

Klamath Marsh Hydrology and Water Rights
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INTRODUCTION

Klamath Marsh National Wildlife Refuge is located in the Klamath Basin of southern Oregon (Figure 1). The 41,000-acre refuge is owned and managed by the U.S. Fish and Wildlife Service (FWS). The refuge was established in 1958 for the protection of migratory birds. This report presents information on the hydrology of the marsh and the water rights of the refuge. In the hydrology section, we begin by discussing the hydrogeologic characteristics, the groundwater/surface water interactions, and the inflows, outflows, and sources of water for the marsh. We present data from some of the water monitoring sites in or around the marsh and identify and examine trends in those data. Lastly, we summarize the important points regarding the hydrology of the marsh. In the water rights section, we summarize information on water rights and water management on the refuge. Appended to this report is information on several water monitoring sites in or around the refuge including the site location and history and the agency responsible for monitoring the site.

KLAMATH MARSH HYDROLOGY

Physical Location and Hydrogeologic Setting

Klamath Marsh is located about 50 miles north of the city of Klamath Falls in the Upper Williamson River Basin of south-central Oregon (Figure 1). The marsh sits in a topographic low near the center of the Williamson River Basin. It is hourglass-shaped, with the narrowest section located at Military Crossing road. The road divides the marsh into two areas that are connected hydrologically: the Upper Marsh and the Lower Marsh. The basin is bounded to the north, east, and south by volcanic buttes and high plateaus of the Basin and Range Province. To the west rise the Cascade Mountains and Crater Lake. The western portion of the basin is underlain by volcanic rocks, including pyroclastics, ash, and breccias interlayered with lava flows, all of which are highly permeable (Cummings and Melady, 2002). The highlands to the north, northeast, and south of the marsh are made up of thinly layered basalt flows of moderate to high permeability. Wildhorse Ridge, directly east of the refuge, is an andesitic lava flow of low permeability. The marsh itself is composed of alluvium of sand, silts, clays, and gravels. Overlying the alluvium is a layer of pumice deposited 7,000 years ago from the eruption of Mount Mazama, now Crater Lake. The thickness of the pumice ranges from only a few feet at the eastern edge of the marsh to 75 feet along Highway 97. The pumice has a very high infiltration capacity and is highly permeable. At the surface of the marsh, above the pumice layer, is a layer of peat and diatomite (Cummings and Melady, 2002).

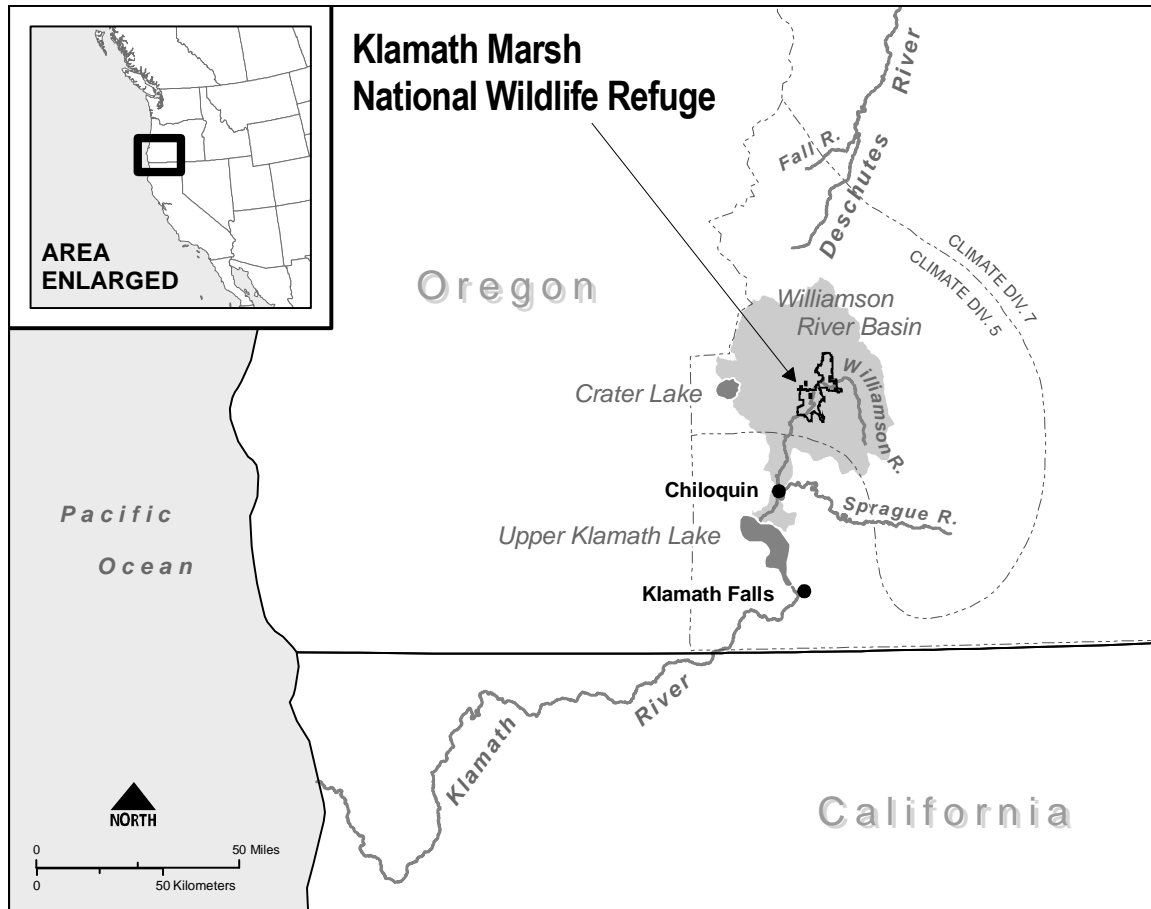


Figure 1. Regional location and vicinity of Klamath Marsh.

Sources of Water for the Marsh

Inflows to Klamath Marsh come from surface water, groundwater discharge, and precipitation falling directly on the marsh. We present data for all three of these sources. The data examined in this report came from several sources:

U.S. Geological Survey (USGS) (accessed on-line at <http://or.water.usgs.gov/> and http://or.water.usgs.gov/projs_dir/or180/waterlevels/index.html);

Oregon Water Resources Department (OWRD) (accessed on-line at <http://www.wrd.state.or.us/>);

Western Region Climate Center (WRCC) (accessed on-line at <http://www.wrcc.dri.edu/spi/divplot1map.html>);

Water Resources Branch, R1 Regional Office, U.S Fish and Wildlife Service.

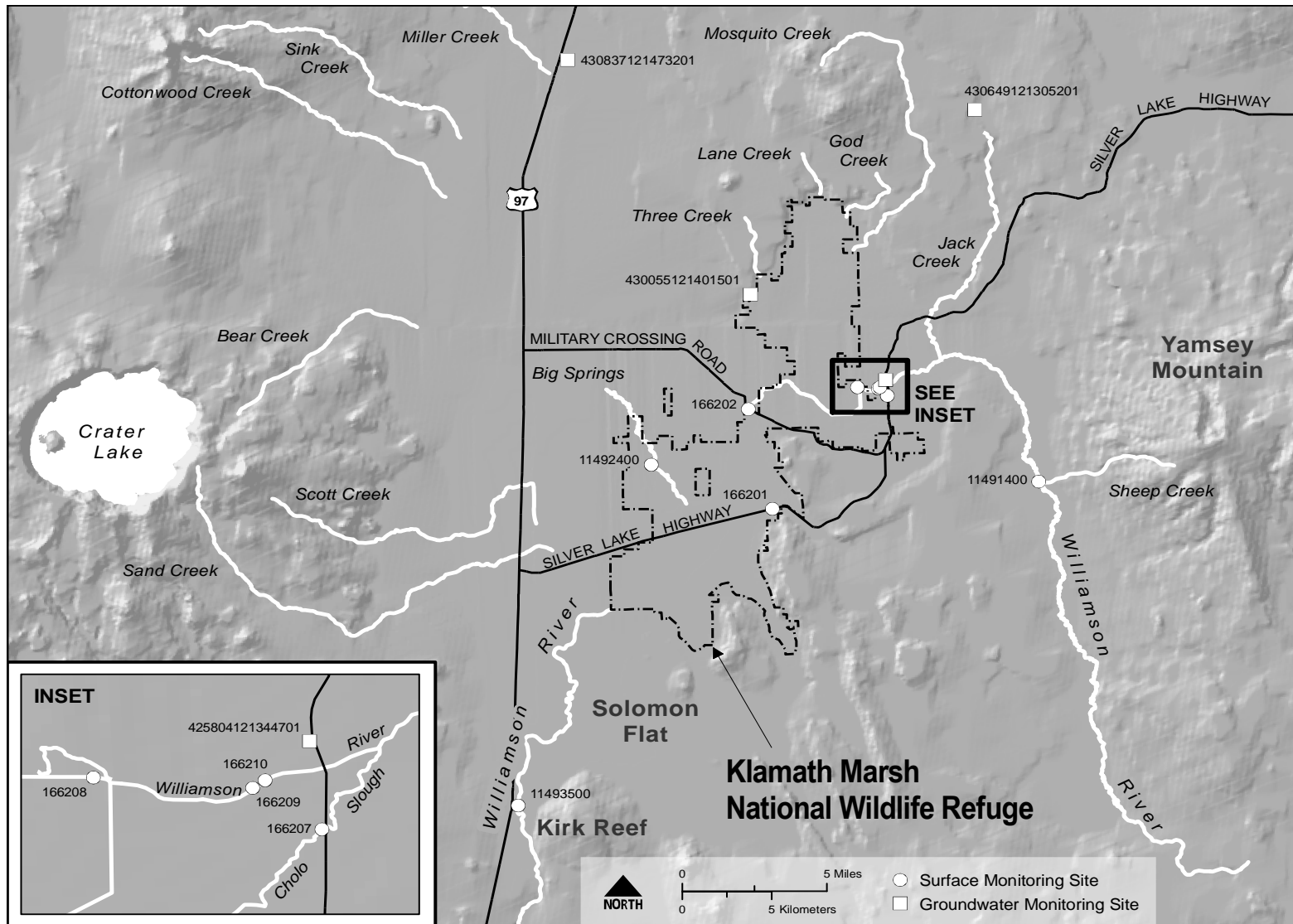


Figure 2. Select hydrography and monitoring sites. See Appendix A for key to site numbers.

Precipitation

Klamath Marsh is located in Oregon Climate Division 5, the High Plateau (Figure 1). Climate divisions are areas of climate uniformity with water-resource data aggregately assessed through principal component analysis, based on information from 10 to 50 individual stations (Keyantash and Dracup, 2004). Monthly precipitation and temperature are available from 1895 to the present, for each climate division nationally. We focused on the period 1950 to 2005 because this is the period for which there was flow data available. Average annual precipitation for Climate Division 5 is 27 inches/yr for this period. Approximately 75% of this precipitation falls from October through March, much of it as snow on the marsh.

Surface Water

The two main surface water sources for the marsh are the Williamson River and Big Springs Creek (Figure 2). The Williamson River emanates from springs and seeps east of the marsh near Yamsey Mountain. Flows on the Williamson were monitored continuously from 1973 to 2003 by the USGS/OWRD downstream of the headwaters, below Sheep Creek. This site is 8 miles upstream of the marsh.

The Williamson River enters the marsh on the east side, near the refuge office, through the main channel and a diversion channel called Cholo Slough (Figure 2). Flows at both of these sites are currently monitored by the FWS. Once on the refuge, a network of channels and canals distribute Williamson water to the southeast section of the Upper Marsh. The channel network ends north of Military Crossing.

South of Military Crossing, the river lacks a defined channel. The river channel reforms in the southwest corner of the Lower Marsh where all surface water exits the marsh. Historically, the Lower Marsh was wetter than the Upper Marsh, with the largest expanse of permanent water. However, in recent years, the Upper Marsh has been wetter. Sedimentation in the river channel downstream of Military Crossing in the 1990s may prevent water from moving to the Lower Marsh, causing the Upper Marsh to be wetter now (Walt Ford, Klamath Marsh NWR Refuge Manager, oral communication, 2002).

Big Springs Creek, the second major surface water source, enters the marsh on the west side south of Military Crossing (Figure 2). The stream originates from springs in the forested pumice plateau at the southwestern edge of Klamath Marsh. A large spring identified as “Big Springs” marks the headwater spring at an approximate elevation of 4535 feet msl (LaMarche, 2002). There is a long period of miscellaneous measurements and two recent periods of continuous measurements for this stream.

Several other streams exist to the west (Sand, Scott, and Bear Creeks) and northwest (Miller, Sink, and Cottonwood Creeks) of the marsh, but none of them currently reaches the marsh as surface flow (Figure 2). Whether they did historically is questionable, although David Evans and Associates (2005) refer to them as tributaries of the Williamson River. During wet years, the

northern area of the Upper Marsh receives water from several intermittent streams (Three Creeks, God, Mosquito, and Lane creeks) that flow in the spring.

After exiting the marsh, the Williamson meanders in a well defined channel through 14 miles of fairly flat land and an open pond, known as Soloman Flat, before reaching a natural basalt plug at Kirk Reef (Figure 2). The USGS has monitored flows at Kirk Reef continuously from 1954 to the present, with a gap in the monitoring from 1995 to 1998. The basalt sill acts as a control for river flow. During summer the water level in the river and wetland usually drops below the elevation of the sill, causing the river to stop flowing at this location. Historically, the flow at Kirk Reef has ceased in about 70% of years.

Ground water

The entire marsh is an area of groundwater discharge. Precipitation, in the form of rain or snow, falls in the surrounding mountains, infiltrates the groundwater system, and discharges to the marsh. The western margin of the basin is the primary zone of groundwater recharge because of the high precipitation in the Cascades. Snowmelt and rainfall in the Cascades readily move underground before rising to the surface at Klamath Marsh. South of the marsh, the basalt sill at Kirk Reef restricts drainage from the marsh causing water to pond up behind it. Groundwater appears to be an important component of the marsh water budget, and may even exceed surface water inflows by some estimates (Norvelle et al., 1981).

There are several observation wells in the Klamath Marsh area that have been monitored by OWRD or USGS (Figure 2). None of these wells has a long period of record. Most have been monitored since about 2000.

Descriptive Statistics and Trends for the Inflows and Outflows at Klamath Marsh

Precipitation

Precipitation potentially represents a considerable input of water to the marsh. At an average annual precipitation rate of 27 in/yr, precipitation would contribute at least 90,000 acre-feet/year (afy) to the 41,000 acre refuge. This is comparable to surface water or groundwater inputs.

Since the 1950s, there has been an overall decline in winter (Oct-Mar) precipitation and a corresponding increase in mean annual temperature in Climate Division 5 (Figure 3). Both trends are considered significant using a Mann-Kendall trend test ($p=0.000$). Crater Lake winter precipitation also shows a weakly significant decline since the 1950s (Mann-Kendall, $p=0.070$) and a significant decline in April 1st snow water equivalent (Mann-Kendall, $p=0.032$). This site is located within Climate Division 5. However, no decline is observed in Oregon Climate Division 7 or at the Klamath Falls weather station, both of which are adjacent to Division 5. Because marsh inflows and outflows are correlated with winter precipitation and marsh evapotranspiration is correlated with temperature, the observed climate trends will likely result in less inflow to the marsh, less outflow from the marsh, and greater evapotranspiration

losses within the marsh with time.

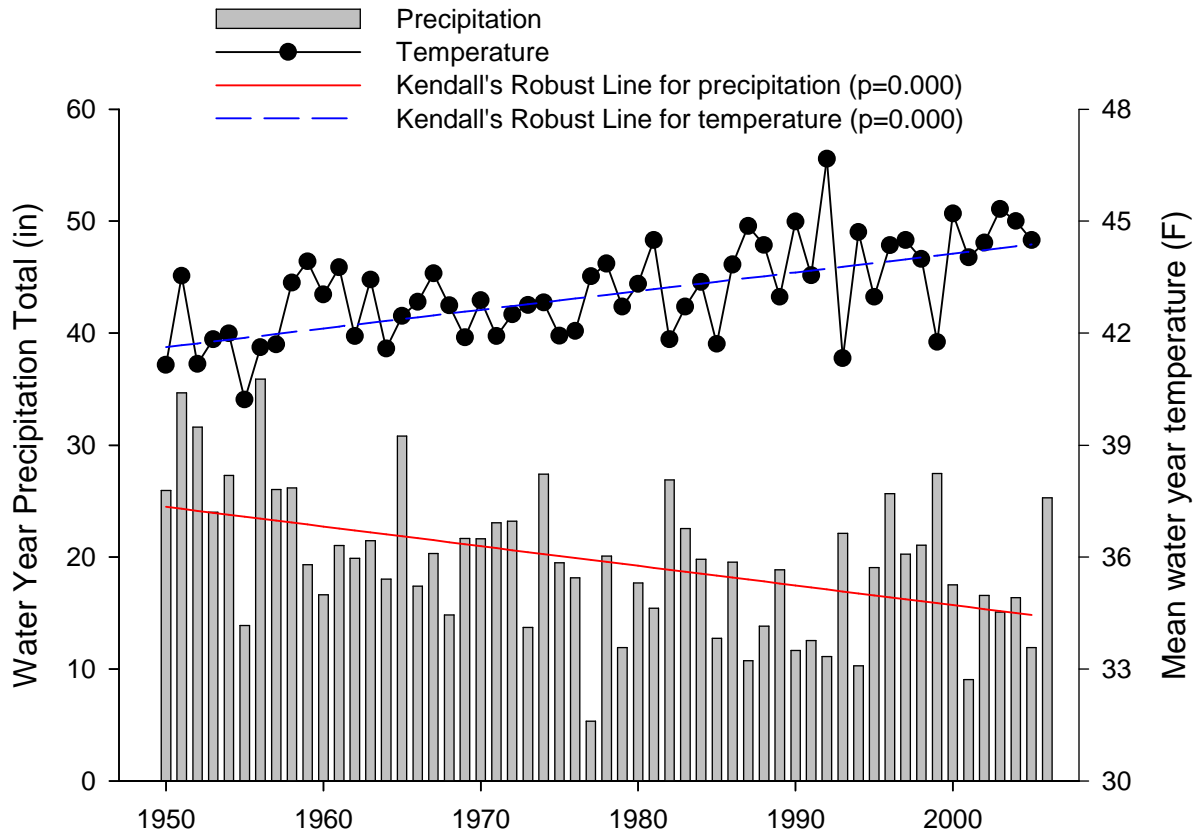


Figure 3. Oregon Climate Division 5 winter precipitation and temperature from 1950 to 2005, with Kendall's Robust Line indicating a statistically significant decrease in annual winter precipitation and increase in mean annual temperature with time.

Williamson Inflows

The average annual flow at the Williamson River below Sheep Creek for water years 1974 to 2003 is 48,441 afy, with a maximum of 71,895 afy in 1983 and a minimum of 32,164 afy in 1992. The river is supported by springs and seeps in the area with a snowmelt-generated peak in the spring in most years (Figure 4a). April – October flows average 28,311 acre-feet or 58% of the total water year flow. Average baseflow in August and September is 51 cfs or 102 acre-feet/day.

Total annual flow is fairly consistent with a coefficient of variation (the standard deviation divided by the mean) of 23%. This is less variability than what is observed at Big Springs or the Williamson River at Kirk Reef, which are both much more variable (Figure 4). Total annual flow at this site appears to be related to winter precipitation, which accounts for 72% of the variance of mean annual flows (Figure 5a). Here, winter precipitation is as expressed as a 3-year

Oct-Mar antecedent precipitation index (API) (Viessman and Lewis, 1996), based on the precipitation record from Climate Division 5. **This means flows at this site respond not only to the current year's winter precipitation but also to the previous two years of accumulated winter precipitation.** The regression equation in Figure 5a could be used in a predictive sense, but it is most beneficial in understanding the multi-year nature of wet and dry year cycles at the marsh.

It is possible to compare the flow in the Williamson River below Sheep Creek to Williamson River measurements collected by the FWS at the refuge boundary, for four years of overlapping measurements (2000 to 2003). The flows at the two sites are about equal on an annual basis but there are diversions and tributary inflows between the two sites which result in seasonal differences. Generally, there is more flow in the Williamson at the refuge boundary in the winter and spring, during the runoff season, and less in the summer and fall, during the irrigation season. June to September totals at the refuge ranged from 75 to 116% of the June to September totals below Sheep Creek for the years 2000 to 2003. At times during the summer of 2003, refuge inflows were less than half the flow measured concurrently upstream below Sheep Creek, indicating **upstream diversions and channel losses can significantly reduce the quantity of Williamson River flow reaching the refuge.**

Big Springs Inflows

Compared to the Williamson River, annual flow at Big Springs is quite variable (Figure 4b). **At times, Big Springs can be a major source of inflow for the marsh; however, at other times, the stream does not contribute inflow at all.** The lack of continuous flow measurements for any length of time prevents a meaningful estimation of the annual mean or coefficient of variation. The stream was reportedly dry from 1931-1951 (Leonard and Harris, 1974), and has been relatively dry during the early 1990s and for the past 5 years. However, the stream reportedly flowed continuously during a relatively wet period from the 1950s to the 1970s, with a low-flow discharge of 20 to 80 cfs (Norvelle et al., 1981). Flows were also fairly high and continuous during the late 1990s (Walt Ford, Klamath Marsh NWR Refuge manager, oral communication, 2004). Assuming average annual flow of 50 cfs or 100 acre-feet/day, total annual inflow of the creek would be 36,500 afy, almost on scale with the total annual inflow from the Williamson River.

Newcomb and Hart (1958) examined the relationship between accumulated precipitation at Chiloquin, OR and the flow at Big Springs. They stated that Big Spring will continue to flow as long as precipitation is normal or slightly above normal, will increase after a rise in accumulated precipitation, and will decrease following a decline in accumulated precipitation. Presumably, if the accumulated precipitation deficit becomes great enough, groundwater levels will drop below the 4535 ft elevation of the spring and flow will cease. LaMarche's (2002) observation that other springs and seeps stop flowing too when the local water table drops below this elevation suggests groundwater inputs to the marsh will be greatly reduced during these dry periods as well.

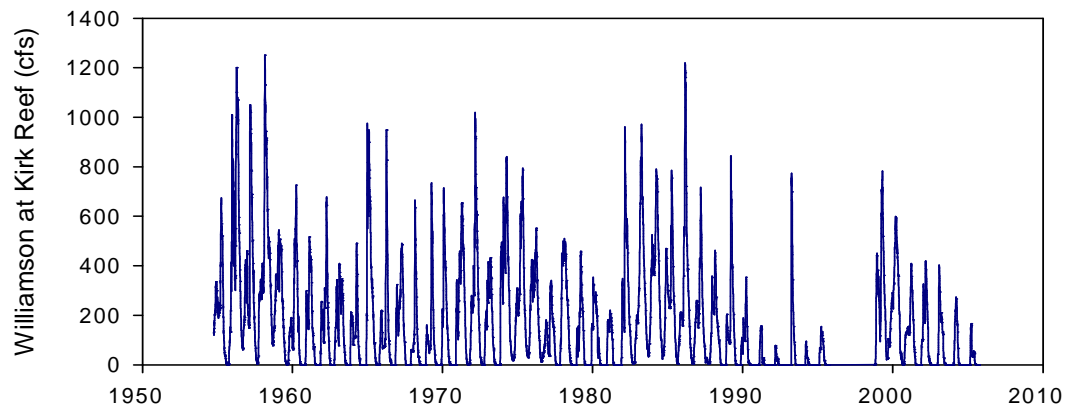
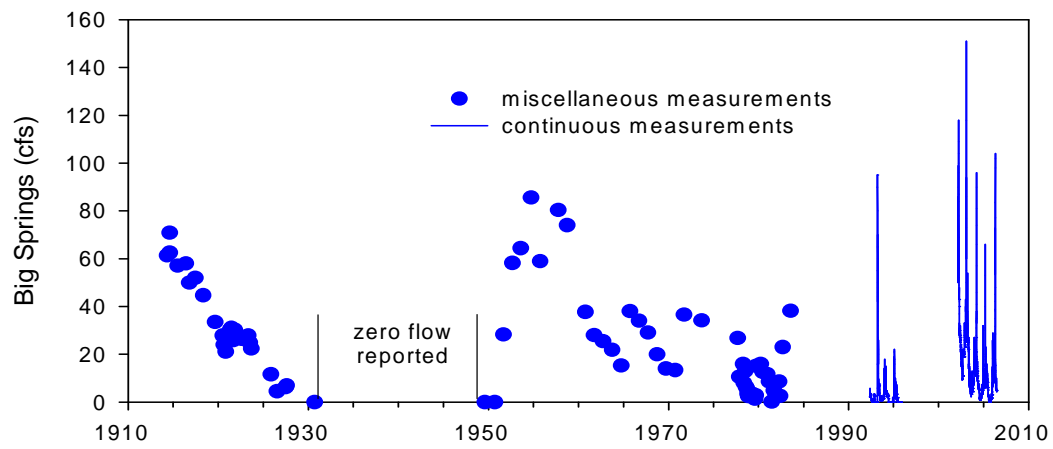
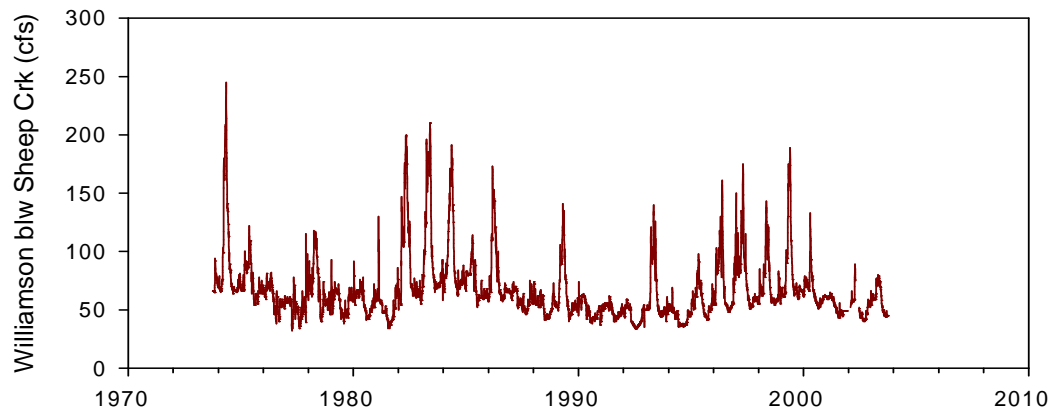


Figure 4. Hydrographs of Williamson River below Sheep Creek (4a, top plot), Big Springs (4b, middle plot), and Williamson River at Kirk Reef (4c, bottom plot). Note the change in scale on the x and y axis for all three plots.

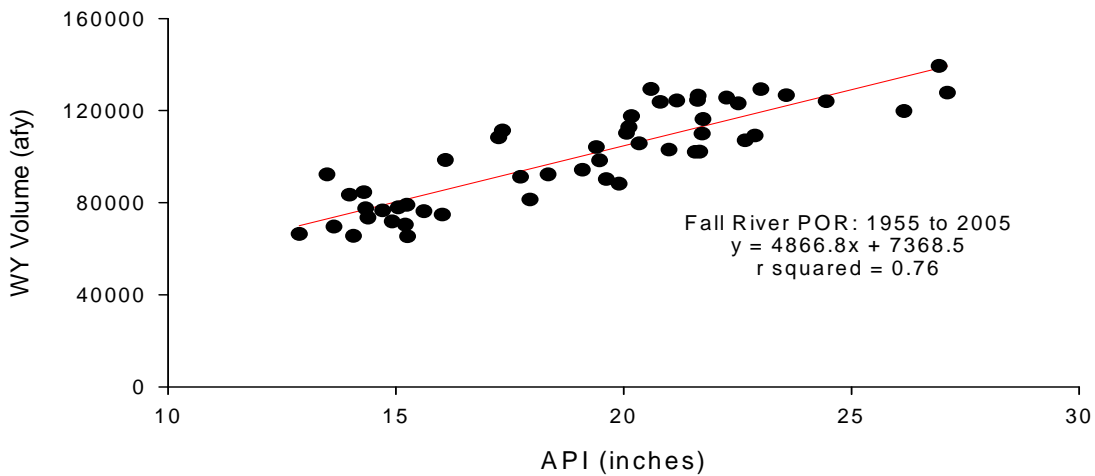
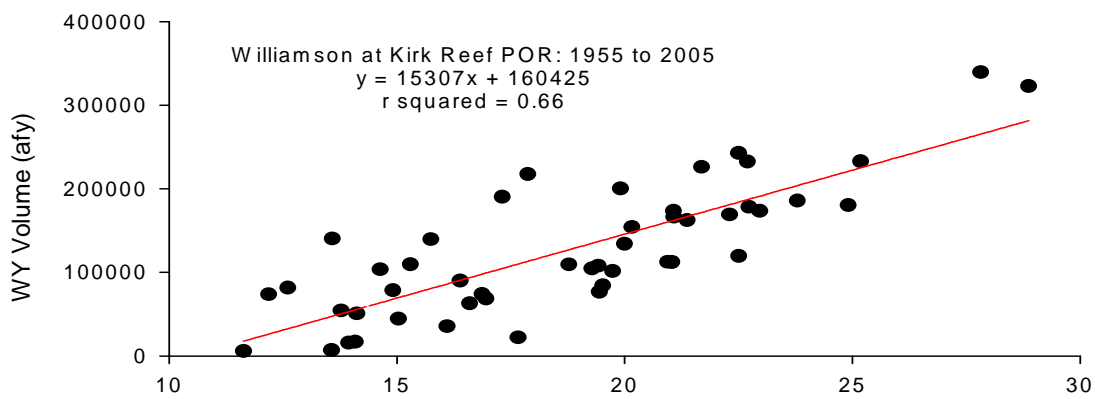
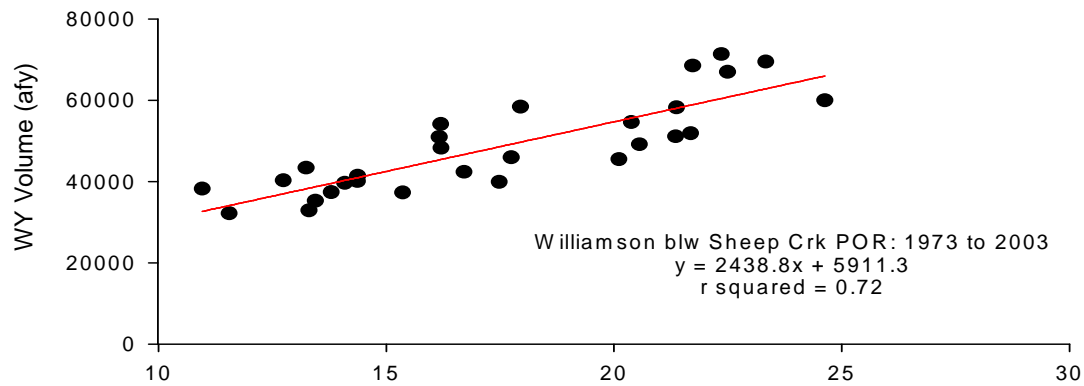


Figure 5. USGS Williamson River below Sheep Creek (Figure 5a), USGS Williamson River at Kirk Reef (Figure 5b), USGS Fall River (Figure 5c) Water Year Totals versus Oct-Mar Antecedent Precipitation Index (API). API is a weighted average of the current year and the previous 2 years winter precipitation for the Williamson sites and the previous 3 years winter precipitation for the Fall River site, based on OR Climate Division 5. The weights are obtained from a multiple regression of annual flow and multiple years of winter precipitation (Viessman and Lewis, 1996).

Williamson Outflows

The period of record for the marsh outflow measured at Kirk Reef extends from 1955 through present, with a gap from 1996 to 1998 (Figure 4c). This is the longest period of record for any Klamath Marsh site. The outflow from the marsh is dependent on both the water surface elevation of the marsh and the inflow to the marsh, with flow ceasing when the marsh drops below the elevation of the basalt sill at Kirk Reef. Average annual flow for water years 1955 to 2005 is 126,775 afy, with a maximum of 339,446 afy in 1956 and a minimum of 5,691 afy in 1992. The coefficient of variability is 61%. The variability in annual flows at this site is much greater than upstream on the Williamson below Sheep Creek and likely reflects the greater variability in spring discharge and groundwater inflow into the marsh.

Like the Williamson below Sheep Creek, mean annual flows at Kirk Reef are correlated with the 3 years of accumulated winter precipitation (Figure 5b). A 3-year Oct-Mar API explains 66% of the variance in annual flows. Risley and Laenen (1999) reported that Williamson and Sprague River flows further downstream near Upper Klamath Lake also responded to three years accumulated precipitation. This relationship is also evident in our analyses of Fall River annual flows. The Fall River is a spring-fed river located just to the north of Klamath Marsh in the Deschutes Basin (see Figure 1). The flows at this site are not affected by development and represent a response solely to natural climatic variability. The source of recharge for the headwaters of this river is in Climate Division 5. Annual flows at the Fall River are well correlated with a 4-year Oct-March API (Figure 5c).

Hydrographs of the Fall River and Williamson River at Kirk Reef between 1955 and 2006 (Figure 6) show wet and dry cycles at approximately 5 to 7 year intervals and an overall declining trend from the 1950s to the present. A Mann-Kendall trend test shows both long-term declines are significant ($p=0.000$). This declining trend mirrors the decrease in precipitation observed in Climate Division 5 (Figure 3). **The decrease in outflows from the marsh, as observed at Kirk Reef since the 1950s, is likely due to the decrease in winter precipitation observed since the 1950s in Oregon Climate Division 5.** The Williamson below Chiloquin and the Sprague River nr Chiloquin, both near Upper Klamath Lake, also show a significant decline in annual flows since 1950 ($p = 0.005$ and $p=0.044$, respectively). The Williamson below Sheep Creek, upstream of the refuge, does not show a significant trend ($p=0.28$), perhaps because of the shorter period of record at this site.

For the period from 1974 to 2003, it is possible to compare flow measurements on the Williamson River both upstream and downstream of the marsh (Figure 4a and 4c). Generally, monthly flows in the Williamson during the winter and spring months are much greater downstream at Kirk Reef than upstream below Sheep Creek. During the summer and fall, because the water surface elevation drops below the basalt sill, outflows from the marsh frequently cease and monthly flows are usually less downstream at Kirk Reef than upstream below Sheep Creek. **On average, 70,000 ac-ft more water exits the marsh in a given water year than flows into it.** Net outflow from the marsh ranges from -26,464 afy in 1992 (a negative value means more water entered the marsh than left it) to 174,312 afy in 1984.

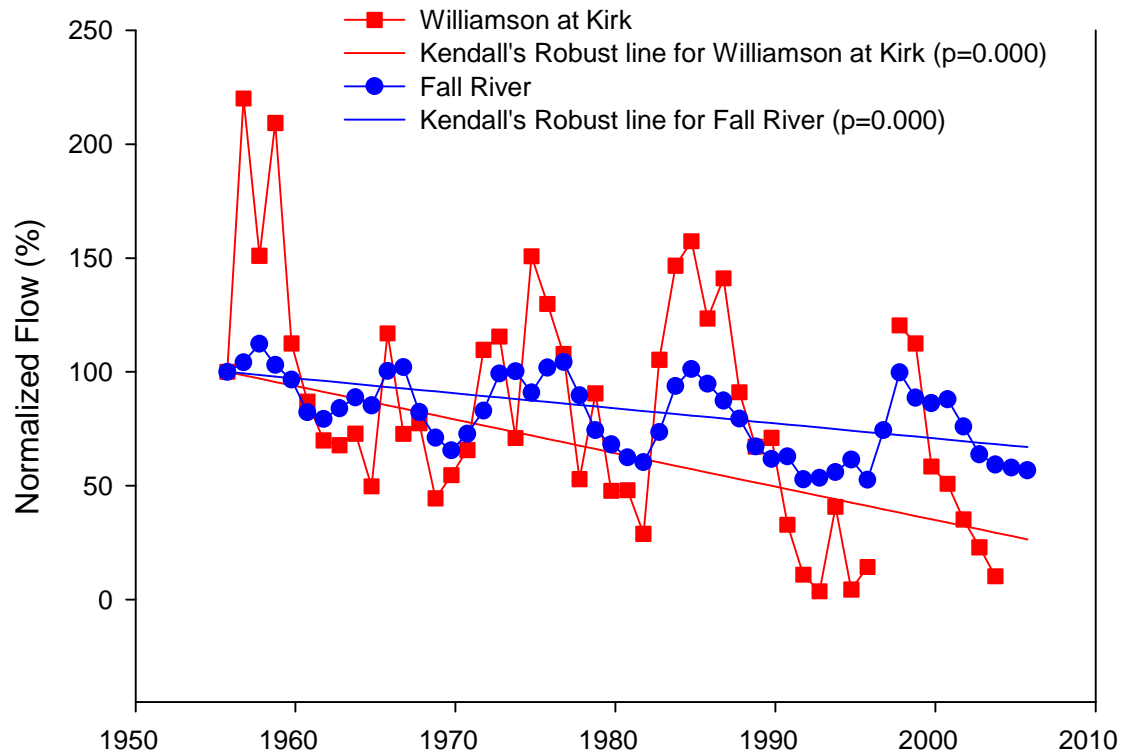


Figure 6. Flows (normalized to the first year's flows in 1955) at Williamson River at Kirk Reef and at Fall River, 1955 to 2005, with Kendall's Robust Line indicating a statistically significant downward trend in time at both sites.

Some of this excess water exiting the marsh is tributary inflow, including flow from Big Springs. Some of this water is precipitation falling directly on the marsh. However, there is also a large evapotranspiration demand that is satisfied before the water flows from the marsh. If the vegetation within the 41,000 acres of marsh has an annual ET rate of 3 acre-feet per acre, that equates to an evapotranspiration requirement of at least 120,000 afy. **The fact that there is still a considerable outflow in many years from the marsh even after evapotranspiration needs are met suggests there is a sizeable groundwater contribution to the marsh in addition to the surface water inflows.**

Estimates of groundwater discharge to the marsh from other studies support this idea. Norvelle et al. (1981) estimated an average groundwater discharge to the marsh of 430,000 afy, with a range from 200,000 afy to 660,000 afy. More recently, Cummings (2005) estimated 92,000 to 110,000 afy of subsurface inflow to the marsh. What seems apparent from the inflow/outflow data is that annual groundwater discharge to the marsh is considerable in many years and quite variable overall.

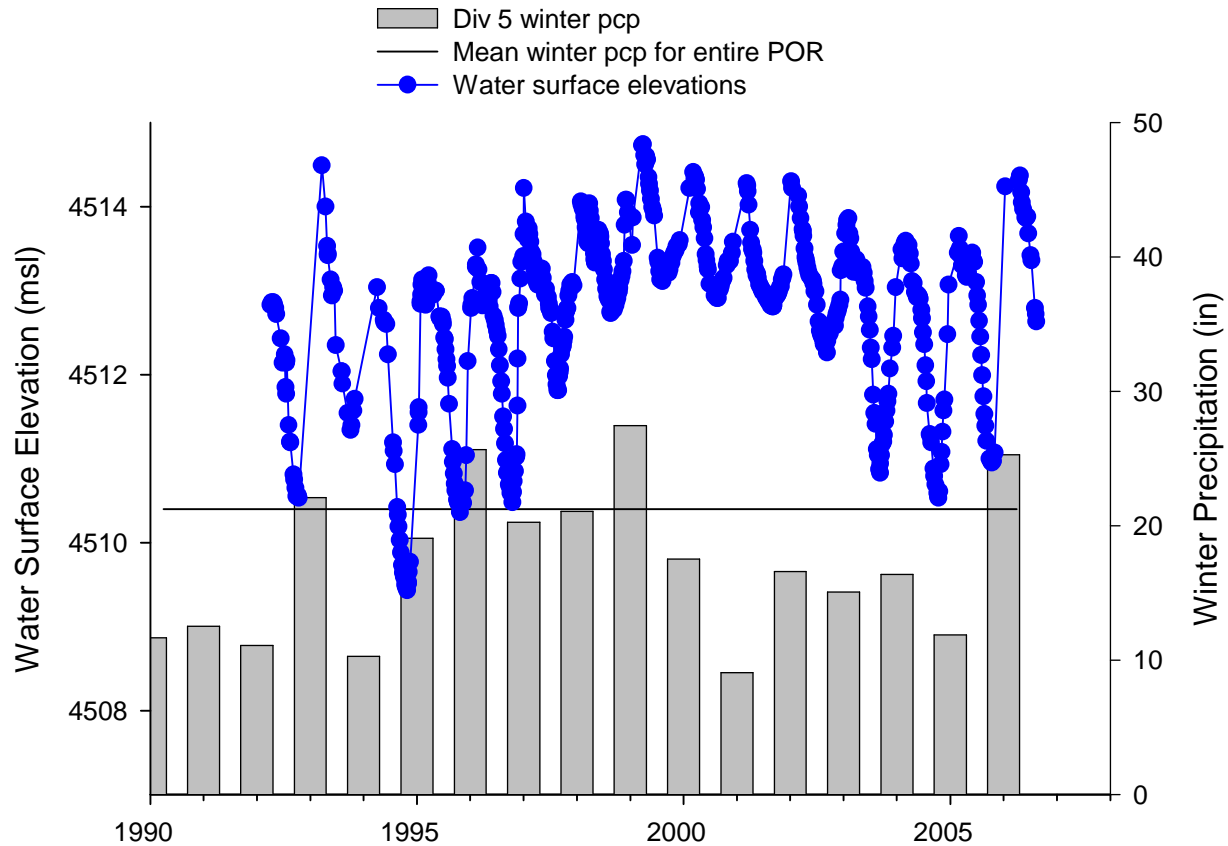


Figure 7. Periodic marsh water surface elevations at Silver Lake Highway and OR Climate Division 5 winter precipitation from 1992 to 2006.

Marsh Levels

The water surface elevations of the marsh vary seasonally and annually, integrating all the climatological and hydrological stresses affecting the marsh. Figure 7 presents periodic measurements of water surface elevations for 1992 to 2006 collected by the refuge staff at Silver Lake Highway and the winter precipitation for Climate Division 5 over the same period. This period encompasses a range of wet and dry conditions. There is an obvious correspondence between precipitation and marsh levels.

More than marsh inflows and outflows, the Klamath Marsh water surface elevation record underscores the marsh’s response to wet and dry year cycles rather than individual years.

For instance, in 2001, marsh levels were basically unchanged from the prior year (Figure 7), despite 2001 being the second driest winter and water year on record in Climate Division 5 since 1895. However, by 2005, following six years of below average precipitation, the annual minimum water surface elevation had dropped by about 2 feet. A two foot lowering of minimum water levels is significant given the fairly flat relief of the marsh. The marsh levels did not respond to a single dry year in 2001 but did respond to a sequence of dry years from 2000 to 2005.

Interestingly, annual minimum elevations appear to be affected more than the annual maximums by wet and dry cycles. Winter/spring water surface elevations vary about 2 feet over the 1992 to 2006 period, from 4512.86 ft in 1992 to 4514.74 ft in 1999 in response to precipitation cycles. Summer/fall water surface elevations vary about 4 feet over the same period, from 4509.43 ft in 1994 to 4513.11 ft in 1999 in response to precipitation cycles. The greater range of minimum elevations is related to several factors. First, the outflow from the marsh increases with increasing marsh elevation, thereby buffering maximum water levels. Second, marsh ET should be relatively constant from year to year while our analyses suggest groundwater discharge is highly variable depending on whether Climate Division 5 is in a wet or dry precipitation cycle. In dry cycles, groundwater discharge will not be available to replenish the surface water lost to ET in the marsh, causing minimum water levels to drop. **This implies that dry cycles will affect summer and fall water levels more than winter and spring water levels. This has implications for the biological resources and management of the marsh.**

As was first noted by Newcomb and Hart (1958), marsh levels appear to be responsive to groundwater inflows and spring discharge. Big Springs may represent a surrogate measure of groundwater inflow to the marsh. In years when Big Springs flow is high, such as 1997 through 1999, marsh levels remain high throughout the summer. Conversely, when Big Springs flow is low, when Big Springs flow is low, such as 2002 to 2005, marsh levels are much lower in the summer.

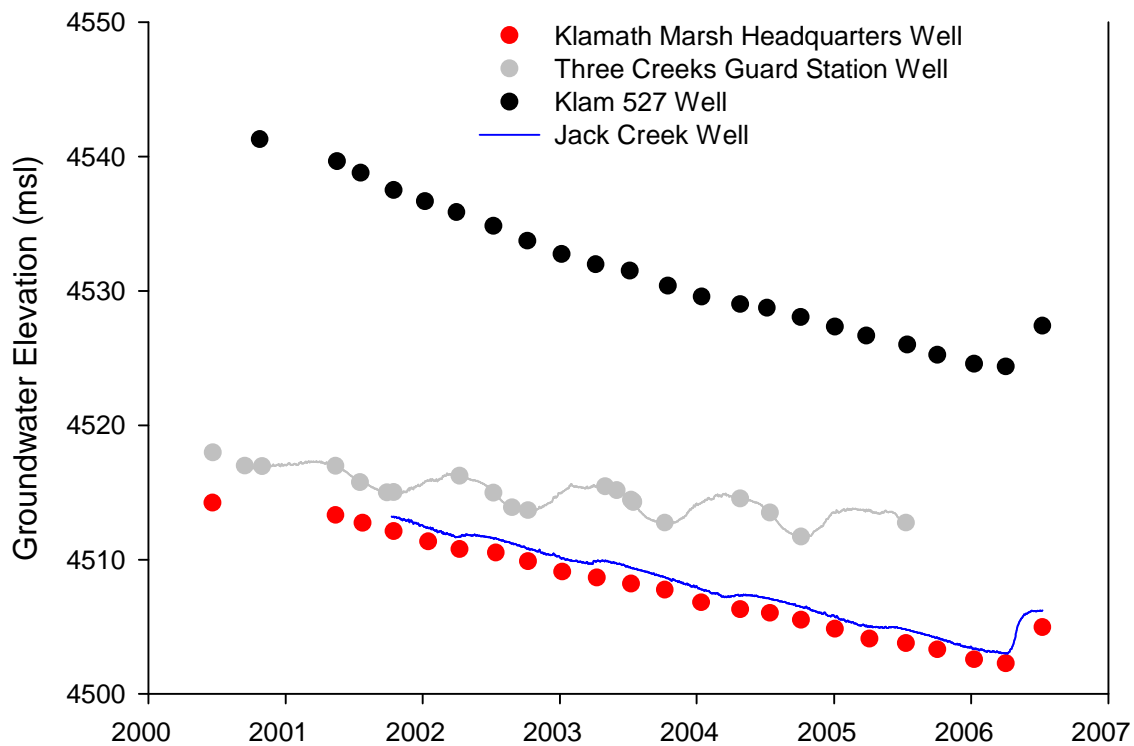


Figure 8. Groundwater elevations in several wells in and around the marsh from 2000 to 2006.

Winter precipitation in 2006 was above average for the first time in seven years (Figure 7). Minimum marsh levels begin to recover in response to the increase in accumulated winter precipitation. The data from the monitoring wells in or near Klamath Marsh show a similar pattern, with a declining trend from 2000 through 2005 and a small recovery in 2006 in the three wells that continue to be monitored (Figure 8). The trends in the wells roughly parallel the trends in the marsh water levels and outflow over the same period and corroborate the idea that groundwater discharge plays an important role in determining marsh levels and outflow.

The relationship between marsh elevation and flow at Kirk Reef is shown in Figure 9. There is about a four day lag between the two variables. The water surface elevation in the marsh on any given day correlates best with the flow 14 miles downstream at Kirk Reef four days later. On the receding limb of the marsh level hydrograph, in the spring and summer, flow at Kirk Reef ceases when the marsh level drops below about 4512.2 to 4512.8 msl at the Silver Lake Highway gage. On the rising limb, the marsh must reach an elevation of about 4512.8 to 4513.4 msl before flow downstream at Kirk Reef resumes again in the fall or winter (see Figure 9). The slightly higher elevation required for flow on the rising limb in the fall and winter is probably due to the greater channel and wetland losses experienced as the wetland fills back up again.

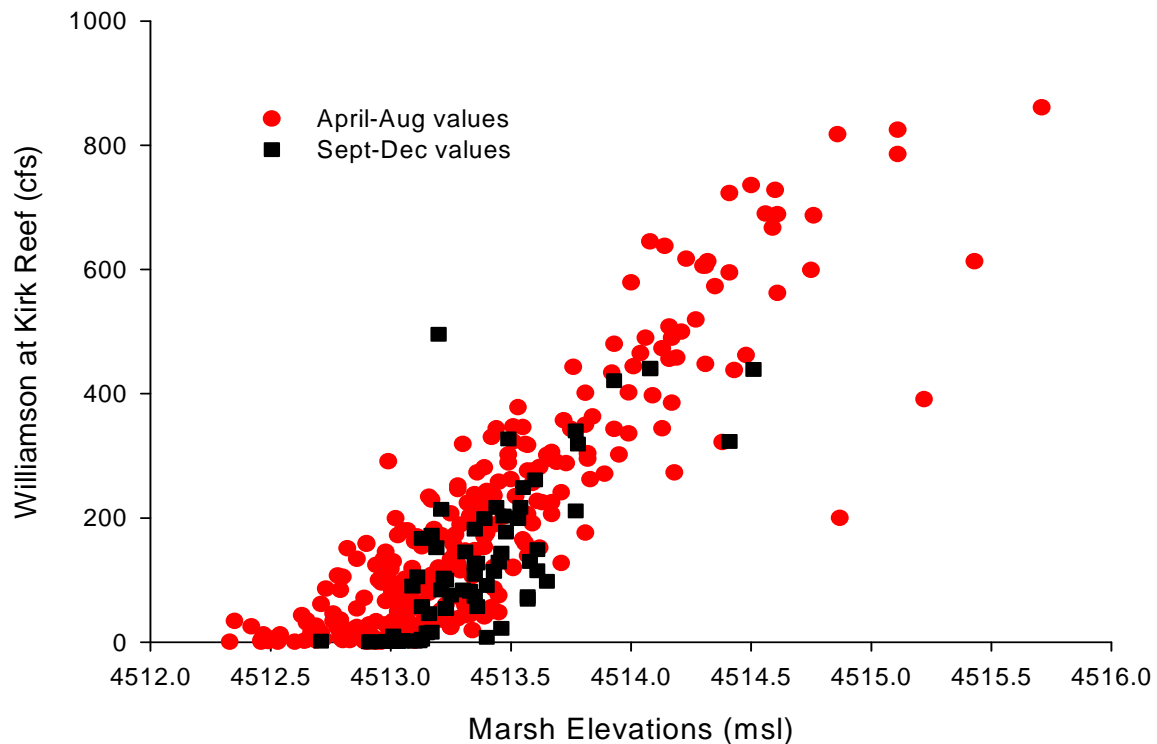


Figure 9. The relationship of marsh water surface elevations and outflows at Kirk Reef. Winter flows and zero flows were excluded since the variables will not be related during periods of ice or no-flow.

Summary of Hydrologic Information and Trends

Klamath Marsh inflows, outflows, and water levels are strongly correlated with accumulated winter precipitation and are more responsive to several years of wet or dry conditions rather than just a single wet or dry year.

Since the 1950s, there has been a statistically significant decline in total annual precipitation and a corresponding increase in mean annual temperature in the Klamath Marsh area. The statistically significant decrease in outflows from the marsh since the 1950s, as observed at Kirk Reef, is likely due to the decrease in precipitation and increase in temperature over the same period. Similar decreases are observed at the Williamson River below Chiloquin, the Sprague River near Chiloquin, and the Fall River just north in the Deschutes Basin.

Annual minimum marsh levels are more sensitive to dry year cycles than are annual maximums. This implies that dry year cycles will affect summer and fall water levels more than winter and spring water levels. This has implications for the biological resources and management of the marsh.

The 70,000 afy of net outflow that occurs on average from the marsh every year suggests that there is a sizeable groundwater contribution to the marsh in addition to the surface water inflows. Marsh levels and well levels show similar trends the last 6 years, and provide additional evidence for the idea of a strong groundwater/surface water connection.

There is a strong correlation between marsh water surface elevations and outflow from the marsh at Kirk Reef. The variability in marsh levels and outflows is likely due to the variability of spring discharge and groundwater discharge to the marsh. Ultimately, this is due to wet and dry year cycles of winter precipitation.

KLAMATH MARSH WATER RIGHTS AND WATER MANAGEMENT

Establishment of the Refuge

The Klamath Marsh was very important historically to the Klamath tribe both as a source of food and for cultural reasons. The main food resource was the water plant known as wocus or yellow pond lily. The marsh was originally part of the Klamath Indian reservation until the 1954 Klamath Termination Act. The 1958 Amendment to the Klamath Termination Act authorized the Federal government to acquire tribal lands in the Lower Marsh to create a national wildlife refuge for the protection of migratory birds. Historically, these lands were the wettest part of the marsh and considered “wastelands” because they were too wet for agriculture or grazing. The refuge was established in 1960 with the purchase of the 16,177 acres of land in the Lower Marsh and was designated the Klamath Forest National Wildlife Refuge. In 1979, FWS acquired 1,190 acres in Big Wocus Bay. In 1989 and 1990, FWS purchased and added 21,235 acres of additional lands to the refuge. The added areas were mainly former ranch lands in the Upper Marsh, with an additional parcel to the west of the Lower Marsh near Big Spring. In 1998, FWES acquired an additional 2,640 acres in the northeast section of the Upper Marsh. That same year, the name of the refuge was changed to Klamath Marsh National Wildlife Refuge. The total acreage of the refuge is presently about 41,000 acres. About 7,000 acres within the approved boundary remain in private ownership. The tribe retains hunting and fishing rights on the refuge.

FWS Water Rights and Claims

The FWS holds both water rights and water right claims for the Klamath Marsh NWR. In the 1970s, the FWS wanted to develop water control and infrastructure on the Lower Marsh area of the refuge but was reluctant to do so without certainty regarding water rights. In 1975, the United States filed suit in federal court for a declaration of water rights in the area of the former Klamath Indian Reservation, including the refuge (*United States v. Adair*). In 1986, the parties to the Adair case negotiated a settlement recognizing a federal reserved water right for “all Klamath Marsh lands now within the Refuge, which has an area of 16,377 acres.” This acreage included the original acquisition in the Lower Marsh. The priority date of the right is 1985 for all parties to the Adair case and 1960 for all others. The settlement left quantification of the federal reserved right for the Klamath Basin Adjudication although it did provide that the United States “has a water right of a quantity of water for the proper mix of free water surfaces, emerging vegetation, and meadow essential to the operation of the Refuge for the purposes set forth in the Orders and Laws creating the Klamath Forest National Wildlife Refuge.”

In the 1990s, the FWS initiated several studies to define the “proper mix” of habitat and quantify the water requirements of this habitat mix (Bidlake 1997; Bidlake and Payne 1998; Weddell 1997; Weddell et al., 1998). This work was used to quantify the volume and timing of water for the federal reserved water right claim in the Klamath Basin Adjudication. In 1997, the FWS filed a federal reserved water right claim (Claim No. 300) in the Klamath Basin Adjudication for 59,549 afy for the “Adair lands” in the Lower Marsh.

The FWS also acquired state appropriative water rights appurtenant to the private ranch lands in the Upper and Lower Marsh that were purchased and added to the refuge after the *Adair* decision. The rights are primarily for stockwater and irrigation. Because the water use on these lands was developed at the time of Indian ownership, or shortly after, and the water has been used continually since that time, these lands are eligible for a Walton water right. In 1997, the FWS filed seven Walton water right claims (Claim Nos. 301 - 307) in the Klamath Basin Adjudication for these lands. The priority date is 1864, the date of establishment of the Klamath Indian Reservation. The point(s) of diversion, duties, place(s) of use, and purposes of the Walton right claims are generally the same as the existing state appropriative water rights for these lands. The major difference between the Walton rights and the existing state appropriative rights is the earlier priority date of the Walton rights. The total volume of water claimed in the Walton rights is 40,339 afy.

The total volume of water under all refuge water right claims filed in the adjudication is 99,888 afy. A final decision on the claims is pending. All water right claims are shown on the water rights maps prepared by the Water Resources Branch (Figure 10).

Irrigation and Water Management

All of the active irrigation and water management on the refuge occurs in a portion of the Upper Marsh. The canals and channels that exist in this part of the refuge are remnants of the former ranching operations in this area. There are three primary canals in the Upper Marsh (Figure 10). Water from the Williamson River is diverted into Cholo Slough canal just upstream of the refuge boundary and runs parallel to the Williamson River on the south side of the valley for about 2 miles. The Williamson River maintains its natural channel for about one mile into the refuge, then becomes channelized at Rock Island, turns south, and merges with Cholo Slough. Downstream of this point, the canal, called Kittredge Canal or Kirk Ditch, runs all the way to Military Crossing. A third primary canal in the Upper Marsh, Mitchell Ditch, carries water west of Rock Island. The refuge uses this canal to supply water to the north and west areas of the Upper Marsh.

Prior to FWS ownership, a number of small ditches and control structures were used to distribute water from Cholo Slough, Kirk, and Mitchell canals to adjacent lands for haying and grazing. Most of these ditches still exist, but some have fallen into disrepair and no longer function. The highly permeable nature of the soils in the marsh means that there is good subsurface movement of water. Much of the irrigation on the refuge in this area is now done by backing up water in the three main ditches and relying more on subsurface seepage and less on direct diversions through the smaller ditches.

Historically, winter runoff from streams in the northern portion of the Upper Marsh was pumped into the Williamson River in March and April to drain the area and allow cattle access in the spring. This same area was irrigated later in the season. The FWS no longer pumps water from these areas in the spring and instead, uses the existing water control infrastructure to hold winter runoff later in the season.

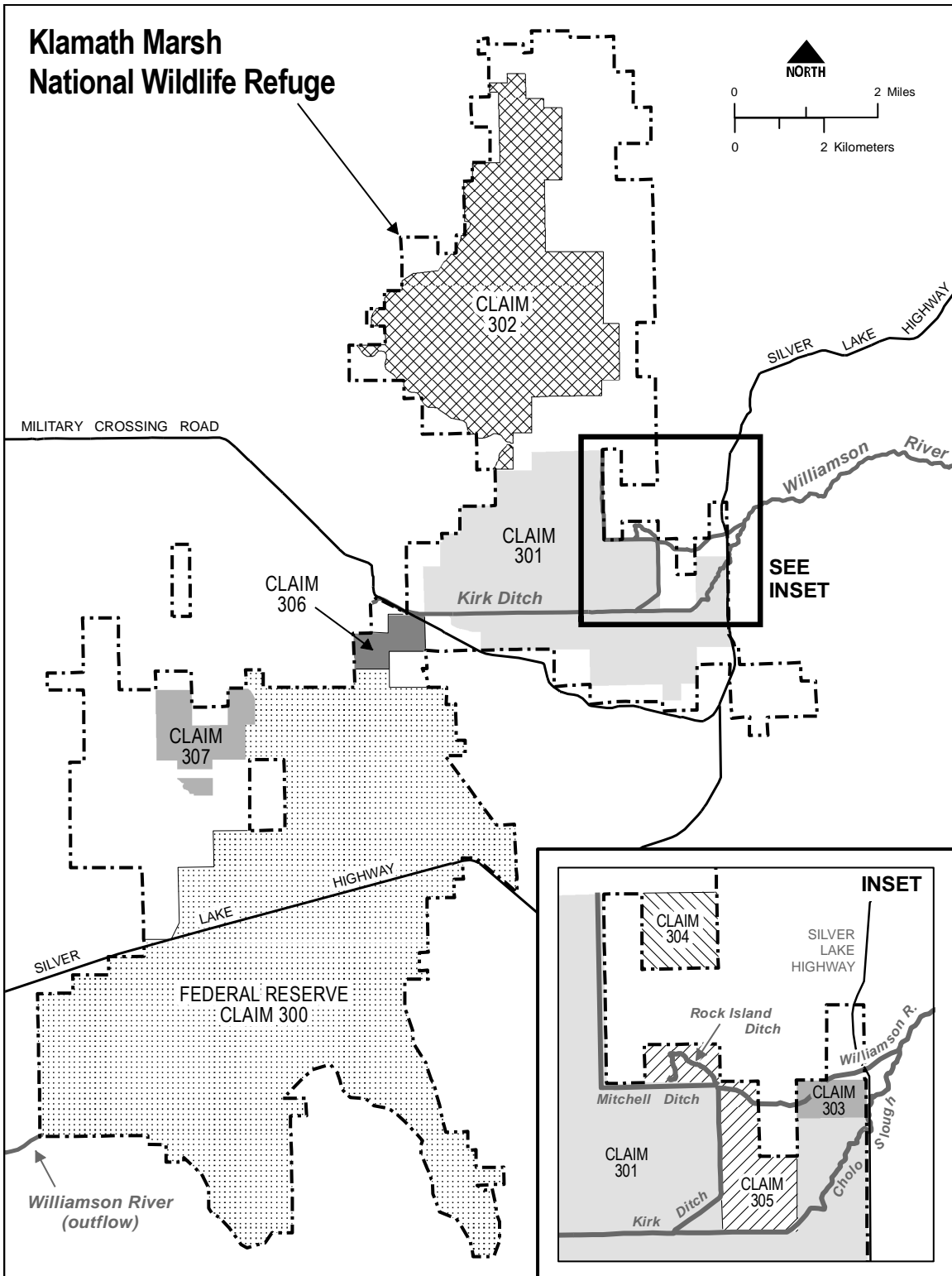


Figure 10. Places of use for adjudication water right claims for Klamath Marsh National Wildlife Refuge.

LITERATURE CITED

Bidlake, W. R. 1997. Evapotranspiration from selected wetlands at Klamath Forest and Lower Klamath National Wildlife Refuges, Oregon and California. Prepared for the U.S. Fish and Wildlife Service. U.S. Geological Survey Administrative Report. Tacoma, WA.

Bidlake, W. R. and K.L. Payne. 1997. Evapotranspiration from selected wetlands at Klamath Forest and Upper Klamath National Wildlife Refuges, Oregon and California. Prepared for the U.S. Fish and Wildlife Service. U.S. Geological Survey Administrative Report. Tacoma, WA.

Cummings, M. L. and J. M. Melady. 2002. Hydrogeology of Klamath Marsh, Klamath County, Oregon. Department of Geology, Portland State University. Final Report prepared under Public Law 104-208 for the U.S. Department of the Interior, Bureau of Reclamation.

Cummings, M. L. 2005. Hydrogeology of the groundwater dominated Williamson River Subbasin, Upper Klamath Basin, Oregon. Presented at the American Geophysical Union, Fall Meeting 2005 in San Francisco, CA.

David Evans and Assoc. 2005. Upper Williamson Watershed Assessment. Prepared for the Klamath Basin Ecosystem Foundation. David Evans and Associates, Portland, OR.

Keyantush, J. A., and J. A. Dracup. 2004. An aggregate drought index: Assessing drought severity based on fluctuations in the hydrologic cycle and surface water storage. *Water Resources Research*, 40.

LaMarche, J. L. 2002. Big Springs Hydrologic Field Study. Draft report, Oregon Water Resources Department, Bend, OR.

Leonard, A. R. and A. B. Harris. 1974. Ground Water in Selected Areas in the Klamath Basin. Oregon State Engineers Ground Water Report No. 21, Portland, OR.

Newcomb, R. C. and D. H. Hart. 1958. Preliminary Report on the Ground-Water Resources of the Klamath River Basin, Oregon. U.S. Geological Survey open-File Report 58-73. 248 pp.

Norvelle, M.E., S.L. Vierck, S. Ince, and A. Dunn. 1981. Preliminary assessment of the hydrologic environment of Klamath Marsh, Oregon. Laboratory of Native Development, Systems Analysis and Applied Technology (NASDAT), Office of Arid Land Studies, University of Arizona. 67 pp.

Risley, J. C. and A. Laenen. 1999. Upper Klamath Lake Basin Nutrient-Loading Study – Assessment of Historic Flows in the Williamson and Sprague Rivers. U.S. Geological Survey Water Resources Investigation Report 98-4198. 22 pp.

Viessman, W. Jr., and G. L. Lewis. 1996. Introduction to Hydrology. HarperCollins College Publishers, New York, NY.

Weddell, B. J. 1997. Amounts and types of wetland habitats needed to fulfill the purposes of the Klamath Forest National Wildlife Refuge. Prepared for the U.S. Fish and Wildlife Service. Draba, Pullman WA.

Weddell, B. J., K. L. Gray, and J. D. Foster. 1998. History and ecology of Lower Klamath, Tule Lake, Upper Klamath, and Klamath Forest National Wildlife Refuges, Oregon and California. Prepared for the U.S. Fish and Wildlife Service. Draba, Pullman WA.

APPENDIX A

Water Monitoring Sites Within or Near Klamath Marsh

There are a number of monitoring sites in and around the marsh that are operated or have been operated by the FWS or other agencies. These sites are shown on the water monitoring map prepared by the Water Resources Branch (Figure 2) and are described below. Sites monitored by the FWS are designated with a FWS site number.

Surface Water Monitoring Sites

Williamson River blw Sheep Cr. (Site No. 11491400) This is a USGS gage on the Williamson River, about 8 miles upstream of the refuge. USGS measured the flow in the river continuously from water year 1974 to 2003. The site was discontinued in October 2003.

Williamson River nr Klamath Agency, OR. (Site No. 11493500) USGS measures the outflow from Klamath Marsh continuously at a site located downstream on the Williamson at Kirk Reef. The period of record is from 1954 to the present, with a gap in the monitoring from 1995 to 1998. It is not certain that USGS will continue to monitor this site after water year 2007 but it is extremely important for understanding the marsh hydrology and the hydrology of the entire Klamath Basin.

Big Springs nr Lenz, OR. (Site No. 11492400) Big Springs has been monitored for several different periods over the years. Most recently, OWRD has monitored it continuously from 2002 to 2006. OWRD is discontinuing the site in water year 2007. The FWS funded the USGS to collect continuous flow data on the stream from 1992 to 1995. Sparse miscellaneous measurements are available from the 1910s through the 1980s. The FWS plans on operating the site, beginning in water year 2007, as a seasonal gage during the summer baseflow period when the site is easier to access.

Williamson River at Ball Dam (FWS Site No. 166209) The FWS began measuring flows continuously in 2000 at several sites on the Williamson River as it enters the refuge. One of these sites is the Williamson River at Ball Dam, near the refuge office. Periodic measurements were collected by FWS prior to the establishment of the continuous gage in 2000. The purpose of this gage is to monitor and report water use under Water Right Nos. S 44534, P 44428, and C 11956 as required under Oregon state law. The sum of flows at this site, in combination with flows from Cholo Slough and Johnson Ditch, gives the total inflow to the refuge from the Williamson River. With the discontinuation of monitoring at the Williamson below Sheep Creek, these sites provide the only measurement of marsh inflow from the Williamson River.

Williamson River at Cholo Slough (FWS Site No. 166207) FWS has monitored this site continuously since 2000. It is located on the diversion channel of the Williamson River as it enters the refuge. The purpose of the gage is to monitor and report a portion of water use under Water Right Certificate 11956 (also measured at FWS Site Nos. 166208 & 166209).

Johnson Ditch Flume Near Williamson River (FWS Site No. 166210) This site has been monitored continuously by the FWS since 2001. Johnson Ditch is on the Williamson River just upstream of Ball Dam. Williamson River water is diverted through Johnson Ditch only for a short period during very high flows in the spring. The purpose of the gage is to monitor and report water use covered under permit S 44426 as required under Oregon State law. However, the flume is out of level and is also subject to submerged conditions, meaning measurements are problematic. It is likely that continuous monitoring will be replaced by periodic measurements at this site in WY 2007.

Williamson River at Rock Island Flume (FWS Site No. 166210) This site has been monitored continuously by the FWS since 1999. It was established for the Oregon water use reporting requirements. It is recommended that the site be discontinued in water year 2007 because the gage monitors an unknown combination of diverted and undiverted flow and really provides no added information on water use or hydrology.

Klamath Marsh Water Levels at Silver Lake Road (FWS Site No. 166201) The refuge staff monitor marsh water levels periodically at the Silver Lake Highway. Marsh levels are available from 1961 to 1980 and from 1992 through the present. Although the site is not reported on, it is very important to the understanding of the hydrology and management of the refuge. It seems that continuous measurements at this site would be useful.

Williamson River at Military Crossing (FWS Site No. 166202)

The FWS funded the USGS to collect periodic flow measurements at this site from 1992 to 1995. The site is no longer monitored.

Groundwater Monitoring Sites

The following four monitoring well sites are all in or near Klamath Marsh. They are being measured as part of the USGS/OWRD Upper Klamath Basin Ground-Water Study. The period of record is 2000 to 2006 for all wells except Three Creeks Guard Station Well, which was discontinued in 2006. It is not certain if these wells will continue to be monitored by OWRD/USGS in the future. The FWS may want to consider monitoring one or more of these wells if they are discontinued.

Klamath Marsh Headquarters Well (Site No. 425804121344701)

Three Creeks Guard Station Well (Site No. 430055121401501)

Klam 527 Well (Site No. 430837121473201)

Jack Creek Well (Site No. 430649121305201)