	110.00	ton
Other hay	65.00	65.00	70.00	66.67	85.00	ton
Pasture	10.00	10.00	10.00	10.00	10.00	aum[a]
Potatoes	4.04	4.44	2.78	3.75	6.06	cwt
Onions	5.00	5.00	5.00	5.00	4.75	cwt
Mint	14.00	14.00	12.00	13.33	12.00	lb (oil)
Rye	3.50	3.50	3.25	3.42	3.50	cwt
Horseradish	500.00	500.00	500.00	500.00	500.00	ton

[a]Animal Unit Month

Source: Tulelake Irrigation District Annual Reports

Data for crop values (farm-gate sales) in Klamath County are presented in Table 8. The estimated crop value in 2001 was $31,526,000, compared to the previous 3-year average of $58,627,000. Klamath County producers were helped somewhat by improved alfalfa and potato prices, but took heavier yield losses in water-stressed crops because of the lower water-holding capacities of most Klamath County soils.

The changes in crop values tended to follow the acreage figures, although improved potato prices in 2001 moderated the overall effect of the potato acreage reduction (Figure 5). The picture was a little more complicated with alfalfa values. Alfalfa acreage was down only slightly, while alfalfa prices were strong in 2001. However, the Klamath County alfalfa yields were greatly reduced by the moisture stresses imposed in 2001. The overall result was a 33 percent reduction in the total farm-gate sales of alfalfa hay, compared to the previous 3-year average.

Several factors need to be considered in a Project-wide assessment of the acreage and yield effects of the reduced water allocation.

- As noted above, Tulelake soils have a much higher water-holding capacity than most of the soils in the rest of the Project. For these and other reasons, the yield losses in dryland alfalfa and grain were less severe in the TID than in the balance of the Project. Furthermore, significant stand losses in alfalfa and pastures are more likely on the lighter soils in Oregon irrigation districts.
- The TID has a significantly greater proportion of high-value row crops compared to the Project as a whole.
- More land in the TID was serviced by wells than was the case in the Klamath County irrigation districts.

Table 8. Klamath County crop production values, 1998–2001.

	Production value ($)				
	1998	1999	2000	3-year average	2001[a]
Barley	4,503,000	5,641,000	6,299,000	5,481,000	2,016,000
Wheat	1,672,000	1,529,000	2,000,000	1,734,000	504,000
Alfalfa hay	29,728,000	25,472,000	24,353,000	26,518,000	17,820,000
Potatoes	14,742,000	14,735,000	8,513,000	12,663,000	7,176,000
Sugarbeets	3,951,000	4,116,000	1,775,000	3,281,000	0
Oats	378,000	4,100,000	5,500,000	3,326,000	500,000
Other hay	4,629,000	5,224,000	5,996,000	5,283,000	3,400,000
Mint	267,000	421,000	336,000	341,000	110,000
Total	**59,870,000**	**61,238,000**	**54,772,000**	**58,627,000**	**31,526,000**

[a]Preliminary

Note: Values in this table may differ from those in other chapters because of differences in data sources and crop category definitions.

Source: Oregon State University, Klamath County Annual Crop Reports

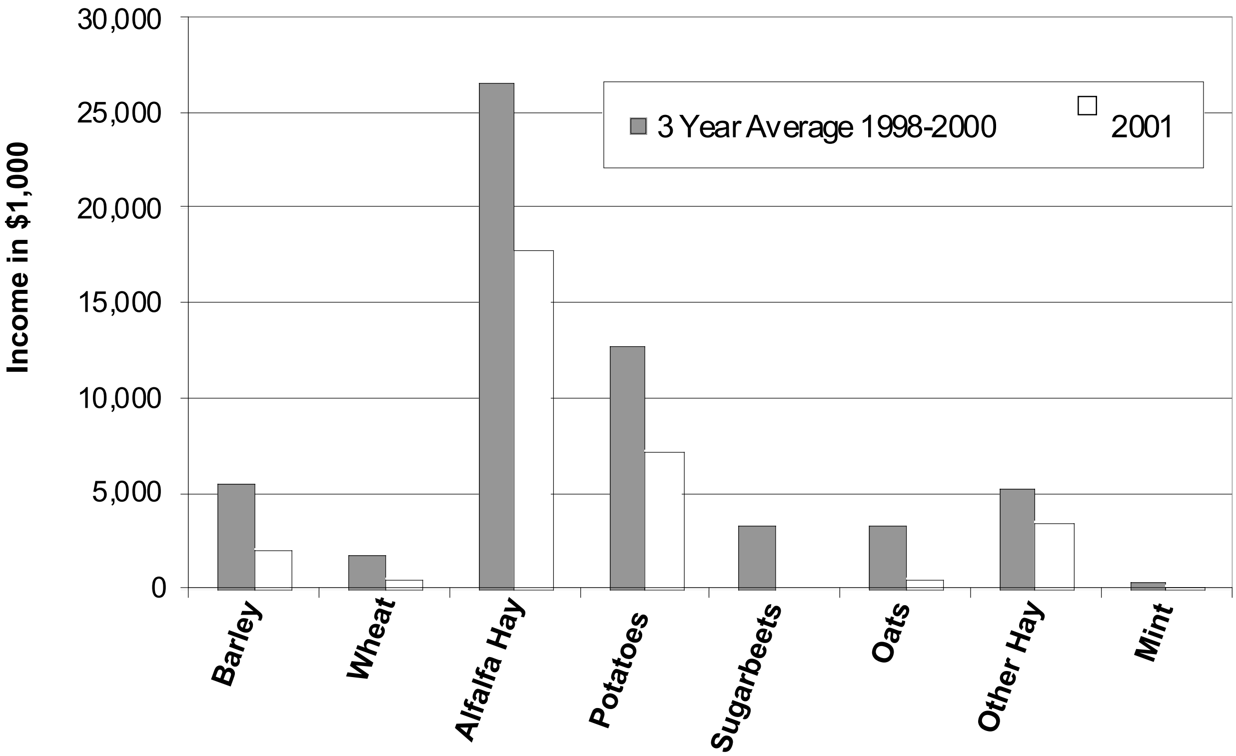

Figure 5. Comparison of 2001 Klamath County crop values with previous 3-year average. Source: Oregon State University, Klamath County Annual Crop Reports

- Counterbalancing those differences are the relatively normal water allocations in Oregon's Langell and Yonna valleys and access to Oregon state water rights in some Oregon irrigation districts.

A more comprehensive Project-wide assessment of the effects on crops will have to await completion of the BOR annual crop report or initiation of an additional data collection effort. Crop production values and the effect of this production on the local and regional economies are covered in detail in other sections of this report (Chapters 12–14).

References

Klamath County. Annual Crop Reports

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Part 4. Communities

9

Communities

Effects of the 2001 Water Allocation Decisions on Project-area Communities

Denise Lach, Leslie Richards, Corinne Corson, and Patty Case

By the winter of 2001, decisions were required on how water would be allocated in the Upper Klamath Basin for protecting endangered and threatened species: shortnose and Lost River suckers, coho salmon, and bald eagles. The previous year's drought resulted in below-normal snowpack in the mountains that feed the lakes, streams, and rivers in the Basin, the source of habitat for endangered species and water for acres of irrigated fields.

The science that contributed to the decision to curtail water to farmers continues to be debated, as is evident throughout this report, and it is made more complex by unresolved conflicts about water rights (see Chapter 18, "Policy," and Chapter 3, "Legal Aspects"). However, for the farmers who rely on the Klamath Reclamation Project, as well as their communities, the decision had direct and drastic consequences in 2001.

During the 2001 season, farmers and community members expressed great concern about the fate of their planted fields, as well as fears for the coming year. Stories about the situation were seen frequently in *The New York Times*, *The Wall Street Journal*, and *The Oregonian.* The reports were not only of farmers challenging the decision through civil disobedience, but also of the increased need for community services, the ideological divisions emerging throughout the community, a sense of loss of a way of life, and a sense of betrayal by elected officials.

We recognize that previous decisions about water and endangered species management contributed to the position in which communities and individuals found themselves during the 2001 growing season. It is vital to remember that the comments and perspectives reported below fit within a history of water use, land management practices, fishing, and other activities in the Project area that resulted in the listing of multiple species as endangered or threatened.

We also recognize that to paint a complete picture of the effects of this decision, further detail is needed about how water management in the Project affects other communities, individuals, and industrial sectors. Among those affected are the downstream fishing industry and the Native American tribes that historically relied on fish for subsistence and cultural values.

This report, however, focuses on the consequences of the 2001 decision to those living in the area covered by the Project—several communities in Klamath County, Oregon, and Modoc and Siskiyou counties, California. Thus, it is only the beginning of efforts to understand the effects of water allocation decisions on all of the communities and individuals in the Klamath Basin.

We begin with a brief discussion of our research methodology, providing details about the sources of interview data and community statistics. Next, we describe the demographic characteristics of the counties in which the Project lies. This demographic portrait is followed by information about the availability and use of social services and social support organizations in the area.

Finally, we present the findings from our interviews with 69 members of the Project-area community. Using the words of local farmers, social service providers, business owners, tribal representatives, federal and state employees, and conservationists, we paint a portrait of a community under stress. While the details of these stories may not be entirely accurate, they construct a reality that shapes the behavior of Project-area residents.

What we did

Consequences of the drought and curtailment of water deliveries to farmers in the Klamath Reclamation Project during the 2001 growing season can be seen at least partially in the economic data in Chapters 12–14 of this report, as well as in publicly available data that describe changes in community structure and services. We looked at data from the U.S. Census Bureau, county and state agencies, and nonprofit organizations, including churches and other community social service providers.

In order to get some sense of whether the past year was unique in any way, we wanted to collect data for 3 years: 1992 (a drought year), 1997 (a year with normal precipitation), and 2001. Unfortunately, data collection and reporting methods for the information we wanted were inconsistent, making a quick assessment impossible. Instead, when data were available, we looked at trends for the entire decade between 1991 and 2000. More typically, we were limited to a few indicators for 1997, 2000, and parts of 2001. In the summaries below, we also report any available 1992 data.

Economic and social service data can help us understand some aspects of consequences for communities when we collect data over the years, average it, and compare it with other years to see whether the situation has changed. This information is essential for understanding consequences to the community over the long term; however, it does not give voice to the people who are living through events as individuals, families, and community members. Numbers and graphs cannot fully capture the complexity of a community's concerns and responses. For that, we turned to a qualitative research approach and asked individuals to describe their own experiences and perceptions.

Qualitative research can be seen as a companion to quantitative research, as well as an independent research method that follows certain processes for thinking about, collecting, examining, and interpreting data. Qualitative research is a way to provide firsthand accounts of the life experiences of individuals from their unique perspective regarding moments, events, and situations. It elicits and makes sense of the meaning of these phenomena in the lives of individuals.

Proponents of quantitative investigation might question the validity of this analysis because it does not include hypothesis testing. Rather, it is a method that attempts to bring out both the subjective and objective meaning of an event—in this case, the 2001 water situation in the Project area—in the lives of those affected (Denzin and Lincoln 1994; Gilgun et al. 1992).

The participants

For this study, we conducted 11 focus groups and 13 one-on-one semistructured interviews (a total of 69 people) to explore effects on individuals, families, and communities. The questions we asked are found in Appendix A.

Focus groups were chosen as a data collection method for several reasons. First, focus groups allowed us to talk in-depth with many people over a relatively short period of time. We also believed that talking and listening with neighbors and colleagues about common experiences would provide participants with an opportunity to describe their own experiences and learn from others.

Although Stewart and Shamdasani (1998) note the advantages of using focus groups to collect data, it is important to remember that the groups are not random samples of the entire population. Therefore, the results cannot be generalized to all people living in the Project area.

Instead, the samples are "purposive" in that we intentionally selected respondents who have been involved in various ways in the current events and activities. Purposive samples are used when we want to explore a complex situation in great detail with exactly the people who are involved, those who have the most experience or knowledge about the situation. Purposive samples do not necessarily represent the general public, but they can provide insight about the situation from multiple perspectives.

For these reasons, the information reported from the focus groups should be considered a snapshot of the experiences and understanding of several community members from September to November 2001. Experiences and emotions change over time, and our results may have been different if we had conducted the research prior to September 11, 2001, for example, or after a decision was made about irrigation water for 2002.

We convened two groups of farmers (trying to separate those who rely most heavily on Project water from those who don't), using a random selection of names from lists of farmers provided by the Klamath County office of the Oregon State University Extension Service and the University of California Intermountain Research and Extension Center in Tulelake. We wanted to make sure that we heard from respondents in both Oregon and California in order to capture any differences due to state-related variables (e.g., regulations, tax laws, or assistance programs).

One group of farmworkers was convened with the assistance of a local translator. He invited participation through announcement of the focus group at a local resource center for farmworkers. This focus group was conducted in Spanish with the assistance of the translator in both the interview and translation of the transcript.

Two focus groups were convened to talk with individuals who worked in existing organizations that provided a variety of social services, including food assistance, health care, mental health, education, and emergency shelter. We began with a purposive sample of social service providers in Tulelake, California. We used a "snowball" sampling technique; we asked a key informant who had been active in the area for a long time to provide the names of others who might be willing to participate. We then asked each of those people, whether or not they agreed to participate, to suggest the names of others.

A matching focus group of service providers from Klamath Falls was then convened. (For example, a food bank director was in both groups.) We conducted a group in Oregon and another in California to capture any differences based on state variables and also to talk with social service providers in both a larger community such as Klamath Falls and in smaller rural communities.

Purposive samples of federal and state agency staff who are on the "front lines"—meeting regularly with community members—were selected with assistance from a staff member at one of the agencies. A single focus group was convened with both state and federal agency participants.

We also used a "snowball" sampling technique to identify individuals who were self-identified as conservationists. While all of these participants claimed membership in local, state, and/or national environmental groups, their level of personal activism ranged from quite passive to very active.

Two business focus groups were convened with a purposive sample—one with business owners from Klamath Falls and the second matched with similar types of businesses in smaller towns (e.g., a grocery store and a restaurant).

A member of the Klamath Tribes helped to organize a conversation with tribal members. This conversation was held at the tribal offices.

In addition, we conducted 13 in-depth, semistructured interviews with individuals who were unable or unwilling to participate in a focus group. These interviews were conducted using the same questions used in the focus groups. Table 1 describes the categories of participants in the focus groups and interviews.

How the focus groups worked

For focus groups to be successful, participants need to be comfortable sharing information in a semipublic setting. While it is the facilitator's responsibility to ensure that people are able to participate, specific strategies are used to create effective focus groups. Every effort is made to keep participation confidential, especially for reporting purposes, by using first names only in the discussion and on the transcript, and by deleting any information that can easily identify an individual. However, participants may know each other through other community contacts, and confidentiality is difficult to maintain. Thus, other techniques are used to create an environment where people feel safe to respond to questions and to interact with each other. One method is to create relatively homogeneous groups. This ensures that existing animosity or enmity is not exacerbated, that conversations move beyond arguments, and that participants hear from others in similar situations.

Each focus group had 4 to 14 participants, and most were conducted with 2 facilitators. One facilitator directed the conversation, asking questions and probing in more depth as issues were raised. The second facilitator took notes and watched to ensure that all participants were heard. The group with farmworkers was conducted in Spanish with a translator.

All focus groups and all but one interview were tape recorded (with participants' permission) and professionally transcribed for analysis. Extensive notes were taken for the interview that was not recorded. We examined the transcripts to identify and characterize the major issues raised by participants as they described their experiences related to the curtailment of water delivery to Project farmers.

Once the issues were characterized, we wrote the report using participants' own words when appropriate. Brackets are used to indicate where we modified participants' words to enhance readability or protect confidentiality.

Community overview

Klamath County, Oregon, is located in the eastern foothills of the Cascade Mountains, bordering northern California. It covers 6,135 square miles, making it the fourth largest county in Oregon. Klamath Falls, the county seat and largest town, rests on the southern shore of Upper Klamath Lake, one of the largest bodies of freshwater in the Pacific Northwest. Oregon towns in Klamath County and in the Project area include Merrill, Malin, and Klamath Falls.

Table 1. Categories of participants in focus groups and interviews.

Focus groups (11)	Interviews (13)
Klamath Tribes	Manager of grocery store
Bonanza farmers	State/federal agency staff (2)
Klamath Falls business owners	Conservationist
Tulelake business owners	Farmers (5)
Tulelake service providers	Urban business owner (not taped)
Klamath Falls service providers	Urban business owner
Tulelake farmworkers	Rural service provider
State/federal agency staff	Klamath Falls service provider
Conservationists	
Merrill farmers (two groups)	

Parts of two California counties are served by the Project. Siskiyou County is directly south of the Oregon border, and Modoc County is located in the northeast corner of California. The only Siskiyou County town within the Project is Tulelake, just south of the Oregon border. Newell, a small, unincorporated town, is the only community within the Project in Modoc County. While all three of the counties can be described as "rural," Klamath Falls (population 19,462) provides major services for most of the communities. Information for each county is shown in Table 2.

Although these three counties and several towns were directly affected by the water situation, the consequences of the decision rippled throughout the region to other farmers and nonfarming community members outside the Project area.

In this section, we review information about social trends in the Project counties, including population, age, employment, and income. We use demographic data available from the U.S. Census Bureau at the national, state, and county levels.

Population

As displayed in Figure 1, the population of Klamath, Siskiyou, and Modoc counties was relatively stable over the decade from 1990 to 2000, with a general rise toward the end of the decade in Klamath County and a slight decline in the California counties.

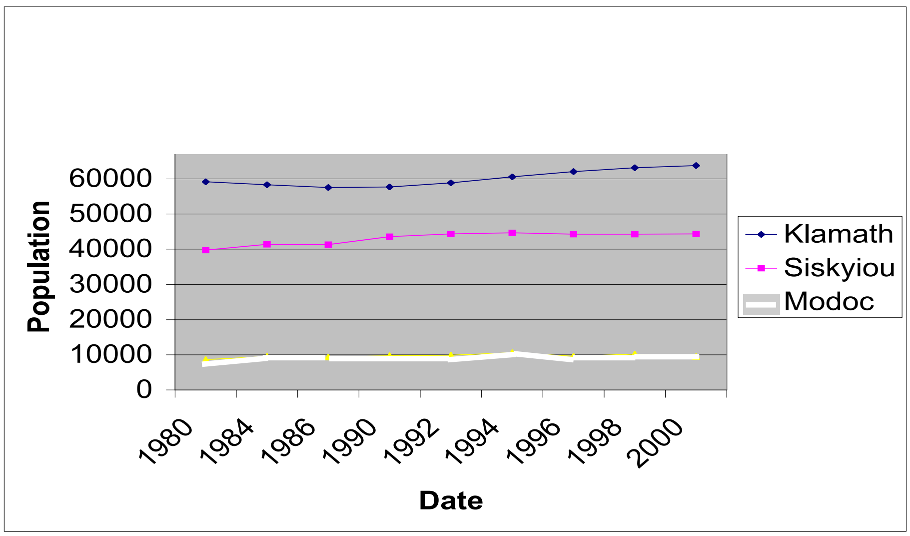

Figure 1. Upper Klamath Basin population, 1980–2000.

Table 2. Description of counties in the Klamath Reclamation Project area, 2000.

County	Area (sq miles)	County population	City/town population	Major industrial sectors
Klamath (OR)	6,135	63,755	Klamath Falls: 19,462 Merrill: 897 Malin: 638	Service Forestry Manufacturing[a]
Modoc (CA)	3,944	9,449	Newell (unincorporated)	Government (44%) Agriculture (14%) Retail (14%)
Siskiyou (CA)	6,281	44,301	Tulelake: 1,029	Government (26.5%) Services (22.5%) Retail (20.6%)

[a]The largest employers in Klamath County include Merle West Medical Center, Jeld-Wen, Sykes Enterprise (high-tech support), Collins Products (particleboard, plywood, siding), and Columbia Plywood.

Source: U.S. Census 2000

Ethnic distribution

All three counties have significant populations of Native Americans and Hispanics. As shown in Table 3, American Indians constitute about 4 percent of the population of each county, compared to a 1 percent share of the national population. According to a tribal memo prepared by the Directors of the Planning, Natural Resources, and Culture and Heritage departments (Klamath Tribes 2001), there currently are about 3,300 Klamath Tribe members, and the population is growing slowly. The Tribes believe that historically the population ranged between 2,700 and 3,000.

While there are about twice as many Hispanics as Native Americans in the three counties, this population concentration is quite low for California, where almost one-third of the population identifies themselves as Hispanic. The Hispanic population in Klamath County is about average for the state of Oregon. The 2000 Census shows that the small communities affected by the decision to curtail water have a high percentage of Hispanic residents: 45 percent in Tulelake, 54 percent in Malin, and 33 percent in Merrill.

Due to the seasonal, temporary nature of their jobs, determining the number of migrant workers is difficult. As shown in Table 3, migrant workers in the Project area are more likely to reside in California than in Oregon. It's important to note that many, if not most, farmworkers in the Upper Klamath Basin are permanent residents of the area and that not all farmworkers are Hispanic.

An aging population

As shown in Table 4, one-quarter to almost one-half of the people in the three Project counties are more than 45 years old. The general age of a population reflects the distribution of experience, knowledge, skill, and (usually) wealth accumulation across generations. This age distribution in the Project counties suggests, among other things, that farmers and ranchers who lose their ability to make a living on their land may be (or feel they are) too old to find other occupational opportunities. Another fear is that families with children are leaving the area because parents are unable to find jobs. With the loss of students comes loss of funding for public education.

We found that this demographic characteristic is of concern to community members. Apprehension was expressed regarding the ability of aging farmers and other affected community

Table 3. American Indian and Hispanic populations in Klamath Reclamation Project counties, 2000.

	American Indian		Hispanic		
	County (%)	State (%)	County (%)	State (%)	Migrant workers (estimated)[a]
Klamath County (OR)	4.2	1.3	7.8	8.0	~200
Modoc County (CA)	4.2	1.0	11.5	32.0	662
Siskiyou County (CA)	4.0	1.0	7.6	32.0	2,658

[a]Source: *Migrant and Seasonal Farm Workers Enumeration Profiles Study,* September 2000. Health Resources and Services Administration (http://bphc.hrsa.gov/migrant/enumeration/enumerationstudy.htm). Includes seasonal and migrant workers; excludes those working with livestock, poultry, and fisheries.

Table 4. Population 45 years and older in Klamath Reclamation Project counties.

	1992		1997		2000	
	Population 45+	% of total	Population 45+	% of total	Population 45+	% of total
Klamath (OR)	21,199	34	24,530	36	16,041	25
Modoc (CA)	3,933	36	3,961	38	2,771	29
Siskiyou (CA)	17,157	38	8,192	38	20,643	47

Source: U.S. Census 2000; Bureau of Economic Analysis (http://www.bea.doc.gov)

members to retrain for new jobs or to find alternative employment if farms or ranches were lost. One 50-year-old farmer told us:

> "It's very, very frustrating when you read career-oriented materials. Bachelor's degree, master's degree. For God's sake, I've got to go to school 3 more years to get there. And, who's going to hire somebody who's in their mid-50s? I guess realistically the only chance you've got in most cases would be somewhere in the public sector. There's very few private enterprises that are going to hire someone that old because how long are they going to get to use you?"

Older farmers were also discouraging their children from going into farming. One farmer told us:

> "I have a son that was kind of wanting to go into farming a few years ago. And he's 22 now, and I love farming, and it's a fantastic life, and I wouldn't want to change unless I absolutely had to. But he was wanting to go into farming and I sort of discouraged it. Because the situation, the way things were going around here."

Another concern related to the aging population is its reliance on farms and land to provide retirement funds, either through a leasing arrangement or outright sale. Without water for irrigation, the values of farms have declined, and few people are willing to take on a farm or ranch without water. One of our participants told us about an elderly family in the neighborhood. The husband has farmed all his life, on a small farm of less than 200 acres.

Table 5. Per-capita income for Klamath Reclamation Project counties.

	Per-capita income ($)		
	1992	1997	2000
Klamath (OR)	15,968	19,485	20,886
Modoc (CA)	15,913	19,054	21,427
Siskiyou (CA)	16,658	19,898	21,092

Source: U.S. Census 2000; Bureau of Economic Analysis (http://www.bea.doc.gov)

> "They are at a position where their acreage is too small to warrant drilling a well. They don't have any extra finances; they're living off their savings. All they have is their home and their property. And that's what their retirement is. That's what they've worked their whole lives for, for the land."

Income and employment

As shown in Table 5, per-capita income continues to grow in the three Project counties, although in 2000 all three lagged behind the average per-capita incomes of the country as a whole ($21,684). The California counties lag behind the average per-capita income of that state ($22,770), but Klamath County per-capita income is slightly higher than the average for Oregon ($20,718) (U.S. Census Bureau 2001).

Table 6. Unemployment rates for Klamath Reclamation Project counties.

	1992 (%)	1997 (%)	2000 (%)	Jan.–Oct. 2001 (average, %)
Klamath County (OR)	10.2	9.8	8.1	8.7
Oregon total	7.5	5.6	4.9	5.7
Modoc County (CA)	11.1	11.5	8.3	6.4
Siskiyou County (CA)	15.0	12.0	9.5	8.3
California total	9.1	6.3	4.9	5.0
United States	7.5	4.9	4.0	4.6

Source: U.S. Department of Labor, Bureau of Labor Statistics (http://www.bls.gov)

As shown in Table 6, average unemployment rates typically are quite high in the Project counties compared to unemployment rates at either the national or state level. This may reflect disinvestment over the past decades in resource industries such as fishing and timber, both of which were major employers in the region.

The Klamath Tribes report that about 60 percent of tribal members live below the poverty line, and tribal "unemployment is six times the level for the rest of the Oregon population" (Klamath Tribes 2001).

The seasonal unemployment pattern for all three counties is similar. Unemployment rates are highest during the months of December, January, February, and March. Then, rates start to decline through summer (June, July, and August), after which they start to rise again. This cyclical pattern, common in areas dominated by a farming economy, has held over the past decade, even during years such as 1992 when average unemployment rates were very high. Interestingly, unemployment rates in the three Project counties began the year high as usual in 2001, but continued to decline over the year, with no upturn at the end of the growing season (U.S. Bureau of Labor Statistics).

Social service use and provider impressions

We wanted to determine whether there were changes in the types or amounts of social services requested by and/or provided to community members in 2001 as a result of the irrigation curtailment. We started out to collect information that could be used to document changes over the past decade (1992–2001), which saw drought years as well as years with normal amounts of precipitation. Unfortunately, we found that few data have been collected consistently by social service providers. For those groups and organizations that did collect data, it was common to find that collection methods had changed sometime during the decade. Thus, it was difficult to compare data from 1992, for example, to more recent information. More information about social service delivery may be available for analysis if more resources are available to recalibrate the data.

We decided to combine the available data with interviews with service providers to present a snapshot of the impressions and concerns about social service needs in the Project counties. This information should be used cautiously because the figures cited below are mostly provider impressions of the current situation.

Difficulties in finding reliable data are exemplified by the data provided by the Klamath County Mental Health Department. The current system for data collection began in 1997, although data for that year cover only the period from February through December and include only information about adult outpatient services. No subprovider information is included. (Subproviders are professionals to whom patients are referred or who contract to provide specific services at the Mental Health Department.) The 2000 and 2001 data, on the other hand, include all services provided by the Klamath County Mental Health Department, including those of subproviders. Therefore, it is impossible to compare current data with the 1997 data in order to detect changes.

The information, however, can be valuable in helping to get a sense of how residents of the Project counties understand what is happening. No rigorous methods were used that would allow us to indicate whether the drought and subsequent water curtailment were responsible for increased problems and/or social service usage. The past year has been stressful for the entire nation, with the contentious and prolonged Presidential election, the economic downturn, and the September 11, 2001 terrorist attacks. All of these events are likely to have contributed to the social consequences observed by our respondents, and it is impossible to untangle the effects of various events.

Due to the difficulties in collecting information in the three counties, we present, for interest only, an example of changes in the amount of mental health services provided in Klamath County. Information about some of the services provided by the Mental Health Department during 2000 and 2001 is shown in Table 7. Because the data for 2001 were for January 1 to October 1 only, we extrapolated the data to the end of the year, assuming that service levels would stay the same. We recognize that this assumption may be flawed.

While these data must be considered cautiously, it seems that there was an increase in 2001 in services for crisis screening and precommitment investigations. Other services, including family and individual therapy, declined. In similar circumstances with timber

Table 7. Changes in a sample of services provided by the Klamath County Mental Health Department.

	2000 service count	2001 service count[a]	Change in service (%)
Assessment: Determination of need, concluding with diagnosis	1,177	1,069	–9
Referral screening: Assessment for referral to non-mental-health services	193	212	+10
Crisis screening: Assessment of immediate need and provision of intervention treatment	694	1,067	+54
Precommitment investigation: Services for determining commitment to Mental Health Division	441	610	+38
Family therapy: Planned treatment for a consumer that includes family participation	831	761	–8
Individual therapy: Planned treatment for a consumer	3,507	2,419	–31

[a]Using the information available through October 1, 2001, we extrapolated the data through the end of 2001 by assuming an equal level of service each month.

Source: Klamath County Mental Health Department families, researchers have found that families were reluctant to use mental-health services even when jobs were lost and communities faltering (Sturdevant 2001).

In addition to providing data, staff at Klamath County Mental Health talked with us about what they were seeing in their day-to-day practice. They told us that one of the big differences in 2001 was the amount of support Mental Health provided to primary-care physicians in the community. They have consulted with physicians so that affected families could be served by the doctors with whom they are familiar and comfortable. One staff member told us:

> "[The] most affected by the water crisis were those not eligible for the Oregon Health Plan due to land and equipment holdings. They were experiencing increased stress and anxiety, needing an [antianxiety] drug or sleep medication, not a referral or treatment by the Mental Health Department."

Mental Health Department staff recommended that we talk directly with the primary-care physicians working with families and individuals in the area. Thus, we asked a family practitioner to describe what he saw happening with his patients. He reported a 70 percent increase in the number of patients he saw during the summer of 2001. The predominant complaint, he reported, was depression. He estimated that prior to the summer of 2001, about 1 in 15 of his patients experienced depression; in 2001 it was 1 in 3.

In addition to depression, he reported a long list of ailments that he attributed to stress in the community, including heart attacks, kidney infections in adult men (uncommon and stress related), approximately three times more hypertension than a year earlier, five cases of bleeding ulcers that led to surgery, and elevated triglyceride and cholesterol levels in people working on the water issue. He also told us that he knew of 14 or 15 divorces since June 2001, two suicides in late winter and early spring 2001, and three heart attacks that he felt resulted from events related to the water curtailment.

We also talked with another health provider in a small-town clinic, who reported that overall client numbers were down at her clinic. She told us that she knew of at least 50 families, mostly Hispanic, who had left the area. She had not experienced the same increase in stress-related services as reported above.

The Klamath Crisis Center/Harbor House provides shelter for women and children who are victims of domestic violence. Because 2001 was their first year in operation, they were unable to compare service delivery with previous years. The Center Director reported a general increase in depression and anxiety-related after-hours crisis calls over the summer and into fall. The shelter (Harbor House) was full during June, July, and August, with 32 women and children in residence. September and October occupancies, however, were down.

The Executive Director of the Klamath Youth Development Center was able to give us information about service provided during

Table 8. Services provided by Klamath Youth Development Center in selected months of 2000 and 2001.

	Total appointments		Emergency calls		New referrals	
	2000	2001	2000	2001	2000	2001
March	1,441	1,782	12	29	65	79
April	1,460	2,350	17	23	67	104
May	1,513	2,348	13	29	79	127

Source: Klamath Youth Development Center

Table 9. Total offenses in Klamath County (not specially arrested or cleared).

	1992	1997	YTD[a]
Crime against person	763	969	424
Crime against property	2,251	3,353	1,210
Behavioral crime	1,476	2,260	918

[a]Year-to-date is for 6 months (January–June 2001).

Source: Report #DRI NO-ORO180000, Oregon Uniform Code Reporting (includes Klamath County Sheriff, Oregon State Police-Klamath Falls, and Klamath Falls Police)

Table 10. Total reported crimes and incidences for Merrill and Malin, Oregon.

	1992	1997	YTD[a]
Merrill	49	140	73
Malin	NA	21	15

[a]Year-to-date is for 6 months (January–June 2001).

Source: City Recorder for Malin; Merrill Police Clerk

March, April, and May in both 2000 and 2001. As displayed in Table 8, all categories of service increased in 2001, compared with 2000. Emergency response calls, for example, more than doubled in both March and May 2001. The Director said he believed that "these increases are a result of the water crisis, although I have no real proof to support the claim."

The Director of the Klamath–Lake Counties Food Bank told us that between July 1 and September 30, 2001, 3,200 households received food assistance 1 to 3 times. However, an additional group (1,025 families) received food 1 to 4 times per month. The Director speculated that the increase was due directly to the loss of agricultural jobs or a cutback in work hours resulting from the irrigation curtailment. She anticipated continued increases as winter heating bills began taking a larger portion of family incomes.

The Migrant Education Service for Modoc and Siskiyou counties reports that there were 290 participants in Migrant Head Start in 2000 and 178 through November 2001. All families in her Head Start program had been in the area for less than 3 years.

As shown in Tables 9 and 10, crime rates in Klamath County and the towns of Merrill and Malin were not significantly higher than in the past decade. If we assume that we can double the rates for 2001, since we have data only for the first 6 months, crime rates would be lower than those for 1997 in Klamath County and only slightly higher for Malin and Merrill. This conclusion is supported by staff at Tulelake City Police and Klamath County Sheriff offices, who commented that they thought crime rates were down.

As described above, some of these data are anecdotal, and others are difficult to compare across time due to missing and inconsistent information. Also, some of the consequences that people attribute to the water situation occurred before April 6, 2001. In the future, with more data and/or time to reflect, people may reattribute consequences and effects that they currently attribute to the decision to curtail water deliveries. For the time being, however, almost all of the service providers who talked with us or provided information reported an increased need for their services. "Real" or perceived, the needs were felt as real at the time, and that reality is what providers use to understand the current situation and make decisions for themselves and their organizations.

These social service providers were anxious not only for their clients, but also for their organizations and groups. They were concerned about continuing to provide services to everyone who needed them. They worried about staff "burnout" from increased workloads and/or anxiety associated with community responses to the water situation. One exception to this trend was the concern we heard from some educational services that reduced numbers, and subsequent reduced funding, would affect their ability to provide services.

Table 11. Benefits and programs of the Klamath County Farm Bureau.

Member benefits	Programs
Insurance programs	Young Farmers and Ranchers
Credit card	Leadership Farm Bureau
Telephone discount	Rural health and safety
Prescriptions/eye care	Ag crime—R.I.P.
Travel and entertainment	Ag in the Classroom
Vehicle discounts	FELS Labor Service
Labor/employer services	Scholarship Foundation
Ag trading on-line	Photo contest
Accuweather	Food check-out day
Industrial supplies	Water quality program
Citizens Network for Foreign Affairs	

Source: Klamath County Farm Bureau

Social capital

For many reasons, life is easier in communities where multiple social organizations create networks and trust as people work and play together. Examples are civic and religious organizations, bowling leagues, reading groups, Little League, and soccer teams. These and other types of involvement with others in the community can create a dense web of relationships that cross political, economic, and ideological boundaries. It is believed that these informal relationships are critical in helping to develop strong and vital communities.

By analogy to physical and human capital, some people call this notion of networking "social capital" (Putnam 1995). All three forms of capital are believed to enhance individual and community productivity and effectiveness in solving problems.

A brief assessment of the traditional forms of social capital revealed a large number of churches, most with energetic congregations, in all communities affected by the water situation. There are 7 churches, for example, in the Tulelake and Newell area, 3 in Malin, 4 in Merrill, and 58 congregations in Klamath Falls.

Traditional networking opportunities for farmers also appeared to be working in the area. For example, the Grange in Tulelake and the three Granges in Klamath County provide benefits such as insurance programs, credit cards, and support for legislative action. The Klamath County Farm Bureau, an advocacy group for farmers that is connected to the larger Oregon and American Farm Bureaus, also provides multiple services and programs as shown in Table 11. For example, the Farm Bureau provides professional services, which are especially helpful to self-employed farmers who have little or no access to these services through other mechanisms. Other types of services provided by the Grange include education activities for farmers and future farmers, community service programs, and even opportunities for members to express themselves artistically through a photo contest.

Other professional associations for farmers and ranchers in the three counties include the Klamath Water Users Association, the Klamath Cattlemen's Association, the Klamath County Cattlewomen, the Klamath Potato Growers Association, the Tulelake Growers Association, and the Tulelake Horseradish Growers Association. University Extension offices in all three counties provide research and education specific to the community's needs.

A community with a robust stock of social capital should be able to respond effectively to challenges that arise. We found that farmers, ranchers, and other community members were able to organize several responses to the drought and subsequent water curtailment. Community members created a Web site that became a clearinghouse for information, on-line discussions, and notices of meetings and other gatherings (http://klamathbasincrisis.org). More than 300,000 people have visited the site since April 26, 2001, when it went live. The Klamath County Chamber of Commerce established the Klamath Ag Relief Fund in April 2001, raised about $34,000, and is distributing funds through various programs such as Operation School Belle, which purchases winter clothing.

In August 2001, the Klamath Relief Fund was formed and registered as a Nevada for-profit corporation doing business in Oregon. Fund organizers say they have plans to convert to nonprofit status. They have collected donations through auctions, relief convoys, and a $15-per-plate benefit dinner, raising about $300,000. About $1,000 was spent fixing a pump, and the rest is in accounts for distribution to farmers.

The Klamath Water Foundation was formed in August 2001 with the objective of uniting the agricultural, retail, and other community entities. The Foundation is made up of various specialized departments, such as communications, education, political awareness, and the environment, each chaired by a Klamath County resident. The departments offer opportunities for community members to participate in various activities. The Foundation is seeking formal certification as both a nonprofit organization and as a political action committee. This organization has raised about $50,000 for pursuing legal cases involving water issues, supporting a bill for amending the Endangered Species Act (ESA), and assisting County Commission efforts to privatize the water delivery system. The stated mission of the Klamath Water Foundation is to "enhance productive coexistence among Klamath Basin water users, to sustain traditional livelihoods, and to protect the local communities, economy, and environment."

Another group, the Farmers Against Regulatory Madness (FARM) collected donations primarily at the head gates and through direct solicitation of area businesses. Finally, the Tulelake Growers Association raised $42,300 for relief and assistance to farmers.

It is obvious from the donations collected by these various groups (more than $400,000 at the time of publication of this report) that individuals in the Upper Klamath Basin and elsewhere want to support farmers. The rapid response of group organization and fund-raising suggests that the farmers had an existing tight network of relationships that enabled them to respond quickly as the situation changed throughout the spring and summer of 2001.

For some other groups, particularly the Klamath Tribes, it is apparent that social capital is not as present and accessible. In comments following release of the initial draft of this report, tribal representatives mentioned many consequences of the steady decline over the past century in the natural resources upon which the Tribes have traditionally relied. They described effects on economic well-being, family and social relationships, physical well-being, and spirituality. Moreover, they mentioned that the nature of their social networks has changed, resulting in tenuous support in their community and churches. The comments below show how the loss of traditional gatherings, where people could work, talk, and play together, affected the cohesiveness of families and the community. For example, the gatherings for fish harvest brought people together and helped

> "to pass on life ways and traditions to the next generation. It was a time for feeling the connection with untold generations who had gone before us, and to know that future generations would feel the same connection to our people and to the earth…. This is an important problem at the family level. Families no longer interact with each other the way they used to…. It is also a problem in our churches. In our community, the churches have always been places where our people talked about the Tribes, where we are going as a people, and what we are trying to do and to accomplish. It is

> difficult now to have those discussions because many people are very skeptical, even cynical, about the likelihood of rebuilding our fisheries.... This has caused the church to evolve into a different role in the community, providing a spirituality more detached from our traditional values and the resources on which we depend. People are unfamiliar with this role, and as a result the ability of our churches to serve the people is diminished."

Social capital that can help communities respond effectively to challenges and opportunities relies on the construction and maintenance of informal networks, relationships, and gathering places. It is through these forums that neighbors learn to count on each other, experience and retell the stories of their lives, and create relationships to which they can return in times of trouble.

Project-area farmers seem to be reaping the results of years of helping and knowing each other in multiple networks; they came together quickly and energetically. The Klamath tribal experience suggests that when gathering places and/or reasons to gather disappear, the networks and relationships that create social capital also begin to disappear or need extra effort to sustain.

Personal, family, and community consequences

As described above, we talked with nearly 70 people living and working in the Project counties to find out how the decision to halt water deliveries to many Project irrigators was affecting them, their families, and their communities. As always occurs when talking in-depth with people, we found complex experiences. People were only beginning to learn what the long-term consequences might be for themselves and their community. We found that an individual's descriptions of experiences and perceptions were contradictory from moment to moment and inconsistent in the retelling, but always painfully raw.

In addition, as Project-area residents began to adapt to new circumstances, the tragedy of September 11, 2001 took the area off the front page of the country's newspapers and turned the attention of many of the people we talked with to other concerns. It is within this context that we discuss our findings from the interviews and focus groups.

After reviewing the transcripts of our conversations, several themes emerged that helped us organize participants' experiences and perceptions. In order to tell the story of the participants' experiences, we use their own words when appropriate (always concealing their identities). In other cases, we develop a summary with information from multiple people. The extent and strength of the responses is described only qualitatively. Unless noted otherwise, we use the word "community" to refer to the entire area supported by the Project because this is how our participants used the term.

We want to reiterate that participants' responses were complex, and this summary cannot do justice to people's experiences. We hope, however, to capture the wide range of experiences and perceptions they described by juxtaposing the contradictions and conflicts in their stories. We hope this will let the reader sense the difficulties our participants had in talking about, explaining, and understanding what was happening. Our report represents the perceptions of participants and does not assess the accuracy of those perceptions.

Community support and community polarization

In addition to the traditional social consequences caused by a sudden change in economic and/or environmental conditions (for example, changes in employment, population, and income), many participants talked about the farmers' response to the decision to curtail delivery of water. Their highly visible strategies for publicizing the irrigators' situation rippled throughout the community, creating strong emotions that were entwined with concerns for the farmers themselves.

A sense of support

When first asked how the water situation affected the community, many participants told us that it had brought the community together. A service provider described the unity she saw in the community during a public rally:

> "You saw, if you were at that rally, 6,000 of us were at the fairgrounds. Where and when have 6,000 of us ever gathered for anything? Short of giving away money, you aren't going to get that many people anywhere."

Highly visible and publicized actions such as the bucket brigade and turning on the water at the head gates suggested to this woman and others that there was a strong sense of community, unity, and support for the farmers.

This theme was illustrated in other ways as well. For instance, a farmer told us that

> "the one positive thing, if there is something, is that it has pulled the whole community together. There's been a lot of support from Klamath businesses…. I think it has always been there, but [I] just wasn't aware of it. When they started shutting off the water, people came together; I mean, the letters to the editor were 99 percent pro ag. A lot of them were not from farmers in the Project area. If it's someone local, you recognize the name, there were people we didn't even know that were supporting us."

Another farmer noted that he was surprised by the support "we got from Eugene, the liberal capital of the world, up there with Berkeley." He cited the positive press in the Eugene *Register-Guard,* along with articles in the *New York Times* and the *Sacramento Bee,* as evidence that "it's finally waking some people up to what's going on in this country."

Another respondent described the 4-H livestock sale in 2001 as an example of public support. People thought that the annual sale would be very low because of the water situation; instead, it had a record year, with a high number of sales and high price per pound for the heifers raised by members. A Klamath Falls business owner told us that this was "because people want to show support for that community and make sure it continues."

This support also was shown by directly helping one another. A small-town business owner told us that in 2001, "where I live there's been more help when you're working cows; there's more help there [if needed] like driving a truck in the spud field or jump[ing] on a hay rake or something." He believed this indicated the strong support between families, friends, and other businesses that came together to help each other.

Another Klamath Falls business owner described how the water issue was considered "just a farmer problem" in the spring. Then, with public-relations activities such as newspaper articles, the bucket brigade, and other community-wide programs, it "very much became a community problem. And it kind of pulled everybody back together."

While a federal/state agency worker who had lived in the area for 6 years did not describe the events as pulling community members together, she did believe that the "incredibly small community—people that lived here all their lives in a very intertwined network—saved us from escalation."

A sense of division

Only slightly below the surface of descriptions of a community coming together were divisions that continued to erupt throughout the interviews. These ranged from tension in long-term relationships to highly polarized and confrontational incidents between farmers and conservationists, farmers and state and federal agencies, farmers and tribal members, and/or farmers and farmworkers.

One of the major issues described by our respondents was their concern that framing the issue as "farmers vs. fish," "farmers vs. Indians," or "farmers vs. feds" had oversimplified the situation and created a sense that others were "out to get the farmers." Conservationists, Native American tribes, and federal and state agencies have all been blamed for the current situation. This created a tense environment for many residents who might support the farmers as members of the community, but hold other perspectives as well. Members from these groups told us that people who became especially vocal in their support of the farmers and ranchers had silenced their own voices and concerns.

For others, the racism that they believe lies mostly below the surface of social life in the Basin emerged as some framed the issue as "Indians vs. farmers."

While each of these issues is discussed in more detail below, a service provider's joking comment about his family is a description of the tensions in the community.

> "My family is all over the board and isn't very tolerant of each other. My [kids] go out on the bucket brigade. My wife is [an ethnic minority] and a liberal Democrat. She says,'Why are the farmers doing all this griping, what about the laborers? They are the ones that were slave labor in the first place. The farmers got property money. What about those immigrants?' And I'm a maniac. I think that we [should] organize and take over the state and feds [agencies]."

Farmers: There was friction among farmers themselves over who received water in 2001, who received drought assistance, and who was willing to sell land. For some residents, the perception of a farming community under siege was evidence of a conspiracy to rid the West of all farmers.

While farmers could describe and appreciate support from the larger community, they found that the relationships among their professional colleagues—both farmers and nonfarmers—were becoming weaker, leaving them isolated from other people, news, and events. It was common for farmer participants to note a loss of sense of community. For example, one farmer from the Merrill area described the situation as follows.

> "People just don't go out and socialize in any venue. They have just disappeared. And when you talk to them they look down a lot. They don't have a lot to say. And these were formerly talkative people, people you might see in the coffee shop every morning … and they're not conserving 75 or 80 cents of a cup of coffee. It's just, it's a little bit of shame, anger, I don't know."

Two other farmers echoed these concerns.

> "People are just not as friendly. You know this is a small town, everyone knows each other. Everyone talks to everyone else; now people just don't talk, they don't go out and socialize, don't go to festivals like the Potato Festival. It's been an annual event for 60+ years. I didn't even go this year."

> "Every other weekend someone would be having a party or barbecue. You'd go over and have a few beers and cook a steak. I don't know that I went to one barbecue all this summer. Nobody wants to socialize, there's nothing to celebrate."

While most farmers told us that this retreat from socialization was to be expected as people dealt with their problems individually, we heard that differences with the potential for polarization were emerging in the farming community itself. One farmer was concerned that "people will get upset because I've got a job … will they start looking at people who are maybe a little more insulated maybe as much by dumb luck as anything?" He described this feeling as "a big cloud hanging over the community."

Another farmer told us that the "willing seller issue" had divided some people. He and others described the tension felt by individuals who would like to sell their farms and leave, yet felt they were somehow betraying the community. He said that he didn't "even want to talk about that with anybody unless I know what their way of thinking [is]. Because there's been a lot of bad situations in the Basin because of that." Another farmer provided more detail about these concerns.

> "So if you do sell your ranch out to the 'willing buyer,' you wouldn't have the community to keep business open. If we lose two or three of these businesses, where do we go for parts? You can't blame the farmers for wanting to sell out, you know, if the money is there and [there is] some way of getting out of this thing. But what does the rest of the community do? It's just a domino effect. Even if they get out, they're not going to spend their money here. They're going to go somewhere else and spend it."

One more farmer said that she "didn't know the whole story behind every single person that wants the buy-out. But I resent the government wanting to spend money for a buy-out."

Participants also talked about the tension emerging as they continued participating in civil disobedience and planning meetings, while at the same time maintaining their farms and ranches and living their lives. One participant told us that "all of a sudden you have to go bale hay, and I took a lot of criticism for leaving, they wanted me to stay at the head gates and help them." Another described his life as follows.

> "You're on all these committees you make a commitment to. Then they turn on the water and you have to get out to the farm to take care of things, equipment and stuff for 3 weeks, trying to generate a few dollars. For a while, all I did was meetings, that was my job. Got all these commitments and plus this other job, there are only so many hours in a day. …How do I balance this out and then, oh yeah, I forgot I had a family, where do they come in?"

Another farmer also reported that he was starting to see that the pressures on farmers involved in planning and organizing were becoming less appreciated by some

> "who have less tolerance with some of the organizations because they're not getting anything done. We want to see them doing everything they can. And the people in the organizations are just starting to get really burnt; they're just burnt out. They meet two, three, four times a day, every day…. And there are a few that are moving away and just not going to the meetings and just complaining like most other farmers do most of the time."

Conservationists: Community members who described themselves as conservationists had concerns as well. All but one of the participants in this group had resided in the area for at least 20 years. The concerns shared by this group about media bias can be summed up in the words of one participant: "There is an assumption that everyone in Klamath Falls feels this way and that it is fine to put down a big bucket in front of the courthouse and that it represents all of our feelings." A common response of these participants is a sense of embarrassment about these actions, illustrated by the following quote.

> "I guess I knew that this was a small community and a very conservative community. At the same time there are a lot of people here who are more broad minded. So when I see the signs on the highway [criticizing the decision] and I know a lot of people coming into Klamath Falls are seeing that, I am embarrassed.[1] I know there are a lot of people here who don't feel that way."

This embarrassment also extended to feelings about the local media, who were described

[1]During our trips to the area, we observed roadside signs expressing concerns such as "New Addition to the ESA: Tulelake Farmers," "Stop Playing God—You Don't Qualify," "An Opinion is Killing our Communities," "No Water, No Barley, No Beer," and "Federally Created Disaster Area." We also saw many signs that were more restrained, including "73 Years of Water Until Now," "Where Water Flows, Your Food Grows," and many creative versions of "Support Our Farmers."

as presenting biased and one-sided information about what was happening. One participant told us:

> "I resent the image the media created, and you had to go outside of the Basin to get balanced representation of the real problem and what the impacts were. Personally, this was the first time in my 30+ years of living in the Basin that I considered moving away … the local media feeding the idiocy, the poor law enforcement. It makes us look ridiculous and I really resent that."

Several members of this group also talked about their fear that violence could erupt during public rallies or during heated conversations with farmers. One told us that she felt

> "a real sense of being afraid in my own community. I [need to] go by the head gates every day as I ride to work. [I'm afraid that they might think that] 'someone on a bike must be against what I have to say.' Watching the Sheriff not enforcing laws … city police not enforcing laws. So I feel unprotected and that has not happened since I lived here."

Another told us that she would never go near the head gates, worried that someone "might be firing a gun around there."

Another member of this group went to the head gates for the first bucket brigade and was surprised at the talk of violence. He heard people name specific conservationists, who they claimed would be hanged if they came down the street. He had the sense that his farming community friends, whom he described as "wonderful, you can't find bigger heart[s]," would participate in a lynching if prominent and active environmentalists ever showed up at a rally.

A conservationist we talked with during a one-on-one interview described how the polarization with the farming community led to, in his words, a "completely ridiculous" outcome.

> "[An employee at a state agency] was [head of the sailing club] this year. It got so far out this year, that they were accusing him of holding back water in Upper Klamath Lake, so he'd have enough water to sail his boat. You know, it is completely ridiculous, but you know it makes good press: self-serving agenda as [head of the sailing] club. And, not only that, the farmers say, 'Oh well, you guys aren't supporting us, all you care about is sailing your boats.'"

None of the conservationists we talked with was happy about the situation in which farmers found themselves. Almost all described themselves as having many friends who had farms and ranches, and they knew of the trouble farmers were having. Furthermore, some were at least as disappointed in the agencies responsible for managing natural resources as the farmers were. One told us that he was

> "ashamed of our agencies. Like I mentioned earlier, I was involved in some of the same agencies which helped created this problem. We were talking about how not to let this happen, and here we are 20 years later and haven't done that. So I have little empathy for these agencies being in the hot seat right now."

Yet, to a person, the conservationists who participated in focus groups and interviews believed that any solution would have to involve the consideration of multiple perspectives, including those of the farmers. They were discouraged, however, that years of friendship and working together on community projects were being destroyed by the short-term actions taken to resolve what they believed was a problem that had been a long time coming.

As one told us, "Even before the water crisis, there's been a long and steady decline in the ag economy for reasons way beyond the water issues. You know, the consolidation of multinational corporations, the grain cartels, NAFTA [North American Free Trade Agreement]. The ag economy isn't what it used to be." He was concerned that after years of working with community members to find solutions for allocation of water, the farmers' desperate response in 2001 would create irreparable splits with others interested in resolving the region's problems.

Indians: Framing the issue as "farmers vs. Indians" revealed a strain of racism that usually ran "quietly beneath the surface," as one farmer said. Members of all focus groups noted incidents where tribal members were shunned or treated badly, and all disassociated themselves from this behavior. A service provider described an incident related to an annual fundraiser held every year for a local treatment facility. The powwow was designed to

> "honor people in recovery, who have gotten jobs, gotten families back, who aren't doing crimes anymore. And it's 90 percent non-Indian. We go around to corporations and places in town and they donate money—$200 to $500—because a powwow is expensive. This year 90 percent of them said 'no' because 'you're associated with the Klamath Tribe.' Most of our clients aren't tribal members, so what's that about?"

Social service providers, many of whom work with the nonwhite population of the area, described multiple incidents in which their clients were treated rudely or even violently.

Klamath Tribes members described how an intentional decision was made that individuals would stay as far from confrontational situations as possible. Tribal members were advised in the tribal newspaper and through word of mouth to "walk away" from arguments or other tense situations. This may have been what this Klamath Falls business owner was seeing when she described the following.

> "We have a lot of Native Americans that come in to use [this service]. And before they were very vocal when they were standing in line, somewhat loud when they were talking with their friends and around everybody else.... But after this happened they would come and they would walk with their head down, they walked slowly, they stood in line quietly, they didn't talk with other people in line, they looked straight ahead, they were very courteous."

Instructions to remain nonconfrontational were hard on tribal members, according to one of our participants, "because we had guns pulled on us, were run off the road, there was one beating where a guy ended up in the hospital pretty bad." This participant also described an incident that occurred in an elementary school when each student was asked to take a position on the water issue.

> "[When] they finally get to an Indian child in this classroom, because of our prompting and parents telling him 'just stay out of it,' the student said, 'I want to stay out of it, I don't want to have a response.' The teacher told him it was a class project and he had to have a response. And, he said, 'Well, I really don't want to say anything.' The kid was sent down to the principal's office, and they actually expelled the kid from school."

The tribal government intervened, sending a letter to the school asking that the child be immediately reinstated and that this type of teaching be discouraged. The student went right back to school, but tribal members were left feeling betrayed by the portrayal of the problem in the public school.

Tribal members believed they had supported the farmers from the beginning; they had gone to Washington, DC "several times and seen Congressmen, Senators, and other legislative people. We've asked for funding and are trying to come up with a solution. Because we didn't want to see anybody lose their livelihood because we know, we've been there." They also maintained low visibility throughout much of the spring and summer, trying to remain out of confrontational situations, as illustrated by the following quote.

> "Imagine, if you will, what would have happened if there would have been a confrontation? We've had offers from other organizations throughout the

> country, just as agriculture has, to come in the area. This could have become a full-blown civil war in the area, and that's not good for anyone."

The tribal members we talked with were convinced that the relationships built with irrigators through the Alternative Dispute Resolution (ADR) process could be salvaged and solutions could be found. One described how, through the ADR, great strides were being made for the adjudication of water rights, even traveling to Washington, DC to describe to others how well they were doing. He continued:

> "Then all of a sudden the drought of 2001 comes along and that's put everything to a screeching halt. But right now we're trying to pick it back up again. We've had meetings with the irrigators where one of them actually said that 'everything that was built up to this point was gone. We're going to have to start at the beginning again.' I told them, 'Well, I don't know about that. You know, we think we can just kind of pick up where we left off.' It took a little encouraging, but finally they said, 'We can go ahead and things that we've already built we'll just keep adding to that.' We're still trying to work with them as much as we can."

Just as conservationists are willing to keep working with irrigators to find solutions that work for everyone, according to our participants, so are the Tribes. It is important to note that all of the people we talked with are local—they live and work with farmers and their families, and they seemed to see the farmers' problems as their problems as well. As one person put it, "We're never going to have a sustainable community if one component of the community is … in the dumper."

State/federal agencies: Finally, we talked with representatives of state and federal natural resource agencies who work in the Project area, most of them for many years. Many in the farming community held the agencies responsible for their problems because of the decision to halt water delivery for the 2001 growing season. Agency folks we talked with were frustrated by the anger from the farming community because they believed staff had been supportive in many ways over the years. In addition, they were frustrated because

> "to a large degree we have lost what little authority we had. Now it is virtually impossible to do anything without regional offices and/or Washington offices involved. I think that it is frustrating that those of us at the local level have a clearer idea of what the problems are and what the possible solutions are, but have no authority to do anything. It is really out of our hands."

Despite their own frustrations with the agencies involved, local employees of the agencies still described themselves as treated as "outsiders," with hostility, and they were uncomfortable in many public situations. One participant said:

> "You know, you are really reluctant to go out into the community and freely associate with people. You try to avoid situations where the water crisis might come out. I feel reluctant to tell people who I am employed by, what my job is."

Another person described herself as "shrinking" because she was unable to express her own views.

Agency staff members also believed that most of the community remained unheard, and that the voices that *were* heard represented the "more extreme views and certainly [don't] represent the range of views that the community has." Instead, there was intimidation to express only the single view that the farming community "must be made whole."

Many agency staff reported feeling "threatened" as they performed their duties, wore their uniforms, or interacted with the public. They believed that people mostly recognized that individuals in the local offices weren't making the decisions, but "collectively, like at the head gates, you run into problems. Because of mob mentality."

These agency staff perceived that their relationships with the public had changed as a result of the drought and subsequent water decisions. People were asked for identification and frisked as they entered federal buildings, immediately setting up an adversarial relationship. One person described how trust with the agricultural community had been harmed, remembering "the times I used to be able to go out on a guy's ranch," and following up with, "there is more reservation there now." Another claimed that the strategy of keeping farmers at the head gates was

> "just to keep up the image without physically taking over … we have to provide guards, and I imagine we've spent well over a million dollars on protecting the head gates. You stop and think about it—there might be something better to do with that money."

Uncertainty about the future and long-term planning

While all of our participants described a complex and dynamic situation, with many contradictory personal and community experiences, they all shared one way of describing the circumstances—intolerably uncertain and increasingly frustrating. The farmers talked about how not knowing whether there would be Project irrigation water in 2002 only exacerbated the uncertainty inherent in agriculture from sources such as weather, prices, and disease. For those not directly involved in farming, the uncertainty had rippled through social service agencies, schools, state and federal agencies, and local businesses.

Yet, we also heard from farmers and others that this "crisis" was unexpected only in its appearance in 2001. Many already had been planning and working to shift reliance from irrigated fields and the agricultural economy to alternative crops and new business sectors.

Living in limbo

Farmers routinely told us that their greatest needs were water and some kind of assurance that they would receive water consistently. Without that, they couldn't plan, as this farmer indicated: "Usually you have a plan, you know what you're going to do with your operation. You're going to do this and do this and at the end of the year you hope it works out and you've made a little money."

A younger farmer said:

> "[I am] young enough, I have [a business degree]. I've had some offers at banks and different places. They say if I ever want to change careers, come see me. If they would come out and say you're never going to have water again, you're done, then I could move."

He went on to say:

> "Where am I going to be 10 years from now? I don't even know where I'm going to be next year. You can't make any long-term plans right now. When I got out of college I had a plan with goals, knew what I was going to do. This is where I wanted to make my career."

We were told by farmers that without a definite decision about the availability of water they wouldn't be able to make it economically. A Merrill farmer told us that couldn't mean

> "waiting until April 6th for a decision, saying, 'oh yeah, you get some water.' I mean, planning and planting takes a lot of time. You don't decide to do this tomorrow. It's a 6-, 8-, 10-month lead time for an individual crop."

Some business owners, especially those in farm-related businesses, saw a decline in their business in 2001. They, too, were unsure how to plan for the future, how much inventory they should stock, how long they could hang on to employees. One Klamath Falls business owner mentioned, "I think people are pretty nervous about how to spend, how to plan for their business futures, and then I think personally people are really nervous too because there's a lot of people out of work." An outdoor-sport-related business owner affected by the water decision wondered whether to make other arrangements for other parts of the state.

Finally, a business owner wondered, "How easy will it be to attract new industry here if you don't know if you can keep an educated workforce?"

The business owners in the small towns of the Project area were more unsettled about the future than were the Klamath Falls owners. As the small towns have relied heavily on the agricultural industry for years, any downturn in that sector will affect them quickly. They were concerned that the true effect of the season without water would only be seen the following winter. One business owner pointed out:

> "There's a lot of people right now that aren't doing too badly because they still have the income coming from last year's potato crop. So they have income and they don't have the outgo of cash that they would have had to plant this year's crop. But when they run out of that money, then this community is really going to feel it. They've all cut back trying to conserve this money and stretch it as far as they can, which has hurt the business community. But when that money's gone, then we're looking at real big problems."

A farmer explained further why many effects would be delayed until the following winter:

> "In this business you grow crops in one calendar year, and 75 percent of that is sold in the next calendar year. So your income comes a year later. All our income from last year, 75 percent comes in this year. We didn't operate our farm [this season] so we don't have the fertilizer bills, the rent payments, the this and that, all the ongoing expenses to offset the income, so we're looking at bankruptcy and possibly a $200,000 tax liability. And no way to generate any money to pay any of it. And there was no way to do any tax preparation or planning because you didn't know it was coming."

The social service providers in the Project area also were seeing how the uncertainty had affected those parts of the community that had little voice in the conflict to date—the farmworkers, the unemployed, and other traditional clients of social service agencies such as Head Start, County Health, Mental Health, etc. One service provider from a small community reported:

> "Suicide calls have increased, they want to end life. They feel like they have no choice—'I can't do this anymore.' We bring it around to what they can't do anymore and it is the fear of living in the unknown. Not knowing what to expect. What's going to happen? What's going to happen to my family? What's going to happen to my kids? I can't take care of myself anymore and no one understands."

Other service providers described a "feeling of powerlessness" and uncertainty, a "constant up-in-the-air feeling" for both staff and clients. This was echoed by a Klamath Falls service provider, who said:

> "One of the things that I think we are all affected by personally is what the future has in store for us as far as what we all do if this place is going to become a dustbowl. Do you buy a home? Do you buy a car? Do you do anything if you're not sure what the future has in store? … you just don't know what is going to happen year to year."

Another said that some of her clients were hoarding food out of fear. "They are not using it, they are hoarding it. They want to make sure that they can get through next year."

In follow-up comments from the Klamath Tribes, a similar sense of futile waiting was reported. It was reported that the income and cultural losses due to the closure of the sucker fishery in 1986 were "compounded by our inability to see an end to the problem. Water management that reduces the species' ability to recover causes people to have little confidence that these resources will again become available in their lifetimes."

Not only did tribal members experience these losses on an instrumental level, they personally took responsibility for the decline in natural resources upon which they have traditionally relied, and they felt that they had failed as "the responsible stewards they are required to be." This was a source of additional anxiety and social stress for the Tribes.

Alternative arrangements

Farmers also told us that they had plans for alternative crops, other jobs, and other ways of organizing their farms. Almost all farmers we talked with had alternative sources of income; either another family member worked off the farm, they held another job themselves, or they were experimenting with "value-added crops." One said, "We're not sitting around twiddling our thumbs either, we're probably trying to be as busy and as inventive as we ever have been to find other venues." A Merrill farmer was somewhat typical in his arrangements.

> "I've got a wife who teaches and so I do have some security. None of my children are involved in agriculture…. I'm looking at transportation, trucking, more and more outside seed sources. And I'm trying to grow higher value crops that we can sell elsewhere."

While most farmers were modest about their planning for the future, they were all involved in making choices that gave them alternatives to their irrigated farms. One farmer we interviewed talked about diversifying through different crops. For the past couple of years, he had been looking for different ways to make money. According to him, "that's a given."

Some business owners told us that although their businesses had not been affected by the water situation, they too had been planning for an economy that is not so heavily dependent on agriculture. One shop owner told us that she had been buying carefully but was surprised to find that her business remained strong. She worked with other local business owners to promote a "buy locally" campaign that she believed had been successful. She found that her sales stayed up, and she was

> "almost embarrassed. I was afraid to tell anyone I was doing well here…. You know how people are suffering and things are happening. So I began to talk slowly to other friends and businesses … [and found that] the other businesses … were doing well…. We have people shopping now that I haven't seen before. So there are new customers, not only old customers…. [I'm] making sure that we have items that are like in the $20 and under range … making sure that we can capture the feel-good dollars."

This business owner identified businesses that weren't doing as well, including ag-related businesses, many restaurants, and hair salons. Ice cream, espresso, and gift shops didn't seem to be affected, in her view. She reported that the Small Business Development Center at the Oregon Institute of Technology told her that most local businesses were up, except for a "select few that were down."

Farmworkers

One group of people who had not been able to develop alternative sources of income were the farmworkers, some of them undocumented, who work the fields and harvest the crops of the Project area. All of the workers we talked with had lived in the area for at least 3 years, many for up to 20. They and their families consider this area their home. Some have incomes that are nonagriculture-related, but most rely on at least two family members working in the fields. They told us, however, that there was little work in 2001. Most workers were unemployed and waiting for a change in the situation, or they had left the area to find work.

One farmworker described how the foreman of the packing shed where her husband worked said, "They were [told by the farmer that he was] gonna pay them as if they were still working. That'd be about 20 hours a week, that they were gonna pay them that … but there's never been a check that they've gotten." Another person in the group continued the story:

> "As an owner I think he would feel terrible [for not being able to pay his workers]. So you might say something stupid like 'I'm going to pay you.' [But when the workers didn't get paid] it felt like they were playing a joke on them. It's a terrible thing because then you plan. 'Whew, I'll have some work.'"

Another participant finished the story, "This farmer got money, they gave him money for not planting because there was no water. But the workers got nothing."

Some of the farmworkers qualified for unemployment, although assistance ran out early in the season. Workers with children born in the U.S. were eligible to receive about $80 to $100 a month in food stamps for a family of four. Undocumented workers received no assistance beyond that provided by nonprofit service agencies such as local food banks. When asked what they needed, one farmworker said, "What we need most of all is work. Because when you're not working, you feel sick."

The role of information

While all participants agreed that information was needed, there was little agreement about what constituted "good" information that could help move conversations and decisions forward. There was almost unanimous disapproval of the way the media had handled the situation, although some claimed the media were too biased toward the farmers and others claimed the farmers weren't getting a fair shake.

One farmer learned through personal experience not to believe everything he read in the paper or heard on the news. He told us about attending a hearing with Congressional representatives, listening carefully, and taking notes. "And then you see an article in the paper by an individual that you know is pro the other side, and it was as if he had been at a completely different meeting."

Others were highly critical of the media for sensationalizing the situation and leading to more polarization. One agency staff told us that she thought "the level of attention has not been equivalent to the amount of adverse effects; that it has been a lot of hype." She believed the media language prevented people from coming together to find a resolution.

Many respondents reported getting calls from family and friends outside the area concerned about their safety after reading or hearing reports in the media. A farmer told us that his brother-in-law flew in over Upper Klamath Lake and couldn't believe what he saw. "From everything I've read in the paper, I thought the lake was dry."

The decline of the suckers was serious enough that the Klamath Tribes stopped harvest on the lake in 1986, 2 years before the fish were listed under the Endangered Species Act. A tribal leader described the type of information needed to restore the system.

> "We need some tremendous studies on the system itself and to start doing some restoration work from the headwaters to the ocean. It's a massive task. We used to have salmon runs before the dams came in and we lost those you know…. We need studies done on the full aquifer system, from the headwaters to the ocean. We need studies on the terrestrial system, what effect logging and everything has had on the watershed and how to do some restoration work for wildlife…. We need to get the studies first for comparison and begin on how to do some restoration work."

We heard that farmers in the area believed that much of the science had been done and only needed to be applied. They echoed the call for good information. They expressed concern that some decision makers listen only to science that supports their agendas and ignore other data.

One farmer told us that he believed the federal agencies

> "are not looking at all the facts that are available. There are a lot of noted scientists out there, some of them work right up here at Klamath Falls, world-renowned even we've got. I mean they know their business. They've presented it to the Fish and Wildlife at some of those meetings we had last winter on those suckerfish. And they just disregarded it. They picked out what they wanted; they just disregarded some very pertinent information on studies that have been done on suckerfish up here for years."

Another farmer told us he believed that "most everyone in the county is capable of making an intelligent decision on something if they have all the facts." There seemed to be great frustration that science had been unable to provide "facts" that would allow water allocation issues to be resolved. Challenges to the science used to make decisions were common, and challenges to scientists' credibility were frequent.

Farmers would like their own local knowledge and experience to count for more in the decision process, "because we live this and we know that some of this stuff is just outright boldfaced lies." Conservationists have challenged the data provided by both the agencies and the farmers, while the Tribes have been collecting their own data all along. The National Academy of Science met in November 2001 to review the science behind the 2001 Biological Opinions, but farmers we talked with were convinced that this review would be the "same old, same old," and that no academic scientists would be challenged on their findings.

> "You get people all pumped up about that [the NAS review] until you find out who is on the review committee. Same old people, same old science, same old answers. They say, 'Oh no, you'll get a fair review.' Bullshit."

When the media are suspect for sensationalizing the news, and science is suspect for not being able to solve community problems, people end up with no shared understanding of the world. Their disagreements are amplified by any lack of common explanation of what is happening. One result is that some farmers and business owners interpreted actions and information about the agencies' decisions as additional evidence of a conspiracy to "save the West from being developed and growing food out here and turn this into huge wetlands."

A general distrust of government was expressed by many of the participating farmers, business owners, and social service providers. Whether the current situation created or enhanced existing feelings is difficult to determine. One farmer told us that the "general feeling in the Basin is betrayal. And our government is doing nothing. Rural America elected the Bush Administration, and they're not helping us hardly at all." He went on to explain:

> "We got the $20 million, but how long did it take them to get that done? Overnight we can find billions of dollars to go to New York. How many flags do you see in Merrill? There are people in Merrill that won't give the Pledge of Allegiance, and I'm one of them."

Getting help

All of the participants we interviewed expressed concern about helping the farming community and others who were not used to receiving assistance. As one social service provider noted, "Food stamps and public assistance really isn't in the vocabulary, especially in the ag community. There is no way." Yet, everyone recognized that without assistance of many kinds, the farmers, farmworkers, and others in the community would continue to be negatively affected.

Farmers, business owners, conservationists, agency staff, and tribal members all described assistance programs available to farmers. One woman described her husband as very successful "with a lot of the assistance programs and the water buy-out programs, the set-aside acreage program." She thought that older farmers might not know how to access these programs, or perhaps didn't use them because of pride and unwillingness to ask. One farmer told us:

> "We've never played government games before. And just in the last couple of years that we've been getting some at all. So now this year is really full bore in trying to get everything you can out of everything… if it wouldn't have been for the government programs this year, we'd be in big trouble."

When asked about support networks, most participants told us that their personal networks were strong, and that support came primarily from family and friends. Very few told us that they had asked for assistance beyond the family. One farmer described how he and his brother had begun to take on more responsibility with their mother because she lost the rental payment from her farm.

> "Social security is not there to support her, pay for insurance, the things on her land, taxes. If the farm is not operating and generating money, she is down to her flat social security check. How does she keep her insurance or the house or car? Right now, we're all here, but if we all leave to find work, she'll be left out here by herself."

Another woman described how she was pitching in to help her son's family by babysitting so that her daughter-in-law could work outside the home.

Agency staff told us that, in general, their offices were close-knit and supportive of each other. One reported, "We have been trying to keep everyone aware of what's happening. That way nobody gets blindsided by some activity." Another person told us that the staff had had a "lot of counseling…. I have lost several employees and am losing another one now. And, quite frankly, it is tough to get people to come here." One agency tried to keep individuals out of the media as much as possible. Agency staff also reported that they had received support and encouragement from agency and professional colleagues around the country.

Another woman told how her children tried to protect her from the unfolding events. They hid the newspaper one day, and she "never found it. There was a bunch of bad news in it, so they rented a comedy at Blockbuster…. So they put up with me being crabby."

Resistance to change

Underneath the stories of solid support, we also heard stories of increased drinking, isolation, and separation and divorce. One farmer said his wife had left, saying that she just couldn't take how the uncertainty and resulting depression affected their marriage. The stress of the situation undoubtedly exacerbated existing problems in the marriage.

Conservationists and agency staff expressed frustration with the farmers and their supporters who insisted on claiming the right to continue current practices even though others were starting to recognize that multiple concerns would need to be considered for any permanent solution. One agency participant remembered how wrenching the shift to considering multiple perspectives had been for him and others.

> "Well, my God, a paradigm shift for me. … After the 1994 drought, we found people knocking at our door. 'Hey, what about us? We are the Indians upstream.' 'What about us, we are the Indians downstream.' 'What about us, we are the ONRC' [Oregon Natural Resources Council]. 'What about us, we are the fishermen.' Open the door and you have to let them all in and start listening to all of them…. that shift—we are a multifaceted agency and we're listening to everybody…. It is easy to have a guidebook that says once you get to this point you lean this way to the farming community or maybe you…. And it isn't that way

anymore. Now you come to a decision point and you don't have a book anymore. How do you do it and make everyone happy? Our guidelines are so fuzzy anymore…."

We heard from a conservationist who noticed that

"people in the agricultural community every year just expect to get their water and now all of a sudden things have changed. How are they responding? Are they being proactive and saying, 'I have to do something differently? Or find water somewhere else? Dig a well? Find a different crop?' Or, are they just saying, 'The government is doing this to me and I am going to lash out and wait for my water to come back.'"

Other participants reinforced this perception that the farmers felt a sense of entitlement to a stable world that others had been asked to move past long ago. A farmer declared:

"So I guess somehow someone has to decide is this community worth having? And to do that as it stands today, that involves irrigation water…. If these people are going to be allowed to live and pursue their happiness and their occupations as they've been pursuing them, there has to be a tolerance of the use of the land as we've been using it."

A business owner in Klamath Falls described how a

"lady comes in and starts crying because they didn't know how they were gonna make it because the rent that they received from someone farming their property was their way of life…. And they're not going to go to Wal-Mart and become greeters. They're just not. Their pride's too thick, it's just too strong to do that."

At the same time, tribal members wanted to remind the farming community that they had been asked to give up their traditional ways of life many times. As one told us, "We know what it is to lose everything, and it's not a good feeling."

Needed: Visionary leadership

As the farmers became more politically active and experienced over the summer, it became clear to many of our participants that the visionary leadership needed to craft workable solutions in the area was not there. A social service provider from a small town found the most frustrating thing was the "complete void in leadership." She explained:

"[That] is not to say that our local politicians and community leaders aren't doing a good job in managing the situation, but in a year from now we are going to be in the same place. Five years from now we're going to be in the same place. And, 5 years ago we were in the same place but just didn't know it because the water was flowing."

Tribal members and agency staff shared their concerns about the leadership void in almost identical terms. It was not clear from our interviews what participants would like from leadership beyond bringing people together. Farmers would like leaders to "make sure that agriculture stays whole to protect our society," while others looked for someone to initiate a broad discussion (conservationist), provide concise national policy from the top (agency staff member), promote education about the situation (business owner), and see the big picture and bring people together (service provider).

Concerns about lack of leadership were supplemented by concerns about slow responses from agencies and the courts to problems being experienced in the here-and-now. One farmer, who is supportive of the Bush Administration, said:

"We're learning a lot about how slow the process is. Once you appoint the Secretary of the Interior, then the undersecretaries, and there's a whole level

> under that. And until the new people are appointed, all the old ones are still there. I think we're finding out how powerful bureaucrats are."

Another farmer, however, recognized that any solution was going to take time, regardless of changes in the national bureaucracy. Yet, he reminded us that

> "you just can't put a career or a life on hold for 10 years while you truly take the time you need to take. The lives and occupations and the farms that are at stake—it's instant."

Conclusions

The area encompassing the Klamath Reclamation Project faces a number of challenges in the coming years. Although the water restrictions in 2001 had a dramatic effect on approximately 1,000 farm families, the effects rippled out beyond those farms. Furthermore, the families directly affected by the lack of water faced difficulties not only in 2001. Rather, they have faced many years of restricted incomes due to high costs and low prices for their crops, and they are likely to face an extended period of recovery.

It is clear from our conversations with farmers, business owners, government employees, representatives from the Hispanic and Native American communities, conservationists, and social service providers, that the consequences of water restrictions are both deep and wide. While many participants talked about the ways in which the community had come together to support the farmers, many also talked about the ways in which the community had become polarized. Farmers who were thinking of selling their farms feared being ostracized by those who wished to continue farming. Conservationists and government workers were particularly scorned, although participants were quick to point out that it was not the local conservationists or government workers who were at fault. Some farmers were quick to blame tribal members, and farmworkers reported that farmers were not doing enough to help them. The polarization resulted in community members' pulling back and avoiding social situations that they perceived to be risky.

In addition to polarization, uncertainty about the future and the inability to make long-range plans troubled our participants. This was particularly true for farmers who were older and faced the prospect of finding a new occupation. Although the unpredictability of water access had encouraged many affected individuals to begin thinking about alternative sources of income and farming strategies, most people we talked with who relied on farming income still hoped that with some precipitation and/or a court decision, they would be able to continue their current practices.

The uncertainty was exacerbated by a perceived lack of information. Many community members felt that information was being withheld; others noted that the media were presenting a very biased view of the situation. The work of scientists was viewed as the "same old science" when answers to the communities' problems were not forthcoming.

Farmers in particular questioned the lack of large-scale assistance, although accepting direct and immediate aid already available through social and financial assistance programs was rare (except possibly food bank usage). Community members, however, were willing and did seek and receive social support from family members and friends. This support seemed, at least so far, to be mutual only within one's particular group.

Finally, frustration was expressed frequently about the resistance to changing how both the water and the land are managed. There was an acknowledgment, most likely precipitated by frustration with current natural resource management policies, that the community was desperate for active and unified leadership that considers the voices of all those concerned.

The communities affected by the curtailment of irrigation water during the 2001 growing season took a social hit, the effects of which are likely to be fully realized only in the months and years ahead. To date, they have shown contradictory and complex responses to a dynamic and ambiguous situation. They have worked together to help the most affected community members, polarized around already existing stress lines, and learned quickly how to operate in a highly visible political arena. It seems that most members of these communities are committed to finding solutions that are acceptable to all. They are likely to craft workable solutions, however, only if they can apply the lessons they are learning as they move forward into the uncertain future.

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Appendix A. Upper Klamath Basin social impact assessment focus group and interview protocol

1. Introduction: Name and pertinent background information (e.g., where they work, what they do, how long they've lived in the area—general get-to-know-each-other details)

2. How has the current water shortage/situation affected your community, friends and neighbors, and any other social group that is important to you (e.g., church groups, membership organizations)?

   How has the current water shortage/situation affected your family?

   How has the current water shortage/situation affected you personally?

   Probe for details about *changes* in physical/mental health, relationships with others, job opportunities, general sense of the world.

   Additional questions for farmers/ranchers, business owners, and others as appropriate:

   - Did you look for alternative income-earning opportunities to compensate for lost income from irrigated agriculture? How successful were you in finding alternative income?
   - Can you estimate the percentage of the losses due to water restrictions that was offset with supplemental earning?
   - Including government payments, what percentage of the losses due to water restrictions was offset by all supplemental sources of income?

3. How has the current water shortage/situation changed the way you do your job(s)?

   Probe for details about *changes* in the way they work, the types of people they interact with, how they approach their job.

4. What types of support or help do you receive from others such as family, friends, neighbors, church groups, public service providers, etc. in dealing with the impact of the current water shortage? Is this different—in type or amount—from the assistance you've received in the past?

5. What other kinds of support or help do you need to get along over the next 6 months? What about in the longer term (1 to 2 years)?

Appendix B. Focus group and interview participants' demographic information

In order to compare the results across the several focus groups we are doing, we would appreciate some general information about you. Your answers to this questionnaire and the things you said during the focus group will be held in strict confidence. All of our reports will summarize statements within and among the focus groups without direct reference by name or details to individuals.

Thank you for your time in the focus group. If you are interested in seeing a copy of our report, please provide your name and address on the signup list.

1. How long have you lived in the area?

2. What is your occupation?

3. How long have you been in this occupation?

4. What is your age?
   18–25
   26–35
   36–45
   46–55
   56–65
   65+

5. What is your gender?
   Male _____ Female _____

6. What is your race/ethnicity?
   ____ White
   ____ Hispanic
   ____ Native American
   ____ African American

7. What is your level of education?
   ____ Less than high school
   ____ High school degree
   ____ Some college
   ____ College degree
   ____ Some graduate school
   ____ Graduate degree

Part 5. Economics

10

Preface to Economics

Preface to the Economics Chapters

William K. Jaeger and Bruce Weber

The following four chapters and Chapter 19 ("Water Allocation Alternatives") consider the economic impacts in the Upper Klamath Basin of the 2001 irrigation curtailment. This preface introduces some of the key economic concepts and terminology used throughout these chapters.

Economics-related chapters

Interpreting economic indicators

Economic indicators provide useful information about the structure of an economy, changes to an economy, or economic gains and losses to sectors or individuals. Frequently, however, these indicators are misunderstood, misinterpreted, or misused. Here we offer some guidance on how to interpret them, as well as how *not* to interpret them.

Gross versus net economic indicators

In all of the economics chapters that follow, two principal types of monetary measures are used to quantify changes in the economies affected by the irrigation curtailment:

- Measures that reflect the scale of economic activity (e.g., gross farm sales, gross revenue, and regional output)
- Measures that reflect net financial changes for individuals and regions (e.g., net revenue, economic loss, and income)

It is important that these two measures not be confused. The following example is offered as clarification.

Consider a homebuilder in Klamath Falls with a contract to build a $500,000 home for a family planning to move to the area from San Francisco. If the contract is cancelled, how should we quantify the economic effects of the cancellation? Did the homebuilder lose a $500,000 sale? Yes. Is the homebuilder's income reduced by $500,000? No. Let's assume the home would cost $400,000 to build (materials, hired labor, subcontracts, etc.). In that case, we can say that losing the contract involves a reduction in "net revenue" or "income" of $100,000 for the builder.

Is this, then, an accurate measure of the builder's "loss"? Not necessarily. If he finds another homebuilding contract or alternative employment during the period of time when he would have been building the original house, he might suffer no economic loss at all. However, if he is idle for this period of time, or if finding another contract or alternative employment is costly, then his loss may be all or part of the $100,000.

Could the builder's loss be greater than $100,000? Yes. If he had already excavated the site, leased equipment, or paid for subcontractors, he cannot recover these "fixed costs," and they will represent additional losses.

For purposes of this example, let's assume the builder's loss is $40,000. The key point to remember is that changes in "gross revenues" or "gross output" caused by an event are not a good measure of the gains or losses to affected individuals. Changes in net revenue or income better reflect economic gains or losses.

Now let's turn to the entire local economy. How should we measure the economy's loss from the cancellation of our hypothetical homebuilding contract? Did the local economy lose a $500,000 infusion of money from San Francisco? Yes. Did the local economy lose $500,000 in income? No. For one thing, materials (and perhaps some subcontractors) would have been brought in from outside the local economy, and payments for these goods and services would not have ended up in local hands.

Also, we need to distinguish again between a change in gross revenue and a change in net revenue for the economy. Assume, for example, that the builder would have paid a local electrician $10,000 for installing the home's electrical systems. Thus, the broken contract will cause an additional reduction in "gross revenue" of $10,000 in the local economy. The regional gross output reduction has increased to $510,000—the sum of the builder's lost $500,000 contract plus the electrician's lost $10,000 subcontract.

Again, however, this is not a reduction in income or net revenues. Some of the $10,000 would have paid for wire and other materials, and, like the builder, the electrician might be able to find alternative employment during the period he was planning to work on the original house. Depending on these factors, the loss, or reduction in income, for the electrician (and the local economy) might be nearly $10,000, or it might be zero.

Let's assume the electrician's net income decreases by $5,000 because of the cancellation. The regional income impact from the broken contract becomes –$45,000—the sum of the builder's $40,000 lost income and the electrician's $5,000 lost income. Using the output measure of $510,000 to reflect this income loss would be highly misleading.

Estimation of gross output is a necessary step on the way to estimating changes in income because it allows us to trace through all of the transactions that add value in the economy. It is not a good measure of gains or losses, however. The problem is that it double-counts sales of inputs. In the above example, it counts the electrician's $10,000 both as a sale to the contractor and again as part of the homebuilder's $500,000 sale of the house.

By contrast, the homebuilder's $40,000 net revenue and the electrician's $5,000 net income are counted only once, when the income is received. For this reason, economists prefer the change in income as a measure of the loss suffered, or gain realized, in a regional economy.

Estimated impacts and reported outcomes

The following chapters present two different kinds of information about regional economic changes. *Impact estimates* usually attempt to predict how a particular event, such as the irrigation curtailment in 2001, would affect gross sales, income, and employment, assuming there are no other changes in the economy. Alternatively, the estimates might take into account some specified government and private responses, while assuming that nothing else changes.[1]

Reported outcomes document how an economy changed over a particular period of time. We must be cautious when drawing inferences about the causes of these changes, however. They may be due to a particular event or to responses to the event (for example, emergency government payments), or they may be the result of unrelated factors, such as price changes, weather, etc.

Suppose a local economy grows after a negative event occurs. Can we conclude that this event had no negative impact? No. It could be that the economic growth occurred for unrelated reasons. If the negative event had not occurred, the economy might have grown even more than it did.

To the extent that we can distinguish between the effects of "unrelated factors" that affect an economy and the effects attributable to the event being studied, we can more accurately estimate the impact of the event. In Chapter 14, "Outcomes," Jaeger combines the available information on estimated impacts, reported outcomes, and unrelated changes in order to produce a set of "inferred impacts."

The distribution of gains and losses

Aggregate changes in an economy frequently mask the distribution of gains and losses. If the aggregate change in net revenue or income due to a particular event is zero, does that mean there were no losses? No. Gains in one part of the economy (or by one individual) may be offset by losses elsewhere. Unless we expect the winners to share their gains with the losers, there likely will be losers even if the change in net income or net revenues (for some group, sector, or for the economy as a whole) is zero.

It would be impossible to analyze the gains and losses of every individual in the Upper Klamath Basin. Thus, we have tried to provide information about changes in the economic circumstances of various groups—Project irrigators, non-Project growers, agricultural services and suppliers, nonagricultural sectors, and the entire regional economy. Where possible, we try to point out what we believe we know about the distribution of gains and losses among members of a particular group. It is useful to bear in mind, however, that for any economic change, even one that raises overall economic circumstances greatly, some individuals' fortunes will move in the opposite direction.

Long-term impacts and unquantifiables

It would be misleading to assume that measured changes in net revenue or income in 2001 reflect all benefits and costs of the 2001 irrigation curtailment. Some impacts on costs of production, asset values, employment, and income may take longer than 1 year to become evident. Many potential social and psychological consequences, furthermore, cannot be quantified, and we have made no attempt to place a dollar value on these kinds of impacts. Evidence of

[1] Impacts are estimated in this report using an input–output (I–O) model, the conventional economic tool for regional impact analysis. An I–O model contains information about the economic transactions in an economy. The accuracy of an I–O model's impact estimate depends on how closely economic behavior conforms to the model's assumptions. I–O models will overstate the reductions in output, income, and employment resulting from a negative event to the extent that firms or individuals respond creatively by changing their activities or producing output in new ways. (The I–O model assumes there will be no substitutions of labor or other productive factors between activities nor changes in production practices.) On the other hand, I–O models will understate the reductions in income to the extent that firms have fixed costs that cannot be avoided. (The I–O model assumes that all costs are variable.)

these kinds of consequences is presented in Chapter 9 (“Communities”).

The difficulties in identifying and quantifying impacts also apply to other groups and sectors with an interest in how water is allocated in the Upper Klamath Basin, including tribal and environmental interests, commercial and sports fisheries, recreation, and tourism. We have limited our analysis to market activity in the year following the irrigation curtailment, and to goods, services, and assets that can be assigned a market value. This is not to say that there are no losses or gains to other groups, nor that these effects are less important.

A roadmap to the economic chapters

The next four chapters provide both an overview of the Upper Klamath Basin economy and its agricultural sector and an examination of the changes in the regional economy during 2001, many of which were related to the 2001 water allocation decisions on the Klamath Reclamation Project.

The first of these chapters (11, “Basin Economy”) is intended to provide some context for understanding the changes discussed in the following three chapters. The next chapter (12, “Crop Revenue”), by Susan Burke, provides estimates of the impact of the 2001 Klamath Project Operations Plan (KPOP) on gross crop production on the Klamath Reclamation Project. It also discusses: (1) the relationship between Biological Opinions and the amount of water available for irrigation diversions on the Project, and (2) the relationship between the amount of water available for irrigation diversions and gross Project crop revenues.

Chapter 13 (“Regional Economic Impact”), by Weber et al., provides two model-based estimates of the potential economic impacts of the KPOP on the Upper Klamath Basin economy. The first is based on an impact scenario that assumes full implementation of the 2001 KPOP as was expected in May 2001, with no adjustments for public or private responses to the curtailment of water allocations. The second set of estimates is based on a scenario that reflects the increased water made available during 2001 and the major public and private responses identified as of February 2002.

The fourth chapter (14, “Outcomes,” by Jaeger) looks at the reported economic outcomes in the Upper Klamath Basin using data available as of March 2002. It compares the outcomes for 2001 with the model-based impact estimates. Many of the differences between reported economic changes and initial impact estimates are due to public and private responses to the 2001 KPOP and to changes in the economy unrelated to the irrigation curtailment. Based on the combination of reported outcomes and revised estimates, a set of “inferred impacts” is presented.

Later in the report, a fifth economics chapter (19, “Water Allocation Alternatives,” by Jaeger) examines a range of water allocation alternatives that could help reduce or avoid the kinds of economic disruptions caused by events in 2001.

11

Basin Economy

The Upper Klamath Basin Economy
and the Role of Agriculture

Bruce Weber and Bruce Sorte

This chapter and the three that follow provide both an overview of the Upper Klamath Basin economy and its agricultural sector and an examination of changes in the regional economy during 2001, some of which were related to the 2001 water allocation decisions on the Klamath Reclamation Project.

The purpose of this overall report—to examine issues related to the 2001 water allocation decisions—led us to focus on the region and economic sector most affected by those decisions. Thus, we concluded that the most appropriate region for analysis was the Upper Klamath Basin, and the most affected economic sector was agriculture.

The Upper Klamath Basin includes parts of five counties in Oregon and California, although most of the Basin falls within three of these counties. Almost all of the Oregon portion of the Basin lies in Klamath County, and the Basin covers most of the county, including the county seat, Klamath Falls (population about 21,000), which is the major regional population center. In California, the Basin covers the northwest corner of Modoc County (not including the county seat of Alturas, population about 3,000) and the northeast corner of Siskiyou County, including the county seat, Yreka (population about 7,500). The Basin also includes very small portions of Jackson and Lake counties in Oregon.

In the long run, water allocation in the Upper Klamath Basin will affect many sectors: electric power, commercial fishing, recreational fishing and hunting, tribal fishing, and agriculture. The decision to allocate water to meet the lake level and river flow requirements of the 2001 Biological Opinions, however, had an effect in 2001 primarily on the agriculture and electric power sectors. Because consequences for the electric power sector likely would be experienced over a very broad geographic area, we chose to focus only on the agriculture sector and related industries. A more complete analysis of the short-run consequences of the decision would include effects on the electric power sector. The Lower Klamath Basin was not included in this study because, although activities in the Upper Basin have affected fish stocks over a long period of time, a 1-year increase in river flows is not linked to fishing-related economic activity in the Lower Basin.

Progress toward resolving conflicts over water allocation in the Basin would be aided by a comprehensive analysis of the historical origins of the current water management regime. A longer run perspective on water allocation will require consideration of other sectors, the Lower Klamath Basin economy, and the economic and cultural importance of fishery resources to Native American tribes. It also will require an analysis of the role of water management in the existence of persistent poverty in the Basin. These analyses belong on the agenda for future research.

Overview of the Upper Klamath Basin economy

Because most regional economic and demographic data are at the county level, we consider the Upper Klamath Basin economy to consist of Klamath County, Oregon, and Modoc and Siskiyou counties in California. Admittedly, this definition includes economic activity outside the Basin in some rural areas and small towns (such as Alturas, California). It also excludes economic activity in the Basin in some small, rural parts of Jackson and Lake counties in Oregon. Nevertheless, it comes closer to capturing the size and character of the regional economy than any alternative. The smaller region most affected by the 2001 Klamath Project Operations Plan—the towns of Merrill, Tulelake, and Malin and the surrounding Klamath Reclamation Project farms—was considered too small to capture many of the economic effects generated by the 2001 water allocation decisions because it is quite economically interdependent with Klamath Falls.

Because it includes the Basin's economic centers, the three-county regional definition captures most of the economic consequences of activity in the Basin. It is in these towns that most of the money brought into the region (particularly that associated with irrigated agriculture) is respent by businesses and households.

Our economic portrait of the Upper Klamath Basin economy was developed using 1998 data—the most recent available—from IMPLAN (*IM*pact Analysis for *PLAN*ing), a software program and database created to assist the U.S. Forest Service and other agencies in estimating the community impacts of policy decisions.[1] The Minnesota IMPLAN Group, Inc. produces, refines, and annually updates the model and data for IMPLAN. IMPLAN can generate input–output models (I–O models) for any county or group of counties in the United States. We cross-checked and revised key components of the model with data from the U.S. Bureau of Economic Analysis, the U.S. Department of Agriculture, and the Oregon State University Extension Service. Appendix A of this chapter indicates the types of economic activity included in each of the North American Industry Classification System (NAICS) sectors used in IMPLAN.

Structural change in the Basin economy, 1969–1999

Over the past 30 years, full- and part-time employment in the Upper Klamath Basin has increased from 40,000 to 60,000 jobs. (Over the same period, Oregon employment more than doubled.) The composition of the regional economy changed dramatically over this time.

One way to describe changes in a regional economy is to look at the sectors that grew or declined the most. In the Upper Klamath Basin, the sectors that grew most rapidly were wholesale trade and services. The share of jobs in the service sector doubled from 13.8 to 26.8 percent (Table 1). Employment in several other sectors showed significant decline: military, transportation and public utilities, and manufacturing. Employment in farming, mining, and federal civilian government grew more slowly than the regional average over the 3 decades. Because of the more rapid growth in other sectors (Figure 1, later in this chapter), the share of jobs in farming declined from 10.3 percent to 7.6 percent (Table 1).

Another way of looking at structural change is to see how various sectors in the region have changed relative to the state or national economy. In this way, we can see the extent to which the regional economy became more or less specialized in particular sectors relative to the state or nation. A relatively simple tool for making this comparison is the "location quotient" (LQ)—the ratio of a region's share of employment in a given sector to the state's or nation's share of employment in that sector. A

[1]1998 data were the most recent available when we began our work. More recent data have since become available.

location quotient greater than 1 indicates that a region is more specialized than the state or nation in that sector.

Table 1 shows location quotients for the Basin for 1969 and 1999, using Oregon as the reference region. In 1969, the Basin was relatively specialized (LQ>1.5) in farming, agricultural services, and federal civilian and military government employment. By 1999, the Basin had increased specialization in two of these sectors—farming and federal civilian government—both of which had seen relatively slow employment growth statewide. Farm and federal civilian employment as a share of total employment declined more slowly in the Basin over the past 30 years than in Oregon overall.

Table 1. Structural change in the Upper Klamath Basin economy.

	1969			1999			1969–1999 change	
	Jobs	Share of total employment (%)	Location quotient[a]	Jobs	Share of total employment (%)	Location quotient[a]	Jobs	%
Total full- and part-time employment	40,392	100.0	1.00	60,101	100.0	1.00	19,709	48.8
Wage and salary employment	31,751	78.6	0.95	44,257	73.6	0.92	12,506	39.4
Proprietors' employment	8,641	21.4	1.26	15,844	26.4	1.33	7,203	83.4
Farm proprietors' employment	2,466	6.1	1.74	2,723	4.5	2.36	257	10.4
Nonfarm proprietors' employment	6,175	15.3	1.14	13,121	21.8	1.22	6,946	112.5
Farm employment	4,144	10.3	1.83	4,592	7.6	2.30	448	10.8
Nonfarm employment	36,248	89.7	0.95	55,509	92.4	0.96	19,261	53.1
Private employment	27,563	68.2	0.88	44,926	74.8	0.89	17,363	63.0
Ag. services, forestry, fishing, and other	1,090	2.7	2.98	1,678	2.8	1.44	588	53.9
Mining	70	0.2	0.85	71	0.1	0.80	1	1.8
Construction	1,442	3.6	0.75	2,528	4.2	0.71	1,086	75.3
Manufacturing	7,171	17.8	0.87	5,883	9.8	0.79	–1,288	–18.0
Transportation and public utilities	3,084	7.6	1.33	2,474	4.1	0.93	–610	–19.8
Wholesale trade	876	2.2	0.43	2,388	4.0	0.81	1,512	172.6
Retail trade	6,291	15.6	1.00	10,213	17.0	0.99	3,922	62.3
Finance, insurance, and real estate	1,965	4.9	0.66	3,573	5.9	0.77	1,608	81.8
Services	5,574	13.8	0.77	16,118	26.8	0.91	10,544	189.2
Government and government enterprise	8,685	21.5	1.30	10,583	17.6	1.39	1,898	21.9
Federal, civilian	1,665	4.1	1.54	1,856	3.1	2.15	191	11.5
Military	2,369	5.9	3.41	320	0.5	0.88	–2,049	–86.5
State and local	4,651	11.5	0.95	8,407	14.0	1.32	3,756	80.8

[a]The formula for calculating a location quotient is LQ*i* = (County*i*/County*t*)/(Oregon*i*/Oregon*t*) where

LQ*i* is the location quotient of the *i*th sector
County *i* is county employment in the *i*th sector
County *t* is total employment in the county
Oregon *i* is Oregon employment in the *i*th sector
Oregon *t* is total Oregon employment

Source: Bureau of Economic Analysis, U.S. Department of Commerce, Regional Economic Information System (REIS) (http://fisher.lib.virginia.edu/reis/). The sectoral aggregation in REIS is based on the former Standard Industrial Code system, which is more highly aggregated than the North American Industrial Classification System used elsewhere in this chapter.

Over the past 3 decades, the Basin economy has grown slowly and has diversified. It has become more specialized in sectors that are growing rapidly in Oregon (services, wholesale trade) and in some slowly growing sectors (farming and civilian federal government).[2] It has become less specialized in other slow-growth sectors (manufacturing, transportation, and public utilities).

Structure of the current Basin economy—an economic base analysis

The Upper Klamath Basin is home to about 120,000 people. The Basin economy produced $4 billion worth of output in 1998, added $2.3 billion in value to purchased inputs, and provided almost 60,000 jobs. Table 2 presents estimates of some basic economic indicators for the regional economy as a whole and by sector.

The four sectors with the largest shares of output in 1998 were wood products[3] (15.5 percent), agriculture[4] (11.1 percent), construction (8.1 percent), and health care/social assistance (7.8 percent). The four sectors with the largest shares of value added were wood products (11 percent), retail trade (8.8 percent), real estate (8.7 percent), and public administration (8.6 percent). The four sectors with the largest employment shares were retail trade (11.1 percent), agriculture (10.7 percent), educational services (10.1 percent), and health care/social assistance (9.9 percent).

[2]An increase in LQ (in specialization) is difficult to interpret. An LQ can increase because the sector is growing regionally more rapidly than it is nationally, or because it is decreasing less regionally than it is nationally. Growth in the LQ can signal that the region has a comparative advantage in the sector because the sector is adding more employees regionally than it is nationally—presumably a good sign. On the other hand, growth in the LQ can mean that regional labor productivity lags behind national labor productivity in a particular sector, or that regional labor resources in that sector are less able to shift to more productive employment than their national counterparts—presumably a bad sign.

[3]Wood products is defined here to include forestry and logging plus wood products manufacturing.

[4]Agriculture is defined here to include the agriculture and related sector plus food, beverage, and textile manufacturing.

Each of these measures provides a perspective on how regional economic activity is distributed among sectors. However, none of them identifies how much the regional economy depends on each sector.

One way of identifying the sectors on which the region's jobs and income depend (i.e., how

Understanding regional economic indicators

A regional economy usually is characterized by describing the shares of output, value added (or income), and employment in each major sector. The following terms are used.

- *Output* is a measure of the dollar value of total production, including the dollar value of purchased inputs used in the production process.
- *Value added* is a measure of the value that is added to purchased inputs in the local production process by local labor and capital. Thus, it equals the dollar value of output minus the value of purchased inputs used in the production process. Value added is *income plus indirect business taxes* such as property taxes. Income—employee compensation, proprietor income, and other property—equals 93 percent of value added in the Basin economy.*
- *Employment* is a measure of the number of full- and part-time jobs in each sector. Sectors in which the share of value added is high relative to the share of employment tend to have relatively high earnings.

Table 2 presents information about each of these indicators for each of the Basin's sectors.

*In the Basin economy, employee compensation is 56 percent, proprietor income is 10 percent, and other property income is 27 percent of value added.

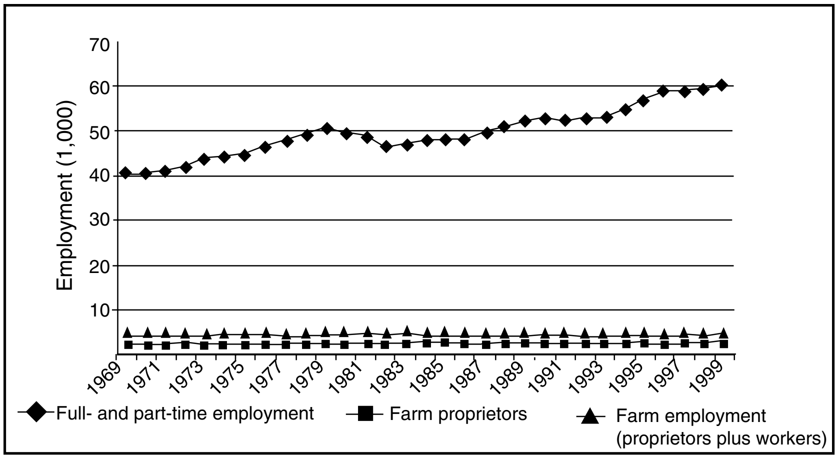

Figure 1. Upper Klamath Basin full- and part-time employment, 1969–1999. Source: Bureau of Economic Analysis, U.S. Department of Commerce, Regional Economic Information System (REIS) (http://fisher.lib.virginia.edu/reis/)

Table 2. Output, value added, and employment in the Upper Klamath Basin, 1998.

	Output		Value added		Employment	
	$ million	Share (%)	$ million	Share (%)	Jobs	Share (%)
Agriculture and related[a]	320	7.9	169	7.3	5,964	10.0
Forestry and logging	30	0.7	16	0.7	248	0.4
Mining	4	0.1	2	0.1	33	0.1
Construction	327	8.1	119	5.1	3,357	5.7
Manufacturing—food, beverages, textiles, and related	128	3.2	20	0.9	407	0.7
Manufacturing—wood products, paper, furniture, and related	598	14.8	241	10.3	4,328	7.3
Manufacturing—high technology and related	17	0.4	3	0.1	94	0.2
Manufacturing—other (e.g., sheet metal products)	113	2.8	35	1.5	844	1.4
Transportation and warehousing	263	6.5	139	6.0	2,257	3.8
Utilities	128	3.2	80	3.4	429	0.7
Wholesale trade	142	3.5	97	4.2	2,036	3.4
Retail trade	235	5.8	205	8.8	6,568	11.1
Accommodation and food services	163	4.0	92	4.0	4,785	8.1
Finance and insurance	197	4.9	138	5.9	2,179	3.7
Real estate, rental, and leasing[b]	279	6.9	202	8.7	1,535	2.6
Other services	186	4.6	84	3.6	3,733	6.3
Information	100	2.5	55	2.3	1,241	2.1
Administrative and support services, etc.	28	0.7	16	0.7	936	1.6
Arts, entertainment, and recreation	31	0.8	19	0.8	1,133	1.9
Health care and social assistance	316	7.8	194	8.3	5,859	9.9
Professional, scientific, and technical services	38	0.9	26	1.1	865	1.5
Educational services	182	4.5	170	7.3	6,010	10.1
Public administration	200	5.0	200	8.6	4,551	7.7
Inventory valuation adjustment	7	0.2	7	0.3	0	0.0
Total	**4,032**	**100.0**	**2,327**	**100.0**	**59,390**	**100.0**

[a]Technically, this is Agriculture, fishing, and related. However, the IMPLAN database for the Upper Klamath Basin identifies almost no fishing employment. Only 18 of the 5,964 jobs in the sector (0.3 percent) are in fishing. Thus, we have renamed the sector Agriculture and related.

[b]Property management services, real estate agents

Sectors based on the North American Industrial Classification System (NAICS). See Appendix A of this chapter for descriptions.

Source: IMPLAN, adjusted with Bureau of Economic Analysis and local data.

much each sector contributes to the regional economy) is to examine a region's "economic base." According to economic base theory, the level of overall economic activity in a region is determined by the region's economic base, which is defined as its "exports to markets outside the region" (Maki and Lichty 2000).[5] In an economic base model, different types of sectors play different roles. Those sectors that "export" a large share of their production or bring large inflows of money into the community are called *basic sectors*. They are said to be "responsible for" the jobs and income in the other sectors (*service sectors)* that sell a large share of their output in the local economy.

In this economic-base framework, the activity of the service sectors depends on the respending of money brought in by the export sectors. In this sense, the employment and income in both basic and service sectors depends on the economic base and on the sectors that bring money into the region from outside.

The preferred method of estimating the economic base of a region is to use an input–output model (I–O model). These models take estimates of exports from each industry and, using multipliers for each sector, generate estimates of the dependence of the regional economy on each sector's exports. A sector's contribution to the regional economy is determined by the dollars brought into the economy by that sector and the subsequent respending of those dollars. The contribution of an industry to the region's employment is the number of employees in all industries whose jobs depend, directly or indirectly (through interindustry linkages), on the exports of that industry (Cornelius et al. 2000).

Table 3 summarizes the contribution of each sector to total regional employment, based on an analysis using the Upper Klamath Basin I–O model. The procedure used to derive the estimates in Table 3 is described in Waters et al. (1999). The table compares the employment *in* a sector (as shown in Table 2) with employment *dependent* on a sector's exports. The jobs under the "Sectoral employment" columns are jobs in the given sector. The jobs in the "Export-dependent" columns are jobs from *all* sectors that depend on the exports from the given sector.

As an example, there are 4,328 jobs *in* the wood products manufacturing sector. However, there are 7,018 jobs in the region *dependent* on wood products exports. Of these, 3,089 jobs are *directly dependent* on the exports of wood products from the county where they were produced. These jobs are related to direct purchases from wood products firms by households, firms, and governments outside the region. In addition, there are 2,126 jobs *indirectly dependent* on wood product exports. These are the jobs created when wood product firms purchase inputs (e.g., logs) from firms within the county and when these suppliers purchase from other businesses in the county. Yet another 1,803 jobs are *induced* by wood products exports. These are the jobs in retail trade, real estate, and health care that are created when households respend income earned in all of the jobs generated directly and indirectly by wood products exports. The spending and respending of money brought into the region by wood product exports generates a total of 7,018 jobs.

Table 3 indicates the dependence of the Basin's regional employment on two natural resource sectors. Agriculture (agriculture and related plus food products manufacturing) supports 13.7 percent of the region's jobs, and wood products (forestry and logging plus wood products manufacturing) support 12.5 percent.

Table 3 also identifies the dependence of the regional economy on two other sectors that often are the focus of local economic development efforts. Although the tourism sector (accommodation and food services; arts, entertainment and recreation) is responsible for 10 percent of the total jobs in the region, it contributes only 3.4 percent of the export employment base. Retail trade, the sector with the largest employment share (11.1 percent), provides only 0.9 percent of the export employment base.

[5]The term "exports," as used here, includes any activities that bring dollars into the regional economy, including federal transfer payments and income to households from outside the region.

Table 3 also shows that regional employment is more dependent on income to households from outside the region than on any single sector. Household income from government transfer payments (e.g., Social Security), dividends, commuters' income, rental payments, and other sources of income originating outside the region is an important part of the export base. In 1998, 17,084 jobs (28.8 percent) were dependent on those payments.

The dependence of the Basin economy on federal and state government and educational institutions also is evident in Table 3. Almost one-fifth of the jobs in the region depend on federal and state funding for services such as education and other public services. Public administration supports 10.2 percent of all Basin jobs. This sector includes federal and state payments to local governments (e.g., federal payments in lieu of taxes, federal forest payments, state-shared cigarette and highway revenues) and to government personnel (U.S. Forest Service, U.S. Department of Agriculture, and U.S. Fish and Wildlife Service,

Table 3. Export base employment, Upper Klamath Basin, 1998.

	Sectoral employment		Export-dependent employment[a]				
	Number of jobs	Share[b] (%)	Direct	Indirect	Induced	Total	Share[b] (%)
Agriculture and related[c]	5,964	10.0	4,530.5	1,051.5	1,004.0	6,586.0	11.1
Forestry and logging	248	0.4	242.5	144.0	52.1	438.6	0.7
Mining	33	0.1	27.0	4.5	8.6	40.1	0.1
Construction	3,357	5.7	2,809.2	1,127.5	1,139.2	5,075.9	8.6
Manufacturing—food, beverages, and related	407	0.7	374.1	865.0	288.2	1,527.3	2.6
Manufacturing—wood products, paper, furniture, and related	4,328	7.3	3,088.6	2,126.0	1,803.2	7,017.8	11.8
Manufacturing—high technology and related	93	0.2	29.7	24.2	11.2	65.1	0.1
Manufacturing—other (e.g., sheet metal products)	844	1.4	727.7	319.9	271.9	1,319.5	2.2
Transportation and warehousing	2,257	3.8	1,102.5	517.8	618.9	2,239.2	3.8
Utilities	429	0.7	35.7	26.1	27.4	89.2	0.2
Wholesale trade	2,035	3.4	351.9	75.6	104.4	531.9	0.9
Retail trade	6,568	11.1	423.2	21.6	82.2	527.0	0.9
Accommodation and food services	4,785	8.1	1,541.0	188.5	226.8	1,956.3	3.3
Finance and insurance	2,179	3.7	138.8	34.5	43.1	216.4	0.7
Real estate, rental, and leasing[d]	1,535	2.6	95.3	49.8	26.4	171.5	0.3
Other services	3,733	6.3	1,110.2	237.5	235.3	1,583.0	2.7
Information	1,241	2.1	143.4	48.6	47.5	239.5	0.4
Administrative and support services, etc.	936	1.6	48.0	6.1	7.4	61.5	0.1
Arts, entertainment, and recreation	1,133	1.9	26.7	5.3	3.4	35.4	0.1
Health care and social assistance	5,859	9.9	370.8	64.5	122.3	557.6	0.9
Professional, scientific, and technical services	865	1.5	77.0	10.2	23.0	110.2	0.20
Educational services	6,010	10.1	4,545.9	86.0	1,207.6	5,839.5	9.8
Public administration	4,551	7.7	4,551.2	33.5	1,492.2	6,076.9	10.2
Households (e.g., Social Security)	—	—	11,952.4	1,946.6	3,185.4	17,084.4	28.8
Total	**59,390**	**100.0**	**38,343.3**	**9,014.8**	**12,031.7**	**59,389.8**	**100.0**

[a]All regional jobs that depend on exports from the given sector

[b]Share of total regional employment

[c]Technically, this is Agriculture, fishing, and related. However, the IMPLAN database for the Upper Klamath Basin identifies almost no fishing employment. Only 18 of the 5,964 jobs in the sector (0.3 percent) are in fishing. Thus, we have renamed the sector Agriculture and related.

[d]Property management services, real estate agents

Sectors based on the North American Industrial Classification System (NAICS). See Appendix A of this chapter for descriptions.

Source: Basin-modified IMPLAN model

Table 4. Upper Klamath Basin export-base-dependent employment, income, and value added, 1998.

	Share of total jobs (%)	Share of total income (%)	Share of total value added (%)
Agriculture and related[a]	11.1	9.1	9.2
Forestry and logging	0.7	0.9	1.0
Mining	0.1	0.1	0.1
Construction	8.56	8.4	8.3
Manufacturing—food, beverages, and related	2.56	2.6	2.6
Manufacturing—wood products, paper, furniture, and related	11.8	14.7	14.5
Manufacturing—high technology and related	0.1	0.1	0.1
Manufacturing—other (e.g., sheet metal products)	2.2	2.4	2.4
Transportation and warehousing	3.8	5.0	5.0
Utilities	0.2	0.4	0.4
Wholesale trade	0.9	0.9	1.0
Retail trade	0.9	0.7	0.7
Accommodation and food services	3.3	1.9	2.0
Finance and insurance	0.4	0.6	0.6
Real estate, rental, and leasing[b]	0.3	0.6	0.7
Other services	2.7	2.0	2.0
Information	0.4	0.4	0.4
Administrative and support services, etc.	0.1	0.1	0.1
Arts, entertainment, and recreation	0.1	0.1	0.1
Health care and social assistance	0.9	0.9	0.9
Professional, scientific, and technical services	0.2	0.2	0.2
Educational services	9.8	8.2	7.8
Public administration	10.2	11.6	11.0
Households (e.g., Social Security)	28.8	28.3	28.9
Total	**100.00**	**100.00**	**100.00**

[a]Technically, this is Agriculture, fishing, and related. However, the IMPLAN database for the Upper Klamath Basin identifies almost no fishing employment. Only 18 of the 5,964 jobs in the sector (0.3 percent) are in fishing. Thus, we have renamed the sector Agriculture and related.

[b]Property management services, real estate agents

Source: Basin-modified IMPLAN model

for example). State and federal funding for educational services (K–12 schools, the community college in California, and the Oregon Institute of Technology, OIT), plus OIT tuition payments by nonresidents, supports 9.8 percent of the region's jobs.

Table 4 provides estimates of the shares of regional income and value added dependent on each sector's exports. The table also includes the comparable employment shares from Table 3. The major sectors on which regional employment depends also drive regional income and value added: household income from outside the region, wood products (manufacturing and forestry/logging), agriculture (agriculture and food manufacturing), and public administration. Because earnings in the wood products sector are higher than in the agricultural sector, the share of regional income that depends on wood products is higher than the share of employment. Conversely, the share of regional income dependent on agriculture is less than the share of employment.

Table 5. Characteristics of Upper Klamath Basin farms and farm operators, 1997.

Farm characteristics	Klamath (OR)	Siskiyou (CA)	Modoc (CA)	Basin total
Number of farms	1,066	733	440	2,239
Land in farms (acres)	713,534	628,745	662,927	2,005,206
Average size of farm (acres)	669	858	1,507	896
Farms with sales >$10,000 (%)	54	55	69	57
Farms with irrigation (farms)	851	556	337	1,744
Irrigated land (acres)	243,205	139,534	159,219	541,958
Market value of agricultural products sold ($1,000)	100,622	74,244	63,797	238,663
Net cash return from agricultural sales for the farm unit ($1,000)	20,104	16,389	11,249	47,742
Average net cash return per farm ($)	18,859	22,359	25,556	21,323
Government payments received ($1,000)	817	1,420	666	2,903
Farms receiving payments (%)	16	21	25	19
Average government payments per farm receiving payments ($)	4,750	9,467	6,055	6,720
Farms with hired labor (farms)	380	259	206	845
Farms with hired labor (%)	37	35	47	38
Number of hired farmworkers (workers)	1,779	2,795	1,664	6,238
Workers working 150+ days (%)	37	17	21	24
Hired farm labor payroll ($1,000)	9,745	11,309	6,169	27,223
Average annual pay per hired farmworker ($)	5,478	4,046	3,707	4,364
Sole proprietor farms (%)	83	82	82	82
Farm operators living on farm operated (%)	82	78	72	78
Operators with farming as primary occupation (%)	58	61	65	60
Farm operators working more than 200 days off-farm (%)	33	27	23	29

Source: 1997 Census of Agriculture

Farming in the Upper Klamath Basin economy

Farms and farm characteristics

There were 2,239 farms in the Upper Klamath Basin in 1997 (Table 5). A farm is defined as "any place from which $1,000 or more of agricultural products were produced or sold, or normally would have been sold, during the census year." Farms thus include many places that do not depend on their farm operations for their major source of income. Indeed, as shown in Table 5, 29 percent of farm operators worked more than 200 days per year off the farm, and only 60 percent considered farming their primary occupation. Just over half the farms (57 percent) have more than $10,000 in annual sales.

Farms averaged 896 acres in size. Most of the farms (78 percent) had some irrigation, and 27 percent of the region's farmland was irrigated.

Most farms (82 percent) were sole proprietorships, and 78 percent were operated by the person living on the farm. About one-third of the farms (38 percent) hired farmworkers. The average annual pay per hired farmworker was $4,364. About one-quarter (24 percent) of the

Table 6. Value of agricultural production in the Upper Klamath Basin, 1998.

	Klamath (OR)	Siskiyou (CA)	Modoc (CA)	Basin total	Share of total value of agricultural production (%)
	($1,000)				
Alfalfa hay	30,726	25,203	12,825	68,754	24.3
Cattle	32,850	23,635	9,000	65,485	23.2
Potatoes	14,217	19,323	7,866	41,406	14.6
Pasture and range	NA	13,005	7,560	20,565	7.3
Other hay	4,856	3,713	3,588	12,157	4.3
Barley	5,225	3,280	2,187	10,692	3.8
Onions	NA	2,862	2,464	5,326	1.9
Wheat	1,660	2,805	859	5,324	1.9
Dairy	13,112	2,442	NA	15,554	5.5
Horseradish	NA	NA	896	896	0.3
Sugarbeets	3,832	NA	3,284	7,116	2.5
Nursery products	NA	17,271	NA	17,271	6.1
Other	1,000	5,319	5,973	12,292	4.3
Total	**107,478**	**118,858**	**56,502**	**282,838**	**100**

Note: Figures in this table may differ slightly from those in other chapters because of differences in data sources and crop category definitions.

Source: Oregon State University Extension Service and the California Agricultural Statistics Service

6,238 farmworkers worked 150 or more days in 1997.

Net cash returns per farm from agricultural sales in the Upper Klamath Basin averaged $21,323 in 1997. Net cash returns equal the value of agricultural products sold minus operating expenses (including cash rent, but not including depreciation).

Almost one-fifth of the farms (19 percent) received government payments in 1997 (from commodity and conservation programs), which averaged $6,720 for those farms receiving the payments.

Production and sales

Table 6 reports the value of agricultural production by commodity for each Upper Klamath Basin county and for the region. The regional value of total agricultural production in 1998 was estimated to be $283 million. Raising hay and livestock are the principal agricultural activities in the region: cattle, hay, and pasture account for 65 percent of the value of production. Potato production is another major agricultural enterprise in terms of value, accounting for 15 percent of the value of production. Additional data on agricultural production are contained in Chapter 12 (“Crop Revenue”) and Chapter 8 (“Crop Production”).

Income

Farm income in the Upper Klamath Basin, as elsewhere, varies considerably from year to year, and from county to county. The U.S. Bureau of Economic Analysis (BEA) provides county-level estimates of “realized net income” from farming, “farm proprietors’ income,” and farm labor income.

“Realized net income” is equal to total cash receipts from marketing plus other income (including government payments, farm-related income such as custom work and rent, and imputed rent for farm dwellings), minus total production expenses (including a land charge and depreciation).

In 1997, realized net farm income in the Upper Klamath Basin was $30 million, with positive incomes in all counties (Table 7).

Table 7. Farm income, employment, and personal income in the Upper Klamath Basin, 1997 and 1998.

	1997	1998
Total farm cash receipts from marketing ($1,000)[a]	291,138	247,950
Plus government payments ($1,000)	3,926	6,010
Plus imputed and miscellaneous income ($1,000)[b]	38,409	37,215
Minus total production expenses ($1,000)	303,317	289,966
Realized net income from farming ($1,000)	30,156	1,209
Plus value of inventory change ($1,000)	9,619	12,023
Minus net income of corporate farms ($1,000)	9,208	1,385
Farm proprietors' income ($1,000)	30,567	11,847
Plus farm wages, perquisites, and other farm labor income ($1,000)	24,082	26,371
Farm labor and proprietors' income (LPI) ($1,000)	54,649	38,218
Personal income, all sources (PI) ($1,000)[c]	2,287,019	2,347,273
Farm LPI as share of total PI (%)	2.4	1.6
Farm proprietors' income as share of total PI (%)	1.3	0.5
Farm employment (jobs)	4,092	4,514
Farm proprietors' employment (jobs)	2,601	2,702
Farm wage and salary employment (jobs)	1,491	1,812
Total regional full- and part-time employment (jobs)	58,732	59,239
Farm employment as share of full- and part-time employment (%)	7.0	7.6

[a]Farm sales (cash receipts) in a given year can differ from production values in that year ($282,838 in Table 6) for several reasons. For example: (1) some agricultural products (such as forage or hay) are fed to cattle, i.e., they are produced but not sold, (2) some agricultural products produced this year may not be sold in this year, i.e., they may be held in inventory, and (3) some agricultural products produced last year may be sold this year.

[b]Imputed income is expenditures that households do not have to make because they own their dwellings or produce food or other items for their own use.

[c]Personal income is estimated by place of residence (for farms, this is the same as place of work). Employment is estimated by place of work.

Source: Bureau of Economic Analysis, Regional Economic Information System (http://fisher.lib.virginia.edu/reis/)

Table 8. Farm income, employment, and personal income in the Upper Klamath Basin, 1998.

	Klamath (OR)	Siskiyou (CA)	Modoc (CA)	Basin total
Total farm cash receipts from marketing ($1,000)[a]	98,127	80,881	68, 942	247,950
Plus government payments ($1,000)	1,845	2,680	1,485	6,010
Plus imputed and miscellaneous income ($1,000)[b]	17,656	11,407	8,152	37,215
Minus total production expenses ($1,000)	125,408	90,245	74,313	289,966
Realized net income from farming ($1,000)	–7,780	4,723	4,266	1,209
Plus value of inventory change ($1,000)	3,878	3,806	4,339	12,023
Minus net income of corporate farms ($1,000)	–1,275	843	1,817	1,385
Farm proprietors' income ($1,000)	–2,627	7,686	6,788	11,847
Plus farm wages, perquisites, and other farm labor income ($1,000)	12,308	8,483	5,580	26,371
Farm labor and proprietors' income (LPI) ($1,000)	9,681	16,169	12,368	38,218
Personal income, all sources (PI) ($1,000)[c]	1,265,488	897,055	184,730	2,347,273
Farm LPI as share of total PI (%)	0.8	1.8	6.7	1.6
Farm proprietors' income as share of total PI (%)	NA	0.9	3.7	0.5
Farm employment (jobs)	2,059	1,587	868	4,514
Farm proprietors' employment (jobs)	1,313	893	496	2,702
Farm wage and salary employment (jobs)	746	694	372	1812
Total regional full- and part-time employment (jobs)	32,427	22,251	4,561	59,239
Farm employment as share of full- and part-time employment (%)	6.4	7.1	19.0	7.6

[a]Farm sales (cash receipts) in a given year can differ from production values in that year ($282,838 in Table 6) for several reasons. For example: (1) some agricultural products (such as forage or hay) are fed to cattle, i.e., they are produced but not sold, (2) some agricultural products produced this year may not be sold in this year, i.e., they may be held in inventory, and (3) some agricultural products produced last year may be sold this year.

[b]Imputed income is expenditures that households do not have to make because they own their dwelling or produce food or other items for their own use.

[c]Personal income is estimated by place of residence (for farms, this is the same as place of work). Employment is estimated by place of work.

Source: U.S. Bureau of Economic Analysis, Regional Economic Information System (http://fisher.lib.virginia.edu/reis/)

In 1998, by contrast, realized net farm income in the Upper Klamath Basin was about $1.2 million. The negative realized farm income in Klamath County (–$8 million) was offset by positive realized net incomes in Modoc and Siskiyou counties (Table 8).

"Farm proprietors' income" adds the value of inventory changes and subtracts the net income of corporate farms. In 1997, farm proprietor income in the Upper Klamath Basin was estimated by BEA to be about $31 million, accounting for 1.3 percent of total regional personal income. In 1998, farm proprietor income was about $12 million, 0.5 percent of total personal income (Table 7).[6]

[6]Different sources of county-level information in the Upper Klamath Basin provide quite different estimates of income. The differences seem to be due to different definitions for seemingly similar indicators. The Agriculture Census 1997, for example, provides an estimate of "net cash return from agricultural sales." This measure is equal to the market value of agricultural products sold minus farm production expenses. It does not include government payments, other farm-related income, or imputed rent, and it does not include deductions for depreciation or changes in inventory values. The 1997 Census estimate of "net cash returns from agricultural sales" for the Basin is $48 million.

Table 9. The Klamath Reclamation Project in the Upper Klamath Basin, 1997.

Irrigated farms		Irrigated acres (1,000)		Value of sales ($1,000)	
Basin total	Project	Basin total	Project	Basin total	Project
1,744	1,400	542	195	238,663	108,539

Note: Figures in this table may differ slightly from those in other chapters because of differences in data sources and crop category definitions.

Source: 1997 Census of Agriculture and Tables 1 and 2 of Chapter 12 ("Crop Revenue")

The BEA estimates farm labor income at $24 million for 1997 and $26 million for 1998 (Table 7).[7]

As the overall economy has grown over the past 3 decades, total farm labor and proprietor income has declined as a share of regional income from just under 8 percent in the early 1970s to around 2 percent in the late 1990s. Farm labor and proprietor income totaled about $55 million in 1997 (2.4 percent of regional personal income) and $38 million in 1998 (1.6 percent of regional personal income).

Employment

Farm employment is not as variable as farm income. The BEA estimates that there were 2,601 farm proprietors in 1997 and 2,702 in 1998 (Table 7).[8] The BEA estimates full- and part-time farm wage and salary employment at 1,491 in 1997 and 1,812 in 1998.[9]

As the overall economy of the Upper Klamath Basin has grown over the past 3 decades, total farm employment (proprietor and farm wage and salary employment) has declined as a share of total full- and part-time employment in the Basin, from about 10 percent in the early 1970s to around 7 percent in the late 1990s. It represented 7 percent of total full- and part-time employment in the BEA estimates in 1997 and 7.6 percent in 1998 (Table 7).[10]

Income and employment data are broken down by county in Table 8.

Role of the Klamath Reclamation Project in Upper Klamath Basin agriculture

The Klamath Reclamation Project provides water to two-thirds (63 percent) of the 2,239 farms—and to 80 percent of the irrigated farms—in the Upper Klamath Basin (Table 9). The Project contains a little more than one-third of the region's irrigated acreage. Project farms produced almost half (45 percent) of the value of agricultural sales in the region in 1997.

Conclusion

The Upper Klamath Basin economy has grown during the past 3 decades and has become more specialized in agriculture and government (relatively slow-growing sectors) and several rapidly growing sectors (services and wholesale trade). Although the share of both income and employment in agriculture has declined since 1969, the Upper Klamath Basin economy depends on agriculture (defined as agriculture and food manufacturing) for 14 percent of the

[7]The 1997 Census of Agriculture estimates "hired farmworker payroll" at $27 million.

[8]The Census of Agriculture reports only 2,239 farm operators in 1997 (shown as the number of farms in Table 5).

[9]The Census of Agriculture reports more than four times as many hired farmworkers (6,238) in the Upper Klamath Basin in 1997 (Table 5). The Oregon Employment Department estimate of total agricultural (worker) employment in Klamath County in 1997 is 1,490, twice the BEA estimate of 784, suggesting that BEA substantially undercounts farmworkers.

[10]The Upper Klamath Basin IMPLAN model estimate of employment in the agriculture and related sector (which includes proprietors and hired farmworkers) for 1998 is 5,964, accounting for 10 percent of total employment.

region's jobs and 12 percent of the region's income. Almost half of the agricultural sales in the region originate on Project farms.

The next three chapters in this report analyze some consequences of the changes in water allocation on the Klamath Reclamation Project in 2001. Chapter 12 ("Crop Revenue") looks at the effects of the drought and the 2001 Biological Opinions on crop revenues on the Project. Chapter 13 ("Regional Economic Impact") examines the economic effects of the changes in Project agricultural production on the overall economy of the Upper Klamath Basin. Chapter 14 ("Outcomes") compares model-based estimates to reported economic data for 2001.

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Appendix A. North American Industry Classification System sector descriptions

Agriculture, fishing, and related: Growing crops, raising animals, harvesting fish and other animals, and services that support natural-resource-based production. Because fishing employment is only 0.3 percent of agriculture, fishing, and related employment in the Upper Klamath Basin, we have called this sector "agriculture and related."

Forestry and logging: Farm production of stumpage, pulpwood, fuel wood, Christmas trees, and fence posts. Operation of timber tracts, tree farms, and forest nurseries, plus reforestation.

Mining: Establishments that extract naturally occurring mineral solids, such as coal and ores; liquid minerals, such as crude petroleum; and gases, such as natural gas. The term *mining* is used in the broad sense to include quarrying, well operations, beneficiating (e.g., crushing, screening, washing, and flotation), and other preparation customarily performed at the mine site or as a part of mining activity.

Construction: Construction of buildings and other structures, heavy construction (except buildings), additions, alterations, reconstruction, installation, maintenance, and repairs. Establishments engaged in demolition or wrecking of buildings and other structures, clearing of building sites, and sale of materials from demolished structures are included. This sector also includes those establishments engaged in blasting, test drilling, land filling, leveling, earth moving, excavating, land drainage, and other land preparation.

Manufacturing—(food, wood products, high technology, other): The mechanical, physical, or chemical transformation of materials, substances, or components into new products. The assembling of component parts of manufactured products is considered manufacturing, except in cases where the activity is appropriately classified as construction.

Transportation and warehousing: Providing transportation of passengers and cargo, warehousing and storing goods, scenic and sight-seeing transportation, and supporting these activities.

Utilities: Provision of the following utility services: electric power, natural gas, steam supply, water supply, and sewage removal. Within this sector, the specific activities associated with the utility services provided vary by utility: electric power includes generation, transmission, and distribution; natural gas includes distribution; steam supply includes provision and/or distribution; water supply includes treatment and distribution; and sewage removal includes collection, treatment, and disposal of waste through sewer systems and sewage treatment facilities.

Wholesale trade: Establishments engaged in wholesaling merchandise, generally without transformation, and rendering services incidental to the sale of merchandise.

Retail trade: Establishments engaged in retailing merchandise, generally without transformation, and rendering services incidental to the sale of merchandise.

Accommodation and food services: Lodging and/or prepared meals, snacks, and beverages for immediate consumption.

Finance and insurance: Firms with payroll primarily engaged in financial transactions (transactions involving the creation, liquidation, or change in ownership of financial assets) and/or in facilitating financial transactions, pooling risk, or underwriting insurance and annuities.

Real estate and rental and leasing: Renting, leasing, or otherwise allowing the use of tangible assets (e.g., real estate and equipment), intangible assets (e.g., patents and trademarks), and establishments providing related services (e.g., establishments primarily engaged in managing real estate for others; selling, renting, and/or buying real estate for others; and appraising real estate).

Other services: Services not specifically provided for elsewhere in the North American Industry Classification System (NAICS). Establishments in this sector are primarily engaged in activities such as repair and maintenance of equipment and machinery; personal and laundry services; and religious, grant-making, civic, professional, and similar organizations. Establishments providing death care services, pet care services, photo finishing services, temporary parking services, and dating services also are included. Private households that employ workers on or about the premises in activities primarily concerned with the operation of the household are included in this sector.

Information: Establishments engaged in the following processes: producing and distributing information and cultural products, providing the means to transmit or distribute these products as well as data or communications, and processing data. The main components of this sector are the publishing industries, including software publishing; the motion picture and sound recording industries; the broadcasting and telecommunications industries; and the information services and data processing services industries.

Administrative and support services, etc.: Routine support activities for the day-to-day operations of other organizations. These essential activities often are undertaken in-house by establishments in many sectors of the economy. The establishments in this sector specialize in one or more of these support activities and provide these services to clients in a variety of industries and, in some cases, to households. Activities performed include office administration; hiring and placing of personnel; document preparation and similar clerical services; solicitation, collection, security, and surveillance services; cleaning and waste disposal services.

Arts, entertainment, and recreation: Establishments that operate facilities or provide services to meet varied cultural, entertainment, and recreational interests of their patrons. This sector comprises establishments that are involved in producing, promoting, or participating in live performances, events, or exhibits intended for public viewing; establishments that preserve and exhibit objects and sites of historical, cultural, or educational interest; and establishments that operate facilities or provide services that enable patrons to participate in recreational activities or pursue amusement, hobby, and leisure-time interests.

Health care and social assistance: Providing health care and social assistance for individuals. The services are delivered by trained professionals. All industries in the sector share this commonality of process, namely, labor inputs of health practitioners or social workers with the requisite expertise. Many of the industries in the sector are defined based on the educational degree held by the practitioners included in the industry.

Professional, scientific, and technical services: Establishments that specialize in performing professional, scientific, and technical activities for others. These activities require a high degree of expertise and training. The establishments in this sector specialize according to expertise and provide services to clients in a variety of industries and, in some cases, to households. Activities performed include legal advice and representation; accounting, bookkeeping, and payroll services; architectural, engineering, and specialized design services; computer services; consulting services; research services; advertising services; photographic services; translation and interpretation services; veterinary services; and other professional, scientific, and technical services.

Educational services: Instruction and training in a wide variety of subjects. This instruction and training is provided by specialized establishments, such as schools, colleges, universities, and training centers. These establishments may be privately owned and operated for profit or not for profit, or they may be publicly owned and operated. They also may offer food and accommodation services to their students. Educational services usually are delivered by teachers or instructors that explain, tell, demonstrate, supervise, and direct learning. Instruction is imparted in diverse settings, such as educational institutions, the workplace, or the home through correspondence, television, or other means. It can be adapted to the particular needs of the students; for example, sign language can replace verbal language for teaching students with hearing impairments. All industries in the sector share this commonality of process, namely, labor inputs of instructors with the requisite subject matter expertise and teaching ability.

Public administration: Administration, management, and oversight of public programs by federal, state, and local governments.

Source: U.S. Executive Office of the President/Office of Management and Budget (OMB). 1999. North American Industry Classification System (Jist Works, Inc., Indianapolis, IN).

The Effects of Water Allocation Decisions on Crop Revenue in the Klamath Reclamation Project

Susan Burke

This analysis focuses on the irrigated land within the Klamath Reclamation Project. Its objectives are twofold:

- To present an estimate of the potential effects of the 2001 Biological Opinions on gross farm crop sales generated on the land within the Project. (For *regional* economic effects, see Chapter 13, "Regional Economic Impact.") The estimates reported in this chapter are based on expectations in early 2001 regarding the effects of the Biological Opinions on crop acreage. (For a discussion of *reported economic outcomes* based on actual acreage, see Chapter 14, "Outcomes.")
- To suggest alternative water allocation mechanisms within the Project that could increase gross farm crop sales without increasing irrigation efficiency or the amount of water allocated to irrigation (For a discussion of *basinwide* strategies, see Chapter 19, "Water Allocation Alternatives.")

After providing brief background information, this chapter contains five sections.

- The first section presents agricultural economic and statistical data about the Project.
- The second section describes irrigation diversions and water allocation within the Project.
- The third section describes the model used to estimate the response of gross farm crop sales to various levels of irrigation diversions.
- The fourth section presents the results of the model. The first two parts of this section correspond to the objectives of this chapter. The first part discusses the effects of the 2001 Biological Opinions on irrigation diversions and gross farm crop sales. The second part describes changes in policies that could make the existing water "go farther" (in terms of increased on-farm net revenue). A final part of this section looks at the accuracy of the model in predicting actual 2001 crop acreage and farm crop sales.
- The fifth section summarizes our findings and discusses possible improvements to the analysis.

Background

Authorized by Congress in 1905, the Klamath Reclamation Project encompasses more than 200,000 acres within the Upper Klamath Basin. Those 200,000 acres represent approximately 37 percent of the irrigated land in the Upper Basin. The farms receiving irrigation water from the Project annually generate gross farm crop sales of approximately $100 million, about 42 percent of the Upper Basin gross farm crop sales. (As in Chapter 11, "Basin Economy," we consider the Upper Klamath Basin economy to consist of Klamath County, Oregon, and Modoc and Siskiyou counties in California.) The primary crops irrigated within the Project are alfalfa hay, pasture, small grains (barley), potatoes, and wheat.

Construction of the Project joined two separate watersheds:

- The Klamath River watershed, which originates above Upper Klamath Lake in Oregon and supplies water to Lower Klamath Lake as well as to the Klamath River
- The Lost River watershed, formerly a closed system, made up of Gerber Reservoir in Oregon and Clear Lake, Tule Lake, and the Lost River in California

The two watersheds are connected by two physical structures. The Lost River Diversion Channel joins the Lost River to the Klamath River and can carry water in either direction, depending on the season and operational needs. The second structure connecting the two watersheds is a pipe, through which irrigation runoff is pumped from Tule Lake to Lower Klamath National Wildlife Refuge.

Because Project lands receive water from two watersheds, farmers within the Project may face different restrictions on their diversions. The reason for these differences is the fact that the hydrology of the two watersheds, or the environmental restrictions they face, may be different in any given year. The importance of this fact will become clear later in this chapter when estimates of gross farm crop sales are made under assumptions of varying quantities of irrigation water deliveries.

Agricultural economic statistics for the Project

Crop mix and acreage

Table 1 shows the acres planted in the Project by crop and watershed for the years 1987 through 2000. Total acres and the mix of crops planted have changed little over this 14-year period.

The Klamath River watershed includes the majority of the land in the Project, approximately 170,000 acres, or 87 percent of the total Project crop acreage. Alfalfa hay, irrigated pasture, and feed grains make up approximately 75 percent of the Klamath River watershed crop acreage. Potatoes (categorized as vegetables) make up the majority of the remaining crop acreage in the Klamath River watershed portion of the Project. Hay and pasture are the primary crops grown in the Lost River portion of the Project.

Sugarbeets, which came into production in 1990 in the Project, probably will no longer be grown due to the closing of a processing plant.

The number of acres in production over this period of time changed little because irrigation insulated farm managers from natural droughts. The years 1992 and 1994 were dry years; however, only 1992 shows a reduction in total acres in production. The greatest reduction in acreage in 1992 occurred in the Lost River watershed. The data for 1988 are incomplete, which explains the low number of acres in production that year.

Gross farm crop sales

Table 2 shows the nominal gross farm crop sales generated on Project lands from 1987 through 2000. Generally, the gross farm crop sales in the Project are near $100 million per year. Farms in the Klamath River watershed generate approximately 90 percent of this total. Potatoes generate 30 percent of the total gross farm crop sales on roughly 16 percent of the total land in the Project.

Table 1. Acres of crops on the Project by crop category and watershed, 1987–2000.

	1987	1988[a]	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
							(1,000 acres)							
Klamath River watershed														
Feed grains	67	59	70	66	63	62	59	58	56	54	52	48	43	42
Food grains	6	5	9	9	6	8	7	6	6	10	9	9	18	13
Hay and pasture	68	53	74	78	81	74	77	78	78	76	80	82	83	86
Miscellaneous crops	2	3	3	3	3	3	3	3	3	3	4	6	7	7
Sugarbeets	0	0	0	1	4	6	8	8	9	7	6	7	7	4
Vegetables	23	17	20	21	18	16	19	19	18	19	18	16	14	12
Klamath River total	167	137	177	178	176	169	173	171	170	168	170	169	170	170
Lost River watershed														
Feed grains	3	4	3	3	1	0	2	1	1	1	1	1	1	1
Food grains	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Hay and pasture	21	21	21	23	24	11	24	24	24	24	23	24	23	24
Miscellaneous crops	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sugarbeets	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vegetables	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Lost River total	25	25	25	26	25	11	26	26	26	26	25	26	25	25
Grand total	**192**	**162**	**203**	**204**	**201**	**180**	**199**	**197**	**196**	**194**	**195**	**194**	**195**	**195**

[a]1988 data are incomplete.

Note: Columns may not sum to totals due to rounding. Acreage in this table may differ slightly from numbers in other chapters, depending on the data source, categories, and rounding.

Source: U.S. Bureau of Reclamation, Annual Crop Reports, multiple years. Obtained from the staff of the Klamath Falls, Oregon, field office.

Table 2. Gross farm crop sales from Project lands by crop category and watershed, 1987–2000.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
							($1,000)							
Klamath River watershed														
Feed grains	14,716	19,320	20,848	16,443	16,690	15,109	13,778	13,902	18,888	17,275	15,525	9,688	9,905	9,026
Food grains	1,910	2,449	3,958	2,837	2,101	3,011	2,249	2,388	3,045	5,096	4,185	2,943	3,009	2,742
Hay and pasture	20,477	17,114	25,119	26,705	26,546	22,783	26,877	28,574	29,519	30,727	35,000	31,660	32,368	29,497
Miscellaneous crops	3,723	4,147	5,086	6,892	6,842	5,075	7,178	5,929	5,478	6,368	9,173	12,505	12,785	11,651
Sugarbeets	0	0	0	932	4,287	6,133	7,868	8,654	9,064	8,107	7,351	5,549	5,673	5,170
Vegetables	28,437	34,769	44,937	46,764	18,033	30,116	37,867	22,633	49,839	28,176	27,148	29,819	30,487	27,782
Klamath River total	69,261	77,800	99,947	100,572	74,500	82,227	95,817	82,079	115,833	95,749	98,381	92,164	94,226	85,868
Lost River watershed														
Feed grains	723	1,182	957	656	250	71	347	337	386	461	308	287	293	267
Food grains	262	77	362	0	0	17	0	55	0	42	36	19	20	8
Hay and pasture	5,053	5,652	6,007	7,516	7,828	4,004	8,698	8,204	8,758	9,306	9,054	8,674	8,868	8,082
Miscellaneous crops	5	0	6	0	0	26	27	0	23	32	4	4	4	4
Sugarbeets	0	0	0	0	40	0	0	103	0	0	220	174	178	162
Vegetables	460	693	1,040	624	442	0	736	491	958	398	535	408	417	380
Lost River total	6,503	7,605	8,371	8,795	8,559	4,118	9,808	9,190	10,125	10,237	10,158	9,567	9,781	8,914
Grand total	**75,764**	**85,405**	**108,319**	**109,367**	**83,059**	**86,345**	**105,625**	**91,270**	**125,957**	**105,986**	**108,539**	**101,731**	**104,008**	**94,782**

Note: Values in this table may differ slightly from numbers in other chapters, depending on the data source, categories, and rounding.

Source: The County Agricultural Commissioner's Report for Siskiyou and Modoc counties in California and discussions with Harry Carlson, superintendent of the Intermountain Research and Extension Center in Tulelake, CA, University of California, and Ken Rykbost, superintendent of the Klamath Falls Experiment Station, Oregon State University

Table 3. Price per ton of crops grown on Project lands, 1987–2001.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001 est.
	($ per ton)														
Feed grains	82	120	110	93	98	90	87	90	125	120	112	75	103	97	96
Food grains	90	145	130	95	110	114	100	115	151	159	136	97	90	93	113
Hay and pasture	62	67	71	75	67	64	72	77	75	82	88	75	98	98	76
Misc. crops	73	73	90	100	100	95	100	100	86	100	100	100	100	100	100
Sugarbeets	—	—	—	45	45	44	44	47	45	50	50	36	25	19	—
Vegetables	59	96	103	104	46	88	92	57	133	71	71	85	101	42	74

Source: County Agricultural Commissioner's Reports for Siskiyou and Modoc counties, multiple years. Hay and pasture prices were estimated with the help of Ron Hathaway and Rod Todd, Klamath County Extension Office, Oregon State University. Potato prices for 1998 and 1999 were obtained from the University of California Intermountain Research and Extension Center.

Volatility in revenue is due to fluctuations in crop prices and yields rather than a change in the quantity of land in production. Table 3 shows historical prices by crop. Notice that the price of potatoes (categorized as vegetables) ranged from $42 per ton to $133 per ton. It is no coincidence that the year with the highest revenue, 1995, is the year of the highest price for potatoes. The prices for 2001 are estimates, and these are the prices used in our analysis.

Irrigation diversions and water allocation on the Project

Irrigation diversions

Figure 1 shows Project-related inflows and releases during the irrigation season (April through October) by source for the years 1961 through 1995. Figure 1 demonstrates two facts.

- Releases in the Lost River watershed (from Clear Lake and Gerber reservoirs) make up a small portion of the total water released into the Project compared to releases from Upper Klamath Lake.
- Historically, the Upper Klamath Lake releases for irrigation in any growing season do not seem to be affected by the amount of inflow into Upper Klamath Lake.

This second point indicates that Project farmers were insulated from drought by the operation of the Project, even after the listing of suckers under the Endangered Species Act. Consider the two driest years on record for this time period, 1992 and 1994. Notice that Upper Klamath Lake releases were just below average in 1992 and above average in 1994, 2 years when Upper Klamath Lake inflows were markedly low.

What was different in 2001 from prior years was the combination of a critically dry year, a Biological Opinion on in-stream flows below Iron Gate Dam, and an increase in the Upper Klamath Lake elevation requirement. The result was curtailment of irrigation diversions to the Project. This topic is explored in greater detail in the subsequent section entitled "Effects on 2001 gross farm crop sales generated on Project lands."

Water rights and allocations

The water rights attached to Project lands fall into one of three categories of *priority use right,* according to the U.S. Bureau of Reclamation (BOR). The three categories are referred to as "A," "B," and "C." Legally, the priority use right indicates the contract dates between the BOR and specific water users (not to be confused with water rights established through the

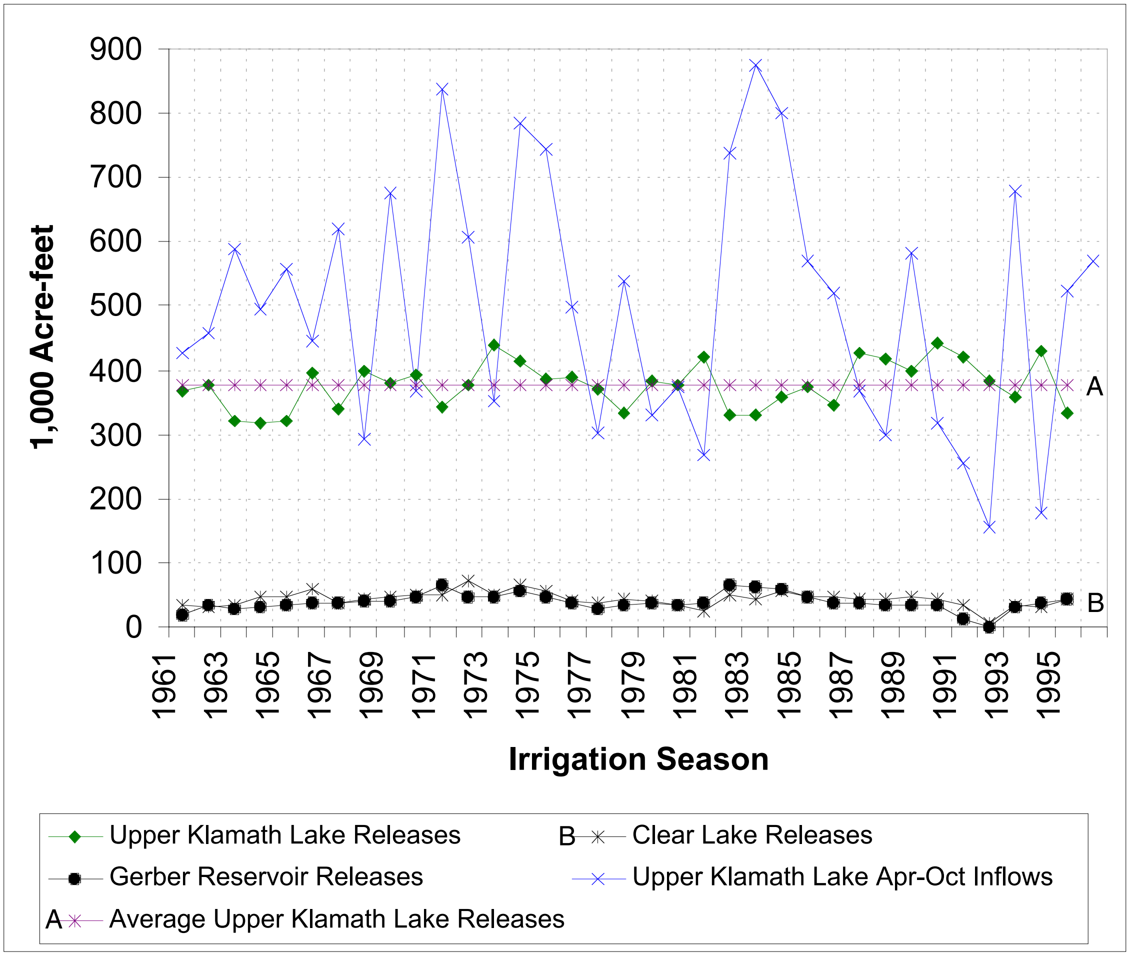

Figure 1. Project-related inflows and releases. Source: U.S. Bureau of Reclamation reservoir operations model (Klamath Project Operations Model (KPOP-SIM)).

state adjudication or permitting process). The A priority use rights holders, or "A users," have the most senior contract type, followed by B users and finally C users. Seniority of contract type means that, when water is allocated among users, the A users receive all of the water they can beneficially use before either the B or C users receive any water. Once the A users receive all of the water they can beneficially use, deliveries begin to B users. Once the B users receive all of the water they can put to beneficial use, C users receive their allocation.

The drought of 2000–2001, combined with the 2001 Biological Opinions, created a situation in which the BOR had to forgo irrigation deliveries to all three priority use right categories in parts of the Project (those areas receiving water from Upper Klamath Lake). In the future, however, the priority use right system may be used to allocate irrigation diversions. Specifically, the BOR may have to determine how to allocate water to Project lands when irrigation diversions are less than a full supply, but greater than zero.

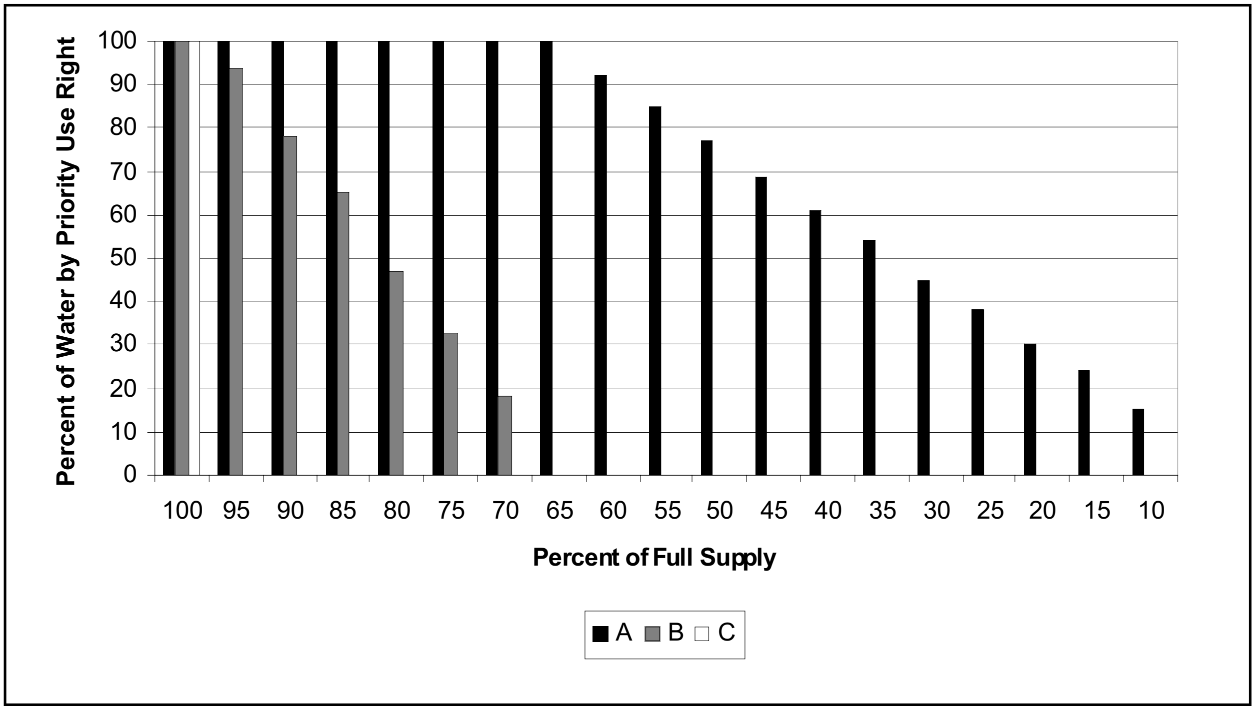

Figure 2. Percent of total irrigation diversions allocated by priority use right.

Table 4. Percentage of Project land by A,B,C priority use right and state.

	Priority use right (% of total Project land)			
	A	B	C	Total
California	28	1	3	32
Oregon	39	29	0	68
Total	67	30	3	100

Source: Personal conversations with staff at the U.S. Bureau of Reclamation Klamath Falls office

Figure 2 details how a percentage reduction in total Project irrigation diversions translates into a percentage reduction in irrigation diversions by priority use right. Figure 2 shows that the C users lose all of their diversions almost immediately, even at 95 percent of full diversions. The B users receive less and less of their diversion until total diversions fall to 65 percent, at which time B users receive no water. The first reduction in delivery to A users occurs when total diversions are 60 percent of full.

Table 4 shows the percentage of land categorized by priority use right and state. Land that holds an A priority use right makes up 67 percent of the total land in the Project. The lands that hold B and C priority use rights represent 30 percent and 3 percent of the land, respectively. Nearly all of the B land is in Oregon, and nearly all of the C land is in California. Thus, if the Project lands suffer a reduction in irrigation diversions between 95 percent and 65 percent, the majority of the reduction will be felt in Oregon (ignoring the small percentage of C lands in California).

The model

This section describes the model we used to estimate the change in gross farm crop sales resulting from various changes in irrigation diversions. We begin by detailing how the model came to be built, and we follow with a description of the use of economic theory in the model. A description of the model's uses and shortcomings concludes this section.

Model development

The model was developed from 1996 through 1998 at Oregon State University (OSU) and the University of California, Davis (UCD) with a grant from the U.S. Department of Agriculture (USDA). The purpose of the grant was to study the economic and hydrologic impacts occurring in the Project resulting from changes to irrigation diversions and water allocations (Burke 1999).

Model development required coordination with staff members at the BOR office in Klamath Falls, Oregon. At the time of the model development, the BOR was preparing to write an Environmental Impact Statement (EIS) for the Klamath Basin. It became apparent that the model being developed by OSU and UCD would be useful in the EIS process. Therefore, the BOR contracted to continue the effort. In September 2000, the BOR funded an effort to incorporate the model into the existing reservoir operations model (KPOP-SIM) currently in use in the Klamath Falls BOR office.

Economic theory used in the model

The model is a combined economic and hydrologic model. The economic model considers farm managers' decisions, while the hydrologic model is based on availability and allocation of irrigation diversions.

The economic model is a short-run model that assumes farm managers maximize their net farm crop sales through cropping decisions and irrigation technology improvements.[1] Management decisions are constrained, in part, by available water, fixed capital, and crop production practices.

The input to the economic model includes historical crop patterns, per-acre average yield of crops grown on the Project, variable costs of production, available water, and crop prices. The output of the model includes estimates of cropping patterns within an irrigation district given a set of inputs. Of primary interest for this analysis is the input that quantifies the amount and allocation of available irrigation diversions to farm managers and/or irrigation districts.

Irrigation diversions enter into the hydrologic model in two ways. First, how much total irrigation diversion is available to the Project? Second, how will the available diversions be allocated?

The answer to the first question comes from translating the available diversions into a percent of full water supply available to the Project. This analysis depends on the time-series of diversion data presented in Figure 1. The answer to the second question is found by taking the available irrigation diversions and allocating them among water users as shown in Figure 2.

The model assumes that farm managers and/or irrigation districts will be informed about how much water is available to them as a percent of full supply. It also assumes that farm managers receive this information in a timely manner so that business decisions can be made with full information about resource availability.

Once the percentage of full supply of water is known, the model is run with various assumptions about how the available water is allocated among irrigation districts and/or farms.

Allocation methods can take many forms. Two examples of ways to constrain limited irrigation diversions are: (1) directly, by constraining water deliveries to farms and irrigation districts, or (2) indirectly, by constraining the amount of land in production. For example, if irrigation diversions are determined to be 50 percent of full supply, either water deliveries can be measured to assure that only 50 percent of full supply is delivered, or the quantity of land in production can be reduced by 50 percent.

[1]The model allows for a wide range of irrigation technology improvements, ranging from relatively small changes (e.g., an increase in the number of irrigation sets with sprinklers) to relatively major changes (e.g., changing from flood to sprinkler irrigation). The model determines whether it is economically feasible to make an improvement given the return of the crop.

The advantage of the first method—directly measuring water deliveries—is the flexibility it gives farm managers to allocate water as they see fit. The disadvantage is the need for measurement devices to manage deliveries to A, B, and C users. Unfortunately, these measurement devices are not in place on the Project.

The indirect method of assuring that the appropriate quantity of water is delivered—by constraining the number of acres of land in production—has the advantage of being a "manageable" method on the Project today. However, it reduces farm managers' flexibility regarding the use of their resources and results in lower overall gross farm crop sales within the Project.

A comparison of the effects of these two allocation methods on gross farm crop sales is presented in the "Results" section of this chapter.

Model uses and shortcomings

Two shortcomings of the model are: (1) the need for a timely and accurate estimate of the percent of full irrigation diversion available in the coming growing season, and (2) the short-run nature of the model. This section discusses these shortcomings and ways in which the model can be useful.

Need for timely information

The model assumes that information about the percent of full supply is available when farm managers are making production plans for the upcoming year. There is a significant amount of controversy around this assumption, relating to two specific issues.

First, many Project farm managers feel they receive little information regarding the availability of irrigation supplies. Furthermore, they say the information they do receive is too late to be of help in making production decisions (for example, planting decisions and securing operating lines of credit).

Some farm managers in the Project feel this information is needed as early as November or December of the year preceding the growing season. Others feel that getting the information later, in the spring of the planting season, would still be useful for planting decisions.

The advantage to announcing available supplies earlier rather than later is that farm managers have more time to make decisions. The drawback is that incomplete hydrologic data are available. Therefore, the estimate of water availability may be far different than the amount of water that ultimately becomes available.

Regardless of the timing of the announcement, or the information content, what is important to point out is that the model assumes something that currently does not occur—that farm managers get full information in a timely manner. Therefore, the relationship between water availability and gross farm crop sales suggested by the model is a best-case scenario.

The second matter of controversy surrounding the assumption of timely information about water availability relates to the accuracy of estimates of available irrigation diversions. The hydrology of the Project is complex. Many factors contribute to available water supplies, including, but not limited to, summer precipitation, average temperature during the growing season, and timing of the runoff from the winter snowpack. Thus, an above-average snowpack year may result in below-average irrigation water availability if above-average temperatures in the spring lead to early snow melt. Conversely, effects of a relatively dry winter could be offset by above-average summer rains. These events have happened on the Project, which makes forecasting available irrigation diversions a difficult task.

The short-run nature of the model

The model assumes that farm managers maximize revenues net of variable costs. Fixed costs are not a factor in the results generated by the model. The benefit of this type of model is that it estimates the on-farm response to short-run (seasonal) changes in inputs. The model was developed this way because, at the time, long-term changes in the structure or scale of agriculture were not expected on the Project. Thus, the model was developed to estimate the effects of occasional annual shortages in available irrigation diversions on gross farm crop sales.

The disadvantage of not including fixed costs in the model is that the "break-even point"—the point at which it no longer is economically feasible to remain in farming in the long term—is not determined. Finding this break-even point is difficult, and the information needed varies by farm. Such an analysis involves the level of long-term debt being carried by the farm manager (not to be confused with annual operations debt).

For the purposes of this chapter, we use a short-run analysis to understand the link between gross farm crop sales and irrigation diversions in the short term. This model should not be used to predict how many farms or acres could remain in production in the long run, given a long-term shift to reduced irrigation diversions.

The results

The discussion of our results is separated into three parts, which describe:

- The effects of natural drought and Biological Opinions on gross farm crop sales generated on Project lands
- Policy changes that could lessen the effect of reduced irrigation deliveries on gross farm crop sales (for example, changes to water allocation methods)
- The ability of the model to forecast actual outcomes accurately

Effects on 2001 gross farm crop sales generated on Project lands

This section looks at two issues:

- The effect of various ranges of Biological Opinions and drought on irrigation diversions into the Project
- The effect of irrigation diversions on gross farm crop sales generated on Project lands

Effect of Biological Opinions and drought on irrigation diversions

Two events significantly affected the level of gross farm crop sales generated on the Project in 2001. First, a severe drought reduced the supply of water available to all water users in the Upper Klamath Basin. Second, a revised Biological Opinion for the level of Upper Klamath Lake, combined with a new Biological Opinion about Klamath River flows, forced the BOR to announce in April 2001 that there would be no irrigation diversions from Upper Klamath Lake into the Project for the year.[2]

Figure 3 (following page) represents a framework in which to discuss how the interaction between hydrologic year-types and Biological Opinions affects irrigation diversions. (Note that Figure 3 does not represent the actual frequency of hydrologic year-types, nor does it quantify the Biological Opinions.)

[2]Subsequent to the announcement that irrigation deliveries from Upper Klamath Lake would be zero in 2001, the BOR released 40,000 acre-feet of water in midseason.

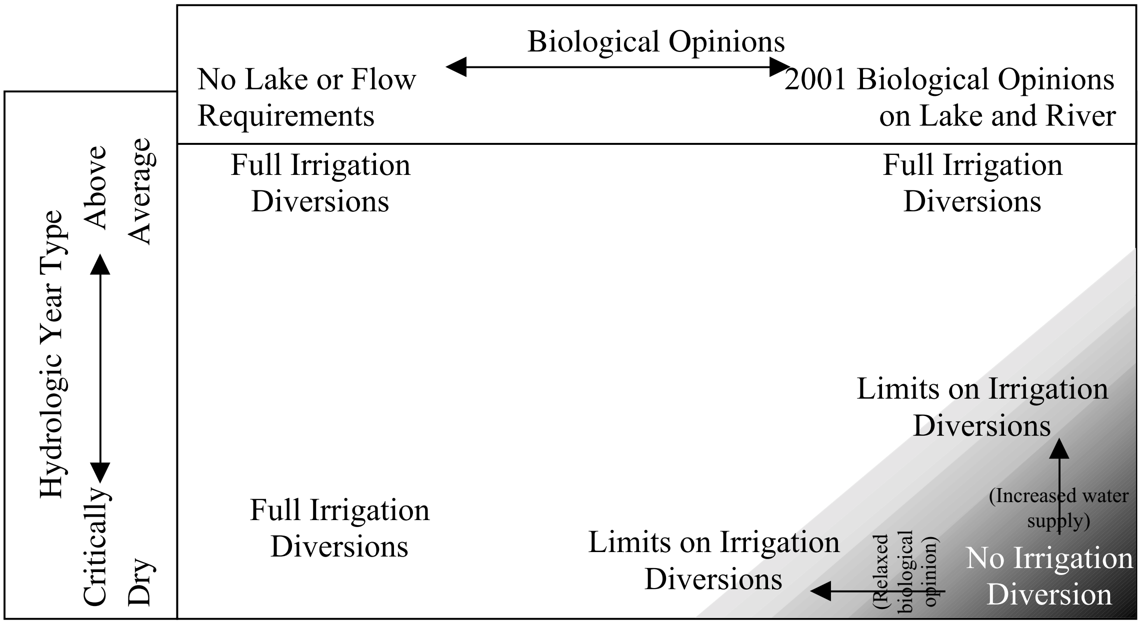

Figure 3. Effect of Biological Opinions and hydrologic year-type on irrigation diversions.

Biological Opinions and hydrologic year-types are shown in Figure 3 on a continuum. Hydrologic year-types (represented vertically) range from above average to critically dry.[3] The continuum of Biological Opinions (represented horizontally) reflects combinations of lake elevation requirements and in-stream flows below Iron Gate Dam. Biological Opinions range from none (on the far left-hand side of Figure 3) to the levels used during 2001 (on the far right-hand side of Figure 3).[4]

The lower right-hand corner of Figure 3 represents the coincidence of the 2001 Biological Opinions and a critically dry year. When this occurs, as in 2001, irrigation diversions are zero. Had the Biological Opinions been relaxed in 2001, irrigation diversions would have been limited, but not eliminated (as shown by the gray shading to the left of the right-hand corner).

If the Project is not managed to provide for minimum flows below Iron Gate Dam, irrigation diversion shortages are not experienced, regardless of whether the surface lake elevation is 4,139 or 4,140 feet above sea level. This was the case in 1992, another critically dry year, when minimum in-stream flows below Iron Gate Dam were not maintained and irrigation diversions were 100 percent of full supply.

Table 5 shows the range of irrigation diversions as a percent of full diversions for four combinations of lake levels and Iron Gate Dam flows (called operational rules in Table 5) with various hydrologic year-types. It also shows the frequency of each year-type during the period from 1961 to 2001. Table 6 provides the details of the operational rules used in Table 5.

[3]The U.S. Bureau of Reclamation defines hydrologic year-types in their annual Environmental Assessments. The definitions refer to the number of standard deviations from average of inflow into Upper Klamath Lake. “Above average” and “below average” designations are given to years that are between average and 1 standard deviation above and below average, respectively. The “dry” designation is given to a water year that is between 1 and 2 standard deviations below average. “Critically dry” year-types are more than 2 standard deviations from average.

[4]Lake levels and river flows in Biological Opinions also can be set higher than their 2001 levels. In this example, nothing is changed by introducing higher levels because the 2001 levels eliminated irrigation diversions.

Table 5. Estimates of the percent of full irrigation diversions for Upper Klamath Lake under various operational rules and hydrologic year-types.

Hydrologic year-type	Frequency (number of years, 1961–2001)	Percent of full irrigation (%)			
		Lake elevation 4,139 feet[a]		Lake elevation 4,140 feet[a]	
		Flow 1992	Flow 2001	Flow 1992	Flow 2001
Above average	21 (51%)	100	100	100	100
Below average	12 (29%)	100	100	100	55–100
Dry	5 (12%)	100	50	100	10
Critically dry	3 (7%)	100	10	100	0

[a]See Table 6 for details of lake elevation and flow requirements.

Source: U.S. Bureau of Reclamation's reservoir operations model KPOP-SIM and the Project operations model KP-HEM were used to develop this analysis.

Table 6. Detail of operational rules.

	Lake elevation[a]		In-stream flows	
	1992 (feet above sea level)	2001 (feet above sea level)	1992 (cfs)[b]	2001 BiOp (cfs)
October	4,139.34	4,140.00	900	1,300
November	4,139.66	4,140.00	900	1,300
December	4,140.00	4,140.00	900	1,300
January	4,141.01	4,141.01	900	1,300
February	4,141.74	4,141.74	500	1,300
March 1–15	4,142.02	4,142.02	500	1,300
March 16–31	4,142.32	4,142.32	500	1,300
April 1–15	4,142.60	4,142.60	800	1,700
April 16–30	4,142.60	4,142.60	500	1,700
May 1–15	4,142.60	4,142.60	500	1,700
May 16–31	4,142.60	4,142.60	500	1,700
June 1–15	4,142.27	4,142.27	450	2,100
June 16–30	4,141.93	4,141.93	450	1,700
July 1–15	4,141.60	4,141.60	400	1,000
July 16–31	4,139.00	4,139.00	400	1,000
August	4,139.00	4,140.79	400	1,000
September	4,139.00	4,139.00	400	1,000

[a]Actual lake elevation, which was based on minimums set in the 1992 and 2001 BiOps. Source: U.S. Bureau of Reclamation (http://www.mp.usbr.gov/kbao/models/index.html)

[b]Approximate flows. In 1992, the PacifiCorp hydroelectric dams were operated pursuant to a Federal Energy Regulatory Commission license, which did establish minimum flows. However, the minimum flows were subject to water availability and senior water rights. The 1992 flows shown here were below the FERC minimums.

As discussed above and shown in Table 5, irrigation diversions are 100 percent of full in all year-types when there is no in-stream flow requirement below Iron Gate Dam, regardless of whether the lake elevation is 4,139 or 4,140 feet. Combining the 4,139-foot lake elevation requirement (the USFWS 1992 Biological Opinion) with the 2001 National Marine Fisheries Service (NMFS) in-stream flow requirement results in estimates of percentages of full irrigation diversion as follows:

- Above-average or below-average years—100 percent of full
- Dry years—50 percent of full
- Critically dry years—10 percent of full

When in-stream flows are at 2001 NMFS levels, and the lake elevation requirement is increased to 4,140 feet (the USFWS 2001 Biological Opinion), irrigation diversions are:

- Above-average years—100 percent of full
- Below-average years—55 to 100 percent of full
- Dry years—10 percent of full
- Critically dry years—0 percent of full

Effect of irrigation diversions on gross farm crop sales

The change in gross farm crop sales associated with various amounts of irrigation diversions from Upper Klamath Lake into the Project is shown in Table 7, using the same format as Table 5. This analysis assumes that allocation of water follows the existing A,B,C priority use right system currently in place. The decrease in gross farm crop sales from increasing the in-stream flow requirement from 1992 levels to 2001 levels, while holding the lake at 4,139 feet, is $29,906,000 in a dry year. When the hydrologic year-type is critically dry, the loss in revenue under the same operational rules is $60,291,000.

Table 7 also shows the loss in gross farm crop sales that occurs in the Project by increasing the lake elevation from 4,139 to 4,140 feet when the in-stream flow requirement is at 2001 levels. In this case, a loss in revenue occurs in below-average, dry, and critically dry years. In a below-average hydrologic year-type, the loss in gross farm crop sales ranges from zero to $27,705,000. In a dry year, the loss is the difference between $58,465,000 and $29,906,000 ($28,559,000). In a critically dry year, the loss is the difference between $74,212,000 and $60,291,000 ($13,921,000).

Gross farm crop sales on the Project are not zero when irrigation diversions are zero because of the availability of groundwater within Project lands. For the purposes of this analysis, the level of groundwater pumping is based on historical levels (45,000 acre-feet) and therefore does not include new sources made available in 2001 with emergency funding from the State of California. (See sidebar entitled “Tulelake well program.”)

Table 7. Change in gross farm crop sales on the Project under various operational rules and hydrologic year-types.

		Change in gross farm crop sales ($1,000)			
		Lake elevation 4,139 feet[a]		Lake elevation 4,140 feet[a]	
Hydrologic year-type	Frequency (number of years, 1961–2001)	Flow 1992	Flow 2001	Flow 1992	Flow 2001
Above average	21 (51%)	0	0	0	0
Below average	12 (29%)	0	0	0	0 to -27,705
Dry	5 (12%)	0	-29,906	0	-58,465
Critically dry	3 (7%)	0	-60,291	0	-74,212

[a]See Table 6 for details of lake elevation and flow requirements.

Tulelake well program

In 2001, the California Department of Water Resources, the Governor's Office of Emergency Services, and the Tulelake Irrigation District began developing supplemental groundwater resources in the California portion of the Upper Klamath Basin. A total of 10 wells were drilled in Siskiyou and Modoc counties for the purpose of providing supplemental water for irrigating 20,000 acres of cover crops in an effort to preserve valuable agricultural topsoil and to augment surface water supplies for future water shortages (see table below). Groundwater development was initiated May 4, 2001, when Governor Davis allocated $5 million to the program in his Klamath Basin Drought Emergency Proclamation.

Tulelake Irrigation District Well Development as of October 12, 2001

Well #	Date started	Date completed	Completed depth (feet)	Production zone (feet)	Pump test yield (gpm)	Date deliveries started	Status
#1	5/26/2001	6/8/2001	740	245–685	9,300	6/27/2001	pumping
#2	7/27/2001	8/3/2001	1,545	1,260–1,540	12,000	8/25/2001	pumping
#3	6/9/2001	6/28/2001	1,680	1,153–1,680	9,000	7/24/2001	pumping
#4	6/28/2001	7/8/2001	1,4432	1,211–1,433	10,000	8/15/2001	pumping
#5	7/14/2001	7/20/2001	1,566	935–1,556	9,500	—	pumping
#6	6/6/2001	6/29/2001	2,380	822–2,358	6,000	7/13/2001	waiting on pump
#7	6/29/2001	7/8/2001	2,030	814–1,687	4,000	9/21/2001	pumping
#8	8/16/2001	8/29/2001	1,810	1,240–1,800	—	—	waiting on pump
#9	7/2/2001	7/8/2001	2,043	1,060–2,022	7,000	—	waiting on pump
#14	6/19/2001	6/26/2001	567	114–554	9,500+	—	waiting on pump

Source: California Department of Water Resources (http://www.dpla.water.ca.gov/nd/KlamathDrought/index.html). Updated on October 12, 2001.

Additionally, the BOR delivery of 40,000 acre-feet of surface water in midseason 2001 is ignored because we assume that farm managers did not plant assuming they would get a midseason delivery.

What Table 7 indicates is that it is possible to frame the change in a Biological Opinion in terms of lost gross farm crop sales. If we know the relationship between Biological Opinions and gross farm crop sales, there is room for a dialogue about the trade-offs between environmental uses and agricultural uses for water. Such a discussion could help to determine a range of water allocations within which both types of users could work.

Options for increasing gross farm crop sales without increasing irrigation diversions or irrigation efficiency

This section covers two topics:

- The general relationship between irrigation diversions and gross farm crop sales
- Ways in which greater flexibility in water allocation could increase gross farm crop sales with the same quantity of water

The first point—the general relationship between irrigation diversions and gross farm crop sales—acts as a background to the subsequent discussion regarding water allocation methods.

This section deals only with ways to reduce the effects of decreased irrigation diversions *within the Project*. It should be noted, however, that spreading the reduction in irrigation diversions *throughout the Upper Klamath Basin*, rather than solely on the Project, results in a smaller overall effect on basinwide gross farm crop sales. Chapter 19 ("Water Allocation Alternatives") analyzes basinwide effects and possible ways to reduce the effects on gross farm crop sales throughout the Basin. The focus of this section is to suggest alternative strategies within the Project boundaries.

General relationship between irrigation diversions and gross farm crop sales

Figure 4 presents the general relationship between irrigation diversions and gross farm crop sales on Project lands. The horizontal axis shows the percent of full supply of irrigation diversions. The left-hand vertical axis represents gross farm crop sales. The right-hand vertical axis shows the percent of gross farm crop sales—as compared to sales when water allocations are 100 percent of full supply.

When irrigation diversions are 100 percent of full supply, gross farm crop sales are near $99 million, and the percent of revenue is 100 percent. When irrigation diversions are 95 percent of full supply, gross farm crop sales are $98 million, and the percent of revenue is just under 99 percent. Therefore, the first 5 percent reduction in irrigation diversions causes a 1 percent reduction in gross farm crop sales. The next 5 percent reduction in irrigation diversions, to 90 percent of full supply, causes a 2 percent decrease in gross farm crop sales.

The rate of decrease in gross farm crop sales increases slightly with each 5 percent decrease in irrigation diversions, until the total decrease in irrigation diversions is 65 percent. At this point, the percent decrease in gross farm crop sales from 65 percent to 60 percent of full irrigation diversion is 3 percent. Below 60 percent of full irrigation diversions, the percent decrease in gross farm crop sales for each 5 percent decrease in irrigation diversions is close to 2 percent, until irrigation diversions fall to 20 percent of full supply. At that time, the percent decrease in gross farm crop sales for each 5 percent decrease in irrigation diversions is between 3 and 4 percent.

This pattern (an increasing rate of change in gross farm crop sales until irrigation diversions fall to 65 percent of full supply, followed by a decreasing rate of change as diversions continue to drop) occurs because of the A,B,C priority use right water allocation method. Near the 65 percent point in irrigation diversion, the allocation of water to B users is completely suspended, while A users are still receiving a full supply (see Figure 2). Assuming that all land is not equally productive, this allocation method forces the highest quality B land completely out of production while the lowest quality A lands are still in production.

Caution should be exercised in interpreting the information shown in Figure 4. Recall that the model generating this data is a short-run model. The implication of a short-run model is that the fixed debt costs of the farm operation are being covered. This may not be the case if the percentage of irrigation diversions consistently falls below historical levels. Thus, the data presented in Figure 4 are helpful only in understanding the 1-year effect of a reduction in irrigation diversions, with the assumption that operations will return to near-normal conditions in following years.

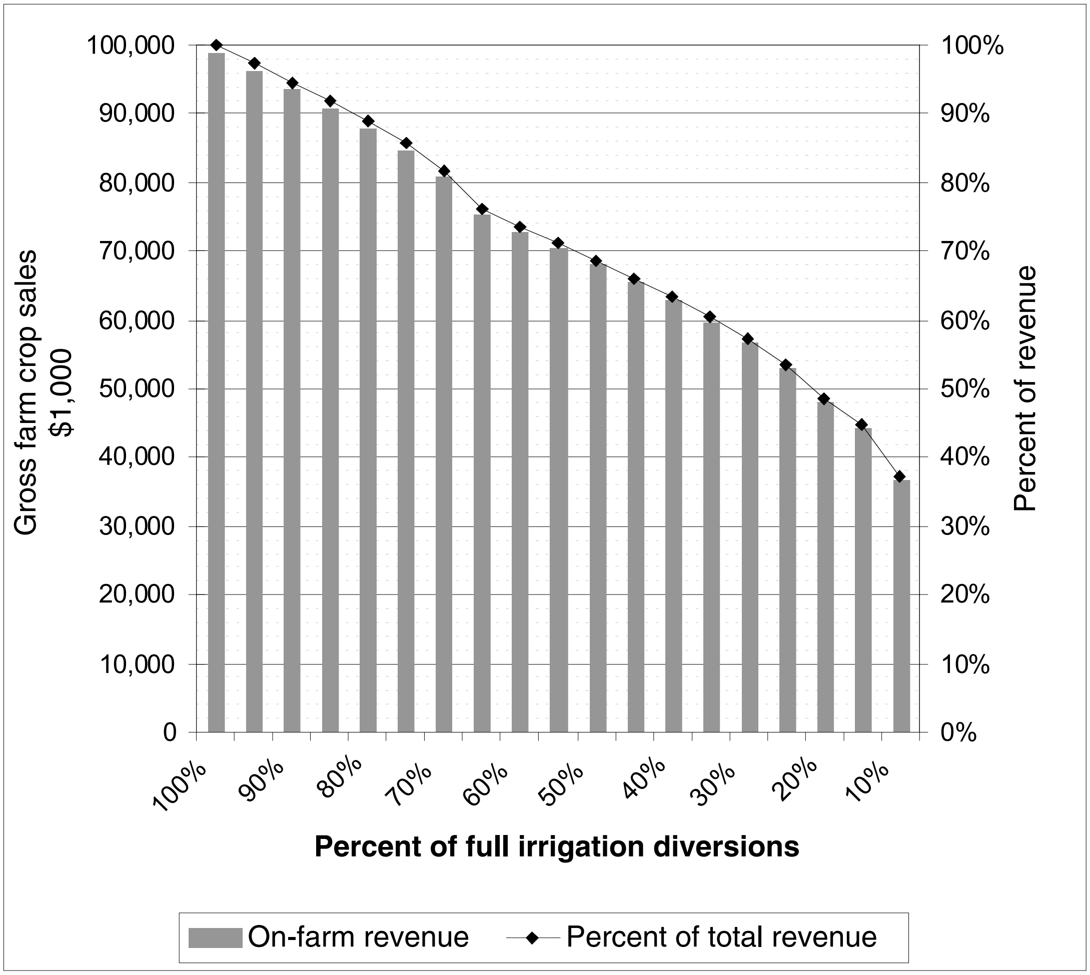

Figure 4. Relationship between irrigation diversions and gross farm crop sales.

Alternative allocation methods that could increase gross farm crop sales

Water allocation in the Project currently follows the A,B,C priority use right method described earlier. This section answers the question "What if there were greater flexibility in the method of allocating water?" Estimates of gross farm crop sales under two different allocation methods are presented. Those methods are as follows.

- Water measurement devices (meters) are installed so that it is possible to constrain water deliveries directly, instead of constraining the number of acres in production. For example, if the amount of water available to a B user is 50 percent of full supply, then he or she receives 50 percent of full water supply rather than being permitted to plant only 50 percent of normal acreage.
- Any reduction in irrigation diversions is prorated equally across all users regardless of the A,B,C priority use right distinction.

How water allocations can affect total gross farm crop sales

Assume the relationship between irrigation diversions and gross farm crop sales follows the pattern:

Percent of irrigation diversion (%)	Percent of gross farm crop sales (%)
100	100
50	70
0	20

Now assume there are three farms, farm A, farm B, and farm C. Farm A holds an A priority use right to water. Farm B holds a B priority use right to water. Farm C holds a C priority use right to water. Assume the quantity of water used on each farm is the same, and each farm produces $100 of gross farm crop sales when irrigation diversions are 100 percent. Therefore, total revenue from the farms is $300. A comparison of the revenue generated under the A,B,C priority use right water allocation method and the proportional method is presented in the table below. Assuming irrigation diversions must be cut to 50 percent of full, total gross farm crop sales under the A,B,C priority use right method are $190, or 63 percent of total. Total gross farm crop sales under the proportional method are $210, or 70 percent of full. Simply because the "pain is shared" in the reduction of irrigation diversions, the decrease in gross farm crop sales can be reduced by 7 percent.

Gross farm crop sales under two water allocation methods.

Farm	Full irrigation deliveries ($)	A,B,C priority use right ($)	Proportional ($)
A	100	100	70
B	100	70	70
C	100	20	70
Total	**300**	**190**	**210**
% of full sales	100	63	70

Figure 5 shows the percent of gross farm crop sales generated under these two allocation methods when irrigation diversions range from 10 to 100 percent of full supply. For reference, the baseline percent of gross farm crop sales (using the current A,B,C priority use right method), originally shown in Figure 4, is included in Figure 5. The percent of gross farm crop sales is higher under either of the alternative water allocation methods than under the baseline method for any level of irrigation diversion.

When meters are used to reduce water deliveries by measuring water rather than fallowing land, the percent of total gross farm crop sales ranges from just slightly higher than baseline to 2 percent above baseline. Since meters generate higher gross farm crop sales, one could determine how long a meter-installation program would take to pay for itself. A 1 percent change in revenue equals roughly $1 million in the Project; thus, if meter installation costs less than $2 million, the payback could take between 1 and approximately 5 years, depending on the percent of irrigation diversions.

The smallest decrease in gross farm crop sales occurs when shortages in irrigation diversions are allocated proportionally across the Project, without regard to A,B,C priority use right designations. For example, when irrigation diversions are 70 percent of full supply, gross farm crop sales are 90 percent of normal under the proportional water allocation method, versus 80 percent under the baseline (current) water allocation method.[5] This result occurs because, under the

[5]The overall impact of such a water allocation approach is to reduce the return flow (unused irrigation water) out of the Project (through the Klamath Straits Drain). Increasing overall Project efficiency may have a detrimental effect on the Lower Klamath and Tule Lake national wildlife refuges. Both refuges depend on return flows of the Project to maintain wildlife habitat.

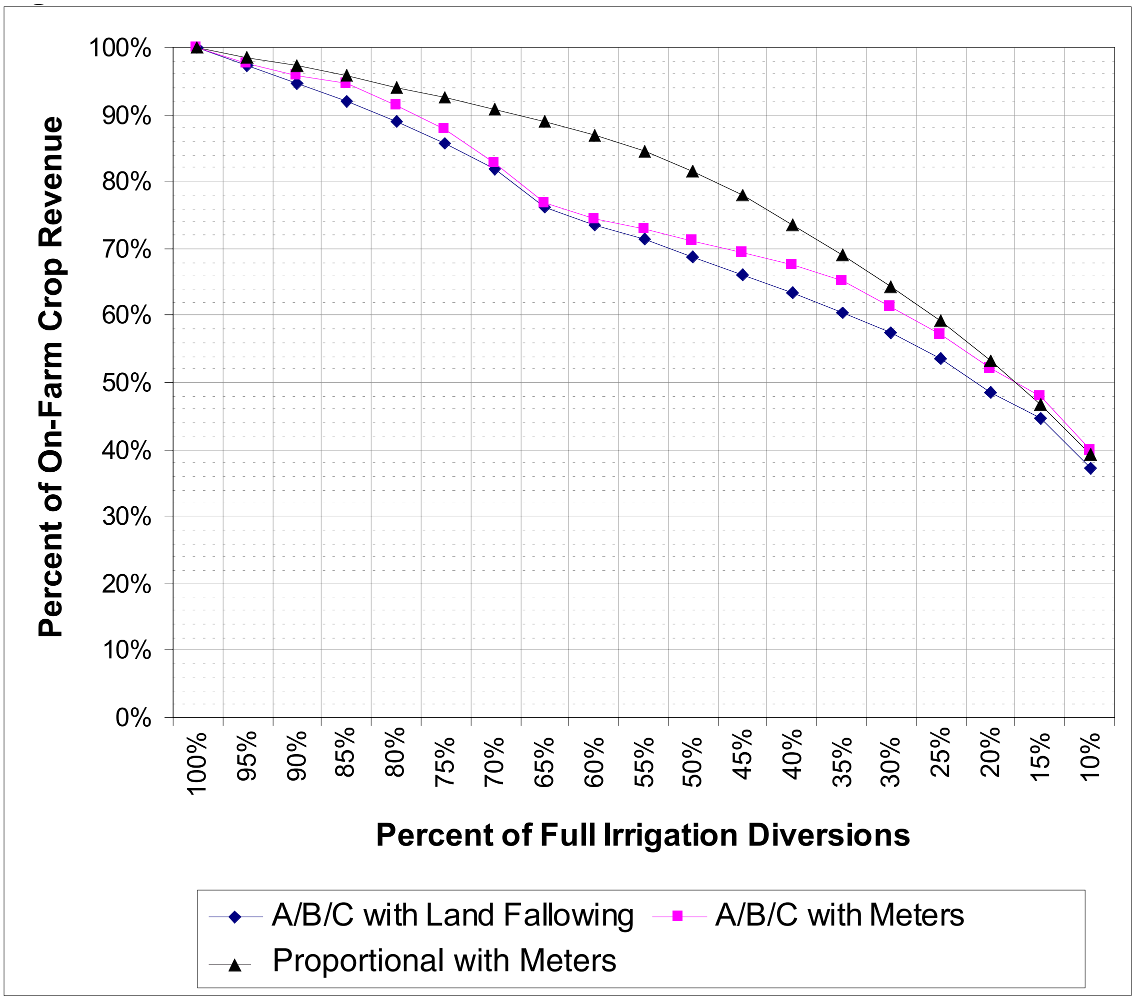

Figure 5. Percent of gross farm crop sales under various water allocation methods and a range of irrigation diversions.

baseline method, B users' water allocation is near zero when irrigation diversions are near 70 percent of normal, while A users are receiving 100 percent of their water supplies. This allocation method forces the highest value B land from production before the lowest value A lands are removed from production. For a simple numerical example of this result, see the sidebar entitled "How water allocations can affect total gross farm crop sales."

The results shown in Figure 5 suggest another method of water allocation that could mitigate the effects of reduced irrigation diversions even more than the proportional allocation. This method is a water market. The proportional allocation method lessens the loss to total gross farm crop sales, when compared to the A,B,C, allocation method, by taking into account the value of the land in production. A water market moves even farther in that direction because it is based on the value of the water in production. If willing sellers could offer water to potential buyers, both parties could be made better off. In this way, water would be used wherever it could generate the most revenue. Increasing the flexibility of water allocation methods—to better reflect the value of each additional amount of water—increases the total output of the Project. (See Chapter 19, "Water Allocation Alternatives," for a discussion of basinwide water markets.)

Table 8. Comparison of the Tulelake Irrigation District "Crop Report 2001" to model results.

	Acres (1,000)			Revenue ($1,000)		
	TID	Model	Difference	TID	Model	Difference
Alfalfa and other hay	18.2	6.3[a]	–11.9	7,247.6	4,296.6	–2,951.0
Pasture	1.3	0[a]	–1.3	3.2	0	–3.2
Other crops	3.4	2.1	–1.3	3,478.7	4,821.4	1,342.6
Potatoes	1.6	3.1	1.5	4,375.6	5,374.5	998.9
Barley and other grain	13.3	0	–13.3	2,005.2	0	–2,005.2
Wheat (red and white)	0.8	0	–0.8	178.0	0	–178.0
Subtotal production	38.6	11.5	–27.2	17,288.4	14,492.5	–2,795.9
Idle	23.0	46.3	22.3	—	—	—
Other (roads/drains, etc.)	1.0	1.0	1.0	—	—	—
Total	**62.6**	**58.8**	**–3.9**	**17,288.4**	**14,492.5**	**–2,795.9**

[a]Irrigated acres

Note: Acreage in this table may differ slightly from numbers in other chapters, depending on the data source, categories, and rounding.

Source: Tulelake Irrigation District Annual Crop Report, 2001

Accuracy of the model to forecast actual outcomes

At the time of this writing (early 2002), the 2001 crop reports for all of the Project lands had not been released by the BOR. However, the Tulelake Irrigation District (TID) had published their "Crop Report 2001." In a press release dated December 19, 2001, the TID reported acreage, yield, and production value of all crops grown in the District for 2001. The TID crop report is compared to the model's forecast of the TID's 2001 revenue in Table 8.

The TID "Crop Report 2001" shows crop revenue of $17,288,400 for the year. The model predicted that the TID's gross farm crop sales would be $14,492,500. Thus, the model underpredicted crop revenue by $2,795,900. It also underpredicted the number of acres in production by 27,200.

There are several reasons for the model's underprediction of acres in production. These reasons can be grouped into two categories. The first includes differences between the model's assumptions about water availability and actual water availability. The second includes shortcomings of the model. Each of these groups of reasons is discussed in the following sections.

Assumptions about water availability

The model assumed that no surface water was available for irrigation and that only historical levels of groundwater would be pumped.[6] In reality, groundwater pumping was increased as a result of funding provided by the California Department of Emergency Services. (See earlier sidebar entitled "Tulelake well program.") Because more irrigation water was available than the model assumed, the model underpredicted the number of acres in production.

Also, the Department of the Interior released 40,000 acre-feet of water late in the growing season. This late delivery of surface water was available for use on alfalfa.

Model shortcomings

The remaining reasons for the difference between the model's predictions and actual results in 2001 fall into the second category, model shortcomings. By crop type, the model underpredicted alfalfa and other hay; pasture; and barley and other grain. On the other hand, it overpredicted potatoes and "other" crops.

[6]For modeling purposes, the 1992 water year was used as a proxy for 2001. In 1992, unlike 2001, deliveries from Clear Lake and Gerber reservoirs were restricted.

One reason the model underpredicted hay and barley is that it does not have a sophisticated root-zone module. Without a root-zone module, the model does not distinguish between crops that have deep roots, and thus can make use of the previous year's soil moisture, and crops more dependent on timely irrigation. As a result, the model predicted that much more land would be idle in 2001 than was the case (47,300 acres versus 24,000 acres).

The model overpredicted both the acres in production and value of potatoes. The overprediction of acres exemplifies the model's previously addressed shortcoming—the assumption that farm managers have full knowledge of water availability prior to the start of the irrigation season. This knowledge would reduce the uncertainty of a crop failure in potatoes. In reality, the uncertainty surrounding the volume of irrigation diversions in 2001 led risk-averse farm managers to limit their investment in potatoes.

The model's overprediction of the value of potatoes resulted from overpredicting acres planted in potatoes. However, the error in predicting value was not as large as the error in predicting acres because the price received for potatoes in 2001 was much higher than the expected price used in the model. The TID "Crop Report 2001" shows a price for potatoes of $6.06 per cwt, versus the model's expected price of $3.70 per cwt.[7]

The model underpredicted the acres of "other" crops planted and overpredicted the revenue generated by these crops. This error results from how the model aggregates crops that historically represent relatively few acres. The model does not predict peas, peppermint, or dry mint, specifically. Instead, the model uses onions as a proxy for all "other" crops. Onions have a higher return than the weighted average return of peas, peppermint, and dry mint. Therefore, the model overpredicted "other" revenue.

[7]Prices reported in other chapters may differ, depending on the data source.

On balance, the model underpredicted the number of acres in production because: (1) it assumed less water was available than actually was available, and (2) it does not accurately account for managing crops that can be grown without timely irrigation or for risk management. Because of the model's shortcoming in predicting deep-rooted crops and risk management, its prediction of crop mix did not match actual planted acres. In reality, farm managers harvested more grain and alfalfa hay, and less potatoes, than the model predicted.

As a consequence of underpredicting and the error in the crop mix, the predicted value of revenue generated was lower than actual revenue. The revenue prediction was, however, closer to actual revenue than the acreage prediction was to actual acreage. Overall, the model's prediction of gross farm crop sales generated on TID lands was $2,795,900, or 20 percent, lower than actual 2001 farm crop sales (Table 8).

This quantification of the size of the model difference with respect to the TID can be used to set upper and lower bounds on the results presented earlier regarding the effect of drought and the 2001 Biological Opinions on total Project gross farm crop sales. However, we must exercise some caution when comparing the TID's results to the Oregon lands in the Project because the TID may have been affected less by the reduction in irrigation diversions than were Project lands in Oregon. Specifically, the TID has: (1) higher soil water-holding capacity, (2) more high-value row crops, and (3) more groundwater available. Using the TID's results to bound the model's prediction results in a prediction of a loss in gross farm crop sales between $74,212,000 and $59,369,600 (80 percent of $74,212,000).

Summary and conclusions

This analysis has considered the effect of the 2001 Biological Opinions and drought on gross farm crop sales in the Project. The results show that with no minimum in-stream flow requirement below Iron Gate Dam in 2001, there would be no loss in gross farm crop sales. With the 2001 requirements for both in-stream flow and lake elevation, the model estimates a loss of $74,212,000 in gross farm crop sales. Comparing model results to actual information from the Tulelake Irrigation District leads to the conclusion that the model may overestimate the loss in gross farm crop sales. The loss may be 20 percent below the estimate, or $59,369,600.

By changing the way in which water is allocated, the economic effects of a water shortfall can be reduced. For example, installing measurement devices would increase gross farm crop sales between 0.3 and 2.4 percent. Using a proportional method to allocate water instead of the existing A,B,C priority use right method could save as much as 10 percent of total gross farm crop sales, depending on the percent of full irrigation diversions available (assuming that the irrigation curtailment is less than 100 percent).

The model used to estimate the change in gross farm crop sales has two shortcomings. First, it is a short-run model. Further extension of this work would include incorporating a long-run analysis in order to fully understand the consequences of changing water allocations in the long run. Second, the model could be improved by including uncertainty about the timing and quantity of irrigation diversions.

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13

Regional Economic Impact

Impact of the 2001 Klamath Reclamation Project Operations Plan on the Economy of the Upper Klamath Basin

Bruce Weber, James Cornelius, Bruce Sorte, and William Boggess

On April 6, 2001, the U.S. Bureau of Reclamation (BOR) released its 2001 Klamath Project Operations Plan (KPOP), which severely limited water deliveries to Project irrigators. This Operations Plan was based on two Biological Opinions (BiOps). The first related to suckers in Upper Klamath Lake; it raised the minimum lake level above that set in the 1992 BiOp. The second related to coho salmon in the Lower Klamath River; it increased minimum flows at Iron Gate Dam above those set by the Federal Energy Regulatory Commission. In meeting these requirements in a critically dry year, the KPOP indicated that the BOR would release no water to many Project irrigators in 2001.

This chapter provides model-based estimates of the economic impacts of the KPOP on the Upper Klamath Basin economy. Chapter 14 ("Outcomes") discusses the reported economic outcomes in 2001. As pointed out in that chapter, many of the economic changes that occurred in the Upper Klamath Basin in 2001 had nothing to do with curtailment of irrigation water. Thus, one would not expect observed economic outcomes to be identical to model-based estimates of the KPOP impact. Jaeger's comparison of estimated short-run impacts and reported outcomes as of mid-2002 demonstrates clearly the role of non-irrigation-related external events in the region's economy. Of course, neither short-run estimated impacts nor reported outcomes known in 2002 can capture longer run effects.

Our analysis in this chapter focuses first on economic impacts on agricultural producers and processors. It then uses an input-output model to estimate the effects of changes in these sectors on firms and households throughout the Upper Klamath Basin. This analysis is not a benefit/cost assessment of the BOR's decisions nor an analysis of alternative economic options for the Upper Basin. We recognize that direct economic impacts may extend well beyond agriculturally related sectors, and that some impacts may extend well into the future and beyond the Upper Basin.

This chapter relies heavily on the information in Chapter 11("Basin Economy"). That chapter presents a detailed discussion of the Upper Klamath Basin economy. As in that chapter, we define the Upper Basin economy to be made up of Klamath County, Oregon, and Modoc and Siskiyou counties in California.

Estimating regional economic impacts with an input-output model

An input-output (I-O) model contains information about economic transactions in an economy. It is used to estimate the impact of a change in policy or an economic shock on regional gross output (sales), personal income, and employment.

The output measure in an I-O model does not net out (subtract) input purchases from other businesses in the region, except in the retail and wholesale sectors. Thus, many sales are "double counted." For example, if a feed mill buys barley from a farmer and then produces and sells processed feed, the values of both the processed feed and the barley input are counted in the region's output. Thus, the value of the barley is counted twice—once when it is sold to the feed mill and once as part of the value of the processed feed. For this reason, the gross output measure of an input-output model is not consistent with the "output" measures used in national income accounts (such as Gross National Product), which count only "final sales," or value added.

Because those concerned about the well-being of people often care more about income and jobs than gross sales, and to avoid the "double counting" problem, economists prefer to estimate income impacts or employment impacts. Income impacts measure value added by economic activity in a region, while employment impacts measure jobs.

When estimating income impacts, an I-O model counts all of the income generated by exports (sales outside the region). In the case of a feed mill, this includes income paid to mill workers, as well as wages and income to the farmworkers and landowners who grew the barley, all of which add value to the production process. All of this income is reflected in the income impact estimate of exports from the feed mill sector.

Input-output models estimate direct, indirect, and induced impacts.

- Direct impacts—changes in output in the sector(s) directly affected by the event
- Indirect impacts—changes that occur in all sectors because the directly affected sectors have more or less money to buy inputs from regional businesses
- Induced impacts—changes in all sectors due to changes in household consumption based on income from directly and indirectly affected sectors

Limitations of input-output modeling

Although input-output modeling is the most common method for modeling economic impacts, it has significant limitations. To the extent that the model's assumptions are not consistent with the actual behavior of firms and households as they respond to economic changes, a model may overstate or understate the impact of a change on the economy. The most important assumptions are as follows.

- Prices of goods and services used as inputs in the production process are assumed not to change.
- Firms are assumed not to adjust their production processes; technology is assumed not to change.
- There are no economies of scale. If a firm cuts its production in half, it will halve its purchase of all inputs. All input costs are treated as variable.
- There are no supply constraints. Firms can purchase all they want of any input at the initial price.

I-O models are most appropriate for short-run analysis of changes of modest size in which the above assumptions are met. Large-scale changes may involve supply constraints, price changes, and substitution of one input for another. Also, prices, technology, and production processes do change over the longer run.

In spite of their shortcomings, input-output models are useful in providing some sense of the general magnitude of impacts in the new equilibrium (when all sectors have adjusted production and consumption as implied by the model) and in suggesting how impacts to a few sectors might work their way ("ripple") through other sectors in the study region.

Accounting for fixed costs

In sectors with high fixed costs, input-output analyses can understate the short-run direct losses in the affected sectors and overstate indirect and induced losses. Since agriculture is a sector with high fixed costs, the conventional input-output model's assumption of no fixed costs is of some importance in the current analysis.

We have attempted to deal with the I-O model's fixed cost limitation by adjusting the impact estimates to reflect the typical fixed costs in agriculture, as well as the situation-specific committed (sunk) costs that some farmers incurred in 2001 prior to the release of the 2001 KPOP. Fixed costs in agriculture typically are associated primarily with land payments and equipment payments. In the Upper Klamath Basin in 2001, however, some additional costs were incurred. In anticipation of a growing season with full irrigation water, for example, farmers may have purchased inputs (such as seed and fertilizer) and taken on other contractual obligations. If they had known sooner that irrigation water would be curtailed, they would not have made these purchases and commitments. We attempted to deal with this issue by developing an estimate of fixed costs (broadly defined) that would represent both types of fixed costs.

Oregon State University (OSU) has produced enterprise budgets that estimate fixed and variable costs for various crops in each growing region in Oregon. These budgets estimate fixed costs using standard depreciation schedules, which commonly are regarded as generous. (Equipment typically has a longer life than estimated in the depreciation schedule.)

Land and equipment costs for the types of crops grown on the Klamath Reclamation Project are estimated in enterprise budgets to average about 43 percent of gross revenues. However, some producers own land outright and do not have land payments, and some use their equipment longer than estimated in the depreciation schedules.

To reflect the fixed costs not accounted for in the input-output model, we use half of the 43 percent total fixed costs estimated in the enterprise budgets (21.5 percent) as our estimate of fixed and sunk cost payments by farmers. To do so, we added 21.5 percent of changes in gross revenues as a cost in estimating the "direct income impact" in Tables 2 and 4.

In the absence of reliable data on the magnitude of these costs in 2001, this estimate represents our best judgment about fixed costs. Using this rough estimate seems preferable to the standard procedure of simply ignoring these costs, which underestimates the direct impacts and overestimates indirect and induced impacts.

Our approach has the effect of increasing the direct income loss estimates relative to those obtained in a standard input-output analysis. This adjustment recognizes that there were irrigators in the Upper Klamath Basin who were not able, because of existing contractual obligations and sunk costs, to adjust input purchases downward in 2001 as required by the assumptions of the conventional input-output model.

Since these costs to farm producers are revenues to suppliers and those receiving land payments, they must be incorporated into the model as payments to suppliers and landowners. Since most of these payments are likely to "leak" out of the model as payments for debt and for equipment produced outside the region, only 10 percent of the fixed costs are considered "respent" on regional services (output) in our analysis. This adjustment has the effect of decreasing the estimated indirect and induced income losses relative to estimates obtained in a standard input-output analysis.

The short-run nature of the analysis

The standard impact estimates from an input-output analysis show estimated impacts on the economy after it has reached a new equilibrium (after all sectors have adjusted their production and consumption in response to the economic shock). As pointed out, contractual obligations control a significant share of costs to the sector most directly affected by the 2001 KPOP. As a result, it is unlikely that these adjustments were fully realized during 2001—the time horizon chosen for this analysis. Thus, this chapter presents only a short-run analysis, capturing the impact on the economy in 2001 before all production and consumption would have been able to adjust to a new equilibrium.

Baseline, impact, and response scenarios for the 2001 KPOP

Impact analysis requires the construction of one or more impact scenarios, which identify what is expected to happen as a result of a specific policy or other change. The impact scenarios are compared to a baseline scenario, which is based on assumptions about what would happen *without* the specified policy or other changes.

As in Chapter 12 ("Crop Revenue"), our *baseline scenario* for the Upper Klamath Basin assumes an "average" water year with pre-2001 lake-level and stream-flow requirements.

The *initial impact scenario* models the 2001 KPOP, which was designed to meet the stream-flow and lake-level requirements of the 2001 Biological Opinions in a critically dry year. In meeting these requirements, the 2001 KPOP provided for no release of irrigation water from Upper Klamath Lake.

The impact of the 2001 KPOP is the difference between estimated output, income, and employment in the baseline scenario and estimated output, income, and employment in the initial impact scenario. Because we estimate the impact of the 2001 KPOP, our estimates in the initial KPOP scenario do not take into account the effects on production of the unanticipated midsummer irrigation releases.

Constructing an impact scenario for the 2001 KPOP involves estimating the changes in Project-related agricultural exports resulting from implementation of the 2001 KPOP compared to agricultural exports in the baseline scenario. These estimated changes in agricultural exports are entered into the Upper Klamath Basin input-output model to estimate the changes in regional output, employment, and income resulting from the 2001 KPOP.

After the announcement of the 2001 KPOP, there were public and private responses intended to offset the negative impacts of the 2001 KPOP (for example, government emergency payments and increased well drilling). In order to capture the effects of these responses, we constructed several *response scenarios.* These involved identifying the amounts of payments brought into the regional economy because of these responses. Several sets of responses are identified and impacts estimated.

Finally, we estimated two *net impact scenarios.* These estimates attempt to quantify the impact of the 2001 KPOP on the regional economy after accounting for the various public and private responses. The first net impact scenario considers only the federal and state grants and increased production due to added water. The second scenario also considers the regional impacts of farm borrowing for well development.

Estimating impacts under the initial KPOP scenario

To arrive at the estimated impact of the KPOP on the overall regional economy, we start with the impact on crop production estimated in Chapter 12 ("Crop Revenue"), assuming no public or private response. From there, we estimate the impact on agricultural exports. Then, we use the I-O model to estimate the overall regional impact.

Impact on agricultural exports

We start with the estimates of crop production on the Klamath Reclamation Project presented in Chapter 12 ("Crop Revenue"). To use these figures to estimate the changes in Project-related agricultural exports under the 2001 KPOP scenario, we made three adjustments.

The first adjustment accounts for the fact that some crop production is used as inputs by other sectors. The forage consumed by range/ranch-fed cattle and the potatoes used as inputs by the dehydrated food products sector had a combined output value of $2.5 million. Thus, the impact on crop production estimated in

Chapter 12 ($74.2 million) was reduced by $2.5 million so that this production would not be counted twice. This $2.5 million in crop losses was moved to and became a component of the estimated losses in the cattle and dehydrated food products sectors.

The second adjustment is to estimate livestock losses. The livestock adjustment reflected reported livestock sales in Klamath County in 2001 and prior years. The primary impact of the reduced water for hay and pasture was a decline in the number of cattle that could be moved into the region later in the season for grazing. Livestock on the Project rely on irrigated pasture primarily during the spring, summer, and fall. Reduction in available forage translates into a loss of feed inputs to the livestock sector.

The economic losses in the livestock sector were estimated as the reduced value of forage produced on the Project, measured in terms of animal grazing units produced on the affected Project acreage. To value these grazing units, we used grazing fees applicable to irrigated pasture in the district: the 3-year (1998–2000) average private grazing rates reported for Oregon by the USDA National Agricultural Statistics Service.

In addition to the foregone value of grazing, livestock producers may have experienced additional losses associated with forced early sales of feeder cattle from these pastures. In the absence of alternative grazing lands in the region, some producers may have sold beef cattle at lower weights and/or prices than anticipated. Our estimates of losses from these forced sales were based on producer estimates of returns from forced spring/summer liquidation, relative to expected returns with normal fall marketing.

The projected extent of forced marketing was based on the size and composition of the herd displaced by the loss of grazing forage, as well as on projected liquidation rates. An adjustment was made to account for grazing expenses that were not incurred as a result of early marketing. The forced-sale losses are applied to feeder cattle only, not to the breeding herd.

The final adjustment involves estimating losses to the dehydrated foods manufacturing sector. The potatoes for dehydrated potato products typically are procured locally. Our estimates assumed that reduction in local potato production would reduce dehydrated food products sector exports proportionately; that is, processors would not attempt to import potatoes to supply their needs. The Upper Klamath Basin I-O model provides an estimate of total dehydrated food exports, the value of purchases of potatoes from local farmers, and the production technology of the dehydrated food products sector. This information was used to estimate the change in local potato exports that would result from reducing the dehydrated food products sector. (The impact of reduced potato production itself is included in the estimated reduction in dehydrated food products sector exports.)

Based on our baseline and impact scenarios, the direct impact of implementation of the 2001 KPOP on output of agricultural producers and processors is shown in Table 1 (following page). Changes in output are treated as changes in exports, based on the assumption that reduced output would lead to reduced exports or increased imports, which tend to have similar negative impacts on the regional economy.

Implementation of the 2001 KPOP would have reduced gross agricultural sector output in the three-county Upper Klamath Basin by an estimated $82 million, as compared with a baseline scenario in which water for irrigation was unconstrained. This represents a 20 percent reduction in output from the agricultural sectors.

Impact on the regional economy

Based on the reduction in agricultural exports shown in Table 1, the I-O model estimated the direct, indirect, and induced impacts of the implementation of the 2001 KPOP on gross output, income, and employment in the Upper Klamath Basin. These estimates are shown in Table 2 (following page).

Table 1. Impact of the 2001 Klamath Project Operations Plan on regional agricultural production and agricultural sector exports (output).

	Production value		Crops counted as inputs in livestock and dehydrated food products	Change in agricultural sector exports
	Baseline[a] ($1,000)	Critically dry year and 2001 BiOps[b] ($1,000)	($1,000)	($1,000)
Range/ranch-fed cattle	54,841	47,247	—	–7,594
Cattle feedlots	4,009	4,430	—	+421
Sheep, lambs, and goats	805	278	—	–527
Other meat animal products	33	9	—	–24
Miscellaneous livestock	2,708	2,053	—	–655
Food grains	2,581	2	—	–2,579
Feed grains	16,366	9	818	–15,539
Hay and pasture	40,721	12,773	1,511	–26,437
Vegetables	31,824	7,223	175	–24,426
Miscellaneous crops	7,313	5,317	—	–1,996
Dehydrated potato food products	2,640	504	—	–2,136
Total	**163,841**	**79,845**	**2,504**	**–81,492**

[a]Average water year and pre-2001 requirements for lake levels and stream flows
[b]2001 Klamath Project Operations Plan

Table 2. Regional impacts of the 2001 Klamath Project Operations Plan without public and private responses.

		Impact of critically dry year and 2001 BiOps[a]				Total
	Baseline[b]	Direct	Indirect	Induced	Total	change (%)
Output ($ million)	4,309	–82	–18	–16	–116	–2.7
Income ($ million)	2,336	–61	–9	–9	–79	–3.4
Employment (jobs)	59,295	–1,306	–403	–247	–1,956	–3.3

[a]2001 Klamath Project Operations Plan, not including partial release, additional well water, or government grants
[b]Average water year and pre-2001 requirements for lake levels and stream flows

The 2001 KPOP would have reduced gross output[1] by about $116 million, or 2.7 percent (Table 2). The *direct* impact of the reduction in Project agriculture and associated processing would have been $82 million (from Table 1).[2] This reduction would have generated an additional estimated $18-million *indirect* output reduction in industries that supply the agricultural and food processing sectors and those whose sales are affected by reductions in agriculture and food processing. These direct and indirect impacts would have *induced* another estimated $16-million reduction in local spending by households employed in the directly and indirectly affected sectors.

Personal income is a measure of local employee compensation, net proprietor income,[3] and other property income. Implementation of the 2001 KPOP would have reduced total personal income by an estimated $79 million, or 3.4 percent (Table 2). Total regional employment would have been reduced by about 3.3 percent, or 1,956 jobs.

Public and private responses

Private businesses, individuals, and public agencies did respond to the 2001 curtailment of irrigation water. In this section, we estimate impacts of major known public and private responses on agricultural exports and regional gross output, income, and employment.

Given the resilience and creativity of people and economies, it is quite likely that other responses not accounted for in this analysis have affected the actual impacts of the water allocation decision on the Upper Klamath Basin economy.

Responses bringing new money into the region

Responses modeled in the "KPOP with response" scenarios that increased exports or brought new grant money into the region include the following.

- ***Additional water, which generated $40 million in additional agricultural production.*** The drilling of new wells and the midseason release of irrigation water from Upper Klamath Lake offset some of the

[1]Our gross output and income estimates are in 2001 dollars. As noted above, gross output is a measure of total local sales and includes the full value of each local transaction before netting out costs.

[2]In our initial estimates of impact, which were reported in May 2001, total gross output was estimated to have been reduced by $134 million (and direct gross output by $95 million). We have revised the estimate of direct impacts on several agricultural sectors based on new data and information provided by reviewers. These adjustments from the May 2001 estimates are as follows.

- We reduced the direct impacts to the agricultural sector to reflect the fact that the dairy, ranch-fed cattle, and miscellaneous livestock industries do not seem as dependent on local feed inputs as indicated in the May 2001 estimates. Based on production data from the Oregon State University Oregon Agricultural Information Network, the impact to the dairy sector was reduced from $1.1 million to zero, the impact to the ranch-fed beef cattle industry was reduced from $7.6 to $1.05 million, and the impact on miscellaneous livestock was reduced from $0.7 million to zero.
- We reduced the dehydrated food products impact from $6.6 to $2.15 million to correct an error in the original scenario, which included an impact for a food drying plant that does not utilize any of the affected crops.
- One adjustment was made to the model baseline. Because the feed mill that operated in the region in 1998 no longer was operating in 2001 (for reasons unrelated to the KPOP), the feed mill sector was dropped from the model. In the original KPOP scenario, the reduction in barley production used by this sector was estimated to reduce feed mill exports by $7.3 million.

Making these revisions adds $12.9 million to agricultural output in the estimate of the initial KPOP scenario. This reduces the impact on the agricultural sector of the 2001 KPOP from –$95 million to –$82 million (Table 1).

[3]Proprietor income is the net income from current production of sole proprietorships, partnerships, and tax-exempt cooperatives.

reduction in water allocations. About 40,000 acre-feet of surface water were released in midseason by the Bureau of Reclamation. With all of these adjustments, Upper Klamath Lake farms had access to an estimated 30 percent of their average water supply.[4]

In addition, both the federal and the state governments responded with emergency assistance.[5] These payments included the following.

- ***Federal and state emergency assistance payments and grants to farmers: $30 million.*** Federal government payments to farmers included $20 million to compensate for crop losses, $1.7 million in payments for groundwater supplementation, and $2.8 million in payments for demand-reduction programs. The State of California also made emergency payments totaling $2.4 million to growers, as well as payments of $1.2 million to irrigators for weed control, uncut grain, and feed. The federal government paid $1.2 million for cover crop seed for the land not receiving irrigation water.

- ***State of California expenditures on infrastructure, public service jobs, and community services: $6.5 million.*** The State of California paid a Nevada well-drilling firm a reported $5 million for drilling wells for the Tulelake Irrigation District. The State of California also spent $1.05 million to create public service jobs, began the construction ($0.2 of a total $0.5-million grant) and operation ($0.15 million) of a Tulelake Community Youth Center, and funded crisis counseling ($0.05 million).

Responses that involved farm borrowing

The responses identified above (additional water and federal and state payments and grants) brought new money into the region without the need for new local debt. There also were private responses leading to increased regional spending that were financed by borrowing against future income.

- ***Loan-financed expenditures on new wells: $5.3 million in loans for well-drilling investments in Klamath County.*** Klamath County irrigators spent an estimated $5.3 million on wells by borrowing from banks and from the state revolving loan fund.

Impacts of responses and net impacts

Table 3 summarizes the revised estimates of impacts to agricultural exports based on the production enabled by additional water. Table 4 identifies how each of the major responses changes the impact relative to the initial "no response" scenario. Table 4 also displays estimates of net impacts.

The many and varied private and public efforts did reduce the estimated short-run negative economic impacts significantly.

Effects of responses bringing new money into the region

- ***Additional water.*** The availability of additional water from new wells and the midseason release is estimated to have substantially reduced the output and employment impacts relative to implementation of the 2001 KPOP without these responses. Direct *output* of agricultural producers and processors was $39.9 million

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[4]The 2001 KPOP did not affect the operations of Clear Lake and Gerber Reservoir. In the 2001 KPOP scenario, water available to irrigators in the Lost River system in a critically dry year was estimated to be 25 percent of the average water supply. In the response and net impact scenarios, Lost River farms were estimated to have received 100 percent of their average water supply. A small part of the differences in agricultural exports and regional economic indicators between the 2001 KPOP and other scenarios is due to the change in estimated Lost River production enabled by this adjustment in Lost River system water.

[5]These payments are described in more detail in Chapter 14 ("Outcomes"). The amounts for these programs listed in Chapter 14 are different from those given here because Chapter 14 reports commitments and our figures represent expenditures between April 2001 and March 2002. Our figures do not include payments under the Noninsured Crop Disaster Assistance Program or the Risk Management Agency's crop insurance program.

Table 3. Impact of the 2001 Klamath Project Operations Plan on regional agricultural production and agricultural sector exports (output) with additional water from new wells and midseason release.[a]

	Production value		Crops counted as inputs in livestock and dehydrated food products	Change in agricultural sector exports
	Baseline[b] ($1,000)	Critically dry year and 2001 BiOps[c] ($1,000)	($1,000)	($1,000)
Range/ranch-fed cattle	54,841	53,791	—	–1,050
Food grains	2,581	628	—	–1,953
Feed grains	16,366	3,932	153	–12,281
Hay and pasture	40,721	26,579	75	–14,067
Vegetables	31,824	22,885	175	–8,764
Miscellaneous crops	7,313	5,966	—	–1,347
Dehydrated potato food products	2,640	504	—	–2,136
Total	**156,286**	**114,285**	**403**	**–41,598**

[a]Table 3 provides information only for sectors whose production and sales were judged to be affected by the additional water from new wells and the midseason release.
[b]Average water year and pre-2001 requirements for lake levels and stream flows
[c]2001 Klamath Project Operations Plan plus additional water from new wells and midseason release

higher than it would have been with no additional water (Table 4). Direct income was $30.6 million higher, and there were 626 more jobs.

The additional production from the added water had indirect and induced effects on the regional economy beyond the direct effects noted above. The total impact of the added production was an additional $57.3 million in output, $40.2 million in income, and 957 jobs (Table 4).

It should be noted that there are differences in pumping costs for surface water and well water. While this difference could have affected 2001 farm income, as well as future income, changes in pumping costs were not considered in estimating farm income. (See Chapter 2, "Klamath Reclamation Project," and Chapter 19, "Water Allocation Alternatives") for discussion of groundwater pumping costs.)

- ***Federal and state emergency assistance payments and grants to farmers.*** Infusion of $30 million in emergency assistance into the regional economy reduced the KPOP's negative short-term impact.

About $2.4 million of the aid was spent to assist in production activity (e.g., weed control); this portion is modeled as a direct output impact and has indirect and induced effects.

We modeled the income effect of the remaining $27.5 million as direct income, since it represents income to regional farm households. We did this by adding the $27.5 million to the direct income column and the total income column. The total direct income effect of the emergency payments is $28.5 million (this $27.5 million plus a $1-million income impact from the $2.4 million spent to assist production).

Since much of this income would be spent in the region, we estimated the induced impact of these government payments on output, income, and employment. We used 70 percent as a conservative estimate of the "disposable" spending of this money after the accelerated payment of some debt and state and federal taxes. Thus, to model the induced impact of this spending, we applied 70 percent of this $27.5 million to personal

Table 4. Regional impacts of the 2001 Klamath Project Operations Plan before and after accounting for selected public and private responses.

	Impact			
	Direct	Indirect	Induced	Total
2001 KPOP (without responses)				
Output ($1,000)	–81,842	–18,041	–15,610	–115,493
Income ($1,000)	–61,413	–9,410	–9,060	–79,883
Employment (jobs)	–1,306	–403	–247	–1,955
Response: Additional water				
Output ($1,000)	+39,894	+9,222	+8,167	+57,283
Income ($1,000)	+30,572	+4,859	+4,740	+40,172
Employment (jobs)	+626	+201	+129	+957
Response: Federal and state emergency assistance payments and grants to farmers				
Output ($1,000)	+2,400	+700	+23,843	+26,943
Income ($1,000)	+28,508	+352	+8,880	+37,739
Employment (jobs)	+25	+13	+240	+278
Response: State of California expenditures on infrastructure, public service jobs, and community services				
Output ($1,000)	+1,982	+111	+571	+2,664
Income ($1,000)	+1,495	+59	+332	+1,885
Employment (jobs)	+35	+2	+9	+45
2001 KPOP with selected responses (except loans)				
Output ($1,000)	–37,565	–8,009	+16,971	–28,603
Income ($1,000)	–838	–4,141	4,892	–87
Employment (jobs)	–619	–187	+131	–676
Response: Loan-financed expenditures on new wells				
Output ($1,000)	+4,045	+664	+1,008	+5,717
Income ($1,000)	+2,255	+363	+586	+3,204
Employment (jobs)	+210	+10	+16	+236
2001 KPOP with selected responses (including loans)				
Output ($1,000)	–33,520	–7,346	+17,979	–22,886
Income ($1,000)	+1,416	–3,778	+5,478	+3,116
Employment (jobs)	–409	–177	+147	–440

consumption expenditure (PCE). The sum of direct, indirect, and induced impacts of the government payments is reported in the "total impact" column of Table 4 (for output, income, and jobs).

Emergency payments did not add much directly to regional output ($2.4 million) or jobs (25). Because the payments did not generate much output, moreover, the indirect impacts were not large: $0.7 million in output, $0.4 million in income, and 13 jobs. These payments did, however, add $28.5 million to the income of those receiving them. Induced impacts from the household spending of the income payments were substantial: $23.8 million in output, $8.9 million in income, and 240 jobs.

- ***State of California expenditures on infrastructure, public service jobs, and community services.*** The $5 million invested by the State of California in wells for the Tulelake Irrigation District was spent mostly with a firm from Nevada that had the size of equipment necessary to drill very large wells. We estimate that 10 percent, or $500,000, was spent locally, primarily on food and lodging for employees while they were working in the region. An additional $0.45 million was spent on the construction and operation of the Tulelake Community/Youth Center and on crisis counseling. Half of the construction impact of the Community Center was estimated to occur after the impact period (April 2001–March 2002). During the impact period, an estimated $0.25 million was expended on construction.

  Another $1 million was spent on hiring local residents displaced by KPOP 2001. This is modeled as state and local government noneducational spending.

  The total impact of the public expenditures on infrastructure and community services was an added $2.7 million in output, $1.9 million in income, and 45 jobs (Table 4).

Net impact of 2001 KPOP with selected responses (except loans)

The exports of agricultural products enabled by the additional water and the government payments brought new money into the regional economy. This infusion of export receipts and government payments greatly reduced the impact of KPOP 2001 on a regionwide basis relative to what would have happened without these responses. Yet, the events of 2001 still reduced economic activity in the region. After these responses, the estimated net impact of the 2001 KPOP (relative to the baseline) was a $28.6 million reduction in regional output, a reduction in regional income of $0.1 million, and a loss of 676 jobs (Table 4).

Effects of responses that involved farm borrowing

- ***Loan-financed expenditures on new wells.*** Well-drilling investments increase regional income, output, and employment, whether funded by grants or by borrowing. Although from a *regional economic* perspective, the impacts of grant-financed drilling are equivalent to those of loan-financed drilling, the implications for future costs to those who secure the wells is quite different. For those whose wells were financed with borrowed money, loan payments will appear as a cost of production in future years, but this will not be the case for those who receive water from grant-funded wells.

  The investments in well-drilling financed by borrowing of Klamath County irrigators increased regional output, income, and employment. Since about three-quarters of the contracts were secured by local firms, the direct impact of the $5.3 million in spending was just over $4 million. The increase in total regional output generated by this spending was $5.7 million. The loan-financed expenditures increased regional income by $3.2 million and regional employment by 236 jobs.

Net Impact of 2001 KPOP with selected responses (including loans)

The net effect of the 2001 KPOP and the responses identified above (the additional production generated by the additional water, the emergency payments to farmers, the public spending on infrastructure and services, and the farm borrowing for new wells) was an estimated *$22.9 million reduction in regional output* and a loss of *440 jobs*. The combination of emergency payments, additional water, grant expenditures, and loan-funded investments is estimated to have increased *regional income about $3 million above* where it would have been in the baseline. These net impacts are reported in the final three lines of Table 4.

As indicated earlier, input-output models are useful in providing guidance about the overall regional impacts of policy and economic change. These models are, however, based on some simplifying assumptions about economic behavior that may be unrealistic, and the apparently precise estimates of economic impact generated by these models mask the high degree of uncertainty inherent in such estimates. Furthermore, neither these estimated impacts nor the outcomes to date identified in the next chapter can fully capture all of the responses and impacts.

Also, some of the responses have had unintended consequences. Drilling of new wells in California to provide irrigation water, for example, has jeopardized the supply of groundwater used for municipal water in the town of Malin, Oregon. Pumping of irrigation water from the new 2,700-foot-deep well last fall forced Malin to switch from its traditional main water source—a 380-foot-deep well—to a foul-tasting backup well.

Conclusion

Reduced water deliveries to agricultural operations in the Klamath Reclamation Project under the original 2001 KPOP would have had a significant economic impact on Upper Klamath Basin agriculture and a modest impact on the regional economy.[6] Based on our assumptions and the estimates of crop production impacts from Chapter 12 ("Crop Revenue"), we estimate that the 2001 Klamath Project Operations Plan would have reduced agricultural output in the Upper Klamath Basin by $82 million, or about 20 percent, if there had been no public and private efforts to mitigate the effect.

The impact of a reduction in agricultural exports is felt in other sectors of the Basin economy because of the economic interrelationships between sectors. We estimate that the 2001 KPOP would have reduced personal income (employment compensation, proprietor income, and other property income) by 3.4 percent (almost $80 million) in the three-county region without the public and private responses outlined in this chapter. These estimates include those directly and indirectly affected by the reduced water allocation.

We estimate that the KPOP would have reduced regional employment by 3.3 percent (almost 2,000 jobs) and total gross output (total sales—with the total value of the sale counted in each transaction)[7] by 2.7 percent ($115 million) during the first year, had there been no mitigating responses.

With the additional water made available by the drilling of wells and the midseason release of some water, we estimate that the impact of the 2001 KPOP on agricultural exports was cut substantially. Gross output impacts were cut from –$82 million to –$42 million in the short run. When combined with the other elements of the federal/state response package (particularly the emergency payments), the direct impact on income is estimated to have been reduced from –$61 million to about –$1 million, and overall regional income changes from –$80 million to less than –$1 million. Estimated regional job

[6]This chapter considers the impacts of the federal government decision from the perspective of the regional economy. There also is a national perspective on this issue, which would consider the net impact of the changes in production and the government payments on national income and its distribution.

[7]In retail and wholesale sales, only the value of the retail and wholesale margin is counted because the goods themselves usually are imported (not produced in the region).

losses were reduced from 1,955 to 676 jobs, and regional output impacts were reduced from –$115 million to –$29 million.

Farm borrowing to finance investments in new wells pumped more money into the economy. These loan-financed investments, combined with the other responses (particularly the emergency payments and added agricultural exports enabled by the additional water), are estimated to have increased overall regional income about $3 million above what it would have been in the baseline, and to have reduced the negative impact of the 2001 KPOP on output and jobs substantially. Employment losses were estimated to have been reduced to 440 jobs (0.7 percent) and output losses to $23 million, or 0.5 percent, by the events of 2001.

The analysis in this chapter aggregates impacts in a way that masks the diversity of experiences in the Upper Klamath Basin. Some firms and individuals benefited from the KPOP and subsequent responses, while others experienced losses. Some agricultural producers experienced losses, while others may have gained. Some businesses saw increased sales because of the emergency assistance and may have received more income than they would have in the baseline scenario. Farmworkers and those whose businesses depend on the spending of agricultural producers may have been the most negatively affected. Also, the use of a three-county region for analysis masks the disproportionate shares of the impacts that likely were concentrated in the towns most directly affected by the irrigation project—Malin, Tulelake, and Merrill.

The impact of future operations plans that reduce or cut off water for irrigation in a critically dry year would likely have very different effects, depending on the willingness of governments to provide emergency relief and on the availability of groundwater for pumping. The estimates in this chapter cannot provide much insight into the impact of curtailments implied by future operations plans because of the uncertainty about how governments, agricultural producers, other businesses, or workers might respond.

The impacts estimated in this chapter are for the short run and assume no change in the underlying economic structure and legal framework. They assume, for example, that there are no changes in water rights adjudication or in water law affecting the trading of water (see Chapter 19, "Water Allocation Alternatives"). This type of analysis does not provide guidance about the longer term impacts of the 2001 decision (such as the debt payments for new wells noted above) nor about the impact of structural changes in the economy or legal framework on the economic future of the Upper Klamath Basin.[8] Such analysis does, however, provide a basis for understanding how major government policy decisions can affect a local area if there are no offsetting responses, and how public and private responses to such decisions can help mitigate the anticipated impacts.

Chapter 14 ("Outcomes") discusses reported economic outcomes in the Upper Klamath Basin in 2001. Those outcomes reflect all of the changes in the regional economy in 2001, not just those related to the irrigation curtailment. Thus, one should not expect the reported outcomes in Chapter 14 to be identical to those estimated in this chapter, which are based on input-output analysis and take into account only those events related to the irrigation curtailment.

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[8]Some longer term implications of the 2001 KPOP for agriculture are discussed in the May 2001 report by the Oregon State University Department of Agricultural and Resource Economics, *Economic Impacts of 2001 Klamath Project Water Allocation.*

References

Oregon State University, Department of Agricultural and Resource Economics. 2001. *Economic Impacts of 2001 Klamath Project Water Allocation* (May).

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14

Outcomes

What Actually Happened in 2001?

A Comparison of Estimated Impacts and Reported Outcomes of the Irrigation Curtailment in the Upper Klamath Basin

William K. Jaeger

Beginning in February 2002, data on economic outcomes in 2001 in the Upper Klamath Basin became available. These data include crop acreage and production, farm sales, and employment. They reflect *all* of the changes that occurred in 2001, not just those due to irrigation curtailment on the Klamath Reclamation Project. Some of these data are preliminary and subsequently may be revised, but they represent the best available data on what actually occurred in the Upper Klamath Basin in 2001—as distinct from estimates of the *expected* impacts based on economic models.

This chapter presents some of these "after-the-fact" data on economic outcomes in the Project and the Basin and compares them to estimated impacts based on economic models (Chapters 12, 13, and 19). Neither these reported data nor model estimations can provide a precise measure of the economic impacts of the irrigation curtailment, since both may reflect measurement errors or omissions. Nevertheless, likely reasons for the differences between the impact estimates and the reported economic data can, in some cases, be identified and quantified. Thus, by comparing the reported data and model estimates, and by taking account of other factors that affected the Project and the regional economy in 2001, we are able in this chapter to better explain how events related, and unrelated, to the irrigation curtailment shaped the outcomes in 2001. In doing so, we draw on model estimates and reported data, as well as other information, to estimate a set of "inferred impacts" of the irrigation curtailment.

As in the other economics chapters of this report, this chapter is limited to examining the short-run economic impacts on the Project of the irrigation curtailment, as well as their repercussions throughout the regional (Upper Basin) economy. As explained in Chapter 10 ("Preface to Economics") and elsewhere, this limited focus should not be taken to imply that agricultural interests are paramount, nor that the value of water allocated to other uses (such as environmental and tribal interests, tourism, or commercial and recreational fishing) is unimportant. We also do not try to quantify the potential long-run impacts of events in 2001. Finally, it should be recognized that quantitative assessments of aggregate impacts frequently obscure the circumstances of individuals, many of whom may have been affected in ways far different than those suggested by the total or average effects. Finally, the values presented below are only estimates and should not be interpreted as exact measures of economic loss or impact.

Reasons for differences between model estimates and reported outcomes

Reported data on economic outcomes can be expected to differ from the estimated effects of irrigation curtailment presented in previous chapters, which are based on economic models. The reasons for these differences fall into three groups: individual responses, public responses, and factors unrelated to the irrigation curtailment. Each is discussed below.

Individual responses

Economic models intended to estimate the impact of a specific event (such as irrigation curtailment) may overstate the impact of that event because it is very difficult to anticipate all of the ways that resourceful individuals will act to minimize the adverse effects of the event. For example, Project growers drilled many new irrigation wells in 2001. In Oregon alone, the number of private wells approved in 2001 was sufficient to provide water for 20,500 acres. Chapter 2 ("Klamath Reclamation Project") reports that overall in the Project, new wells may have provided water equivalent to 15 to 20 percent of previous years' surface water diversions for agricultural and wildlife refuge use. By contrast, in the model of Project irrigation in Chapter 12 ("Crop Revenue"), groundwater pumping was assumed to occur only at average historical levels of about 25,000 acre-feet. In fact, actual groundwater pumping was about triple historical levels, resulting in irrigated acreage in 2001 that exceeded the model estimations.

Many other types of responses by growers would have been nearly impossible to predict. For example, a mint grower in Tulelake was able to divert wastewater from a potato processing plant onto his fields in order to keep the plants from dying, and a potato packing operation bought potatoes from outside the region in order to fulfill its contracts.

These kinds of hard-to-predict responses occur at the regional level as well. As a result, input-output models may overstate the impact on revenue of an adverse shock to the regional economy. They also are not designed to account for the additional costs incurred by individuals when responding to unexpected shocks. In short, these models are not intended to represent all of the possible actions that individuals may take, or the added costs they may incur, in response to a negative economic shock.

In particular, input-output models make simplifying assumptions about employment, assuming that workers who lose their jobs due to an economic shock will neither earn nor spend income during the period under study. In reality, however, out-of-work farm laborers are likely to seek employment in other sectors or outside the region. The reemployment of these displaced workers, their income, and subsequent spending are not taken into account in input-output models. The possible reemployment of other resources (e.g., capital equipment) also is ignored, as are the effects of idled labor from the affected sector on employment, wages, or sales in other sectors. If estimated impacts of irrigation curtailment on crop production are overstated, these regional responses may compound these effects at the regional level.

Public responses

The second source of divergence between model estimates and reported outcomes involves public responses to the initial event. The events of 2001 began with the curtailment of irrigation deliveries to most of the Project by the Bureau of Reclamation (BOR). Later, the BOR and other federal and state agencies responded to this initial event. Economic models intended to estimate the impact of the initial event will differ from those that include both the initial event and the public responses.

In the case of the 2001 irrigation curtailment, public responses included commitments for $35 to $37 million in federal and state emergency payments to farmers, plus additional amounts made available for well drilling, through crop insurance, and to aid other members of the affected communities. (Actual payments may have differed slightly, as reported in Chapter 13, "Regional Economic Impact"). Commitments for direct payments to farmers and landowners included:

- Compensation for crop losses under the Klamath Basin Water Conservation Program, in which $20 million was distributed to eligible landowners or growers at $129 per acre (covering 95,944 acres or about one-half of the Project)
- Payments to farmers for groundwater they supplied to the Project (BOR funds of $2.2 million for 65,000 acre-feet of water)
- A federally funded demand-reduction program whereby landowners and growers were paid, based on a sealed bid process, to leave their land idle ($2.76 million paid on 16,500 acres, averaging $167 per acre)
- Payments to growers from the State of California ($3 million to Project irrigators at $37 per acre over 81,000 acres; $1.2 million for weed control, livestock feed, and purchases of uncut marginal grain)
- Payments reimbursing farmers' expenses for seed to plant cover crops ($1.2 million) on roughly 35,000 acres
- Payments under the Noninsured Crop Disaster Assistance Program (USDA-NAP) to eligible landowners, tenants, or sharecroppers (total payments expected to reach between $3 million and $6 million)
- Property tax reductions in Klamath County (approximately $0.5 million)
- Crop insurance payments under USDA's Risk Management Agency crop insurance program ($2.4 million on 50,000 acres)

In addition to these cash payments to farmers and landowners, about $10 million in expenditures and commitments were made for wells and community support programs. Examples include public employment and assistance to families ($3.8 million in California) and development of irrigation wells ($5 million in California and a $2-million appropriation and loan program in Oregon).

In addition, the BOR made a midseason release of 40,000 acre-feet of surface water to the Project.

As indicated below, economic models that estimate only the impact of the irrigation curtailment will generate much higher estimates of impact than models that also attempt to reflect public and private responses. When one considers all of the actions and reactions related to the irrigation curtailment in 2001, including those by government agencies and nongovernmental organizations, the impact on the regional economy is likely to have been somewhat reduced, with some of the costs shifted to state and federal taxpayers.

Unrelated factors

The third source of difference between estimated impacts and reported outcomes involves changes that are unrelated to the curtailment of water deliveries. Examples include changes in commodity prices, expansion or contraction in other sectors of the economy, and unusually favorable or unfavorable weather. Key changes of this kind in 2001 included high beef prices for a second straight year, a rise in potato prices, and a decline in peppermint oil prices. There also was significant contraction in the wood products sector and in construction.

Economic models that generate estimated impacts generally assume that nothing else in the economy changes. If changes do occur, they could raise or lower the actual impact. For example, a price increase for a particular crop could raise the value of the foregone opportunity to sell at the new price.

Typically, economic models use recent prices (prices from a "typical year" or an average over a recent time period). By contrast, the reported data on gross farm sales for both Klamath County and the Tulelake Irrigation District (TID) use 2001 prices. These 2001 data are compared to the data from prior years, which reflect the prices that were observed during those years. Thus, depending on the question being asked, both approaches can be useful. For example, we sometimes want to know the impact of a given action when holding all else constant (so as to not confuse price effects with other effects). In such a case, we would use the previous year's prices or perhaps an average price from the past few years. The reported changes in crop revenues, on the other hand, reflect both quantity changes and price changes in 2001. Thus, these data would accurately reflect the impact of the irrigation curtailment only if no other confounding changes occurred (for example, weather, pests, or price changes induced by the irrigation curtailment).

The first two types of divergence (caused by the omission of private and public responses from the model) tend to produce an overstated estimate of the impacts of an event such as an irrigation curtailment. Changes in the economy unrelated to the irrigation curtailment could have either a positive or negative effect on impacts.

Estimating inferred impacts

In short, it is not possible to measure the "actual impacts" of the 2001 irrigation curtailment directly. All of the methods we might use have shortcomings. For example, a comparison between reported outcomes in 2001 with those in 2000 would reflect the actual impact only if there were no unrelated changes that affected the economy (and if there were no measurement errors in the reported data). By contrast, the revised model estimate of impacts from Chapter 13 ("Regional Economic Impact") reflects a scenario that includes some, but probably not all, of the public and private responses. Moreover, these model estimates do not take account of the effects of price changes in 2001.

Given these shortcomings, our understanding of what actually happened in the Upper Klamath Basin in 2001 as a result of the irrigation curtailment may best be served by simultaneously appraising and comparing the data on reported outcomes with the model estimates. In effect, we are trying to solve a puzzle. We have some of the pieces, but not all. We have some data on economic outcomes, but these data reflect all of the changes that occurred in 2001, not just those attributable to the irrigation curtailment. We have initial and revised estimated impacts, but they may reflect biases and omissions, and in most cases they have used past prices rather than current 2001 prices to value changes in agricultural production. We also have information on some of the unrelated changes that occurred in 2001, but not all of them.

Although there are pieces missing from this puzzle, the pieces we do have enable us to describe a rough picture of the economic story, or inferred impacts from the irrigation curtailment. By inferred impact we mean a measure of the impact of the irrigation curtailment that is based on an interpretation of three types of data:

- Reported economic data for 2001
- Estimates from several economic models
- Information on specific "unrelated changes" that occurred in 2001

To the extent that we can identify and quantify the impacts of specific unrelated changes, we can come somewhat closer to (1) identifying the impacts of the irrigation curtailment and associated responses, and (2) reconciling the reported data with the estimated impacts. In the following sections, we use this approach to examine impacts of the irrigation curtailment on irrigated acreage, gross crop revenues, net farm revenues, regional agricultural production value, agricultural employment, and total regional employment.

Table 1. Project irrigated acreage—predicted impacts, reported outcomes, and inferred impacts, 2001.

	Initial estimated impact[a]	Revised estimated impact[b]	Reported outcome[c]	Inferred impact[d]
Change in Project irrigated acreage				
Acres	–170,000	–112,000	–102,338	–102,338
Percent (%)	–86	–57	–53	–53

[a]Assumes only historical levels of groundwater pumping.

[b]Reflects observed increases in groundwater use.

[c]Includes acres receiving full irrigation from either Project or non-Project sources (including wells) compared to previous 5 years. Excludes 95,400 acres that received only midseason partial irrigation.

[d]In this case, inferred impact equals reported outcome because it is unlikely that unrelated factors affected acreage.

Agricultural estimates, outcomes, and inferred impacts

Overall, the data on reported economic outcomes in the Upper Klamath Basin in 2001 indicate that both the agricultural sector and the regional economy fared better than most observers expected. This result can be attributed to a combination of private and public responses, as well as to factors unrelated to the irrigation curtailment.

Project irrigated acreage

Starting from the ground up, BOR data for the Project in 2001 indicate that crops were grown with full irrigation (using BOR and private water) on slightly less than half (47 percent) of the normal irrigated acreage. In other words, irrigated acreage was reduced by 53 percent (Table 1). Burke (Chapter 12, "Crop Revenue") initially estimated that only 14 percent of normally irrigated land would be cultivated (a reduction of 86 percent), but this scenario did not anticipate the large increase in public and private groundwater irrigation.

In the case of acreage irrigated on the Project, the data for 2001 were collected by the BOR, and they represent the best available data on irrigated acreage. Errors may exist, but these data most likely were affected only by changes related to the irrigation curtailment or responses to the curtailment. With these data in hand, the economic models were revised to estimate the impact of the irrigation curtailment (and responses) on revenues, income, and employment.

Project gross crop revenues

To estimate the impact of irrigation curtailment on gross crop revenues, we have two sources of reported data and two kinds of economic models. All four of these approaches have shortcomings, but taken together they provide a range of values that represents the best available estimations.

The first approach relies on reported data for Klamath County (which includes all of the Oregon portion of the Project) and the Tulelake Irrigation District (TID) in California. The second approach is based on the 2001 BOR acreage report for the Project. The third and fourth are based on economic models. Each is discussed below.

First, we have data on gross crop production values for Klamath County and the TID. About 90 percent of the Project falls within these two areas. Although gross crop revenues for Klamath County also include some non-Project irrigated areas as well as some nonirrigated areas, nearly 80 percent of crop revenues in Klamath County are from the Project. Thus, we expect these data to represent the best available estimate of general trends in crop revenues in 2001.

In Klamath County, crop production values declined by $24.4 million in 2001 compared to the average for the previous 5 years, a reduction of 34 percent (Table 2). In the TID, crop production value declined by $23 million, or 57 percent. Together, these data show a reduction of $47.4 million from the average of $111 million over the previous 5 years (Table 2). However, only 90 percent of the Project lies within these two areas. If we assume that the remaining 10 percent of the Project experienced reductions in gross crop revenue similar to Klamath County and the TID, the total reduction for the Project would be about $52 million (Table 3).[1]

Our second approach for estimating the change in gross crop value is based on comparing the BOR's 2001 and 2000 acreage reports for the Oregon portion of the Project. In 2001, there were 56,242 fully irrigated and partially irrigated harvested acres (54,472 acres irrigated or preirrigated at 100 percent and 1,770 partially irrigated acres). Using the change in acres harvested between 2000 and 2001, and applying average yields and prices for 1996–2000, we can estimate the change in gross crop revenues for the Oregon portion of the Project. Only

[1]This method may overstate growers' revenue losses to the extent that drought conditions also reduced revenues in non-Project areas.

Table 2. Changes in gross agricultural production value in 2001, Klamath County, Oregon, and Tulelake Irrigation District.

	Gross production value ($ million)		
	Average 1996–2000	2001	Change in 2001
Klamath County			
Grains	8.50	3.34	–5.16
Hay and forage	35.50	22.16	–13.38
Field crops	17.04	7.29	–9.76
Specialty crops	7.31	3.37	–3.93
Nondisclosed crops	2.61	10.39	+7.77
All crops	**70.99**	**46.55**	**–24.44**
Change (%)	—	—	–34.40
Livestock	53.22	75.06	+21.84
All crops and livestock	124.20	121.60	–2.60
Change (%)	—	—	–2.10
Tulelake Irrigation District			
All crops	**39.97**	**16.90**	**–23.00**
Change (%)	—	—	–57.00
Total crop production value	**111.00**	**63.84**	**–47.44**
Total gross agricultural production value	**164.17**	**138.89**	**–25.60**

Note: Figures in this table may differ slightly from those in other chapters due to differences in data sources and crop categories. Columns may not sum exactly due to rounding.

Sources: (1) Oregon State University Extension Service, Oregon Agricultural Information Network (OAIN) database (http://ludwig.arec.orst.edu/oain/SelReport.asp). Crops are classified according to the OAIN Agricultural Commodity list. Nondisclosed crops include those not reported separately in order to protect growers' confidentiality. (2) Tulelake Irrigation District annual crop reports.

harvested acres are included. We assume normal yields in 2001 only for those acres that were fully irrigated; for those receiving less than full irrigation, an 80 percent reduction in yield is assumed. This approach produces an estimated reduction in gross crop revenues of $26.8 million for the Oregon portion of the Project. When combined with the data from the TID (a $23-million reduction), and adjusting for the 10 percent of the Project not included in either Oregon or the TID, the estimated reduction in gross crop revenue is $54 million (Table 3).[2]

The third and fourth approaches are based on economic models that simulate the impact of irrigation restrictions on crop revenues.[3]

The third approach is based on the economic-hydrologic model presented in Chapter 13 ("Regional Economic Impact"), which in turn is based on the model described in Chapter 12 ("Crop Revenue") by Burke. This model involves a detailed representation of the hydrology of the Project. When the model is used to reflect (approximately) the irrigated acreages reported by the BOR (Table 1), the revised impact estimate on gross crop revenue is –$38 million, as shown in Table 3 (assuming a 57 percent reduction in irrigated acreage).

The fourth approach is based on the economic model in Chapter 19 ("Water Allocation Alternatives") by Jaeger. This model reflects a detailed differentiation of lands in the Project according to soil class and crop rotation. When irrigated acreage is limited to the 102,000 acres that received full irrigation in 2001 (according to the BOR), this model indicates a change in gross crop revenues (–$37.5) that is nearly identical to the $38 million estimated by models in Chapter 12 and Chapter 13. Thus, both economic models produce nearly identical estimates, which are somewhat lower than those produced by the two methods based on reported data.

Thus, these four approaches yield a range of estimated reduction in gross crop value of –$37.5 to –$54 million. None of these approaches takes account of unrelated factors, such as commodity price changes, that occurred in 2001. We now turn to this topic.

Price changes in 2001

As indicated above, potato and hay prices were higher in 2001 than in recent years. Other crops, including peppermint oil and alfalfa, experienced price declines in 2001. If we use "normal prices" (from recent years) to estimate changes in gross revenues from the irrigation curtailment, the losses suffered by farmers may be understated in the case of potatoes and hay, but overstated in the case of mint and alfalfa.

In most years, one might expect such price changes to offset each other so that the presumption of "normal prices" produces a reasonably accurate estimate of losses. In 2001, however, this seems not to be the case, primarily due to unusually high prices for fresh potatoes in late 2001 and early 2002. Potatoes in the Project typically are half fresh and half processed, with an average price between $4.50 and $5.00 per hundredweight (cwt). Because of the $9.00-per-cwt price (when averaged over the marketing period) for fresh potatoes following the 2001 season, the average price for 2001 is estimated to be $7.50 per cwt, or about $2.75 higher than in typical recent years.[4] Given a decline in potato harvests of 5 million hundredweight (based on the data in Chapter 8, "Crop Production"), the $2.75 price increase suggests that an additional $14 million in revenue might have been generated had potatoes been produced at their normal levels.

Additional losses are estimated due to price increases for hay and oats, but they are partially

[2]This method may overstate growers' revenue losses to the extent that some growers were able to shift some higher value crops to non-Project lands. In that case, the reduction in crop revenues on Project lands will overstate the total reduction in crop revenues accruing to Project growers. There is some anecdotal evidence that such shifts did occur to some extent.

[3]These two approaches may understate growers' revenue losses because they assume that the available water is used "optimally," that is, applied to the highest value lands and crops. Since neither surface water nor groundwater was always available in proximity to the highest value crops or lands, this maximum value was unlikely to have been achieved.

[4]The potato market is highly variable and complex. The price estimates used in this analysis were arrived at in consultation with Don Micka, Malin Potato Co-Op, Inc. (Micka 2002).

Table 3. Project gross crop revenues—predicted impacts, reported outcomes, and inferred impacts, 2001.

	Initial estimated impact[a]	Revised estimated impact[b]	Reported outcome[c]	Inferred impact[d]
Change in Project gross crop revenues				
$ million	–74.2	–38	–52 to –54	–48 to –64
Percent (%)	–75	–39	–53 to –55	–49 to –65

[a]From Chapter 12 ("Crop Revenue") and Chapter 13 ("Regional Economic Impact"); assumes only historical levels of groundwater pumping.

[b]Reflects observed increases in groundwater use applied to the two initial impact models.

[c]Based on data for Klamath County and Tulelake Irrigation District (Table 2). These two areas include 90 percent of the Project.

[d]A measure of the impact of the irrigation curtailment that is based on an interpretation of three types of data: (1) reported data on what actually occurred in 2001, (2) estimates from economic models in Chapters 12, 13, and 19, and (3) information on price changes in 2001.

offset by price declines for onions, mint, alfalfa, wheat, and barley. The net result from considering all of these price changes suggests that the loss in gross crop revenue in 2001 was $10 million greater than loss estimates produced by the four methods above, none of which takes account of how price changes affected the value of foregone production in 2001. If we adjust the estimates to account for these price changes, the estimated impact on gross crop revenues increases to between $48 and $64 million.

Thus, based on these four methods for estimating changes in gross crop revenues, and adjusting for price effects, we conclude that the inferred impact of the irrigation curtailment on Project gross crop revenues lies somewhere between $48 million and $64 million (Table 3).

Project net farm revenues

Reductions in net farm revenue (net income) are of particular interest because this indicator most closely reflects the financial loss to irrigators and landowners. Reported data on net farm income are difficult to obtain in general and are not available for 2001 at this time. Net earnings for the kinds of agriculture practiced in the Project typically are between 10 and 30 percent of gross farm revenues, depending on the crop, land productivity, and the way in which land rents are accounted for. In Chapter 19 ("Water Allocation Alternatives"), net revenue estimates are computed based on land price differentials. The weighted average for the Project was estimated at $80 per acre, or 18 percent of gross revenues.

For the current analysis, however, these long-run net revenue values are inappropriate because they do not take account of the "fixed costs" incurred by growers who are confronted with an unexpected, short-run curtailment of irrigation. As explained in Chapter 19, the net revenue (NR) generated by an acre of irrigated land equals total revenue (TR) minus variable cost (VC) and fixed cost (FC). Thus, under normal circumstances the irrigator expects to earn NR = TR – VC – FC. The unexpected loss of water denies the farmer revenues TR and allows the farmer to avoid variable costs VC. The farmer is left without NR, but must continue to pay fixed costs FC. Thus, the difference between water delivery and no water delivery is a net loss (NL), which is equal to the sum of the lost net revenue and the fixed costs that still must be paid. Algebraically, we write this as –(NR + FC). We also can think of this loss as being equal to the difference between variable cost (costs avoided when not cultivating) and total revenue (revenues foregone when not cultivating), or NL = –(TR – VC). These two ways of defining net loss will produce the same result if the components (VC, FC, TR, NR) are the same.

If production involved zero fixed costs, the short-run and long-run values of water should both equal NR. But because fixed costs are an integral part of agriculture in the Upper Klamath

Basin, and because the water shortage that occurred in 2001 was short-run and unanticipated, the short-run measure of loss is considerably higher than NR, and it is the most relevant to assessing the overall cost of irrigation curtailment.

The model and analysis used in Chapter 19 ("Water Allocation Alternatives") includes a detailed representation of gross crop revenues, fixed costs, and variable costs associated with each crop and cropping rotation for each soil class in each portion of the Project. The estimated short-run losses, or reductions in net farm revenues, are based on these data. Compared to the long-run average net revenue of $80 per acre, the short-run loss per acre when fixed costs are included[5] (e.g., equipment, buildings, insurance, property taxes), more than doubles, to an average value in the Project of $178. (See Chapter 19 for explanations and especially Table 5 for loss estimates across location and soil class.)

Using the approach developed in Chapter 19, but with the revised figures on acreage identified above, the reduction in gross crop revenues resulting from the irrigation curtailment is estimated to be –$46 million. The change in net revenues is estimated at –$13 million (28 percent of gross revenues). If we assume that the affected farmers and farm laborers were unable to find other employment in 2001, then we would include these reductions in income as part of the loss estimate, raising the figure to –$19 million (41 percent of the change in gross crop revenues).[6]

The relationship between net revenues and gross revenues varies, depending on whether labor is considered a variable cost or a fixed cost and on whether losses are calculated by adding net revenues and fixed costs or by subtracting variable costs from total revenues (if these components have been estimated and thus are not exactly consistent with the algebraic expressions discussed above).[7] These two algebraic approaches, applied to the data available, produce average values for the change in Project net crop revenues (loss) that are 39 percent and 33 percent of total revenues, respectively (when labor costs are excluded). When labor costs are included, the two approaches produce measures of loss that are 49 percent and 43 percent of gross revenue, respectively. The ratio of loss to total revenue is higher for some higher value lands in some locations due to differences in the crops grown.

Given the variations in revenues and costs across the Project, the average short-run losses tend to fall between 40 and 60 percent of the change in gross revenue. Based on this range, the change in net crop revenues for the Project in 2001 would have been between –$15 million and –$32 million (when the change in gross crop revenue is assumed to be between –$38 million and –$54 million).[8] See Table 4 (following page).

Changes in net Project revenues in 2001 were affected by a number of factors that are not captured by these loss estimates. We can take account of three of these factors and make adjustments to the above estimates. First, expenses for additional groundwater pumping were incurred by growers on an estimated 72,000 acres. (This acreage does not include preirrigated acres, but does include all acres irrigated with groundwater, whether public or private). Operating costs for groundwater pumping vary widely, but may range from as low as $2 per acre to $10 per acre (including depreciation of capital), based on figures in Chapter 2 ("Klamath Reclamation Project"). The depths from which groundwater had to be pumped in 2001 may allow us to rule out the low end of this range. In 2001, the BOR purchased groundwater

[5]Derived from crop enterprise budgets.

[6]Even if some farmers and farmworkers found other employment, their earnings may have been lowered and the costs of finding alternative employment may have been considerable.

[7]Actual losses might be greater due to added expenses for groundwater pumping, cover crops, and extra maintenance for clearing canals of vegetation. Actual losses might be lower because crop enterprise budgets tend to reflect relatively high fixed costs based on conservative assumptions regarding the rate of depreciation, cost of leased land, etc.

[8]These estimates of reductions in gross crop revenue exclude the $10 million effect of price changes discussed above. When computing the relationship between gross and net revenues, we do not want to include the price effects because they affect both gross and net losses. In other words, no farm-level costs are associated with crop price increases.

in the Project for $25 to $40 per acre-foot from 24 growers who had private wells (an average of $32.50 per acre-foot). Erring on the conservative (high) side, we will assume that costs incurred by growers were between $20 and $35 per acre-foot. For the entire 72,000 acres that received groundwater irrigation in 2001, an additional 144,000 acre-feet of water would be required to provide consumptive use of 2 acre-feet per acre.[9] Using this quantity and range of costs, we calculate supplemental groundwater pumping costs to be between $2.9 and $5 million.[10]

Second, we want to adjust these estimates to take account of the price changes in 2001 discussed above. This adjustment adds an additional $10 million to the net losses to growers.

Third, some growers received indemnity payments from Risk Management Agency crop

[9]Application rates on individual fields will necessarily exceed the 2 acre-feet per acre of consumptive use. However, the return flows of water into ditches and canals and their reuse by other irrigators in the Project typically result in an overall irrigation efficiency of nearly 100 percent (all water applied contributes to crops' "consumptive use"). As a result, using 2 acre-feet of groundwater per acre is a reasonable approximation.

[10]A number of irrigators invested in new wells in 2001, only some of which benefited from public financing such as subsidized loans from the State of Oregon. The Oregon Water Resources Department (OWRD) approved applications for 89 wells in the region (Chapter 2, "Klamath Reclamation Project"). The per-acre costs utilized above assume normal amortization of these investments; however, there is some question whether future use of these wells will generate enough benefits to cover their initial investment cost. The OWRD indicated in 2001 that the drought permits for these wells would be converted to permanent permits, as was done following droughts in the early 1990s. Depending on how public and private wells are used in the future, these investments may end up representing a significant loss or a significant gain to irrigators in the area.

Table 4. Estimated changes in net farm revenues from the 2001 Project irrigation curtailment ($ million).

Change in gross crop revenues		**–38 to –54**
Change in net farm revenues (40 to 60 percent of gross revenues)		**–15 to –32**
Adjustments		
Groundwater pumping costs	–2.9 to –5	
Price change losses	–10	
Risk Management Agency payments (private crop insurance with partial government subsidy)	+2.4	
Cover crop costs[a]	–1.2	
Total adjustments	–11.7 to –13.8	
Total change in net farm revenue		**–27 to –46**
Emergency payments		
Federal and state emergency programs	+29.2	
Noninsured Crop Disaster Assistance Program (Farm Services Agency)	+4 to +6	
Cover crop payments[a]	+1.2	
Property tax reduction	+0.5	
Total emergency payments		**+35 to +37**
Overall change in net farm revenues[b]		**+10 to –11**

[a]Cover crop costs are included as a separate, exceptional cost borne by growers, but also are included as a government payment because they were reimbursed under a federal program.

[b]The low end of the range is found by combining the smallest (or most negative) figures for net farm revenues and emergency payments. The high end of the range is found by combining the highest (most positive) figures.

insurance, mainly for barley, wheat, and potatoes. These government-subsidized payments exceeded $2.4 million (Paul 2002). After all of these adjustments, the change in net revenue is estimated at –$27 to –$46 million (Table 4).

Combining the aggregate estimated losses with the government's disbursements of $35 to $37 million in emergency payments, the net effect is between +$10 million and –$11 million (Table 4).[11] It is important to recognize, however, that the disbursement of emergency payments does not eliminate the costs of the irrigation curtailment; rather, these costs are shifted from irrigators to taxpayers. Indeed, the initial reductions in farm income due to the irrigation curtailment represent a loss to both farmers and taxpayers since lower farm incomes imply reductions in those irrigators' income tax payments. Similarly, the emergency payments received by irrigators are taxable, so portions of them will be returned to government.

Validation of loss estimates

These loss estimates are based on many components and assumptions. It is reasonable to ask whether they are accurate and represent a reasonably good measure of total economic damages on the Project. To validate or "ground truth" these estimates, we can compare them to estimates from other comparable agricultural settings. The Supreme Court has ruled that estimates of the marginal economic value of water may be used as the basis for awarding damages in cases where irrigation water is withheld or diverted (*Kansas v. Colorado,* No. 105, 2000).

The loss estimate of $27 to $46 million in 2001 corresponds to an affected area of 102,388 acres (the Project acres that did not receive full irrigation). Given an average consumptive use of 2 acre-feet of water per acre of land, this represents a loss in the range of $132 to $225 per acre-foot of water used by crops. To state these values per acre-foot of water *applied* (as opposed to water used), we assume an average application rate of 3 acre-feet per acre. The result is a value of $88 to $150 per acre-foot of water.

These values seem to be well within the range of estimates from a variety of other agricultural settings. For example, as noted in Chapter 19 ("Water Allocation Alternatives"), market transactions in the Klamath Basin and in other parts of Oregon suggest short-run values of water ranging from $23 per acre-foot of consumptive use (based on contracts by Oregon Water Trust) to $150 per acre-foot (based on land leases in Klamath County, Todd 2002). Recent contracts for lease lands on the national wildlife refuges near the Project indicate per-acre-foot values between $26 and $42.

In a study of the potential value of water to produce alfalfa, pasture, and wheat in the John Day region of Oregon, the BOR found that water was worth between about $15 and $35 per acre-foot of applied water per year (when adjusted by an index of crop prices since the time of the study; U.S. Bureau of Reclamation 1985). By contrast, other estimates for higher value crops such as sugarbeets and vegetables range from about $110 to $190 per acre-foot of applied water in Arizona (in 2001 dollars; Kelso et al. 1974; Martin et al. 1979). Finally, in *Kansas v. Colorado*, Kansas estimated its historical losses at $129 to $233 (in 1997 dollars) per acre-foot of applied water.

Overall, then, the estimates presented in this chapter seem to fall within the range of other estimates of the marginal value of water, as evidenced by market transactions, economic studies, and relevant court cases. The current estimates fall toward the higher end of that range, partially due to the impact of high potato prices in 2001–2002. This factor alone accounts for nearly $70 of the $132 to $225 loss per acre-foot of water.

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[11]The midpoint of this range, –$0.5 million, is very close to the estimate of "direct income" reductions based on the input-output model (when also taking account of fixed costs) developed in Chapter 13 ("Regional Economic Impact"). Their estimate is about –$0.8 million when loan-financed expenditures on new wells are omitted, and +$1.4 million when these expenditures are included. Because these estimates are based on different models and data—and even slightly different definitions of income or loss—we would not expect the resulting figures to be identical. However, neither should we expect to see large differences between them.

The distribution of losses and compensation

The evidence presented above suggests that federal and state government responses to the irrigation curtailment offset a significant share of the aggregate financial losses resulting from the irrigation curtailment. This analysis says little, however, about the loss or compensation for individual farms or for households that depend indirectly on Project agriculture for their livelihood. Our analysis indicates that many farms suffered substantial losses, while some received payments in excess of their losses.

For example, a landowner expecting to receive $250 per acre for leasing land received no income from prospective tenants in 2001, and the $129 per acre in federal emergency payments covered only about one-half of that loss. Even in California, where irrigators received an additional $37 per acre, total payments did not cover the losses suffered on lands where high-value crops such as potatoes or alfalfa would have been grown.

Moreover, federal payments went to landowners in most cases, not to the growers who had planned to lease or sharecrop the land. In such cases, tenants had neither irrigable land to farm nor a share of the emergency payments. Although some of these growers may have found other work, others surely did not. Many farmworkers also found themselves unemployed and left the area to look for work. By contrast, well drillers experienced high demand for well and pump installations, reportedly resulting in higher rates for their services.

Consider the differences in compensation under varying circumstances for a grower who farms 400 acres of Project land. If the land is Class II and Class III, and the grower owns the land, federal emergency payments of about $50,000 ($129 per acre) likely would be insufficient to cover losses averaging $274 per acre for Class II soils and $173 per acre for Class III soils ($109,600 for a 400-acre operation on Class II soil), based on loss estimates in Chapter 19, “Water Allocation Alternatives”). For Class IV and V soils that typically rent for $50 per acre, however, a grower’s income might have been $30,000 higher from emergency payments than it would have been under a typical lease arrangement.

The divergence between losses and payments was compounded by overlap between various independently administered programs. For example, the BOR purchased about 65,000 acre-feet of groundwater for $2.2 million from growers with wells (at an average of $32.50 per acre-foot). This total payment was distributed among 25 participants in the program, but two recipients together received 40 percent of the total. A number of individuals took considerable risk, however, by drilling wells (at a typical cost of $50,000) that may not produce water or may not prove valuable in the future.

A few growers benefited in multiple ways from emergency programs. Growers report that in some cases irrigators were paid for groundwater and in turn were able to have a portion of the water applied to their own land. Additional payments, for example under the Noninsured Crop Disaster Assistance Program, were made independent of compensation from other sources. The Noninsured Crop Disaster Assistance Program is one program under which sharecroppers and leasers may be eligible for compensation. Payments under several of these programs were made in a relatively timely fashion, yet the distribution of total emergency payments left many individuals without full compensation.[12]

Long-term consequences

Finally, the estimated losses reported here do not include long-term effects such as the dissolution of trained crews, displacement costs for farm laborers, and the restoration of weed-choked canals. Nor do they account for the uncertain future payoffs from public and private well development in 2001.

[12]A local tax accountant who serves many Project irrigators estimates that 30 to 40 percent of irrigators had an excellent year financially, 20 percent had an average year, and the remaining 40 to 50 percent suffered considerable financial loss (Rusth 2002).

Table 5. Regional agricultural sales—predicted impacts, reported outcomes, and inferred impacts, 2001.

	Initial estimated impact	Revised estimated impact	Reported outcome	Inferred impact[a]
Change in regional agricultural sales				
Percent (%)[b]	–20[c]	–9[d]	–2.1[e]	–13 to –17

[a]A measure of the impact of the irrigation curtailment that is based on an interpretation of three types of data: (1) reported data on what actually occurred in 2001, (2) estimates from several economic models, and (3) information on specific "unrelated changes" that occurred in 2001

[b]No dollar value is shown since reported data (Klamath County only) would not be comparable to the values for initial and revised estimates and inferred impacts, all of which are for the three-county region.

[c]Impact on total agricultural sales, excluding state and federal emergency payments and loan-financed wells. Assumes only historical levels of groundwater pumping.

[d]Impact on total agricultural sales, excluding state and federal emergency payments and loan-financed wells. Reflects observed increases in groundwater use.

[e]Reported gross farm sales for Klamath County compared to previous 5 years. The omission of dehydrated food products from this measure, compared to the initial and revised estimated impacts, which include it, has a negligible effect on the comparison of percentage changes.

Given the large year-to-year fluctuations in farm prices, the financial stress of the 2001 events will depend, for some irrigators, on recent and future price patterns. For fresh potato growers, the 2001 irrigation curtailment came during a year of high prices following a year when prices were very low. The inability of growers to take advantage of high prices in 2001 may cause long-term financial distress. By contrast, growers who also produce livestock (approximately two-thirds of Klamath County farms, according to the 1997 *Census of Agriculture* for Klamath County) benefited from 2 very good years in 2000 and 2001. High livestock prices raised the value of livestock production in Klamath County by nearly $22 million, or more than 40 percent, in both 2000 and 2001, compared to the previous 5-year average.

Similarly, the analysis here and elsewhere in this report has not attempted to quantify the impacts of the irrigation curtailment, positive or negative, on the current and future abundance of fish and other species, nor on the economic sectors and communities who benefit from those species.

Regional agricultural production value

Gross farm production value in Klamath County declined only slightly, by $2.6 million (2.1 percent), in 2001 compared to the average for the previous 5 years (Table 2). This overall change, however, reflects a sharp decline in crop production value (–$24.4 million compared to the average during the previous 5 years) and a $21.8-million increase in livestock production compared to the same period.

The high value of livestock sales was due partly to favorable prices, which already existed in 2000. When livestock sales are compared only to 2000, however, there was a small decline in Klamath County compared to a small increase for Oregon overall. This difference may result from "distress sales" in which livestock owners sold animals earlier than planned (and at lower-than-optimal weight) due to the unavailability of adequate pasture or to offset low crop earnings. Indeed, average price per head in Klamath County declined by 5 percent in 2001, compared to an increase of 3.5 percent in other counties in Oregon. Distress sales in the livestock sector in 2001 can be expected to reduce inventories and future sales to some degree.

The initial regional impact model from Chapter 13 ("Regional Economic Impact") estimated a 20 percent reduction in agricultural production value (–$82 million), as shown in Table 5. When the model was revised to reflect acreage reported in the 2001 BOR report, the estimated impact was reduced to –9 percent (–$37.5 million). Neither of these figures includes state and federal emergency payments and purchases. The inferred impact of the irrigation curtailment on regional agricultural production value (including processing industries) is determined to be between –\$48 and –\$64 million. (This value equals the inferred impact on gross crop revenues from Table 3, which includes the reduced value of forage produced and hence includes impacts on the livestock sector.)

These figures represent an inferred impact for the irrigation curtailment of between –13 and –17 percent of agricultural production value (Table 5), which contrasts with the much smaller percentage reported change for Klamath County agriculture (–2.1 percent). These contrasting figures suggest that the higher value of non-Project agriculture, especially livestock sales, accounts for the small overall reported change despite the sharp decline in Project crop revenues.

Agricultural employment, reported data

The reported agricultural and agriculture-related employment in Klamath County declined by 147 jobs, or 11 percent, in 2001 compared to 2000. This corresponds to a 6 percent decline in total wages paid in "covered" agricultural and agriculture-related employment (jobs covered by unemployment insurance). Covered payrolls in establishments engaged in crop production declined by 12 percent, while establishments involved in livestock saw payrolls increase by 14 percent. Not all of the contraction can be attributed to the irrigation curtailment. For example, 38 jobs were reported lost in vegetable wholesaling because of closure and downsizing of potato sheds due to preexisting market conditions (Sicard 2002f).

These agricultural employment data are for Klamath County only and do not include the portions of the Upper Klamath Basin in Modoc and Siskiyou counties of California. Nor do they include "noncovered" employment, which includes many farmworkers. Reliable data on total agricultural employment (including noncovered employment) are not available at the county level, but noncovered farmworkers and sole proprietors clearly were seriously affected by the irrigation curtailment. Based on partial evidence from several sources, Kevin Sicard of the Oregon Employment Department suggests that perhaps 300 individuals from these two groups, and their families, were adversely affected.

Regional economic outcomes

In light of the smaller-than-expected decline in Project crop revenues, the high level of gross farm sales in Klamath County, and \$45 to \$47 million in emergency payments and other public expenditures, we can expect that the regional economy in 2001 did better than initially expected—due to the combined effects of these and other private and public responses and to factors unrelated to the irrigation curtailment.

Regional employment

The irrigation curtailment seems to have had only a modest effect on total employment in the regional economy in 2001. In Klamath County, total employment declined in 2001 by 470 jobs, or about 2 percent, compared to 2000. In Modoc County, employment grew by 3.7 percent; in Siskiyou County, employment declined by 1.7 percent. For the three counties combined, total employment fell by 946 jobs, a decline of 2.3 percent (Sicard 2002d; California Employment Development Department 2002).

These data are compared to the estimated impacts from Chapter 13 ("Regional Economic Impact" in Table 6. The initial impact estimate from Chapter 13 ("KPOP" scenario) was for 1,956 fewer jobs (a decline of 3.3 percent), while the estimate based on the revised scenario ("KPOP with response") was for a decline of 440 jobs (–0.7 percent). This large difference is due to inclusion in the revised scenario of the reported increase in groundwater irrigation as well as the government emergency payments.

For economy-wide variables such as regional employment, it is very difficult to identify and account for all of the related and unrelated factors that may have affected the regional economy. The irrigation situation in 2001 in the

Table 6. Regional employment—predicted impacts and reported outcomes, 2001.

	Initial estimated impact[a]	Revised estimated impact[b]	Reported outcome[c]	Inferred impact[d]
Change in regional employment				
Jobs	–1,956	–440	–946	unknown
Percent (%)[e]	–3.3	–0.7	–2.3	unknown

[a]From the input-output model in Chapter 13 ("Regional Economic Impact"), based on initial estimated acreage.
[b]From the input-output model in Chapter 13 ("Regional Economic Impact"), based on revised acreage.
[c]Based on the change in total employment in Klamath, Modoc, and Siskiyou counties between 2000 and 2001.
[d]There are too many unknown variables to allow estimation of an inferred impact for regional employment.
[e]Percentage changes differ between impact models and reported outcomes in part due to different baselines.
Sources: California Employment Development Department and Oregon Employment Department

Upper Klamath Basin attracted a great deal of media and political attention and many visitors. This activity may have had a positive effect on the overall economy, especially services. The infusion of emergency payments and other public disbursements also would have a positive effect, as would the continued high revenues in the livestock sector. Unlike the difference between the estimated and reported Project acreage or gross revenues, there are too many unknown variables to allow us to produce an inferred impact in this case.

In Klamath County, nearly all of the decline in employment in 2001 was due to factors unrelated to the irrigation curtailment, according to Sicard. The decline is attributable to two significant events: contraction in the lumber and wood products sector (a loss of 190 jobs) and contraction in the construction sector (a loss of 420 jobs) due to completion of several large construction projects (Sicard 2002a, c). Of the nonfarm job losses in Klamath County in 2001, Sicard attributes only 24 of those jobs to the drought and irrigation curtailment (Sicard 2002d), a reduction of 0.1 percent.

It would be misleading to suggest that the only ripple effects of the irrigation curtailment were those caused by changes in Project revenues. The curtailment had dramatic effects on people's expectations and on their confidence in future water availability and economic stability. A heightened sense of uncertainty about one's economic circumstances may lead consumers to behave with caution and to alter or restrain their spending practices. Such psychological effects could affect the local and regional economy in ways that are not yet apparent from available data.

Other economic outcomes

In addition to the outcomes reported above pertaining to the general level of regional economic activity, other direct, short-run economic consequences include the effect of irrigation curtailment on the production and allocation of energy. The water cutoff had a positive financial effect on PacifiCorp relative to what would have occurred under normal operation of the Project. (The drought, on the other hand, had an adverse effect on PacifiCorp, reducing the company's energy production by 25 percent of normal.) PacifiCorp supplies the BOR and Project growers with electricity to pump irrigation water at very low rates resulting from a long-term government contract ($0.003 to $0.006/kwh, or 80 to 90 percent below current market rates). The 2001 Biological Opinions had three effects on PacifiCorp.

First, energy demand for irrigation was reduced by about 45 percent based on comparisons of Project and non-Project demand. (Project demand typically was 40 percent higher than non-Project demand in the years prior to 2001; it was 22 percent lower in 2001.) As a result, PacifiCorp was able to sell this power to other customers. Given the very high market rates for power in the spring and summer of 2001 (around $0.2/kwh during the relevant period) and the drought, which reduced PacifiCorp's power generation and forced the company to buy power at market rates to meet obligations to customers, this reduction in Project demand for energy represented considerable cost savings for PacifiCorp.

Second, PacifiCorp is obligated by contract to install line extensions to well and pump sites in the Project at no cost to irrigators. Given the sharp rise in groundwater development in 2001, this requirement represented a significant additional cost to PacifiCorp.

Third, the irrigation curtailment resulted in additional stream flows in the Klamath River, which generated additional electricity for PacifiCorp. The increase in stream flow in the summer of 2001 due to the irrigation curtailment is difficult to estimate precisely, but it may have been as high as 100,000 acre-feet. This amount of additional water is likely to have generated as much as 75,000 MWh of power given the average generation rates at that time of year. Given the drought conditions and very high energy prices at that time, coupled with PacifiCorp's lack of additional generating capacity to meet its obligations to its regulated customers, this additional power likely represented a significant financial gain for PacifiCorp. Taking these three effects together, the curtailment of irrigation on the Project likely had a sizable net positive financial impact on PacifiCorp.[13]

Other economic outcomes arising from the irrigation curtailment, such as those resulting from changes in aquatic habitats in 2001, cannot be measured at this time. Changes in economic activities such as recreation and tourism or commercial and sport fishing are more difficult to evaluate for two reasons. First, there is considerable scientific uncertainty about the effects of the changes in water levels that occurred in 2001 on populations of fish and other species. Second, any possible effects of changes in fish and wildlife populations on the economic circumstances of individuals and communities are likely to occur in the future.

Conclusions

Our understanding of the economic changes that occurred in the Upper Klamath Basin in 2001 is based on a combination of recently available economic data and revised impact estimates based on models. We cannot fully separate the changes due to the irrigation curtailment from those due to unrelated events. We have some data on economic outcomes—but these data reflect all of the changes that occurred in 2001, not just those attributable to the irrigation curtailment. We have estimated impacts with and without specific public and private responses, but these estimates may involve omissions or errors that over- or understate the facts.

We also have information on some of the unrelated changes that occurred in 2001, but not all such changes. Thus, there are pieces missing from this puzzle, but the pieces we do have enable us to describe a rough picture of the economic story.

The analysis above suggests that the 2001 irrigation curtailment carried a high economic cost and that a large portion of that cost was shouldered by taxpayers. Many groups within the region incurred considerable economic losses, including farmworkers, tenant farmers and sharecroppers, and agricultural input suppliers. Many landowners and owner-operators also suffered considerable economic hardship. On the other hand, these groups benefited to some extent from government emergency programs, and in some cases payments exceeded individuals' direct losses.

In the aggregate, net losses on the Project are estimated to be between $27 and $46 million. Total government emergency payments were

[13]PacifiCorp staff contributed to and reviewed this analysis (Bornemeier 2002; LaBriere 2002), including quantitative estimations placing the net overall gain to PacifiCorp as high as $20 million.

between $35 and $37 million. These two figures, however, should not be added together as a measure of total cost to society. The losses on the Project were losses to the local economy *and* to the national economy. The emergency payments, by contrast, were transfers from one group (taxpayers) to another (irrigators and landowners). Thus, they represent income changing hands rather than wasted resources or forgone opportunities.[1]

The availability and eligibility for public emergency programs played an important role in separating those who were at least partially compensated for their losses from those who were not. The evidence suggests that groups closely tied to agriculture in the Project, but who did not receive public compensation for their losses, suffered the most as a result of the irrigation curtailment. These groups include farmworkers, tenants, sharecroppers, and agricultural input suppliers.

For the region overall, agricultural outcomes were better than originally expected based on the initial model estimates. The main reasons were additional private and publicly funded groundwater pumping, emergency payments and other public appropriations, and higher prices for livestock and potatoes.

The public response contributed toward a significant increase in the amount of land that was irrigated, and it also mitigated the financial costs for many growers. These responses came at a high cost to taxpayers, however. Indeed, the estimated $45 to $47 million government cost is nearly double the income generated on the entire Project (about $25 million including farm labor income) in a typical year.

There should be little doubt that the approach taken in 2001 to respond to water scarcity arising from drought and ESA requirements does not represent a desirable or sustainable model for responding to future water shortages. In future years, or in other agricultural communities facing water shortages, it is doubtful that governments will provide the level of response observed in the Project in 2001. Hence, it is incumbent upon all parties interested in finding lower cost solutions to conflicts over water to seek ways to avoid a repeat of the events of 2001. Creating the institutions necessary to allow for flexible, market-based responses to water shortages could dramatically reduce the risks, costs, and disruptions associated with shortages. For example, the cost of the irrigation curtailment in 2001 is estimated to have been *five* times higher than it might have been if water markets or water banks had been available to irrigators in the Upper Klamath Basin. (See Chapter 19, "Water Allocation Alternatives," for a detailed analysis of these issues.)

The long-term impact of the events of 2001, on irrigators as well as on fishers, tribes, and other groups, is impossible to predict. In large part, future consequences will depend on the institutional changes that are made in response to the events of 2001.

Table 7 (following page) summarizes the findings discussed in this chapter.

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[1]These government transfers (emergency payments) and other public expenditures may generate an additional cost to society depending on how they are financed (e.g., raising taxes, public borrowing, or reductions in other public programs). Given the degree of substitution and comingling among sources and uses of government funds, however, any claims about the size of this added "distortionary" cost would be entirely speculative.

Table 7. Summary of estimated impacts, reported outcomes, and inferred impacts in the Upper Klamath Basin, 2001.

	Initial estimated impact	Revised estimated impact	Reported outcome	Inferred impact
Project level				
(A) Change in Project irrigated acreage				
Acres	–170,000	–112,000	–102,338	–102,338
Percent (%)	–86	–57	–53	–53
(B) Change in Project gross crop revenues				
$ million	–74.2	–38	–52 to –54	–48 to –64
Percent (%)	–75	–39	–53 to –55	–49 to –65
(C) Change in Project net farm revenues				
Loss in net crop revenues ($ million)	–33 to –37.5	–15 to –32	not available	–27 to –46
Gain from emergency payments ($ million)	—	—	+37 to +35	+37 to +35
Overall change ($ million)	—	—	not available	+10 to –11
Regional level				
(D) Change in regional agricultural sales				
Percent (%)	–20	–9	–2.1	–13 to –17
(E) Change in regional employment				
Total employment	–1,956	–440	–946	unknown
Percent (%)	–3.3	–0.7	–2.3	unknown

(A) Change in Project irrigated acreage: Initial estimate (from Chapter 12, "Crop Revenue") assumes only historical levels of groundwater pumping. Revised estimate reflects observed increases in groundwater use. Reported outcome includes acres receiving full irrigation from either Project or non-Project sources (including wells) compared to the average for the previous 5 years. Inferred impact equals the decline in reported irrigated acreage. None of these figures includes lands irrigated only during the midseason release.

(B) Change in Project gross crop revenues: Initial estimate is from Chapter 12 ("Crop Revenue") and Chapter 13 ("Regional Economic Impact") and assumes only historical levels of groundwater pumping. Revised estimate reflects observed increases in groundwater use applied to the two initial impact models. Reported outcome is based on data for Klamath County and the Tulelake Irrigation District (TID) as reported in Table 2. These two areas include more than 90 percent of the Project. Inferred impact reflects the entire range of estimates that reflect reported irrigated acreage, including those based on models and those based on reported data.

(C) Change in Project net farm revenues: Initial impact estimate is from Chapter 19 ("Water Allocation Alternatives"). Revised impact estimates are based on the inferred impacts on gross crop revenues reported on line B, which reflect reported acreage. These figures also account for crop insurance payments and additional outlays for groundwater pumping and cover crops.

(D) Change in regional agricultural sales: Initial and revised estimated impacts are from Chapter 13 ("Regional Economic Impact"), excluding state and federal emergency payments. Initial estimate assumes only historical levels of groundwater pumping. Revised estimate reflects observed increases in groundwater use. Reported outcome equals gross farm revenues for Klamath County compared to previous years. (No dollar value is shown because reported data for Klamath County only would not be comparable to the values for initial and revised estimates and inferred impacts, all of which are for the three-county region.) Inferred impact reflects the inferred impact on gross crop revenues (from line B), which includes the reduced value of forage produced and hence includes impacts on the livestock sector.

(E) Change in regional employment: Initial and revised estimates are from the input-output model in Chapter 13 ("Regional Economic Impact") for the initial and revised irrigated acreage. Reported outcome is based on the change in total employment in Klamath, Modoc, and Siskiyou counties between 2000 and 2001. There are too many unknown variables to produce an inferred impact.

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Part 6. Wildlife

15

Bald Eagles

Relationships between Bald Eagle Biology and Federal Environmental Decisions on the Klamath Reclamation Project

Jeff Manning and W. Daniel Edge

The bald eagle (*Haliaeetus leucocephalus*) historically ranged throughout North America except in extreme northern Alaska and Canada and central and southern Mexico (Stalmaster 1987). One-quarter to one-half million bald eagles were present in North America when Europeans arrived (Gerrard and Bortolotti 1988). After European settlement, bald eagle populations exhibited a slow, but widespread, decline due to habitat loss, reduced availability of winter foods (e.g., bison carrion, anadromous fishes such as salmon, waterfowl, and shorebirds), and persecution.

The first major decline probably began in the mid- to late 1800s (Gerrard and Bortolotti 1988). Nesting sites were lost to shore development, and eagles were shot, trapped, and poisoned as livestock predators (Dale 1936). Alaska paid a bounty for killing eagles between 1917 and 1952. Eagles were believed to prey on domestic lambs, and thus were shot by many sheep ranchers. Beginning in the 1930s, they also were shot from aircraft (Dale 1936). These, and other factors, reduced bald eagle numbers throughout the 1930s.

During the 1940s, dichloro-diphenyl-trichloroethane (DDT) was used to control mosquitoes in coastal and wetland areas. As a result of eagles' foraging on contaminated prey, the bald eagle decline accelerated. In the late 1960s and early 1970s, it was determined that DDE, the principal breakdown product of DDT, builds up in the fatty tissues of adult female bald eagles, thereby preventing the calcium release necessary to produce strong eggshells. The result was reproductive failure throughout the bald eagle's range.

In response to declining eagle populations, on March 11, 1967, the Secretary of the Interior listed populations of the bald eagle south of the 40th parallel as endangered under the Endangered Species Preservation Act of 1966. However, the decline continued until DDT was banned from use in the United States on December 31, 1972. In 1978, the eagle was listed as endangered throughout the lower 48 states except in Michigan, Minnesota, Wisconsin, Washington, and Oregon, where it was designated as threatened (USDI 1978).

In the 1970s, the U.S. Fish and Wildlife Service (USFWS) developed a recovery program for the bald eagle that divided the lower 48 states into 5 geographically separate recovery regions. By 1995, the bald eagle had met most numerical population goals established in the Recovery Plan, and it was reclassified as threatened in all of the lower 48 states (USDI 1995). It has recovered across most of its range, with the population essentially doubling every 7 to 8 years (USDI 1999).

In 1998, the total population in the lower 48 states exceeded 5,748 nesting pairs, thereby providing support for a proposal in 1999 to remove the bald eagle from the federal endangered species list (USDI 1999). The proposal to delist the species is pending. Thus, the bald eagle is a success story for the Endangered Species Act in that it was placed on the list as endangered, later downlisted to threatened status, and likely to be removed from the list in the near future.

Because of its location, high prey abundance, and relatively mild winter weather, the Upper Klamath Basin of Oregon and California supports the largest wintering population of bald eagles in the United States outside of Alaska. More than 1,000 individuals have been counted during a single winter day in an area that encompasses the Upper Klamath Basin and the Klamath Reclamation Project.

The Oregon portion of the Klamath Basin Management Zone (KBMZ), as defined in the Bald Eagle Pacific Recovery Region (PRR) Recovery Plan (USFWS 1986), supports 117 breeding pairs of eagles (31 percent of the population in Oregon, according to Isaacs and Anthony 2000).

Bald eagles in the Upper Klamath Basin feed primarily on waterfowl and fish (Frenzel 1985), plus other prey species. According to the 2001 Biological Assessment for the Klamath Reclamation Project (page 60), “The manipulation of the timing and amount of water available across the landscape of the Upper Klamath Basin (which is largely controlled by the Klamath Project) directly and indirectly affects the survival of bald eagle populations.”

This chapter provides information on the legal status of bald eagles, aspects of their biology in the PRR and KBMZ, recent federal environmental documentation and decisions, and effects of these decisions on bald eagle populations.

Legal status of bald eagles

Bald eagles in the Upper Klamath Basin receive protection under two state and four federal environmental acts. The type and date of initiation of protection provided by each act is described below.

- California Endangered Species Act—The bald eagle was listed as endangered in 1971, with a revision in 1980. The eagle currently is considered endangered at nesting and wintering sites.
- Oregon Endangered Species Act—The bald eagle was listed as threatened in 1987.
- Migratory Bird Treaty Act (16 U.S.C. 703)—Passed in 1918, this act affords protection to bald eagle adults, nests, and nest contents.
- Bald Eagle Protection Act (16 U.S.C. 668)—Passed in 1940, this act made it illegal to kill, harm, harass, or possess bald eagles (live or dead), as well as eggs, feathers, or nests.
- Lacey Act (SS 42)—Passed in 1981, this act prohibits bald eagle importation into the United States or any territory of the United States.
- U.S. Endangered Species Act of 1973 (ESA)—In 1978, the bald eagle was listed as endangered throughout the lower 48 states except Michigan, Minnesota, Wisconsin, Washington, and Oregon, where it was designated as threatened (43 FR 6233, February 14, 1978). Because the main goal of the federal Endangered Species Act is to restore endangered and threatened species to the point where they are again viable, self-sustaining members of their ecosystems, the ESA contains provisions for recovering a species after it is listed.

The bald eagle also is afforded additional consideration and/or protection by the Convention on International Trade in Endangered Species, Clean Water Act, Federal Land Policy and Management Act, Fish and Wildlife Coordination Act, and National Environmental Policy Act.

In the 1970s, the USFWS developed a recovery program for the bald eagle that divided the lower 48 states into 5 geographically separate recovery regions. The Pacific Recovery Region (PRR) consists of California, Nevada, Oregon, Washington, Idaho, Montana, and Wyoming. A recovery plan was prepared for each recovery region, and the plan for the PRR was completed in 1986 (USFWS 1986). The plan states that "the primary objective … is to outline steps that will provide secure habitat for bald eagles in the 7-state Pacific Recovery Region and increase populations in specific geographic areas to levels where it is possible to delist the species."

Each state is further divided into management zones. Oregon encompasses 10 zones, in part or whole, one of which is the Klamath Basin Management Zone (KBMZ), which includes all of the Upper Klamath Basin in Oregon plus Lower Klamath Lake, Tule Lake, and Clear Lake national wildlife refuges in California.

The Pacific Recovery Plan specified that delisting should occur on a region-wide basis and should be based on four criteria.

- There must be a minimum of 800 nesting pairs in the 7-state PRR.
- Nesting pairs should produce an average of at least one fledged young per year, with an average success rate per occupied site of not less than 65 percent over a 5-year period.
- Population recovery goals must be met in at least 80 percent of the management zones.
- A persistent, long-term decline in any wintering population greater than 100 eagles would provide evidence for not delisting the species.

Because it has met most numerical population goals in the United States, the bald eagle was reclassified as threatened in all of the lower 48 states in 1995 (USDI 1995). In 1999, it was proposed for removal from the federal endangered species list (USFWS 1999). However, as of February 2002, no further action has been taken, and the bald eagle remains listed.

Management and monitoring activities

Management

Consideration of bald eagles in land-use management decisions has increased tremendously since the federal listing of the species in 1978. In Oregon and California, the special needs of bald eagles are incorporated in land management plans developed by all of the major federal landowners, including the National Park Service, U.S. Forest Service, Bureau of Land Management, Department of Energy, Department of Defense, U.S. Army Corps of Engineers, Bureau of Reclamation (BOR), and the USFWS Refuge System. Native American tribes also are committed to monitoring and managing bald eagles under their jurisdiction.

The ESA extends additional consideration of bald eagle needs to every project that receives federal funds or requires a federal permit. This requirement affects a wide variety of activities, including land and water development projects, transportation projects, hydroelectric dam licensing, irrigation systems operation, airport operations, and any work carried out with federal grant monies. It produces benefits to bald eagles through required project modifications, such as avoidance, minimization, and mitigation measures. These measures are project-specific, but most often involve protecting habitat, maintaining an adequate food supply, and minimizing human activities around nest and roost sites.

Nesting surveys

The Oregon Cooperative Fish and Wildlife Research Unit, located at Oregon State University, has monitored occupied bald eagle territories throughout Oregon and in the Washington portion of the Columbia River Recovery Zone since 1971 (Isaacs and Anthony 2001). The Research Unit monitors previously active territories and searches for new ones each year (Isaacs 2001, personal communication).

In their 2001 report, Isaacs and Anthony provided a list of previously unknown sites and nests, a summary of activity and productivity for Oregon and the Columbia River Recovery Zone, landowners with bald eagle nest trees in Oregon, activity and productivity for the past 5 years by recovery zone, highlights of the survey, and population and productivity graphs. Contributors to this extensive effort include numerous federal and state agencies, local families, and foundations.

Midwinter bald eagle surveys

Midwinter surveys of bald eagles have been conducted across the nation for 4 decades. In 1979, the National Wildlife Federation (NWF) assumed the task of coordinating a nationwide agency and private volunteer winter count (Knight et al. 1981; Steenhof et al. 2001). According to Steenhof et al. (2001) and Stinson et al. (2001), the NWF's 1984 guidelines standardized midwinter survey routes and survey methods. NWF also recommended that the same experienced observers conduct the surveys each year.

These midwinter counts can be an effective way to monitor long-term changes in bald eagle populations (Steenhof et al. 2001). Steenhof further explained that this method allows for monitoring changes or threats to habitat or important wintering areas. Standardized routes across Oregon and California have been surveyed since 1984, and one route runs through the Upper Klamath Basin.

The USFWS has conducted routine annual counts of waterfowl and bald eagles in the Lower Klamath National Wildlife Refuge since 1982 (Thomson 2001, personal communication). Although these surveys are not part of the nationwide midwinter bald eagle survey, they seem to follow the guidelines recommended by the National Wildlife Federation. One distinction is that the national wildlife refuge surveys often are conducted more than once each January. The Upper Klamath Basin midwinter survey data are available on the Internet (http://www.klamathnwr.org/cenfindex.html).

Bald eagle biology

Breeding population size, rate of recruitment, and productivity

An increasing breeding population is a strong indicator that bald eagle productivity (young fledged per nest) and recruitment (first-year survival of young) into the adult population have risen. Since 1970, the breeding population has essentially doubled every 7 to 8 years, exceeding 5,748 nesting pairs in the lower 48 states in 1998 (Figure 1).

The number of breeding pairs in the PRR has increased steadily, from 861 in 1990 to 1,480 in 1998, a 72 percent increase (Figure 1). In 1998, 321 nesting pairs (22 percent of the PRR total) were in Oregon, and 107 (7 percent) were in the KBMZ (Isaacs and Anthony 2000). The number of breeding pairs continues to rise in Oregon, with 372 in 2000 and 393 in 2001 (Isaacs and Anthony 2001). Some of these pairs are resident in Oregon year-round, while others migrate to wintering areas outside of Oregon.

Between 1990 and 1998, the total number of young raised per year increased in the PRR. Productivity (young fledged per nest) in the PRR has remained relatively stable throughout that period, ranging from 0.95 to 1.17, with an average of 1.04 (Steenhof, unpublished data). Thus, the number of young fledged per nest has remained stable, while the number of breeding pairs continues to increase, resulting in a continual increase in the total number of young produced in the PRR.

There are numerous influences on bald eagle recruitment and productivity. For instance, Anthony and Isaacs (1989) found that productivity was higher at nests farther from human disturbance compared to nests that were closer.

Hansen et al. (1986, page 119) tested three alternative explanations for the regulation of breeding by bald eagles in southeast Alaska and reported that: "(1) food abundance in spring strongly influences where or if … eagles lay eggs and when they lay eggs, (2) habitat quality is important when breeding eagles select a breeding area …, and (3) food supplies during incubation and rearing regulate offspring survival." They concluded that food supplies influence egg and chick survival.

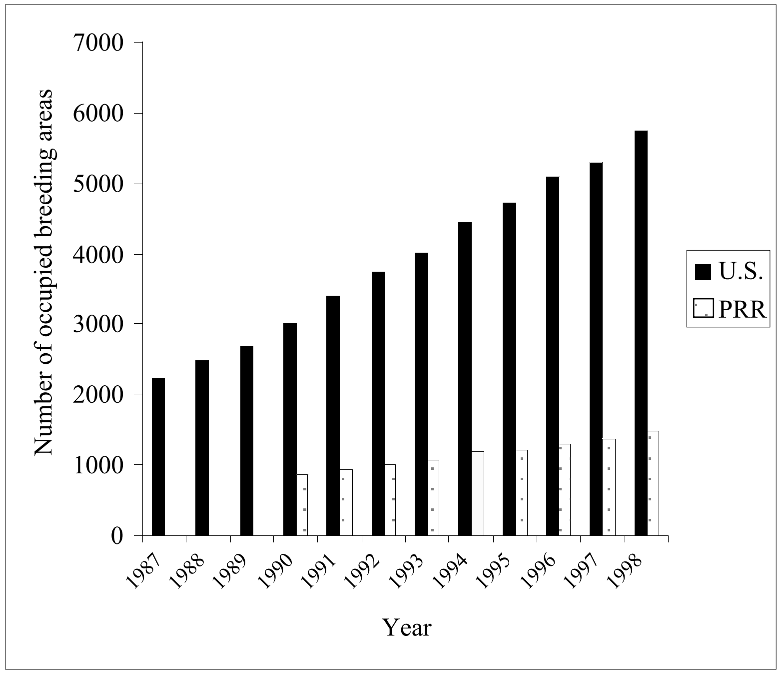

Figure 1. Total number of bald eagle breeding pairs in the 48 conterminous states and Pacific Recovery Region (PRR), 1987–1998. Source: U.S. data (1987–1998) from U.S. Fish and Wildlife Service Web site (http://midwest.fws.gov/RockIsland/activity/endangrd/eagle.htm); PRR data (1990–1998) from Steenhof, unpublished.

Nests

Bald eagles nest in large trees that are close to open bodies of water, which function as aquatic foraging areas (Anthony and Isaacs 1989). In Oregon, all nests have been found within 7.2 km (4.3 miles) of permanent bodies of water, and most nests (85 percent) are within 1.6 km (1 mile) of water (Anthony and Isaacs 1989).

Nest trees usually are the tallest in the forest stand. In the Pacific Northwest, nest trees are from 30 to 96 percent taller than adjacent stands (Stalmaster 1987). In Oregon, ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) are the most frequently used species for nest construction (Anthony and Isaacs 1989). Most of these nest trees are located on the top quarter of slopes. Nests are positioned from 0 to 45 percent below the tops of nest trees (Anthony and Isaacs 1989).

In the Upper Klamath Basin, territorial eagles lay eggs as early as mid-February. Pairs are known to repair nests throughout the year (Isaacs 2001, personal communication). Breeding pairs of bald eagles repeatedly return to the same nest unless it is destroyed.

Life span and age of sexual maturity

Bald eagles in the wild have a life span of at least 28 years (Schempf 1997). Captive birds have lived more than 47 years, and they are believed to be capable of reproducing for 20 to 30 years (Stalmaster 1987). Harmata et al. (1999) estimated a maximum life span of 15.4 years for bald eagles produced in the Greater Yellowstone Ecosystem, where most of the known fatalities were human related.

Breeding generally begins at age 6, but sometimes bald eagles defer breeding until age 7 or 8 in populations at carrying capacity—the maximum population the ecosystem can support (Bowman et al. 1995; Harmata et al. 1999; Buehler 2000). However, when food is particularly abundant, or when a population decline has left many territories vacant, raptors breed at a younger-than-usual age (Newton 1979). Consequently, bald eagles may attempt to breed at age 4 where there is little competition for food and limited potential for mates (Gerrard et al. 1992; Buehler 2000).

Ecologists refer to species such as the bald eagle as K-strategists (MacArthur and Wilson 1967). These species are relatively long lived and large bodied. They produce few young, and they exhibit slow development, delayed reproduction, and long-term parental care of young. These life-history traits combine to give bald eagles limited ability to respond to chronic increases in juvenile mortality and even less ability to respond to increased adult mortality (Congdon et al. 1993). Consequently, bald eagle populations, when compared with shorter lived organisms, require both high adult and juvenile survival rates (Congdon and Dunham 1997).

Sources of mortality

The bald eagle is subject to many sources of mortality. Recovery Plan task 2.221 is to "determine the main causes of eagle mortality" (USFWS 1986). Based on 1,429 eagle carcasses examined between 1963 and 1984, the most prevalent causes of death were gunshot (23 percent), trauma (21.1 percent), poisoning (11.1 percent), and electrocution (9.1 percent) (National Wildlife Health Laboratory 1985). Red-tailed hawks (*Buteo jamaicensus*), ravens (*Corvus corax*), crows (*C. brachyrhynchos*), magpies (*Pica* spp.), gulls (*Larus* spp.), wolverines (*Gulo luscus*), raccoons (*Procyon lotor*), and black bears (*Ursus americanus*) may eat eggs and hatchlings (McKelvey and Smith 1979; Nash et al. 1980; Doyle 1995; Perkins et al. 1996). Nestlings sometimes are killed by their nestmates (Brown 1977), and juvenile bald eagles are prone to accidents, predation, or starvation during their first year (Stalmaster 1987).

Adults have few natural enemies, and the most frequently reported causes of adult mortality are human related (Stalmaster 1987; Franson et al. 1995; Harmata et al. 1999). Adult bald eagles occasionally die in aggressive encounters with other bald eagles, golden eagles (*Aquila chrysaetos*), or peregrine falcons (*Falco peregrinus*) (Jenkins and Jackman 1993; Driscoll et al. 1999).

Grier (1980) emphasized that, although survival rate is perhaps the most important component of population regulation, it is the least studied population parameter in bald eagles. Because bald eagles are K-strategists, survival is believed to be the most critical element in maintaining or increasing their populations, with production of young as secondary (Grier 1980; Stalmaster 1987).

Grier (1980) suggested that a population with moderate nest success and productivity, such as that found in the PRR, must have high survival of juveniles (70 percent) and adults (90 percent) for the population to grow. However, Driscoll et al. (1999) and Harmata et al. (1999) suggested that higher juvenile survival and adult immigration from adjacent regional populations may account for increasing populations in some areas of Washington despite higher-than-expected adult mortality. This view highlights the importance of regional bald eagle populations, such as the wintering population in the Upper Klamath Basin.

Migration

Bald eagles generally follow migration corridors between spring/summer and wintering areas in the Pacific Northwest (Figure 2). Eagles leave northern breeding grounds during fall to seek milder climates, where prey are concentrated during the winter. Fall migration may be a response to dwindling food supplies in breeding areas or to a lack of feeding opportunities when lakes and rivers freeze over in the interior.

The relatively mild winter climate, abundant winter waterfowl, and small mammal populations in the Upper Klamath Basin (Keister et al. 1987; Frenzel and Anthony 1989) attract bald eagles from as far away as Glacier National Park, Montana (McClelland et al. 1994; Young 1983), the Skagit River, Washington (Watson and Pierce 2001), and southern California (Isaacs 2001, personal communication). Watson and Pierce (2001) provided evidence that bald eagles wintering in the Upper Klamath Basin travel vast distances across the Pacific Northwest and from as far away as Alaska.

Some eagles that winter in the KBMZ exhibit a rare behavior of reverse migration; in the fall, they travel from southern California northward to the Upper Klamath Basin (Frenzel 1985; Detrich 1986). Although the winter climate is considerably colder in the Basin, this reverse migration is thought to be a response to the relatively greater availability of prey in the Basin compared to the arid southern California region.

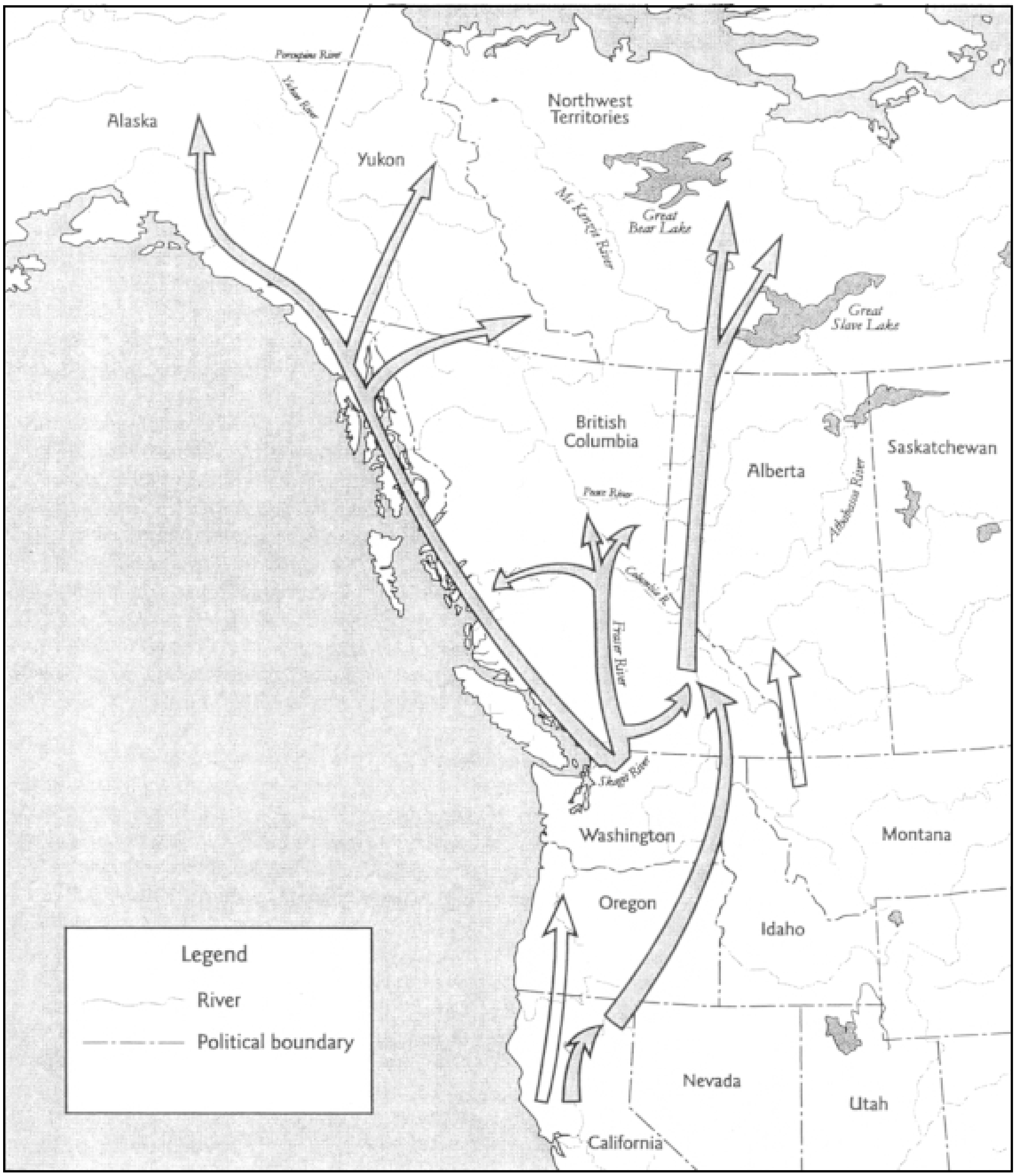

Figure 2. Bald eagle migration corridors in the Pacific Northwest. Shaded arrows based on Watson and Pierce 2001; clear arrows based on McClelland et al. 1994 and Sorenson 1995. Source: Reprinted with permission from Stinson, D.W., J.W. Watson, and K.R. McAllister. 2001. Washington State Status Report for the Bald Eagle *(Washington Department of Fish and Wildlife, Olympia).*

Winter congregations

The midwinter bald eagle surveys represent a unique source of baseline data that provide an opportunity to monitor the general status of wintering congregations. Between 1986 and 2000, midwinter counts in the lower 48 states increased an estimated 2 percent per year (Steenhof et al. 2001). Sixty-three percent of the survey routes showed increasing trends; however, the Northwest region was essentially unchanged. The number of wintering bald eagles fluctuated in the Upper Klamath Basin during that time (Mauser and Thomson 2001).

Bald eagles generally winter in areas with a relatively mild climate that support a combination of communal roosts and abundant available food. Specific characteristics of communal roosts influence their use, and the size of food resource patches often influences the size of the eagle concentration. The juxtaposition of these two habitat features across the landscape is essential.

Communal roosts

Communal roosts have been defined variously as sites where more than one eagle roosts for more than one night (Buehler et al. 1991) or as sites where at least three eagles roost for at least two nights (Anderson et al. 1985). Bald eagle communal night roosts are recognized as important components of wintering habitats (Anthony et al. 1982). The Pacific States Bald Eagle Recovery Team recommended that communal roosts be identified and protected (USFWS 1986).

Characteristics of forest stands, roost trees, and size of roosts used by bald eagles vary considerably among regions of the 48 contiguous states (Keister and Anthony 1983). In general, bald eagles prefer to roost in trees that are taller and more open in structure than those in the surrounding forest stand. Eagles especially prefer defoliated trees, such as snags, spike-topped conifers, and large deciduous trees. In northwest Washington (Hansen et al. 1980), bald eagles prefer to roost communally in Douglas-fir, but they will roost in ponderosa pine where this species is dominant.

In the Upper Klamath Basin, five primary bald eagle communal roosts have been identified (Keister and Anthony 1983). They are referred to as the Bear Valley, Caldwell, Cougar, Three Sisters, and Mount Dome communal roosts (Figure 3). All are described as being in old, open-structured trees close to feeding areas (Keister and Anthony 1983). The forest stands in which these communal roost trees occur have a mean density of 53.1 trees per hectare (21.2 per acre), diameter-at-breast-height of 54.3 cm (21.7 inches), height of 26.4 m (87.1 feet), and 7.3 percent spikes and snags (Keister and Anthony 1983). Four of the five roosts are in ponderosa pine stands.

The adaptive significance of communal roosts is based on their proximity to foraging areas. Edwards (1969) showed that bald eagles used roosts nearest hunting territories with high prey densities and that they shifted hunting areas when disturbed or when prey became scarce. Additionally, Hansen et al. (1986) found that the density of bald eagles in habitats adjacent to foraging areas was about 10 times higher than in areas far from foraging areas.

More than one factor, such as flight distance, influences how bald eagles select communal roosts, but greater distances between foraging areas and communal roost sites undoubtedly result in increased energy expenditure. Keister et al. (1985) showed that distances greater than 5 km (3 miles) between foraging areas and roosts created an energy disadvantage to communally roosting bald eagles that wintered in the Upper Klamath Basin

However, Keister et al. (1985), using a model of energy consumption (calories used for flight and roosting) in bald eagles, and considering distances between roost and forage areas, reported that energy demand did not influence the use of communal roosts during winter in the Klamath Basin. They proposed that this finding was due to: (1) high food availability and relatively mild winter weather during their study, or (2) an increase in energy output required to fly a

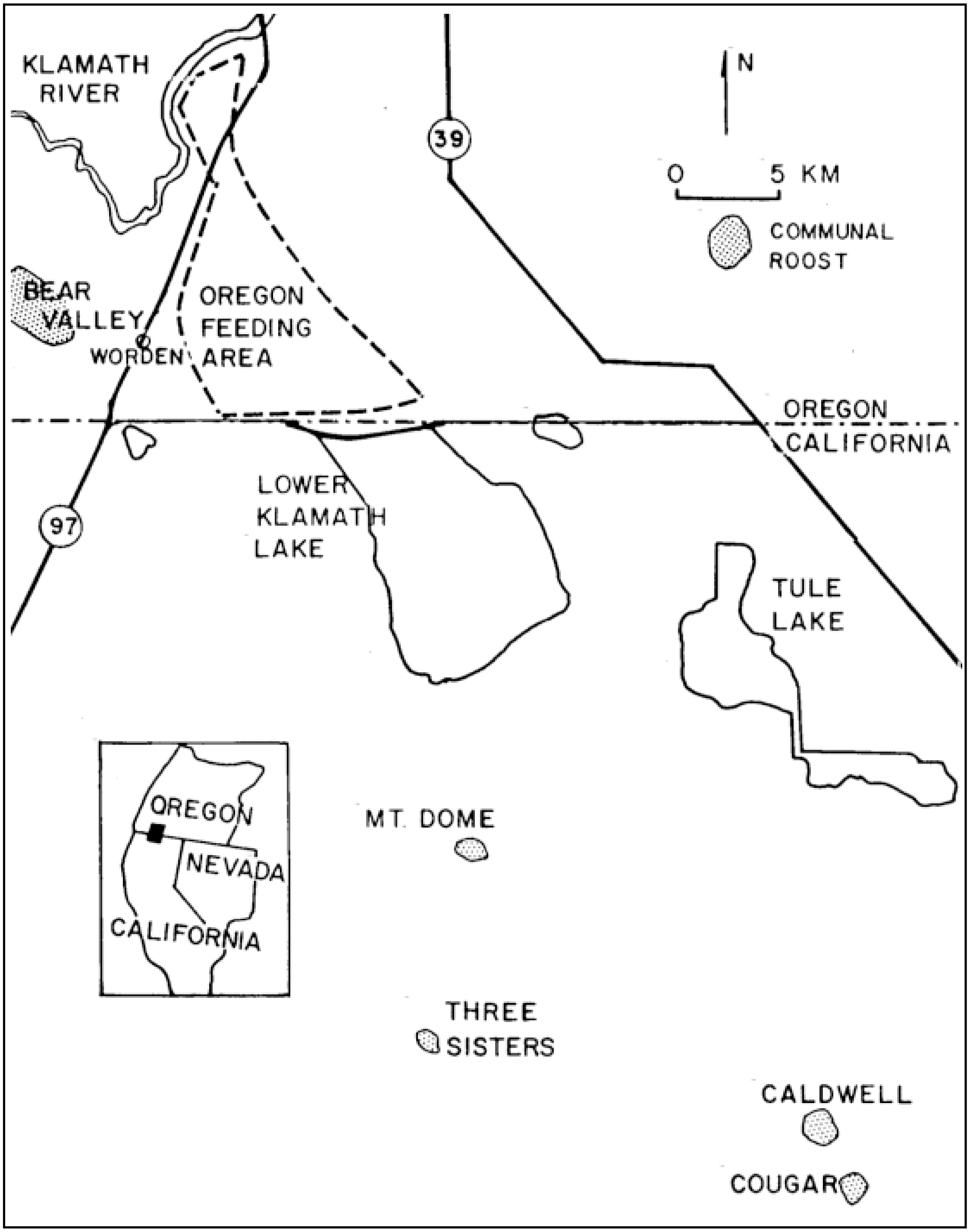

Figure 3. Major bald eagle wintering areas in the Upper Klamath Basin of southern Oregon and northern California. Source: Reprinted with permission from Keister, G.P. and R.G. Anthony. 1983. "Characteristics of bald eagle communal roosts in the Klamath Basin, Oregon and California." Journal of Wildlife Management *47:1072–1079 (© The Wildlife Society).*

greater distance to a roost with a microclimate affording only a slight increase (4 to 7 percent) in nightly energy savings.

Distances between roost sites and foraging areas are highly variable in Oregon. Maximum straight-line distances are as great as 21 km (12.6 miles) in the Crooked River area (Isaacs et al. 1993), 5.6 km (3.4 miles) in the Upper John Day River area (Isaacs et al. 1996), and from 6 to 20 km (3.6 to 12 miles) in the Upper Klamath Basin (Keister et al. 1985).

Food resources

"Winter raptor populations are often food-limited" (Newton 1979, page 80). Consequently, it is not surprising that this view extends to bald eagles (Sherrod et al. 1976; Stalmaster 1981). Hansen et al. (1982, page 57) emphasized the importance of food for bald eagles by stating, "The thread that interconnects virtually all aspects of bald eagle ecology is the bird's relentless pursuit of food." During fall and spring, bald eagles migrate to areas such as the Upper Klamath Basin, where weather conditions generally are milder, and food patches support a large abundance of available prey compared to other areas in the PRR.

There are two ecologically important patterns of bald eagle food distribution across a region: (1) small, but regularly dispersed, predictable units, and (2) large resources (Hansen et al. 1986). Small but predictable food resources include individual fish in a lake, large mammal carrion, and gut piles during a hunting season. Large resources include salmon spawning grounds (Servheen 1975; Stalmaster et al. 1979; McClelland et al. 1982), lakes and waterfowl refuges with high concentrations of wintering waterfowl (Keister 1981; Isaacs and Anthony 1987; Mauser and Thomson 2001), dam sites where fish kills are common (Southern 1963; Steenhof 1976), and areas with abundant large mammal carrion (DellaSala et al. 1989; Isaacs et al. 1993) and small mammals (Platt 1976; Keister et al. 1987; Isaacs et al. 1993).

It seems that the Upper Klamath Basin supports the largest predictable food resource for wintering bald eagles in the PRR, primarily waterfowl.

Relationship between winter eagle numbers and food resources

The abundance of bald eagles at wintering areas is related to the quality, quantity, availability, and predictability of food resources. The correlation between numbers of wintering bald eagles and their prey has been reported by several studies (Servheen 1975; Griffin et al. 1982; Stalmaster and Gessaman 1984; Restani et al. 2000).

In the Upper Skagit River, Washington, the number of eagles varied consistently with abundance of chum salmon (*Oncorhynchus keta*) carcasses. Years with more carcasses had more eagles (Mills 2000).

Hansen et al. (1982) reported that the eagle population in the Chilkat Valley, Alaska, was most closely correlated with salmon abundance; the number of eagles increased with fish abundance until about 1,400 fish carcasses were available. Hansen et al. (1982) suggested that when food abundance was greater than the threshold level, it no longer limited the size of the eagle population in their study area. They also postulated that the downward turn in the relationship at higher levels of fish abundance might be a function of date because the higher fish counts occurred in mid-January, when most eagles had already migrated out of their study area.

There are numerous other examples of a relationship between bald eagle abundance and the availability of food resources across the PRR. Keister et al. (1987) studied the use of communal roosts and foraging areas by bald eagles in the Upper Klamath Basin, Oregon, and concluded that eagle and waterfowl numbers were related. Nonetheless, the highest numbers of eagles were not associated with the highest numbers of waterfowl in a particular year. They further suggested that numbers of waterfowl in the Basin, even during midwinter lows, provided sufficient food for more than 500 eagles.

Additional evidence comes from the Pacific Northwest coast (Hansen et al. 1986), Upper John Day River, Oregon (Isaacs et al. 1996), Crooked River, Oregon (Isaacs et al. 1993), and Harney Basin, Oregon (Isaacs and Anthony 1987).

The common theme among these studies is that eagle abundance varied through time due to the effects of weather on the availability of prey. Specifically, periods with deep snow and/or ice reduced availability of prey. The relationship between food abundance and the size of fall and winter eagle concentrations in Washington state was used to develop an energetics model that accurately predicted population size as a function of food levels and weather conditions (Stalmaster 1983).

Because winter weather conditions affect the availability of prey, it is not surprising that Hansen et al. (1982) emphasized food availability rather than abundance for defining food resources used by bald eagles. Regardless of the abundance of a food resource, its accessibility influences an eagle's ability to successfully forage on it, therefore determining its functional value to a wintering population. For example, an abundance of fish carcasses imbedded in ice along the shoreline of a river is not accessible. Hansen et al. (1982), McClelland et al. (1982), and DellaSala et al. (1989) also described important winter food resources as being predictable from one year to the next.

There is evidence that bald eagles can switch from one food resource to another within the same wintering area. Bald eagles wintering in the Upper Klamath Basin are adapted to switching from one type of prey to another, and they eat at least 25 species of birds, 2 species of mammals, and 1 species of reptile (Frenzel and Anthony 1989). Of the 25 bird species, 22 are waterfowl, representing 94 percent of all prey (Frenzel and Anthony 1989).

Prey switching depends on the timing and availability of the alternative prey species. For example, Keister et al. (1987, page 419) reported, "Several factors determined use of feeding areas by bald eagles (in the Klamath Basin). Season … was the important factor influencing use of the Oregon feeding area as flooding of agricultural fields with use of montane voles (*Microtus montanus*) as prey occurred only during last winter. Waterfowl populations at Lower Klamath Refuge … were most important in predicting eagle use at that location, and ice cover was … most important at Tule Lake."

In its Biological Opinion on effects of the Klamath Reclamation Project on bald eagles, the USFWS used results from Mauser and Thomson's (2001) examination of midwinter counts of bald eagles and waterfowl in the Lower Klamath National Wildlife Refuge (NWR) to identify a predator-prey relationship between these species. As shown in Figure 4, there is a pattern of increasing variance in eagle numbers at high waterfowl numbers (more than 125,000). The USFWS interpreted this pattern as likely evidence of prey swamping, meaning that prey abundance surpasses predator need. Thus, food availability no longer would be a factor in determining predator numbers (Craighead and Craighead 1956; Ricklefs 1983).

In the Biological Opinion (Section III, Part 1, page 23), the USFWS concluded that 125,000 waterfowl represented the level at which prey would not be limited for any number of eagles that historically wintered in the basin. (As many as 958 eagles have been counted on the Lower Klamath NWR in a single day.) USFWS developed a strategy to provide a mix of permanent and seasonal wetland habitats and winter-irrigated small grains sufficient to "provide for the number of eagles that are likely (given historical data) to winter in the Lower Klamath NWR in most years." The USFWS further stated, "However, years of unusually high numbers of eagles above the documented range would increase the bald eagle's need above the threshold."

The pattern of agricultural production as it relates to waterfowl use of the Basin is another poorly understood factor in bald eagle use and distribution in the Basin. Lower Klamath Lake NWR is the most important waterfowl habitat in

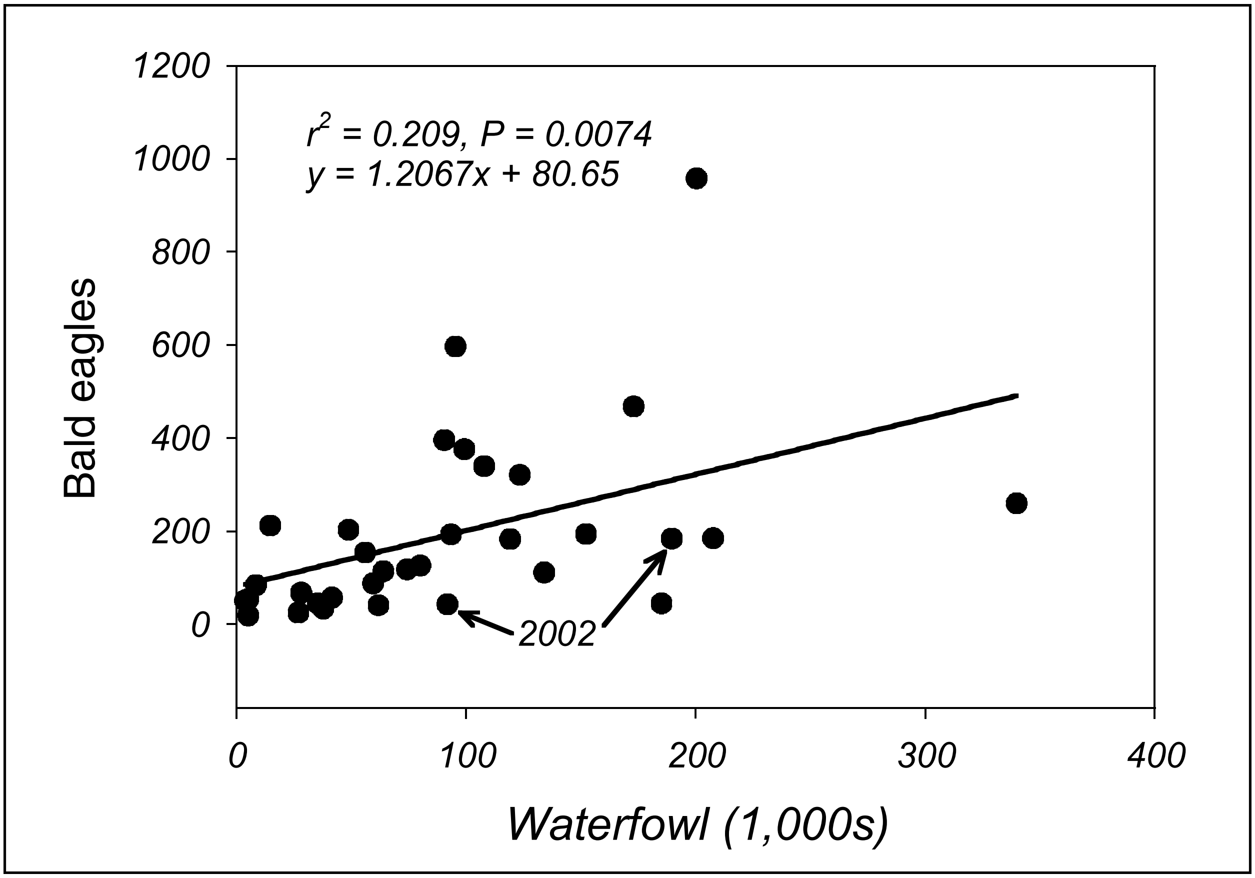

Figure 4. Scatterplot and correlation between numbers of bald eagles and waterfowl in the Lower Klamath NWR. Source: Mauser and Thomson 2001, plus USFWS 2002 winter surveys (http://www.klamathnwr.org/cenfindex.html)

the Basin (see Chapter 16, "Waterfowl"). However, agricultural fields throughout the Upper Klamath Basin, especially wheat and barley, are important food sources for waterfowl.

Effects of human activities on bald eagle foraging and nesting behavior

Responses by eagles to human disturbance have been reported in several studies. DellaSala et al. (1989) found that most bald eagles foraged more than 50 meters (165 feet) from roads in the Willamette Valley, where domestic sheep carrion was the primary food. Marr et al. (1995) postulated that the significant increase in persistence of sheep carcasses located less than 200 meters (660 feet) from a road or house in the Willamette Valley was explained by the fact that these carcasses were unlikely to be used by eagles.

Isaacs et al. (1993) reported that use of large mammal carcasses by bald eagles was affected by distance from human activity. He also found that carcass condition and the likelihood that a feeding eagle would fly from a carcass because of human activity along roads decreased with distance from roads. Stalmaster (1980) and Skagen (1980) reported similar responses by wintering bald eagles to boating activities along rivers in northwest Washington, where salmon carcasses were the primary food.

Human activities also influence the selection of nests within breeding territories (Anthony and Isaacs 1989). Present USFWS guidelines (1981) for managing eagle nesting habitat suggest distances of approximately 100 meters (330 feet) for a primary zone and 200 meters (660 feet) for a secondary zone from the nest tree. No habitat modifications are permitted within the primary zone, but some modifications can occur within the secondary zone during nonbreeding periods. These distances correspond to areas of 3.2 and 12.7 ha (8 and 31.8 acres), respectively.

According to Anthony and Isaacs (1989), these areas are too small, and the guidelines do not provide flexibility for site-specific management. Based on the breeding season (Isaacs et al. 1983), Anthony and Isaacs (1989) recommended that human activities within 800 meters (2,640 feet) of nests be restricted between January 1 and August 31.

Human-related changes are not always negative for bald eagles. For example, a variety of freshwater fish have been introduced to Oregon and California waters, and reservoirs have created habitat for fish and concentration areas for wintering waterfowl. Dam-caused fish fatalities may have made some fish species more available to eagles. Eagles can scavenge the afterbirth and carcasses of livestock (Isaacs et al. 1993). Hunter-crippled waterfowl and other game probably are more available to eagles, and road-killed deer are a significant new food source (Isaacs et al. 1996).

The 2001 federal environmental documentation and decisions

The ESA attempts to bring populations of listed species, such as the bald eagle, to healthy and sustainable levels so that they no longer need special protection. To reach this goal, in addition to prohibiting activities that may harm listed species, the ESA requires federal agencies to use their authority to conserve threatened and endangered species (16 U.S.C. §§ 1531(c), 1526(a)(1)).

Section 7 of the ESA applies exclusively to federal agencies, such as the Bureau of Reclamation (BOR). It requires the listing agency (in this case the USFWS) to prepare a Biological Opinion for listed species that might be affected by a federal action (in this case, the BOR's proposed operation of the Klamath Reclamation Project). The most recent Section 7 consultation process for the Project began on December 18, 1999, when the BOR requested reinitiating consultation with the USFWS regarding the 1992 Biological Opinion.

During this process, the USFWS considered in detail the effects of the Project on the bald eagle. The key issue related to bald eagles was the amount of water expected to be delivered to the national wildlife refuges.

The following information addresses some of the documentation and decisions relating to bald eagles that were developed by the BOR and the USFWS through the Section 7 consultation process. It is important to note the legal imperative for the USFWS to make decisions despite large uncertainties (National Research Council 1995).

The Society of Conservation Biology's statement on "Independent Scientific Review in Natural Resource Management" (Meffe et al. 1998) provides several insightful recommendations for improving the application of independent scientific review to complex environmental policy decisions. Specifically, the USFWS must seek peer review during public comment periods, document reviewers' opinions, and maintain a record of all materials received on listings and recovery plans prepared under the ESA (USFWS-NMFS 1994). However, because the ESA does not require the USFWS to seek peer review of Biological Opinions (USFWS-NMFS 1994), the following review of the 2001 federal environmental documentation and decisions is not required, nor was it requested by the USFWS.

Biological Assessment

Procedural aspects of interagency consultation under Section 7 required the BOR to prepare a Biological Assessment (BA) to identify protected species likely to be affected by the proposed action (operation of the Klamath Reclamation Project). The BA must outline the nature and extent of the Project's impacts on the species (16 U.S.C. § 1536(c)). USFWS then must prepare a Biological Opinion in response to BOR's proposal. The BOR's proposed Operations Plan did not include a plan to provide any minimum amount of water to Lower Klamath NWR. Based on water rights priorities (the refuges have junior rights to the Project), the USFWS concluded that water deliveries to the refuge would be reduced or nonexistent in drought years (such as 2001). In response, the Klamath Falls USFWS office prepared its Biological Opinion.

To determine the full effects of the Project on the bald eagle, the BOR and USFWS must evaluate and determine the magnitude of direct, indirect, and cumulative effects on the species (50 C.F.R. § 402.14(g)(3)).

Direct and indirect effects

According to these regulations, direct effects are Project activities that result in immediate effects on bald eagles. Indirect effects occur later in time. Examples are reduced acreage of wetlands and irrigated crops available for maintaining waterfowl (bald eagle prey) as a result of reduced water allocations.

The 2001 Biological Assessment included a section on the effects of the Project on bald eagles. It described effects on nesting, wintering, and nonbreeding bald eagles (immature, subadults, and adults) in the vicinity of the Project (contained in the Biological Opinion 2001).

In the 2001 Biological Assessment (Biological Opinion 2001, page 60), the BOR stated, "The manipulation of the timing and amount of water available across the landscape of the Upper Klamath Basin (which is largely controlled by the Klamath Project) directly and indirectly affects the survival and recovery of bald eagle populations." It further reported on the status of breeding eagles in the area and stated that "because they are dependent on water bodies for food supply most of these nesting pairs could be affected by the proposed action" (page 61). It continued, "Forage availability is expected to be lower for some time following periods of large draw-downs, and this may in turn result in lower reproductive rates among the resident bald eagles." The assessment concluded, "Impacts to the wintering birds are not just a local impact but a significant regional one."

Cumulative effects

Cumulative effects refer to the additive impacts of state, local, or private actions, unrelated to the Project, on bald eagles (50 C.F.R. § 402.02, 51 Federal Register 19932 (1986)). An ESA cumulative effects analysis begins by determining the total impacts of the Project and its connected activities on a hypothesized resource "cushion." The solicitor general for the USDI defined this resource cushion as "that amount of a particular natural resource like water, air, vegetation or habitat (upon which a given listed species is dependent), that could be utilized or consumed, without jeopardy to the continued existence of the species" (USDI 1982). Thus, the analysis must determine the total amount of human activity and habitat modification that could occur in the Project area before the eagle population would be affected.

The 2001 Biological Assessment (Biological Opinion 2001, Section 9.0, pages 84–89) provided a detailed description of cumulative effects on suckers, including activities such as grazing, forestry, and private water diversions. However, the BOR did not identify cumulative effects relating specifically to the bald eagle.

Biological Opinion

According to the "consultation history" (Section 1.1) in the 2001 Biological Opinion (BiOp), the USFWS has completed nine Section 7 consultations with the BOR that required a decision on the effects of the Klamath Reclamation Project on bald eagles. Five of these were formal consultations, four were reinitiating previous formal consultations, and all resulted in a determination of "no jeopardy to the bald eagle." One was completed in 1991, four in 1992, and one each in 1994, 1995, 1996, and 2001. All of these earlier Biological Opinions were superceded by the 2001 BiOp (Biological Opinion 2001).

Prior to the 2001 BiOp, discussions regarding effects on bald eagles were virtually absent. The 2001 BiOp provides detailed information on the historical and current natural history, status, distribution, and recruitment of bald eagles in the Klamath Basin. It also extends its assessment of impacts of the Project on bald eagles to the PRR, and it compares these effects to the four recovery criteria identified in the Pacific States Bald Eagle Recovery Plan (USFWS 1986, Section 111, Part 1, page 29). This detailed information appears for three reasons.

First, the BOR's 2001 Biological Assessment contained an incomplete description of specific Project operations and how such operations might affect the bald eagle. This omission established footing for the USFWS to examine, as well as determine, the magnitude of the full effects of the Project on this species (50 C.F.R. § 402.14(g)(3)).

Second, new information on the number, distribution, and productivity of nesting bald eagles in the Upper Klamath Basin and across the PRR indicated an increase in the breeding and wintering populations. There are 117 nesting pairs of bald eagles in the Basin, and many of their territories overlap the Klamath Reclamation Project.

Finally, the USFWS needed to consider the effects of the Project on the proposed delisting (USDI 1999). The Recovery Plan specifies that, before delisting, "wintering populations greater than 100 individuals should be stable or increasing" (USFWS 1986).

The Upper Klamath Basin supports the largest population of wintering bald eagles outside of Alaska, ranging from 200 to 1,100 eagles during a single survey day. Eagles are known to travel from Alaska, Montana, Washington, and southern California to take advantage of winter forage, communal roosts, and the relatively mild climate in the Basin. In the Biological Opinion (Section III, Part 1, page 8), the USFWS states, "The combination of abundant food and roosting habitat is so unusual and important that its protection was cited as the reason the Bear Valley National Wildlife Refuge was established in 1978. Bear Valley NWR is one of the few refuges or sanctuaries of its kind in the United States."

Effects on nesting bald eagles

The USFWS concluded that the type and intensity of impairment and injury of nesting bald eagles likely to result from the BOR's proposed operation of the Project would be broad. These impacts were based on the proposed lake level in Upper Klamath Lake and the likely distribution of water within the Lower Klamath and Tule Lake NWRs.

Furthermore, "likely effects range from temporary periods of hunger and increased energy expenditure for less concentrated or lower quality food, increased exposure to injury risks at food sources, increased exposure to inclement weather and lowered fat reserves, to the more extreme forms of reduced fitness during breeding initiation, and death through starvation or injury" (Biological Opinion 2001, Section III, Part 1, page 31).

However, the 117 nesting pairs in the Upper Klamath Basin represent a relatively small percentage of the total nesting pairs (1,480) in the PRR. This fact is emphasized in the 2001 BiOp (Section III, Part 1, page 29). It stated, "The effects of the proposed action would likely reduce nesting success of some or all 117 pairs that currently use the Klamath Basin …[given] the . . . number of nests [in the Upper Klamath Basin] as compared to the estimate of 800 [in the PRR] needed to recover the species, the reduction in nesting success of bald eagles is not likely significant." In other words, even if all nests in the Basin were affected by the proposed action, more than enough nests occur outside the Basin to meet the recovery goal of 800 nests for the PRR. Thus, although some or many of the eagles nesting in the Basin might be affected by operation of the Project, those effects would not substantially affect the bald eagle recovery goals for the PRR.

Effects on wintering populations

In the 2001 Biological Opinion (Section III, Part 1, page 32), the USFWS stated, "Given the historical range of numbers of eagles that winter on Lower Klamath NWR, the Service anticipates up to 950 eagles could be incidentally taken [adversely affected], mainly through reduced access to food, per year as a result of the proposed action when water delivery from all sources to the Lower Klamath NWR is below 32,255 acre-feet." Thus, based on the record high eagle count for a single day, the USFWS BiOp stated that water operations proposed in the BA might adversely affect as many as 950 eagles.

The basis for these conclusions

In the 2001 Biological Opinion, the USFWS based its effects analysis on two factors: (1) a required waterfowl threshold based on the relationship between bald eagle and waterfowl numbers (Mauser and Thomson 2001), and (2) a derived minimum water delivery (DMWD) to provide waterfowl habitat necessary to sustain the waterfowl threshold (Biological Opinion 2001). In other words, USFWS estimated the number of waterfowl needed to sustain a certain population of bald eagles and then estimated the amount of water needed to maintain habitat for that population of waterfowl. The BiOp required the BOR to supply that amount of water to the refuges *if* water was available after meeting the lake elevation and river flow requirements for suckers and coho, respectively.

These two analyses contain uncertainties, but they satisfy the ESA directive to the USFWS, BOR, and Secretary of the Interior to use the "best scientific and commercial information data available" (16 U.S.C. § 1536(a)(2)). Decision-making in this context not only requires careful evaluation of existing data, but also entails consideration of major scientific uncertainties (National Research Council 1995).

Analysis of the 2001 Biological Opinion

In the following paragraphs, we evaluate the major scientific uncertainties faced by the USFWS during the Section 7 consultation process. We consider the type of data and analysis used by Mauser and Thomson (2001) to estimate bald eagle populations in the Basin, and we provide additional analyses and an alternative interpretation of Mauser and Thomson's (2001) data.

Eagle population estimates

In order to determine the number of waterfowl needed to support a given bald eagle population, one first must estimate the bald eagle population. The 2001 Biological Opinion relies on analyses by Mauser and Thomson (2001), which made use of existing available data sets to estimate the wintering population size in the Upper Klamath Basin. They found a daily average population of 195 bald eagles in the Lower Klamath NWR.

The midwinter aerial survey data used by Mauser and Thomson (2001) were collected using a method similar to that recommended in the 1984 guidelines established by the National Wildlife Federation (Knight et al. 1981; Steenhof et al. 2001). Unlike the NWF guidelines, however, their data included multiple counts each January.

These data sets contained problems (resulting from the way the data were collected) that could not be corrected during analysis. We recognize four concerns with the eagle count data used by Mauser and Thomson (2001) that might result in underestimates of the wintering population size. An underestimate of the wintering bald eagle population would mean that a larger, but unknown, number of eagles might be affected by the water allocation decisions.

First, Mauser and Thomson's data represent a sample of midwinter counts collected using a single method (aerial flights), which were intended to provide an index to winter eagle numbers in the Basin. While using a single method reduces variability in the data that might be caused by differences in observers and methods, Anthony et al. (1999) and Isaacs et al. (1993) reported that single-method counts resulted in variable and negative bias (underestimates) compared to the double-survey method (simultaneous aerial and ground surveys).

Double surveys always include bald eagles that are seen from the ground but not observed from the air, and vice versa. Subadult eagles and those that are flying or perched at locations other than on the ground or on fence posts often are missed during aerial surveys (Isaacs et al. 1983).

The level of negative bias in bald eagle counts in the Upper Klamath Basin is unknown. The even terrain and low vegetation cover on the Lower Klamath NWR enhance visibility of bald eagles and should reduce the number of uncounted eagles.

Second, Mauser and Thomson's (2001) surveys generally were conducted in early January. Consequently, they may not reflect the time when eagle numbers are at their peak in the Basin. The "highest estimates of the population … [occurred] during the second week in January and the first week of February" in the Basin (Keister et al. 1987, page 416).

Mauser and Thomson (2001) used early January data because it represented the last period for which waterfowl populations were made up entirely of birds remaining from the fall migration. Waterfowl numbers observed later likely would be augmented by some early northbound migrants.

Third, the survey data used by Mauser and Thomson (2001) seem to have been considered in the 2001 Biological Assessment and the 2001 Biological Opinion as total numbers of individual eagles wintering in Lower Klamath NWR. However, many of Mauser and Thomson's (2001) counts were from a single survey conducted during January, resulting in an inability to determine the number of unique individuals in the survey area. For instance, counts of unmarked eagles during a single winter day, as used by Mauser and Thomson (2001), preclude obtaining an estimate of the number of individual bald eagles present throughout the winter.

Young (1983) observed movements of radio-tagged bald eagles at American Falls Reservoir, Idaho, and estimated that as many as five times the maximum daily count of bald eagles may have used the area for periods ranging from 1 day to all winter. The proportion of the wintering bald eagle population on the Lower Klamath NWR that is counted at any one time is unknown, but the total population during an average winter is likely to be much greater than the estimated 958 (the maximum number counted on the refuge on a single day).

Finally, Mauser and Thomson's (2001) data set consists of single counts during some years, which prevent measuring the repeatability (precision) and bias in the data. To calculate an estimate of mean bald eagle abundance and a measure of precision for each estimate (i.e., standard error or confidence limits), at least three counts should be conducted within each period of interest, in this case, midwinter. Without a measure of precision, it is unclear whether or not the counts differed from 1 year to the next.

We propose three alternatives for identifying the current wintering bald eagle population size. The population size then can be used to determine the minimum waterfowl numbers and associated water requirements.

The first alternative stems from Congress' instruction to the USFWS to provide the "benefit of the doubt" to the listed species when formulating its Biological Opinion (Connor v. Burford, 848 F.2d 1441-1454 (Ninth Cir. 1988)). When there is uncertainty, as exists in any complex ecosystem such as the Upper Klamath Basin, this instruction suggests that the USFWS might select upper confidence limits. In this case, such an approach would lead to an upper-level estimate of the number of bald eagles wintering on Lower Klamath NWR. Using this approach, the size of the wintering population during an average year can be estimated by adding the mean number (195) of eagles from Mauser and Thomson's (2001) data to the standard error of the mean (SE)(36) = 231 bald eagles.

The second method is more subjective and is based on the Recovery Plan. According to the Recovery Plan, "Wintering populations greater than 100 individuals should be stable or increasing" before delisting of the bald eagle can occur (USFWS 1986). This approach suggests that operation of the Klamath Reclamation Project should not result in impacts to eagles that might lead to destabilizing or reducing the eagle population currently wintering on the Lower Klamath NWR.

Because the eagle population has continued to increase over the years, and as many as 958 eagles wintered on the refuge in 1992, it is reasonable to suspect that the population can exceed 958 when environmental conditions and prey abundance are optimal. Therefore, a wintering population size of at least 958 is plausible. The peak 1992 count followed the 1991 drought, during which waterfowl winter habitat likely was reduced throughout much of the Pacific Flyway. The result was a relatively high number of waterfowl concentrated on the Lower Klamath NWR, which may have made bald eagles easier to count because they were more concentrated.

The third way to identify the size of the wintering bald eagle population requires a differentiation between daily and overall winter population sizes. Mauser and Thomson's (2001) count data were daily counts in early January, representing the daily population size in the Lower Klamath NWR. However, individual eagles arrive in the Upper Klamath Basin, while others depart, throughout the winter.

In a study of marked individuals, maximum daily counts represented only 20 percent of the daily and wintering estimates because of continued arrivals of individuals (Young 1983). Thus, many more eagles may use the Lower Klamath NWR than the maximum observed in any one day.

If the pattern reported by Young (1983) is used for identifying the average size of the wintering population in the Lower Klamath NWR, the number would be 975 eagles (5 x 195, the daily average reported by Mauser and Thomson). This may represent the average size of the wintering population during the period when the data were collected, but the current size of the wintering population in the Lower Klamath NWR is likely to be larger.

Additional evidence that the overall winter population size may exceed the peak number counted in a single day is provided by Driscoll et al. (1999) and Harmata et al. (1999). They suggested that migration from adjacent regional populations may account for increasing populations in some areas. Furthermore, Keister (1981) reported increasing numbers of eagles in the Upper Klamath Basin during his study and proposed that the increase was due to: "(1) the loss of wintering habitat elsewhere, with major shifts in use to the Klamath Basin, and (2) the increase of western bald eagle populations."

Relationship of bald eagle populations to number of waterfowl

In addition to problems with the data itself, we suggest that there are problems with Mauser and Thomson's (2001) analysis of the relationship between bald eagle populations and waterfowl numbers. Their analysis does not take into account the effects of time, weather, increasing bald eagle populations, or prevalence of waterfowl disease. These factors may explain some of the variation they detected at waterfowl numbers greater than 125,000. We provide two alternative interpretations for the pattern of increasing variation in the data.

First, the number of breeding pairs in the PRR has consistently increased since 1986. It exceeded 800 beginning in 1990 and has continued to do so over the past decade (USDI 1999). In 1998, there were 1,480 pairs in the PRR (USDI 1999). Because the U.S. bald eagle population essentially doubles every 7 to 8 years (USDI 1999), the high counts used by Mauser and Thomson (2001) may not be related to waterfowl numbers, but may represent a growing population across the Northwest.

Second, the increased variation (trapezoidal shape) in bald eagle numbers with increasing numbers of waterfowl is inherent in many biological data sets (Neter et al. 1989). It may simply represent naturally increasing variation in eagle numbers corresponding to greater numbers of waterfowl. For example, large numbers of waterfowl move in and out of the KBMZ during the winter in response to freezing and thawing of lakes and wetlands. Bald eagle movements in response to these changes in waterfowl numbers may result in periods when eagle numbers are low and waterfowl numbers are high and vice versa.

We reanalyzed Mauser and Thomson's (2001) data to determine whether factors such as variation among years (time) and population levels could further explain variation in the data (Burnham and Anderson 1998). We fitted nine separate simple linear regression models to the data, each of which represented an alternative hypothesis relating winter eagle numbers to waterfowl numbers (Table 1). The piecewise regression model chosen by Mauser and Thomson (2001) with an asymptote (change from an increasing slope to a flat line) at 125,000 waterfowl was included as one of the nine models.

Table 1. Nine models, associated hypotheses, and fit statistics from simple linear regression analyses[a] carried out on Mauser and Thomson's (2001) bald eagle and waterfowl count data used in the 2001 Biological Opinion.

Model	Hypothesis	No. of parameters	AICc[b]	DAICc[c]
lwaterfowl	Eagle numbers vary as a loge function of waterfowl numbers (threshold)	3	415.2	0.0000
waterfowl	Eagle numbers vary as a linear function of waterfowl numbers	3	415.3	0.0773
ldate lwaterfowl	Eagle numbers vary as a loge function of waterfowl numbers through a loge time trend (threshold with additive effects of waterfowl and year)	4	417.6	2.3480
date lwaterfowl	Eagle numbers vary as a loge function of waterfowl numbers through a linear time trend (threshold with waterfowl with linear year effects)	4	417.8	2.5508
date waterfowl	Eagle numbers vary as a linear function of waterfowl numbers through a linear time trend (threshold with effects of waterfowl and linear year effects)	4	417.9	2.6492
ldate	Eagle numbers vary as a loge function of time (threshold)	3	420.1	4.8233
piecewise[d]	Eagle numbers vary as a piecewise function with waterfowl numbers, having two linear slopes changing at a known number of waterfowl (piecewise regression chosen by Mauser and Thomson (2001), which assumes eagle numbers change linearly at 125,000 waterfowl)	3	420.6	5.3711
date	Eagle numbers related linearly to time trend (time trend)	3	420.8	5.5902
date2	Eagle numbers vary through time (time effects)	19	499.2	83.9759

[a]Regression analysis carried out using SAS, version 8 (1999).

[b]Akaike's Information Criterion. Lower values indicate better fitting models (Burnham and Anderson 1998).

[c]Change in AIC. A change ≥2 represents strong support that the preceding model is a better fit of the data (Burnham and Anderson 1998).

[d]Regression model consisting of two pieces (Neter et al. 1989) with the slope changing at 125,000 waterfowl (Mauser and Thomson's model).

We then used the information theoretic approach (Akaike's Information Criterion, or AIC) to select the model that "best" fit the data (Burnham and Anderson 1998).[1] This analysis resulted in two models fitting the data best (competing AIC-values). These models hypothesized that eagle numbers vary as a linear and natural log function of waterfowl numbers (Table 1). In other words, increasing waterfowl numbers would result in increasing bald eagle numbers regardless of the size of the waterfowl population.

Because both models have the same number of parameters and fit the data equally, there is no basis for selecting one over the other. Nonetheless, this analysis provides evidence that the original linear regression model used by Mauser and Thomson (Figure 4) fits the data better than their piecewise regression model used in the 2001 Biological Opinion.

The point of this analysis is to provide additional insight into the influence of time, as well as the type of relationship between numbers of eagles and waterfowl. It seems that the increase in eagle population levels over time do not contribute greatly to variation in the data.

A straight-line relationship, based on all 31 observations, is "best" for representing the data. This result suggests that, although variation in eagle numbers increases with increasing waterfowl numbers, the variation is not sufficient to warrant a change in the slope of the relationship at 125,000 waterfowl. Thus, the straight-line model seems to be most appropriate for representing a relationship between bald eagle and waterfowl numbers in the Lower Klamath NWR.

However, it should be emphasized that neither the relationship proposed by Mauser and Thomson (2001) nor the best-fitting model that we identified is very strong. Both of these models provide only a qualitative tool for suggesting how bald eagle numbers may change as a result of changes in waterfowl numbers.

Implications for the Biological Opinion

Our three alternatives for estimating wintering bald eagle population size reveal the uncertainty in estimating the size of the wintering bald eagle population in the Lower Klamath NWR. As a result, the USFWS faced a challenge in anticipating whether implementation of the Klamath Reclamation Project would result in incidental take of (harm to) bald eagles.

Furthermore, our three alternatives, as well as the analysis used in the 2001 Biological Opinion, examined Mauser and Thomson's (2001) data, which are only for the Lower Klamath NWR. These analyses did not take into account the total number of bald eagles throughout the area affected by the Project.

The ecology of bald eagles in the Upper Klamath Basin is complex. Eagles use a large area (approximately 1,600 km^2, or 640 square miles) with variable use of three foraging areas and five communal roosts on a weekly basis (Keister et al. 1987). "Therefore, management will have to focus on the entire basin, regardless of state or federal boundaries.…" (Keister et al. 1987).

The USFWS considered take throughout the Upper Klamath Basin by stating, "The maximum amount of take would be equal to the peak number of eagles using the Klamath Basin and winter roosts during that year" (Section III, Part 1, page 32). If the bald eagle population is underestimated, the USFWS's anticipated amount of take (950 eagles) given the implementation of the Project (Section 6.1 in Section III, Part 1, page 32) would fall short of the total number of bald eagles that might be adversely affected by the Project.

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[1]The best-fitting model balances model bias with the amount of variation that is explained by the model. This approach is considered superior to traditional statistical analyses using p-values, and it is widely used in the field of wildlife ecology (Burnham and Anderson 1998). To prevent problems in interpretation, the response variable (eagles) was not transformed to correct the lack of constant variance because we transformed the explanatory variable (waterfowl) using the natural log transformation to test for a pseudothreshold.

Finally, if the relationship between eagle and waterfowl numbers is a straight line, there is no basis for selecting a minimum number of waterfowl to support a wintering population of bald eagles in the Lower Klamath NWR. This represents a major scientific uncertainty in the data.

Effects of the 2001 federal decisions on bald eagles

The federal water management decisions on the Klamath Reclamation Project in 2001 had the potential to affect both breeding and wintering populations of bald eagles. Bald eagles potentially could be affected by changes in the distribution, abundance, and availability of prey.

Irrigation curtailment caused by the requirement to maintain minimum lake levels in Upper Klamath Lake (for suckers) and minimum flows over Iron Gate Dam (for coho salmon) reduced grain production, a source of waterfowl food. On the other hand, to maintain prey for bald eagles, the USFWS Biological Opinion required some water deliveries to Lower Klamath NWR to maintain waterfowl habitat, although the acreage of marshes and flooded grain fields was less than in previous years. Water delivery began in August, and, in all, the refuge received about 30 percent of normal water delivers between January and October 2001. In November, precipitation, water removal from Sump 1A at Tule Lake NWR, and continued deliveries through the ADY Canal recharged seasonal wetlands.

The changes in water distribution within the Upper Klamath Basin did not result in changes in the population of breeding bald eagles. The number of nesting pairs increased to 120 in 2001 (Figure 5), a trend consistent with the previous 25 years of data. Furthermore, nest success was 66 percent in 2001, suggesting that forage resources were adequate to maintain productivity at levels desired by the bald eagle recovery plan (USFWS 1986).

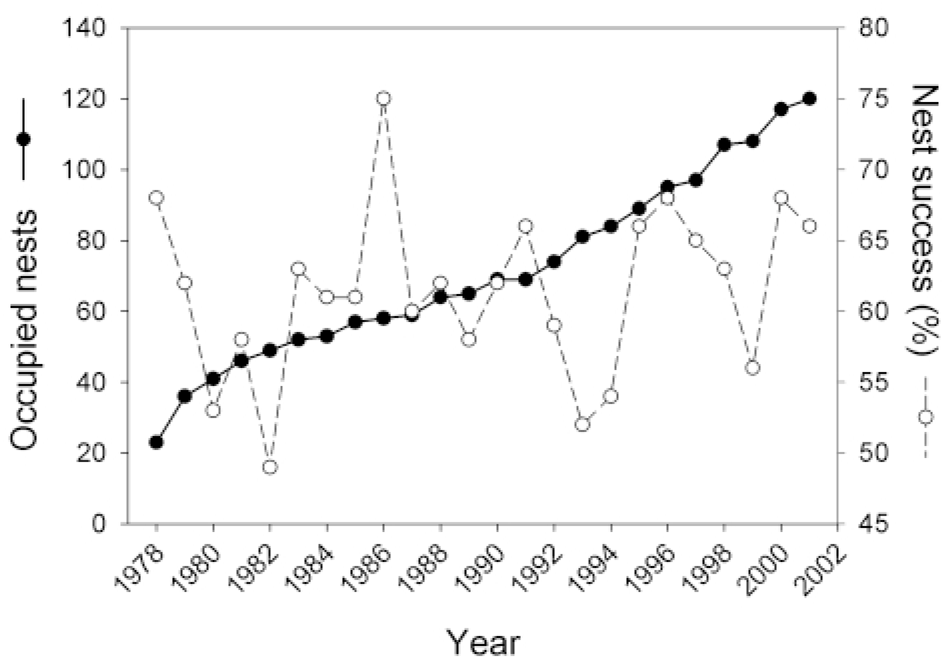

Figure 5. Number of occupied bald eagle nests and nest success by year in the Upper Klamath Basin, 1978–2001. Source: Data courtesy of Robert Anthony and Frank Isaacs, Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University

Changes in water allocations in 2001 also did not seem to affect the winter bald eagle population in 2002. Although waterfowl populations during the fall migration were substantially lower than in normal years (see Chapter 16, "Waterfowl"), fall and early-winter precipitation and availability of irrigation water recharged most waterfowl habitats in the Upper Klamath Basin by January 2002. Consequently, January 2002 waterfowl and bald eagle counts were within the normal range of variation in previous years' counts. Thus, these short-term changes in water distribution and abundance resulted in no measurable impact on bald eagle populations.

Data gaps

There are numerous gaps in our knowledge of bald eagles across the PRR and in the Upper Klamath Basin. Data gaps exist regarding the:

- Current breeding population size across the PRR
- Current wintering population size across the PRR
- Number of individuals that use the Basin or Lower Klamath NWR during winter
- Importance of the Basin to bald eagles across the PRR
- Changes in the spatial distribution of all age classes across the Basin, southern Oregon, northern California, and the entire PRR that occur when winter prey is unavailable at traditional foraging areas
- Importance of Lower Klamath NWR winter habitat to juveniles, subadults, nonbreeding adults, and breeding adults in the Basin, southern Oregon, northern California, and the entire PRR
- Importance of winter habitat and prey conditions in the Lower Klamath NWR to productivity of eagles that winter in the Basin, but nest elsewhere
- Survival of all age classes under all water management and regional water conditions

Future needs

We prepared the following list of future needs to help direct monitoring efforts and future research toward answering questions asked by the biologists who must make regulatory and management decisions for bald eagles.

- Continue nesting surveys to document the size and distribution of the nesting population under all conditions, including the California portion of Recovery Zone 22.
- Conduct satellite telemetry to determine movements of eagles nesting and wintering in the Upper Klamath Basin, including following residents from nestling to maturity.
- Continue monitoring population size and distribution in the Basin in winter.
- Initiate studies of feeding habits of wintering eagles during years of high and low winter waterfowl abundance on refuges.
- Investigate the relationships among wintering bald eagles, waterfowl, and agricultural food sources in the Basin.
- Investigate the relationship between water level and bald eagle nesting success at Upper Klamath Lake.
- Analyze the complete bald eagle and waterfowl count data recorded from December through February each year by the Lower Klamath NWR.

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16

Waterfowl

Effects on Waterfowl
of the 2001 Water Allocation Decisions

Robert L. Jarvis

Because of its location and extensive wetlands, the Upper Klamath Basin is a major staging area for waterfowl migrating to and from wintering areas farther south in California and Mexico. This area includes the connected Lost River–Klamath River watersheds above Iron Gate Dam. It has been estimated that 75 to 80 percent of the waterfowl in the Pacific Flyway pass through the Basin (Laycock 1973). The Basin probably contains the single largest concentration of waterfowl in North America, with upwards of 5.8 million waterfowl counted during a single day (1958). Currently, fall migrant populations peak at about 1 to 2 million, with about half that many during spring migration.

The most important areas for fall migrants are Tule Lake and Lower Klamath national wildlife refuges (NWR), with 55 to 60 percent of the birds using these two areas. Upper Klamath Lake has about one-third of the birds in the fall but only 15 percent in the spring. Spring migrants are more widely distributed because temporary wetlands that are dry in the fall usually contain water in the spring.

Historical background

The Upper Klamath Basin has been extensively altered during the past 150 years, and understanding those changes is essential to understanding the response of waterfowl to water management during the 2000–2001 drought.

Prior to European-American settlement and agricultural development, the Basin contained large complexes of wetlands associated with streams and lakes. In the southeastern portion of the Basin, the Lost River followed a circuitous route from Clear Lake to Tule Lake, a marsh-fringed lake with a surface area that fluctuated between 50,000 and 110,000 acres (Abney 1964). During major flood events, the Klamath River overflowed through Lost River Slough into the Lost River and hence to Tule Lake. High water during normal spring runoff annually recharged wetlands throughout much of the course of the Lost River.

Subsequent agricultural development consisted of suppressing the recharging of wetlands and the inflow to Tule Lake by retaining water in Clear Lake Reservoir and by diverting excess Lost River runoff to the Klamath River via the Lost River Diversion Channel. During the summer, water is diverted from Lost River to irrigate cropland in the upper Lost River Valley through a network of canals. In most years, water is diverted from Upper Klamath Lake and the Klamath River to irrigate lands in the lower Lost River Valley and in the dry Tule Lake bed. Tule Lake now consists of two sumps (water-storage depressions) totaling about 13,000 acres. Inflows to the Tule Lake sumps now come from the Lost River and as return flows from lands in the Tulelake Irrigation District. (Return flows are applied irrigation water that is unused by crops and is recaptured in canals for reapplication elsewhere.)

In the southwestern portion of the Basin, the 80,000-acre marshy Lower Klamath Lake originally exchanged water with the Klamath River through Klamath Straits (Weddell 2000). A railroad grade was constructed, which blocked the flow from the river to Lower Klamath Lake, thus converting much of the land in the Lower Klamath Lake area to agricultural use. The Klamath Straits Drain was created to remove excess water in the spring from Lower Klamath and Tule Lake agricultural lands. The ADY canal and related canal systems were constructed to move Klamath River water for irrigation of these lands.

The remnants of Lower Klamath Lake currently consist of diked marsh, crop, and upland units normally comprising about 22,000 acres of wetlands in the Lower Klamath NWR. The principal source of water for Lower Klamath NWR is now from the Tule Lake Sumps via the D Plant, which pumps water from Tule Lake through the Tule Lake Tunnel under Sheepy Ridge. The ADY canal is a secondary source of water from the Klamath River.

In the northern portion of the Basin, construction of the Link River Dam and breaching of the reef at Klamath Falls were done to facilitate delivery of irrigation water from Upper Klamath Lake to the lower Lost River Valley and Tule Lake (USFWS 2001). About 40,000 acres of wetlands surrounding Upper Klamath Lake were diked off, drained, and converted to agricultural use (USFWS 2001). Some of these areas now are being reconverted to wetlands.

Overall, well over half of the wetlands in the Upper Klamath Basin have been drained. Most of the remnant wetlands are in public ownership. Intensive management on some public wetlands is aimed at increasing wetland foods for migrant waterfowl.

These changes have meant much less wetland habitat for waterfowl, but abundant food for species adapted to field feeding on small grains (i.e., dabbling ducks and geese). Other species, such as diving ducks, have not fared as well, as is the case throughout North America.

Waterfowl biology

There are 28 species of waterfowl that commonly migrate through and breed in the Upper Klamath Basin. While each species has unique characteristics and habitat requirements, they can be divided into four groups: dabbling ducks, two groups of diving ducks, and geese.

Dabbling ducks are the most common, making up 55 percent (spring) to 75 percent (fall) of the ducks using the Upper Klamath Basin. They are the most adaptable waterfowl and inhabit the broadest array of wetland habitats (Baldasarre and Bolen 1994). Dabbling ducks readily adjust their migration routes in response to local and regional wetland habitat conditions.

Some dabbling ducks, such as mallards and pintails, readily feed in dry, harvested croplands. Others (gadwall, wigeon, and green-winged teal) occasionally feed in croplands, especially when they are flooded with a few inches of water. Still others (shovelers and cinnamon teal) feed exclusively in wetlands.

Diving ducks are much less common than dabbling ducks, and they have more specific habitat requirements. They show less flexibility in adjusting migration routes, but do demonstrate shifts in response to long-term changes in habitat availability. Some diving ducks (for instance, redheads and canvasbacks) require marshes with extensive emergent and submergent vegetation; they do not feed in dry cropland and only rarely in flooded cropland.

The other group of diving ducks using the Upper Klamath Basin (mergansers, goldeneyes, ruddy ducks, etc.) use deeper water lakes and streams.

Four species of geese, representing many distinct population units, migrate through the Basin. One species also breeds in the Basin. Geese maintain very traditional migration routes and rarely make permanent changes in migration routes or wintering areas. Geese are the most terrestrial waterfowl and readily feed in dry cropland.

Migration

In the fall, waterfowl migrate to wintering grounds. In the spring, they return to breeding grounds. The term "staging" is used to describe the biology of waterfowl at migration stopover points. During staging, birds regain the reserves used to get to the stopover area (Baldasarre and Bolen 1994).

In the fall, birds are mostly recovering from energy expenditures, and young birds also are completing their growth. Food usually is fairly abundant, especially when augmented by cropland, but wetlands are at their lowest point in the annual cycle. Consequently, birds concentrate in large numbers on available wetlands.

In the spring, birds are storing large energy reserves for migration and reproduction, and they often have specialized nutritional needs not present in the fall. More wetland habitat is available in spring, so birds are more widely dispersed at that time.

Fall migration peaks in September and October in the Upper Klamath Basin. Spring migration peaks occur in March and April.

Breeding

Breeding waterfowl have three major needs, which are fulfilled by specific habitats (Baldasarre and Bolen 1994). The first need is nutrition; extra energy is required for reproduction and specific nutritional needs. Females lay down fat stores prior to egg laying, so they need diets high in carbohydrates and/or lipids. During egg laying, dietary protein for egg production becomes a priority.

Some species change their diet and foraging habitat at this time. Seed-eating dabbling ducks first seek out wetlands with high seed productivity and then move to temporary wetlands with abundant invertebrates. Diving ducks and some dabbling ducks seek wetlands containing invertebrate species with a high lipid content. Newly sprouting grasses provide a high-carbohydrate, high-protein, low-fiber food for geese.

The second need is for secure nesting sites. Dabbling ducks conceal their nests in upland vegetation. Thus, interspersed wetlands and upland nesting cover are important for their reproduction. For many species, grasslike vegetation remaining from the previous year is a key to successful reproduction.

Most diving ducks build overwater nests in robust wetland vegetation; hence, they need semipermanent wetlands. Geese nest on elevated structures, usually over water. Such sites give geese the ability to repel predators, especially mammals.

The third habitat needed for successful reproduction is brood habitat. Young waterfowl need security and nutrition. Seasonal and semipermanent wetlands generally are the most productive of the plant and animal foods needed by broods. All waterfowl use water, sometimes combined with emergent vegetation, to provide security for young from predators.

Each species of waterfowl has specific needs and unique ways of satisfying them within these broad patterns. Hence, the most productive habitats usually are complexes of a variety of wetland types and sizes interspersed among uplands with abundant grasslike vegetation (those with an untended, weedy appearance). Lower Klamath NWR is managed to produce just such a habitat complex and is highly productive of a variety of waterfowl and other wetland species. In contrast, Tule Lake NWR, consisting of two large, permanent wetlands and a large block of cropland, is much less productive and has fewer breeding species of water birds.

Molting

During mid- to late summer, waterfowl molt their flight feathers, thus becoming flightless for at least 3 weeks while they regrow a new set of wing feathers (Gill 1994). Geese are flightless while raising their young during midsummer in the Upper Klamath Basin. Male ducks desert their mates at the beginning of incubation; they then gather together and move to large, emergent marshes to undergo the wing molt in midsummer (Baldasarre and Bolen 1994). Females do not molt until their young are raised, usually sometime later in the summer.

Emergent marshes with abundant aquatic food and dense emergent vegetation are critical to successful completion of the molting stage. Marshes in the Upper Klamath Basin are used extensively by molting ducks, including females that breed as far away as central California (Yarris et al. 1994).

Waterfowl habitat in the Upper Klamath Basin

There are three major habitat units for waterfowl in the Upper Klamath Basin: Tule Lake NWR, Lower Klamath NWR, and Upper Klamath Lake. In addition, there are several secondary and many minor units.

Wetland habitat is more abundant in the Basin in the spring than in the fall because of the moisture provided by winter storms. This is especially true of the shallow, temporary wetlands that are most productive of high-value waterfowl foods. Waterfowl take advantage of the many temporary wetlands that appear throughout the Basin in the spring. Hence, waterfowl tend to be more widely distributed in the spring than in the fall, but Tule Lake and Lower Klamath NWRs still receive more usage than any other area.

Tule Lake NWR

Formerly, the most important unit in the Basin was Tule Lake NWR. The refuge consists of two large marsh sumps (remnants of the former Tule Lake) surrounded by cropland, which is managed in part to provide food for migrant waterfowl.

Traditionally, the sumps have been maintained over a narrow range of water levels (about 6 inches). This nearly constant water level has resulted in a decline in productivity of the sumps for waterfowl, and use for migration and breeding has declined substantially over the past 50 years. Currently, the sumps serve as little more than resting areas for terrestrial-feeding species. A renovation program involving the sumps and croplands is in the planning and experimental stage; it includes about 640 acres of experimental seasonal wetlands.

Refuge lands leased to private farmers are irrigated in the summer. Most crops are harvested, but a portion is left unharvested to provide food for migrant waterfowl. Fields are left untilled during fall and winter so waterfowl can feed on grains spilled during harvest.

The primary use of Tule Lake NWR in both fall and spring is by geese and several species of dabbling ducks, principally mallards and pintails. These waterfowl forage in harvested crops and rest on the large, permanent marsh sumps. The sumps also serve as migration habitat for diving ducks, especially canvasbacks.

Lower Klamath NWR

As use of Tule Lake NWR has decreased over the past decades, use of Lower Klamath NWR has increased. This refuge now hosts more migrants and breeding birds than Tule Lake NWR. It has the greatest abundance and diversity of migrant waterfowl and other water birds. It also has substantial populations of breeding aquatic birds, including waterfowl.

Lower Klamath NWR consists of about 22,000 acres of wetlands (some permanent and some seasonal), as well as uplands and croplands managed for migrant and breeding waterfowl and associated wildlife. Seasonal marshes are flooded in fall and allowed to dry in spring and early summer. This moist-soil management practice provides an abundance and variety of plant and insect foods for various species of fall migrant waterfowl. Drying during the summer eliminates conditions favorable for disease outbreaks.

Maintenance of permanent wetlands depends on water deliveries. Without summer delivery of water, these wetlands would dry up by September. Drying of the permanent wetlands would effectively eliminate reproduction by aquatic birds because predators would have easy access to nests and young. Another critical period of water delivery occurs in September–October (to flood seasonal wetlands and croplands for migrant waterfowl).

Most fields at Lower Klamath NWR are planted to barley. Fields are preirrigated in late winter/early spring prior to planting and are not irrigated during summer. Some fields are harvested, while others are left unharvested and flooded in the fall to provide food for migrant waterfowl.

Typically, extra water becomes available from fall storms beginning in November, but most waterfowl leave the Upper Klamath Basin in November. Filling seasonal wetlands in winter, however, does provide wetland habitat for spring migrants.

Upper Klamath Lake

The third major waterfowl habitat unit is Upper Klamath Lake. Although large in size, it contains relatively small amounts of vegetated wetlands. Recent conservation efforts at the Wood and Williamson river deltas have increased the amount of vegetated wetlands.

In addition to providing wetland foods for migrant waterfowl, vegetated marshes provide protection during fall storms, especially from wind and waves. Because of the size and orientation of Upper Klamath Lake, protection from wind-driven waves during storms may be a key element in determining duration of use by fall migrant waterfowl.

At Upper Klamath Lake, marsh habitat is a function of lake levels, which traditionally were based on irrigation needs and, since 1992, on conservation of suckers. The lake-margin wetlands begin to dewater when the surface lake elevation falls to 4,140 feet above sea level, and all but the channels are dry at elevations below 4,139 feet. Typically, the lake is at its lowest level in September, which coincides with the peak fall use of the lake by waterfowl. The short duration of use in the fall likely is related to the often marginal state of the lake-edge marshes.

Croplands are much less abundant at Upper Klamath Lake than at Tule Lake and Lower Klamath NWRs, especially since Tulana Farms was reconverted to marshland at the mouth of the Williamson River.

Upper Klamath Lake provides habitat for a slightly different community of waterfowl than do Tule Lake and Lower Klamath NWRs. Upper Klamath Lake has more habitat for marsh-feeding dabbling ducks and lake-feeding diving ducks, but less habitat for field-feeding dabbling ducks, than do Tule Lake and Lower Klamath NWRs. Consequently, Upper Klamath Lake seems to operate as a separate subsystem for migratory waterfowl.

Other habitat units

Secondary habitat units for migrant waterfowl include Klamath Marsh NWR, Klamath Wildlife Area, Alkali Lake, and Swan Lake. Each of these areas hosts 10,000 to 50,000 waterfowl during the fall migration. Alkali Lake is part of the Lost River system, and hence water levels are influenced by operation of the Klamath Reclamation Project.

The Upper Klamath Basin contains many minor habitat units for migrant waterfowl. Most are on private land along stream courses or croplands; some are managed for waterfowl hunting during the fall.

Status of waterfowl in the Upper Klamath Basin

Waterfowl are counted routinely in the Upper Klamath Basin (and elsewhere) via aerial censuses conducted from low- and slow-flying aircraft. These counts provide reliable estimates of the number of birds present at the time of the count. However, they do not provide an estimate of the total number of waterfowl passing through the Basin because the rate of movement of birds into and out of the Basin is unknown and likely quite variable.

Census flights are made at 2- to 6-week intervals, long enough to allow for substantial movement of waterfowl into and out of the

Basin. Consequently, the generally accepted practice is to use the highest counts during a migration season as an index of waterfowl abundance. The convention of reporting these "peak" counts is used in this chapter.

The longest, most consistent series of counts are those made on the Basin's national wildlife refuges. These counts date from 1953 to the present, usually with two aerial counts per month during the fall and spring migration seasons. In recent years, the entire Upper Klamath Lake has been counted, rather than just the peripheral marshes that constitute the Upper Klamath NWR. Those marshes make up only a small portion of Upper Klamath Lake.

Migrant waterfowl—refuge use, 1953–2000

All census data for waterfowl in the Upper Klamath Basin have been entered into a database managed and maintained by the U.S. Fish and Wildlife Service. The entire series of data for the Klamath Basin National Wildlife Refuges (KBNWR) has been analyzed and reported in a draft report (Gilmer et al. no date). We relied on that report for historical trends of waterfowl use on the KBNWR.

Numbers of waterfowl

There are no reliable records of waterfowl numbers in the Upper Klamath Basin prior to the initiation of routine aerial waterfowl surveys in 1953. However, partial counts and anecdotal accounts leave little doubt that waterfowl were much more abundant than at present (Abney 1964). The extensive wetlands of Tule Lake and Lower Klamath Lake harbored an enormous abundance of waterfowl prior to their conversion to cropland and refuges in the early part of the 20th century. In the second half of the 20th century, the highest peak count for the KBNWR complex was 5.8 million waterfowl in the fall of 1958.

The numbers of waterfowl using the KBNWR complex in the fall and spring have declined in recent decades (Table 1). Average fall peak counts were about 1.5 million from 1953 to 1976, but only slightly more than 500,000 from 1977 to 2000. Spring peak counts remained consistent at about 360,000.

Species composition

Dabbling ducks are the most abundant group of ducks using the refuges; they constitute on average 67 percent of fall populations and 55 percent of spring populations (Table 2). Pintails make up about half of the dabbling ducks. Pintail numbers have declined throughout North America since the early 1980s. Pintails declined from about 45 percent of all waterfowl at Tule Lake NWR before 1997 to less than 10 percent since then. Their decline contributes substantially to the overall decline in waterfowl usage of the Upper Klamath Basin.

Geese constitute 15 to 30 percent, and diving ducks about 5 to 10 percent, of all waterfowl on the KBNWR complex.

Use by area

Use patterns in the fall at Tule Lake and Lower Klamath NWRs have shifted dramatically since midcentury (Table 3). About 60 percent of the waterfowl currently use Lower Klamath NWR in the fall, up from about 40 percent prior to 1977. Use of Lower Klamath NWR in spring also increased, from less than 50 percent prior to 1977 to slightly over 60 percent since then.

Fall waterfowl use at Tule Lake NWR declined from about 60 percent before 1977 to about 30 percent since then. Spring populations of all waterfowl at Tule Lake NWR declined from about 45 percent to about 30 percent of those counted on the KBNWR complex.

Upper Klamath NWR contains less than 10 percent of the waterfowl counted on the KBNWR complex, but the refuge is only a small portion of the waterfowl habitat on Upper Klamath Lake.

Table 1. Average peak numbers of waterfowl counted in spring and fall on the Klamath Basin refuge complex, 1953–1976 and 1977–2000.

	Number of waterfowl (1,000)			
	Spring		Fall	
	1953–1976	1977–2000	1953–1976	1977–2000
Tule Lake NWR	169	107	814	197
Lower Klamath NWR	173	223	527	375
Upper Klamath NWR	11	13	31	42
Other	11	18	13	8
Total	**364**	**361**	**1,385**	**622**

Source: Gilmer, D.S., J.L. Yee, D.M. Mauser, and J.M. Hainline. No date. "Waterfowl Migration Patterns on Klamath Basin National Wildlife Refuges, 1953–2001" (unpublished manuscript).

Table 2. Composition of waterfowl on the Klamath Basin refuge complex during spring and fall peak counts, 1953–2000.

	Spring		Fall	
	1953–1976 (%)	1977–2000 (%)	1953–1976 (%)	1977–2000 (%)
Dabbling ducks	66.4	68.4	53.8	56.5
Diving ducks	4.8	8.3	10.0	11.7
Geese	17.1	14.7	29.2	24.1
Other	11.7	8.6	7.0	7.7
Total	**100.0**	**100.0**	**100.0**	**100.0**

Source: Gilmer, D.S., J.L. Yee, D.M. Mauser, and J.M. Hainline. No date. "Waterfowl Migration Patterns on Klamath Basin National Wildlife Refuges, 1953–2001" (unpublished manuscript).

Table 3. Distribution of waterfowl during spring and fall peak counts on the Klamath Basin refuge complex,1953–1976 and 1977–2000.

	Spring		Fall	
	1953–1976 (%)	1977–2000 (%)	1953–1976 (%)	1977–2000 (%)
Tule Lake NWR	46.4	29.7	58.8	31.7
Lower Klamath NWR	47.5	61.8	38.1	60.3
Upper Klamath NWR	3.0	3.6	2.2	6.8
Other	3.1	4.9	0.9	1.2
Total	**100.0**	**100.0**	**100.0**	**100.0**

Source: Gilmer, D.S., J.L. Yee, D.M. Mauser, and J.M. Hainline. No date. "Waterfowl Migration Patterns on Klamath Basin National Wildlife Refuges, 1953–2001" (unpublished manuscript).

Migrant waterfowl—Basin use, 1990s

Counts for the 1990s were taken directly from the U.S. Fish and Wildlife Service waterfowl census database. These counts include all of Upper Klamath Lake, Agency Lake, and bordering marshes, not just the refuges.

Numbers of waterfowl

During the 1990s, average fall peak counts of waterfowl in the Upper Klamath Basin were about 2,000,000. Average spring peaks were about 1,250,000 (Table 4).

Species composition and use by area

Slightly less than half of all waterfowl used Lower Klamath NWR in spring and fall. Upper Klamath Lake (the entire lake) had slightly higher usage than Tule Lake NWR in the spring and substantially higher usage in the fall; about one-third of all waterfowl in the Upper Klamath Basin in the fall were found on Upper Klamath Lake.

Species composition varied among the three major use areas (Table 5). At Tule Lake NWR, geese were slightly less than half of all waterfowl present in the spring, and slightly more than one-third in the fall. Dabbling ducks constituted about one-third of all waterfowl present in spring and fall. At Lower Klamath NWR, dabbling ducks were the dominant group, making up 70 percent of all waterfowl counted in the spring and 84 percent in the fall.

At Upper Klamath Lake, diving ducks were a major component of the waterfowl population, comprising one-third in the spring and one-fourth in the fall. Dabbling ducks also were important, especially in the fall, when they constituted 70 percent of all waterfowl counted on Upper Klamath Lake. Shovelers, a strictly marsh-feeding dabbling duck, made up two-thirds to three-fourths of all dabbling ducks on Upper Klamath Lake in the fall. In the spring, one-third of all waterfowl on Upper Klamath Lake were dabbling ducks, and one-fourth were geese.

The species composition reflects the habitats at each of the three major use areas. At Tule Lake NWR, cropland and permanent wetlands are attractive to geese for feeding and to several species of dabbling ducks for loafing. At Lower Klamath NWR, the combination of shallow seasonal marshes and flooded cropland is attractive to all species of dabbling ducks. The large expanse of shallow, open water at Upper Klamath Lake is attractive to many species of diving ducks and to marsh-feeding shovelers. Additionally, the combination of open water, peripheral marshes, flooded pastures, and cropland at Upper Klamath Lake is attractive to a diversity of waterfowl species.

Waterfowl production

Although best known as a migration area, Upper Klamath Basin wetlands are capable of producing substantial numbers of waterfowl. Estimates of production are available only for the KBNWR complex. Lower Klamath NWR is the most important unit, producing an annual average of nearly 71,000 waterfowl (ducks, geese, and coots) from 1993 to 1998. During that same period, Tule Lake NWR produced an average of 9,000 waterfowl, and Upper Klamath NWR an average of 4,000. Estimates of production on Upper Klamath Lake outside the refuge are not available.

Use by molting waterfowl

Molting waterfowl also make extensive use of permanent marshes in the Upper Klamath Basin. Estimates are available only for Lower Klamath NWR, where 50,000 to 100,000 waterfowl are present during the late summer molting period. Birds breeding as far away as Suisun Marsh in the San Francisco Bay area have been tracked moving to Lower Klamath NWR to molt (Yarris et al. 1994).

Effects of drought and irrigation restrictions

Effects on migrants

Distribution of waterfowl in the Upper Klamath Basin was substantially affected by the distribution of irrigation water in 2001. However, some of the changes were offsetting. Peak population in the fall of 2001 was 1,618,000 waterfowl, about 20 percent below the average peak in the 1990s (Table 6).

Most of the 20 percent reduction in peak numbers of waterfowl in the Basin in 2001 was due to the reduction at Lower Klamath NWR (Table 6). Increased use on Tule Lake NWR did not compensate for lower use on Lower Klamath NWR, as there were 27 percent fewer waterfowl on the two refuges combined compared to the 1990s average. Nonetheless, more waterfowl

Table 4. Peak numbers of waterfowl at major waterfowl use areas in the Upper Klamath Basin, 1990s.

	Average (1,000)		Minimum (1,000)		Maximum (1,000)	
	Spring	Fall	Spring	Fall	Spring	Fall
Tule Lake NWR	159	270	100	200	260	375
Lower Klamath NWR	564	875	440	550	910	1,825
Upper Klamath Lake	186	654	91	368	371	1,026
Other	327	243	—	—	—	—
Total	**1,236**	**2,042**	**842**	**1,359**	**1,818**	**3,715**

Source: Gilmer, D.S., J.L. Yee, D.M. Mauser, and J.M. Hainline. No date. “Waterfowl Migration Patterns on Klamath Basin National Wildlife Refuges, 1953–2001” (unpublished manuscript).

Table 5. Composition of waterfowl at major use areas in the Upper Klamath Basin, 1990s.

	Tule Lake NWR		Lower Klamath NWR		Upper Klamath Lake	
	Spring (%)	Fall (%)	Spring (%)	Fall (%)	Spring (%)	Fall (%)
Dabbling ducks	33.5	38.6	69.0	83.7	33.0	70.4
Diving ducks	15.0	13.0	8.8	5.2	34.8	23.0
Geese	46.4	36.4	14.2	4.7	24.7	1.6
Other	5.1	11.9	8.0	6.3	7.5	5.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Gilmer, D.S., J.L. Yee, D.M. Mauser, and J.M. Hainline. No date. “Waterfowl Migration Patterns on Klamath Basin National Wildlife Refuges, 1953–2001” (unpublished manuscript).

Table 6. Peak number of waterfowl at major waterfowl use areas in the Upper Klamath Basin (fall 1990s average and fall of 2001).

	1990s average peak (1,000)	2001 peak (1,000)
Tule Lake NWR	270	346
Lower Klamath NWR	875	494
Upper Klamath Lake	654	665
Other	243	124
Total	**2,042**	**1,618**

Source: Gilmer, D.S., J.L. Yee, D.M. Mauser, and J.M. Hainline. No date. “Waterfowl Migration Patterns on Klamath Basin National Wildlife Refuges, 1953–2001” (unpublished manuscript).

still used Lower Klamath NWR during the fall migration than used Tule Lake NWR.

Early-winter precipitation and availability of irrigation water recharged most waterfowl habitat in the Upper Klamath Basin by January 2002. Consequently, January 2002 waterfowl counts were within the normal range of variation in previous years' counts.

Tule Lake NWR

During the 2001 fall migration period, there was a shift of birds away from Lower Klamath NWR and toward Tule Lake NWR (compared to the distribution between these two areas in recent years). Peak waterfowl numbers at Tule Lake NWR during the fall migration were about 346,000, which is 28 percent above the 1990s average fall peak (Table 6).

Almost all of the increased use at Tule Lake NWR was due to converting Sump 1B from a constant-level permanent marsh to a moist-soil, managed, seasonal marsh. As part of the refuge's planned management for 2001 (unrelated to the curtailment of water deliveries), the sump was left dry in the spring and summer. It began receiving water in late August and reached normal level by mid-November. This created a 3,500-acre seasonal wetland that provided abundant food and water for roosting. This area was very attractive to migrant waterfowl in the fall, especially pintails and green-winged teal.

The seasonal wetland at Sump 1B offset some negative habitat changes during 2001. For example, crops at Tule Lake NWR usually are irrigated during the growing season, and the lack of irrigation in 2001 adversely affected crop production. Also, 640 acres of experimental seasonal wetlands received insufficient water in the fall of 2001, and they remained dry, making them unavailable to migrant waterfowl.

Tule Lake has a history of waterfowl die-offs from botulism and avian cholera. Botulism results from a nerve toxin produced by *Clostridium botulinum* (Friend 1987). Botulism outbreaks in waterfowl are associated with shallow flooding of vegetated mudflats during warm weather, usually in August and September. It has been only a minor problem at Tule Lake NWR in recent years and was not affected by restriction of summer water deliveries in 2001. The minimum water level required in Sump 1A for suckers was sufficient to minimize the likelihood of botulism outbreaks, and no outbreak occurred in 2001.

Avian cholera is a highly contagious bacterial disease (Friend 1987). Transmission distances are short, and transmission is enhanced by concentration of birds on wetlands. Outbreaks often occur when wetlands begin to freeze, as birds become crowded on decreasing areas of open water and are stressed by cold temperatures. Death occurs quickly, and large numbers of birds can succumb in a matter of days. Major die-offs are easy to detect, but very difficult to manage. Low-level chronic outbreaks are difficult to detect, but may kill substantial numbers of birds over a longer period of time than acute outbreaks. There is no effective treatment for wild birds.

When larger-than-normal numbers of fall migrant waterfowl use Tule Lake NWR, the likelihood of serious losses from avian cholera increases, especially if early snowfall and freeze-up create crowding of birds. The winter of 2001–2002 was mild and arrived late, and there were no disease outbreaks.

Lower Klamath NWR

Lower Klamath NWR is the most important area in the Upper Klamath Basin for migrant waterfowl. During the fall migration period in 2001, it was the most severely affected area, as the presence of abundant food in dry fields could not compensate for the small area of wetlands. Peak waterfowl counts in October were 494,000, only about half the average peak fall count in the 1990s (Table 6). Birds were crowded onto the small amount of wetlands, increasing the potential for an outbreak of avian cholera, although none occurred.

There normally are a total of about 22,000 acres of permanent and seasonal marshes in Lower Klamath NWR and 4,000 acres of flooded grain. The BOR's proposed Project Operations Plan did not state a plan to provide water delivery to the refuge at any minimum level. In preparing its Biological Opinion, the USFWS estimated minimum acreages of wetlands needed at the refuge, based on a calculation of the population of waterfowl required to support the area's population of threatened bald eagles. (See Chapter 15, "Bald Eagles," for a more detailed discussion.) These minimum acreages were 2,670 acres of seasonal wetlands, 6,094 acres of permanent wetlands, and 2,431 acres of flooded grain. The 2001 BiOp stated that the BOR should provide water necessary to meet these minimums *if* water was available after lake level and river flow requirements were met for suckers and coho, respectively.

Water delivery sufficient to maintain 6,100 acres of permanent marsh and 5,320 acres of seasonal marsh for fall migrants began in early August. In all, the refuge received about 30 percent of normal water deliveries between January and October 2001. In November, precipitation, water removal from Sump 1A at Tule Lake NWR, and continued deliveries through the ADY Canal recharged seasonal wetlands.

Crops at Lower Klamath NWR are not irrigated during the growing season. Rather, fields are preirrigated during the winter and spring prior to planting. Thus, lack of summer water delivery had no effect on crops in 2001. Crop production (mostly barley) at Lower Klamath NWR was near normal.

Normally, some fields are left unharvested and flooded during the fall migration period. In the fall of 2001, however, no croplands were flooded. Thus, despite the near-normal amount of grain crops present in the fall of 2001, the lack of flooded fields reduced their attractiveness to waterfowl.

Upper Klamath Lake

Upper Klamath Lake seems to have supported its normal contingent of waterfowl during the fall 2001 migration (Table 6). Peak waterfowl counts in the fall of 2001 on Upper Klamath Lake were 665,000, slightly less than 2 percent above the 1990s average fall peak count (Table 6).

Habitat conditions for waterfowl on Upper Klamath Lake in 2001 were similar to a normal year because of the retention of water in the lake. Surface elevation in the fall (about 4,139 feet) was the same as the average fall elevations in the 1990s, but much higher than the 4,137 feet in the dry years of 1992 and 1994. Hence, waterfowl habitat, both quantity and quality, was "average."

Wetland vegetation on the margins of Upper Klamath Lake has developed as a long-term response to water levels and to annual and long-term fluctuations in water levels. These habitats respond to changes in the water level regime slowly, over a period of decades. If higher lake levels are sustained, the result likely will be increased lake-edge emergent marsh habitat.

Beyond the Upper Klamath Basin

In addition to peak numbers and distribution of waterfowl in the Upper Basin, duration of use is a key component of the value of the Basin to Pacific Flyway waterfowl. Whether waterfowl cope with wetland shortages in the Upper Klamath Basin by bypassing the Basin and/or shortening their stay depends at least partly on the availability of wetland habitat in other parts of the flyway.

High-quality wetland habitat occurs in several areas east of the Basin, but those areas normally are even more affected by drought than the Upper Klamath Basin. Hence, they are not a viable alternative in dry years.

The Central Valley of California is a primary winter destination for waterfowl passing through the Upper Klamath Basin. Wetlands in the Central Valley are in poor condition early in the fall, but improve as winter progresses. Thus, they provide a poor alternative to the Upper Klamath Basin for waterfowl in September and October. Additionally, less than 10 percent of the original wetlands in the Central Valley remain, further restricting options for waterfowl choosing to bypass the Upper Klamath Basin. Coastal wetlands are limited in extent and have much lower capacity for waterfowl than those in the Upper Klamath Basin.

The high proportion of Pacific Flyway waterfowl that use the Upper Klamath Basin (75 to 80 percent) indicates the value of the Basin wetlands, even in their current deteriorated state. The best alternative sites support no more than 100,000 migrants, compared to the 1,500,000 to 2,000,000 that stage in the Basin.

The severe restriction in waterfowl habitat that resulted from the lack of water deliveries to the refuges and other Project lands was expected to be detrimental to Pacific Flyway waterfowl during the fall of 2001 and winter of 2001–2002. Effects on spring migrants may be less severe since winter storms provided water for flooding of wetlands left dry in the fall.

Effects on waterfowl production and molting waterfowl

Production of waterfowl at Tule Lake NWR probably was minimally affected in 2001 because of the BiOp's requirement to maintain Sump 1A at normal pool level to maintain habitat for endangered suckers. However, the lack of water may curtail the marsh enhancement program, causing productivity of the refuge wetlands to remain low and perhaps continue to decline.

Lower Klamath NWR is a substantial producer of waterfowl and other water birds, but production in 2001 was expected to be essentially zero. Water deliveries began in early August, much too late to benefit nesting waterfowl. The reduction in permanent wetlands, along with their shrinking size during the summer brooding period, would have made females and young highly vulnerable to predators.

Additionally, molting waterfowl either would be forced to find other suitable habitat or would be crowded onto the limited habitat present at Lower Klamath NWR. When faced with poor habitat conditions, waterfowl, as a last resort, can forego breeding, but they cannot forego molting. Molting occurs regardless of the quantity and quality of habitat. Molting waterfowl in inferior habitats are easy prey for predators (e.g., coyotes, hawks, and owls).

Compared to recent drought years, production at Upper Klamath Lake was likely to be enhanced as a result of maintaining lake levels during the summer of 2001. It is unlikely that higher production at Upper Klamath Lake compensated for production lost at Lower Klamath and Tule Lake NWRs, however, because of the small amount of breeding habitat on Upper Klamath Lake. The Upper Klamath Lake marshes, especially Upper Klamath NWR, may have hosted more molting waterfowl in 2001, certainly more than occurred in the drought years of 1992 and 1994, when the marshes were dry by early to midsummer.

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Mule Deer

Relationships between Mule Deer Biology and the 2001 Federal Environmental Decisions on the Klamath Reclamation Project

Jeff Manning and W. Daniel Edge

Trade-offs between wildlife and the values of reservoirs, timber management, agriculture, and other land use and water development activities commonly occur. Confrontations also may arise between the conservation needs of threatened or endangered species and those of managed, nonlisted species such as big game.

The effects on big game of the 2001 federal decisions to restrict water allocation to parts of the Klamath Reclamation Project have not been considered by federal agencies. Federal decisions associated with the Project resulted from interagency consultation between the Bureau of Reclamation (BOR) and both the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) under Section 7 of the Endangered Species Act. State agencies provided comments regarding the effects of the decisions on big game, but federal agencies were not required to consider those comments.

In this chapter, we summarize the status and wildlife value of mule deer (*Odocoileus hemionus*) in the area served by the Klamath Reclamation Project, introduce key aspects of mule deer physiology and reproduction, and discuss how the 2001 federal environmental decisions for managing water on the Project might influence this species.

Status of mule deer

Mule deer are the most sought-after big-game species in Oregon, with annual harvests since 1952 ranging from 16,000 to nearly 98,000 (Verts and Carraway 1998). They are one of five species of big game in the Klamath Basin. The other four are elk (*Cervus elaphus*), pronghorn (*Antilocapra americana*), cougar (*Felis concolor*), and black bear (*Ursus americanus*).

Estimated populations in North America increased from about 500,000 to 4.7 million between the 1920s and 1960s (Julander and Low 1976; Rue 1978). Between 1926 and 1933, population estimates for national forests in Oregon ranged from 28,654 to 55,570, suggesting that mule deer were abundant (Bailey 1936). They also were believed to be abundant in nonfederal areas during that time (Cliff 1939).

In 1964, McKean and Luman concluded that the mule deer population in Oregon had declined since the 1930s. In 1990, the population in Oregon was estimated to be 256,000 (ODFW 1990).

To manage game species such as mule deer, the Oregon Department of Fish and Wildlife (ODFW) has divided the state into 77 Wildlife Management Units (WMU). Present management strategies differ by WMU based on buck:doe (male:female) ratios (ODFW 1990).

Seven WMUs lie within the Oregon portion of the Upper Klamath Basin, and mule deer are present in all seven (ODFW 2001). The majority of the Oregon portion of the Klamath Project lies within the Klamath Falls and Keno WMUs. Deer population trend estimates for the Klamath Falls WMU were 3 mule deer per survey mile in 1999 and 3.1 in 2000 (ODFW 2001).

Development of the Klamath Reclamation Project in the early 1900s substantially modified mule deer habitat. Grass and shrub habitats within the Project, which historically were important winter range, were converted to agriculture. Remaining habitats within the Project were fragmented and isolated among fields used for agricultural production. Although many of these fields provide important forage for mule deer, the cover component of mule deer habitat was substantially reduced. Thus, current mule deer populations on the Project rely primarily on upland habitats at the fringe of the area from spring through fall, although some deer occur within the irrigated portion of the Project year-round. Mule deer move to lower elevation, agricultural areas during the winter.

Wildlife value of mule deer

Mule deer evolved in North America before the presence of humans. Their prevalence throughout western North America makes them important in human subsistence, recreation, and nonconsumptive aesthetics. A total of 1,162 hunters purchased hunting tags for the Klamath Falls WMU in 2000, and 37 percent successfully harvested deer.

No Oregon-specific data are available on the economic value of mule deer hunting. An economic analysis by Loomis et al. (1989) estimated the average value of a deer-hunting trip to a hunter in California at $191, or $115 per recreation visitor-day. Additionally, the general public in California derived an average value of $11 per trip on outdoor trips where they saw deer and $15 per trip on trips taken primarily to view deer. In 1987, California deer hunters spent $184 million on permits, equipment, travel, and lodging (Loomis et al. 1989).

Mule deer also contribute significantly to the structure and functions of ecosystems, and they are considered ecological indicators. In other words, the health and size of mule deer herds are indicative of how well an ecosystem is functioning (Hanley 1996). Mule deer have large home ranges, often exhibit seasonal migrations, and require spatially diverse habitat elements such as food and cover. Mule deer are prey for various mammalian predators and birds of prey. They also substantially affect vegetation composition and basic ecosystem processes such as nutrient cycling, thereby functioning as a keystone species—a species whose removal from the ecosystem would result in a cascade of changes throughout the system (Hanley 1996; Hobbs 1996).

Sources of data

ODFW and the U.S. Department of Agriculture's Animal Plant Health Inspection Service, Wildlife Services (USDA, APHIS, WS) are primary sources of data on big game in the Oregon portion of the Upper Klamath Basin. The Portland Office of ODFW maintains a comprehensive database on damage by ungulate game species, from which we received information on deer, elk, and pronghorn. For each Wildlife Management Unit, ODFW maintains an annual tally of the number of kill and hazing permits issued, fence contracts completed, tree cages used, haystacks protected, repellents and noise-makers used, hazing efforts completed, trapping efforts completed, and advice given.

ODFW also compiles "Big Game Statistics" each year, which contains population data and harvest survey information on big game harvested in Oregon. ODFW estimates trends in mule deer populations rather than attempting to estimate the population size per se. Trend counts also include herd composition data (e.g., male:female ratio).

Mule deer physiology

Mule deer physiology can be broken down into growth, fat deposition and mobilization, water requirements, and thermal relationships (Demarais and Krausman 2000). All of these factors influence survival. However, we suggest that fat deposition/mobilization and water requirements may be the best factors to consider when examining the influence of the Klamath Reclamation Project on mule deer, so these are the factors covered here.

Fat deposition and mobilization

Generally, mule deer store fat in spring and summer and deplete it in fall and winter (Anderson et al. 1972; Wallmo 1981). Males reach their lowest level of fat storage following fall rut and into winter and early spring (Anderson et al. 1972), and they consequently suffer greater mortality during winter than do females (Flook 1970; White 1973; Kie and White 1985).

Females undergo a less pronounced annual cycle of fat deposition and loss compared to males. They also maintain greater fat reserves during critical winter periods than males. Females reach a low point in their fat-storage cycle during lactation in the summer because of the high energy demand of feeding fawns (Anderson et al. 1972).

Water requirements

Mule deer that live in arid and semiarid environments are adapted to scarcity of free-standing water. Hazam and Krausman (1988) and Hervert and Krausman (1986) reported that desert mule deer in Arizona visited sources of water on average once a day and consumed 5 to 6 liters of water per visit during the hot summer months. Visitation rates and amount of water consumed per visit declined during cooler seasons of the year.

They also found that female mule deer drink more water than males during late summer, presumably because of the demands of lactation. Females often are found closer to sources of water than males, and they may remain close to water sources year-round (Bowyer 1984; Fox and Krausman 1994; Boroski and Mossman 1996; Main and Coblentz 1996).

Mule deer are capable of obtaining water from a variety of sources. They can obtain water by consuming succulent plants, from dew on plant surfaces, and through metabolic processes (Anderson 1981). Whether mule deer require freestanding water has been debated (Severson and Medina 1983). Lauteir et al. (1988) suggested that although mule deer may exist for periods of time without access to freestanding water, survival may be marginal during these periods.

The abundance and spacing of water sources can influence the distribution of mule deer in a local area. In northern California, mule deer averaged 1.19 to 1.55 km (0.7 to 0.9 miles) away from water sources, with a mean maximum distance of 2.46 km (1.5 miles) (Boroski and Mossman 1996). The differential proximity of male and female deer to water led to recommendations for managing artificial water developments for mule deer in northern California. These recommendations included spacing the water developments less than 3.2 km (1.9 miles) apart, with a maximum of 4.6 km (2.8 miles) (Wood et al. 1970; Boroski and Mossman 1996).

Mule deer reproduction

Mule deer are polygynous (one male will breed with multiple females), and they breed during the autumn (Thomas and Cowan 1975). Females usually breed for the first time at 17 to 18 months of age, and they usually give birth to one young at 24 to 25 months. Older females give birth to twins 64 percent of the time (Hines 1975).

Timing of reproduction is an adaptation to long-term climatic patterns that helps ensure that females have adequate nutrition during late gestation and birthing and that fawns are born at an optimal time of the year (Robinette et al. 1977; Wallmo 1978; Bowyer 1991).

In most populations, adult females outnumber adult males by more than 2:1 (Robinette et al. 1957). Significantly more females can occur in heavily hunted populations (Mackie et al. 1982), and this seems to be the case in the Klamath Falls WMU (237 females and 27 males, according to ODFW 2001).

The interactions between forage, predation, and weather

Forage, predation, and weather interact in several ways to influence mule deer survival and reproduction. Understanding these interactions is important when considering potential effects of water management decisions on mule deer.

Forage is necessary for animals as a source of energy and for growth and maintenance. Mule deer diets vary by location, season, sex, and other factors (Kufeld et al. 1973; Wallmo 1978; Main and Coblentz 1990). When given access to seasonally abundant, nutritious, herbaceous plants of high digestibility, deer will select those species over species of lower digestibility (Demarais and Krausman 2000).

In the Project area, mule deer forage on natural vegetation in upland habitats along the fringe of the Project as well as on irrigated crops such as grains, alfalfa, and sugarbeets (Hainline 2001, personal communication). When natural vegetation in upland areas is reduced during drought years, irrigated crops provide nutritional value for mule deer during autumn and winter.

A reduction in the quantity and quality of forage may increase physiological stress and reduce reproduction in mule deer. The reproductive potential of mule deer is lower in habitats having poor-quality forage than in those with high-quality forage (Taber and Dasmann 1957). Well-nourished females might breed at 17 months of age, while those in poor condition might not breed until as late as 41 months of age (Mackie et al. 1982; Anderson and Wallmo 1984). Adult female mule deer commonly give birth to two fawns in areas with adequate nutritional levels, while females breeding for the first time, and those with inadequate nutrition, may conceive only a single fawn (Anderson and Wallmo 1984).

Interactions between forage and other aspects of mule deer biology may influence deer survival. For instance, McNamara and Houston (1987) and Sinclair and Arcese (1995) reported an interaction between foraging and predation. For example, better forage conditions enable deer to spend less time feeding, thereby lowering chances of predation (Kie et al. 1991; Kie 1999). Thus, they emphasized that it is meaningless to consider these factors in isolation. Bailey (1984) also suggested that habitat condition—including forage quality, availability of water, and weather—should not be considered as a population-regulating factor without simultaneously considering predation.

Weather is a variable factor capable of large effects on wildlife and habitats. Because it is unpredictable, weather adds uncertainty to the predictions of wildlife managers and requires frequent review of management decisions. Extreme climatic conditions may override the effects of management on wildlife populations, perhaps requiring a reversal of management strategies (for example, see Severinghaus 1972).

It is important to consider weather conditions when discussing the theoretical influences of the 2001 federal environmental decisions on mule deer populations. Weather can affect wildlife directly by harming and killing individual animals, such as young, that are especially vulnerable to severe weather. It also can affect wildlife populations indirectly by restricting movement; destroying, preventing access to, or reducing the production of food and cover resources; and changing the abundance of competitors, predators, and disease organisms (Bailey 1984).

The quantity and quality of forage production vary substantially among years, depending on the amount and seasonal distribution of precipitation. Reproductive success in mule deer has been correlated with seasonal precipitation patterns (Shaw 1965), and improved forage conditions during years with extra moisture are one factor related to higher reproduction (Wallmo 1978; Anthony 1976). Summer drought conditions also may result in decreased fawn and yearling nutrition, which in turn may cause poor physical condition and lead to decreased winter survival.

Drought conditions can have additional effects on mule deer survival. For example, limited forage supplies during drought periods might reduce small mammal populations, resulting in a shift of coyote (*Canis latrans*) predation to deer (Bailey 1984).

Potential influences of 2001 federal environmental decisions

The changes to operations of the Klamath Reclamation Project resulting from the 2001 water allocation decisions modified the timing and amount of water available across the landscape in the Project area. Such changes, coupled with drought conditions, likely increased distances among available water sources and reduced the availability of nutritionally rich, irrigated forage crops.

These changes might have direct and indirect influences on big game, including mule deer. Potential direct influences include physiological stress (particularly on mule deer bucks after the rut, on pregnant females during the winter, and on young fawns during the spring and summer) and, consequently, decreased survival and reproduction. Indirect influences might include shifts in local and regional distributions, increased risk of automobile collisions while traveling long distances, and crowding at remaining forage and water sources. Additionally, animal damage complaints from individual producers might rise due to increased foraging on ornamental plantings and irrigated cropland.

We can summarize the potential consequences as follows.

- The reductions of water in the Project area likely would result in a reduction in the quantity and quality of natural vegetation and the quantity of irrigated crops available as forage to mule deer. These changes would result in changes in the local distribution of mule deer as individuals move to areas where higher quality forage is available. They also might lead to poorer nutritional condition, decreased fat reserves, and reduced survival rates. Increased winter kill would be an indicator of such conditions.
- We suspect that big-game damage would increase on farms that did receive water because the availability of green vegetation was limited.
- It is not clear whether reduced water and forage availability would affect males more than females because of their lower winter fat reserves. If so, increased losses of adult males could affect sex ratios.
- Females might delay the onset of reproduction, and adult females might produce fewer fawns.
- Poor nutritional condition might result in low birth weights and subsequent higher fawn mortality.
- There might be reduced availability of water sources (for example, irrigated crops where mule deer can obtain dew from plant surfaces). Surface water levels might be reduced, but it is unlikely that water sources would be eliminated. The presence of water in the major lakes, rivers, and some canals of the Project likely would meet water requirements for mule deer. Only in areas where irrigated crops did not receive water, or where secondary or tertiary canals were dry, were mule deer likely to change distribution patterns due to a lack of available water.

Problems inherent in the data collected during mule deer counts will limit their use in assessing individual and population-level responses by mule deer to the 2001 decisions. The problem is that the data are based on broad geographic areas that encompass a variety of natural and human-modified habitats, weather conditions, and water sources. For example, increased complaints of wildlife damage might be due to changes in human land use rather than the status of big-game populations. In the long term, natural habitats may be converted to agriculture or houses, thereby encroaching on previously available habitats. In the short term, damage complaints in the Project area actually declined in 2001 because so few farms produced a crop that attracted deer.

In addition, weather conditions are highly variable. Thus, availability of natural and human-made water sources may vary depending on season, climate, and agricultural and domestic use by humans.

Consequently, it probably will not be possible to determine whether changes identified in the data are based on habitat conditions, loss of existing habitat, weather conditions, availability of water, or size of the wildlife population. Furthermore, precision of the available data, both from the standpoint of variation among annual counts and the landscape scale at which it is collected, makes it unlikely that changes in deer population can be attributed to changes in water distribution in the Project area.

Conclusions

Wild animals are well adapted to variable weather conditions within their environment (Kelsall and Telfer 1971). Nevertheless, weather extremes do cause mortality. Human-induced habitat losses and changes, such as those potentially caused by managing water on the Klamath Reclamation Project, may exacerbate weather conditions. Thus, the combination of drought conditions and decisions to reduce water deliveries may reduce availability of water sources and forage. There are several potential effects on mule deer. The most likely effect is a change in the distribution of mule deer, leading to increased use of irrigated crops. There also may be population crowding, reduced reproduction, and physiological stress on mule deer in the Project area.

Monitoring of mule deer in the Upper Klamath Basin is needed for several years following the period affected by the federal environmental decisions to determine, if possible, the extent of the influence of changes in Project operation on the mule deer population. This information, coupled with knowledge of water allocation imposed by federal environmental decisions, would prove valuable in adjusting mule deer harvest limits in response to current weather, habitat, water allocation, and herd conditions.

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Part 7. Public Policy

18

Policy

A Policy Assessment of the 2001 Klamath Reclamation Project Water Allocation Decisions

George Woodward and Jeff Romm

Prior to 2001, the Bureau of Reclamation (BOR) had provided water first and without fail to farmers for almost a century, insulating Klamath Reclamation Project growers from climatic variability, competing federal commitments, and the effects on others of agricultural water diversions. In 2001, climatic, ecological, and institutional circumstances aligned to place greater emphasis on the needs of endangered species and, less directly but more fundamentally, on water regimes that sustain the treaty-assured natural resource basis of tribal livelihoods and traditions. In effect, federal law determined the allocation of water in the Upper Klamath Basin in 2001, a process that, in the absence of federal preemption,[1] is decided by state law.

The abruptness and magnitude of the resulting irrigation curtailment signified a major reordering of *de facto* priorities for water allocation in the Upper Klamath Basin. In the process, farmers, farmworkers, and farm communities suffered real and immediate losses unprecedented in prior applications of the Endangered Species Act (ESA). The loss of irrigation water immediately reduced productivity, jobs, income, the value of farm assets, community and regional economies and services, and family and social stability. It also raised questions about the acceptable level of private burden for satisfaction of a public purpose.

Although such real and abrupt losses were unprecedented under the ESA, they were not unprecedented in the Klamath Basin. As the forces of Euro-American settlement and economic formation spread into the Basin in the 1800s, Native American tribes experienced immediate and drastic economic and social decline resulting from several developments, including:

- Initiation of the reservation system and loss of ancestral lands in the 1850s
- Development of widespread irrigated agriculture under the Reclamation Act of 1902[2]
- Termination of the Klamath Reservation in 1954, despite recognized capacities of the Klamath Tribes to succeed within it[3]
- Diversion of Trinity River waters, the main tributary of the Klamath River, to the Central Valley of California several decades later

[1]The Endangered Species Act and federal Indian water rights are pertinent examples of forces behind federal preemption in the Klamath Basin.

[2]See Chapter 3 (“Legal Aspects”) for discussion of the Reclamation Act.

[3]During the period of the termination policy in the 1950s, almost 1.4 million acres were removed from tribal ownership by Congressional act. (See, for example, Prucha 1990.) Sixty-three percent of the total terminated acreage nationwide came from the Klamath Reservation, and more than 80 percent from the Klamath and Menominee reservations combined (Prucha 1984).

Over the course of 150 years, the Klamath, Hupa,[4] Yurok, and Karuk tribes suffered massive declines in the natural resources on which they depended, despite federal treaty guarantees. In 2001, in the midst of a severe drought, irrigators faced a similarly drastic change, catalyzed by the ESA, despite almost a century of contractual assurance of water deliveries. Irrigation water contracts and tribal treaty guarantees collided within the legal framework of endangered species protection, which dominated both.

The 2001 irrigation curtailment fueled an ongoing national debate about the application of the ESA. In ESA conflicts elsewhere—the Central Valley and Delta of California, for example—the Department of the Interior[5] developed elaborate alternatives to strict ESA compliance in order to reduce economic impacts and avert a political backlash against the law. In the Klamath Basin, in contrast, the long-simmering tensions around water allocation were left unattended as all sides sought relief in the courts rather than agreement with one another.

The cast of Klamath Basin interests is complex. At one level, it includes federal, state (California and Oregon), and tribal sovereignties. At another, it includes a range of federal agencies with apparently contradictory, or at least uncoordinated, missions and programs. At a third level are user groups representing the Basin's farmers, environmentalists, fishers, tribes, and various regions. Within this complex setting and in a year of extreme drought, judicial enforcement of the ESA culminated in the abrupt and almost total cutoff of irrigation water on the Klamath Reclamation Project.[6]

In preparing this chapter, we began with two questions consistent with the intent of this report.

- Does the 2001 water allocation decision on the Klamath Reclamation Project change the framework of public policy?
- Does it stretch the policy envelope of acceptable events under the ESA, or is it consistent with the normal patterns of resolution for such issues?

We sought to answer these questions in several ways. We evaluated the decision in light of related judicial interpretations regarding tribal water rights, federal–state–tribal relations in water allocation, the Endangered Species Act, "takings" of private property for public purposes, and the specific qualities of these issues in the Klamath Basin. We then compared the institutional basis, i.e., the organized patterns of social relations, in the Klamath Basin with that of other river basins, to try to understand why problems that seem to have been solved elsewhere became a "train wreck" in the Klamath Basin.

As we proceeded, however, our question evolved from "What were the consequences?" toward an assessment of the lessons the situation provided about future opportunities. In other words:

- Why did this crisis happen?
- What changes are necessary to prevent a similar crisis from happening again?

These questions fed a growing sense of humility toward the complexity of the Klamath situation. In effect, the events of 2001 brought to a flashpoint historic tensions between federal, state, and tribal governments; competing federal missions; and strongly polarized interests of farm communities, tribes, environmentalists, and fishers—with the powerful water interests of California as a backdrop.

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[4]Hupa refers to the people; Hoopa (a word invented by the federal government) refers to the reservation. We have chosen to use Hupa throughout this chapter except where Hoopa is part of a quotation.

[5]Many agencies (both state and federal) and several Cabinet-level departments respond to the challenges in the Bay-Delta.

[6]The water supply options available to Project farmers vary by location within the Project, with respect to Upper Klamath Lake, Gerber and Clear Lake reservoirs, and the availability of groundwater. Irrigation technology and crop type also affect the ability of farmers to respond to nondelivery of Project water. In 2001, farmers located in areas served by Gerber and Clear Lake reservoirs obtained about 70,000 acre-feet of water from the Project. Late in the season, approximately 75,000 additional acre-feet were released from Upper Klamath Lake to Project irrigators.

We are policy analysts, not lawyers, representatives, or administrators. Although we have strong working ties within the Klamath Basin, we are not residents of the Basin. What we can offer, at best, is one way to frame the situation, which may lead to greater understanding of its policy implications. Some may agree with our approach and findings; others will not. In both instances, however, we believe that understanding can increase. Our purpose is not to prescribe, but to support the kinds of debates and developments that will prevent similar crises for any of the Basin's residents in the future.

Our approach, we hope, is straightforward. We define three fundamental tiers of relationship in the Klamath Basin: intergovernmental, interagency, and among communities of interest. We then seek to understand the context and nature of relationships within and between these categories to see whether and why the outcomes of the 2001 water allocation decision pressed against the boundaries of "normal" and to explore ways in which better results might be achieved in the future.

This chapter has three sections. First, we review the legal context within which the decision occurred, approaching this formidable task not as legal scholars, but as policy analysts. Then, we review the institutional context of the Basin—the organized patterns of relationships among jurisdictions, agencies, and interest groups—through which the ESA achieved such unmoderated force when compared with its application elsewhere. Finally, we present for discussion various issues raised by the events of 2001 and suggestions for strengthening institutional relationships.

Legal context of the 2001 Klamath Project Operations Plan

The legal context of water allocation in the Klamath Basin involves various competing mandates and processes that as yet have had only judicial avenues for resolution. Of particular relevance for the 2001 Klamath Project Operations Plan (KPOP) are the following:

- Federal treaties with the Klamath Basin tribes, beginning in the 1850s
- Patterns of relative authority between state water law systems and federal water rights from the 1870s to the present
- Federal reclamation and energy laws (starting with the Reclamation Act of 1902)
- Federal environmental laws, including the Endangered Species Act (beginning with the National Environmental Policy Act of 1969 and its process requirements)

These families of law support distinctive agencies and modes of control that operate with virtual autonomy in the context of the Klamath Basin. Issues of sovereignty, economic opportunity, and environmental sustainability in the Basin continue to reside in the courts, without Executive vehicles for coordination at the federal level or in federal–state–tribal relations.

Tribal rights

Four federally recognized Indian tribes reside in the Klamath Basin. Three are in the Lower Basin in California. The Hupa Reservation is located at the juncture of the Trinity and Klamath rivers. The Yurok Reservation is west of the Hupa near the mouth of the Klamath River. The Karuk Reservation is upstream of the Hupa on the Klamath. The Klamath Tribes are located far upstream and several hundred miles away in Oregon, above the Klamath Reclamation Project. The Project straddles the California–Oregon border.

Three of these tribes have treaty-based rights.[7] This means that their resource rights are defined by the timing and terms of the original treaties they possess as sovereigns. Treaty rights do not depend on the existence of reservations, but are tied to the tribal groups whose ancestors signed the treaties. When applied to water, they create a federal reserved right that is tied to the water needs of entitlements specified in the treaty (for example, the right to a hunting and fishing lifestyle). Another class of federal right, the implied reserved right, is attached to a tribe's reservation and is a right to water necessary to satisfy the purposes for which the reservation was created.[8] Under prevailing judicial interpretation, the Klamath Basin tribes with treaty-based reserved water rights are entitled to sufficient water to sustain a moderate livelihood in the manner they have enjoyed—hunting, fishing, and foraging—"since time immemorial," whether or not the tribes have a reservation.

The Upper Klamath Basin tribes

The Upper Basin tribes entered into a treaty with the United States in 1864. They relinquished aboriginal claim to about 12 million acres of land in exchange for a reservation of approximately 768,000 acres above Upper Klamath Lake.[9] The treaty specifically protected the Indians' existing right to pursue their traditional culture and means of livelihood, while encouraging them to develop agriculture. Under prevailing judicial interpretation,[10] the tribes possess a treaty-based reserved right for sufficient water to protect their culture and livelihood. This is not a grant of rights to the Indians, nor merely an implied right deriving from the purpose of the Klamath Reservation (as is the right to water for a reservation's agricultural purpose), but rather a reservation of rights already possessed.

In 1887, Congress passed the General Allotment Act, which changed the nature of land ownership within the Reservation. Instead of allowing only communal ownership, the Act also permitted individual ownership. Approximately 25 percent of the original Klamath Reservation went into individual Indian ownership, and many of these allotments passed into non-Indian hands.

The Klamath Reservation was terminated in 1954 under the Klamath Termination Act.[11] Before and after termination, the United States purchased most of the Reservation for inclusion in national forests and wildlife refuges. The balance was placed in a private trust for the remaining tribal members. In 1973, the United States condemned most of the remaining land held in trust, eliminating tribal title. The Klamath Tribes lost federal recognition at the same time, later to have it restored under the Klamath Restoration Act of 1986.[12]

This brief discussion begins to illuminate the complexity of relations among federal, state, and tribal sovereigns in the Klamath Basin. For example:

- Treaties between the U.S. and the tribes assure the protection of natural resources the tribes need to sustain their cultures and

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[7]In *Parravano v. Masten*, 70 F.3d 539 (1995 U.S. App 9th), the court addressed the alleged distinction between rights created by treaty and those created by executive order. It found that "tribal rights derived from executive order are treated the same as treaty rights" and explicitly rejected the distinction. The Yurok and Hupa rights derive from executive orders in 1876 and 1891. The District Court determined that these executive orders and the 1988 Hoopa–Yurok Settlement Act, 25 U.S.C. § 1300i, vested the Hupa Valley and Yurok tribes with federally reserved fishing rights. The *Parravano* appellate court affirmed the District Court.

[8]*Winters,* 207 U.S. 564 (1908); *Arizona v. California,* 373 U.S. 546, 83 S.Ct. 1468, 10 L.Ed.2d [**23] 542 (1963); *United States v. New Mexico*, 438 U.S. 696 (1978)

[9]Treaty between the United States of America and the Klamath and Modoc tribes and Yahooskin Band of Snake Indians, October 14, 1864, 16 Stat. 707

[10]*U.S. v. Adair* (U.S. District Court 478 F. Supp. 336 (*Adair* I), on appeal 723 F.2d 1394 (*Adair* II), and most recently 2002 U.S. Dist. LEXIS 3397 (*Adair* III) for the Klamath, and *Parravano v. Masten* 70 F.3d 539 (1995 U.S. App 9th) for the Hupa and Yurok

[11]Approximately 80 reservations were terminated during the era of the termination policy, although two of them—the Klamath and the Menominee—were considered at the time to have been very successful in economic and governance terms.

[12]Pub. L. No. 99-398, 100 Stat. 849

traditional livelihoods. These rights are tied to the tribe rather than to a piece of land, and they date to the origins of tribal occupation.

- Federal reserved water rights are tied to the purposes for which Congress reserves a piece of land from the public domain. An example is the right to use water for agricultural purposes on the former Klamath Reservation.

- Despite the prevalence of federal control of land and water rights in the West, actual water allocation among claimants generally is the prerogative of state law.[13] Under both Oregon and California law, the priority of a claim depends, among other things, upon the date of initial use (and, for federal lands, upon the date of reservation from the public domain). California and Oregon apply additional considerations when adjudicating the equitable distribution of a stream's flow among various right holders.

U.S. v. Adair (1979, on appeal 1983, and continuing jurisdiction review 2002)

In *U.S. v. Adair*, the federal government and the Klamath Tribes sought a District Court declaration that "since 1864 no one has been entitled to divert or appropriate water from the [Williamson] River, if the diversion or appropriation would threaten the Marsh and forests" on and adjacent to Upper Klamath Lake. The Williamson River is one of the upstream tributaries to Upper Klamath Lake. Ben Adair et al. (private landowners) and the State of Oregon were the defendants in this case. The questions raised in the case fell within three basic categories:

- Were water rights reserved for the use of Klamath Reservation lands in the 1864 treaty?

- Did such rights pass to the government and to private persons who subsequently took fee title to Reservation lands?

- What priorities should be accorded the water rights of each of the present owners and users of former Reservation land?[14]

The court did not decide any question concerning the quantification of water rights, leaving this matter for the Oregon adjudication process under state law (see Chapter 3, "Legal Aspects"). It found that the exclusive fishing and gathering rights secured by the 1864 treaty to the Indians were "not a grant of rights to the Indians, but a reservation of rights already possessed,"[15] and that these rights survived the termination of the Reservation in 1954.[16]

Judge Solomon declared, "When, by treaty, the Government withdraws land from the public domain and reserves it for a federal purpose, the Government impliedly reserves appurtenant unappropriated water to the extent needed to fulfill the purposes of the reservation."[17] The Judge reasoned that the Indians were entitled to whatever water was necessary to maintain their hunting and fishing rights and that the priority date of the Indian water rights was "time immemorial." This priority date establishes the Tribes as the senior right holders in the Upper Basin.[18]

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[13]In *United States v. New Mexico,* 438 U.S. 696 (1978), the Supreme Court wrote that "... [where] Congress has expressly addressed the question of whether federal entities must abide by state water law, it has almost invariably deferred to the state law. See *California v. United States*, ante, at 653–670, 678–679. Where water is necessary to fulfill the very purposes for which a federal reservation was created, it is reasonable to conclude, even in the face of Congress' express deference to state water law in other areas, that the United States intended to reserve the necessary water. Where water is only valuable for a secondary use of the reservation, however, there arises the contrary inference that Congress intended, consistent with its other views, that the United States would acquire water in the same manner as any other public or private appropriator."

[14]In addition, the District Court explicitly addressed the question of federal jurisdiction in the determination of water rights. We discuss this topic in greater detail later in this chapter.

[15]Citing *United States v. Winans*, 198 U.S. 371, 25 S.Ct. 662, 49 L.Ed. 1089 (1905).

[16]Citing *Kimball v. Callahan*, 590 F.2d. 768 (9th Cir. 1979).

[17]Citing *Winters*, 207 U.S. 564 (1908); *Cappaert*, 426 U.S. 128, 138 (1976); *Arizona v. California*, 373 U.S. 546, 83 S.Ct. 1468, 10 L.Ed.2d [**23] 542 (1963); *United States v. Powers,* 305 U.S. 527, 59 S.Ct. 344, 83 L.Ed. 330 (1939).

[18]Note that some parties prefer a more narrow reading of *Adair* that confines the reserved water rights to the "litigation area."

The *Adair* court established the basis for setting priorities among tribal and other federal water rights. Since *Winters* (1908), the Supreme Court has held that the reserved water for Indian reservations has priority relative to appropriations made under state law after the date of reservation.

The District Court explicitly addressed the question of whether federal or state courts are the appropriate forum for addressing matters related to federal or tribal water rights. In *Colorado River Water Conservation District v. United States* (1976),[19] the Supreme Court found that the McCarran Amendment (1952)[20] allows concurrent state and federal jurisdiction over various aspects of water rights disputes. It also found that the state's jurisdiction extends to federal reserved water rights, including Indian water rights, because the McCarran Amendment expressed a "clear Federal policy" to avoid "piecemeal adjudication of water rights in a river system" where a comprehensive state system for adjudication of water rights is available.

In *Adair,* Judge Solomon found that it was appropriate and necessary for the federal court to determine the rights of the Indians under federal law, although the actual allocation of water among various right holders falls under state jurisdiction. The key distinction is between a federal court's capacity to determine what groups hold federal water rights (and the relative priorities of those rights) versus the jurisdiction of state courts over actual allocation of water among claimants.

The *Adair* court retained continuing jurisdiction[21] in anticipation of the need for future supervision of the distribution of water consistent with the opinion.

Both sides appealed the *Adair* decision in what is known as *Adair* II. The State of Oregon and individual defendants argued that the District Court should have dismissed the federal suit and had erroneously awarded water rights to the Tribes and to the United States as the Tribes' successor, a process that should fall under the jurisdiction of state law. The United States and the Tribes argued that the District Court erroneously awarded water rights to non-Indian successors of Indian landowners.

In 1983, the U.S. Court of Appeals affirmed the District Court's *Adair* I determinations, with one exception—the lower court's decision not to separately declare the federal government's water rights.[22] The appellate court also interpreted the District Court's statement of the tribal entitlement to water as confirming the amount necessary to support the Tribes' hunting and

[19] 424 U.S. 800, 96 S.Ct. 1236

[20] In full, the Amendment states that:

(a) Consent is given to join the United States as a defendant in any suit (1) for the adjudication of rights to the use of water of a river system or other source, or (2) for the administration of such rights, where it appears that the United States is the owner of or is in the process of acquiring water rights by appropriation under State law, by purchase, by exchange, or otherwise, and the United States is a necessary party to such suit. The United States, when a party to any such suit, shall (1) be deemed to have waived any right to plead that the State laws are inapplicable or that the United States is not amenable thereto by reason of its sovereignty, and (2) shall be subject to the judgments, orders, and decrees of the court having jurisdiction, and may obtain review thereof, in the same manner and to the same extent as a private individual under like circumstances: Provided, That no judgment for costs shall be entered against the United States in any such suit.

(b) Summons or other process in any such suit shall be served upon the Attorney General or his designated representative.

(c) Nothing in this section shall be construed as authorizing the joinder of the United States in any suit or controversy in the Supreme Court of the United States involving the right of States to the use of the water of any interstate stream (43 U.S.C. § 666 (1976)).

[21] Jurisdiction was retained for a period of 5 years from the date of final judgment on appeal.

[22] The appeals court modified the initial judgment to incorporate a declaration of the government's water rights. The court specified the federal government's appurtenant water rights as the same as other non-Indian successors and the quantity and priority of their reserved water rights as consistent with the purposes and dates of the reservation. The court declared that "actual quantification of the rights to the use of waters of the Williamson River and its tributaries within the litigation area will be left for judicial determination, consistent with the decree in this action, by the State of Oregon under the provisions of 43 U.S.C. § 666 [the McCarran Amendment]." The McCarran Amendment waives the United States' sovereign immunity for the limited purpose of allowing the government to be joined as a defendant in a state adjudication of water rights (see footnote 20).

fishing rights as "currently exercised to maintain the livelihood of the Tribe members, not as these rights once were exercised." This language became the focus of the District Court's next *Adair* opinion (*Adair* III) in 2002. The appellate court also found that, although the Klamath Tribes once had exclusive access to the region's natural resources, their water right was limited to the amount necessary to "provide the Indians with a livelihood—that is to say, a moderate living."[23]

In *Adair* III, the District Court: (1) confirmed that the Tribes' reserved rights extend to gathering, and (2) rejected any argument that would have the practical effect of setting the Tribes' reserved water right at a level that does not support productive habitat.[24] Because diversion of water is not required to support fish and game, the water right reserved to further the Tribes' hunting and fishing purposes is "unusual in that it is basically non-consumptive…. Rather, the entitlement consists of the right to prevent other appropriators from depleting the streams [sic] waters below a protected level in any area where the non-consumptive right applies."[25]

As defined by the *Adair* courts, treaty rights apply only to members of the Tribes and cannot be transferred to nontribal successors. Specifically, the United States and individual non-Indian successors did not acquire water rights of the same type that tribal members possess when they acquired reservation lands. Rather, they acquired water rights consistent with the purposes of their own reservation of the land (in the case of the federal government) or individual land uses (in the case of private landowners), with priority dates based on the date when the reservation was created.[26]

The progress of the *Adair* cases reflects a continuity of judgment over the past 25 years. The courts have consistently affirmed that the Klamath Tribes are senior right holders, that their priority dates to "time immemorial," and that tribal water rights are subject to state adjudication for quantities, although no adjudication may result in amounts below the minimum "necessary to support productive habitat."

The downstream tribes

In 1855, the President, by executive proclamation, established the Klamath Reservation (now the Yurok Reservation) in California. The Hupa Valley Reservation was formally set aside for Indian purposes by executive order in 1876. (An 1891 executive order "extended the Hoopa Valley Reservation to include the old Klamath Reservation and the strip of land connecting the two reservations.")[27] The executive orders establishing the downstream reservations also reserved rights to an in-stream flow of water sufficient to protect the tribes' rights to take fish within their reservations. The Yurok and Hupa Valley tribes' fishing rights entitle them to take fish for ceremonial, subsistence, and commercial purposes.[28]

The 1988 Hoopa Yurok Settlement Act (HYSA)[29] reaffirmed these rights and partitioned the Reservation into the present Hupa Valley and Yurok reservations, declaring the assets of each reservation held in trust by the United States for the benefit of the respective tribes.[30] "As with the Klamath Tribes, the Yurok and Hoopa Tribes' water rights include the right to prevent other appropriators from depleting the streams' waters

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[23]Quoting from *Arizona v. California*, 373 U.S. 546, 83 S.Ct. 1468 (1963).

[24]In addressing an attempt by some defendants to interpret the appellate court's "as currently exercised" language as the definitive measure for quantifying the tribal water right, the court stated that the quantification standard must focus on fulfilling the purpose of the reservation. The court established the minimum level of the tribal water right as that which is "necessary to support productive habitat." "A stream without water cannot be reconciled with the purpose of the tribal right which is to 'guarantee continuity of the Indians' hunting and gathering lifestyle.'"

[25]Quoting from *Adair* II.

[26]Here the *Adair* II court cites *Colville Confederated Tribes v. Walton*, 647 F.2d 42 (9th Cir. 1981).

[27]See *Mattz v. Arnett*, 412 U.S. 481, 493–494, 37 L.Ed.2d 92, 93 S.Ct. 2245 & app. (1973).

[28]*United States v. Eberhardt*, 789 F.2d 1353, 1359 (9th Cir. 1986)

[29]25 U.S.C. § 1300i et seq.

[30]25 U.S.C. § 1300i-l(b)

below a protected level."[31] The Karuk claim an unextinguished aboriginal fishing right and are seeking federal clarification of this right.[32]

Federal–state–tribal relations

The State of Oregon has been in the process of adjudicating the allocation of water in the Upper Klamath Basin since 1976 (see Chapter 3, "Legal Aspects"). Nonetheless, despite general judicial and Congressional deference to state law in water allocation, federal ESA and treaty responsibilities led the federal government to, in effect, reallocate Klamath River and Upper Klamath Lake water in 2001. Tribally commissioned studies of fish populations helped to construct the legal and scientific basis for this action.

Unanswered at this time is how the exact quantification of water rights in the Klamath Basin will occur.[33] Although the courts have located quantification clearly within state jurisdiction, the quantity and timing of in-stream water required to support game and fish now are the subject of federal agency-managed inquiry under the ESA. Tribal claims fortify this process. Federal deference to state water law, combined with federal responsibilities to the tribes and under the ESA, creates an unresolved ambiguity. Affected agricultural interests have sought review of relevant federal decision-making and its underlying science, the current *de facto* determinants of Upper Klamath Basin water allocation. Where states show the capacity and willingness to respect and settle tribal claims,[34] opportunities for cooperative outcomes tend to increase.

The Endangered Species Act

Congress enacted the ESA in 1973 "to provide a program for the conservation of ... endangered and threatened species."[35] The Act requires federal agencies to avoid causing jeopardy to any such species through actions that affect the viability of the species or its habitat. In the drought year of 2001, avoidance of jeopardy for Upper Klamath Lake suckers and Klamath River coho salmon required a major federal reallocation of water from agriculture to habitat protection. The cost fell heavily on farmers, farmworkers, and farm communities.

Although the Project uses, on average, only one-third of the available flow into Upper Klamath Lake, and a far smaller portion of the Klamath River system's total discharge, it was required to respond to a basinwide problem that was only partially of its own creation. Many factors outside the Project have contributed to the decline in fish populations. Among them are:

- Upstream land-use practices that increase nutrient runoff and stimulate algal blooms in Upper Klamath Lake
- Development and diversion of water resources in downstream tributaries that decrease spawning habitat and diminish water quality and quantity
- Overfishing
- Hydroelectric facilities that block natural fish migration
- Logging practices along the length of the Klamath River
- Road-caused erosion and water redistribution
- Sediment from construction and fire sites

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[31]Solicitor Opinion, 1995, citing Joint Board of Control, 832 F.2d at 1131–1132; *Adair*, 723 F.2d at 1411; and also *Kittitas Reclamation District*, 763 F.2d at 1033.

[32]Although the Karuk were not included in *Parravano*, their proximity to and apparent similarity with the Hupa and Yurok tribes suggest that their rights are of similar origin.

[33]Note that the Lower Basin Yurok, Karuk, and Hupa tribes are not party to Oregon's Upper Basin adjudication because their reservations are in California, a vivid example of the jurisdictional fragmentation common in the Klamath Basin.

[34]See Thorsen (1986) and Sly (1988) for discussion of negotiated settlements between states and tribes over the extent of reserved rights. The State of Montana has been particularly active in the use of such settlements, which typically involve various types and amounts of federal contribution to help resolve remaining issues.

[35]16 U.S.C. § 1531(b). The purposes of the ESA are "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve [these] purposes…." Id. § 2(b).

Although the ESA has not been applied to many of these activities, the Bureau of Reclamation is forbidden from inflicting further jeopardy on a listed species through its actions.[36] Thus, in 2001, the ESA seemed to become the dominant water policy in the Upper Klamath Basin, and its federal processes controlled water allocation decisions. Several court cases help us to understand the legal sources of this power.

TVA v. Hill (1978)

In this case, the U.S. Supreme Court examined the legislative background of the ESA in great detail and established Congress' clear and unambiguous intent that species preservation is among the "highest priorities." The Court determined that the ESA requires federal agencies to avoid jeopardy "whatever the cost."

The case involved the nearly complete Tellico Dam in Tennessee and a small, endangered fish, the snail darter. The snail darter's habitat would be destroyed if the reservoir behind the nearly complete dam was filled. The Secretary of the Interior declared the affected section of the Little Tennessee River "critical habitat," and environmental groups sued to halt dam construction. The Supreme Court affirmed the Court of Appeals injunction to halt all activities that would destroy or modify critical habitat, even though Congress had appropriated, and the TVA had expended, about $100 million on dam construction.

The underlying situation in the TVA case was analogous to that in the Upper Klamath Basin, but there are two major differences. First, the Klamath situation involved existing beneficiaries (irrigators) who depended on water deliveries that had been reliable for a century, while the Tellico Dam had not begun to yield tangible benefits or dependence upon them. Second, the costs resulting from the Court's decision in *TVA* never were placed solely on local communities, but were absorbed nationally,[37] while the costs in the Upper Klamath Basin initially fell entirely on the agricultural population in and around the Project. (Taxpayers subsequently have paid more than $30 million of the cost in the form of federal and state transfer payments to Project irrigators and landowners, as well as various community assistance programs.) This differential distribution of burden reflects a substantial shift of ESA applications from situations with lighter consequences or wider sharing of burden (e.g., the Tellico Dam) toward one with greater consequences and narrower placement of burden (the Upper Klamath Basin in 2001).

Klamath Water Users Association v. Patterson (1998)

This case, too, was driven by ESA compliance and impacts of water operations on endangered species. The BOR proposed operation of the Klamath Reclamation Project in a way that would have resulted in flows of 1,000 cubic feet per second (cfs) from the Link River Dam, the flow-controlling structure at the outlet of Upper Klamath Lake. However, this level of flow would have violated the Federal Energy Regulatory Commission (FERC) license of PacifiCorp, the private operator of the dam, which specified a flow of 1,300 cfs in September. The two parties resolved the discrepancy in flow standards by making the BOR's recommended flow contingent on concurrence by FERC. The Klamath Water Users Association (KWUA) sought a temporary restraining order, arguing that the redistribution of flows would damage their interests and that they were, therefore, entitled to third-party beneficiary status.

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[36] 16 U.S.C.A. § 1536 (2) states: "[each] Federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency (hereinafter in this section referred to as an 'agency action') is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with affected States, to be critical, unless such agency has been granted an exemption for such action by the Committee pursuant to subsection (h) of this section. In fulfilling the requirements of this paragraph each agency shall use the best scientific and commercial data available."

[37] After the *TVA* decision, Congress exempted the TVA project, the snail darter was successfully relocated, and the Tellico Dam was completed.

Project irrigators had water delivery contracts with the BOR (known as "repayment contracts"). Judge Michael R. Hogan's opinion stated that the "vast majority"[38] of these contracts provided that in the event of "drought, canal breaks, inaccuracy in distribution, or other causes, there may occur at times a shortage in the water supply provided for herein for lands of the [Reclamation] District and, while the United States will use all reasonable means to guard against such shortages, in no event shall any liability accrue against the United States ... for any damages, direct or indirect, arising therefrom.…"[39]

This case illuminates the complexities of water contracts and the conditionality of their benefits—i.e., their dependence on water availability, other water claims, and federal regulations not specified in the contract. Judge Hogan decided that PacifiCorp and members of the KWUA had separate contractual arrangements with the BOR—the former for dam operations, the latter for irrigation water. Although PacifiCorp and the KWUA relied on the same flow and contracted with the same agency, distinct contracts and conditions governed the relationship in each case. Thus, the KWUA was not a third-party beneficiary under PacifiCorp's contract with the BOR and could not legally influence or otherwise seek to modify the relationship between them. Judge Hogan further stated that the KWUA members' contract rights were subordinate to senior tribal rights and to the claims of subsequent legislation such as the ESA.

The KWUA appealed the decision in *Klamath Water Users Assoc. v. Patterson* (1999). Judge A. Wallace Tashima found that federal law controlled the interpretation of the contracts in this situation. Looking to *Kennewick I.D. v. U.S.*[40] for guidance, he declared that a contract must be read as a whole and that its terms are to be given their ordinary meaning (i.e., what a contract says in plain language is preferable to other ambiguous meanings). The appeals court distinguished between intended and incidental beneficiaries and affirmed the District Court finding, including the BOR's responsibility to "divert the water and resources needed to fulfill the Tribes' rights [that] take precedence over any alleged rights of the irrigators."

Pacific Coast Federation of Fishermen's Ass'n v. Bureau of Reclamation (2001)

In May 2000, various conservation and fishing interests filed a lawsuit challenging the BOR's 2000 KPOP. They alleged that the BOR violated the ESA in 2000 by releasing water for irrigation and water flows in the Klamath River prior to required consultation with the National Marine Fisheries Service (NMFS) regarding the Project's effects on coho salmon. Judge Sandra Brown Armstrong agreed. In a ruling on April 3, 2001, she enjoined the BOR from sending irrigation deliveries to the Project when the Klamath River at Iron Gate Dam dropped below certain minimum flows.

The specified minimum flows were those recommended in a study commissioned by the Department of the Interior and the Bureau of Indian Affairs, known as the Hardy Phase I report after Dr. Thomas Hardy, the leader of the scientific team.[41] These flow standards would hold until the BOR completed a plan and consultation with the NMFS to guide operations in the new water year (2001). The BOR's consultation with the NMFS required either a formal "no jeopardy" finding by the NMFS or its written concurrence that the 2001 KPOP was unlikely to adversely affect coho salmon.

Judge Armstrong's decision in *Pacific Coast Federation* sheds additional light on the complex interactions among various water contracts and

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[38]*Klamath v. Patterson,* 15 F. Supp. 2d 990; 1998 U.S. Dist. LEXIS 1884

[39]Declaration of Karl Wirkus [# 163] Ex. B, pp. 12–13. Cited in *Klamath v. Patterson* (1998), affirmed in *Klamath v. Patterson*, 204 F.3d at 1213 (9th Cir. 1999).

[40]880 F.2d 1018, 1032 (9th Cir. 1999)

[41]Prepared by the Institute for Natural Systems Engineering (INSE), Utah Water Research Laboratory, Utah State University. The report sometimes is referred to as the INSE report.

laws within a legally established hierarchy of federal responsibility. It stated:

> "[T]he Secretary of the Interior, through the Bureau of Reclamation, must manage and operate the Klamath Project pursuant to various legal responsibilities. Pursuant to the Reclamation Act of 1902 the Bureau of Reclamation has entered into contracts with various water districts and individual water users to supply water, subject to availability, for irrigation purposes. Two national wildlife refuges, the Lower Klamath and Tule Lake national wildlife refuges, also are dependent on the operations of Klamath Project and have Federal reserved water rights to the amount of water, unreserved at the time of creation of the refuges, necessary to fulfill the primary purpose of the refuges. In addition, the Secretary of the Interior has recognized that a number of Oregon tribes, including the Klamath, Yurok and Hoopa valley tribes, hold fishing and water treaty rights in the [Klamath] basin. The Bureau of Reclamation has an obligation to protect tribal trust resources, including the Klamath River coho salmon. It also has an obligation under the ESA not to engage in any action that is likely to jeopardize the continued existence of an endangered or threatened species or result in the destruction or adverse modification of the critical habitat of such a species" [citations omitted].

The 2001 KPOP

The Armstrong decision set the stage for the 2001 KPOP, and the Klamath conflict came to a head in the 3 days following the decision. The BOR had initiated formal ESA consultations in early 2001 by forwarding Biological Assessments of the effects of Project operations on suckers and coho salmon to the USFWS and the NMFS. Both agencies had found that Project operations likely would jeopardize the species under their purview, suckers and coho salmon, respectively. The USFWS proposed a Reasonable and Prudent Alternative (RPA) for a minimum elevation of Upper Klamath Lake to improve water quality, increase habitat for juvenile and adult suckers, and provide greater access to spawning areas (see Chapter 5, "Suckers"). The NMFS RPA proposed a range of minimum in-stream flows to increase riparian habitat for coho salmon in the Klamath River below Iron Gate Dam from April through September 2001, as well as to assist migrating salmon smolts in the spring (see Chapter 6, "Coho Salmon"). Upon review of these draft Biological Opinions, the BOR informed the USFWS and the NMFS that the forecasted water supplies for 2001 were insufficient to meet the needs of both RPAs.

On April 6, 2001, the USFWS and the NMFS released their final Biological Opinions. They adjusted the minimum Upper Klamath Lake elevations and Klamath River flows to reflect the reduced water availability in the 2001 water year. On the same day, the BOR issued its 2001 KPOP. The Plan incorporated the conclusions contained in the Biological Opinions and implemented the RPAs. So little water remained that most Project lands received no water deliveries in 2001.

Basin water users filed a procedural challenge to the 2001 KPOP in the U.S. District Court for the District of Oregon.[42] Stephen Kandra, David Catka, Klamath Irrigation District, Tulelake Irrigation District, Klamath Water Users, et al. sought injunctive relief from implementation of the plan, claiming that it breached their contracts and was "arbitrary and capricious" under the Administrative Procedures Act (APA).

The National Environmental Policy Act of 1969[43] requires federal agencies to issue an Environmental Impact Statement (EIS) if they undertake a "major federal action." Kandra et al.

[42] *Kandra et al. v. U.S.,* 145 F. Supp. 2d 1192 (2001)

[43] 42 U.S.C.A. §§ 4321–4361

asserted that the operational changes in the 2001 KPOP constituted such an action. The court disagreed. If it were to find otherwise, it noted, federal agencies would be constantly preparing EISs. Additionally, even if an EIS were required, the BOR would not be able to obtain the required information (stream flow forecasts from the Natural Resources Conservation Service, Biological Opinions from the NMFS and the USFWS) in time to prepare an EIS before the irrigation season.

> "As an initial matter, plaintiffs' characterization of Reclamation's duty to protect ESA species and tribal resources as a 'change in operations' implemented in response to various 'demands' is inaccurate. Reclamation has responsibilities under the ESA as a Federal agency. These responsibilities include taking control of the [Project] when necessary to meet the requirements of the ESA, requirements that override the water rights of the Irrigators."[44]

Similarly, the United States, as trustee for the Tribes, is obligated to protect the Tribes' rights and resources. Water rights for the Klamath Tribes "carry a priority date of time immemorial."[45] These rights "take precedence over any alleged rights of the Irrigators."[46] The BOR, therefore, has a responsibility to divert the water and resources needed to fulfill the Tribes' rights. As such, its "change in operation" was mandated by law, and the requirements of NEPA did not apply.[47]

Judge Ann Aiken wrote that, as in *TVA v. Hill*, "the ESA requires an agency to avoid jeopardy [to an endangered] species, 'whatever the cost.'" In this case, that meant reallocating water for fish habitat. Her opinion identified the endangered shortnose and Lost River suckers and threatened coho salmon and bald eagles as species for which the Bureau of Reclamation is accountable. It also identified the BOR's responsibilities to the Klamath, Hupa, Yurok, and Karuk tribes. It recognized the need for a long-term operations plan and chastised the BOR for not completing one.

While Judge Aiken acknowledged that undisputed economic hardship would occur as a result of the 2001 KPOP, she stated:

> "Threats to the continued existence of endangered and threatened species constitute ultimate harm. Congress has spoken in the plainest of words, making it abundantly clear that the balance has been struck in favor of affording endangered species the highest of priorities, thereby adopting a policy which it described as 'institutionalized caution.'[48] As recognized by the District Court and the Ninth Circuit, the plaintiffs' contract rights to irrigation water are subservient to ESA and tribal trust requirements (see *Patterson*). Therefore, plaintiffs could not assert breach of contract based on the BOR's allocation of water to protect suckers and coho salmon."

Kandra et al. also argued that the NMFS and the USFWS selectively reported information in the Biological Opinions and ignored other relevant scientific evidence. They would have had the court substitute its analysis of the relevant science for that of the expert agencies. Under the Administrative Procedures Act, however, an agency decision must be upheld unless it is "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law."[49] The court is not empowered to substitute its judgment for that of the agency.[50]

> "When specialists express conflicting views, an agency must have discretion to rely on the reasonable opinions of its own qualified experts even if, as an original

[44] *Patterson*, 204 F.3d at 1213

[45] *Adair*, 723 F.2d at 1414

[46] *Patterson,* 204 F.3d at 1214

[47] *National Wildlife Federation v. Espy*, 45 F.3d 1337, 1343 (9th Cir. 1995)

[48] *Tennessee Valley Authority v. Hill*

[49] 5 U.S.C. § 706

[50] *Citizens to Preserve Overton Park, Inc. v. Volpe,* 401 U.S. 402, 416, 28 L.Ed.2d 136, 91 S.Ct. 814 (1971)

matter, a court might find contrary views more persuasive.[51] In other words, a court may reverse the agency's decision as arbitrary or capricious only if the agency relied on factors Congress did not intend it to consider, entirely failed to consider an important aspect of the problem, offered an explanation that ran counter to the evidence before the agency, or offered one so implausible that it could not be ascribed to a difference in view or the product of agency expertise."[52]

Absent a showing that the NMFS or the USFWS failed to consider relevant, available, scientific data, plaintiffs were unlikely to prevail on this claim. Even if they could have succeeded on the merits of their ESA claims, the ESA explicitly prohibits the relief they sought—an injunction against implementation of the KPOP.

The *Kandra et al.* decision relied on *TVA* and was consistent in favoring protection of endangered species over other interests. Unlike the Klamath situation, however, *TVA* did not involve an existing set of beneficiaries who had immediate need of, and reason to expect, deliveries of water. Although these circumstances do not affect the legal construction, legitimacy, or implications of the court's verdict, the social effects in the Upper Klamath Basin are considerably more immediate and certain than in previous instances. In this way, the underlying circumstances of the *Kandra* case may be understood to expand the range of acceptable economic consequences of the ESA. We also note that similar effects have been avoided in other basins with equivalent stakes through efforts to find compromise solutions. (See "Cohesion and coordination," later in this chapter.)

Differential application of the ESA

The financial stakes in the Klamath Basin are modest when compared with those in other basins that confront ESA issues, such as the Columbia and Sacramento-San Joaquin. In those cases, similar sets of federal and state agencies faced conflicts like those in the Klamath Basin. However, those basins have integrated systems of hydroelectric plants, water storage and conveyance structures for agricultural and municipal use, and navigation enhancements that directly serve tens of millions of people. The costs of rigid ESA compliance in those circumstances would be magnitudes greater than those incurred in the Klamath Basin. To date, those basins have avoided rigid ESA compliance through a variety of alternative arrangements.

Takings

"[T]he Fifth Amendment is violated when land-use regulation 'does not substantially advance legitimate state interests or denies an owner economically viable use of his land.'"[53] This situation is termed a "taking." The courts have found takings to be a compensable action: the government must compensate property owners if it denies them the use of their property. Here we examine the defining Supreme Court takings case, *Lucas*, and a recent Court of Federal Claims trial that shares characteristics with the situation in the Upper Klamath Basin, the *Tulare* case.

Lucas v. South Carolina Coastal Council (1992)

This is a (if not the) leading takings case. It involved a beachfront property owner with "investment-backed expectations" who was prohibited from developing his property by subsequent state legislation. In defining the boundaries of the Beachfront Management Act, South Carolina imposed the burden of preventing dune erosion on a subset of property owners of which Lucas was a member. The principal question posed was whether the owner had been deprived of all economically beneficial use of the land (bundle of rights) as a consequence of regulation. (Even where that is the case, however, it is argued that if "background principles" are in existence that preclude nuisance or other

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[51] *Marsh v. Oregon Natural Resources Council*, 490 U.S. at 378

[52] *Western Radio Service Co. v. Espy*, 79 F.3d 896, 900 (9th Cir. 1996) (citing *Dioxin/Organochlorine Center v. Clarke*, 57 F.3d 1517, 1521 (9th Cir. 1995))

[53] Justice Scalia quoting from *Agins*, 447 U.S. at 260 in the *Lucas* opinion.

undesirable uses of a property, the state may prohibit those uses without compensation. In other words, those uses were not part of the title to begin with, and the owner always was prohibited from them.)

In *Lucas,* the Supreme Court found that the lower court had used the wrong standard in determining whether the state beachfront management statute effected a taking of Lucas' property. The Court sent the case back to the lower court for proceedings "not inconsistent" with the Supreme Court's verdict, where the state's action was held to be a taking.[54]

The principle of disproportionate burden is implied in the Supreme Court's verdict, although it is not the focus. In the Upper Klamath Basin situation, however, this is a key argument. The jurisdiction of the BOR is a subset of burdened *property* users within a larger group of users in the Basin. We emphasize property, because the repayment contracts under which water is provided to Klamath Project irrigators contain "hold harmless" clauses, which specifically state that interruptions in water delivery for a variety of reasons are not a breach of contract.[55] This fact makes Project irrigators' takings claim more difficult to argue, since the claim would be based not on an alleged breach of contract, but on an alleged taking of their right to economically beneficial use of property. Such a claim evidently is not beyond reach, as the next case, *Tulare*, demonstrates.

Tulare v. U.S. (2001)

This trial concerned two species of fish that the USFWS and the NMFS determined to be in jeopardy of extinction, the delta smelt and the winter-run chinook salmon, respectively. The agencies' efforts to protect the fish by restricting water outflows in California's primary water distribution system, the Bay-Delta, brought the ESA into conflict with California's century-old regime of private water rights. Judge John P. Wiese wrote that "[t]he intersection of those concerns, and the proper balance between them, lie at the heart of this litigation." Note that this case is controversial, and the decision may yet be appealed and overturned.

In this case, water contractors chose not to rely on arguments based on their water contracts, which contained specific exclusions. Instead, they made the claim against the regulatory agencies (the NMFS and the USFWS) that issued Biological Opinions requiring the contracting agency (the California State Water Project) to leave water in the watercourse for species and habitat protection. The water contractors claimed that they were deprived of water as a result of these regulatory actions.

In his discussion of the case, Judge Wiese wrote that "[t]he Fifth Amendment to the United States Constitution concludes with the phrase: 'nor shall private property be taken for public use, without just compensation.'" The purpose of that clause is "to bar Government from forcing some people alone to bear public burdens which, in all fairness and justice, should be borne by the public as a whole." At issue was not whether the federal government has the authority to protect the winter-run chinook salmon and delta smelt under the ESA, but whether it could impose the costs of their protection solely on plaintiffs.

The decision explained the difference between physical and regulatory takings. A physical taking occurs when the government's action amounts to a physical occupation or invasion of the property, including the functional equivalent of a "practical ouster of [the owner's] possession." By contrast, a regulatory taking arises "when the government's regulation restricts the use to which an owner may put his property." Judge Wiese found that the federal government's actions, through the USFWS and the NMFS, were a physical taking. He found that "the Federal government is certainly free to preserve the fish; it must simply pay for the water it takes to do so."

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[54]See Sax, J. 1993. "Property rights and the economy of nature—Understanding *Lucas v. South Carolina Coastal Council*," *Stanford Law Review*, Vol. 45, No. 5 (May):1433–1455, for an extended discussion of the significance of this decision.

[55]See the discussion in the section entitled "*Klamath Water Users Association v. Patterson,*" earlier in this chapter.

With this decision, Judge Wiese found irrelevant all recent state–federal agreements, such as those under the CALFED[56] umbrella, which emphasize the correlative nature of response to scarcity. In correlative responses, all parties absorb scarcity through mutually equitable adaptations to available supply.[57] Instead, the decision highlights a fundamental tension between dynamic ecosystems, sustainability, and evolving water policy on the one hand and water rights claims and "promissory assurances" written into contracts frozen in time on the other.

A takings claim has been filed in the Upper Klamath Basin in the Federal Claims court based on the reasoning that prevailed in *Tulare*. Following *Tulare*, filing suit against the USFWS and the NMFS is a charted course that the Klamath Water Users Association can and has readily adopted, with the same legal representation (Marzulla & Marzulla) that succeeded in *Tulare*.

Executive responses to judicial decisions

When courts rule against the federal government, the Administration and its agencies can choose how to respond. The option selected shapes policy direction and implementation.

For example, in *Alsea Valley Alliance v. Evans,*[58] District Court Judge Hogan held that the NMFS erred by not including hatchery-bred salmon in determining ESA listings.[59] The NMFS, having the choice to appeal or not, refrained from appealing the decision and instead chose to review its hatchery fish policy for the listed coho salmon, as well as for 20 other ESA listings that include hatchery-bred salmon. In the absence of an appeal, the argument that hatchery and wild stocks are no different goes unchallenged. Subsequent litigants, courts, and agencies facing species listings thus will be offered an untested precedent.

The Administration also may appeal too weakly to win a case. In *State of Idaho v. United States Forest Service* (2001),[60] for example, the Justice Department conceded that the Forest Service's roadless rule, which restricts access to designated areas within national forests, would cause logging and snowmobiling interests irreparable harm. With this statement, the Administration undermined any defense of the rule, while publicly announcing its support for it.

By choosing not to appeal or by offering a weak appeal, rather than an effective one, an Administration may advance the case that the costs of the ESA are disproportionate to the benefits it provides, or at least are allocated inequitably. Its choice may depend on the extent of the financial stakes in the particular case. No direct monetary damage has been alleged against the United States in the *Idaho* case, thus reducing the likelihood of interagency friction—between agencies with financial responsibility and those with substantive responsibility—over the Administration's decision to present a weak defense. The *Tulare* case, on the other hand, involves monetary damages, so different parts of the Administration (the Department of Justice and the Department of Interior, for example) may have different views on the appropriate response. Although the penalty phase has not yet occurred in *Tulare*, newspaper reports cite estimates of up to $15 million in compensation due to the plaintiff irrigators.

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[56]CALFED is a large-scale state–federal cooperative effort to resolve complex water problems in and around the California Bay-Delta. See further discussion under "Balance of responsibility and capacity," later in this chapter.

[57]Examples include the Bay-Delta accord in 1994 and the Framework for Action and Programmatic Record of Decision in 2000.

[58]Case No. 99-6265-HO (D. Ore. September 10, 2001)

[59]The court ruled that because the NMFS had not distinguished hatchery-spawned coho salmon and wild stocks as "distinct population segments" when it listed coho as endangered in 1998, it cannot develop ESA compliance strategies based on extinction threats for wild salmon runs alone. The NMFS must treat both hatchery stocks and wild stocks as a single resource under the ESA, despite the fundamental differences in spawning behavior caused by human intervention in hatchery operations.

[60]Case No. CV01-11-N-EJL, District Court for the District of Idaho, April 2001

Issues raised by the 2001 KPOP

Our assessment of the legal context of the 2001 KPOP shows that the decisions leading up to the abrupt halt of irrigation supplies to Project irrigators from Upper Klamath Lake were consistent with existing law and did not set precedents of judicial interpretation. However, the consequences of these decisions seem to raise some issues to potentially precedent-setting levels. In particular, these issues relate to:

- The legitimate extent of private burden for a public purpose
- The appropriate balance between scientific uncertainty and socioeconomic burden
- The reasonable stress between administrative procedures and the natural and social processes in which they are used
- The acceptable tension between absolute water claims and dynamic natural and social systems
- The relationship between tribal treaty rights, state systems of water rights adjudication, and federal laws that effectively control water allocation in certain circumstances

These issues arose from an outcome that was more extreme than any previous application of the ESA. In other words, although the policy was consistent with prevailing law, its application may test the "whatever-the-cost" standard. When viewed in combination with the *Tulare* decision, the Upper Klamath Basin water allocation decisions of 2001 may lead "stakeholders," legislators, agencies, and courts confronting claims in the Columbia, Sacramento-San Joaquin, and other river basins to weaken the ESA. Alternatively, these circumstances could motivate Klamath Basin interests to coalesce and build a social fabric that can shape how the ESA is implemented, and how the benefits and burdens of satisfying specific public interests are distributed, within a context of diverse and important basin interests. A later section of this chapter, "Strategies for change," discusses that possibility.

Social and institutional fragmentation of a common river

Although the parts of a river basin are hydrologically interdependent, a basin rarely, if ever, displays social integration in the absence of major commitments to unify and coordinate activities affecting shared interests.[61] Basins are divided among groups, agencies, and jurisdictions that respond to forces—markets, politics, culture, law, and administrative demands—originating elsewhere and unrelated to the basin in which they happen to converge. Policy impacts depend on how well the jurisdictions, agencies, and interest groups within a basin overcome their differences to advance a common vision and to distribute benefits and burdens so as to move actions toward the common good.

As the previous section shows, the ESA is a clear and strong policy. Congress and the courts have given priority to the protection of endangered species, "whatever the cost." Court interpretations have given it dominance over tribal rights, and tribal rights over irrigators' rights. But the actual consequences of a policy, as contrasted with its legal form, depend partly on the capacities and inclinations of the jurisdictions, agencies, and communities that implement the policy and/or respond to its implementation. A policy's outcome depends on actions that intervene between the words setting forth the policy and the tangible effects of the policy. The motives, qualities, and strengths of these actions vary tremendously from place to place. Thus, a policy, although uniform in word for all, will result in very different tangible effects from place to place.

The strong consequences of the ESA in the Upper Klamath Basin reflected the Basin's amorphous capacities to turn the law toward preferable ends, and perhaps toward easier and better fulfillment of the intent of the law. The

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[61]Romm J. 1994. "Watersheds and social systems: Linking causes and consequences of watershed activities." In D. Erman, ed. *Obstacles to Watershed Management* (Water Resources Center Report No. 81, University of California, Davis).

Klamath Basin is characterized by sharp social and jurisdictional divides. It is no different in this regard than any other basin. However, the Klamath has not yet developed a set of shared interests that could help to overcome divisions, as has occurred elsewhere. Moreover, changes in the relative powers among Basin interests—e.g., agricultural, tribal, and environmental—have left agencies with formal responsibility and authority (such as the Bureau of Reclamation) stranded on a foundation of eroding social power. The consequences are weak collective capacity for the Basin as a whole and distributions of authority and responsibility that are inconsistent with distributions of capacity for effective action. In these circumstances—social and institutional fragmentation and basinwide responsibility placed on an agency whose capacity is too narrow to satisfy this responsibility—a policy such as the ESA takes on the power of coordination by default.

In this section, we review the distribution of power and interest within the Klamath Basin and their relations with existing structures of authority. We draw comparisons with situations in which applications of the ESA have drawn forth outcomes different than those that have developed thus far in the Klamath. We also examine patterns of response in basins with analogous distributions of social power, but where compensating capacities have permitted some reasonable balance in the distribution of responsibility, benefits, and burdens of decisions. Our analysis suggests possible strategic directions for creating institutional relations that can prevent future crises and advance interests in the Klamath Basin as a whole.

The Klamath Basin

The social and jurisdictional fabric of the Klamath Basin is characterized by fragmentation. Divisions exist between the tribes and Euro-American settlers, between upstream and downstream populations, and between agricultural and environmental interests (see Chapter 9, "Communities"). They also exist among federal, state, and tribal forms of sovereign power. Even among federal agencies, divisions are seen between older, propertied agencies (e.g., the BOR, Forest Service, and Bureau of Land Management) and ascending specialized, functional agencies (e.g., the NMFS, USFWS, and Environmental Protection Agency). The former hold upland territory, while the authority of the latter is penetrating swiftly upstream via specialized authorities for species, water quality, and habitat.[62]

The division of the Basin between California and Oregon complicates the situation. The two states have, despite certain appearances of similarity, different systems of water law and administration, which must function within dramatically different political, demographic, and economic contexts. The Upper and Lower Basins have operated as virtually separate provinces, connected primarily by the shared flow of the river.[63]

Each of the four major tribes represents a different group of Native American languages, ethnicities, and histories.[64] The Yurok Tribe is the westernmost extension of the Algonquin group, which also includes the Cree, Ojibwa, Cheyenne, and Blackfoot. The Hupa are part of the Athabaskan group, which ranges from the Navajo and Apache in the south to the Kweich'in in arctic Alaska and the Yukon. The Karuk are northernmost in a group that includes the Pomo, the Chumash of the Tehachapi region, the Yuma

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[62]Romm, J. 2000. "California forest policy must bend to the new social order." *California Agriculture* (March):35–42.

[63]The Trinity diversion, under BOR responsibility, has sent approximately 800,000 acre-feet per year into the Central Valley system. Administration promises in 2000 to almost halve the flows diverted from the Trinity-Klamath Basin seem to have stalled. The Hupa have sued for fulfillment of these promises.

[64]See, for example, Heizer, R.E. and M.A. Whipple. 1971. *The California Indians: A Source Book,* 2nd ed. (University of California Press, Berkeley); Josephy, A. 1968. *The Indian Heritage of America* (Houghton Mifflin, Boston); Powers, S. 1877 (reprinted 1976). *Tribes of California* (University of California Press, Berkeley); Boaz, F. and J.W. Powell. 1966. *Handbook of American Indian Languages (1911) and Indian Linguistic Families of American North of Mexico (1891)* (University of Nebraska Press, Lincoln); Heizer, R., ed. 1978. *Handbook of North American Indians: California* (Smithsonian Institution, Washington, DC).

and Havasupai in the Colorado Basin, and various tribes in Mexico. The Klamath-Modoc are part of a group that includes the Nez Perce and Yakima northward and the Maidu and Miwok to the south.

The essential institutional quality of the Klamath River system is a fragmentation of interests and authorities without compensating relationships for conflict resolution and cooperation. Several aspects of this quality are readily visible. For example, the Klamath River's major tributary, the Trinity, has been managed primarily as an extension of the Central Valley and greater California water system. Thus, it is subjected to a different and external set of institutional and political dynamics that effectively isolates it from the Klamath. The tribes, although holding senior water rights, have until recently been largely isolated from decision processes about the river.

Other aspects of fragmentation are less obvious, but nonetheless significant. For example:

- Existing institutions for water allocation are both ambiguous and unbalanced in their distributions of *authority* (the formal responsibility to affect outcomes) and *power* (actual capacity to affect outcomes). Thus, the Bureau of Reclamation and the Project's irrigation districts have controlled the dominant levers of *authority* over Klamath River flows for almost a century, during which time the relative *powers* of tribal, environmental, and downstream interests have grown. The flip side of this situation is that the BOR and irrigation districts increasingly bear the responsibility and burden for satisfying others' increasingly powerful interests. The relationship between responsibility and capacity—or authority and power—in the Basin is unbalanced.

- With occasional exceptions, water allocation has been left to state law by the Constitution, the courts, and Congress. On the other hand, federal laws such as the Reclamation Act, the Termination Act, and the Endangered Species Act have tended to override this deference, creating *de facto* allocation of water by federal agencies. Native American water rights have been particularly vulnerable to the ebbs and flows of federal water allocation because they have depended so much on federal policy and often have been acknowledged only residually in state water allocation regimes. The resulting instability and uncertainty in water allocation would decline dramatically if federal, state, and tribal governments worked to form and fulfill a compact tied to the specific conditions of sovereignty in the Klamath Basin.

State water regimes focus upon the equitable allocation of water among users. Federal influences on water allocation arise from responsibilities for satisfaction of a national purpose. Tribal rights, which are federally administered under treaty and trustee relationships with the tribes, involve actual *and prospective* uses that satisfy a reservation's purpose *and* treaty-assured water regimes that secure *environmental conditions* necessary to sustain traditional livelihoods and cultures. The differences of interest that exist within this state–Indian–federal triangle of relationships create inherent fault lines and have caused state attention to tribal rights to depend heavily on federal representation of those rights.

Sly (1988) offers a concise summary of the divides among the corners of this triangle:

"Both states and tribes are insecure about their sovereignty. From a state perspective, the history of western water rights and water development is a continuing effort to retain local control over the resource. Federal funds are welcome, but not federal control. Long and difficult struggles have been fought by western states to retain primacy over their water administration systems. Now the federal government is reducing its funding for water projects in the West—at the same time its regulatory presence is increasing.

Thus, states are very sensitive to a federal- or Indian-system of regulation undermining state administrative power.

"Tribes are also sensitive to the historical efforts of states to absorb Indian reservations within their borders. Tribal sovereignty and powers are a primary concern to many tribal members, and state efforts to assert jurisdiction over reservation lands are seen as a threat to the tribal prerogative of self-government" (p 11).

The Klamath River Basin Compact was established in 1957 in an attempt to rationalize these relationships in a manner that advanced collective vision and enterprise. Reflecting the concerns of the time, it set priorities among *actual uses* of water and a basis for joint activities among the federal government and the states of Oregon and California. Tribes were included only as users the federal government was obligated to protect. Reflecting the power structure of the time, irrigation was assigned priority above all uses except drinking water. Federal regulation of in-stream quality and flow and tribal assertions of sovereignty (the Klamath Reservation was in the process of being disbanded) had no foothold in the social concept of the Klamath Basin in the mid-1950s.

- The authority of state water law and process over water allocation has grown steadily relative to property-based federal water rights, such as those of the BOR. At the same time, however, federal control over the qualities and consequences of water flow (fish populations, habitat, and water quality) has grown even more rapidly, leading to increased federal control over flow regimes themselves. Among the consequences are unresolved disparities between formal responsibility and actual capacity to control water allocations—disparities that exist between federal and state governments, among different federal agencies, and between the tribes and the states.

The ESA has great power in such a situation because it provides a source of cohesion and coordination where other sources are absent, and because it creates opportunities for influence by interests—tribes, environmentalists, and fishers—who lack formal authority commensurate with their capacity to control events. Below, we examine other situations in which the outcomes of the ESA have differed, apparently as a result of greater cohesion and coordination among interested parties.

Cohesion and coordination

Although no less divided than the Klamath Basin, systems with more cohesive relationships have bent the influence of the ESA to produce outcomes acceptable in their circumstances. In some cases, such as the Northwest Forest Plan to protect the spotted owl, federal funds and interagency coordination created incentives for the development of a collective interest and provided compensation for some associated losses. In other cases, such as the four-county Habitat Management Plan for the endangered gnatcatcher in southern California, local initiative, state brokerage, and federal interest provided impetus to a coalition of counties, real estate developers, environmentalists, and bankers, leading to patterns of urbanization that protected gnatcatcher habitat in financially viable ways.

In the Eel River Basin, a coalition of local environmental groups, the Round Valley tribes, fishers, and associated agencies (e.g., the NMFS, EPA, USFWS, and Bureau of Indian Affairs) has used the ESA to strengthen basinwide organization to promote return of Eel River water, now diverted to the Russian River, to the Eel Basin for salmon recovery and habitat restoration.[65]

[65]See Langridge, R. 2002 (forthcoming). "Changing legal regimes and the allocation of water between two California rivers." *Natural Resources Journal.*

In the Bay-Delta system of California, the endangered delta smelt provoked applications of the ESA that, instead of systemic seizure, produced CALFED, a consensus-oriented process of coordinated planning, finance, and investment.[66] Although the ESA provided the needed motivation and opportunity to develop CALFED, it now has been absorbed largely within the CALFED process as one of many rules and targets the CALFED is intended to satisfy (e.g., stabilized water supplies; increased efficiency of water storage, distribution, and use; and augmentation of delta flows by 800,000 acre-feet to improve smelt habitat). CALFED also creates a mode of federal–state cooperation that implicitly expands joint administrative control of water allocation, thus creating a new layer of water distribution mechanisms in California.[67]

A final example is the Tennessee Valley Authority,[68] which emerged predominantly through huge, New Deal infusions of federal money, capacity, power, and authority. These inputs compensated for the dearth of such resources in the seven basin states, and they were justified by satisfaction of a national purpose—the economic, social, and ecological development of perhaps the nation's most impoverished region. TVA became the first major legal target of the ESA (*TVA v. Hill*), perhaps because it was so clearly a federal project and had the capacity to distribute its losses widely.

The consequences of the ESA depended in all of these situations on the social context in which it was or might have been applied, and on the extent to which institutions could be developed to address water allocation questions in ways that were consistent with the variety of interests and capacities involved. In some cases, such as the Eel, relatively local coalitions sufficed for the initial stages of basinwide connection. In others, such as the gnatcatcher habitat plan, relatively equally distributed authorities, powers, and financial stakes required brokerage of various deals among the state, counties, and the private sector, thus leading to a collectively valuable regional arrangement. In CALFED, extensive federal engagement was essential in order to improve coordination among federal agencies, to dilute financial stresses that otherwise would overwhelm the potential for cohesive action, to establish reasonable federal parity with a strong state, and to solidify a system of joint federal–state responsibility and capacity for water allocation.

Balance of responsibility and capacity

As noted above, threats to endangered Klamath Basin fish derived from causes spread throughout the Basin, but the ESA placed the primary responsibility for protection on the Bureau of Reclamation. As a result, in 2001, the full burden initially fell solely on the Klamath Reclamation Project, its irrigators, farmworkers, and communities. In other words, there was a wide gulf between the dispersed causes of species endangerment and the concentrated responsibility for species protection.[69]

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[66]See Connick, S. 2002 (forthcoming). "The Use of Collaborative Processes for Making Water Policy in California: The San Francisco Estuary Project, the CALFED Bay-Delta Program, and the Sacramento Water Forum" (Ph.D. dissertation) for an extensive discussion of the CALFED process.

[67]California water law embodies a number of different water rights doctrines and distributive approaches. In one way or another, for example, it involves the riparian doctrine, the prior appropriations doctrine, and federal reserved water rights (treaty-based and reservation-based), as well as localized uses of the pueblo doctrine, implicit use of Mormon approaches to communal irrigation, administrative control and adjudication by the State Water Resources Control Board, and cooperative federal–state regulation of water quality and associated patterns of diversion, treatment, discharge, and land use.

[68]See Selznick, P. 1949. *TVA and the Grass Roots: A Study in the Sociology of Formal Organization* (Harper Row, New York) and Lilienthal, D. 1944. *TVA: Democracy on the March* (Quadrangle Press, Chicago).

[69]This situation would be described as "institutional failure" in resource economics, meaning that the boundaries and modes of exchange do not permit exchange that will overcome the disparity between those who cause and those who absorb the consequences of actions. See Chapter 19 ('Water Allocation Alternatives") and Chapter 20 ("Synthesis") for a discussion of analogous circum-stances within the Project.

Furthermore, the diversion of the Klamath River's main tributary, the Trinity, although also a federal action, was held apart from consideration of coho salmon habitat. In these circumstances, common cause between the people of the Project and those most affected by the Trinity diversion, e.g., the Hupa and Yurok tribes, might have been expected. As another example, the federal government might have felt that the costs of effective interagency coordination were justified by the public benefits of endangered species protection. In this case, it might have undertaken an approach similar to its efforts in the formation of CALFED under similar circumstances. Such actions did not occur, however, so the asymmetry between responsibility and capacity became a fundamental source of the strength of the ESA in the Basin.

Asymmetric patterns of responsibility and capacity exist elsewhere, and various institutional relationships have developed to compensate for them. We offer four examples, selected from far and wide for the clarity of their lessons about the relative distributions of power and authority. In the first, the dominant power is concentrated in the river delta (much as it once was concentrated in the Upper Klamath Basin), but it has gradually expanded its influence upstream and into the upland areas of the basin. The other three examples demonstrate organizational responses to basin relations in which the dominant power is located in the midreaches and upland sources of rivers. In these examples, as in the *TVA* case, national intervention has been required in order to achieve basinwide management of basinwide processes.

CALFED—California

CALFED has been discussed above. Here we return to it briefly as an example of a system built on delta-centered power. Agricultural, environmental, and urban interests had converged over time in response to the shared importance of the delta as the distributive core of California water. Catalyzed by impending applications of the ESA to delta species, CALFED gradually expanded its coordination, cooperation, and finance upstream from its core. It now involves, for example, increasing commitments to watershed restoration. At some future time, if the Klamath Basin is a useful comparison, CALFED's capacity no longer will suffice for the new constituencies and issues its authority comes to incorporate. In response, the organization likely will be transformed or replaced, or its functions may become more limited and specialized.

The Ganges-Brahmaputra Basin—India, Nepal, and Bangladesh

The Ganges-Brahmaputra Basin[70] contains almost half a billion people in three nations—Nepal in the headwaters, India in the midreach, and Bangladesh in the delta. Although the authorities of the three nations are equal—all have one vote in the United Nations, for example—India has the preponderant share of population, income, and financial and technical capacity. In this context, India has no motivation to enter into a basin arrangement in which all three parties have equal voice. Instead, cooperative arrangements have developed primarily through a triad of bilateral relations.

One side of the triad links upland Nepal and delta Bangladesh, joined by their need to influence midreach India's strategies of water storage, distribution, and use. For example, Nepal and Bangladesh cooperate in pushing for Indian reservoir storage in Nepal, with payment to Nepal and sufficient flows for Bangladesh in its dry season to satisfy ecological needs and compelling economic requirements. India and Bangladesh negotiate directly over the level and timing of transboundary flows of the Ganges and potential Ganges augmentations in India through diversions of the Brahmaputra River. Nepal and India negotiate on a basin-by-basin approach with respect to shares of political and financial entitlement and responsibility in cooperative projects. On a basinwide scale, consultative expertise, coordinated scientific investigations,

[70]See Rose, L., J. Romm, and B. Crow. 1997. *Regional Arrangements for Environmental Security and Sustainable Development in the Ganges-Brahmaputra Basin* (United Nations Development Programme, New York).

political and technical arenas for shared problem identification, and cooperative pursuit of financing are concentrated in various institutes, associations, and networks. The result is a loose fabric for addressing needs shared by all three nations.

The Mekong River—Southeast Asia

The Mekong River offers a different example. There, China is building a series of dams in the upper reaches of the river, and downstream nations—Laos, Thailand, Cambodia, and Vietnam—fear flows in their rivers will be disrupted.[71] The question is how the downstream riparian nations, currently organized in the Mekong Commission, can encourage China to assume responsibility for, and favorably modify, its downstream impacts.

One organizational option is to include China in a Commission that coordinates and finances infrastructure improvements throughout the Basin, as well as facilitating exchanges among nations to balance the benefits of river modifications. Another option may be to acknowledge the unequal distribution of power (capacity) among the nations and seek a bilateral relationship between the current Mekong Commission nations and China under loose mediation and technical support of the United Nations or another intermediary.

The Lo and Da rivers—Vietnam

When Vietnam shifted from a command-and-control economic and political system to a privatized and decentralized approach in 1989, basinwide authorities for the Lo and Da tributaries to the Red River were deemphasized and dismantled, and their responsibilities for water allocation and flood control were devolved to local units.[72] At the same time, the privatization of capital markets drained public investment from these localities. The result was a decline in the control and security of water flows, contraction of irrigation systems, intensification of agriculture on lands with secure access to water, movement of poorer farmers into the hills to cultivate rainfed crops, forest decline, and a shift in activities in increasingly flooded localities toward fisheries or employment outside the region.

Responding to these consequences over the past 5 years, districts and provinces have gradually increased their efforts to reestablish the fundamentals of coordination and investment—through cooperative activities among localities as well as among groups with specialized expertise at higher levels of governance. The national government has created specialized agency programs in land and forest management as well as low-interest loans and grants for public needs. Regaining the capacity for effective water control has required strengthened convergence of power and responsibility at higher levels of governance.

The above examples illustrate principles of institutional basin relationships with respect to different underlying distributions of capacity and control. Specifically, there is a need for a relative fit between the distributions of capacity and responsibility—or power and authority—among sovereigns, jurisdictions, and interests, and for modes of cooperation and exchange that reduce disparities for the sake of the common good. These examples suggest considerations for development of capacities for cohesion and coordination in the Klamath Basin, in circumstances where existing authorities reflect unbalanced strengths among sovereigns, jurisdictions, and interest groups.

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[71]Romm, J. 2003 (forthcoming). "The Mekong River." In *The Encyclopedia of Environmental History* (Routledge, New York).

[72]Romm, J. and D.T. Sy. 1996. "The impacts of economic liberalization on the people and environment of Lap Thach District." Pages 73–110 in L.T. Cuc, A.T. Rambo, K. Fahrney, T.D. Vien, J. Romm, and D.T. Sy, eds. *Red Books, Green Hills: The Impact of Economic Reform on Restoration Ecology in the Midlands of Northern Vietnam* (East–West Center, Honolulu).

Strategies for change

What are the requirements of an effective institutional strategy to reduce the chance of future water allocation shocks in the Klamath Basin? We suggest several fundamentals that derive from the principles of a fit between power and authority and of cooperation and exchange as means to resolve disparities:

- Sufficient commitment of federal authority and resources to overcome the disparate directions of federal agencies and to mediate among the interests of Oregon, California, and the tribes

  The clashing missions of federal agencies in the Klamath Basin have weakened the federal government's ability to play a constructive role. The BOR, USFWS, NMFS, and Bureau of Indian Affairs, for example, are guided by vastly different missions that often lead them toward conflicting priorities among uses of water. As each agency works to fulfill the purposes for which it was created, those purposes may come into direct conflict, as they did in 2001. A constructive role for federal agencies would include interagency coordination, as well as oversight and funding of scientific and technical studies needed as a basis for equitable water allocation.

  Currently, the federal commitment is weak in relation to the Basin's complexity and fragmentation. Some of the problems are legal and procedural. Others arise from the fragmentation of political constituencies and the absence of a common Klamath Basin voice. Still others arise from federal reluctance to engage state and tribal water interests in a basin with multiple states and tribes, except in specific instances of public trust responsibility, such as application of the ESA.

- Acknowledgment, respect, and support for tribal rights

  Although senior right holders in the Klamath Basin, the tribes continue to be treated as residuals in Oregon and California water allocation processes, implying that they get what is "left over" after other needs are met. Diversions of the Trinity and the Eel to other basins, for example, despite dramatic impacts on tribal livelihoods, continue to face state and federal reluctance to acknowledge tribal claims and fulfill legal obligations for water. States generally treat tribal claims as those of weak interest groups rather than of holders of treaty-based sovereign rights that establish seniority. This is a permanent call for trouble because it denies normal access to process and encourages extra-process strategies such as litigation and federal intervention. Although coded in terms of the Endangered Species Act, tribal claims form the subliminal bass beat in the Klamath Basin. The claims are strong and strengthening, and continuing to deny them perpetuates conflicts.

- Recognition of tribes as sovereigns as well as water claimants

  The roles of the tribes as sovereigns and as water claimants too often are confused. The former locates the tribes in relation to the federal and state governments. The latter locates them in relation to agricultural, environmental, urban, commercial fishing, and forestry interests. The two roles require seats in very different councils, one for basin governance, the other for resolution of competing water needs.

- A governing principle of adaptive water allocation in times of scarcity

  The absoluteness of agricultural water expectations in the Upper Klamath Basin reflects a sense of entitlement, based on long-standing water use contracts, and a social dominance of agriculture that no longer exists in the Basin. Other basins have faced this situation and have recognized that water allocations to one party must take into account the needs of others within the limits of available supply. This type of allocation is termed "correlative." A correlative approach to resource allocation requires institutions that support exchanges of water and accommodate all interests as much as possible in times of stress. A purely competitive approach is not a viable stance in a context of interdependence and growing equality among interests.

An effective framework for resolving water allocation issues in the Basin would seem to require several mechanisms for cooperation and exchange, each with its own critical functions:

- A council of federal, state, and tribal governments to deal with broad policy and jurisdictional issues
- A subordinate mechanism for coordination among agencies
- A forum for negotiation, exchange, and cooperation among agricultural, tribal, environmental, urban, and other local interests as a way to broaden engagement in and knowledge of the problems of the entire Basin

The current growth of subbasin watershed groups and basinwide interest groups—environmental, tribal, and agricultural—is a crucial source of energy and capacity. Relations between the BOR, NMFS, and USFWS, forged in the crucible of intense controversy, also may offer opportunities for more systematic cooperation. The sustained engagement of Oregon State University and the University of California could provide research, education, facilitation, and other contributions to stronger institutional relationships in the Basin.

Conclusions

The 2001 water allocation decision has been argued in terms of environment versus agriculture, or as an ESA issue. In reality, however, it is an artifact of two specific features of the Basin: (1) deep social and political divides that have eroded possibilities for conciliation and control, and (2) an increasingly unbalanced distribution of capacity and responsibility between the structure of basin water control and the social scope of its influence. Fragmentation and concentrated authority have been indulged for so long that it is impossible to avoid wreaking havoc on one interest or another. The costs are huge. The problem is not caused by those whose interests are in dispute, but by a broader institutional incapacity to create relationships that achieve equitable allocations in scarce times.

Elsewhere, effective relations have had the capacity to transform the impacts of the ESA so as to achieve relatively equitable, viable, and sustainable changes in unique local and regional circumstances. In the Klamath Basin, on the other hand, weak relations—among federal, state, and tribal governments; between states; among federal agencies; and among interest groups—defaulted a controlling power to the ESA, as it had to the Reclamation Act a century ago. The ESA offers the sole source of clear coordination in the Basin at this time.

In our exploration, we have concluded that the Klamath crisis emerged from the relationship between a strong and precise federal law and generally unformed capacities within the Basin to shape the law's application and influence. Absent a clear, shared vision among the Basin's various governments, agencies, and communities, the ESA gained a degree of control over water allocation that had been avoided elsewhere. In effect, issues that pervade the full history of the United States converged in one time and place, as they had at other times in the Klamath Basin, to bring into question whole sets of assumptions upon which the nation has depended.

The federal government is one source of the difficulty. It has yet to reconcile the divergent directions among its various agencies. Nor has it sought methods of coordination in the Klamath Basin that make sense in view of the shift in power toward specialized agencies and away from the territorial agencies with which resource-dependent regions are identified. The federal government also chose not to use its capacities to avoid the dire outcomes of the 2001 decision, either by court appeal or conciliation. The lack of a common voice among Basin interests may have discouraged the kinds of Administration initiatives that, by appeals of court decisions, subsidy of conciliation efforts, and delays for scientific review, have helped to achieve resolutions elsewhere.

A second source of difficulty is the states' tendency to treat the tribes, the senior right holders, as residual claimants. Tribal claims to water, based on treaty assurances and upheld by court rulings, are a crucial component of any water allocation solution in the Basin.

As a result of these factors, and despite its size, the Klamath Basin has been kept at the margins of state and federal institutions. It has remained insulated as other basins have adapted to similar stresses. One consequence is that, until now, it has not influenced broader discussions of public policy and has become an extreme case in the outcomes of policy application. The 2001 experience has provided lessons about policy flaws, particularly the risks of absolutes of any kind. At the same time, it demonstrated the need and opportunity for a basinwide institutional fabric consistent with the intensity and range of interdependent interests in the Basin.

Does the 2001 decision affect public policy more generally? Despite the unique circumstances of the Klamath Basin, the events of 2001 raise issues that have meaning for the nation as a whole. These issues indicate ways in which the 2001 decision stretched the range of previously accepted outcomes of the ESA, and they lead to important questions. For example:

- To what extent should one group bear the burden of satisfying a public purpose?

  Virtually all takings cases have involved the loss of potential future property values as a consequence of public actions. What is distinctive about the irrigation curtailment on the Klamath Reclamation Project is that the costs were real and immediate rather than potential or speculative. Klamath farmers, farmworkers, and communities absorbed the full brunt of species protection in 2001. In the past, the tribes bore the full brunt of laws such as the Reclamation and Termination acts, which were thought to satisfy the public interest of their day. Such imbalances cause crises.

  As our analysis suggests, the problem is partly structural, arising from the absence of means to share burdens widely, whether within the basin or among national citizens. In this absence, the problem is confined to the courts, which seem to face a distinctive challenge in the Klamath Basin with regard to the "whatever-the-cost" standard and the equitable distribution of costs between Basin agriculturalists and a more general public.

- How do we weigh scientific uncertainty against socioeconomic burden?

  In accordance with law, the 2001 decision was based on the best science available to the agencies required to make the decision. The science provided a basis for projecting the effects of water storage and flow regimes on two endangered and one threatened fish species (see Chapter 5, "Suckers," and Chapter 6, "Coho Salmon"). As with all science, the projections were surrounded by uncertainty about the validity of the models used and the responses of natural systems to unknowable future circumstances. The scientific uncertainty of the projected biological outcomes can be compared with the real and immediate impacts on Upper Basin farmers, farmworkers, and farm communities. This question is not a matter of simple balance—the loss of an endangered species is forever, while the loss of agricultural structure and function depends on the sufficiency of compensating actions. Such a comparison does, however, point to the need for opportunities to consider the relative certainties of projected scientific and socioeconomic consequences, and to strengthen safeguards against irrevocable negative outcomes on all sides. For example, irrevocable or immediate outcomes might enjoy stronger standing and safeguards than transitory or prospective losses. Thus, less scientific certainty might be required for decisions that threaten irrevocable losses than for those that can be repaired; more certainty might be required when real and immediate, rather than prospective, losses are involved.

- Do current ESA environmental review procedures suffice for decisions that must be made on the basis of time-bound hydrologic information?

  Many observers have criticized the BOR for not undertaking ESA consultation in a timely fashion in 2001, or for not developing a viable long-term strategy in the previous decade. However, the procedural path the BOR had to follow (ESA consultation with the USFWS and the NMFS) did not mesh with the narrow window for obtaining essential hydrologic information. Nor did it accommodate the requirements of biological science for long-term research or the absence of an institutional way to resolve conflicts. The Section 7 ESA consultation process is a source of rigidity amid dynamic natural and social processes that are largely beyond administrative control. Alternative procedural mechanisms that mesh better with the realities of specific problems and places might be considered.

The search for answers to these difficult questions in the Klamath Basin could make significant contributions to sustainable environmental, economic, and social development not only in the Basin, but also throughout the nation.

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19

Water Allocation Alternatives

Water Allocation Alternatives
for the Upper Klamath Basin

William K. Jaeger

Alternatives for managing water resources in the Upper Klamath Basin are varied and numerous. A long-run strategy to protect fish and other species, while at the same time providing water for agriculture and other interests, likely will include restoring riparian vegetation, screening irrigation canals, reducing nutrient loads, reforestation, dam removal, continued controls on fishing, etc. Indeed, many of these actions have been recommended in recent and earlier Biological Opinions pursuant to the Endangered Species Act (ESA).

In addition to these broad actions to improve water *quality* and fish habitat, however, alternatives involving water *quantity* and its allocation also may have advantages over current and past approaches. The aim of this chapter is to appraise the merits of several water allocation alternatives from an economic perspective. The estimated impacts of an irrigation curtailment used in this chapter are model based. For a discussion of reported economic outcomes in 2001, see Chapter 14 ("Outcomes").

Our effort is set in the context of the 2001 irrigation curtailment and the prospect that water shortages may occur again in the future. Alternatives will be evaluated primarily on their direct cost to the agricultural sector in the Upper Klamath Basin. However, this should not be interpreted as implying that agricultural interests are paramount, nor that the value of water allocated to other uses, such as environmental and tribal interests, tourism, or commercial and recreational fisheries, is unimportant or peripheral.

Unlike Chapter 12 ("Crop Revenue"), this analysis focuses not only on the Klamath Reclamation Project, but on the entire Upper Basin. In that chapter, Burke considered alternative ways of allocating water within the Project that could reduce the losses to gross farm crop sales resulting from an irrigation curtailment. Here we look instead at all irrigated areas within the Upper Klamath Basin that could reasonably be considered interconnected for purposes of satisfying the mix of competing ecological and agricultural demands. Our definition of the Upper Klamath Basin is broader than many; we include the combined Klamath River–Lost River watershed and also the Shasta and Scott rivers (Figure 1, following page). Thus, the Shasta and Scott valleys are included in this analysis.

Clearly, it is important to recognize the relationships between past, current, and future competing demands for water among agricultural and nonagricultural uses. However, it is beyond the scope of this chapter to quantify and compare the long-term costs and benefits of irrigated agriculture in the region. Nor do we attempt to place a value on in-stream uses of water, declining fish populations, or the consequent inability of the Klamath and downriver tribes to avail themselves of their legally recognized fishing rights. We recognize that by using the late 1990s as our benchmark for comparison, we are implicitly selecting as "normal" a

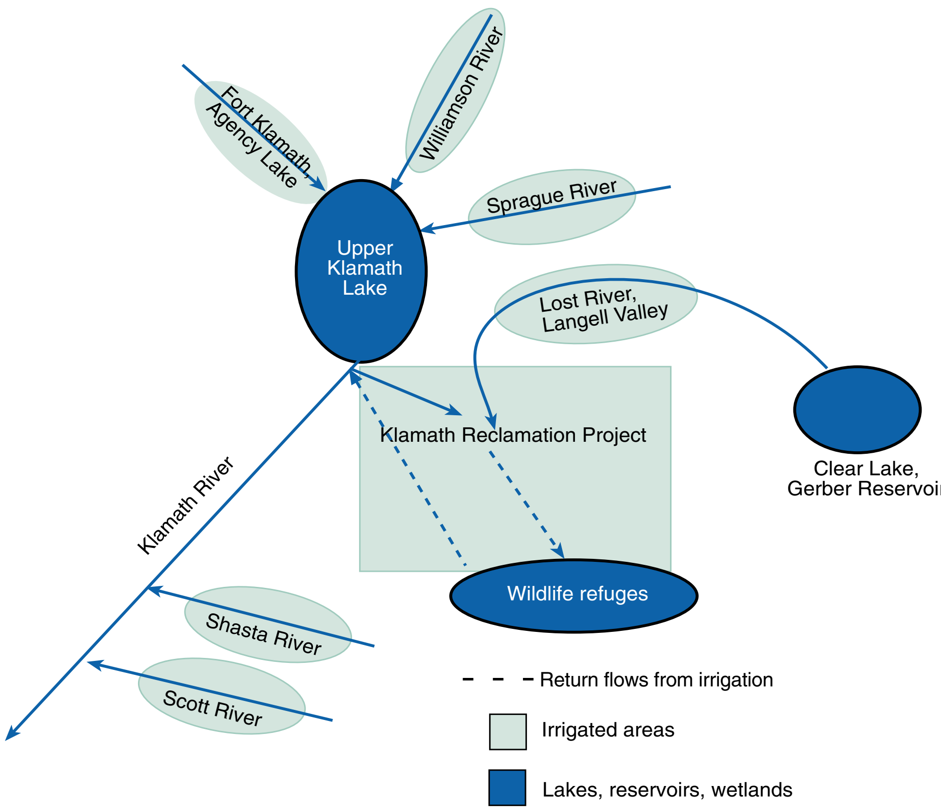

Figure 1. Key features and irrigated areas in the Upper Klamath Basin and Klamath River system.

situation that reflected decades of water allocation decisions and outcomes that may have benefited some groups more than others.

As competing demands on water resources in the Klamath Basin continue to grow, there are likely to be additional constraints on irrigation diversions. In addition to limitations imposed under the Endangered Species Act, changes in water allocation may result from the resolution of tribal water claims in the ongoing adjudication process. Moreover, relicensing of the Iron Gate Dam by the Federal Energy Regulatory Commission (FERC) in 2006 will require giving equal consideration to power and nonpower benefits (such as recreational use and the provision of fish and wildlife habitat) under the Electric Consumers Protection Act of 1986 (see Chapter 6, "Coho Salmon"). Whether this requirement will influence required summer flows in the Klamath River mainstem is unclear.

In the midst of these conflicts, future droughts are likely to give rise to future water scarcity. More cost-effective approaches to the allocation of scarce irrigation water may represent ways to minimize the costs of future shortages—provided there is public support and the institutional capacity needed to carry them out (see Chapter 18, "Policy").

Thus, our focus is on alternatives that deal directly with the *quantity* of water available and the allocation of that water among competing uses. In addressing these issues, we estimate the net gains and losses from allocating water to different soils in different locations. Thus, the cost of short-run curtailment of irrigation supplies forms the basis for comparing alternative responses to shortages.

An economic description of agriculture in the Upper Basin is the starting point for this analysis and for interpretation of the results. Two key characteristics of irrigated agriculture in the Upper Klamath Basin emerge as crucial to the analysis. First, the acreage within the Klamath Reclamation Project that did not receive water in 2001 represents only about 35 percent of the total irrigated area in the Upper Basin. Second, the irrigated soils throughout the Upper Klamath Basin range in productivity classification from Class II to Class V (see Chapter 7, "Soil Resources"). These differences give rise to large variations in the economic gains from irrigation based on differences in the market values for irrigated and nonirrigated lands.

In the face of limits on irrigation, allocating water in ways that reflect these productivity differences will promote "economic efficiency" (produce the highest value of agricultural output with a given amount of water) and thus help minimize the overall cost of water scarcity. If water is withheld from its highest value uses, while irrigation continues in locations where the benefits are minimal, there will be a high overall cost compared to an efficient, cost-minimizing allocation. A decentralized response to water shortage, one that accounts for the very different marginal losses and gains across plots, will achieve the desired reduction in irrigation withdrawals at a much lower cost.

Thus, this analysis will consider alternatives that meet this criterion. For example, if irrigators can transfer water, create water banks, or buy and sell water rights, those with the most to lose

Gross versus net economic indicators

As explained in the Preface to the economics chapters, we use two main types of dollar measures to describe agriculture in the Upper Klamath Basin in economic terms and to measure the effects of events in 2001. Each measure is intended for a specific use. To avoid confusion, differences between these measures are reiterated here.

The first monetary measure is intended to reflect the benefit or economic value of a resource. "Net revenue" and "income" are economic measures of this kind. They are intended to reflect the *net* gains from farming. Thus, they include revenue from the sale of a crop minus the cost of the inputs used to produce it. These measures represent the net financial benefit to the farm owner or operator. This chapter uses this type of measure to look at the net gain associated with a particular activity, piece of land, or quantity of irrigation water.

The second monetary measure is referred to as "gross farm revenue" or "gross farm sales." This measure is intended to indicate the scale of the farm economy, but it does not accurately reflect the gains accruing to an individual, group, or specific resource because it does not subtract the cost of inputs. As a result, a region's gross farm revenue or sales always is higher than its net revenue or net farm income. This type of measure is used extensively in Chapter 12 ("Crop Revenue") to evaluate changes in the scale of agriculture in the Project. Similarly, "regional economic output" is a measure of changes in the gross value of goods and services produced in the regional economy. This measure is emphasized in Chapter 13 ("Regional Economic Impact").

Each of these monetary measures is appropriate for addressing particular questions. Gross farm revenue and regional economic output are useful for describing changes in the scale of economic activity in agriculture or in the region. In this chapter, however, we are interested in assessing the value or return on an investment, as well as the willingness of individuals to pay for, or be compensated for, gains or losses in resource availability. For these purposes, "net revenue," "loss," or change in "income" are the appropriate measures. In general, we expect such measures to correspond to the market price—the amount that individuals should be willing to pay to acquire a given quantity of land, water, or other resource.

from a water cutoff could assure themselves of a more reliable supply. Partial reductions in irrigation deliveries, or "deficit irrigation," represent another way to achieve efficiency.

The aim of this analysis is, first of all, to identify ways in which the overall cost of irrigation restrictions could be reduced by promoting economic efficiency in water allocation. Alternative scenarios or policies of this kind will produce economic and social consequences that affect individuals in different ways. Whether those alternatives are viewed positively or negatively will depend on many factors, including the overall cost of any given scenario.

We recognize that some alternative responses to a water shortage may generate undesirable social or environmental side effects. Before implementing any alternative, those consequences should be considered as part of an overall assessment of the quantitative and qualitative differences between alternative courses of action. In principle, if an alternative approach substantially lowers the overall cost of a water shortage, other actions could be taken to offset possible negative consequences.

The economic value of irrigation water

In this section, data on irrigated areas, land prices, crops, and yields are used to estimate the economic value of applied irrigation water, as well as the cost of withholding water. These data generate an economic portrait of irrigated agriculture in the Basin, one that provides a basis for evaluating a range of water allocation options.

For these purposes, it is crucial to look at the differences in irrigated agriculture across locations and soil classes rather than simply characterizing the entire region based on average values. We must take into account how these agronomic differences translate into differences in revenues, costs, and the economic value of water used in irrigated crop production (i.e., water used in combination with other inputs such as equipment, energy, labor, and land).

Understanding long-run versus short-run value

For this analysis, when measuring the value of water, we need to distinguish long-run value from short-run value. The "long-run" value of water in irrigated agriculture reflects the net revenue (income) generated when irrigation water is applied regularly to an acre of land of a given soil class over time. It reflects the efficient, planned use of water in combination with equipment, labor, and other inputs. We expect this measure of value to be reflected in market sales and prices of land or water rights. It is especially relevant to decisions about investing in irrigation infrastructure or other capital assets.

Given efficient capital and land markets, we expect the sale price of agricultural land to reflect the present value of the income that can be generated annually by farming it. The relationship between the annual income (Y) made possible by farming a piece of land and its purchase price (P) involves an interest rate (r). As with a financial asset such as a stock or annuity, an asset with a face value of P can be expected to generate annual dividends of r times P. (We can write this relationship as $Y = r * P$.)

This relationship allows us to infer the value of irrigation water by comparing the sales prices of irrigated and nonirrigated lands. For example, if the difference between the purchase prices of similar irrigated and nonirrigated land is $1,000, we can infer that the difference reflects the benefits resulting from irrigation. Then, we can use the formula above to estimate that the annual net benefits of irrigation equal r * $1,000. For a 6 percent interest rate, this suggests that $60 per year is the net benefit of irrigation water in this example (0.06 * 1,000).

In addition to long-run values, a "short-run" measure of the value of irrigation water is important. This value more accurately reflects the losses suffered by growers who go without water unexpectedly or temporarily.

The short-run losses associated with reductions in water availability can be expected to exceed the long-run measures discussed above. The difference between the short-run and long-run measures arises from the fact that some production costs are "fixed costs" and cannot be avoided in the short run.

In the short run, growers are likely to incur some fixed production costs whether water is available or not. Examples include equipment that would be idled without water, insurance, and depreciation. Given these fixed costs, the short-run cost of having water withheld is higher than the long-run values discussed above. In other words, short-run changes or "surprise" adjustments in the amount of water available will produce per-acre losses that exceed the long-run value of water reflected in land prices.

Consider how this works. A farmer's net revenue (NR) is equal to total revenues (TR) minus variable costs (VC) and fixed costs (FC). Thus, NR = TR – VC – FC. Giving up farming in the long run means giving up NR. Giving up farming in the short run means losing TR and eliminating VC, but the farmer still has fixed costs, which now are not offset by revenues. The loss then is NR + FC, which also is equal to TR – VC.

Suppose a farmer's total revenue (per acre) with irrigation is $750. If variable costs are $300, and fixed costs are $200, the farmer's net revenue is $250. If irrigation water is withheld in the short run, total revenue and variable costs fall to zero. Fixed costs of $200 remain, however, so that net revenue becomes –$200. The difference between net revenue with irrigation ($250) and net revenue without irrigation (–$200) is $450, which equals NR + FC or TR – VC. This is the farmer's net loss, which represents the short-run value of irrigation water, or the cost of withholding water.

If production involved zero fixed costs, then the short-run and long-run values of water should be equal. A grower who anticipates a 1-year pause in irrigation (for example, a voluntary agreement to leave water in-stream for 1 year) may avoid some of the fixed costs (for example, by renting equipment to other growers). Nonetheless, he or she likely still will incur some fixed costs. In this case, the costs of irrigation curtailment should be lower than in the short-run, "surprise" scenario, but higher than the long-run values of irrigation water. This kind of anticipated short-run cost is relevant to the discussion of water markets and water banks later in this chapter.

Because the water shortage that occurred in 2001 was short-run and unanticipated, the measure of short-run loss is the relevant measure for assessing the overall cost of irrigation curtailment. For other considerations, such as the development of additional storage capacity, improved irrigation efficiency, or permanent retirement of irrigated land, the long-run value of water is more relevant.

It also is important to recognize that the value of an "incremental" or marginal change in the amount of water available often differs from the "average value" of water. Irrigation water may have a very high *average* value when applied to the most productive lands in a given region, but the *marginal* value of an additional unit of water may be quite low. This situation occurs when adequate water already has been applied to existing high-productivity lands, while the additional lands that could be irrigated are much less productive.

Value of irrigation water in the Upper Klamath Basin

Based on available market, crop, and farm enterprise data, we have estimated both short-run and long-run values of water by soil class for each location within the Upper Klamath Basin. The primary data source is the Klamath County Assessor's office (Klamath County Assessor 2001). Data from this source include irrigated land areas by soil class, cropping pattern, and market value (as distinct from the assessed values used for tax purposes). These data were supplemented with additional data from the county assessors in Modoc and Siskiyou counties in California, the U.S. Bureau of Reclamation office in Klamath Falls, and the Oregon State University (OSU) Extension Service (for crop budget data).

Soils in the Upper Basin range from Class II to VI. Higher numbers indicate progressively greater limitations and narrower choices for practical use (see Chapter 7, "Soil Resources").

Crops and crop rotations vary by location and soil class. For the Upper Basin overall, 54 percent of irrigated land is pasture, 22 percent is alfalfa, 15 percent is cereal grains (barley and wheat), and 5 percent is other hay. These are followed by 3 percent for potatoes and 0.5 percent for peppermint. Other crops, such as onions, each account for less than 1 percent of the area planted, although they may represent a larger share of total revenue. Alfalfa, cereals, potatoes, and peppermint are grown on Class II and III soils; pasture is grown almost exclusively on Class IV and V soils.

Long-run value of irrigation water

Data on irrigated land areas for the Klamath Basin are presented in Table 1. These data indicate that irrigated soils range from Class II to V, with most being Class III and IV.

Table 1. Irrigated acreage in the Upper Klamath Basin by location and soil class.

	Irrigated acres				
	Class II	Class III	Class IV	Class V	Totals
Areas above Upper Klamath Lake					
Fort Klamath Valley	0	1,800	8,025	26,055	35,880
Modoc Point to Chiloquin	2,710	6,475	7,215	335	16,735
Sprague River Valley	0	640	54,120	910	55,670
North Country	0	5,410	16,865	1,530	23,805
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	2,620	8,310	14,930	0	25,860
Bonanza (non-Project)	4,541	6,425	6,354	0	17,320
Langell Valley (non-Project)	3,145	6,611	5,209	535	15,500
Poe Valley (non-Project)	525	697	778	0	2,000
West of 97 to Keno (non-Project)	2,388	9,048	11,367	198	23,000
Lower Klamath Lake (non-Project)	69	4,614	309	7	5,000
Klamath Reclamation Project areas					
Merrill-Malin	2,030	13,965	6,205	0	22,200
Poe Valley	4,424	5,873	6,562	0	16,859
Midland-Henley-Olene	7,625	18,555	11,890	0	38,070
Bonanza-Dairy-Hildebrand [a]	*2,569*	*3,635*	*3,596*	*0*	*9,800*
Langell Valley [a]	*3,315*	*6,969*	*5,491*	*565*	*16,340*
Lower Klamath Lake	211	14,021	941	23	15,195
Malin Irrigation District	300	2,905	120	0	3,325
Shasta View District	1,000	3,100	1,100	0	5,200
West of 97 to Keno	387	1,467	1,843	32	3,730
Tule Lake/California portion	13,244	40,000	20,000	0	73,244
Shasta and Scott valleys	8,000	41,100	35,000	0	84,100
Total	**59,103**	**201,620**	**217,920**	**30,190**	**508,833**

[a]Portions of the Project that received surface water in 2001.

Note: Figures in this table may differ slightly from those in other chapters due to different data sources and geographical categories.

Sources: County assessors in Klamath, Modoc, and Siskiyou counties (personal communications)

Table 2. Average market values for irrigated land by location and soil class.

	Market value of land ($ per acre)				
	Class II	Class III	Class IV	Class V	Nonirrigated (Class VI)
Areas above Upper Klamath Lake					
Fort Klamath Valley[a]	—	1,100	850	600	400
Modoc Point to Chiloquin	1,700	1,100	850	600	400
Sprague River Valley	—	1,000	750	300	200
North Country	—	750	750	250	200
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	2,100	1,450	750	370	200
Bonanza (non-Project)	2,100	1,450	750	370	200
Langell Valley (non-Project)	2,100	1,450	750	370	200
Poe Valley (non-Project)	2,600	1,400	1,000	500	300
West of 97 to Keno (non-Project)	1,700	1,100	850	600	400
Lower Klamath Lake (non-Project)	2,600	1,900	1,000	300	300
Klamath Reclamation Project areas					
Merrill-Malin	2,600	1,350	1,000	500	300
Poe Valley	2,600	1,400	1,000	500	300
Midland-Henley-Olene	2,600	1,400	1,000	500	300
Bonanza-Dairy-Hildebrand[b]	*2,100*	*1,450*	*750*	*370*	*200*
Langell Valley[b]	*2,100*	*1,450*	*750*	*370*	*200*
Lower Klamath Lake	2,600	1,900	1,000	300	300
Malin Irrigation District	2,600	1,900	1,000	300	200
Shasta View District	2,600	1,350	1,000	300	200
West of 97 to Keno	1,700	1,100	850	600	400
Tule Lake/California portion	2,600	1,800	1,100	—	300
Shasta and Scott valleys	2,000	1,650	1,050	—	300
Average	**2,278**	**1,402**	**895**	**421**	**276**

[a]Values based on agricultural use. Recreational demand has increased land values in this area.

[b]Portions of the Project that received surface water in 2001.

Sources: County assessors in Klamath, Modoc, and Siskiyou counties (personal communications)

In Table 2, average land values by soil class indicate the extreme variability in productivity of irrigated land across locations. Land values vary from Class II irrigated areas that sell for $2,600 per acre to Class V lands that sell for between $250 and $600 per acre. We expect these market prices for land to reflect the capitalized value of the annual income generated from current use. Our data on average market values reflect transactions and markets during a number of years prior to the events of 2001.

These land-value data also provide an indication in relative terms of the economics of farming in the Upper Klamath Basin. The value of farm real estate in 1998 averaged $960 per acre in Oregon and $974 per acre in the U.S. In the Upper Klamath Basin, the market value of Class II lands is double these levels, and it is 50 percent higher for Class III lands. This suggests that the income-generating capacity of an acre of these lands is significantly higher than the average for Oregon or for the nation as a whole. Indeed, the market values on Class II and III soils are comparable to those in Iowa, one of the most productive agricultural areas in the country. By contrast, the value of irrigated Class V land in the Upper Klamath Basin ($421 per acre) is at the low end of state-averaged land values, comparable to those in North Dakota, where dryland farming predominates.

By combining the data in Tables 1 and 2, we can estimate the total value of irrigated land in the Basin at $654 million. Using an interest rate of 6 percent, this asset value suggests an annual income from irrigated agriculture in the region of $39 million. This figure is very close to the $38 million figure for farm labor and proprietors' income (1997) reported by the U.S. Bureau of Economic Analysis.

As explained above, the long-run value of irrigation water can be estimated by looking at the difference between the values of irrigated land and similar nonirrigated land. From Table 2, we see that the difference between the per-acre market value of Class II irrigated and Class VI nonirrigated lands in much of the Project is $2,300 ($2,600 – $300). The difference between irrigated Class III soils and nonirrigated Class VI soils ranges from $550 to $1,700 per acre. For Class IV soils, the difference averages $620 per acre.

Notice that for some locations, and especially for Class V soils outside the Project, the differences in land values suggest very low values to irrigation. For example, the difference in market value between Class V irrigated and Class VI nonirrigated land ranges from $0 to $200 per acre. This suggests that applying water to Class V soils in these regions generates low net revenues as irrigated pasture.

Even ignoring the extreme low estimates of $0 and $50 per acre, these data indicate that the value of applied water varies by a factor of 23 between the most productive lands ($2,300 per acre) and least productive lands ($100 per acre). On average, the data suggest that irrigation water adds about $1,000 per acre to the value of land. This interpretation is corroborated by a local farm appraiser with many years of experience in the region, who estimates differences between irrigated and nonirrigated lands to be between $900 and $1,000 (Caldwell 2001).

When these estimates are used to estimate the annual value of applied water (multiplying by a 6 percent interest rate), we arrive at the marginal per-acre annual values for water presented in Table 3. Average values range from $9 for class V soils to $103 for Class II soils. The lowest value is $0 for Class V soils in the Lower Klamath Lake area. The highest value is $144 for Class II soils in the Malin and Shasta View irrigation districts.

We can compare these values to estimates for similar soil classes in Malheur County, Oregon, which were developed using a more detailed statistical approach (Faux and Perry 1999). The Malheur County values are nearly identical to the soil class averages in Table 3, with the exception of the Class V soils. Klamath-area Class V soils seem to be significantly lower in value than those in Malheur County. One reason for this difference may be the higher elevation and shorter growing season in the Upper Klamath Basin.

Table 3. Marginal value of applied water in irrigated agriculture by location and soil class.[a]

	Marginal value of water ($ per acre per year)				
	Class II	Class III	Class IV	Class V	Weighted average
Areas above Upper Klamath Lake					
Fort Klamath Valley[b]	—	42	27	12	17
Modoc Point to Chiloquin	78	42	27	12	41
Sprague River Valley	—	48	33	6	33
North Country	—	33	33	3	31
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	114	75	33	10	55
Bonanza (non-Project)	114	75	33	10	70
Langell Valley (non-Project)	114	75	33	10	67
Poe Valley (non-Project)	138	66	42	12	76
West of 97 to Keno (non-Project)	78	42	27	12	38
Lower Klamath Lake (non-Project)	138	96	42	0	93
Klamath Reclamation Project Areas					
Merrill-Malin	138	63	42	12	64
Poe Valley	138	66	42	12	76
Midland-Henley-Olene	138	66	42	12	73
Bonanza-Dairy-Hildebrand[c]	*114*	*75*	*33*	*10*	*70*
Langell Valley[c]	*114*	*75*	*33*	*10*	*67*
Lower Klamath Lake	138	96	42	—	—
Malin Irrigation District	144	102	48	6	104
Shasta View District	144	69	48	6	79
West of 97 to Keno	78	42	27	12	38
Tule Lake/California portion	138	90	48	—	87
Shasta and Scott valleys	102	81	45	—	68
Unweighted average	**103**	**68**	**37**	**9**	**—**
Weighted average	**—**	**—**	**—**	**—**	**60**
Estimates for Malheur County, Oregon[d]	105	67	35	32	—

[a]Based on comparison of market price data for irrigated versus nonirrigated land.
[b]These values reflect agricultural use. Recreational demand has increased land values in this area.
[c]Portions of the Project that received surface water in 2001.
[d]Based on Faux, J. and G.M. Perry. 1999. "Estimating irrigation water value using hedonic price analysis: A case study in Malheur County, Oregon." *Land Economics* 75:440–452.

Two other data sources provide estimates that generally are consistent with those presented here. First, the Oregon Water Trust purchases water from irrigators in Oregon to augment in-stream flows and protect fish habitat. Data on these transactions over the past several years are presented in Table 4. There are two types of transaction: permanent purchases of water rights and 1-year leases. These data also are presented as the annual value (per acre-foot), using a 6 percent interest rate in the case of the permanent purchases.

Detailed data on soil class are not available for these transactions. However, given the organization's desire to minimize costs and to target small tributaries in upper basins, we expect that most of these transactions involve Class IV and V soils. For a consumptive use of 2 acre-feet per acre (the average irrigation use in the Upper Klamath Basin), the average annual value per acre-foot for Class IV and V soils is $11.50, which is close to the $9.16 average paid by the Oregon Water Trust.

Additional information on transactions by the Oregon Water Trust (reported in Niemi et al. 2001) is remarkably consistent with Faux and Perry (1999). Niemi et al. report that for water rights previously associated with pasture and irrigated hay, Oregon Water Trust paid growers $6 to $17 per acre-foot per year. For water previously used in producing wheat (likely to be grown on Class II or III soils), purchase prices were $22 per acre-foot per year. Similarly, Landry (1995) surveyed water rights transfers in Oregon in the early 1990s and found that the average price corresponded to an annualized value of $22 per acre-foot per year.

Second, the U.S. Bureau of Reclamation manages the annual leasing of lands within the Upper Basin's national wildlife refuges. Using a sealed bidding process, irrigators compete for use of these relatively high-productivity lands. These data, therefore, are on a per-acre basis and are primarily for Class II, III, and IV lands. In 2000, the successful bids averaged between $51 per acre for "area K" grain production to $83 per acre for "Sump 3" lands (where only one-third of the land may be planted with row crops; the rest typically is planted with grains). These prices are comparable to those for Class III and IV lands in Table 3. Assuming 2 acre-feet per acre, they also are close to the range of prices paid by Oregon Water Trust under 1-year leases.

Short-run losses from irrigation curtailment

As defined above, the short-run losses from curtailed water deliveries reflect the financial changes faced by farmers. These losses cannot be inferred from market prices for farmland alone.

Short-run losses vary, depending on the crops grown and other circumstances faced by individual farmers. Average values reflect expected net revenues from crop sales as well as fixed costs. Losses facing individual farmers may be higher or lower than the estimated averages due to fluctuations in crop prices or other differences. Losses are likely to be higher for growers of perennial crops.

Average values for short-run losses can be estimated by combining information on long-run irrigation values and fixed costs. Fixed costs are crop-specific and must be estimated based on the crop rotations common to each location and soil class. Using data on observed cropping patterns in conjunction with OSU crop enterprise budgets, we have estimated fixed costs for all locations and soil classes in the Upper Klamath Basin. The per-acre loss associated with withholding irrigation water is the sum of (a) net revenues or marginal values of applied water (from Table 3) and (b) nonland fixed costs from the OSU crop enterprise budgets. (See "References.") These losses include the amortized fixed cost of establishing perennial crops such as peppermint and alfalfa.

Table 4. Recent water rights transactions to augment stream flows.

Location	Current use	Contract type	Consumptive use (acre-feet/year)	Price ($)	Cost per acre-foot per year[a] ($)
Rogue River, Sucker Creek	Fallow	Purchase	67.80	8,800	7.79
Rogue River, Sucker Creek	Fallow	Purchase	107.62	13,627	7.60
Rogue River, Sucker Creek	Fallow	Purchase	57.47	8,138	8.50
Deschutes River, Squaw Creek	Pasture	Purchase	417.19	42,900	6.17
Deschutes River, Squaw Creek	Pasture	Purchase	308.08	44,352	8.64
Deschutes River, Squaw Creek	Pasture	Purchase	48.14	7,425	9.25
Deschutes River, Squaw Creek	Pasture	Purchase	8.46	870	6.17
Deschutes River, Squaw Creek	Pasture	Purchase	96.27	13,860	8.64
Rogue River, Little Butte Creek	Hay	Purchase	173.95	20,000	6.90
Hood River, Fifteenmile Creek	Wheat	Purchase	71.76	26,307	22.00
Average (purchases)					**9.16**
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	6,630	33.69
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	6,630	33.69
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	6,630	33.69
Grande Ronde River, Crow Creek	Hay	1-year lease	194.00	1,600	8.25
Umatilla River, East Birch Creek	Hay	1-year lease	238.50	2,500	10.48
Deschutes River, Trout Creek	Hay	1-year lease	1,135.50	23,843	21.00
Deschutes River, Trout Creek	Hay	1-year lease	270.00	4,680	17.33
John Day River, Hay Creek	Hay	1-year lease	248.80	14,500	58.28
Rogue River, South Fork Little Butte Creek	NA	1-year lease	83.34	1,438	17.25
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	6,630	33.69
Grande Ronde River, Crow Creek	Hay	1-year lease	197.70	5,272	26.67
Deschutes River, Tygh Creek	Pasture	1-year lease	94.50	945	10.00
Rogue River, South Fork Little Butte Creek	NA	1-year lease	83.34	1,438	17.25
Grande Ronde River, Crow Creek	Hay	1-year lease	197.70	5,136	25.98
Deschutes River, Tygh Creek	Pasture	1-year lease	94.50	945	10.00
Rogue River, South Fork Little Butte Creek	NA	1-year lease	83.34	1,438	17.25
Umatilla River, Couse Creek	Wheat/Pea	1-year lease	1,065.9	23,800	22.33
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	5,000	25.41
Grande Ronde River, Crow Creek	Hay	1-year lease	197.70	5,136	25.98
Rogue River, South Fork Little Butte Creek	NA	1-year lease	83.34	1,438	17.25
Umatilla River, Couse Creek	Wheat/Pea	1-year lease	1,065.9	23,800	22.33
Umatilla River, Couse Creek	Wheat/Pea	1-year lease	1,065.9	23,800	22.33
Average (1-year leases)	—	—	—	—	**23.19**

[a]Assumes a 6 percent discount rate to compute annualized cost of permanent acquisitions.

Source: Oregon Water Trust

Nonland fixed costs range from $25 for pasture to $207 for alfalfa. When net revenues are included, the short-run loss estimates range from $206–$312 on Class II lands to $25–$37 on Class V lands (Table 5). Like the long-run values of irrigation water estimated above, per-acre losses vary greatly (in this case, by more than a factor of 12) across location and soil class.

To validate our loss estimates, we can compare them to two sources of market data involving short-run transactions or temporary transfers—land rentals and annual water leases. In these situations, however, landowners are likely to make arrangements to avoid leaving equipment idle (e.g., they may rent it out or use it on other lands). They will want to cover their forgone net revenue and the cost of the land (the capital tied up in land ownership), but nonland fixed costs may be zero or very low if their equipment and vehicles are fully utilized elsewhere.

Table 5. Estimated per-acre losses from irrigation curtailment by location and soil class.

	Losses ($ per acre)				
	Class II	Class III	Class IV	Class V	Weighted average
Areas above Upper Klamath Lake					
Fort Klamath Valley	—	67	52	37	42
Modoc Point to Chiloquin	232	182	52	37	131
Sprague River Valley	—	210	58	31	59
North Country	—	58	58	28	56
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	236	162	58	35	110
Bonanza (non-Project)	309	260	58	35	199
Langell Valley (non-Project)	242	106	58	35	115
Poe Valley (non-Project)	297	158	67	37	159
West of 97 to Keno (non-Project)	206	134	52	37	100
Lower Klamath Lake (non-Project)	307	159	67	25	155
Klamath Reclamation Project areas					
Merrill-Malin	312	232	67	37	193
Poe Valley	297	158	67	37	159
Midland-Henley-Olene	297	247	67	37	201
Bonanza-Dairy-Hildebrand [a]	*309*	*260*	*58*	*35*	*199*
Langell Valley [a]	*242*	*106*	*58*	*35*	*115*
Lower Klamath Lake	307	159	67	25	155
Malin Irrigation District	295	243	73	31	242
Shasta View District	299	217	211	31	232
West of 97 to Keno	206	134	52	37	100
Tule Lake/California portion	259	211	73	25	182
Shasta and Scott valleys	273	228	70	—	167
Unweighted average	**274**	**173**	**69**	**33**	—

[a]Portions of the Project that received surface water in 2001.

The loss estimates in Table 5 correspond very closely to observed market prices from the active land rental market in the Upper Klamath Basin, where per-acre rental prices are $200 to $300 for row crops, $125 for alfalfa, and $30 to $50 for pasture (Todd 2002). We also can compare them to the annual water leases from farmers by the Oregon Water Trust. As shown in Table 4, these leases indicate an average value of $23 per acre-foot of consumptive use on pasture and hay fields. Assuming 2 acre-feet per acre, this value corresponds to an implicit price of $46 per acre, about 35 percent higher than the $33 short-run loss estimate for Class V soils.

Estimates of short-run costs exceed the long-run estimates of the economic value of water (compare Tables 3 and 5) by more than a factor of 2. This result is consistent with the expectation that a large-scale, unexpected curtailment of irrigation is more costly to growers than small-scale individual transactions that are anticipated and planned.

It is important to recognize that certain kinds of losses in the Upper Klamath Basin are not captured by these estimates. Examples include dissolution of experienced and trained crews and loss of contracts with crop processors and purchasers.

Implications of these data

Two striking features emerge from these data.

- The value of irrigation water varies widely across locations and soil types in the Upper Klamath Basin.
- In relative terms, the variations across soil class and location are large for both long-run and short-run measures of the value of irrigation water. Per-acre values differ by a factor of 12 or more across soil classes in both cases.

The limitation on irrigation water imposed in 2001 represented only about 35 percent of the water normally applied throughout the Basin, yet the reductions were made by imposing 100 percent reductions on a subset of irrigators—those within most of the Klamath Reclamation Project. Most of the areas within the Project that did not receive water in 2001 were high-productivity Class II and III soils. By contrast, many of the areas outside the Project that did receive water in 2001 are Class IV and V soils. Examples include areas north and east of Upper Klamath Lake and in the Scott and Shasta valleys.

This observation raises questions about the cost-effectiveness of the way in which irrigation curtailment was implemented in 2001 and suggests ways to reduce losses with more cost-effective responses.

The role of government farm payments and other subsidies

In examining the economic value of water based on its use in agriculture, it should be recognized that in the Upper Klamath Basin, as in the nation as a whole, there are significant government payments to farmers via commodity support and other programs. In the Klamath Basin, payments are made to eligible farmers based on their past production of any one of three crops—wheat, barley, or oats. Payments are made under the Agricultural Marketing Transition Act, the Market Loss Assistance program, and the Loan Deficiency Payments program.

These government payments averaged about $5 million per year from 1990 through 1999 in the three counties, according to the Bureau of Economic Analysis (www.bea.gov). Payments represented about 15 percent of total farm labor and proprietors' income.

While these transfers affect land values and other economic data in the region, the magnitude of the effects may not be large. Although the three eligible crops are grown on about 30 percent of the land within the Project (2000 data), and about 15 percent of the land in the Basin overall, they represent only 17 percent of revenues from the Project and are grown almost exclusively on Class II and III soils. Current payments are based on levels of production of these three crops prior to the mid-1990s, so they do not influence current cropping decisions.

To consider the effects of these subsidies on farm values or agriculture generally in the region, one needs to ask: “What would be different if these subsidies were unavailable?” Without these subsidies, or since the mid-1990s (after which payments no longer were tied to current production), farmers are likely to have reduced the acreage allocated to the three eligible crops, while increasing production of other crops that can be grown profitably in rotations on the same Class II and III soils.

With these substitutions to other crops, changes in net returns per acre might be small. Land rental rates paid by farmers to landowners might decline, but because the net benefits of farm subsidies tend to become capitalized into land values or land rental rates, the effects on the more than 50 percent of farm operators who rent land likely would be negligible. Moreover, in terms of overall irrigated agriculture in the Upper Klamath Basin, these programs likely have no effect because the economically marginal lands (Class V) used for pasture and hay are unaffected.

These government payments may have a small positive effect on estimates of the long-run value of irrigation water presented in Table 3. Without these payments, the values on Class II and III lands might be $19 per acre lower on average ($5 million annually spread over 260,000 acres).

Irrigators in the Project also benefit from a 50-year BOR contract with PacifiCorp for electricity provided at 80 to 90 percent below market rates (as low as $0.003 per kwh). This implicit subsidy amounts to an average of $6 to $9 per acre per year, or between $1.2 million and $1.75 million annually for the Project overall.

These subsidies have a modest effect on the net returns to agriculture in the Project. They amount to 8 to 12 percent of the average long-run value of irrigation water for those portions of the Project not receiving water in 2001 (based on figures in Table 3).

The current energy contract ends in 2006. The elimination of these energy subsidies likely would reduce the long-run net returns to agriculture on Project lands by $6 to $9 per acre per year.

Economic costs of irrigation curtailment

The data presented above form the basis for a mathematical representation, or model, of irrigated agriculture in the Upper Klamath Basin. This analysis differs from the estimates in Chapter 12 (“Crop Revenue”). That analysis reflects only the Klamath Reclamation Project, and she estimates changes in gross revenues rather than changes in net revenues. It also differs from the analysis in Chapter 13 (“Regional Economic Impact”), which focuses on changes in the scale of economic activity throughout the region.

This analysis does not attempt to represent all potential consequences of irrigation curtailment that might affect individuals in the region. Nor does it attempt to quantify the “benefits” of irrigation curtailment arising from increased stream flow, improvements in aquatic habitat, and possible (but uncertain) improvements in fish populations, fish harvests, or other related changes. Putting a dollar value on all of these impacts within and outside the Upper Klamath Basin would represent an impossible task—in part because the biological relationships are so uncertain.

Our model is essentially a system of accounting equations representing the land areas, soil types, costs, and revenues discussed above and described in Tables 1–5. The model characterizes 16 areas in Oregon and California. Ten of these are portions of the Project; others include irrigated areas around and above Upper Klamath Lake and in the Shasta and Scott valleys of California.

Typically, there are about 509,000 total irrigated acres in the Upper Basin. The model assumes that each acre is irrigated fully or not at all. (It does not allow for reduced, or deficit, irrigation on a given acre nor for groundwater supplementation.)

For the analysis of short-run losses, we start from a base case in which all of these acres are irrigated and earn "normal" net revenues. We want to evaluate the losses from curtailment of irrigation on some portion of those lands.[1]

Losses from the 2001 curtailment

Our first scenario replicates the 2001 situation, but without supplemental groundwater or the midseason delivery of canal water. All of the areas that were cut off from irrigation are required to receive zero water. These areas are estimated to equal 177,823 acres, or about 35 percent of the 509,000 total irrigated acres in the Upper Basin. Areas receiving full water suffer zero losses; areas receiving zero water suffer losses as indicated in Table 5.

By replicating the actual allocation of water in the Basin in 2001, the model produces an estimate of losses of $33 million in net revenues. This loss corresponds to a decline in gross farm revenues of $87 million (which is about 17 percent higher than the $74.2 million estimated in Chapter 12 ("Crop Revenue") by Burke, who included some groundwater-based irrigation). Wage payments to farm labor were estimated to have been reduced by $8.2 million. The reductions in net revenues and farm wages amount to 48 percent of the reduction in gross farm revenues.

This estimate will overstate actual direct losses if some of the 177,823 acres assumed to have been cut off from irrigation were cropped using publicly or privately provided groundwater or the midseason canal flows allowed by the BOR. (In Chapter 14, "Outcomes, by Jaeger, actual Project acreage in 2001 is reported to have been 102,338 acres below normal.) This change was primarily the result of supplemental public and private groundwater irrigation.

Conversely, this estimate will understate actual direct losses if additional costs were incurred by growers. Examples might include costs associated with groundwater pumping, planting cover crops, clearing canals of weeds, losses from early "distress" sales of livestock, and idled or underemployed farm labor. If we assume that half of the farm labor normally employed on the cutoff acres was unable to find other employment, the estimate of losses would rise from $33 million to about $37.5 million.

Losses under efficient water allocation

We are particularly interested in evaluating how the losses of the 2001 curtailment would have differed if there had been more flexibility in how water was allocated. We expect that the losses could have been significantly lower had a cost-effective, loss-minimizing approach been possible—one that cut off water from those lands that would suffer the least.

To estimate these differences, we ask the model to choose the most cost-effective way to reduce the total irrigated area by the same number of acres. In other words, the total loss (TL) to the region is minimized, while still reducing irrigated acreage by 177,823 acres, as was assumed in the 2001 scenario.[2]

This cost-minimizing scenario generates an estimated cost of only $9.5 million, or about 71 percent lower than the $33 million cost under a scenario replicating the curtailment in 2001. Rather than curtail irrigation only on the Project, the model identifies Class IV and V lands throughout the Basin as the ones where irrigation can be eliminated with the least amount of loss. In particular, substantial areas along the Sprague and Williamson rivers, Fort Klamath, and in the Horsefly and Langell Valley areas would be cut off. No lands in the Shasta or Scott river valleys would be affected.

These scenarios involve choosing which acres to irrigate, but not how much water to apply to each. Since water scarcity has only recently become a direct concern for irrigators in the Basin, precise measurement of applied water

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[1]A curtailment of irrigation for an area A, in zone i, of soil type j, (A_{ij}) will produce a loss, L_{ij}.

[2]Algebraically, we can write this procedure as:

Minimize: $TL = \sum L_{ij} A_{ij}$

subject to: $\sum A_{ij} = A^*$

where A^* =177,823, the acreage not receiving water

Table 6. Estimated loss in net farm revenues from restricting irrigation diversions in the Upper Klamath Basin under alternative allocation methods.

Losses from 2001 restrictions on the Project (177,823 acres without water)	$33–37.5 million
Losses for equivalent restrictions but with cost-minimizing acre-to-acre transfers	$9.5–12 million
Losses for equivalent restrictions but with acre-to-acre transfers and deficit irrigation	$6.3–7.6 million

has not been practiced. If gauges and volume meters were available throughout the Basin, one could "fine tune" the allocation of water to include partial reductions in the applied water for some fields. Such "deficit irrigation" may lower the cost of irrigation reduction even more than the "acre-to-acre" reallocation reflected in the model above.

The cost of installing gauges and metering devices must be considered. For flood irrigation diversions, the installation of flumes and meters can cost $2,500 at each diversion point. For piped diversions, the cost may be $1,000. An inventory of diversion points in the area counts about 300, but there are about 850 irrigated farms. If one metering device is required for each irrigated farm, and if about half of the diversions are piped, the average cost of installation would be about $3 per acre. Given an additional 10 percent cost for annual maintenance and depreciation, the cost of metering amounts to less than 50 cents per acre per year. Therefore, these costs do not seem to significantly weaken the case for metering water in the Basin.

An analysis of irrigation management involving deficit irrigation and fine tuning of water deliveries was undertaken for the Project by Adams and Cho (1998). They included only the Project in their model, but their results provide some evidence of the additional potential for cost reductions provided by this method. They find that for small percentage reductions in irrigation deliveries (less than 20 percent), the cost is about $17 (per "acre equivalent"), compared to the $30 to $35 short-run loss for leaving an acre of pasture completely dry.

With a combined approach that would leave 100,000 acres of pasture dry and require deficit irrigation (of 18 percent) on other acres, the same reduction in total diversions as was imposed in 2001 could be achieved at a cost of $6.3 million, or 80 percent less than the estimated actual cost. If half the labor reduction is assumed to be left idle, the estimate rises to $7.6 million. A summary of these cost estimates for different water allocation alternatives is presented in Table 6.

Two caveats remain. First, it is important to recognize that any change in the allocation of scarce water will produce consequences for many individuals that differ from the circumstances of 2001. Some would see these changes as improvements, others would not. For example, reductions in irrigated acres would cause operating and maintenance costs for the affected irrigation districts to be shouldered by a smaller production base. Second, implementing cost-effective water management is more difficult than simply estimating the cost savings that might result. How the legal, administrative, and political institutions might be realigned to facilitate cost-effective responses to scarcity is a critical question facing the region.

Ways to reallocate water among irrigators

> "Water is becoming increasingly scarce in the United States. Demand is rising along with population, income, and an appreciation for the services and amenities that streams, lakes, and other aquatic ecosystems have to offer…. Ordinarily, Americans count on prices and markets to balance supply and demand and allocate scarce resources…. As conditions change, markets enable resources to move from lower- to higher-value

uses. Market forces, however, have been slow to develop as a means of adapting to water scarcity" (Frederick 1999).

The analysis presented in this chapter suggests that about 80 percent of the cost of the 2001 irrigation curtailment in the Upper Klamath Basin was due to inefficiencies in the way irrigation water was allocated. In other words, only 20 percent of the cost was directly attributable to water scarcity arising from the drought and ESA-related requirements.

The situation facing growers in 2001 contained the two characteristics that economists recognize as working against producers in any industry: a high degree of uncertainty and few options or flexibility. Not only was irrigation interrupted on the most productive, highest value acreages in the Basin, but there existed no mechanism—such as a market—to reallocate other irrigation water between low-value and high-value uses.

This is not to suggest that water markets could have been introduced on short notice as the 2001 situation became apparent. In the future, however, if similar water scarcities arise, the ability of irrigators to transfer water rights via markets could transform a potentially very high-cost event into a much less significant one.

Water markets

Water markets or water banks represent the option to buy needed water or to sell water to others. The willingness to buy or sell water will reflect differences in land productivity, crops, and fixed costs. Growers who have the most to lose from a cutoff of water are likely to benefit most from the ability to buy additional water in such circumstances. Likewise, irrigators of low-productivity lands or those with low fixed costs may decide they would be better off selling their water to others.

Although water markets and water rights transfers are a relatively recent phenomenon in the western U.S., there is growing evidence of their use and beneficial effects. In Texas' Rio Grande Valley, transfers of 74,966 acre-feet occurred prior to 1990. The net benefit of these transfers has been estimated at more than $1 trillion (Griffin 1998). Active water markets have long existed in Colorado, Utah, and New Mexico, and more recently in Arizona, Wyoming, and California (Howe 1998).

The thousands of applications documented in Colorado, Utah, and New Mexico include permanent sales of water rights as well as temporary transfers to accommodate short-term needs, such as those that occur during drought. Approved trades in these states include many transfers among irrigators and from agriculture to nonagricultural uses, and a few from nonagricultural uses to agricultural ones. Colorado long ago adopted a water court system in which proposed water transfers may be challenged by parties who believe they will be "injured" by the transfers.

In California, during the early 1990s, federal and state legislation helped clarify water rights in order to facilitate rights transfers, although these changes have not yet achieved their full intent involving long-term transfers (Archibald and Renwick 1998). Nevertheless, California has developed informal intraseasonal spot markets and annual lease markets, both of which have been dominated by trades within agriculture. A state-run "water bank" has handled 40 percent of all water transfers since 1992, demonstrating that annual lease arrangements could benefit the willing buyers and sellers in these markets (Howe 1998). This water market activity has averaged 122,000 acre-feet in each drought year during the early 1990s. In the case of the 1991 water bank, the statewide net benefit was estimated to be $104 million, including $32 million in benefits to agriculture (Howitt 1998).

Existing Oregon water law is quite conducive to water markets. Water right transfers have been common in the state since the 1980s. Oregon law allows water rights to be transferred between beneficial uses, including in-stream flow, following an application and approval process through the Oregon Water Resources Department (OWRD).

The number of applications rose from about 100 to more than 200 per year between the 1980s and 1990s. Currently, OWRD receives more than 250 applications per year for out-of-stream uses and 5 applications for transfers to in-stream uses such as protection of fish habitat. The total includes about 50 temporary transfers. About half of commercial water right transfers convey water rights from one agricultural use to another, according to a survey conducted in the early 1990s (Landry 1995). The average sales price in these water markets was $360 per acre-foot, which corresponds to an annual value of about $22 per acre-foot (using a 6 percent interest rate).

Potential effects of water markets in the Upper Klamath Basin

There is continued uncertainty about the total amount of water available for irrigation in the Upper Klamath Basin. It also is possible that future curtailments may be implemented in ways that do not promote efficiency, as they were in 2001. In the face of these circumstances, irrigators may wish to increase their options in such situations.

The suggestion that water markets could play a central role in solving Klamath water conflicts frequently is met with two kinds of objections. First, growers in the region typically dismiss it as an idea that "can't work" and will "never happen." Second, they are concerned that so much water might be transferred from irrigation to other uses that the scale of the local farming economy would be greatly reduced, thus threatening the viability of their rural communities. These issues are discussed in this and the following section.

Permanent market transfers or "swaps" of water rights with different priority dates may be advantageous to some growers. The financial risk associated with not receiving water varies among irrigators, depending on their crops, soils, and production technologies. Our estimates of short-run losses from losing access to water vary from $25 to $312 per acre. Efficiency suggests that the highest priority water rights will have the highest financial value when held by those irrigators with the highest risk of loss.

Consider an example. If a senior water right is held by a grower facing losses of only $25 per acre (due to lower productivity land), while a junior water right is held by a grower facing losses of $300 per acre (due to having highly productive land and higher risk crops), there are obvious gains from an exchange of assigned priority rights between these two growers. Assume the high-loss, junior-right holder expects to lose access to water 1 year out of 4. He likely would be willing to pay up to $300 every 4 years to avoid that loss. The low-loss, senior right holder, on the other hand, could exchange his senior right for a junior right and face only a $25 loss once every 4 years.

Thus, after taking into account the changes in their expected losses over time, the high-loss grower should be willing to pay up to $1,250 for a permanent trade of priority dates, while the low-loss grower should be willing to accept anything higher than $104. The combined gain from this swap is $1,146 per acre.[3]

Oregon law allows for these kinds of water rights transfers, both permanent and temporary, provided there are no adverse "third-party effects." When a water right transfer changes the point of diversion, it is possible that holders of water rights between the two points of diversion will be affected adversely. Such transfers would be prohibited by the OWRD.

There is reason for optimism that water right transfers would be allowed in the Upper Klamath Basin. Most transfers would move senior water rights from upstream to downstream, where they could be used on more productive land. This would reduce the likelihood of this kind of "third-party effect" because more water would be flowing past intermediate diversion

[3]The present value of these changes in seniority is computed by annualizing the expected losses (dividing by 4), and then applying the formula for a perpetuity (dividing by the interest rate). Using 6 percent, we calculate for the high-loss grower an increase in the present value of his water right of $(300 \div 4) \div 0.06 = \$1{,}250$; for the low-loss grower, there will be a loss in present value terms of $(25 \div 4) \div 0.06 = \$104$.

points rather than less. If the ownership of water rights evolved so that most senior water rights were in the Project area, basinwide management of water allocation would involve restricting water diversions among the junior-right holders in the upper reaches of the Basin to ensure adequate supplies for the senior-right holders below.

Were such a reallocation of priority rights to occur, an unintended, but desirable, side effect would be more water left in-stream in the upper portions of the Basin and in Upper Klamath Lake. Additionally, in years when water supplies were inadequate to provide water to junior-right holders, the curtailment of water deliveries in these upper reaches would reduce stream and lake contamination from agricultural chemicals and animal waste by reducing agricultural runoff in the upper portions of the watershed.

For the Upper Klamath Basin overall, the exception to the idea of fully functioning water markets and transfers of water rights involves the Scott and Shasta valleys in California. There are multiple obstacles to including those areas in any realistic scenario. First, there is no physical way to move water from those tributaries upstream to the Project. Second, it is unclear whether individual water transfers between right holders in different states would be allowed under the laws of either California or Oregon.

Nevertheless, other mechanisms for including Scott and Shasta valley irrigation as part of a comprehensive solution are possible. For example, government agencies or nongovernmental organizations might take actions to augment in-stream flows in the Scott and Shasta rivers. To the extent that these actions improve fish habitat, it might be possible to relax requirements for in-stream flows below Iron Gate Dam.

In addition to the possibility that these transactions might increase economic efficiency, the adjudication of water rights might reduce the losses from water shortages in a secondary way. In the long run, junior-right holders can be expected to alter their production decisions based on the recognition that they face a relatively higher risk of not receiving water. Given this fact, they are likely to take precautionary measures that reduce their vulnerability. For example, they might be able to choose a different combination of fixed and variable costs of production, or they might prepare contingency plans to minimize their losses in the event of drought. An example is the purchase of insurance against water loss.

One variation on the water market theme may be appealing to irrigators and a good fit for the current administrative structure of the Project. This variant is called a "water bank." It can be thought of as a cooperative arrangement among growers for the distribution of water and payments for its use.

In the case of the Project, a water bank might work as follows. Each grower could be entitled to a proportional share of the available water based on the size of his or her farm. In a drought year, when the total amount of water available is limited, these shares may not represent enough water to fully irrigate each acre of land. In that case, farmers may offer to forgo irrigation and "deposit" their water in the water bank. Other irrigators may be willing to pay the bank in order to obtain additional water. The bank acts as a clearinghouse between buyers and sellers of water, all of whom are growers in the Project.

What if all growers wanted additional water? In that situation, the Project, or a district within the Project, may be willing and able to look elsewhere for additional water, for example, by buying water from irrigators above Upper Klamath Lake.

A well-functioning water bank can achieve an efficient allocation of water similar to a water market. However, a water bank may be better suited to the existing collective arrangements and operations of the Project; it may facilitate the necessary coordination within the Project better than a decentralized water market.

Without conducive and supportive institutions, it is unlikely that adjudicated water rights will be transferred via water markets or water banks to reduce financial risks to the agricultural sector overall. External funding might serve as a catalyst to purchasing, and then reselling, high-priority water rights.

Reallocation of water from agriculture to nonagricultural uses

How water will be allocated in the future between irrigators within the Project, irrigators outside the Project, and nonagricultural uses is a central concern for everyone in the region. The events of 2001 have raised the level of concern, apprehension, and uncertainty about future water allocation in the Basin.

The events of 2001 and the conflicts between ecological and agricultural uses of water have led some to question whether agriculture is compatible with competing ecological goals. This is a complex question that does not have a simple "yes" or "no" answer, certainly not one based solely on the existing methods for valuing and comparing benefits and costs. Moreover, the eventual outcomes for water allocation in the Basin will be based in part on legal determinations involving tribal rights, the Endangered Species Act, Bureau of Reclamation obligations, and competitive forces in national and international agricultural markets. Although it is not possible to predict the future path of water allocation within the Upper Klamath Basin, it can be expected to evolve in response to changes in the legal, economic, demographic, and political setting.

Economic forces also can be expected to be at work, by influencing legal and political processes, and by creating individual and collective incentives to allocate water in ways that reflect the most valuable uses of that water to society. In that context, some observations about the allocation of water between agricultural and nonagricultural uses are possible, based on the economic description of agriculture in the Upper Klamath Basin and the estimates of the value of water when used on various classes of agricultural land.

When water rights adjudication in the Basin is complete, Oregon water law allows purchases of water rights from individual irrigators to augment in-stream flows, so long as there are no direct "third-party" effects that limit the legal diversions by other water rights holders. Whether and how much water might be returned to in-stream flows is unclear. However, there is little evidence to suggest that such transactions will result in the complete demise of agriculture in the Upper Klamath Basin. The following evidence should dispel such fears.

First, while there are examples of large transfers of water from agricultural to nonagricultural uses via water markets (for example, in Texas' Rio Grande Valley, where 99 percent of water rights transfers were from agricultural to nonagricultural uses), much of the agricultural water that was sold would otherwise have been unused by its owners (Griffin 1998). In addition, nearly all of these transfers were near large urban centers and went to municipal uses or to accommodate urban sprawl. In the Upper Klamath Basin, there are no comparable circumstances in which water is unused, nor is there large unmet urban demand for water nearby. Long-distance conveyance seems impractical at this time.

Second, the estimates presented above of the long-run agricultural value of water rights, especially on the highly productive "prime" Class II and III farmlands, seem to be more than environmental groups have been willing to spend, except in exceptional circumstances. Most of the Class II and III soils are estimated to generate between $75 and $144 per acre per year, or between $37 and $72 per acre-foot of water. Purchases of water rights for in-stream flow, for example by the Oregon Water Trust, tend to be in the range of $6 to $22 per acre-foot. Thus, the agricultural value of water on these soils is 1.5 to 12 times higher than the prices that have been paid elsewhere in the region.

This evidence suggests that, given scarce funding for the improvement of aquatic ecosystems and fish habitat, available funds are likely to be targeted where they can do the most good (in terms of improving fish habitat) at the lowest cost. Some of the Class IV and V soils in the Upper Klamath Basin, where estimates of the value of water are within the range of $6 to $22 per acre-foot, might be candidates.

This economic evidence may or may not be a good predictor of the course of legal challenges and political support for ESA-related restrictions on irrigation diversions. It also is not clear whether the introduction of water markets would alter the political balance among interest groups in any predictable way. To the extent that market transactions are used to improve stream flow and aquatic habitats in the region, the status of threatened and endangered species may improve, and pressures for additional legal or political challenges may abate. Moreover, market transfers involve direct compensation to those water right holders who willingly sell their water rights. Generally speaking, a water market also will put the agricultural economy in a better position to reduce the economic effects of any future restrictions on irrigation, both in terms of individual farmers and the overall agricultural community.

It is important to recognize that with water markets, land retirement would have a smaller effect on the agricultural economy than if land were taken out of production arbitrarily or by some other procedure that did not take account of market values. When irrigation water rights are bought by environmental interests to protect fish, a market approach will encourage and facilitate the purchase of those water rights with the lowest agricultural value. These rights are likely to be those associated with Class IV and V soils, where net revenues may be only 7 percent of those on the most productive soils. As a result, the retirement of those lands will have the smallest effect on the region's agricultural economy.

For example, we estimate that if 20 percent of the lowest value irrigation water rights were purchased for in-stream use, total net farm revenues for the Basin would be reduced by only about 10 percent.

A change of this magnitude would have a very modest effect on the agricultural economy overall. For example, this change is less than the typical year-to-year percentage change (positive or negative) in gross farm sales in Klamath County, and it is about half as large as the typical year-to-year change in revenues for Oregon counties such as Sherman and Gilliam, where rainfed agriculture predominates.

None of the foregoing analysis is intended to provide an answer to the question of which uses for water in the Klamath watershed produce the highest social value. In addition to agriculture, other individuals and groups with interests in how water is allocated in the Upper Klamath Basin include the commercial fishing industry, recreational users, and Native American tribes throughout the Basin and in coastal communities, as well as urban, regional, and national groups who value the protection of species and aquatic ecosystems. As much as one would like to quantify these different (and difficult-to-measure) values in order to compare them to agricultural values (including the values associated with the protection of farm communities), it would be an extremely costly endeavor unlikely to achieve a credible result.

Biological flexibility

The mechanisms for water transfers discussed above involve introducing flexibility in the ways in which irrigators are able to respond to water scarcity. It is reasonable to consider how flexibility in the biological requirements for lake elevation in Upper Klamath Lake and stream flow below Iron Gate Dam can be part of a cost-minimizing way to allocate water among competing uses. In the event of a drought, is there room for flexibility in the ESA requirements?

Several recent Biological Opinions have been responsive to drought conditions in considering how much water would be required to support fish populations. However, the limited flexibility in the 2001 decisions raised questions about how biological flexibility might best be managed, while at the same time offering reasonable and prudent protection for fish. A rule-based, long-term approach that incorporates drought-year compromises by both in-stream and irrigation uses might be a way to avoid large negative consequences for either agricultural or environmental interests.

Given the language contained in the Endangered Species Act, to a large extent this is a question for biologists and court interpretations. (See Chapter 5, "Suckers," and Chapter 6, "Coho Salmon," for discussion of the biology of these issues.) The ESA indicates that costs should not be taken into account when devising plans to protect endangered species; yet, it also instructs that responses should be "reasonable and prudent."

More flexible rules for species protection that allow exceptions to a general rule (for lake elevation or stream flow) under certain circumstances would seem to be consistent with the directive for "reasonable and prudent" approaches, so long as these rules would not compromise the protection of the species. To illustrate, consider the possibility that the required lake elevation in Upper Klamath Lake could be lowered by 1 foot below the desired minimum, say, once every 5 years (but no more frequently, regardless of whether multiple droughts occurred within a 5-year period) and that the in-stream flow requirement below Iron Gate Dam could be relaxed by 25 percent, say, once every 5 years. Given these rules, water shortages sometimes would restrict irrigation diversions by farmers, and they sometimes would reduce flows or lake levels for fish.

Based on the distribution of hydrologic year-types, how often, and to what extent, would severe irrigation restrictions be necessary? Depending on the biological requirements and frequency of low-water years, a flexible allocation mechanism of this kind might make it possible to completely avoid severe irrigation reductions like the one experienced in 2001. Instead, there might be only infrequent, modest restrictions.

Although the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), and the Bureau of Reclamation (BOR) have at times made provisions for relaxing the biological requirements in drought years, they have not established a regular, long-term directive that would rule out sequential, or closely timed, reductions in lake level or stream flow that might place fish in jeopardy.

The BOR proposals for managing lake elevation in Upper Klamath Lake and stream flow below Iron Gate Dam, for example, allowed for relaxing lake elevation and stream flow requirements in dry years and critically dry years. The BOR proposal, however, would relax biological requirements in all dry or critically dry years, even if they occurred consecutively. The alternative suggested here would allow for relaxed biological water requirements only if those requirements had not been relaxed in the previous 5 (or some other number of) years. To avoid considering every year to be a special case, rule-based limits on the frequency of compromises must be upheld.

In principle, arrangements of this kind recognize the uncertainty of future water availability, and they also implicitly recognize that small reductions in water supplied to several uses might be preferable to large reductions in supply to any one group. This approach is yet another way in which flexibility, if managed effectively, can promote better use of a scarce resource. Once again, however, the possibility of implementing a proposal of this kind would depend on scientific and court interpretations of the ESA as to whether such an approach could be considered "reasonable and prudent" and not likely to jeopardize the continued existence of species listed as threatened or endangered under the ESA.

Increasing the water supply

Many observers would like to see the quantity of water in the Basin increased in some way. Proposals include using groundwater in times of drought, building new reservoirs, and "saving water" through the adoption of technologies with higher irrigation efficiency.

These solutions are appealing because they avoid making hard choices to resolve the conflict over existing scarce water; they simply make more water available so that all users can have what they want. In practice, these solutions rarely work. The options for increasing supplies tend to be very expensive relative to the value of their intended use, and they often are environmentally damaging (Frederick 1999).

The sections below evaluate the economics of two approaches that have been suggested as ways to increase the amount of available water. Analyses of other options are beyond the scope and resources of the current study. For example, we do not look in detail at augmenting water storage with new reservoirs.

Supplementing irrigation with groundwater

In drought years, might it be feasible to supplement irrigation diversions by pumping groundwater, or by using groundwater to augment in-stream flow so that additional irrigation diversions could be permitted? There are important hydrological concerns about doing so on a large scale, as there is evidence that such pumping would have adverse effects on local aquifers, private wells, public drinking water supplies, and subsurface irrigation in nearby areas (see Chapter 2, "Klamath Reclamation Project"). For these reasons, there may be legal obstacles as well.

Our goal here, however, is to provide an approximate picture of the economic costs and benefits to farmers of such an approach. The question is whether the installation of high-volume groundwater pumps can be an economically viable way to respond to drought conditions in the Upper Klamath Basin. We are not asking whether such pumps can be economically justified to permanently augment irrigation supplies, but rather whether they could be used as a source of supplemental irrigation water in times of extreme need.

In 2001, for example, the Tulelake Irrigation District projected that, with $5 million, wells producing 170 cfs could be developed. Assuming 100 days of pumping and 2 acre-feet per acre, this volume would serve about 17,000 acres.

A key question is how often this supplementation would be required. The drought conditions observed in 2001 and 1992 represent extreme conditions that occur only 5 percent of the time based on data from the past 41 years. Changes in forests, climate, and biological requirements may mean that irrigation water scarcity will occur much more frequently in the future. If we assume that supplemental water is needed once every 5 years, can the costs estimated by the Tulelake Irrigation District be economically justified? It depends on how the available water is otherwise allocated.

Based on the $5-million investment cost and a 5 percent annual cost for maintenance and depreciation (given usage only 1 year in 5), the cost when supplementation is offered would be $162 per acre for the investment and depreciation. Assuming pumping requires 100 feet (total dynamic head), and with a commercial rate for energy (or opportunity cost) of $0.035 per kwh, the energy cost per acre would be $9. Thus, the total cost of supplemental pumping would be $171 per acre.

If a groundwater pumping activity permits 17,000 additional acres to be irrigated, which acres would these be? In the absence of groundwater pumping, efficient water allocation would involve irrigating high-value lands and leaving lower value lands dry. If we assume that efficient allocation occurs (for example, via water markets), then the additional areas irrigated as a result of groundwater pumping would be lower value lands. Since one-half of the acreage normally irrigated is Class IV and V soils, where losses due to an irrigation cutoff generally are $33 to $70 per acre, supplemental irrigation with groundwater pumping cannot be justified if it costs $171 per acre.

If an efficient allocation of water in drought years is not possible, and the most productive lands are required to be left dry 1 year out of 5, then the $171 per-acre cost would be justified to avoid per-acre losses ranging from $173 to $312 for Class II and III soils. However, this conclusion requires one to assume that surface water will be allocated in a highly inefficient manner during future water shortages, as it was in 2001.

Improving irrigation efficiency

Irrigation efficiency is defined as the ratio of the amount of water actually consumed by the crop to the total amount of water diverted (from surface water or groundwater) for irrigation. Depending on the irrigation technology used, a farmer may need to apply twice as much water as the plants need. The water that is not consumed by plants flows back to the stream, percolates down through the soil, or evaporates.

It generally is assumed that water that percolates into the subsoil eventually finds its way back into the stream. This may take hours, days, or years, depending on soils, geology, and distance to the stream. The benefits to fish of changes in irrigation diversions vary greatly, depending on what is assumed about the amount and timing of changes in these return flows.

Evaporation varies as well, depending on temperature and humidity, but it often is assumed to account for no more than 10 to 15 percent of the water applied.

Surface (flood) irrigation efficiency may be less than 50 percent; sprinkler efficiency may be higher than 70 percent. In the Upper Klamath Basin, surface irrigation is most common, especially on the less productive lands. For most high-productivity lands, sprinkler irrigation is used. Conveyance efficiencies (typically canals for transporting water) of 70 to 80 percent are common in the Northwest, although efficiencies for unlined canals can be as low as 20 percent. Overall efficiencies, including conveyance and irrigation delivery, average less than 50 percent, and in some cases are as low as 20 percent (Butcher et al. 1988).

Several western states have passed legislation encouraging farmers to invest in improved on-farm irrigation technology (Huffaker and Whittlesey 2000). However, while irrigation efficiency may be an important factor affecting the potential for satisfying agricultural and ecological demands, it should not be assumed that improved irrigation efficiency in agriculture will result in less water being diverted from the stream. Thus, it does not necessarily leave more water for fish or other in-stream uses. Reality is more complicated, since improved irrigation efficiency also reduces return flows.

Assume a farmer diverts 400 acre-feet with an irrigation efficiency of 40 percent. This means that his consumptive use is 160 acre-feet, and return flows are 240 acre-feet. What happens if this farmer adopts improved irrigation technology that raises irrigation efficiency to 70 percent? With higher irrigation efficiency, the farmer may alter production methods or even switch to different crops that take advantage of the improved irrigation technology. As a result, consumptive use may increase. Assume, for example, that consumptive use increases from 160 to 175 acre-feet. With 70 percent irrigation efficiency, the stream diversion would be lowered from 400 to 250 acre-feet (175 ÷ 0.7). On the face of it, this would seem to be good for fish because it leaves an additional 150 acre-feet in streams or lakes.

However, the return flow now is only 75 acre-feet (250 – 175) instead of the previous 240 (400 – 160), a decrease of 165 acre-feet. Return flow has decreased by 165 acre-feet, while diversion has decreased by only 150 acre-feet. Thus, stream flow is reduced by 15 acre-feet as a result of the adoption of the new technology.

This hypothetical example illustrates the possibility that investment in improved irrigation efficiency can substantially *reduce* the amount of water left for streams or lakes. The actual outcome depends on what changes the farmer makes in farming practices and on how irrigators downstream respond to changes in the availability of stream flows at different times—especially where surface water is overappropriated via existing senior- and junior-right holders.

This issue is especially relevant to the Upper Klamath Basin, where water that is “wasted” due to inefficient irrigation technology frequently provides ecological benefits elsewhere. In areas above Upper Klamath Lake, return flows from irrigation return to streams or to Upper Klamath Lake, either reentering the Project for irrigation or providing in-stream flows below Iron Gate Dam. Return flows in the Lost River watershed and the Project are believed to be reused several times by other irrigators as these waters are collected in lateral canals or seep into canals, wells, and subsurface irrigation throughout the Project. Because of this recycling of water across the Project, overall irrigation efficiency is estimated to be above 90 percent.

In addition, return flows within the Project supply water to Tule Lake and Lower Klamath national wildlife refuges. Return flows in the Shasta and Scott river areas supplement stream flows and augment habitat for coho salmon. Overall, it is hard to make the case that improved irrigation efficiency will make more water available for fish and wildlife habitat.

If, however, return flows are very slow, so that "wasted" irrigation water does not return to lakes and rivers during critical months, there may be potential gains from improved irrigation efficiencies—but not without a cost. Ultimately, the cost of making more water available for fish through improved irrigation efficiency must be compared to the cost of the alternatives.

Even in cases where improved irrigation efficiency makes more water available for fish, the farmer may not benefit. For some crops, especially low-value crops, the cost of improved irrigation technology may be higher than the net revenues from production. For high-value crops, sprinkler irrigation may provide some gains to farmers due to increased yields, lower labor and pumping costs, or the possibility of switching to a higher value crop.

The principal costs of improved irrigation efficiency are the capital costs of the new technology and associated maintenance costs. Sprinkler systems can cost from $400 to $1,200 per acre to install. The annualized cost for these investments would amount to $24 to $72 per acre per year. Given the net revenues for Class IV and V soils reported in Table 3, the cost of these investments would be prohibitive unless they enable irrigators to increase revenues or lower costs in other ways.

Concluding comments

The legal and political institutions and infrastructure that currently exist in the Upper Klamath Basin were developed over the past 100 years to fit the circumstances of that period—one in which per-capita income was low and natural resources were relatively abundant. For these historical reasons, improvements in the institutions and infrastructure necessary for efficient water allocation have not kept pace with other changes in the region. In particular, the current lack of adjudicated water rights and the absence of water-metering devices are two key obstacles to managing water in a way that would reduce uncertainty, promote efficiency, and avoid costly events like the one experienced in 2001.

Costs are minimized most directly by flexible mechanisms that allow scarce irrigation water to be transferred among growers so that it finds its way to the highest value uses through voluntary exchange. The analysis above suggests that more than 80 percent of the costs of the 2001 water situation could have been avoided had water markets or other transfer mechanisms been available at that time. Given the high value of agriculture within the Project, and the presence of large areas of significantly lower value agriculture in other parts of Klamath County, a cost-minimizing approach to reducing irrigated acreage would involve full irrigation for the Project and curtailed irrigation in other, less productive areas. Indeed, a comparison between the $6.3 million in estimated cost for a cost-minimizing irrigation curtailment equivalent to the one imposed in 2001 and the $27 to $46 million in estimated losses in 2001 (Chapter 14, "Outcomes") is sobering.

This analysis suggests that in the Upper Klamath Basin, the absence of water transfer mechanisms such as water markets or water banks magnified the costs of drought and ESA determinations fourfold. The cost of future water shortages could be reduced if mechanisms for transferring water rights were put in place. In addition, the incorporation of rule-based biological flexibility into the species-related decisions also could lessen the prospect of costly restrictions on irrigators during future droughts.

The completion of the adjudication process promises to create a new opportunity for the reallocation of water rights among groups and users with different interests and risks. Whatever the outcome of tribal water right claims or future ESA rulings and Biological Opinions, if water rights can be transferred across different locations within the Basin, it will be possible for water available to irrigators to be allocated with the greatest certainty to those users with the most to lose from not getting their water. Users with junior water rights may develop contingency arrangements to reduce their short-run losses, plant crops more tolerant of deficit irrigation, or diversify their farm activities.

Other mechanisms, such as insurance against curtailed water deliveries, may develop as ways to reduce uncertainty, promote flexibility, and encourage cost-effective responses. When combined with long-term actions to address water quality issues throughout the Basin, there is reason for optimism that a sustainable balance can be found among the competing demands for the Basin's water.

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Synthesis

A Synthesis: Policy Analysis and Public Institutions

Emery Castle

This chapter considers possible improvements to the performance of federal, state, and local institutions that could lead to long-term solutions to water allocation issues in the Upper Klamath Basin. It attempts to synthesize information throughout this report and outlines possible future directions. It draws mainly on Chapter 18 ("Policy"), Chapter 19 ("Water Allocation Alternatives"), and Chapter 3 ("Legal Aspects"). In addition, the chapters dealing with natural resources, as well as those concerned with economic and social matters, provide the reality with which institutions and policies must deal.

Institutions and policies reflect the formal and informal arrangements made by individuals for dealing with one another in groups. This synthesis is concerned mostly with formal institutional arrangements—the means by which obligations, responsibilities, rights, and entitlements are stated in the law and take shape in policies, programs, and organizations. Under the U.S. system of government, all three branches—legislative, judicial, and executive—typically are involved in public policies. Additional complexity arises from divisions of power among federal, state, and local governments.

Particular institutions, policies, and programs usually come into existence at a particular time to serve a specific purpose or purposes. An institution may be effective in serving the purpose for which it was created at the time it was created, but social needs change over time. New programs often come into existence to serve needs that were not apparent when an earlier policy was established. As a result, conflicts, inconsistencies, unclear responsibilities, and fragmented authority may develop.

This report documents numerous inconsistencies and unintended consequences stemming from government programs in the Upper Klamath Basin in 2001. In addition, Native American tribes point out that they, and others, have borne the consequences of similar inconsistencies in the past. In other words, institutional weakness may have received a great deal of attention in 2001, but it certainly did not appear for the first time that year.

These conflicts and inconsistencies do not necessarily mean that particular programs have failed or are dysfunctional. Rather, they may indicate that government activity, taken as a whole, is not performing effectively. Corrections or improvements in institutional performance can take one of two avenues. One approach is to consider the particular situation under review as an *exception*. This means the situation is considered to be unique; thus, institutional rules or guidelines can be suspended and a solution sought by other means. The other avenue is to *modify* one or more institutions. When this avenue is chosen, it suggests that conditions either are different than they were when the institutions were established, or that something important was neglected at that time.

Uniqueness may be judged as to whether a particular situation, such as that existing in the Klamath Reclamation Project in 2001, might occur elsewhere or has elements that might be duplicated elsewhere. In other words, is it possible that these issues will arise elsewhere in the West?

Woodward and Romm (Chapter 18, "Policy") consider the Klamath situation to be unique and believe it should not serve as a legal precedent. This judgment is based largely on a comparison of institutions in the Klamath Basin with those relating to other California rivers. This issue was not discussed to any significant extent elsewhere in this report. Yet, it needs to be considered if potential lessons from the Klamath experience are to be applied elsewhere. It is unlikely that the conflicting needs of endangered species, economic systems, communities, Native Americans, and government agencies will come together elsewhere precisely as they did in the Project area. Similar, conflicting interests are present elsewhere, however, and the lessons of the Klamath may be useful.

Uniqueness also may stem from the events that triggered the problem. In this case, the 2000–2001 drought was one event, among many, that led to the irrigation curtailment. If the drought is considered an event unlikely to be duplicated, it would not make sense to modify institutions to provide for such an unusual event.

This report presents considerable data about long-term weather patterns in the Klamath Reclamation Project area. Yet, remaining differences of opinion suggest that there are inadequate data to permit a definitive judgment regarding the uniqueness of 2000–2001. Clearly, the probability of a similar drought occurring in the future is important in deciding whether it should be considered an exception under the law.

Possibilities for institutional change

Three alternative, highly preliminary, views are sketched here of how institutional change might result from the events in 2001. Alternative I considers the 2001 situation to be an anomaly, or highly unusual event, and treats it as an *exception* to events that established institutions were designed to address. Alternative II is labeled here as a *moderate modification.* Alternative III describes a *major modification.*

Alternative I—dealing with an exception

Alternative I proposes minimal institutional change, but suggests fundamental improvements in operating procedures. Suggestions made in Chapter 12 ("Crop Revenue") and Chapter 19 ("Water Allocation Alternatives") are consistent with this alternative. One is for water users in the Upper Klamath Basin to collectively formulate water use contingency plans to be used when water is in short supply. Such plans might provide evidence that progress is being made toward the accomplishment of, for example, Endangered Species Act (ESA) objectives.

Additionally, Woodward and Romm (Chapter 18, "Policy") suggest that the court decision in *Tulare v. United States* might be tested to determine whether compensation must be paid when the cost of a "taking of water rights" falls heavily on a particular group. In this case, water contractors sought compensation when normally diverted water was kept in the watercourse for the protection of fish. The issue was not whether the federal government had authority to protect endangered species, but whether it could impose the costs of doing so solely on the plaintiffs. Judge Wiese wrote in his decision, "The federal government is certainly free to preserve the fish; it must simply pay for the water it takes to do so."

If this decision is upheld, conflicts would be addressed on a case-by-case basis. If there is disproportionate cost, the government would be required to pay compensation. If *Tulare v. United States* is not upheld, presumably the Court would address any obligation that might exist for the Bureau of Reclamation to supply irrigation water, for example to the Klamath Reclamation Project. To summarize, the particular circumstances existing in a particular case would be considered within the framework of existing institutions.

Alternative II—moderate modifications

Consider next Alternative II, moderate institutional modification. The key assumption here is that certain institutions are more basic than others and should not be changed in a fundamental way. Less basic institutions are modified to make the basic institutions perform better or to remove inconsistencies among institutions. The Endangered Species Act, reclamation legislation, Native American rights, and California and Oregon state water laws are considered here to be basic institutions. The legal standings of endangered species, Native American water rights, and out-of-stream water uses are not questioned.

Possible changes in other institutions are the essence of this alternative. The strategy here is to create a more adaptable, flexible system for managing water, while leaving the basic institutional framework intact. Adaptability and flexibility are time-honored techniques for addressing uncertainty.

One way of providing for adaptability and flexibility in water management is to require, or permit, resource interdependencies in the basin to be incorporated into the institutional framework. Chapter 19 ("Water Allocation Alternatives") provides evidence that water could be used more effectively if a broader perspective were employed in decision-making. Interdependence among Basin water uses and users then could be a source of adaptability and flexibility. So long as out-of-stream use occurs in the Upper Klamath Basin, recognition of the interdependencies in water allocation decisions within the Basin will improve water use within the Basin and, as a consequence, improve the quantity and quality of water downstream.

Consider the following examples.

- The Klamath Reclamation Project does not exist in a vacuum. Land use in the Project is not the only activity in the Klamath Basin that affects Upper Klamath Lake levels, water quality, or the amount of water that flows into the lower Klamath River. (See the final section in Chapter 6, "Coho Salmon.")
- Biological information presented in this report makes it clear that water quality, as well as quantity, is important for many in-stream water uses. Furthermore, water quality varies geographically within the Basin. So long as water requirements do not recognize qualitative considerations, the waters of the Basin will not be put to their highest social use. Many public and private decisions currently are made with reference only to water quantity. Social gains would result from a consideration of water quality in decision-making. For some purposes, for example, 0.8 acre-foot of water might be as useful as an entire acre-foot of water that is 2°F warmer.

Jaeger (Chapter 19, "Water Allocation Alternatives") discusses institutional modifications that would be necessary to accommodate such interdependencies. Some modifications would be minor, others difficult.

Water markets are one means for moving water rights among uses, users, and locations. They provide one means of minimizing the costs of water allocation decisions. For example, if it is determined that the federal government should pay compensation for disproportionate costs, the government would be able to purchase water from low-productivity lands and avoid paying compensation for water interruptions on high-productivity lands. Even if compensation were not paid, water markets would permit irrigators on high-productivity lands to purchase water from irrigators on lower productivity lands.

Assuming water rights are quantified, both California and Oregon water law can accommodate water markets. Water markets require that rights in water be specific with respect to place, quantity, and ownership. Such conditions do not exist in much of the Klamath Basin. Part of the reason lies in Oregon law, but part reflects regional conditions. For example, do water rights for the Klamath Reclamation Project reside with the Bureau of Reclamation, the irrigation districts, or individual farmers? How are Native American water rights to be quantified? Until such questions are answered unambiguously, it will be difficult for water markets to function well. Nonetheless, the fact that basinwide institutions and water markets exist elsewhere indicates that moderate modification of water institutions is a viable option.

Chapter 14 ("Outcomes") demonstrates the substantial economic cost that arose in 2001 as a result of denying water to most of the Klamath Reclamation Project. The existing institutional framework did not permit the selection of options that would have minimized these costs.

An elementary principle of economics states that if an economic system is to achieve its potential, the incremental value of a useful scarce resource must be equal in all alternative uses. Clearly, this condition is not met in parts of the Klamath Basin. In the Upper Klamath Basin, irrigation constitutes the principal out-of-stream water use. Yet, as Jaeger notes in Chapter 19, irrigation practices and productivity vary greatly in the Basin. A revised institutional arrangement would reflect this variability.

Alternative III—major modifications

Alternative III, major institutional modification, would involve consideration of significant changes in basic water institutions. For example, some might believe that significant acreage of irrigated agriculture is not compatible with ecological integrity in some parts of the Klamath Basin. Others maintain that the Endangered Species Act does not provide the flexibility needed to reconcile conflicting interests in the nation's natural resources.

Significant institutional change might be required to accommodate these or other opinions about policy direction in the Klamath Basin. This report did not investigate changes of this nature to any great extent. The emphasis in this report was on the consequences of the 2001 water allocation decisions, which took certain institutions as given.

Even so, some of the findings have direct implications for institutional design. For example, Chapter 19 ("Water Allocation Alternatives") presents data suggesting that substantial irrigated acreage could be consistent with the known requirements of the Endangered Species Act.

Although this report did not explicitly consider major institutional modifications, there is one clear message that emerges from a careful reading of various chapters—the difficulty, if not the impossibility, of managing the ecosystem of an entire Basin by controlling a limited number of variables. A single agency, with the responsibility to protect species one at a time, may have the authority to affect the water use of only a particular group of users. This situation suggests fundamental inadequacies in the highly fragmented institutional framework for managing water in the Klamath Basin. Recommendations and implications are to be found throughout the report consistent with reducing institutional fragmentation and moving decision-making toward a basinwide approach.

A respected scholar has written: "We should be looking for features of institutions that facilitate not only good outcomes, but how we arrive at those institutions, and what makes them stable" (Sobel, Joel. 2002. "Can social capital be trusted?" *Journal of Economic Literature,* volume XL (March): 139–154, page 148).

The economic chapters in this report emphasize 2001 outcomes. There is less consideration of how reliable institutions are developed and what makes them stable. These are fundamental questions, and they provide perspective when evaluating outcomes for a particular year.

Interpreting economic outcomes

Outcomes are of many kinds. Economic outcomes, especially those expressed in terms of dollars or numbers of jobs, typically attract considerable attention. When interpreting such numbers, it is important to understand their intended purpose and how they were obtained. The economic chapters in this report make clear what was measured and what was not in each case.

Economic impacts of the 2001 decisions must be estimated or inferred from other data. Some of the data, such as crop acreage, prices, and yields, were reported for the 2001 crop year. As noted in Chapter 14 ("Outcomes"), the economic consequences, or income and cost effects, of these reported data had to be assembled and interpreted on the basis of secondary information collected for other purposes.

Judgment is required throughout the data collection and interpretation process. Where possible, the results presented in this report have been compared with other information and reviewed for plausibility. Readers will do well to consider them an indication, probably a reliable indication, but an indication nevertheless, rather than a precise measurement of a particular outcome.

Numbers have meaning only in terms of a specific type of analysis. For example, the area under consideration in Chapter 13 ("Regional Economic Impact") was the Upper Klamath Basin. Thus, the tools of regional economic analysis (e.g., an input–output model) were used. Another perspective was adopted by Jaeger in Chapter 19 ("Water Allocation Alternatives"). He examined costs and returns to Project farmers and thus employed analytical techniques appropriate to that task.

A third possibility is to take a national perspective and examine how a particular policy, project, or event affects the net national product. Cost–benefit analysis is used for this type of analysis.

No attempt was made in this report to measure the net national economic impact of the 2001 water curtailment to the Klamath Reclamation Project. To do so would have required more resources and time than were available. Some of the water curtailment costs were estimated in the various economic analyses, but many were not.

Net farm revenue reductions result in sacrifices in national economic output. These reductions were estimated by Jaeger to lie within a range of –\$27 to –\$46 million (Chapter 14, "Outcomes"). Jaeger also estimated government emergency payments to be between \$35 and \$37 million.[1] Hydroelectric power effects of the curtailment (see Chapter 14), on the other hand, would be considered a cost offset. The power saved by not pumping irrigation water was put to a more lucrative use. Downstream benefits resulting from enhanced stream flows, such as improved commercial, recreational, or tribal fishing, also would reduce the cost of the curtailment. A national perspective also would require an accounting of the costs of reduced return irrigation flows to the wildlife refuges below the Project.

It is clear that a national accounting of the costs of the 2001 water curtailment would be a formidable undertaking. Yet, there was another, even more fundamental, reason for not undertaking such a task. Even if all costs and cost offsets

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[1]If the emergency payments reflect government funds that would have been appropriated and spent elsewhere if the curtailment had not occurred, they represent transfers from one program to another. In this case, they would cause no reduction in national income. In the event, however, that such payments require additional taxes or result in greater government debt, they may come at a cost to the national economy. Whether such a cost occurs depends on whether the private economy is affected and, if so, by how much and in what way by additional taxes or government borrowing. There is no single view among economists as to how such estimates might be made, although a consensus exists that such costs should be considered. Some of the emergency payments in the Klamath Basin in 2001 came from budgets of programs that were authorized and funded prior to the 2001 water curtailment; others came from specially authorized appropriations. No estimate of the cost of making these payments is made in this report.

of the water curtailment were considered, the result would be only one side of a cost-benefit analysis. A separate analysis of the benefits of species preservation would be needed. In reality, however, under the Endangered Species Act, the benefits of species preservation are assumed to justify any cost. Thus, such an accounting is unlikely to be relevant to a specific policy issue.

There is an important policy reason for understanding these costs, however. As Woodward and Romm note (Chapter 18, "Policy"), an underlying assumption of the Endangered Species Act is that the cost of compliance will be distributed generally throughout society. That assumption is challenged if particular groups or individuals bear a disproportionate share of the costs of complying with the Act.

Based on the economic analyses in Chapters 12 through 14, we can draw several inferences and ask several questions. Some inferences pertain to where costs would have fallen if government payments had not been made. Others concern the distribution of government payments. Questions are raised about the implications of the Klamath experience for other areas, as well as adjustments that might be made in the Klamath Basin as a result of the 2001 experience.

- The aggregate level of economic activity in the Basin was not affected significantly. Government payments of various kinds, well drilling and pumping, individual adjustments, and the provision of additional water in July offset many of the negative economic effects resulting from the water curtailment. However, these aggregate results mask the wide variation in experiences of individuals and businesses.

- Agricultural output and farm receipts on the Project were reduced significantly. Government payments offset many of these losses in the aggregate. Land ownership was an important criterion for the receipt of government funds. Farm laborers and tenant farmers did not benefit significantly from government payments.

- If government payments had not been made to farmers and landowners, it is clear they would have borne a significant part of the cost of the water curtailment. As the events of 2001 unfolded, and as government payments were made, some farmers apparently gained. Yet, the data also suggest that others experienced losses. These are the people who bore a disproportionate share of the cost of the water curtailment.

- The Klamath Reclamation Project soils are some of the most productive in the Basin. If water denied the Project had been taken from less productive lands elsewhere in the Upper Klamath Lake drainage area, there would have been much less reduction in agricultural output, perhaps one-fifth the reported amount (Chapter 19, "Water Allocation Alternatives," by Jaeger). Jaeger's analysis points to the need for institutional reform to facilitate water exchanges or the purchase of water rights.

- If the ESA were applied in comparable circumstances elsewhere, would the same level of government support be forthcoming? Did government payments help, or hinder, efforts in the Klamath Basin to achieve a more sustainable long-term distribution of water?

- The economic chapters in this report make it clear that economic analysis centered on particular groups, or on the economy as a whole, may overlook effects felt by some individuals and groups. When the authors are aware of such omissions, they have identified them. Examples include input suppliers, especially those in small farming communities, as well as community activities, such as rural schools. Farm laborers and workers in related industries may have been among those most adversely affected, but their situation attracted little attention.

The fact that farm laborer wages did not have to be paid lessened irrigators' losses and reduced the cost of the curtailment as measured by standard cost–benefit analysis. However, this type of analysis assumes that idled workers will find other employment. This assumption may be appropriate in a vibrant economy. At the time of the 2001 water curtailment, however, the Klamath County unemployment rate was approximately 7.3 percent, above the average for Oregon (6.1) and the nation (4.5).

There are few official data relating to how farm laborers responded to the loss of employment. Anecdotal information indicates that some families left the area soon after the curtailment. In other instances, an adult member of the household sought employment elsewhere, and the family remained in the area. Some workers were able to obtain other employment in the area. Many, and perhaps most, farm laborers were not eligible for unemployment insurance. Thus, they and other workers in similar circumstances may have benefited the most from public assistance programs (see Chapter 9, "Communities").

It is important to keep in mind the perspective provided by the passage of time. With the benefit of hindsight, it was possible to construct an input–output model that better described the Basin economy than did the model originally used to predict the impact of the curtailment. By the same token, it is useful to consider how the future might have looked to participants as events unfolded in 2001. Consider, for example, the period after the water curtailment was announced in the spring of 2001, but before the government responded with financial assistance and additional water. Chapter 14 ("Outcomes") makes it clear that it would have seemed at the time that a significant percentage of the cost of the curtailment would be borne by irrigators.

A look to the future

As the quote by Sobel earlier in this chapter indicates, institutions affect not only economic outcomes, but also the stability of those outcomes and subsequent institutional arrangements. It was beyond the scope of this report to investigate institutional development in the Upper Klamath Basin, but this topic remains important. Clearly, the events of 2001 were a major disruption for some people and businesses. Some of these disruptions may have long-run consequences. The result may be positive if they lead to more stable arrangements in the future.

It is not yet clear whether the water curtailment or the 2001 emergency payments will result in more stable institutional arrangements, although they have stimulated consideration of alternatives. For example, it is reported that consideration is being given to modifying the government-sponsored crop insurance program to permit coverage of crop losses from application of the ESA. This change would permit the cost of compliance to be spread more uniformly across society. However, if it discouraged longer term adjustments to water allocation institutions, it would not necessarily be desirable.

We must keep one fundamental point in mind: problems arose in the Klamath Basin in 2001 largely because of human-created institutions, not because Mother Nature played a dirty trick on the people there. Unless those institutions are examined as a consequence, much of the pain experienced will not have served a useful purpose.

In examining each of the three alternatives related to institutional reform from a local, state, and federal perspective, it becomes clear that institutional modification should be considered at every level of government. Attention is directed specifically to the concluding sections of Chapter 18 ("Policy"). This chapter, as well as Chapter 19 ("Water Allocation Alternatives") and Chapter 3 ("Legal Aspects") provide support for the remainder of this synthesis.

Federal institutions

Consider first the perspective of the federal government. The 2001 water allocation decisions were at least partly the result of conflicting missions of federal agencies and inconsistent application of some government programs. These conflicts and inconsistencies resulted in the imposition of exceedingly high economic costs on irrigators and farmworkers who participate in the Klamath Reclamation Project, as well as ecological costs on wildlife refuges. Similar conflicts and inconsistencies have had negative consequences on other users in the past. The compensation that has been paid has done little to move the economy to a sustainable trajectory over time.

Chapter 18 ("Policy," by Woodward and Romm) calls attention to the unusually severe consequences of the Endangered Species Act in the Klamath Reclamation Project in contrast to its application elsewhere. They contrast the lack of adequate local institutions to deal with variations in water supply with institutional arrangements on other California rivers.

Woodward and Romm note that in *TVA v. Hill* the Court upheld the decision to give species preservation the "highest priority," saying that species jeopardy must be avoided "whatever the cost." If this decision is interpreted literally, and the Endangered Species Act applied consistently, local institutional arrangements, the number and economic importance of out-of-stream uses, and competitive in-stream uses will not be taken into consideration.

Woodward and Romm indicate that a more selective procedure is followed in practice. One of the greatest challenges faced by supporters of the Endangered Species Act arises from the lack of confidence that the ESA is applied impartially. Until that confidence is gained, those who suffer a disproportionate cost from its application are likely to maintain that they are being treated unfairly. A review and comparison of the application of the Endangered Species Act in various locations with different economic and institutional conditions would be exceedingly valuable.

The Bush Administration has announced the formation of a Cabinet-level task force, chaired by Secretary of the Interior Gale Norton, to address natural resource and environmental issues in the Klamath Basin. This development is most promising, especially because assurances have been given that all local interests will be considered.

State institutions

Consider next the perspective of the state government, particularly the State of Oregon. There is little disagreement that a clarification of water rights in the Oregon portion of the Klamath Basin is required if effective water management institutions are to be developed. Until that occurs, there will be great uncertainty in the minds of all water users, and many possible adjustments in individual or group use will not be made.

The adjudication of water rights has been delayed because of conflicting claims to water. Particular attention is directed to the claims set forth by Native Americans. These conflicting claims need to be settled legally. Yet, as Woodward and Romm note, there is question as to the appropriate role of state and federal courts in this matter. Only when this matter is resolved are local institutions likely to be developed to provide for a sustainable regional economy.

Local institutions

Both federal and state governments have essential roles to play. Nevertheless, under our system of government, local governance is important as well. The most basic decision the regional communities must make is whether they wish to continue the divisiveness that characterizes the current situation.

In order to reduce the present uncertainty and divisiveness, some traditional expectations for water must change. It should now be clear to all that the Endangered Species Act trumps other claims to water when the survival of a species is in question. It also is clear that claims to water by Native American communities have a legal standing, although how those claims will be quantified is not yet known. Irrigators and other out-of-stream water users need to recognize these realities. It is important to note that these realities are not necessarily inconsistent with a sustainable combination of in-stream and out-of-stream water uses.

Agricultural interests often have opposed water markets, for instance, preferring to rely instead on political power to preserve their water rights. The evidence is now clear that environmental laws and Native American rights make such a strategy highly dubious. Water markets offer agricultural interests a possible means of avoiding massive interruptions of water as well as compensation if water is put to another use. Chapter 19 (“Water Allocation Alternatives”) discusses the potential for water markets in the Upper Klamath Basin.

Conclusion

The events surrounding the 2001 Klamath Reclamation Project water allocation decisions demonstrate the need for substantial institutional improvement at every level of government. Local communities need to articulate a vision of the future in order to establish a sustainable trajectory for the area over time. The cooperation of state and federal government will be essential if that vision is to become reality.

Any lasting solution to conflicts surrounding allocation of scarce resources requires that the needs of **all** interested parties be addressed. In the Klamath Reclamation Project area, the legitimate interests of Native Americans, irrigators, and endangered species all must be recognized and considered. Significant benefit would result from the regional communities achieving success with a few common undertakings. To that end, two observations are made.

- The Klamath River Basin Compact commission is one of the few institutions that can assemble all, or most, of the major interests in the area. While the commission itself has limited means to address certain problems, it may have unrealized potential as a forum and an incubator for ideas. Consideration should be given to enabling a robust and viable commission, or some comparable group, to play such a role.
- Each of the alternatives considered here directs attention to the fundamental importance of the adjudication process for water. Clarity with respect to water rights is necessary for the proper functioning of water institutions under all of the alternatives considered. All, or most, of the significant water users could unite in an effort to bring this process to a prompt and reliable conclusion. Both federal and local government might well emphasize the importance of this process and offer their assistance to that end.

This report has emphasized, in one way or another, the allocation of water among competing uses. Little attention is given to the distribution of income that would result from various water allocations or a possible judicial decree. Yet, even if such matters were considered sufficiently, it would not be a simple matter to decide how compensation should be paid for failure to deliver water when there is a good-faith agreement to do so. Again, the way in which water rights are defined, and in whom they reside, is of great importance. This fact demonstrates, once again, the fundamental importance of the adjudication process.

References

Sobel, J. 2002. “Can social capital be trusted?” *Journal of Economic Literature,* volume XL (March): 139–154.