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Water Resources

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Introduction

Surface water, stored in Klamath Irrigation Project facilities, including Upper Klamath Lake (UKL), and delivered to nearly 200,000 acres of agricultural land through a complex system of canals, drains, and pumping stations, has served as the lifeblood of the region's agricultural industry for nearly a century. The effect of federal agencies' policies to protect endangered suckers in UKL and threatened coho salmon in the lower Klamath River, combined with regional drought conditions, has been the elimination of normal surface water supplies for about 170,000 acres of agricultural land and severe restrictions on supplies to two very important wildlife refuges dependent on Project facilities and irrigation return flows.

Understanding the complex hydrology of the Upper Klamath Basin requires an extensive description of historical and current conditions. Factual data on the Bureau of Reclamation (USBR) Klamath Irrigation Project (Project), including a map of the Project, is appended. The most important structures and geographical, climatic, and hydrologic aspects of the region are briefly described. 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 the Assessment 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 (Biological Opinion, 2001), prepared by the Klamath Falls Fish and Wildlife Office in April 2001, provides an exhaustive description of the Project. Rather than rewrite extensively what has already been written about the important features of the Project, much descriptive material has been taken from this report, with the written permission of Mr. Steven Lewis, U.S. Fish and Wildlife Service (USFWS). All material taken directly from this report will be presented in *italics*.

Climatic conditions and weather records

Limited Klamath Falls weather records are available dating back to 1884. The U.S. Water Bureau monitored rainfall at Klamath Falls until an official National Oceanic and Atmospheric Administration (NOAA) station for Klamath Falls 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 one-half 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 USBR 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. Water Bureau annual rainfall records are complete from 1884 through 1948 except for the years 1890–1901 and 1903 (Rykbost and Charlton, 2001b). More detailed weather records from 1949 to the present are available from NOAA and from KES annual research reports for 1987 through 2000. The long-term annual rainfall at Klamath Falls has been about 13 inches per year with a range of 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 annually is observed.

High elevation areas in the upper watershed receive much higher precipitation. Crater Lake receives an average of 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 (UKL). The majority of the region's precipitation occurs from November through March. Over the past 16 years, Klamath Falls has experienced an average of about 5.5 inches of precipitation from April through October, out of a total annual average of 13 inches (Rykbost and Charlton, 2001b).

The drought of 2000–2001 started in March 2000. Total rainfall recorded at KES from March 1, 2000 through October 2001 was 10.5 inches, about 55 percent of normal. The drought followed a 4-year period (1995–1998) of the highest rainfall 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 rainfall 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.

Upper Klamath Basin groundwater resources

Current year groundwater studies and monitoring efforts being performed by several agencies should provide new information regarding local groundwater hydrological conditions. With the 2001 decision to withhold surface water from most of the Project, a flurry of well development activities was initiated. Private individuals developed several wells in the Project in late spring. Funding from California and Oregon legislatures to assist irrigation districts in well development is expected to result in up to 20 new large irrigation wells. TID has brought six new wells into production as of August, with maximum production approaching 12,000 gallons per minute (gpm) for the largest producing well. (For conversion to other measures, approximately 450 gpm = 1 cfs = 2 acre-ft over 24 hours). Pump test yields on nine TID wells have ranged from 4,000 to 12,000 gpm with six of nine wells exceeding 9,000 gpm. Depths of the nine completed wells range from 571 ft to 2,380 ft. All but two of the wells are more than 1,400 ft deep.

An optimistic projection of 150 to 175 cfs from a $5 million fund in California, and 50 to 75 cfs from the $2 million fund in Oregon, would account for about 15 to 20 percent of typical surface-water diversions for agriculture and refuge use. To date in 2001, the Oregon Water

Resources Department (OWRD) has approved 89 of 92 applications for drought/supplemental-use wells in the region, representing 20,500 acres (Ned Gates, OWRD, personal communication).

Depths to aquifers suitable for irrigation wells vary from 150 ft in southern portions of the Project in Copic Bay to more than 2,000 ft in other areas. The upper surface of water-bearing basalt bedrock ranges in depth to over 1,000 ft. Several wells developed in 2001 are more than 2,000 ft deep. An unsuccessful well in the Henley area stopped at 2,146 ft without finding a productive aquifer. Fortunately, static water level in most of these wells rises to within 50 ft 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 California Water Resources Department, OWRD, and U.S. Geological Survey hydrologists.

Failures of 17 domestic wells and 10 livestock/yard wells in the Henley and Merrill areas, and 5 domestic wells in the Tulelake area, were reported by late July. All of the failed wells in the Henley and Merrill area were shallow wells that receive recharge from canal and surface application seepage (Ned Gates, OWRD, personal communication). In some cases these may 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. Several irrigation wells in the southern portion of TID are reported to have lowered static water levels considerably in nearby wells. Static level in a well in Malin, Oregon, declined by more than 20 feet in 2001. Full-season pumping will be required to have any assurance of the extent to which wells can replace surface irrigation supplies on a season-long basis.

The economic consequences of replacing surface water with wells are significant. Energy requirements will vary with well depth, static water levels, capacity, and source of power, but in any case will be considerably greater than costs for pressurizing surface water. Installation costs for newly developed wells currently are ranging 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.

The latest projection for well development at TID with the $5 million in state funding indicates production of 75,000 gpm may be achieved. This equates to about 170 cfs, or 340 acre-ft/day. Assuming 100 days of pumping and 2 acre-ft crop use, this volume would serve about 17,000 acres. Based on an initial investment of $5,000,000, 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 at TID was 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.

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

In Oregon, permanent water rights for new wells may be difficult to acquire. Most of the wells within the Project that were developed in the early 1990s are permitted 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. Fully developing a well involves deepening the well through the bearing aquifer (Ned Gates, OWRD, personal communication).

California has fewer regulations for development of wells, 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.

In one respect, substitution of well water for surface supplies for agricultural and refuge use is contrary to water quality concerns. Discharge of nutrient-rich, warm water from Klamath Lake to the Lower Klamath River puts salmonids at risk below Iron Gate Dam. If Klamath Lake water were used for irrigation and the refuges and cool, high-quality groundwater were discharged to the river, benefits for fish may be realized. This issue may receive more attention in the future.

The Upper Klamath Basin watershed

Klamath/Agency Lake

"*UKL (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 USBR area capacity table cites a surface area of 77,593 acres at 4,143.30 ft and 44,200 acres at 4,136.0 ft elevation). *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 or natural bedrock constriction at the head of Link River 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 data). However, the range may have been even greater, from 4,139.9 to 4,145 (USBR 2000b). 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, as described below"* (Biological Opinion, 2001).

There is contradictory published and anecdotal evidence regarding pre-Project lake elevation minimums (elevation refers to height above mean sea level). John C. Boyle (1987) cites an elevation of 4,137.8 ft for the reef at Link River. A picture in the book shows fishermen standing among rocks in the Link River above Favell Museum with no water visible in the river. The picture's footnote, dated July 18, 1918, states that high south winds pushed the water level below the reef. U.S. Water Bureau rainfall records indicate an extended drought from 1914 through 1919. The U.S. Army Corps of Engineers (1982) cites a natural low-water minimum elevation of 4,137.1 ft and the elevation of the upper reef at 4,137.8 ft. Grover *et al.* (1923) cite a minimum elevation of 4,139.63 ft on September 2 and November 5, 1917 and states: "stage somewhat lower in July, 1918, recorder not working."

Artifacts were found at several sites exposed at low lake levels in 1992 and 1994, indicating these may have been semi-permanent or seasonal campsites used by indigenous inhabitants during pre-settlement times. Early settlers were reported to have harvested grass hay at McCornack Point, Caledonia Marsh, and Hank's Marsh, which are currently inundated (Donald Hagglund, personal communications).

UKL has a storage capacity of approximately 486,828 acre-ft at a full pool elevation of 4,143.3 ft. In 1994, lake elevation declined to 4,136.8 ft, with storage capacity at 39,201 acre-ft (USBR data). Storage capacities at 4,140.0 and 4,139.0 ft are approximately 241,000 and 174,000 acre-ft, respectively. Management of lake elevations at 4,140.0 or 4,139.0 ft, versus allowing the elevation to decline to dead storage at 4,136.0 ft, represents a reduction in available water for other uses of 241,000 or 174,000 acre-ft, respectively.

Modeling of the hydrology of UKL by USBR (2001) has been based on the period from 1961 through 1998. Year types have been classified based on net inflow to the lake from April through September. The average (arithmetic mean) net inflow for the 38-year period was calculated as 500,400 acre-ft. The standard deviation of the mean was 187,000. Years when inflow was above 500,400 acre-ft from April through September were classified as above average. Years with inflow between 500,400 acre-ft and less than one standard deviation below (312,000 to 500,400 acre-ft) were classified as below normal. Years with inflow between one and two standard deviations below the average (185,000 to 312,000 acre-ft) were termed dry years. In 1992 and 1994, inflows were 155,000 and 179,000 acre-ft, respectively. These years were classified as critical years.

The 1961 to 1998 era included 20 above average, 11 below average, 5 dry, and 2 critical year types. The USBR has based recommendations for Project operations plans on these hydrologic year classes and 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. USBR data indicated net inflow to UKL from April through September 2001 was about 200,000 acre-ft, exceeding April through September inflow to UKL in 1992 and 1994.

Lake elevation records from the USBR show lower average lake elevations were maintained during the 30-year period from 1922 to 1951 than the average for the 1961–1998 period. For August through October, mean end-of-month elevations were approximately 1.0 ft lower during the first 30 years following construction of the Link River Dam. During this period, lake levels declined below 4,138.0 ft in 8 of 30 years. From 1961 to 1998, lake levels fell below 4,138.0 ft in only 4 years out of 38.

The decade of the 1990s included the extremes of water supply since the Project was established in 1905. Table 1 summarizes Project hydrology for the 10-year period from 1991 through 2000. Data are presented on a calendar-year basis. While hydrology data for the Project are usually presented on a water-year (October 1 to September 30) basis, 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. For example, the Lost River Diversion Channel is a major component of the system, but data sets do not indicate the direction of flows.

Tributaries and inflow sources for Upper Klamath Lake

Williamson River

The single largest source of inflow to UKL is the Williamson River, which discharges into northeast Klamath Lake. Major tributaries to the Williamson River include Sycan River and

Sprague River, with headwaters in the Gearheart Mountains to the east; and Spring Creek, which dominates late summer flows below its confluence with the Williamson River above Chiloquin, Oregon. Miller and Tash (1967) estimated the Williamson River contribution to UKL inflows at 46 percent.

Table 1. Hydrologic data for the Upper Klamath Basin for 1991 through 2000 and for January 1 through September 30, 2001. Precipitation data are from the Klamath Experiment Station and flow data are from the Bureau of Reclamation Klamath Project Office. All data are presented on a calendar-year basis.

	Total	UKL Releases[2]		Diversions		Releases		Discharge	Klamath River Flow	
Year	annual precip.	Link River	A Canal	North Canal	ADY Canal	Gerber Reserv.	Clear Lake	Straits Drain	Keno Dam	Iron Gate Dam
	inches	1,000 Acre-ft								
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[1]	4.24	556	40	16	26	35	65	17	559	757

1/January through September 30

2/Releases from Upper Klamath Lake

Significant agricultural diversions out of the Williamson, Sprague, and Sycan rivers have occurred since before 1905. Diversions from the Williamson River by USFWS to the Upper Klamath Marsh and by The Nature Conservancy to the Sycan Marsh have been expanded since the late 1980s, reducing inflows to UKL (James Ottoman, Robert Sanders, Edward Bartell, personal communications). Newly developed or planned wetlands in the Williamson River Delta Preserve also are likely to require more water than agricultural production on this property operated as Tulana Farms. Kann (2001a) estimates evaporation losses from open water surfaces at 3.23 ft/year and from wetlands at 70 to 83 percent of this or 2.26 to 2.68 ft/year. Bidlake (1997) reported evapotranspiration loss from Wocus Bay and Sagebrush Point wetland sites from May through October 1996 of 26 and 27 inches, respectively. Bidlake and Payne (1998) reported evapotranspiration from wetland sites at Wocus Bay and Upper Klamath NWR for May through October 1997 at 35 and 27 inches, respectively. This exceeds water use for cereals and row crops, as will be discussed later in this report.

Wood River

The Wood River enters Agency Lake at the northeast corner and accounts for 18 percent of total inflow (Miller and Tash 1967). The Wood River, which originates as springs at Kimball Park, includes flows from streams originating within Crater Lake National Park (Anne and Sun Creeks), and 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 and some 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 UKL inflow. Precipitation and pumped drainage from agricultural properties adjacent to the lake was estimated at 4.4 and 5.1 percent, respectively. The remaining 17.4 percent of lake inflows were estimated to be coming from springs discharging directly to the lake.

Miller and Tash (1967) estimated losses from the lake at 78 percent for discharges to the Link River and A-Canal, 20.4 percent from evapotranspiration, and 1.5 percent for pumping and diversions for agriculture. It is recognized that inflow contributions will vary with year type hydrologic conditions. For example, in drought years, springs and spring-fed streams will contribute more, while the Williamson River system will contribute a greater percentage in years with high rainfall and heavy snowpacks.

Discharges from Upper Klamath Lake

Link River/Lake Ewauna/Klamath River

Discharges through the Link River Dam traverse about 1 mile in Link River, enter Lake Ewauna, and leave the upper basin at the Keno Dam located 21 miles below the Link River. Elevations in the Klamath River above Keno can vary by up to 3.0 ft but are maintained within a range of about 6 inches most of the time. In addition to Klamath Lake discharges, the Klamath River above Keno receives inflow from the Lost River Diversion Channel, the Klamath Straits Drain, Klamath Falls and South Suburban sewage treatment plants, and Collins Products and Columbia Plywood mills.

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. Flows at Keno Dam are managed to meet required flow targets at Iron Gate Dam. Between Keno Dam and Iron Gate Dam, accretions from springs and minor tributaries add about 300,000 acre-ft annually or about 400 cfs averaged over the year (USBR data). During the April to September irrigation season, accretions below Keno are usually in the range of 250 to 350 cfs. In the drought years of 1992 and 1994, annual accretions were about 200,000 acre-ft (Table 1).

Major elements of the Klamath Irrigation 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, 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"* (Biological Opinion, 2001).

Entrainment or passage of endangered suckers into the A-Canal is a major concern for future operations of the project. The USBR, the Klamath Irrigation District (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, current patterns 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. For several years, USBR and USFWS have been recovering entrained fish during the draining of the canal in October and returning them to UKL.

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 this structure have ranged from about 220,000 to 280,000 acre-ft. During the drought years of 1992 and 1994, the A-Canal diversions were 227,000 and 226,000 acre-ft, respectively (Table 1) (USBR data).

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 Tulelake National 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 (Service 1992a); recently Reclamation has had to control lake levels because of dam safety issues. Approximately 8,000 acres of irrigated land in the Langell Valley depends 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 (Service 1994b).

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 [1992 Biological Opinion minimum lake elevation—4,519.29 ft] *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 (Service 1994b).*

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. 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" (Biological Opinion, 2001).

During the high rainfall years from 1995 through 1998, Clear Lake was allowed to fill only to approximately 400,000 acre-ft 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 $6,000,000 (John Cook, USBR, personal communication). 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 allow raising storage capacity to the original design capacity. The 2001 Biological Opinion requires a minimum elevation of 4,521.0 ft in Clear Lake on September 30. The storage sacrificed at this level compared to Reclamation's minimum of 4,519.29 is about 17,000 acre-ft.

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

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"* (Biological Opinion, 2001).

Proposals have been made to raise Gerber Dam by 3 to 5 ft. This is projected to increase storage capacity by up to 20,000 acre-ft at a cost of approximately $3,000,000 (John Cook, USBR, personal communication). However, in most years Gerber Reservoir does not receive sufficient inflow to fill current capacity. USBR proposed a minimum elevation of 4,796.52 ft for Gerber Reservoir for 2001. The Biological Opinion requires a minimum elevation of 4,802.0 ft on September 30. The difference in storage at these elevations is less than 4,000 acre-ft (USBR data). The 2001 Biological Opinion allowed for diversion of a combined volume of 70,000 acre-ft from Clear Lake and Gerber Reservoir for irrigation in the LVID and HID and for a minimum lake level in Tule Lake. As of late September, the 2001 combined releases from these reservoirs were about 100,000 acre-ft (USBR data) (Table 1).

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

Lost River

The Lost River traverses approximately 100 miles from Clear Lake Reservoir to Tule Lake. Throughout most of its length, the river is highly channelized and managed. 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-ft to TID. The Lost River has lost all semblance of a natural river system and is a highly managed feature of the Project with several impoundments. USBR documents refer to the Lost River as the Lost River Improved Channel. Implementation of the decision to drain and reclaim Tule Lake and the Lower Klamath Lake for agricultural production required changes in and management of the Lost River.

Lost River Diversion Channel

"*The Diversion Channel, operated by Reclamation, begins at Wilson 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. 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"* (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 in 1912 (USBR 1953). In 1932, a dike system was constructed to confine the drainage waters entering Tule Lake to a central sump 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 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 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 levels below ice cover" (Biological Opinion, 2001).

The above discussion makes an important point about historical, unaltered hydrology of the region. 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. The flows down Klamath River during 1995-1999 were enhanced by a significant contribution from the Lost River watershed. In an unaltered state, a portion of Klamath River flows would have been diverted through the Lost River Slough to Tule Lake, where it would have evaporated.

In studies to determine flow requirements for Iron Gate Dam, historical flows have been based on flows observed in 1905–1912 (Balance Hydrologics, Inc. 1996). This was a period of above-normal precipitation. U.S. Water Bureau records indicate an average annual precipitation at Klamath Falls of 15.82 inches for the 8-year period, compared with an average of 13.22 for 1884–1949 (Rykbost *et al. 2001).* The dike constructed in the Lost River Slough in 1890 prevented overflow from Klamath River going to its historic destination in Tule Lake during these years of above average water supply. Basing historical flows on this period inflates flows from two perspectives: use of a period when precipitation records for Klamath Falls indicate water supply was 20 percent above normal; and use of a period when natural overflow from Klamath River to Tule Lake was prevented.

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" (Biological Opinion, 2001).

Average annual discharge of drainage water to the Klamath River from the Klamath Straits Drain for the period from 1991–2000 is approximately 81,000 acre-ft, with peak flows occurring in late winter. During drought years of 1992 and 1994, discharge was 31,000 and 61,000 acre-ft, respectively (Table 1). During the other years of this 10-year period, the discharge ranged from 75,000 to 128,000 acre-ft.

An analysis of water quality conditions in the Lost River sub-basin for purposes of establishing Total Maximum Daily Load (TMDL) targets, identified the Klamath Straits Drain as a potential point source pollution contributor of nutrients from agricultural activities to Klamath River. Water quality concerns include pH, dissolved oxygen (DO), temperature, nutrients, bacteria, and chlorophyll-a. Recirculation of Straits Drain water through agricultural 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 wetland filtering prior to discharge to the river also has been investigated.

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. Drainage from the Tule Lake refuge, through Sheepy Ridge to the Lower Klamath refuge and out through the Straits Drain, contributes significant quantities of discharge that were historically lost as evaporation from Tule Lake. From 1996 through 1999, over 100,000 acre-ft annually was discharged to the Klamath River through the Straits Drain (Table 1). A portion of this originated in the Lost River watershed and would not have reached the Klamath River under natural conditions.

Prior to development of the Project, a reef at Keno, Oregon backed up Klamath River, forming Lower Klamath Lake. This lake ranged in size to about 75,000 acres depending on watershed conditions. In 1907, a dike was constructed to isolate Lower Klamath Lake from the Klamath River and 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. This change resulted in increasing river flows by eliminating access of Klamath River to the Lower Klamath Lake area, thus reducing evaporative losses in the upper basin.

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"* (Biological Opinion, 2001).

Average annual diversion out of Klamath River to the Lower Klamath Lake area through the ADY Canal for 1991 to 2000 was 86,000 acre-ft (Table 1). A minor portion of this is used to irrigate about 500 acres of crops or pastures and the remainder is diverted to refuge lands. In 1999 and 2000, total diversions from April through October were about 60,000 and 50,000 acre-ft, respectively (USBR data). Off-season diversions are used to flood habitat in the Lower Klamath National Wildlife Refuge. Diversions to the ADY Canal have been quite consistent from year to year, ranging from 71,000 to 108,000 acre-ft from 1991 to 2000. Additional water is diverted to the Lower Klamath NWR by Pumping Plant D, through Sheepy Ridge. Water use in the refuge is discussed later.

The intake for the ADY Canal and the final pumping station for the Straits Drain are located immediately adjacent 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 may be an alternative to avoid discharge of contaminants to Klamath River at critical times of the year. It is a concept worthy of investigation. 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 Klamath Drainage District.

North Canal

The North Canal diverts water from Klamath River to approximately 10,000 acres of private agricultural lands in the Klamath Drainage District of the Lower Klamath Lake area. The diversion has a capacity of approximately 300 cfs. Total annual diversions through the North Canal have ranged from a low of 28,000 acre-ft in 1992, 1994, and 1998, to a high of 49,000 acre-ft in 1995 (Table 1). In 1999 and 2000, the total April through October inflow was about 35,000 acre-ft (USBR data). Winter flooding of agricultural fields provides control of rodents (drowning and/or exposure to raptor predation), weeds, and plant diseases, and habitat for waterfowl. Surplus water is discharged to the Klamath Straits Drain. The 10-year average diversion to the North Canal has been 37,000 acre-ft. Much of this returns to the Klamath River through the Straits Drain after flood irrigation during winter months. As in the ADY Canal, gates to Klamath River are left open and the canal is holding water year-around at the elevation maintained in the Klamath River.

Other Klamath Project features

Additional features of the Project are not described in detail, but are important in the overall functioning of the project. It is beyond the scope of this report 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 water to the lower Klamath River. However, it is noteworthy that minor laterals, which divert 95 percent of actual deliveries to farms, include 680 miles of channels. A total of 728 miles of drain ditches range in depth from a few ft to 10 ft, with discharge capacities up to 600 cfs (Straits Drain) (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 has been clearly demonstrated during the current drought by many wells becoming inoperable by mid-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 provide several thousand acres of habitat for birds, amphibian species, reptiles, and mammals.

Tule Lake and Lower Klamath National Wildlife Refuges

"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. 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.

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% exceednce 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 NWR, 2001).

The Tule Lake National Wildlife Refuge receives water from the Lost River and drainage from the TID. Lost River supplies can originate from Clear Lake or Gerber Reservoirs or from UKL via the Lost River Diversion Channel. Water for the Lower Klamath Wildlife Refuge is provided by pumping drainage from Sump 1A through Sheepy Ridge or from Klamath River through the ADY Canal diversion.

Data on water use within the Lower Klamath NWR for 1998, 1999, and 2000, provided by USFWS-NWR, is presented in Table 2. Total usage was about 88,000 acre-ft in 1998 and 1999 and 80,000 acre-ft 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.

The estimation of water use in the refuges indicates an average consumptive use of 3.25 acre-ft/acre for the Tule Lake sumps, which are primarily permanently flooded. The Lower Klamath refuge consumptive use averages 2.45 acre-ft/acre. Over 50 percent of this refuge is devoted to seasonal flooding or grain production. In contrast, crop consumptive-use ranges from about 1.75 acre-ft/acre for grain to about 2.0 acre-ft for potatoes and onions, and 2.5 acre-ft/acre for alfalfa and pastures. Data for these crops for 1999 and 2000 are available on the USBR AgriMet Web site.

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 2001 Biological Opinion calls for maintenance of a minimum surface elevation of 4,034.6 ft in Sump 1A. Other than this requirement, no provisions are made in the Biological Opinion or the USBR 2001 Operations Plan for supplying water to the refuges. At mid-summer, it was expected that only 1,000 acres of permanent wetlands could be maintained in the Lower Klamath NWR (James Hainline, USFWS-NWR, personal communications). In late summer, arrangements were made by interested parties to augment this supply from several sources, including newly developed wells in California, discharges from Clear Lake and Gerber Reservoirs, and depletion of storage behind dams in the Klamath River.

Table 2. Estimated water use in Lower Klamath National Wildlife Refuge by month for permanent marsh, seasonal marsh, and grain units in 1998, 1999, and 2000.[1]

		Water Use (acre-feet)												
Units	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

[1/]Data provided by U. S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuges.

Water quality concerns in the Upper Klamath Basin

Temperature

Most of the water bodies in the Upper Klamath Basin are included as water-quality limited for temperature in the Oregon 303D list. While some of the tributaries feeding UKL meet target temperatures, UKL, the refuges, Lost River, and Klamath River exceed temperature standards during summer months. Several springs in the Lost River near the Olene Gap discharge warm water directly to Lost River. Geothermal wells occur in several areas of the watershed. Wells on the east side of the Lower Klamath Lake area discharge water at >195^{0}F. Several wells within the Lower Klamath NWR produce water at 140 to 180^{0}F. Markle (this report) mapped springs near Bare Island in UKL during low lake levels in 1994, and found many with temperatures exceeding 86^{0}F. While some reduction in stream temperatures at higher elevations might be realized by improvements in riparian areas, significant temperature reductions in large reservoirs above and below Klamath Lake will be difficult to achieve.

Hypereutrophic conditions of Upper Klamath Lake

"*The hypereutrophic* (nutrient rich) *status and resultant seasonally adverse water quality in UKL is well documented (USACE 1982; Kann and Smith 1993; Kann 1993a,b; Martin and Saiki 1999; Perkins et al. 2000b; Welch and Burke 2001; Walker 2001). Extensive blooms of the cyanobacterium* Aphizomenon flos-aquae (AFA) *cause significant water quality deterioration due to photosynthetically elevated pH (Kann and Smith 1993) and to both supersaturated and hypoxic concentrations (Perkins et al. 2000b; Welch and Burke 2001; Walker 2001). AFA is the dominant primary producer in UKL, comprising >90% of the primary producer biomass during blooms. Both high pH and low DO* (dissolved oxygen) *reach levels in UKL known to be lethal to* *suckers, and as such are important parameters affecting survival and viability of native fishes. Bioassays have shown that pH values >9.55 caused a loss of equilibrium in juvenile SNS (Falter and Cech 1991), and that values >10.3 proved lethal to larval and juvenile LRS and SNS (Saiki et al. 1999). Bioassays also show that DO levels <2.4 mg/l are lethal to larval and juvenile SNS. It is important to note that sub-lethal effects are likely to occur prior to reaching the lethal levels described above (Kann and Smith 1993; Reiser et al. 2001). Meyer et al. (2000) and Lease (2000) documented structural changes in the gills of larvae exposed to un-ionized ammonia concentrations 3.5 times lower than the lowest concentration at which significant growth and mortality effects occurred. Swimming performance was reduced at pH 10.* (Saiki *et al* [1999] reported 96-hour LC-50 un-ionized ammonia concentrations of 0.5 and 0.8 ppm for LRS and 1.1 and 0.5 ppm for SNS larvae and juvenile, respectively.)

Lake volume and mean depth have a direct effect on physical, chemical, and biological processes. There is a direct reduction of habitat available for fishes as lake level is lowered, particularly the reduction in shoreline rearing habitat of larval and juvenile endangered sucker species (Dunsmoor et al. 2000; Klamath Tribes 1995; Reiser et al. 2001). In addition, lowered lake elevation and volume can exacerbate various productivity-related water quality problems" (Biological Opinion, 2001).

This discussion of water-quality effects related to lake elevation is greatly amplified in the Biological Opinion and was the basis for establishment of minimum lake-elevation targets to protect endangered sucker species, promote recruitment of additional year-classes, and improve water quality. Detailed discussions in the Biological Opinion consider phosphorous (P) loading/pH relationships, the extent of anthropogenic contributions to P loading, temperature/lake elevation relationships, wind speed/water quality relationships, and water-quality relationships to fish kills experienced in 1995–1997. It is beyond the scope of this report to repeat a description of the interrelationships between the water quality parameters of concern. However, there is not consensus on interpretation of the many studies and reports related to these and other aspects of natural resource issues in the region. Several aspects of the assumptions and interpretations used as a basis for lake elevation management are discussed below.

External and internal P loading of Upper Klamath Lake

Defining studies on nutrient loading in UKL were reported by Miller and Tash (1967) and Snyder and Morace (1997). Both studies investigated the contributions of drainage water from agricultural properties adjacent to UKL to P loading. Studies reported by Walker (1995), Kann and Walker (1999), Perkins *et al*. (2000b), and Walker (2001), building on the data and theories from these and other studies, have developed models projecting solutions to water quality problems based on reduction of P loading from agricultural activities and maintenance of high lake elevations (dilution effect).

Miller and Tash (1967) attributed 26 percent of external P loading to pumped drainage from agricultural properties discharged directly into UKL. Snyder and Morace (1997) arrived at a similar conclusion, although they devoted a full page of their report to "Limitations and Concerns Involved in Calculations of Nutrient Loads and Values." Their summary stated "these loading estimates are only an indication of the order of magnitude of nutrient contributions from these areas." Neither of these studies describes natural background P sources in any detail, although Snyder and Morace (1997) reported high P concentrations in three artesian wells on the Wood River Ranch property.

Kann and Walker (1999) report on the monitoring of UKL nutrient concentrations at nine sites from 1991 through 1998. They modeled nutrient loading of the lake and attributed 40 percent of external P loading to anthropogenic (caused by human activities) sources, as did Walker (1995). In the construction of their nutrient budget, Kann and Walker (1999) only include nutrient loads at the source (springs) as background, and assign all other external nutrients to anthropogenic influence. They estimate external sources contribute 39 percent, while internal sources (re-suspension of sediment P and discharge from springs in UKL) account for 61 percent of total P loading in UKL. As a worst case, their anthropogenic contribution accounts for only about 16 percent (0.39 X 0.40) of total P loading. An extensive data set on lake water nutrient concentrations included in an appendix in Kann and Walker (1999) was not considered in the Biological Opinion.

More recent research (Rykbost *et al.*, 1999; Rykbost and Charlton, 2000; Rykbost and Charlton 2001a) demonstrates natural background P sources are partially responsible for P loading in drainage waters from agricultural properties adjacent to UKL. Water applied to properties at the southern end of UKL to recharge soil profiles comes out of Klamath Lake with a high nutrient load. Nutrient concentrations in numerous springs and artesian wells are also reported, indicating high natural P loading in aquifers in the Wood River Valley. Major springs feeding tributaries to UKL contain sufficient P to support algal blooms in the absence of anthropogenic contributions, as evidenced by the eutrophic condition of UKL pre-dating settlement of the region. During an expedition to the region in the 1840s, John C. Fremont would not allow horses to drink from Klamath Lake at Rattlesnake Point because of the foul water quality (Fremont 1845).

Other water quality factors in Upper Klamath Lake

Numerous references to un-ionized ammonia toxicity effects on endangered species suggest the importance of this to lake management. The Biological Opinion emphasizes theoretical models of lake depth/wind speed/Relative Thermal Resistance to Mixing (RTRM)/ and P/pH relationships. An extensive empirical data set that documents ammonia concentrations in UKL over 10 years also exists. This data from Kann and Walker (1999) is summarized in Tables 3–5. Table 3 shows mean lake-wide concentrations of total P, total N, and ammonia N by month averaged over years. Small sample size for winter months suggests these data may not be useful. Extensive sampling was conducted from June through October, when water quality is most affected by algal blooms and high temperatures. Concentrations of P, N, and ammonia peaked in July and were at minimum levels in spring months. Table 4 compares lake-wide nutrient concentrations averaged over years. While differences between years were minor for total P and total N, differences in ammonia concentration were greater than an order of magnitude. High ammonia concentrations were observed in years of high lake level (1996–1998) while the lowest concentrations were observed in 1992 and 1994 when lake levels were very low. Table 5 focuses on the summer months when algal blooms and fish die-offs occur.

Table 3. Lake-wide mean concentrations of total phosphorus (TP), total nitrogen (TN) and ammonia nitrogen (NH_3 - N) by month for Upper Klamath/Agency Lake, 1991 - 1998. [1]

Month	No. of Samples	Total Phosphorus (TP)	Total Nitrogen (TN)	Ammonia Nitrogen NH_3 - N
		ppm		
January	6	0.09	1.42	0.48
February	22	0.07	0.95	0.08
March	40	0.05	0.60	0.08
April	84	0.06	0.72	0.04
May	105	0.06	0.67	0.05
June	142	0.12	1.67	0.14
July	149	0.22	2.25	0.35
August	146	0.19	2.03	0.21
September	127	0.19	1.88	0.27
October	118	0.14	1.73	0.23
November	34	0.09	1.21	0.26
December	1	0.09	2.42	0.84

1/ Data from Appendix I (Kann & Walker 1999)

Table 4. Lake-wide mean concentrations of total phosphorus (TP), total nitrogen (TN) and ammonia nitrogen (NH_3 - N) averaged for all months in Upper Klamath/Agency Lake for 1991 through 1998.[1]

Year	No. of Samples	Total Phosphorus (TP)	Total Nitrogen (TN)	Ammonia Nitrogen NH_3 - N
		ppm		
1991	126	0.18	1.76	0.09
1992	138	0.14	1.46	0.04
1993	134	0.10	1.35	0.15
1994	117	0.11	1.44	0.03
1995	159	0.15	1.81	0.07
1996	94	0.12	1.52	0.28
1997	124	0.15	1.64	0.60
1998	129	0.12	1.28	0.41
Mean	128	0.13	1.53	0.21

1/ Data from Appendix I (Kann & Walker 1999)

Table 5. Lake elevation at June 30 and October 31 and mean lakewide nutrient concentrations for July through October in Upper Klamath/ Agency Lake, 1991 - 1998.[1]

Year	Lake Elevation		Mean Nutrient Concentration		
	6/30	10/31	TP	TN	NH_3 - N
	ft		ppm		
1991	4141.5	4138.2	0.26	2.37	0.07
1992	4139.5	4137.6	0.16	1.67	0.02
1993	4142.6	4139.6	0.13	1.63	0.23
1994	4140.8	4136.9	0.13	1.63	0.02
1995	4143.1	4139.4	0.22	2.35	0.05
1996	4142.2	4139.0	0.18	2.07	0.39
1997	4142.2	4140.3	0.22	2.29	0.91
1998	4143.0	4140.2	0.16	1.65	0.42

1/ Lake elevation data from BOR and nutrient data, Appendix I (Kann & Walker 1999)

High ammonia concentrations in 1996 and 1997 coincided with severe fish die-offs. Ammonia concentrations were low during summer months from 1991 through 1995. The Biological Opinion, while not discussing ammonia data in detail, mentioned ammonia in reference to fish die-offs. "*From June through August 1996, un-ionized ammonia levels were generally higher than in any of the previous five years sampled. Mean lake-wide ammonia concentrations were 70–95 ug/l (Perkins et al. 2000b).*" Data from Kann and Walker (1999) indicate ammonia concentrations of 50—1,020 ug/l for this period with levels above 400 ug/l on four of eight sampling dates. From June through October 1997, ammonia concentrations ranged from 350 to 1,644, with an average of 779ug/l. Perkins, Kann, and Scoppettone (2001), in their Figure 1, show un-ionized ammonia concentrations peaking at about 0.30 ppm in July and again in September 1996 and at about 0.9 ppm in late July 1997. They do not present data for years prior to 1995.

Weather conditions and lake water quality

Differences in weather conditions, including water temperature and wind speed, are cited as a main reason for fish kills in the Biological Opinion. "*Data indicate that the 1996 die-off was linked to a combination of meteorological and biological conditions (Perkins et al. 2000b). Specifically, warm weather and relatively calm conditions during July and August led to warm water temperatures, stratification of the water column, and increased biological activity. Warm temperatures increased respiration rates and sediment and water column DO demand. AFA populations bloomed in June were generally declining. A lack of wind mixing likely reduced aeration and consequently fish were exposed to stressful levels of low DO leading to disease outbreaks and mortality.*

In reviewing the Klamath Falls meteorological data records, weather conditions before and after the 1996 die-off were unusual. For example, the mean monthly July temperature was 73.5^{0}F, making it the second warmest in 69 years of record at the Klamath Falls airport. The

August mean monthly temperature, 70⁰F was ranked 11th over the 69-year record. Warm weather was also associated with previous fish die-offs in 1995, 1986, and 1971.

Klamath Falls wind data indicate that July 1996 was ranked 4th out of the last 27 years for lowest mean monthly wind speed (3.2 mph). August was also a relatively calm month with an average wind speed of 3.0 mph (5th out of 27 years). Wind records from the Klamath Falls airport generally indicate that winds are mostly light during the summer. However on a daily basis, winds vary, but typically are highest during afternoon and early evening hours" (Biological Opinion, 2001).

An alternative to comparing the 1996 and 1997 years with 69- or 27-year data sets, a period during which a significant deterioration of water quality in UKL may have occurred, is to compare conditions over the most recent 10 years of 1991–2000. Table 6 shows mean monthly air temperatures recorded at the KES station for April through October for these years. It should be noted that during years when both Kingsley Field and KES stations were in operation, daily mean air temperatures were 2 to 3⁰F higher at the airport. This was thought to be due to the proximity of the airport station to large buildings and extensive paved areas. In this 10-year data set, July mean temperatures were the same for 1992, 1996, and 1998. Only 1993 and 1995 were several degrees cooler for both July and August. The August 1996 mean temperature was essentially the same as in 1991, 1992, 1997, and 1998; three years of no fish die-offs and one year with a die-off. At lower lake elevations, 1991 and 1992 may have experienced higher water temperatures relative to air temperatures because of reduced buffering capacity, a relationship pointed out in the Biological Opinion.

Tables 7 and 8 show mean daily wind speed and the number of days per month when mean wind speed exceeded 5 mph, measured at the KES station in June through September for 1991 through 2000. Wind speeds were lower with fewer days of speeds above 5.0 mph in July and August 1996 compared with 1991–1994. The years 1998 and 2000, which experienced no fish die-offs, were equally low in wind speeds. KES data were the same as airport data for July and August of 1996.

Table 6. Mean monthly air temperature for April through October measured at the Klamath Experiment Station, Klamath Falls, OR for 1991 - 2000.

	Year										Mean
Month	91	92	93	94	95	96	97	98	99	00	84-99
	Mean Monthly Air Temperature (⁰F)										
April	42	48	42	45	42	44	43	43	42	47	44
May	46	59	53	54	51	49	56	47	49	51	51
June	54	62	65	58	57	58	58	58	56	61	59
July	68	64	57	69	63	69	64	69	62	63	65
August	65	67	61	62	61	66	65	67	63	64	64
September	63	57	58	60	60	55	58	62	59	64	58
October	52	50	49	45	47	48	47	45	49	45	48
Mean	56	58	55	56	54	56	56	56	54	56	56
June-Aug Mean	62	64	61	63	60	64	62	65	60	63	63

Table 7. Mean monthly wind speeds in miles/hour measured at the Klamath Experiment Station weather station for June through September in 1991 - 2000.

Month	91	92	93	94	95	96	97	98	99	00	Mean
	Year										
	miles/hour										
June	5.1	5.6	4.5	4.4	5.3	3.8	4.8	3.1	4.7	4.6	4.6
July	3.8	3.8	4.1	4.2	3.6	3.2	3.2	3.1	3.6	3.2	3.6
August	3.4	3.3	3.4	3.3	3.5	3.0	3.2	2.8	3.3	3.1	3.3
September	3.5	3.3	2.6	3.3	3.1	3.3	3.0	3.5	3.8	3.0	3.2
Mean	4.0	4.0	3.7	3.8	3.9	3.3	3.6	3.1	3.9	3.5	3.7

Table 8. Number of days/month when mean daily wind speed measured at the Klamath Experiment Station weather station exceeded 5.0 miles/hour in 1991 - 2000.

Month	91	92	93	94	95	96	97	98	99	00	Mean
	Year										
	days/month										
June	13	18	10	7	13	2	8	8	12	10	6.1
July	2	7	5	7	4	2	1	1	6	0	3.5
August	3	3	2	1	5	1	2	0	2	1	2.0
September	3	5	0	3	3	7	2	4	8	3	3.8
Mean	5.3	8.3	4.3	4.5	6.3	3.0	3.3	3.3	7.0	3.5	3.9

The Biological Opinion states *"Fish kills are not related to lake levels. They occurred in years of average, above-average, and below-average median August elevations (Welch and Burke 2001). Median August elevations are the most appropriate data for comparing lake levels and fish kills because August was the month when most kills occurred. Lake elevations in 1971 and 1995 were above average; 1986 was average, and 1997 and 1996 were below average. Therefore there is no clear relationship between lake elevation and fish kills."*

In fact, lake elevation remained higher in 1997 (4,140.0 ft at end of September) than in 1995 (4,139.7 ft at end of September). The value used for August average lake level is not indicated, but it is above 4,140.0 ft. This is higher than the long-term average for the Project since 1905. It should be noted that no fish kills have been reported in any of the 13 years since 1905, when minimum lake elevation fell below 4,138.0 ft. In 1932, when a fish kill was observed, the mid-August lake level was also above 4,140.0 ft. During the first 30 years following the construction of Link River Dam (1922–1951), lake elevation fell below 4,138.0 ft in 10 years (USBR data). The 1932 fish kill occurred at a relatively high lake elevation. In 30 years since 1971, five fish kills have occurred while minimum lake levels have been maintained 1 ft higher than during the 1922–1951 era during late summer and have fallen below 4,138.0 ft on only four occasions.

Role of pH in Upper Klamath Lake water quality

"Kann and Smith (1999) suggested that efforts to improve water quality in UKL and Agency Lake might be focused on reducing AFA productivity to a point that pH levels can be tolerated by the fish community. The results of analysis showed that a 50% reduction in Chl-a [chlorophyll-a] *levels, from 200 to 100 mg/l, would result in a 45% reduction in the probability of exceeding a pH of 9.5. Modeling by Welch and Burke (2001) found similar reductions. Such a reduction may be possible if anthropogenic nutrient inputs, especially TP (*total phosphorus)*, to the lake are reduced 30–50% (Walker 2001). Walker (2001) points out that this could be achieved since an 8% decrease in TP was observed in the past decade, likely as a result of watershed and wetland restoration"* (Biological Opinion, 2001).

The Biological Opinion makes several references to massive and early algal blooms and poor water quality in 1992 and 1994. Unpublished data from USBR compares several water quality parameters for 1990 through 1999 during summer months. The data do show high chlorophyll-a levels in June and early July of both 1992 and 1994, but low levels in August and September. In 1995, 1996, and 1997, chlorophyll-a peaks occurred later in July, when temperatures were probably higher, but also occurred in September. While the reasons are unclear, algal blooms extended much later into the season in years with high lake elevations.

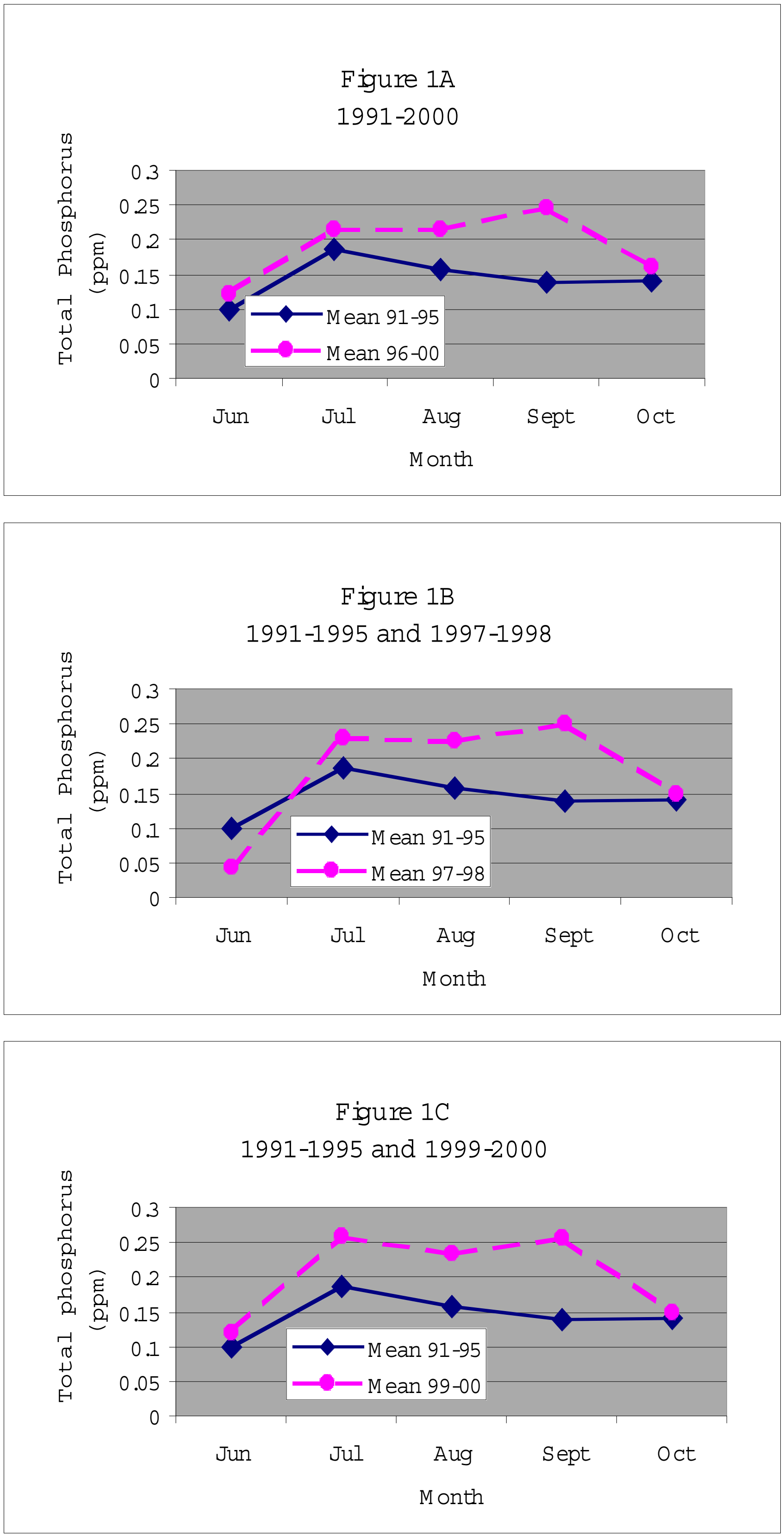
Walker (2001) indicates an 8 percent reduction in external TP loading to UKL has been achieved in March through May during the 1990s. Presumably, this is attributed to less pumping of drainage water from agricultural properties that have been taken out of production for restoration of wetlands or development of water storage (Wood River Ranch, Tulana Farms, Agency Lake Ranch). If this is the case, it is not reflected in data on TP concentration of UKL lake water at the south end of the lake.

Kann and Walker (1999) present a data set on TP concentration at the Fremont Bridge over the 1991–1998 period. Rykbost and Charlton (2001a) monitored the nutrient loading at the A-Canal headworks during May through October in 1999 and 2000. These sites are within about 300 ft of each other. Comparisons of TP concentrations over the 10-year period are shown by month for June through October in Figure 1. Each comparison indicates higher TP concentrations in the latter years. In combination with greater lake volume, the trend suggests much greater TP was discharged from the lake during the past 5 years. In a recent Technical Memo, Kann (2001a) concludes "the apparent decreasing March-May lake TP trend for the years 1991–1998 reported in Walker (2001) does not hold when 1999 and 2000 data are added to the analysis."

Klamath Lake water quality summary

"*The Service concludes that the pre-project minimum lake levels of 4,140 ft (and similar minimum lake levels presented in the RPA) are necessary to protect suckers from adverse water quality and are based on the best available science. In reaching this conclusion, the Service recognizes that a relationship between water quality and lake levels in UKL that is statistically significant, for example at a 95% confidence level, has not been established. However, based on our analysis of the best available science, we conclude that minimum UKL elevations approximating those experienced pre-project are supported. The dominant factors controlling water quality in UKL are weather and climate, which are not controllable, whereas lake levels can be managed. Considering the high risk that adverse water quality poses to sucker survival, managing UKL using pre-project lake levels with a minimum elevation of about 4,140 ft is considered by the* *service to be necessary to ensure sucker survival and recovery"* (Biological Opinion 2001)

Figure 1. Total Phosphorus Concentration at UKL Outlet



This statement summarizes USFWS reasons for lake level management. Other interpretations of available data can lead to a different conclusion. There is clearly evidence that fish kills have occurred at relatively high lake levels and not at very low lake levels. In low lake-level situations in 1991, 1992, and 1994, ammonia concentrations in the lake were very low, while very high concentrations were observed in 1996 and 1997 when major die-offs occurred. In 1991, a new year-class of SNS and LRS was successfully recruited even though lake level fell to 4,138.18 late in the season. This class survived the low lake levels experienced in 1992 and 1994. A 1992 year-class was "well represented" in the 1996 fish kill (Biological Opinion 2001) and recent U.S. Geological Survey data on sucker captures at spawning sites indicate the presence of both 1992 and 1994 year classes in the population (Rip Shivley, USGS, unpublished data).

As noted earlier, there is not consensus on pre-project minimum lake elevations. Boyle (1987), U.S. Army Corps of Engineers (1982), and Grover *et al* (1923) all suggest that lake elevations fell below 4,140 ft on several occasions prior to construction of Link River Dam. Available data not cited in the Biological Opinion show higher P concentration in UKL during the high lake level years of 1996–2000, than during the period of low lake levels from 1991 through 1994. Much of the water quality analysis is based on theory and models, while empirical data from 8 years in Kann and Walker (1999), one of the major studies cited throughout the BO, was not considered.

Water quality in other water bodies

Discharges to the Klamath River at the Straits Drain have been a focal point for concern over several parameters, including nutrients. Past and current studies suggest P concentrations of 0.3 to 0.4 ppm are common during portions of the year. The discharge includes drainage from agricultural fields irrigated with diversions from the North and ADY canals and drainage water from the Lost River via Tule Lake and Lower Klamath refuges. Ongoing unpublished studies by U.C. Davis and U.S. Geological Survey personnel will attempt to define the nutrient loading in greater detail.

Rykbost and Charlton (2000, and 2001a) monitored nutrient loading to the Project from diversions at the A-Canal, North Canal, and ADY Canal during 1999 and 2000. Total loading from these diversions was estimated at approximately 180,000 lb P and 2,000,000 lb N in both years. Preliminary data from the Straits Drain (Kaffka, unpublished data) indicate an annual discharge of approximately 100,000 lb P. Thus the Project, including refuges and any inputs from the Lost River system and Klamath River via the Lost River Diversion Channel, is a net sink for P diverted out of Klamath Lake and Klamath River. A comparison of P concentration at A-Canal and diversions from the river indicates an increase in P concentration between Link River Dam and North and ADY canals. This may be due to discharges from Klamath Falls and south suburban sewage treatment plants, storm drains, and lumber mills. Contributions from waterfowl in the Miller Island reach of the river and decomposition of wood debris in river sediments also may be involved.

The other major concern for water quality is related to water temperature at the Iron Gate Dam, as it affects threatened Coho salmon. Given conditions of water bodies in the upper basin, little can be done to avoid high temperature at the dam during summer months. This has been well documented in models developed by Deas and Orlob (1999) based on empirical data collected over several years and locations. Higher flows released from the upper basin may increase the temperature at Iron Gate Dam because of greater dilution of accretions below Keno Dam, which are coming into the river as cool spring water. Summer temperatures in UKL frequently exceed 70^{0}F. An unpublished data set from multiple locations in UKL identifies temperatures at specific sites as high as 82^{0}F.

Flow requirements at Iron Gate Dam

The reduction in available water for agriculture and refuge use resulting from maintaining UKL at a minimum elevation of 4,139.0 ft in a critical year type is about 174,000 acre-ft compared to available water if the elevation were allowed to go to 4,136.0 ft, at dead storage. In contrast, the high flows at Iron Gate Dam required by the National Marine Fisheries Service (NMFS) 2001 Biological Opinion for Coho salmon have far greater effect on water supply in the upper basin.

Table 9 illustrates flows past Iron Gate Dam under several scenarios. During the droughts in 1992 and 1994, total flows from April 1 through September 30 were about 150,000 acre-ft and 250,000 acre-ft, respectively. In the 2001 Biological Assessment (BA), USBR proposed a flow regime for April 1 through September 30 of about 180,000 acre-ft. The NMFS requirement for that period for 2001 was about 500,000 acre-ft. This was a compromise from the initial draft Biological Opinion submitted on January 19, 2001, which called for 790,000 acre-ft during April-September. The difference between the USBR BA proposal and the Operations Plan (320,000 acre-ft) is about equal to the 10-year average diversion for the A-Canal, North Canal, and ADY Canal less the return to Klamath River at Straits Drain.

Table 9. Iron Gate Dam monthly flows in acre-ft proposed by INSE (Institute for Natural Systems Engineering), Trihey and Associates and Reclamation.

			Bureau of Reclamation			
Month	INSE	Trihey	Above Ave.	Below Ave.	Dry	Critical
	Flow (1000 Acre-ft/month)					
January	90.8	73.8	69.3	82.0	54.6	62.2
February	100.4	89.3	50.5	85.9	41.5	29.2
March	128.0	92.2	124.8	98.3	44.6	31.4
April	148.9	92.2	101.5	82.1	44.1	34.0
May	167.1	83.3	84.1	61.9	51.9	31.5
June	189.0	92.2	44.7	42.4	39.4	30.1
July	196.8	119.0	42.6	42.7	33.5	26.4
August	187.9	153.7	62.2	43.1	39.8	24.5
September	133.8	101.2	61.6	43.1	44.6	32.0
October	105.4	61.5	81.7	80.4	52.4	55.6
November	82.8	61.5	79.6	78.8	51.9	54.1
December	83.0	59.5	85.3	88.2	54.7	56.2
Total	1,613.9	1,079.4	887.9	828.9	553.0	467.2

Table 9 presents Iron Gate Dam flows by month in acre-ft requested in the January 2001 draft Biological Opinion, suggested in the Trihey and Associates (1996) report, and proposed under four year-classes in the 2001 USBR BA. USBR proposed flows are based on the hydrology of the Project since 1961 and take use of water for irrigation and refuges into consideration. The INSE (Hardy Phase I) and Trihey models do not allow flexibility to adjust for hydrologic conditions in any given year. The INSE model calls for flows equal to the average annual inflow to UKL. With accretions below

Keno Dam accounting for about 300,000 acre-ft in an average year and inflow to UKL averaging 1,300,000 acre-ft, the INSE Iron Gate flow requires all average available UKL water.

An analysis of the hydrology of the project from 1961 through 1997 compared INSE required flows with discharges from UKL. The analysis showed that under INSE required flow regimes, in 13 years out of 37, flows could not have met INSE targets even if no water had been diverted for irrigation or the refuges. Only in 15 years of 37 was sufficient water available to meet the flow targets and historical use for irrigation and refuges. This analysis did not take minimum lake elevations into consideration. Holding lake levels at a minimum of 4,139.0 ft or higher would increase the number of years not meeting flow targets.

The flows suggested in the Trihey report would have left no water for irrigation or refuges from UKL in 1992 and 1994 and less than current use quantities in an additional 6 of 37 years. The modified plan for 2001 operations 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 will result in significant shortfalls in surface water supply for the Project.

Economics of irrigation water in the Project

Users of Klamath Project irrigation water pay operation and maintenance (O&M) fees to the irrigation districts delivering these supplies. Fees range from $12/acre for the Van Brimmer Ditch Co. to $70/acre for the pressurized Shasta View Irrigation District. (Smith and Rykbost 2001). The fees are due irrespective of water delivery. There is no charge for the water.

In view of the supply shortfall anticipated for the 2001 season, the USBR offered Project users an opportunity to submit bids for foregoing surface water in 2001 and to Project users or others that could deliver groundwater from wells to Project delivery systems. Bids, submitted for nearly 25 percent of the Project acreage, ranged from $55 to $4,000/acre. USBR accepted bids on about 150 parcels at up to $300/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/acre. The groundwater purchasing program acquired about 67,000 acre-ft of groundwater at an average price of about $33/acre-ft and a total cost of about $2,208,000. Accepted bids for well water ranged from $25 to $52/acre-ft (USBR data).

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/kw-h. 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, Pumping Plant D, which pumps drainage from Tule Lake NWR Sump 1A to the Lower Klamath NWR, typically costs $50,000/year to operate at rates of $0.003/kw-h during non-peak or $0.005/kw-h 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 the Tulelake Irrigation District members by about $7.00/acre, a 25 percent increase.

Effects of water management in 2001

The Project Operations Plan for 2001 provided about 70,000 acre-ft 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 well water, 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-ft) 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. An additional acreage that only received the late delivery in August was considered to have received no water for tax assessment purposes. The late release from 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.

Failure to charge the Project canals resulted in elimination of habitat for numerous species in thousands of acres of canals and drain ditches. The lack of seepage from these sources contributed to the failure of a number of shallow wells used for domestic and livestock supplies.

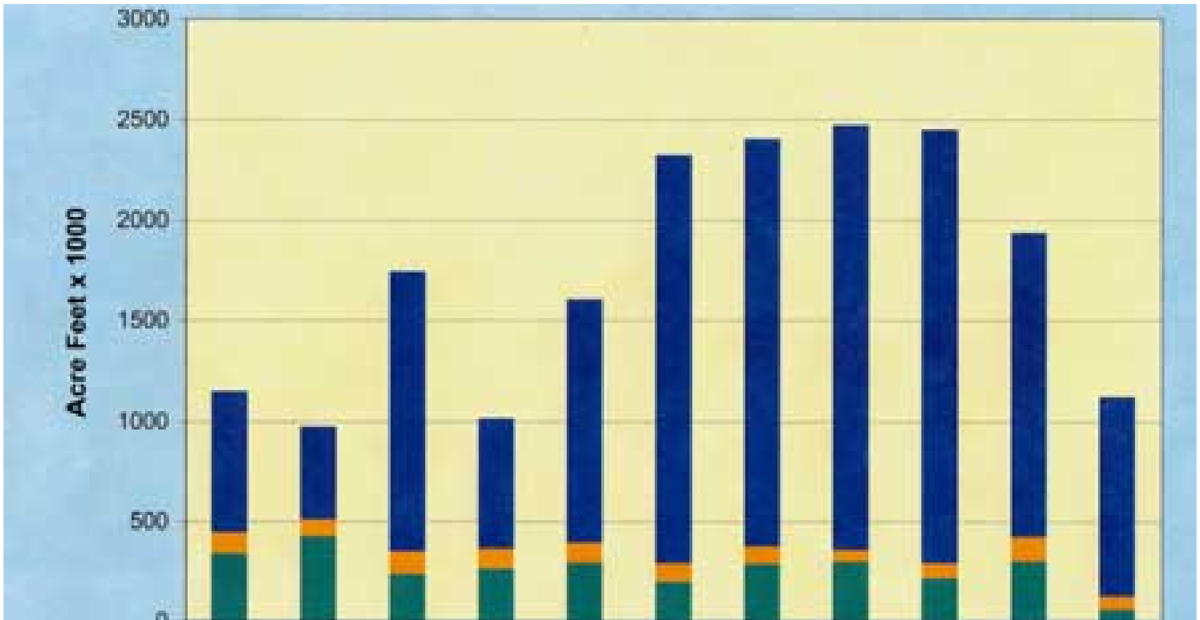
The major change in water allocation implemented in 2001 is illustrated in Figures 2 and 3. Data provided by USBR shows relative allocation of water from UKL to Iron Gate Dam flows, Tule Lake and Lower Klamath National Wildlife Refuges, and agricultural lands in the Project. Data does not include water use supplied by the Lost River system or from groundwater wells. In 2001, agriculture received 22 percent of the average diversion for 1991–2000. In contrast, Iron Gate Dam flows were 68 percent of the 1991–2000 mean and refuge use was 71 percent of the 1991–2000 mean. Figure 3 compares UKL water allocation during drought years of 1991, 1992, 1994, and 2001. Total water availability in 2001 was greater than in 1992 and 1994 and similar to the supply in 1991.

Project storage water made unavailable by minimum elevations established in the USFWS 2001 Biological Opinion included 4,000 acre-ft in Gerber Reservoir, 17,000 acre-ft in Clear Lake Reservoir, and 174,000 acre-ft in UKL. 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-ft/acre, or 85,000 acres of alfalfa or pasture using 2.25 acre-ft/acre.

The water lost to higher flows at Iron Gate Dam imposed by the NMFS 2001 Biological Opinion can be determined from pre-listing flow regimes. Prior to the listing of Coho salmon, the standard flow requirements for Iron Gate Dam were based on Federal Energy Regulatory Commission (FERC) minimum flows established at the time Iron Gate Dam was licensed. These minimums were 1,000 cfs for May, 710 cfs for June and July, 1000 cfs for August, and 1,300 cfs for September. Using the period from May through September, actual 2001 flows at Iron Gate Dam were about 408,000 acre-ft. FERC minimum flows would have been about 300,000 acre-ft. The difference would have provided adequate irrigation water for about 60,000 acres of cereals or potatoes or 48,000 acres of alfalfa or pasture.

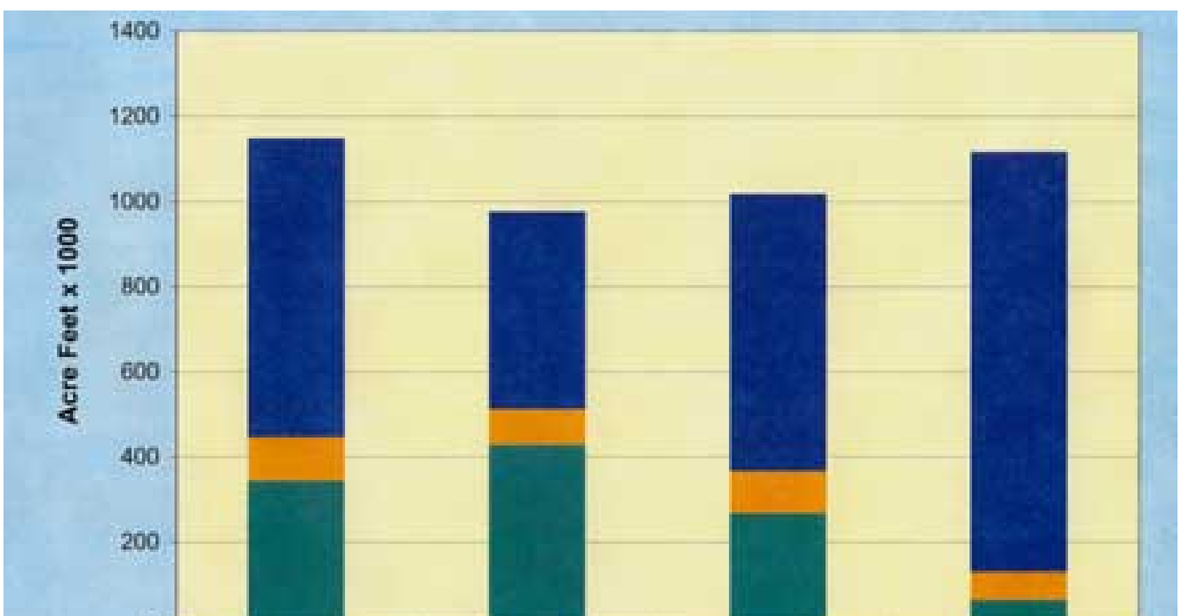
In summary, operation of the Project under the 1992 USFWS Biological Opinion and FERC minimum flow requirements would have resulted in near-normal irrigation and refuge water supply in 2001. Including 174,000 acre-ft of lost storage in UKL, 75,000 acre-ft of water released in July and August, and 108,000 acre-ft of reduced flows from May through September, UKL could have provided 357,000 acre-ft for irrigation and refuges. This represents nearly exactly the 1991–2000 average diversions to the A-Canal, North Canal, and ADY Canal.

Figure 2. Klamath Lake waters allocation for Iron Gate Dam flows, refuges, and agriculture for 1991-2001 (USBR).



	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

Figure 3. Klamath Lake water allocation for Iron Gate Dam flows, refuges, and agriculture in drought years of 1991, 1992, 1994, and 2001 (USBR).



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

Summary

The basis for the change in water allocation from historical practice was the opinion that increased flows past Iron Gate Dam and increased lake levels in Upper Klamath Lake would improve water quality and habitat for threatened and endangered species. This report has attempted to provide additional data related to water quality issues, particularly in relation to UKL.

Empirical data from UKL suggest water-quality improvements anticipated for high lake levels required by the Biological Opinion will not be realized. Data from the 1990s indicate high lake levels during fish kills in 1995–1997 were associated with massive late-season algal blooms and high ammonia levels. Limited data collected by Burleson Consulting in August 2001 indicated ammonia concentrations near Eagle Point and Ball point ranged from 0.4 to 1.3 at a lake elevation of about 4,140 ft (Nadia Burleson, personal communications). Ammonia concentrations were very low during years of relatively low late-season lake levels from 1991 to 1994.

Empirical data also indicates that maintenance of relatively high lake levels from 1996 to 2000 was not accompanied by reduced phosphorus, the driving force for algal blooms in UKL. Phosphorus concentration in UKL during summer months has been higher in 1996–2000 than during 1991–1995. Algal blooms have persisted into late summer in each year since 1996.

Increased flows past Iron Gate Dam may have a detrimental effect on water quality by diluting cool water from accretions below Keno Dam with warm and nutrient-rich water from UKL. Summer temperatures in excess of 70^{0}F are common in UKL. High volumes of water at this temperature below Iron Gate Dam may result in death of resident fish. In late August 1994, flows were increased from about 500 cfs to 900 cfs in an effort to encourage salmon to move into the river. A resulting fish kill of adult salmon in the Klamath River mainstem was documented.

Through September 2001, flows at Iron Gate Dam have been maintained at a minimum of 1,000 cfs. Releases from UKL account for about 70 percent of the flow. With high nutrient loads from June through late summer, UKL water is delivering more nutrients to the lower river than would be the case with lower flows and diversion of UKL water into the Project.

Documentation of the many effects of elimination of surface water supply to most of the Klamath Irrigation Project lands in 2001 will require long-term monitoring. A very important part of that will be to document water quality in UKL and at Iron Gate Dam. Similarly, any effects of the actions taken on listed species, including bald eagles, should be documented. State water resource agencies and the U.S. Geological Survey are monitoring groundwater development. Providing detailed accounting of the knowledge gained about groundwater hydrology will assist in planning future use of this resource. Timely availability of information developed to all stakeholders will be important.

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