DIAMOND LAKE RESTORATION PROJECT

Diamond Lake Ranger District
Umpqua National Forest

Report on Streamflow Regime, Stream Water Quality, Channel Morphology, and Related Aquatic Conservation Strategy

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SURFACE WATER – STREAM ECOLOGY

Streams are relevant to three issues identified in scoping and described in Chapter 1: water quality (significant), wetlands (significant), and water rights (other). Scoping identified a concern that rotenone treated water would escape Diamond Lake through Lake Creek and negatively impact water quality and fish and wildlife species in Lake Creek and the North Umpqua River System. This issue is tracked under the title streamflow regime and is also discussed in fish and wildlife sections of this chapter. There is a concern that a lake draw down would negatively affect water quality in Lake Creek and downstream water bodies. This issue is tracked under the title water quality. Scoping identified a concern that drawing down Diamond Lake would have a negative impact on wetlands adjacent to the lake and Lake Creek. This issue is tracked under the title streamflow regime and is also discussed in the groundwater and terrestrial and wetland plant sections of this chapter. There is also a concern that a draw down and lake refill period would impact the physical integrity of Lake Creek and holders of water rights around and downstream of Diamond Lake. These issues are tracked under the titles channel morphology and streamflow regime respectively.

STREAMFLOW REGIME

AFFECTED ENVIRONMENT

The project boundary is within the High Cascades physiographic sub-province (Peck and others, 1964). The streamflow regime for the project area is uniquely influenced by the High Cascade sub-province geology and spring snowmelt (Diamond Lake and Lemolo Lake Watershed Analysis, 1998). This underlying geology is the controlling factor in the development of the High Cascade aquifer (Diamond Lake and Lemolo Lake Watershed Analysis, 1998; Sherrod, 1995; Ingebritsen, 1994). Streamflow is dominated by groundwater. The geologic characteristics influence a high volume and storage capacity of groundwater that slowly releases to channels. The surficial pumice soil of the area allows rapid water infiltration that generally drains to the relatively young, deeply fractured basalt bedrock. The common occurrence of joints and fracture patterns in the bedrock provides the opportunity for rapid infiltration and migration of water vertically as well as horizontally over a wide area. Low stream density is common in this geology with the higher infiltration rates and less tendency for surface water to concentrate.

The resulting streamflow regime is not only slow responding, but also persistent with small annual flow fluctuations (i.e., difference between summer to winter flow). This flow condition provides cool and consistent summer flow while producing less winter responsive runoff[1]. Annual river flow in the North Umpqua River below the Lemolo Reservoir is approximately half of the annual precipitation for the watershed, which is typical of High Cascade streams. In contrast, streams in the Western Cascade sub-province tend to runoff over 70% of the precipitation because of much less storage ability in the older geology.

Precipitation and Air Temperature

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[1] This streamflow regime is a direct contrast to the warmer and lower summer flow and more responsive winter runoff of downstream Western Cascade sub-province geology.

Precipitation in the project area is predominantly winter rain and snow. Summer precipitation is limited while about 60% of the total annual precipitation occurs in December to February at Diamond Lake[2]. Winter precipitation is influenced by marine weather patterns, which usually occur as storm fronts with warmer storms (rain, not snow) out of the southwest. The snowpack tends to be "warm" with an internal snow temperature near 0ºC or 32º F (Harr and Coffin, 1992), which requires little heat energy to initiate snowmelt. Summer rainfall can be a result of thunderstorms that have intense rainfall, but for short durations. Thunderstorms have produced up to 0.5 inches over about a 2-4 hour period during 1981 to 2002 (USDA, Natural Resource Conservation Service, 2003). However, direct rainfall to the lake from these summer storms amounts to less than 1% of the lake volume.

Snowpack in the Diamond Lake area historically has exceeded 100 inches for specific months. Figure 1 below displays the mean and the maximum monthly snow depth for the snow course near Diamond Lake (station #22F18). These values represent about a thirty-day period and do not distinguish individual snowstorms, which could produce a short-term deep snowpack.

The total mean annual precipitation (that is total inches of water from rain + snow) for the years 1981-2002 as recorded at the NRCS SNOTEL station at Diamond Lake is 49 inches. Mount Bailey, which is west of Diamond Lake, appears to create a precipitation rain shadow[3] east of the mountain, which includes Diamond Lake and part of this project area. The precipitation modeling by the Oregon Climate Service (State Climatologist Office[4]) also identifies this situation. General winter observations around the lake have noted that the snowpack tends to be greater in the south to southwest than the north area of Diamond Lake. This varying precipitation pattern around the lake results in an uneven spatial water input to the surface and groundwater hydrology of Diamond Lake.

[2] Data collected by the Natural Resource Conservation Service (NRCS) at the Diamond Lake SNOwpack TELemetry (SNOTEL) Station #22F18 from 1981 to 2002.

[3] Rain shadow is where precipitation is suppressed because of a topographic feature. As a moisture-laden air mass passes over mountains, the existing moisture in clouds tends to evaporate on the leeward side and is less available for precipitation.

[4] State Climatologist Office, Oregon Climate Service, Oregon State University's College of Oceanic and Atmospheric Sciences, Corvallis, OR 97331-2209.

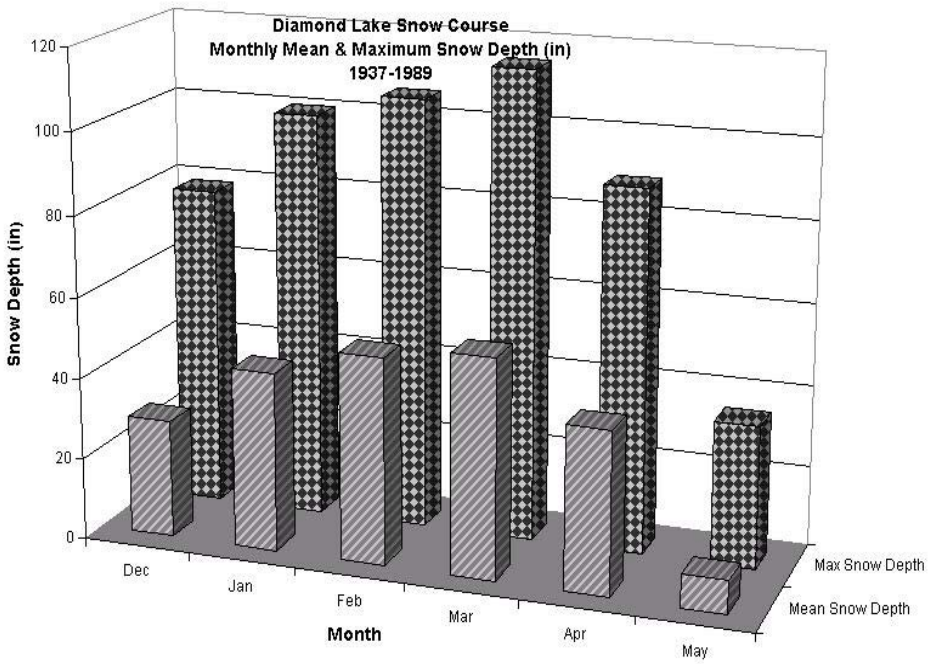

Figure 1. Monthly Mean and Maximum Snow Depth at Diamond Lake For 1937-1989 (NRCS historical snow course data from web site)

Air temperature has been measured at the NRCS –SNOTEL (1988-2002) site at Diamond Lake. Looking at the winter months December through February, the mean of the minimum daily temperature was the same for each month at 21º F (-6º C) while the mean of the maximum daily temperature for these months has ranged from 39º to 43º F (4º to 6º C). The weather is cool enough and for long enough period to allow ice to cover the lake during some years. Summer temperatures for June to August allow the lake to warm and thermally stratify. The summer maximum mean daily temperature can range from 64º to 75º F (16º to 26ºC).

Streams and Streamflow

The snowpack annually influences the streamflow regime during the spring period. Figure 2 displays the historical mean monthly streamflow (U.S. Geological Survey, 2003) for the Lake Creek gaging station immediately downstream of the Diamond Lake outlet. The second rise in the hydrograph appears to more commonly occur in June as the result of warm weather causing snowmelt and a spring runoff; however, earlier snowmelt has been observed.

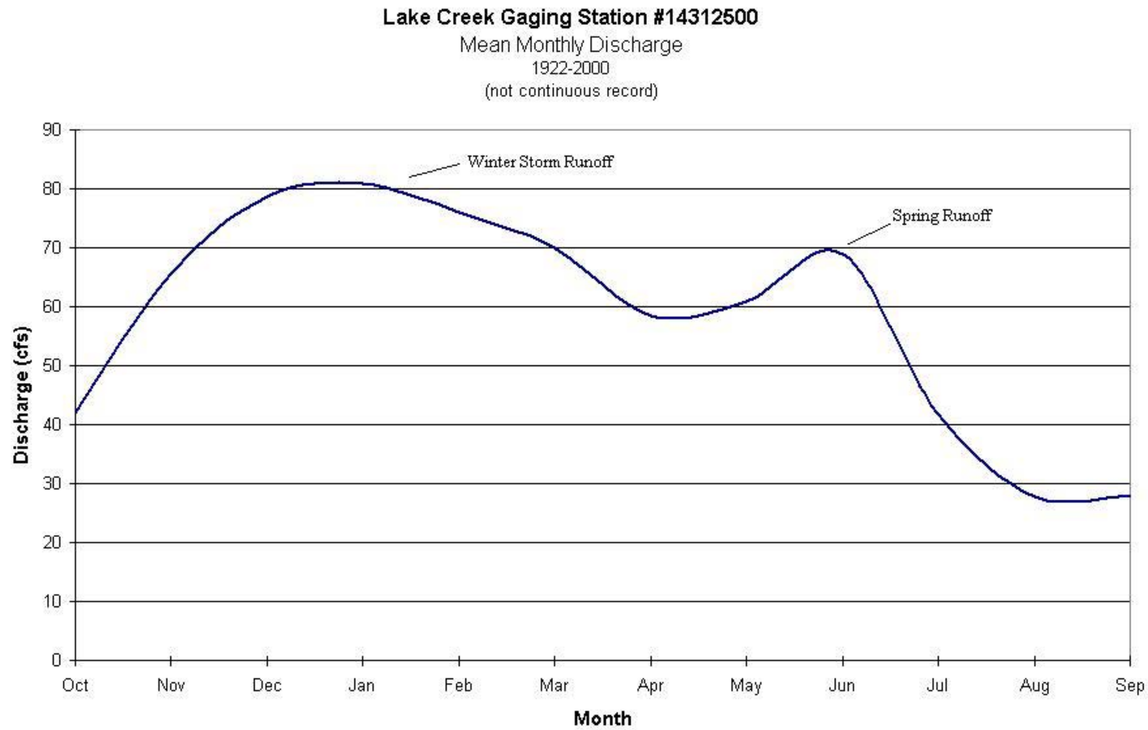

Figure 2. Lake Creek Historical Hydrograph for Mean Monthly Streamflow[5].

The streamflow at bankfull level is the "channel-forming or effective discharge" (Leopold, 1994) when flow is the most effective at maintaining the channel physical form under the current climatic regime. Bankfull flows for the greater Umpqua Basin occur about every 1.5 years on average, or can be reached or exceeded two times in three years.

The bankfull flow is unique to the channel setting. High Cascade streams in the basin generally have bankfull flows that are less than 10 cubic feet per second per square mile (cfsm) while streams draining similar size areas in the older Western Cascades to the west of this project generally have bankfull flows that range from approximately 30 to 50 cfsm[6].

Stream power is directly related to the amount of flow. Stream power refers to the rate at which the energy of a stream does work in the channel such as bed or bank erosion. High Cascades streams in comparison to Western Cascades have potentially lower stream power at bankfull flow.

The bankfull flow for Lake Creek is approximately 110 cubic feet per second (cfs) or about 2 cfsm at the US Geological Survey (USGS) Gaging Station (#14312500). The streamflow statistics for the Lake Creek Gaging Station show that streamflow can peak above bankfull

[5] Streamflow data collected and published by the U. S. Geological Survey.
[6] Western Cascade streams used were Susan Creek, Rock Creek, and Cavitt Creek from the crest gage study on or near the Forest. High Cascade streams also evaluated were Thielsen Creek and Clearwater River from the same study (Friday, 1972).

level as a result of winter storms and spring melt. High Cascade streams like Lake Creek are influenced by deep groundwater and do not respond quickly to precipitation input through rapid runoff. Lake Creek streamflow during runoff is also further dampened by Diamond Lake, which is its source. Because of these factors, Lake Creek has low stream power at bankfull or flood levels.

Stream velocity is also directly related to stream power. The average bankfull velocity at the Lake Creek Gaging Station is noticeably lower than Fish Creek Gaging Station, which is west and not in the High Cascades. Lake Creek bankfull velocity is about 2 feet per second (fps) compared to about 6 fps for Fish Creek. This comparison assumes that channel slope and channel slope control operates similarly in these two streams and that the bed materials, which influence frictional forces, are similar. The lower bankfull velocity has lower potential stream power to erode the channel and cause turbidity and sedimentation.

The mean-daily streamflow for the period of record at the Lake Creek Gaging Station is displayed in Figure 3 in comparison to the approximate 1.5-year bankfull flow. Based on the historical data displayed in Figure 3, Lake Creek mean daily streamflow has frequently exceeded the 1.5-year bankfull flow (110 cfs) during some years. For the period of record, there were 875 occurrences (14,328 mean daily flows in total record) when mean-daily flow was greater than bankfull flow, which represents about 6% of the total record (more than 35 years plus some partial years). These peak streamflow events have occurred both in the winter and spring runoff periods. The duration of these runoff events have lasted from a single day to an average of two weeks, with the larger and longer events during the winter.

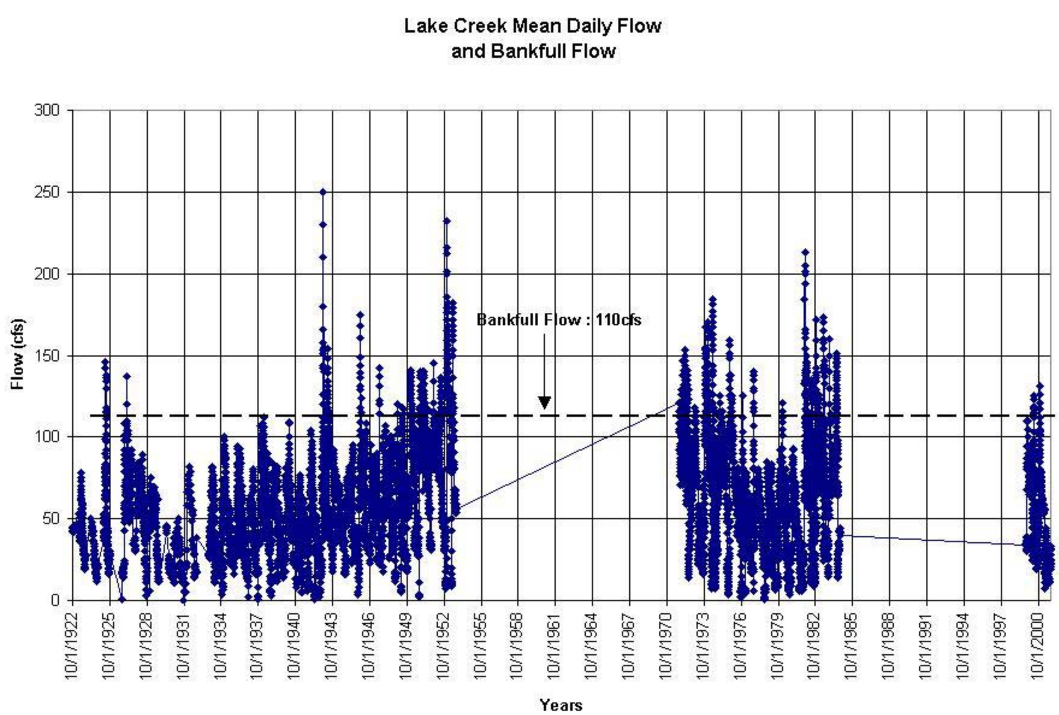

Figure 3. Lake Creek Mean-Daily Streamflow for the Period of Record in Comparison to the 1.5-Year Bankfull Flow of 110 Cubic Feet per Second.

The surface water hydrology of Diamond Lake is strongly influenced by groundwater-dominated systems and snowmelt. The primary surface inflow to the lake is from Silent Creek (about 30 cfs in summer) in the southwest and Short Creek (about 10 cfs in summer) in the southeast. Other surface channels are Two-Bear Creek, Spruce Creek, Porcupine Creek, Dry Creek, Camp Creek, Discovery Creek, Hemlock Creek, and at least three unnamed streams. Most of the streams appear to be seasonal and are influenced by snowmelt. However, Two-Bear Creek and Spruce Creek are more strongly influenced by groundwater through springs. The spring area for Two-Bear Creek has been developed as a water source for the Diamond Lake Resort under the State water right appropriation process. The surface water connection for Two-Bear Creek from source to the lake appears to exist under the boathouse at Diamond Lake Lodge. The only surface outflow is Lake Creek. Oregon Department of Fish and Wildlife (ODFW) regulates the outflow in accordance with a water right to store water above the normal lake surface.

The surface water inflow and outflow for Diamond Lake appears to account for all water movement. However, groundwater movement is an important factor for streamflow in the High Cascades, but is not recognizable in the surface flow measurements. Streamflow measurements taken in May 2001 immediately after the spring melt peak indicated that inflow equaled outflow[8]. However, water loss from evaporation, which could be about 0.12 inches per day[9] during May, would create an imbalance. Evaporation would result in an additional loss of approximately 15 to 20 cfs. In the U. S. Environmental Protection Agency (EPA) study of Diamond Lake (1979), the evaporation averaged 0.15 inches per day (approximately 20 cfs) for July 1973, and for August 1974, evaporation was equal to the outflow in Lake Creek (16 cfs[10]), which would be about 0.13 inches per day. Groundwater appears to be gaining and losing in such away as to create a surface water balance.

Oregon Department of Fish and Wildlife (ODFW) has the right to store a maximum 5,800 acre-feet (ac-ft) in Diamond Lake under water right certificate number 54598. The stored water is released during the lower flow season to supplement the flow in the North Umpqua River for downstream diversion and use at Rock Creek Fish Hatchery (about 70 river miles downstream). This becomes critical during below average low flow periods when the 1974 instream water right[11] is not met. ODFW's water right is junior in time to the instream water right and would be required to stop water use when the instream water right is not met. The release of this stored water allows ODFW to continue using water from the North Umpqua River if this occurs.

A downstream water right under certificate number 67321 allows Oregon Department of Transportation (ODOT) water use that would also be affected. This water use is limited to

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[8]The inflow was determined by streamflow measurements for Silent Creek and Short Creek. The outflow was determined by the Lake Creek streamflow at the gaging station.

[9] Evaporation was estimated for the month of May using 3 stations (N. Willamette Experimental Station NOAA Index No. 6151, Detroit Dam NOAA Index No. 2292, and Medford Experimental Station NOAA Index No. 5424) outside but the closest to the project area with monthly average pan evaporation.

[10] August mean monthly flow determined from the mean daily flow measured by the U. S. Geological Survey and published in Surface Water Resources Data for Oregon, 1972.

[11] "Instream water right" as defined in Oregon Revised Statutes 537.332, means a water right held in trust by the Water Resources Department for the benefit of the people of the state of Oregon to maintain water instream for public use. An instream water right does not require a diversion or any other means of physical control over the water (Oregon Administrative Rules 690-077-0010, Instream Water Rights - Definitions).

0.01 cfs from Lake Creek near the Road 4700-710 crossing (intake upstream of Thielsen Creek and downstream of Sheep Creek) for their truck equipment repair shop which includes shop uses and sanitary facilities.

Wetlands Hydrology

Two primary wetland locations are adjacent to Diamond Lake and identified by the U.S. Fish and Wildlife Service in the National Wetlands Inventory. The larger location is along the southwestern shore (immediately west of South Shore Picnic Area) and is approximately 140 acres. The smaller location is along the northwestern shore (north of Thielsen View Campground) and is approximately 6 acres (mapped as two distinct but adjacent units).

Local groundwater movement toward the lake during the driest period of the year has been observed in the vicinity of the larger wetland. The water table appears to slope toward the lake along the south shore (Breeden, 2003). The smaller wetland appears to be more influenced by the lake level.

Other wetland locations are along Lake Creek. Between Diamond Lake and the Highway 138 crossing of Lake Creek, there are a number of scattered, but small wetlands (less than 5 acres). However, North of Highway 138 wetlands are more abundant and generally larger than those south of the highway. The wetland locations appear to be influenced by both Lake Creek and upslope groundwater moving toward these sites. Where Lake Creek flows through or immediately adjacent to the wetlands, it was assumed that the stream has some direct influence on the water table, creating the wetland. The remaining wetland locations are at least slightly upslope from Lake Creek where a direct influence was not assumed. Lake Creek appears to have some influence on about 70% of the mapped wetland locations between Diamond Lake and Lemolo Reservoir.

ENVIRONMENTAL EFFECTS

Figure 4 provides a reference for locations on Lake Creek referred to throughout this section. The following different project phases are also referenced in this section in the discussions of the potential effects on Lake Creek:

> Draw Down- The project phase that lowers Diamond Lake 8 feet by increasing the lake outflow to bankfull flow while passing winter or spring runoff events. This phase would dewater the natural outlet (Lake Creek) and utilize an existing canal to control lake outflow.
>
> Pass Through- The phase following completion of the draw down that maintains the 8-foot draw down level of Diamond Lake by releasing the same amount of water out of the lake that comes into the lake by surface flow and groundwater.
>
> Canal Closure- The phase when the canal gate is closed for rotenone treatment and no surface outflow from Diamond Lake would be released to Lake Creek.
>
> Refill- The phase when the canal gate is partially opened to release less than typical outflow to Lake Creek while storing more flow than normal to refill Diamond Lake.

It would be necessary to maintain access to the canal gate during the winter months in order to successfully accomplish lake draw down and refill. Additionally the canal gate must be appropriately designed to operate during winter conditions. Although winter conditions present operational challenges, impacts of snow, ice, and cold weather are not expected to make the lake draw down or refill infeasible. Therefore, the effects analysis assumes winter conditions are adequately addressed.

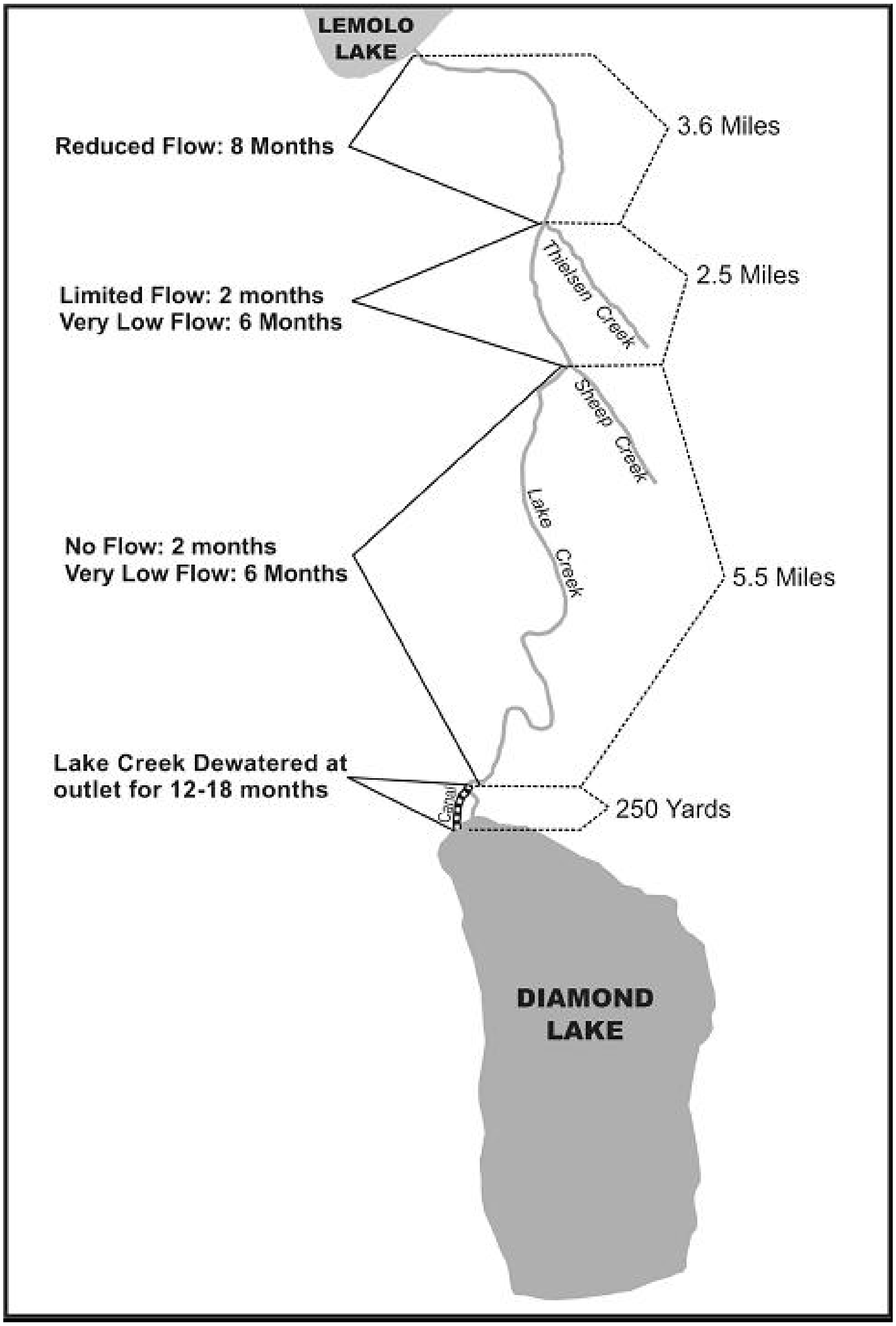

Figure 4. Referenced Locations along Lake Creek and Discussed in the Environmental Effects of a Lake Draw Down.

Direct Effects: (Lake Creek at the Diamond Lake Outlet)

Alternatives 2, 3, and 5 would directly affect the streamflow regime for Lake Creek at the Diamond Lake outlet through all four phases (draw down, pass through, canal closure, and refill) of the project. The draw down flow was identified as the bankfull flow (110 cubic feet per second) after considering the need to protect channel stability and limit biological and water quality impacts while releasing enough flow to drain Diamond Lake eight feet through the fall to spring period. During the draw down phase, outlet flow would be bankfull except during early fall storms when resulting higher flow would be passed in order to maintain the draw down. The streamflow would be released at a volume that is typical of historic high flows as documented at the gaging station immediately below the outlet of Diamond Lake. However, because of the duration of flow, a similar condition has only occurred once before in 1954 when the lake was first drawn down, but at a much higher flow for the same purpose of treating the lake.

The draw down would initiate in the existing lake outlet when ODFW pulls the storage boards to drain approximately 5,800 acre-feet of stored water according to their water right. This would take up to six weeks to drain the stored water at bankfull flow (i.e.; average monthly flow for September and October is 35 cubic feet per second plus an additional release of 75 cubic feet per second would equal bankfull flow). As the release of ODFW stored water is near completion, the canal would be opened to compensate for the reduced flow at the outlet in order to maintain bankfull full. Lake Creek outlet would become dewatered when about 2-3 feet of draw down is reached. At that time, the canal would carry the outflow from the lake until the lake refills. Lake Creek channel would remain dewatered from the natural outlet to where the canal enters the stream channel (approximately 1,400 feet) for about 12-18 months depending on precipitation during the refill phase. The canal section (1,100 feet long) would be dry for about 2 months during the canal closure phase.

Under Alternatives 2, 3, and 5, the canal and downstream Lake Creek would experience extended bankfull flow (or higher during winter storm or spring snowmelt runoff events) for about eight months in order to drain Diamond Lake eight feet (Figure 5: a possible scenario for the duration of drawing down the lake). Runoff events would be passed through the canal and down Lake Creek to Lemolo Reservoir, which would simulate winter or spring runoff. Bankfull flow would not be added to the naturally occurring higher runoff flow. The natural higher flow event would be passed and only the difference between the long-term mean daily flow for the specific time of the event and bankfull would be added to maintain the draw down rate (i.e.; less than 110 cfs).

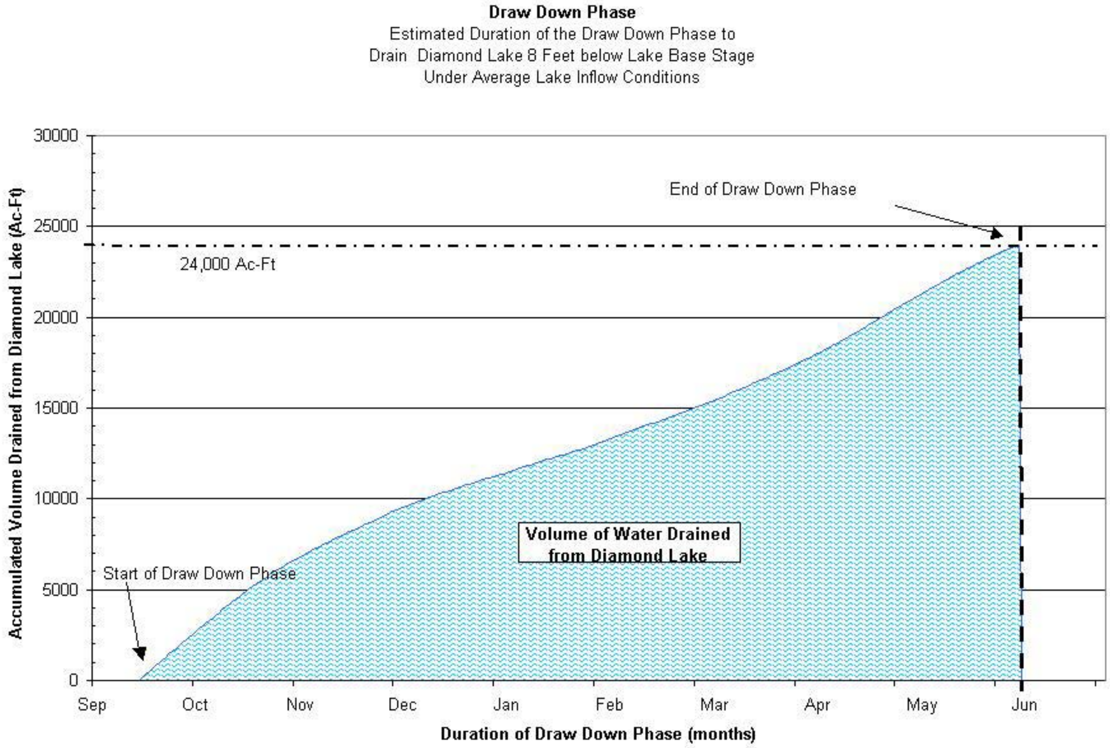

Figure 5. Estimated Duration of the Draw Down Phase with Higher Streamflow in Lake Creek to Drain Diamond Lake.
(Note: The curve does not include likely runoff events.)

Figure 5 is a simulated hydrograph that was developed to contrast a worse case scenario of the effects of Alternatives 2, 3, and 5 on streamflow with: 1)the actual mean daily flows from the Lake Creek stream gaging record for an extremely wet year (Water Year[12] 1953); 2) and the long-term mean daily flows for the period of record (over 35 years). This simulated hydrograph assumes a very wet climatic condition during the draw down phase. The actual flow would probably be less; however, unknown weather conditions during the draw down would determine the actual hydrograph.

The overall effect of the draw down would be higher daily flows in the canal and Lake Creek than for an average seasonal. The atypical duration of high flow in Lake Creek would be a short-term impact to the streamflow regime only for the draw down phase. For the long-term, streamflow would return to the pre-treatment level after lake treatment.

[12] Water year begins on October 1 and ends on September 30. The year designation is the calendar year that it ends.

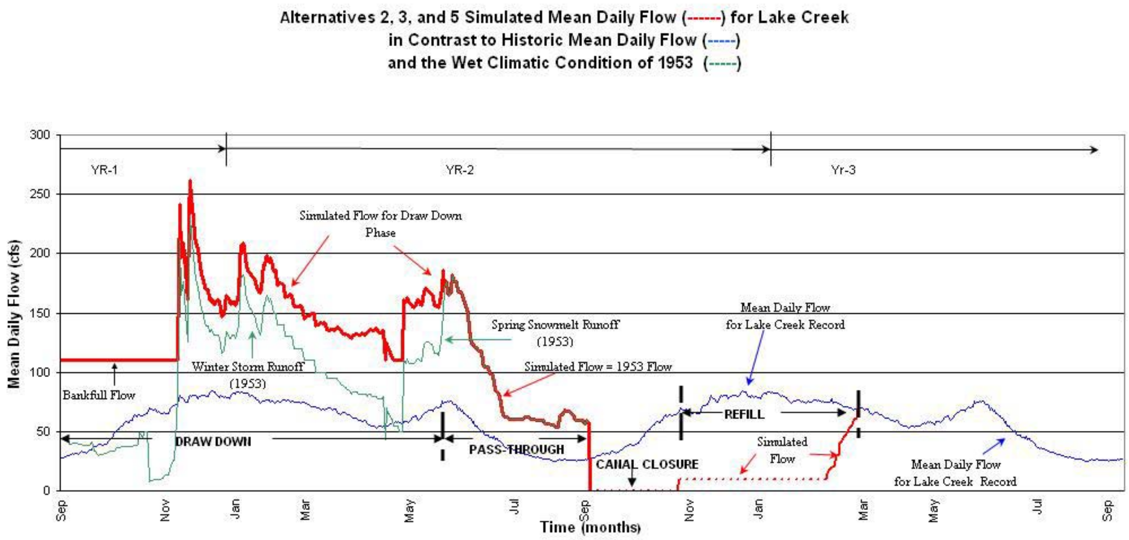

Figure 6. Simulated Mean Daily Flow for Alternatives 2, 3, and 5 over the Project Period in Comparison to Actual Mean Daily Flow from the Lake Creek Gaging Station.

Alternatives 2, 3, and 5 are the only proposed actions that draw the lake down which would likely have an effect on the two identified wetlands adjacent to the shoreline of Diamond Lake. As the lake is drawn down, the groundwater table in the wetlands would potentially lower with the lake elevation. This response would tend to dry the wetland surface. Because of the higher precipitation during the winter, a drying response would be more noticeable after the draw down and during the pass-through flow, canal closure, and refill phases. The effect of a lower water table would carry through at least part of the refill phase. During the spring when refill of the lake is near completion, the groundwater table would likely show recovery and wetland moisture levels would return.

Connected actions by Diamond Lake Resort associated with these alternatives are described in Chapter 2. These connected actions would have no impact on streamflow regime.

Alternatives 1 and 4 do not involve lake draw down and would not affect the streamflow regime of Lake Creek at the outlet or downstream. These alternatives would maintain the existing streamflow regime; therefore no direct effects would occur.

Indirect Effects: (Lake Creek Downstream)

Alternatives 2, 3, and 5 are the only alternatives that would have indirect effects on streamflow. Under Alternatives 2, 3, and 5, Lake Creek would flow at bankfull from the canal entry into the channel to Lemolo Reservoir. The draw down phase would maintain a larger than average wetted perimeter and wetter soils adjacent to the channel. The immediate riparian areas along the channel would have greater potential for a persistent water table, since groundwater normally draining toward the channel would experience a flatter gradient between groundwater and stream surface elevation. However, these affects may be very slight since the draw down period occurs during the winter and spring months when greater precipitation would also affect upslope moisture draining to the channel.

Once the draw down flow reaches Lemolo Reservoir, it would be absorbed through reservoir operations. PacifiCorp is a partner in this project and would work with the draw down operation to avoid large changes in reservoir storage and release. Therefore, no major changes in the seasonal streamflow regime below Lemolo Dam in the North Umpqua River would be expected.

The greatest difference between historic flow and bankfull flow would occur at the start of the draw down phase. The additional flow in Lake Creek would represent 18-20% of the mean monthly flow during September and October draining into Lemolo Reservoir according to the historic record for the gaging station immediately downstream of Lemolo Reservoir. However, the same additional flow during September and October would represent less than 10% of the total flow in the upper extent of the Wild & Scenic section of the North Umpqua River, which is about 26 miles downstream from Lake Creek mouth. Since the accuracy of flow measurements for the North Umpqua River gaging stations below Lemolo and the upper Wild & Scenic section is ±10% of true value for 95% of the daily flows, the greater fall flow addition would not be meaningfully detected in the Wild & Scenic section.

After the draw down period, the canal outflow would equal inflow to Diamond Lake, in order to maintain the 8-foot draw down from late spring to the end of the summer. During this period, the flow in Lake Creek would be natural streamflow and reflect the natural watershed responses.

Before chemical treatment of the lake under Alternatives 2, 3, and 5, the canal would be closed and the only flow in Lake Creek would be from groundwater and tributaries. A low flow investigation of Lake Creek (Breeden, 2003) revealed that there would be little accretion of flow from groundwater or tributaries from the outlet to Sheep Creek, about 5.5 miles downstream. The flow measured in Sheep Creek was about 0.84 cfs. The 5.5 mile segment of channel would likely have little to no flow with only some pooled water for about 2 months during canal closure (Figure 4).

From about 5.5 miles to 8 miles, Sheep Creek and Thielsen Creek would be the primary tributary inflow. The largest tributary flow contribution to Lake Creek would be from Thielsen Creek, about 8 miles downstream of the lake outlet. Thielsen Creek may contribute as much as 5 cfs during the canal closure phase. The no-flow to very low flow (less than 1 cfs)to reduced flow conditions from the outlet to Sheep Creek and Sheep Creek to Thielsen Creek and downstream of Thielsen Creek, respectively, would not change until lake water becomes safe to be released through the canal after treatment. Flow would be gradually released from Diamond Lake about 2 months after closing the canal to aid refill. The initial late fall release would be about 10 cfs, when flows historically have been about 7 times greater as measured at the USGS gaging station on Lake Creek.

Following a rotenone treatment, the risk of precipitation refilling Diamond Lake and spilling chemically treated lake water into Lake Creek before it is determined to be safe is very low. Assuming that the canal closure would be from September 15 to November 15, the largest rainfall total for this period over the past twenty-two years was about 16 inches (Diamond Lake SNOTEL station 22F18). If it rained 16 inches during the two-month period following a rotenone treatment, Diamond Lake would still have adequate room (volume) for additional rainfall and related runoff from the surrounding watershed. It would take over 20 inches of rainfall to raise the lake surface to the elevation that treated water would begin flowing out of Diamond Lake into Lake Creek through the natural channel outlet. The average rainfall for this time period was 7.5 inches and the probably of getting even 16 inches of rain was less than five percent.

In the unlikely situation of the lake refilling before the water is determined safe, a safety contingency plan would be in-place. The canal gate and natural channel outlet would include structures capable of ensuring that chemically treated lake water would not enter Lake Creek before it is determined to be safe (see Chapter 2).

Figure 6 below displays the average annual snow water equivalent (swe) for the period 1981, 1983-2003 at the Diamond Lake SNOTEL station. Refill of Diamond Lake would depend on climatic input, which would allow outflow to be ramped up as the lake fills. The February-March average monthly snowpack is about 40 inches, which has about an average of 12 inches[13] of water content[14] (snow water equivalent). Considering that Lake Creek annual runoff is less than thirty percent of the upstream annual precipitation, the snowmelt alone would likely be about 10,500 ac-ft while direct precipitation input to the lake would also occur. However, a winter similar to water year[15] 1981 or recently 2003 would prolong the refill time.

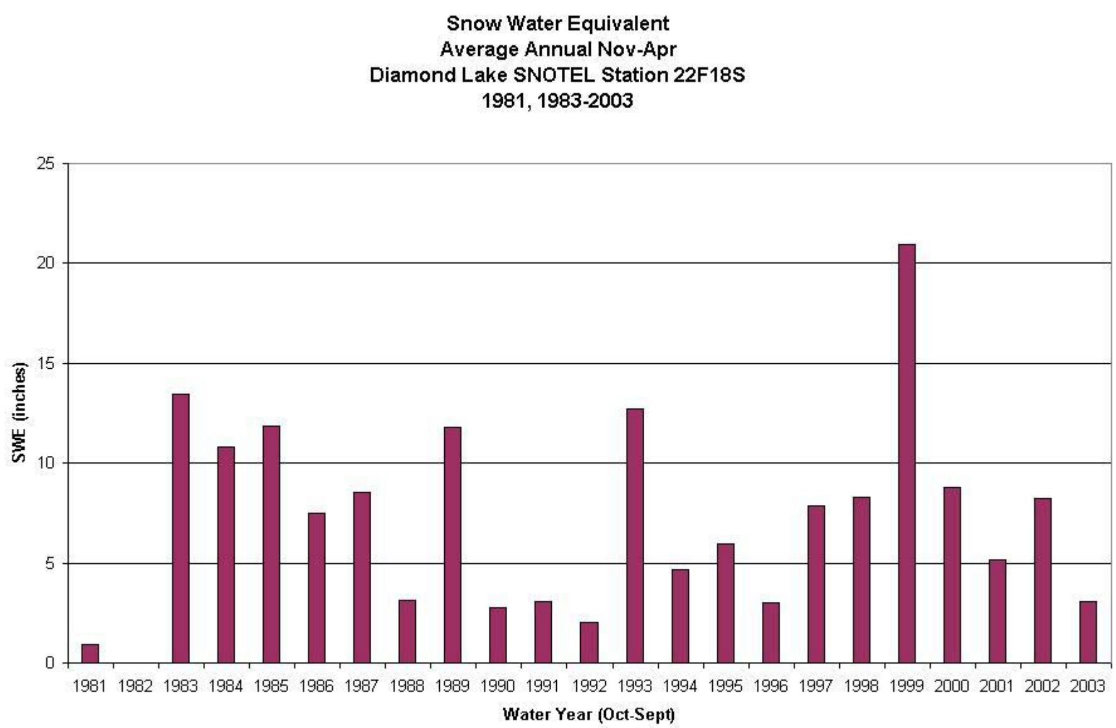

Figure 7. Average Annual (Nov-Apr) Snow Water Equivalent (SWE) for Diamond Lake.

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[13] NRCS SNOTEL data from Diamond Lake site 22F18, 1981-2003.
[14] The water content of the snow is referred to as the snow water equivalent (swe) or the depth of water in the snowpack, if the snowpack would melt in inches (NRCS).
[15] Water year begins on October 1 and ends on September 30. The year designation is the calendar year that it ends.

These effects to streamflow under Alternatives 2, 3, and 5 would overall last about 16-18 months and then return to pre-treatment condition after the lake refills and would not carry into future years.

Alternatives 2, 3, and 5 would affect downstream water rights. ODFW would not be able to store water for one season when the lake is drawn down and treated. The hatchery operation at Rock Creek would depend on the natural flows of the North Umpqua River that are above the 1974 instream water right and be operationally at risk if flow regulation occurs. Lack of water at the hatchery would likely cause ODFW to release fish earlier than scheduled.

ODOT would not likely be able to use water from Lake Creek after the draw down when the canal is closed and this stream segment would have less than 1 cfs. Although Sheep Creek contributes flow to Lake Creek, the amount of flow would not likely provide enough depth across the channel to maintain the intake operation unless the intake is lowered. The release of 10 cfs about 2 months after treatment when lake water is determined safe would likely provide enough water depth for this water use through the existing intake elevation. Because very little water is used by ODOT, the impacts to their operations from this short-term restriction of use would be minor considering the possibility of trucking water to the site.

Alternatives 2, 3, and 5 would potentially influence the water table of the adjacent ground along Lake Creek during draw down, canal closure, and refill phases. The draw down phase would have greater potential for a persistent water table in the adjacent wetlands, because groundwater that would normally drain toward the channel would experience a higher stream surface elevation, creating a flatter groundwater flow gradient between the adjacent wetland and channel. This effect would be similar to winter conditions when marine storms move into the High Cascades creating very wet soils and runoff. However, it would last much longer than under normal conditions.

During the canal closure phase, Lake Creek would likely have no flow to very low flow from Diamond Lake to Thielsen Creek. Wetlands along this segment of channel would likely experience a drier condition. The groundwater table would have a steeper gradient between wetlands and channel, which would encourage more rapid water movement toward the channel. Although Sheep Creek does contribute flow to Lake Creek, it only represents about 7% or less of the low flow. Therefore, Sheep Creek flow would not be expected to lessen the potential drying effect to the wetlands downstream. However, in this segment of stream, there are very localized tributary inputs that would provide some moisture at specific sites. This unnaturally dry condition would last about 2 months.

The release of flow after treatment during the early refill phase would be smaller than the average historic flow in Lake Creek and would tend to encourage groundwater movement to the channel and a lower wetland water table. If the winter months are wet with rain and snowmelt, the weather would help to locally recharge wetlands. Wetland moisture would not likely recover until well into the refill phase.

Cumulative Effects: (Lake Creek Combined with Other Actions)

Alternatives 2, 3, and 5 are the only alternatives that would potentially combine with other past, present, and reasonably foreseeable future actions downstream of Diamond Lake to influence the streamflow regime. Several other activities are proposed within the downstream analysis area that have the potential to influence the processes of streamflow.

Within the Lemolo Lake Watershed, other activities proposed include pre-commercial thinning over the next five years, natural fuels treatments under Lemolo Fire Hazard Reduction CE, Bear Paw timber sale (9 acres), and Lemolo Watersheds Projects (timber harvest and natural fuel treatments). The focus on streamflow influence from these activities is associated with rain-on-snow response to canopy removal. Since the combined canopy removal from these proposed activities would not reduce the hydrologic recovery to a level of concern that would cause greater rain-on-snow runoff (Lemolo Watershed Projects Supplemental DEIS – water resource analysis, 2003), then additional streamflow from the combined proposed projects would not be expected to incrementally add to the draw down flow during the winter months. No other flow reduction is proposed or planned that would further reduce Lake Creek flow during canal closure and refill phases, which would affect wetland moisture as described previously.

No other projects are proposed or planned that would further reduce Lake Creek flows or wetland moisture. Therefore, no cumulative effectives associated with low flow conditions are expected.

PacifiCorp's hydropower operation exists within the analysis area and can potentially affect streamflow because of flow regulation at storage structures. PacifiCorp would pass the additional flow during the draw down phase when higher flows (winter runoff) would likely occur. Figure 7 displays the historic monthly flow in the North Umpqua River before Lemolo Dam in contrast to the post dam construction and operation period. Bankfull flow from Lake Creek would likely be proportionately higher to current flow releases from Lemolo Reservoir, but less than historic flows that have developed the downstream channel of the North Umpqua River. Winter storm runoffs, which would be greater than bankfull in Lake Creek, would continue to combine with upper North Umpqua River runoff in Lemolo Reservoir. A comparison of historic peak flows (actual paired peak) for Lake Creek and North Umpqua River (at the dam site and before construction) illustrated that Lake Creek contributed about 15 percent of the average peak flow for the upper North Umpqua at the present dam site. Mean annual runoff showed a similar relationship; that is, Lake Creek contributes about 14 percent to the annual runoff in the upper North Umpqua River (includes Lemolo and Diamond Lake Watersheds). Therefore, Lake Creek flow would not be considered a major flow influence to the upper North Umpqua River.

Since PacifiCorp operations of Lemolo Dam would pass additional draw down flow, there would be a short-term higher flow below the dam for this phase in comparison to the post dam regulated flow. Overall, only this short-term cumulative flow effect would be expected immediately downstream of the Lemolo Dam while below the last PacifiCorp structure (Soda Springs Dam) where the upper reach of the North Umpqua River Wild and Scenic starts, increased flows would not be detectable.

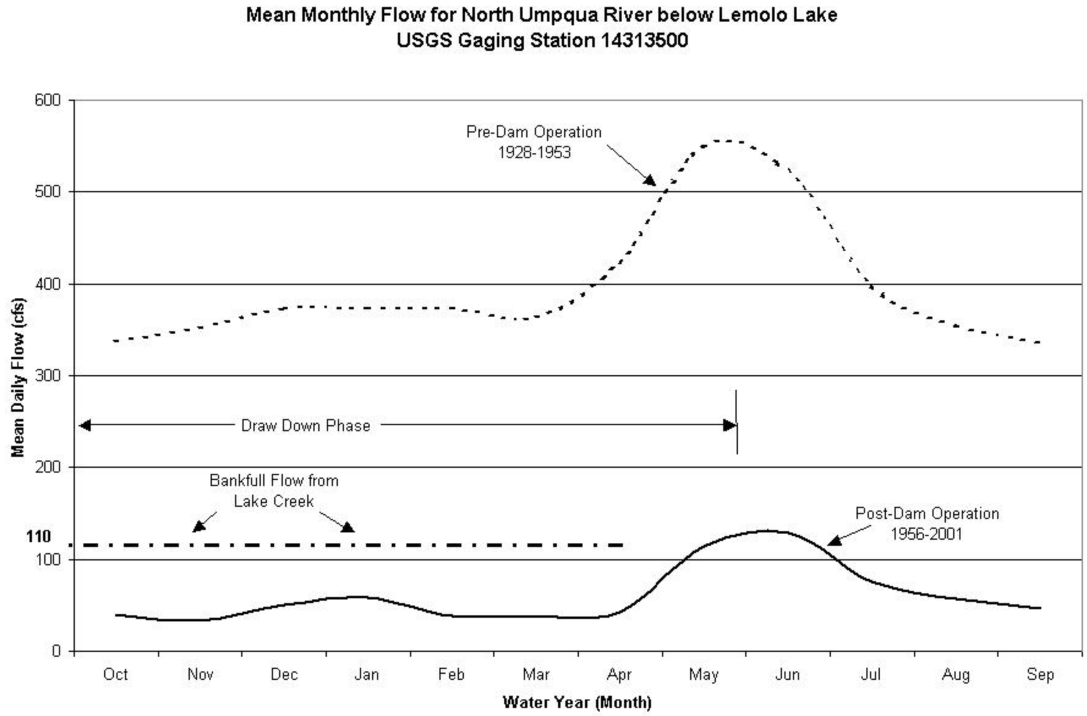

Figure 8. Mean Monthly Flow at North Umpqua River below Lemolo Dam, USGS Gaging Station 14313500 Before and After Dam Operation.

Conclusions:

Alternatives 2, 3, and 5 would have the only impact on the streamflow regime of Lake Creek. During the draw down period, Lake Creek would have at least bankfull flow (110 cfs). Although this amount of flow is not unusual, the proposed duration of bankfull flow is unusual and would not occur under a normal hydrologic cycle.

A short segment of stream (approximately 250 yards from the outlet to where the canal enters the channel of Lake Creek), would be dewatered for more than 12 months. Not until the lake is nearly refilled would this segment of Lake Creek have appreciable streamflow. When the canal is closed, the hydrologic cycle would be at low flow for all sections of Lake Creek. About 5.5 miles of Lake Creek would not have connectivity of flow. Thielsen Creek would be the only meaningful contribution to Lake Creek at about eight miles downstream. Loss of flow would also temporarily affect two water rights and the moisture regime in the wetlands in the vicinity of Lake Creek.

Wetlands adjacent to Diamond Lake and along Lake Creek would become drier after the canal closure. Recovery of wetland moisture would likely occur near the end of lake refill as moisture recharges with snowmelt and upslope moisture drains toward channels and wetlands.

Alternatives 1 and 4 would not affect the existing streamflow regime.

Aquatic Conservation Strategy:
Aquatic Conservation Strategy (ACS) Objectives 6[16] and 7[17] address in-stream flow, floodplain inundation and wetland water table. Since Alternatives 1 and 4 would not affect streamflow, the attainment of these ACS objectives would occur. Therefore, objectives 6 and 7 would be maintained under these alternatives for the short- and long-term at the sub-watershed and watershed level.

Alternatives 2, 3, and 5 would alter the streamflow regime during the implementation of these actions. Both alternatives would result in bankfull flow for about eight months over the length of Lake Creek and little to no flow from the outlet to Sheep Creek for 2 months. These represent local, short-term impacts; however, for the long-term, streamflow would return to the pre-action level, which would allow attainment of ACS objective 6 at the sub-watershed and watershed level. Wetlands adjacent to Diamond Lake and along Lake also would likely dry, during the short-term. However, this temporary effect would not prevent the long-term attainment of ACS objective 7 once the project is complete and streamflow returns to pre-action levels. The higher flows of winter and spring would be passed through the canal similar to historic flows. Therefore, objective 7 would be met for long-term at the sub-watershed and watershed level.

WATER QUALITY

The water quality of the affected environment streams is characterized by water temperature and nutrients. Dissolved Oxygen (DO) and pH do not appear to be a concern for Lake Creek, but the situation is potentially different in Lemolo Reservoir and below the Lemolo Dam. There is also the potential for algal toxin to enter Lake Creek from Diamond Lake (see toxin discussion in Limnological section) and move downstream. Sedimentation and turbidity are discussed later in the section Channel Morphology.

Stream Temperature

AFFECTED ENVIRONMENT

Lake Creek is a water quality limited stream on the State 303(d) List as defined in the federal Clean Water Act (Section 303(d)) for elevated water temperatures. The specific concern identified is the warm temperatures during the spawning (year round) and rearing (summer) periods[18] for resident fish and aquatic life.

Lake Creek flow at the outlet is lake surface water running out of Diamond Lake. Because of the direct exposure to sunlight (solar radiation input), the surface water and outflow is naturally warm in the summer. Lake Creek maximum summer water temperatures closely parallel summer daytime temperatures. The warm water condition is not typical for High Cascade streams that are usually influenced by groundwater through seeps and springs. For example, the maximum summer temperature for Lake Creek at the outlet has been measured at greater than 75 degrees Fahrenheit (°F) or 23.9 degrees Celsius (°C) while the maximum

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[16] ACS objective 6: “Maintain and restore in-stream flows sufficient to create and sustain riparian, aquatic, and wetland habitats and to retain patterns of sediment, nutrient, and wood routing. The timing, magnitude, duration, and spatial distribution of peak, high, and low flows must be protected.”
[17] ACS objective 7: “Maintain and restore the timing, variability, and duration of floodplain inundation and water table elevation in meadows and wetlands.”
[18] Oregon Department of Fish and Wildlife District Offices determine the spawning and rearing periods.

temperature of Thielsen Creek, a tributary, was 52º F (Diamond and Lemolo Lakes Watershed Analysis, 1998). Across the lake, Silent Creek maximum temperature was less than 50º F (10º C) for the summer of 2003 (Eilers 2003). However, over the stream distance from Diamond Lake to Lemolo Reservoir, exchange of cool groundwater with surface water as well as tributary flow help to reduce Lake Creek's temperature. The maximum summer temperature for the mouth of Lake Creek at Lemolo Reservoir is about 10 degrees cooler than at Diamond Lake outlet[19] (Diamond and Lemolo Lakes Watershed Analysis 1998). Riparian and topographic shade also contributes to the cooler stream temperature in the downstream direction.

The current water temperatures in Lake Creek are likely similar to pre-management activity. Vegetation disturbance from timber harvest, road construction, and recreational management activities has been limited along Lake Creek over the past 60 years (Lemolo and Diamond Lakes Watershed Analysis, 1998). Temperatures are likely to have improved since the 1940's, when sheep grazing ended.

ENVIRONMENTAL EFFECTS

Direct Effects: (Lake Creek at the Diamond Lake Outlet)
Alternatives 1 and 4 would maintain the existing stream temperature regime, as no draw down or reduction of flows in Lake Creek would occur; thus, there would be no direct effects.

Alternatives 2, 3, and 5 involve lake draw down and no outlet flow to Lake Creek. The pass-through flow and canal closure phases would occur during the time of warmer stream temperatures, while the other phases are during the cooler months. Since the pass-through flow phase would be similar to the existing condition, no stream temperature changes would be expected.

During the canal closure phase, Lake Creek would not have flow immediately below the outlet during the summer, when stream temperature peaks. Any water in the immediate channel, such as in pools would be susceptible to atmospheric warming and possible direct solar radiation over the period that the outlet is dewatered. However, maximum air temperature would be decreasing through the canal closure phase limiting atmospheric heating of surface water; therefore, allowing surface water temperature to decrease compared to the warmer atmospheric condition of the summer months of July and August. This segment of channel would not transfer warm water downstream. Therefore, the direct effect of warming would be limited and would not contribute to any downstream warming.

Connected actions proposed by Diamond Lake Resort would have no direct, indirect, or cumulative impact on stream temperature.

Indirect Effects: (Lake Creek and Downstream)
Alternatives 1 and 4 would maintain the existing stream temperature regime, as no draw down or reduction of flows in Lake Creek would occur; thus, there would be no indirect effects.

As discussed under direct effects for Alternatives 2, 3, and 5, the critical phase would be the canal closure. After the canal is closed, there would be little to no flow for about 5.5 miles of

[19] Diamond Lake Ranger District temperature monitoring that occurred in 1997.

stream until Sheep Creek. Any water in the channel would be expected to pool and not likely to flow. The water that is pooled would warm with atmospheric conditions and possibly direct solar radiation. However, maximum air temperature would be decreasing through the canal closure phase (September to November) limiting atmospheric heating of surface water. The amount of flow from Sheep Creek during this time of year would only provide very shallow flow but very cool temperatures that would potentially warm because of the large temperature difference between the air and stream (Breeden [2003] found that Sheep Creek temperature was near expected groundwater temperature at about 42.8° F (6° C) in late summer or about 50% cooler than Lake Creek in 2003). At the confluence with Thielsen Creek, cool water would dominate the limited streamflow in Lake Creek from the confluence to Lemolo Reservoir (about 3.5 miles). Although volume of flow would be reduced, Lake Creek stream temperature would likely be cooler downstream than typical since Sheep Creek and Thielsen Creek would dominate the flow and are cooler groundwater systems than Lake Creek normally is. Any stream temperature changes in Lake Creek during any part of these alternatives would be offset once flow reaches Lemolo Reservoir where Lake Creek normally represents less than 20% (Anderson and Carpenter, 1998) of the total flow entering the reservoir during summer and a smaller percentage during canal closure. The cooler and higher volume flow of the upper North Umpqua River that flows into Lemolo Reservoir dominates the reservoir volume. Therefore, the reservoir would be the downstream extent that possible stream temperature influences would occur.

Cumulative Effects: (Lake Creek Combined with Other Actions)
Alternatives 1 and 4 would maintain the existing stream temperature regime, as no draw down or reduction of flows in Lake Creek would occur; thus, there would be no cumulative effects.

Alternatives 2, 3, and 5 are the only alternatives that would potentially affect Lake Creek temperature as discussed under indirect effects. There are no ongoing or planned actions that would reduce riparian shade along Lake Creek or tributaries. The Riparian Reserve land allocation under the Northwest Forest Plan provides for water quality protection and is applied to all activities near streams, which would protect effective shade. Therefore, the temporary impacts associated with these three alternatives are not expected to cause consequential cumulative effects to the Lake Creek stream temperature within or downstream of the project area.

Conclusions:

Lake Creek would likely lack continuous flow from the outlet downstream for 5.5 miles until Sheep Creek during the critical summer period when streams warm. Therefore, streamflow temperature would not be a measurable condition in this segment. However, pooling of water would likely occur, which would warm with atmospheric conditions and direct solar radiation, but lack connectivity downstream. As such, warm water would not be delivered to downstream areas. The cool water of Sheep Creek and Thielsen Creek would dominate Lake Creek stream temperature from the confluences to Lemolo. Lake Creek temperature would be cooler than typical in this segment where Thielsen Creek dominates the flow.

Alternatives 2, 3, and 5 would temporarily create a cooler, but smaller flow segment of Lake Creek from at least Thielsen Creek to Lemolo. However, the natural stream warming and conveyance would not be permanently altered through these proposed actions but would return to pre-treatment levels after the lake is refilled.

Alternatives 1 and 4 would have no effects on stream temperature.

Nutrients and Algal Toxins

AFFECTED ENVIRONMENT

Phosphorus and nitrogen are the two primary nutrients associated with primary production and algal growth in streams. High concentrations of phosphorus in steams are associated with the volcanic soils of the High Cascades geology that is found in the project area. In contrast, the scarcity of nitrogen in the waters of the greater North Umpqua River Sub-Basin (within and beyond the project boundaries) implies that the algae are potentially "nitrogen limited," making plant available nitrogen (inorganic nitrogen) difficult to detect[20] (Anderson and Carpenter, 1998). Phosphorus and nitrogen are exported from the surface water of Diamond Lake through the outlet and down Lake Creek to Lemolo Reservoir.

Phosphorus is delivered to Diamond Lake through surface water, groundwater, and precipitation, however; only a small portion leaves the lake through Lake Creek (see Lake Ecology and Water Quality section). During 1992-2000,the total phosphorus concentration was approximately 4 times greater coming into the lake than measured in Lake Creek below the outlet (Salinas, 2001). The US Geological Survey also sampled the mouth of Lake Creek (Anderson and Carpenter, 1998) within the same time period (1995) and found that total phosphorus and orthophosphate[21] were similar in concentration to the outlet. Phosphorus concentrations measured by Eilers (2001) were also similar over the length of Lake Creek. It appears that total phosphorus has no net retention or meaningful change over the length of Lake Creek.

Inorganic nitrogen (nitrate, (NO_3)) is the primary form of nitrogen externally delivered to Diamond Lake at low concentrations through the groundwater (see Lake Ecology and Water Quality section). With the phytoplankton active on the lake surface, outflow into Lake Creek is higher in organic nitrogen than inorganic. However, organic nitrogen is converted (nitrification) to inorganic nitrogen as water flows down Lake Creek, reducing the concentration of the organic form at the mouth. Inorganic nitrogen was found to be as much as 70 times greater at the mouth of Lake Creek compared to the concentration at the lake outlet. Figure 9 displays the nitrogen and phosphorus characteristics of Lake Creek at the outlet and mouth that were sampled by Eilers in 2001.

The presence of toxin produced by algal blooms in Diamond Lake was identified in 2001. Populations of the blue-green algae (cyanobacteria) *Anabaena flos-aquae* and *Microcystis aeruginosa* have occurred in Diamond Lake during the summers of 2001, 2002, and 2003 (Eilers and Kann, 2002) and produced measurable levels of toxin. *Anabaena flos-aquae* is usually associated with the neurotoxin anatoxin-a and *Microcystis aeruginosa* produces microcystins, which can affect the liver.

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[20] In nitrogen limited streams, algae and other plants rapidly use up inorganic nitrogen (nitrogen that is in solution or dissolved in the water) as soon as it becomes available in the water column. High inputs of inorganic nitrogen into these types of streams can result in algae blooms.

[21] Orthophosphate is one of three classes of dissolved phosphorus that can be found in natural waters, but the only form readily available for biotic uptake (MacDonald, Smart, and Wissmar, 1991).

A level of concern for anatoxin-a has not been established by the US Environmental Protection Agency. However, Dr. Wayne Carmichael of the Department of Biological Sciences at Wright State University suggested to the Umpqua National Forest that 100 micrograms per liter (µg/L) "would be an acute lethal risk to animals (pets) drinking from inshore areas where the bloom would be more concentrated (and hence the toxin as well) (2001)". The World Health Organization has established a guideline value for microcystins at 1 µg/L in drinking water (Chorus and Bartram, 1999).

Toxin sampling at the time of peak algal blooms in Diamond Lake during the summers of 2001, 2002, and 2003 detected levels of both anatoxin-a and microcystins. The location of concern for toxin is where algal mats or blooms concentrate. These bloom concentrations are not evenly distributed on the lake, but tend to gather in open water and along the shore. Anatoxin-a concentrations ranged from "no detection" to two samples at 300 µg/L in 2001. Microcystin concentrations were less that 1 µg/L except for one sample in 2003 (2.54 µg/L). The presence of toxin during these three summers prompted lake closure for part of each summer for public safety.

Toxins delivered to Lake Creek through the outflow are available to be transported downstream. However, the observed increased streamflow in Lake Creek from groundwater and tributary inflow would dilute any original lake concentration downstream. If toxins reach Lemolo Reservoir, it would be further diluted and undergo photo degradation.

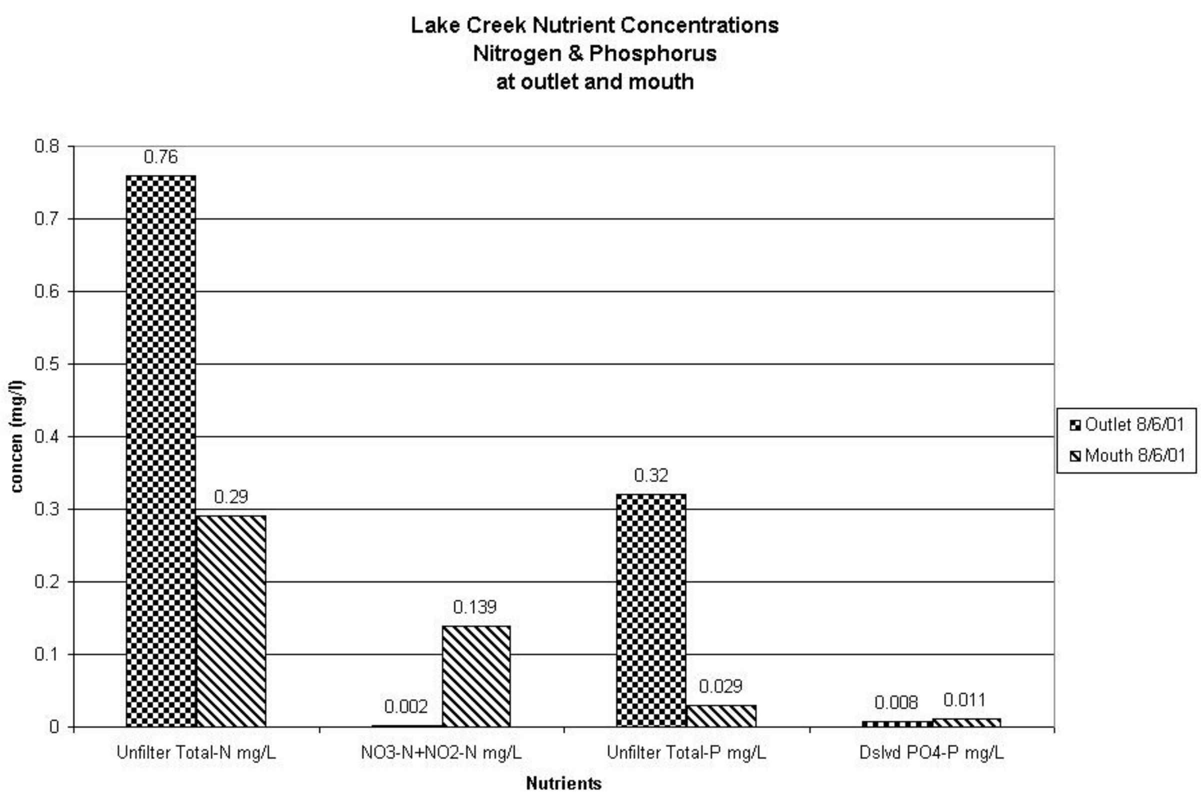

Figure 9. Nitrogen (Unfiltered Total-N and NO_3-N + NO_2-N) and Phosphorus (Unfiltered Total-P and Dissolved PO_4-P) Concentrations (mg/L) in Lake Creek at Outlet and Mouth (Eilers, 2001).

ENVIRONMENTAL EFFECTS

Direct Effects: (Lake Creek at the Diamond Lake Outlet)
Alternative 1 would maintain the existing phosphorus and nitrogen profiles as described in the affected environment. Blue-green algae blooms would continue to occur and produce anatoxin-a and microcystin, which reduce the summer water quality and raise public health concern.

Under Alternatives 2, 3, and 5, the draw down and the refill phases would not occur during the summer when primary productivity influences nutrient occurrence and movement through Lake Creek and downstream. Canal closure would potentially dewater Lake Creek to the confluence of Sheep Creek and eliminate nutrient conveyance. Therefore, the direct nutrient consequences of these phases are minor.

Alternatives 2, 3, and 5 have the greatest potential to influence phosphorus and nitrogen movement during the pass-through flow of the summer. During the pass-through flow, Lake Creek at the outlet would be dewatered and lack any connection to phosphorus and nitrogen from Diamond Lake. The canal would carry the flow and nutrients downstream to a lower segment of Lake Creek. Therefore, the outlet segment would not be able to convey or respond to local nutrients.

After chemical treatment under Alternatives 2, 3, and, 5, the canal would be opened to allow about10 cfs to leave Diamond Lake. The fish carcasses remaining in the lake would potentially contribute to a nutrient release to the water leaving the lake through the canal during the refill phase (see Water Quality under Surface Water – Lake Ecology). However, the refill phase was designed such that nutrient rich water from Diamond Lake would be moved through the canal in the fall, winter, and early spring when potential nutrient utilization in primary productivity (e.g.; algal activity) would be limited. Therefore, additional nutrient lease from fish carcasses at the canal outlet would not be expected to cause an adverse response because of the timing of release.

The presence of algal toxins under Alternatives 2, 3 and 5 would also occur during the pass-through flow phase of the summer. Algal toxin that is produced in Diamond Lake would be available to enter Lake Creek through the canal and carry downstream. As mentioned for nutrients, the outlet would be dewatered and not able to convey toxins.

Connected actions proposed by Diamond Lake Resort and described in Chapter 2 would have no direct, indirect, or cumulative effects on stream nutrients or toxins.

Alternative 4 would maintain the existing phosphorus and nitrogen profiles as described in the affected environment for about seven years of treatment. After seven years, some lake improvement would be expected, resulting in a reduction of phytoplankton and nutrient delivery to Lake Creek at the outlet. However, this alternative would not completely remove the tui chub (see Aquatic Biology section). The remaining tui chub would continue to feed on the lake zooplankton, which would allow a reduced level of phytoplankton activity. This condition would result in the continued delivery of organic nitrogen into Lake Creek, but again, at a somewhat lower level than the existing condition for a period of time.

Algal toxins would likely remain presence at the outlet under Alternative 4 with some possible improvement because of mechanical treatment disrupting algal activity during blooms. As discussed above for nutrients, a noticeable reduction of phytoplankton (blue-green algae) would be expected after seven years, which would also result in toxin reduction. However, the remaining tui chub would continue to influence the ability of zooplankton to control the phytoplankton. Therefore, there would be continued risk of future algal blooms and the presence of toxins at the outlet.

Indirect Effects: (Lake Creek and Downstream)
Alternatives 1 would maintain the existing phosphorus and nitrogen profiles as described in the affected environment in the downstream channel segments. Since the North Umpqua is a nitrogen-limited system, passage of even small amounts of nitrogen downstream would likely encourage algal growth, which would represent a potential negative impact on water quality.

Under Alternatives 1, potential toxins from algal bloom concentrations in Diamond Lake would continue to be delivered to Lake Creek and downstream. Groundwater and tributary inflow to Lake Creek would dilute the already low toxin concentrations between Diamond Lake and Lemolo Reservoir. If toxin enters Lemolo Reservoir, it would be further diluted because of the volume of the reservoir in comparison to Lake Creek flow. The resident time of reservoir water is equal to or less than a half of month, which would not allow continued toxin input to concentrate to a level of concern. The open setting of the reservoir would allow photo degradation to reduce remaining toxin concentrations well below the original Diamond Lake values. Toxins would not likely be detectable below Lemolo Reservoir.

The ODOT water right on Lake Creek is not for drinking water. However, if diluted concentration of toxins from Diamond Lake were present at the intake of this water right, it probably would be below the suggested level of concern for toxin concentration published by the World Health Organization. This condition would be similar for all the action alternatives during the summer when algal blooms occur.

Eilers and Raymond (2001) investigated the existing movement of these nutrients through the PacifiCorp hydropower project. From Lemolo Reservoir to below the last PacifiCorp dam on the North Umpqua River, the results indicated that overall some phosphorus is retained in sediments in the project storages structures. Total nitrogen indicated slight gain downstream. Nitrogen gains from fixation (atmospheric nitrogen) by blue-green algae appear to be balanced by retention and storage in sediments.

For Alternative 2, 3 and 5, as described under the direct effects, the pass-through flow phase (using the canal not the lake outlet) would be the primary phase of concern. During this phase, the existing nutrient process would be generally unchanged. Lake Creek's profile for phosphorus and nitrogen would likely follow the existing condition. Therefore, nutrients would continue to be conveyed downstream through the hydropower project and down the North Umpqua River. In three years, phytoplankton density in Diamond Lake would be expected to reduce because of the chemical treatment of tui chub. Lower concentrations of organic nitrogen and total nitrogen would be delivered to Lake Creek. The shift would be a result of lower phytoplankton densities in Diamond Lake that would fix less atmospheric nitrogen into organic nitrogen as algal cells. This represents a long-term beneficial effect to the aquatic system and water quality.

The refill phase would deliver additional nutrients downstream because of fish carcasses. The greater potential to cause adverse nutrient response in Lemolo Lake and the North Umpqua River would be during the summer when water temperatures are warmer and more light is available encouraging primary productivity (e.g.; algal activity). However, the timing of release discussed under direct effects would limit the potential response. In addition, PacifiCorp's integral role in continuing to move nutrient rich water out of Lemolo Lake and through the North Umpqua River system during the non-summer season was recognized early in the project planning process.

Algal toxins delivered to Lake Creek during the pass-through flow phase would respond similarly to the existing condition as discussed under the indirect effect for Alternative 1.

Under Alternatives 2, 3, and 5, the draw down phase would release nutrient rich water from Diamond Lake down Lake Creek to Lemolo Reservoir. During the time of release, primary productivity would be low because of the cooler water temperatures and limited light of the fall through spring period. It would be important for PacifiCorp to release the draw down flow to the North Umpqua River and not store this water. This condition would allow the nutrient rich water from Diamond Lake to pass through the hydropower system and down the North Umpqua River before summer when algal productivity would utilize nutrients in PacifiCorp impoundments or the river.

Total nitrogen would be elevated in Lake Creek and downstream during at least the early half of the refill phase and immediately after the canal is opened. The increase in total nitrogen would be in organic nitrogen from the dead aquatic life after chemical treatment. Because of the time of year, organic nitrogen would not be converted to inorganic nitrogen as readily as in the summer. Streamflow would be increasing with cooler water temperatures and less available light in this final phase. As identified for the draw down phase, it would also be important that PacifiCorp release the early refill flow to the North Umpqua River and not store this water. Downstream nitrogen levels would become diluted with increasing flow. Therefore, the higher total nitrogen would be expected to pass through the North Umpqua system before aquatic life would effectively utilize it during the following summer. Inorganic nitrogen (nitrate; NO_3) would remain at low concentrations downstream, which would likely be less than observed during the summer (see Figure 8).

Alternative 4 would show little to no improvement over the existing nutrient profile for about seven years. After seven years, some reduction in phytoplankton would be expected in Diamond Lake, which would lower organic nitrogen and total nitrogen concentrations exported down Lake Creek. However, this alternative would not completely remove the tui chub (see Aquatic Biology section). The presence of tui chub would likely continue to influence the amount of organic nitrogen exported from the lake. Based on recent data from Lava lakes (Eilers, personal communications), there is considerable uncertainty regarding the long-term effectiveness of mechanical tui chub removal limiting algal blooms and associated eutrophication. This alternative would likely export more total nitrogen than Alternatives 2, 3, and 5, but less than Alternative 1.

Algal toxins would likely remain presence at the outlet and carry downstream under Alternative 4. The downstream toxin transport and processes would be similar to the existing situation and described under Alternative1. However, some possible improvement would likely occur for the short-term because of the mechanical treatment, which would indirectly reduce the potential for high density blooms to develop. As described in the direct effects, a downstream improvement would be expected after seven years with a noticeable reduction of phytoplankton (blue-green algae). However, the remaining tui chub would continue to influence the ability of zooplankton to control the phytoplankton. Therefore, there would be the risk of future algal blooms and the presence of toxins downstream of the outlet.

Cumulative Effects: (Lake Creek Combined with Other Actions)
All the alternatives would have the potential to incrementally add nitrogen to other planned and proposed activities that also have potential nitrogen input to Lake Creek. Within the Lemolo Lake Watershed, other activities planned and proposed activities include various intensities of harvest and fuel treatments (see streamflow - Cumulative Effects – Lake Creek Combined with Other Actions). These types of activities would release nitrogen with the potential to be transported through the groundwater to Lake Creek.

There are no other situations downstream of Diamond Lake that are existing, proposed, or planned that would input algal toxins to the Lake Creek system and accumulate downstream. Although Lemolo Reservoir is water quality limited for pH because of algal activity, toxins have not been identified in the reservoir in association with the existing phytoplankton blooms.

Alternative 1 would maintain the existing nutrient profiles as described in the affected environment. This alternative would have the greatest opportunity to incrementally add to other planned and proposed activities because of the lack of corrective measures and the indefinite time frame to allow cumulative effects to develop.

Alternatives 2, 3, and 5 would have the potential to add inorganic nitrogen to Lake Creek that potentially would incrementally add to other planned and proposed activities with nitrogen output in the short-term. However, in three years, phytoplankton activity would be expected to reduce, which would lower the total nitrogen concentration and organic nitrogen in Diamond Lake and delivered to Lake Creek. There would be a general shift in the nitrogen forms from organic to inorganic. There would also be less organic nitrogen to undergo nitrification in Lake Creek. Overall, less inorganic nitrogen would be available for plant growth in Lake Creek and Lemolo Reservoir, resulting in a long-term (beyond the three year post treatment) beneficial improvement. However, it is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur.

Alternative 4, in seven years, would also have a reduction in phytoplankton active, which would lower the total nitrogen concentration including organic nitrogen that Diamond Lake would deliver to Lake Creek. The similar response as Alternative 2, 3, and 5 would be expected for this alternative except it would allow seven years instead of three years for potential incremental effects to occur and it would likely export more total nitrogen during the critical period of summer for more years than Alternatives 2, 3, and 5, but less than Alternative 1. The treatment intent would be to control the tui chub population by mechanical removal plus predacious fish stocking in contrast to chub removal through chemical treatment. As described under direct effects, some tui chub would remain and be a potential source of organic nitrogen from chub excretion. This additional organic nitrogen would be available to incrementally add to future downstream sources of nitrogen during the alternative lifetime at the sub-watershed (Lake Creek) and watershed scale (Lemolo

Reservoir). Annual mechanical removal and predacious fish stocking, which is identified in the contingency plan, would increase the likelihood of maintaining lower total nitrogen export in the long-term (greater than seven years). Therefore, a beneficial response in nutrient reduction would be expected under Alternative 4, but less than Alternatives 2, 3, and 5.

Conclusions:

Under Alternative 1, the existing nutrient and toxin process would continue. The available nitrogen, phosphorus, and toxin delivered from Diamond Lake to Lake Creek would be influenced by the phytoplankton activity. As a result, high concentrations of organic nitrogen would continue to be delivered to Lake Creek. Over the length of Lake Creek, the organic nitrogen would be converted to inorganic nitrogen. This readily available form of nitrogen to algal growth would continue to be delivered to Lemolo Reservoir where elevated pH would continue to affect the reservoir water quality. Toxin produced by blue-green algae in Diamond Lake would continue to deliver to Lake Creek outlet and possibly downstream in very dilute to non-detectable concentrations. Downstream transported effects of toxins would dissipate completely once Lake Creek mixes with Lemolo Reservoir.

Under Alternatives 2, 3, and 5, the nutrient process and toxin production would occur during the summer pass-through flow phase. A potential nutrient pulse from fish carcasses would occur during the refill phase. The winter draw down and refill phases would occur when low light and cool water temperatures limit nutrient processes and no toxin production. PacifiCorp would pass this nutrient rich water downstream to allow it to move down the North Umpqua River during lower primary productivity. The remaining canal closure would eliminate any downstream connectivity. However, the phytoplankton density would reduce three years after treatment. Lower total nitrogen output from the lake would be expected with a shift from the present high levels of organic nitrogen. Total available nitrogen delivered to Lemolo Reservoir would also be reduced, which would help to reduce planktonic activity and pH in Lemolo. Toxin production in Diamond Lake would reduce with lower phytoplankton density.

Under Alterative 4, the same type of improvements as described under Alternatives 2, 3, and 5 would be expected to occur after seven years, but to a potentially lesser degree. Long-term (beyond seven years) chub harvest would increase the likelihood of maintaining water quality improvement. Because some lower number of tui chub would still be present, nutrient cycling would still occur, but at a reduced level from that of Alternative 1. Continued long-term chub harvest and predacious fish stocking would increase the likelihood of maintaining water quality improvement.

Dissolved Oxygen and pH

AFFECTED ENVIRONMENT

Lake Creek naturally aerates[22] between Diamond Lake and Lemolo Reservoir in fast water segments. The U. S. Geological Survey did a synoptic[23] study of the water quality and algal

[22] A stream naturally aerates when atmospheric oxygen becomes mixed into the water because of turbulence caused by the channel profile.

conditions in the North Umpqua River, which included Lake Creek at the mouth and the North Umpqua River at the inlet to Lemolo Reservoir (Anderson and Carpenter, 1998). The DO at the Lake Creek site was 97% saturated[24] (8.9 milligrams per liter) in the morning and 110% (9.2 milligrams per liter) in the afternoon, in late July. DO concentrations can be a concern during the summer months when stream temperatures are the warmest and natural solubility[25] of oxygen is lower. Lake Creek at the lake outlet re-aerates as the water moves quickly out of the lake. The lake surface water that moves out of the lake also has high levels of DO because of wind-induced aeration of the lake surface water and photosynthetic activity of phytoplankton and macrophytes in the summer. Winter DO may also be saturated, because water temperature is low, solubility of oxygen is higher, and higher flow incorporates more oxygen into the water from the atmosphere.

From the same USGS study, pH at the mouth of Lake Creek ranged from 7.2 to 7.6 over a twelve-hour period in late July, which is when higher pH has been measured in other Forest streams and water bodies. The pH for the surface water of Diamond Lake during the summer is usually above 8.0 and driven by phytoplankton primary production. Salinas (2001) found that over a 6-year sampling period during the summers of 1992-2000 that Lake Creek's average pH was 8.5 at the outlet. Because of lower water temperature and light, the winter primary productivity is greatly reduced and pH is also lower.

Downstream summer DO and pH in Lemolo Reservoir have responded to algal activity in the upper 13-19 feet of the water column of Lemolo Reservoir (DEQ, 2002). The pH has exceeded the water quality standard (pH >8.5) and Lemolo Reservoir has been listed as a Water Quality Limited Water Body (DEQ 303d List). DO has shown daily swings because of algal photosynthesis (elevated DO) and respiration (depressed DO). Nitrogen rich water from Diamond Lake that is carried by Lake Creek has been identified as a source of concern for Lemolo Reservoir.

ENVIRONMENTAL EFFECTS

<u>pH</u>

Direct Effects: (Lake Creek at the Diamond Lake Outlet)
Under Alternative 1, there would be no change or improvement in the pH of Lake Creek at the outlet. Phytoplankton (algae) blooms would continue on the lake surface in the summer months, driving pH above the water quality standard (>8.5) in the surface water of Diamond Lake and conveying this high pH water to the lake outflow and Lake Creek.

Alternatives 2, 3, and 5 would dewater Lake Creek at the outlet during the draw down phase. Flow at the outlet would not return until the lake refills to an elevation that allows surface outflow to connect Lake Creek. This phase of these alternatives would occur during winter when primary productivity is reduced along with water temperature and light. The lower winter primary productivity would result in lower pH (<8.0) for the lake surface water flowing out the canal.

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[23] A type of water-quality sampling that occurs during one short time period to provide a snapshot of conditions (Anderson and Carpenter, 1998).
[24] Percent saturation refers to the amount of dissolved oxygen in water in comparison to the amount the water can potentially hold (higher the percent for a certain temperature and atmospheric pressure the more oxygen dissolved in water).
[25] The solubility refers to the ability of oxygen to dissolve in the water.

During the pass-through flow phase of the summer months, phytoplankton blooms would likely occur while the lake is drawn down. Therefore, high pH in the lake would be expected, which would be conveyed through the canal to Lake Creek.

The canal closure phase would dewater the canal outlet segment and most of Lake Creek to the confluence with Sheep Creek for 2 months (late summer-early fall period). There would be no flow connectivity between Diamond Lake and Lake Creek to convey water with high pH. However, when flow is again released during refill phase, it would occur during the winter months of low primary productivity and potentially lower pH.

After chemical treatment, the pH of the lake surface water and Lake Creek outlet would probably continue to be high in the summer for approximately three years because of phytoplankton blooms. However, noticeable improvement is expected to occur after this time period with lower planktonic activity resulting in lower pH outflow from the lake surface to Lake Creek. Therefore, long-term improvements in pH are expected; however, it is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur.

Connected actions proposed by Diamond Lake Resort under Alternatives 2, 3, and 5 would have no direct, indirect, or cumulative effects on stream pH.

Under Alternative 4, the high planktonic activity and elevated pH would likely continue for about seven years similar to the existing condition while annual mechanical fish harvest and predacious fish stocking gradually take effect. After seven years, lake improvement would be expected, resulting in a noticeable reduction of phytoplankton and pH in the lake surface water and outflow to Lake Creek. However, this alternative would not completely remove the tui chub (see Aquatic Biology section). The presence of tui chub would continue to allow an influence on lake zooplankton, which would likely allow phytoplankton activity and pH response. A pH response would be conveyed to Lake Creek at the outlet.

Indirect Effects: (Lake Creek and Downstream)

Under Alternative 1, there would be no change or improvement in the pH of Lake Creek and downstream related to the pH process discussed under direct effects.

Under Alternatives 2, 3, and 5, the draw down, canal closure, and refill phases would occur during either the time period (winter) when there is reduced phytoplankton productivity in water bodies and streams or loss of flow connectivity to downstream channel segments. Phase discussion and pH process are discussed under direct effects. Therefore, pH response in Lake Creek would not be expected during these phases.

After the draw down period, Lake Creek would receive a pass-through flow. Planktonic activity would likely occur in Diamond Lake as is currently happening and discussed under direct effects. The pH from the outlet to the mouth of Lake Creek would continue the existing pattern. At the outlet, pH would be greater than 8.0 (Salinas, 2001) compared to a high range of 7.6 to 7.9 (Anderson and Carpenter, 1998; Eilers, 2001) at the mouth of Lake Creek. The pH level in Lemolo and further downstream is not necessarily tied to Lake Creek at the outlet, but is more closely associated with local processes and nutrient transport.

Therefore, changes in pH in Lake Creek near the outlet would not be expected to result in pH changes in downstream channel segments.

After treatment, the same response described under the direct effects would be expected. In three years, the pH at the outlet and mouth of Lake Creek would be more similar and lower than the existing condition.

Alternative 4 response would be the same as discussed under the direct effect. Downstream responses would be similar to the existing condition until the treatments take effect. As discussed under Alternatives 2, 3, and 5, pH levels would not carry below Lake Creek at the mouth.

Cumulative Effects: (Lake Creek Combined with Other Actions)
Under Alternative 1, there would be no change or improvement in the pH of Lake Creek and downstream. There are no other planned or proposed actives that currently or in the foreseeable future would elevate Lake Creek pH.

As discussed under indirect effects, the pass-through flow phase for Alternatives 2, 3, and 5 would have the most phase influence downstream as high pH lake outflow moves down Lake Creek. However, pH would not additively occur downstream. As a hydrogen ion concentration of water, pH in Lake Creek flow would either be diluted by lower pH flow or it would increase the pH of receiving water. The former situation presently exists where Lake Creek pH level lowers downstream as tributary flow such as Thielsen Creek and groundwater exchange helps to lower pH. The latter situation does not exist with Lake Creek flowing into Lemolo Reservoir. The high pH of Lemolo Reservoir is a product of local surface water planktonic activity.

Under Alternative 4, the pH in Lake Creek would operate as describe above for Alternatives 2, 3, and 5. No influencing change to Lake Creek pH would be expected until after seven years of mechanical fish removal and stocking of predacious fish. However, this alternative would not completely remove the tui chub (see Aquatic Biology section). The presence of tui chub would continue to prey on lake zooplankton, which would likely result in some increase level of phytoplankton activity and pH response in the future(i.e. high pH's would likely recur).

Conclusions:

Lake Creek's pH in the upper reaches is influenced by the planktonic activity in Diamond Lake. The outflow from the lake surface water into Lake Creek is at a high pH level in the summer (>8.0). This effect becomes less downstream as streamflow aerates and groundwater exchange and tributary inflow dilutes the higher pH water.

Alternative 1 would not change the existing condition, where Lake Creek at the outlet would continue to experience high pH levels in the summer as a result of lake planktonic activity. Alternatives 2, 3, and 4 would reduce the pH in Lake Creek at the outlet, but in different time frames and possibly to different potential levels. Alternatives 2, 3, and 5 would reduce pH in three years by initially eliminating the tui chub and its effect on the zooplankton, which would result in increased grazing on phytoplankton. Alternative 4 would take about seven years, but would only reduce the tui chub, which would likely result in less control on the phytoplankton and pH. The overall result would be that pH throughout Lake Creek would be lower and more equal from Diamond Lake to Lemolo Reservoir. Alternative 4 would likely result in a smaller pH improvement with less certainty regarding sustaining water quality improvement in the long-term (beyond seven years). It is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. Contingency plans associated with all alternatives may increase the likelihood that water quality improvements are sustained over time.

Table 1 provides a summary of important conclusions and a comparison of the alternatives effects on pH.

Table 1. Comparison of Alternatives' Effects on pH in Downstream Water Bodies.

Stream/Water Body	Alternative 1 - No Action	Alternative 2 -Rotenone with Put, Grow and Take Fishery	Alternative 3 - Rotenone with Put and Take Fishery	Alternative 4 - Mechanical & Biological	Alternative 5- Modified Rotenone and Fish Stocking
Lake Creek (near outlet)	**Short-term** pH would remain high and continue to degrade water quality.	**Short-term** From years 1-3 after treatment, pH expected to remain high and lower water quality.	**Short-term** From years 1-3 after treatment, pH expected to remain high and lower water quality.	**Short-term** From years 1-7 after treatment, pH expected to remain high and lower water quality, but show slight improvement over time.	**Short-term** From years 1-3 after treatment, pH expected to remain high and lower water quality.
	Long-term pH would remain high and continue to degrade water quality.	**Long-term** After 3 years, pH expected to decrease and result in noticeable improvement in water quality over time. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.	**Long-term** After 3 years, pH expected to decrease and result in noticeable improvement in water quality over time. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.	**Long-term** After 7 years, pH expected to decrease and result in noticeable improvement in water quality. However, if annual mechanical removal fails or is stopped, the tui chub population would rebound and subsequent increases in pH and declines in water quality are expected. The likelihood of achieving or maintaining improvements in the water quality in the long-term would be increased with annual implementation of the described contingency plan over time.	**Long-term** After 3 years, pH expected to decrease and result in noticeable improvement in water quality over time. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.

Stream/Water Body	Alternative 1 - No Action	Alternative 2 -Rotenone with Put, Grow and Take Fishery	Alternative 3 - Rotenone with Put and Take Fishery	Alternative 4 - Mechanical & Biological	Alternative 5- Modified Rotenone and Fish Stocking
Lake Creek (downstream)	**Short-term** pH in upper reaches would remain high and continue to lower water quality but in downstream reaches pH would continue to be lower.	**Short-term** From years 1-3 after treatment, pH in upper reaches expected to remain high and continue to lower water quality but downstream reaches pH would continue to be lower.	**Short-term** From years 1-3 after treatment, pH in upper reaches expected to remain high and continue to lower water quality but downstream reaches pH would continue to be lower.	**Short-term** From years 1-7 after treatment, pH in upper reaches expected to slightly reduce over time while downstream would remain unchanged.	**Short-term** From years 1-3 after treatment, pH in upper reaches expected to remain high and continue to lower water quality but downstream reaches pH would continue to be lower.
Lake Creek (downstream)	**Long-term** pH in upper reaches would remain high and continue to lower water quality but in downstream reaches pH would continue to be lower.	**Long-term** After 3 years, pH in upper reaches expected to decrease and result in noticeable improvement in water quality over time while downstream would remain lower and unchanged. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.	**Long-term** After 3 years, pH in upper reaches expected to decrease and result in noticeable improvement in water quality over time while downstream would remain lower and unchanged. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.	**Long-term** After 7 years, pH in upper reaches expected to decrease and result in noticeable improvement in water quality while downstream would remain lower and unchanged. However, if annual mechanical removal fails or is stopped, the tui chub population would rebound and subsequent increases in pH and declines in water quality are expected. The likelihood of achieving or maintaining improvements in the water quality in the long-term would be increased with annual implementation of the described contingency plan over time.	**Long-term** After 3 years, pH in upper reaches expected to decrease and result in noticeable improvement in water quality over time while downstream would remain lower and unchanged. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.

Stream/Water Body	Alternative 1 – No Action	Alternative 2 –Rotenone with Put, Grow and Take Fishery	Alternative 3 – Rotenone with Put and Take Fishery	Alternative 4 - Mechanical & Biological	Alternative 5- Modified Rotenone and Fish Stocking
Lemolo Reservoir	**Short-term** pH would remain high and continue to degrade water quality near the surface with nutrient contribution from Diamond Lake and delivered by Lake Creek.	**Short-term** From years 1-3 after treatment, pH would remain high and continue to degrade water quality near the surface with nutrient contribution from Diamond Lake and delivered by Lake Creek.	**Short-term** From years 1-3 after treatment, pH would remain high and continue to degrade water quality near the surface with nutrient contribution from Diamond Lake and delivered by Lake Creek.	**Short-term** From years 1-7 after treatment, pH near the surface expected to remain high and degrade water quality with nutrient contribution from Diamond Lake and delivered by Lake Creek, but showing slight improvement in the latter years.	**Short-term** From years 1-3 after treatment, pH would remain high and continue to degrade water quality near the surface with nutrient contribution from Diamond Lake and delivered by Lake Creek.
	Long-term pH would remain high and continue to degrade water quality near the surface with nutrient contribution from Diamond Lake and delivered by Lake Creek.	**Long-term** After 3 years, pH expected to decrease near the surface with reduced nutrient from Diamond Lake and result in noticeable improvement in water quality over time. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.	**Long-term** After 3 years, pH expected to decrease near the surface with reduced nutrient from Diamond Lake and result in noticeable improvement in water quality over time. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.	**Long-term** After 7 years, pH expected to decrease near the surface with reduced nutrient from Diamond Lake and result in noticeable improvement in water quality. However, if annual mechanical removal fails or is stopped, the tui chub population would rebound and subsequent increases in pH and declines in water quality are expected. The likelihood of achieving or maintaining improvements in the water quality in the long-term would be increased with annual implementation of the described contingency plan over time.	**Long-term** After 3 years, pH expected to decrease near the surface with reduced nutrient from Diamond Lake and result in noticeable improvement in water quality over time. At some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur. However, if/when tui chub recur the likelihood of sustaining improvements in the water quality over time would be increased with annual implementation of the described contingency plan.

Stream/Water Body	Alternative 1 - No Action	Alternative 2 -Rotenone with Put, Grow and Take Fishery	Alternative 3 - Rotenone with Put and Take Fishery	Alternative 4 - Mechanical & Biological	Alternative 5- Modified Rotenone and Fish Stocking
North Umpqua River	**Short-term** Alternative would have no effect on pH below Lemolo Reservoir	**Short-term** Alternative would have no effect on pH below Lemolo Reservoir	**Short-term** Alternative would have no effect on pH below Lemolo Reservoir	**Short-term** Alternative would have no effect on pH below Lemolo Reservoir	**Short-term** Alternative would have no effect on pH below Lemolo Reservoir
	Long-term Alternative would have no effect on pH below Lemolo Reservoir	**Long-term** Alternative would have no effect on pH below Lemolo Reservoir	**Long-term** Alternative would have no effect on pH below Lemolo Reservoir	**Long-term** Alternative would have no effect on pH below Lemolo Reservoir	**Long-term** Alternative would have no effect on pH below Lemolo Reservoir

Dissolved Oxygen (DO)

Direct Effects: (Lake Creek at the Diamond Lake Outlet)
Alternatives 1 and 4 would not manipulate the flow in such a way that stream aeration would be changed. Therefore, the existing DO level would not be affected. The DO in Lake Creek is primarily influenced by the natural aeration process.

Alternatives 2, 3, and 5 are the only proposed alternatives that would alter stream aeration through flow manipulation. The treatment phases that would change the DO of Lake Creek at the outlet are the draw down and canal closure. Lake Creek at the outlet would be dewatered during both of these phases. DO would not be a measurable parameter at the outlet until the lake refills to an elevation that allows surface outflow into Lake Creek channel.

The DO for the post-treatment time would likely return to pre-treatment levels as streamflow returns and aerates in the fast segments at the outlet. Natural stream aeration would affect DO more than the treatment in Diamond Lake. In contrast, The DO in Diamond Lake is influenced by planktonic and macrophyte activity and intermittent wind across the lake surface.

Under Alternatives 2, 3, and 5, connected actions proposed by Diamond Lake Resort would have no impact on stream DO because they would not involve in-water work.

Indirect Effects: (Lake Creek and Downstream)
Alternatives 1 and 4 would not have indirect effects on the DO in Lake Creek, because no stream flow manipulations would occur.

The phase of Alternatives 2, 3, and 5 that would have the greatest influence on downstream Lake Creek DO would be the canal closure. When the canal is closed while stream temperatures are warm and water has lower ability to retain DO, there would be little to no flow for about 5.5 stream miles to Sheep Creek confluence. The very limited flow from Sheep Creek would potentially have lower DO concentrations. The cool water of Thielsen Creek and the natural aeration would allow high and continuous concentrations of DO in Lake Creek below this confluence to Lemolo Reservoir. Lake Creek would not influence the DO of Lemolo Reservoir. Where there would be little to no flow in Lake Creek, any pooled water would likely warm during the summer and cause local DO levels to drop. This would be a local effect. However, this situation would occur in most pools from the outlet to the Thielsen Creek confluence.

Cumulative Effects: (Lake Creek Combined with Other Actions)
There would not be a cumulative effect for DO under any of the alternatives. Stream re-aeration would quickly restore any DO reduction in short stream distances of fast water.

Conclusions:
Alternatives 1 and 4 would maintain the existing condition.

The DO of Lake Creek is most influenced by the ability of the stream to aerate, but warm stream temperatures are also a factor. During the summer when streams warm, a pass-through flow would be maintained and Lake Creek would continue to naturally aerate through the fast water segments throughout the stream length. The canal closure phase would dewater about 5.5 stream miles and forgo aeration and DO processes. Therefore, DO would not be degraded by Alternative 2, 3, and 5.

Aquatic Conservation Strategy – Water Quality

Aquatic Conservation Strategy (ACS) objective 4[26] addresses water quality. Alternative 1 would not address the existing deteriorated water quality condition for pH, algae, and toxin in Diamond Lake. This alternative has the potential to retard the attainment of meeting objective 4 at a local in Lake Creek at the outlet for the sub-watershed level and would continue to influence the downstream condition in Lemolo Reservoir at the watershed level in the long-term.

Under Alternatives 2, 3, and 5, the water quality of Lake Creek at the outlet would have short-term impacts after implementation for about three years. Following this period of time, nutrient, pH and toxin improvements would be expected, which would lead to improved water quality in the long-term and the attainment of objective 4. It is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if/when tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current water quality problems would be expected to recur.

Alternative 4 would also contribute toward attainment of objective 4; however, progress toward meeting this objective would be extended during the seven-year treatment period. Water quality of Lake Creek at the outlet would continue to reflect the lake condition during this time. After the seven-year treatment, tui chub would not be completely removed, which would likely allow a reduced level of nutrient cycling, pH and toxin response to continue. Although there would be an expected trend toward water quality improvement, the presence of tui chub would create less certainty for long-term effectiveness.

CHANNEL MORPHOLOGY

AFFECTED ENVIRONMENT

Channel stability and fish habitat inventories have given insight into the erosional and channel morphological processes within headwater streams in the watershed (Diamond Lake and Lemolo Lake Watershed Analysis, 1998). Results have shown that stream channel stability is moderate to high for all types of geologic settings surveyed, with little evidence of significant slope failure or mass wasting, and minimal amounts of excessive stream bank erosion or deposition of fine sediment. However, channel adjustment from past heavy grazing by sheep in the watershed during the late 1800's and early 1900's may still be occurring to riparian areas (soil compaction) and stream channels (width/depth ratio). Significant adjustment in channel morphology following elimination of grazing disturbance has occurred on a decadal time scale.

[26] ACS objective 4: "Maintain and restore water quality necessary to support healthy riparian, aquatic, and wetland ecosystems. Water quality must remain within the range that maintains the biological, physical, and chemical integrity of the system and benefits survival, growth, reproduction, and migration of individuals composing aquatic and riparian communities."

Overall, channel stability within the greater managed watershed areas does not significantly differ from those in unmanaged areas. These channels are relatively stable with properly functioning systems that efficiently process both flow and sediment under the current climate condition (Diamond Lake/Lemolo Lake Watershed Analysis, 1998). Although these types of channel (meandering with smaller substrate) can be sensitive to high flows, the channels appear to be stable due to the nature of the streamflow regime, which is characterized by peak flows that generally are not high energy, the abundance of large wood, and riparian areas that are mostly intact.

Diamond Lake was drawn down in 1954 and treated with rotenone. The draw down period was July 15 to September 21 and approximately 20,000 ac-ft was drained from the lake (U.S. Geological Survey, 1963). From these facts, the estimated average daily flow was about 180 cfs. Because of the 69-day duration of flow, the annual exceedance probably was less than 1%, which means that the flow over the draw down period was greater than a 100-year flood event (Wellman, 1993). The draw down flow in 1954 did not appear to cause significant slope failures or channel adjustment. Observations of Lake Creek by the Diamond/Lemolo Lake Watershed Analysis hydrologist and geologist and results from fisheries surveys do not substantiate that channel adjustments from 1954 occurred (Diamond Lake and Lemolo Lake Watershed Analysis, 1998). Therefore, any assumed impacts from the 1954 draw down on Lake Creek channel are more likely less extensive than originally thought.

Downstream of the proposed canal confluence with Lake Creek, the channel has bedrock segments and large particle size material in the banks. The resistive material is both bedrock and glacial drift rock (small to large boulders). The boulder size glacial drift provides channel control points and influences channel gradient.

Aerial photo interpretation found three erosional features that are potential bank erosion sites along Lake Creek. The first is located between the outlet and Sheep Creek (about 2.5 miles downstream of the outlet) and the other two are downstream of Pit Lake (see Geology section) and Thielsen Creek confluence (about 8 miles downstream of the outlet). These lower two sites are where fluvial[27] action by Lake Creek is eroding a steep exposure of Mazama pyroclastic ash-flow deposit that defines the valley wall of Lake Creek. Overtime the Mazama ash deposit in this area was eroded by Lake Creek to define a valley that is an average of 0.3 miles wide. The fluvial erosion has exposed the older glacial deposits. These three sites were visited to photo document the existing condition.

The soil type is similar at the three erosional features (referred to in the Geology Report as sites 3, 4, and 6) and in general along Lake Creek. The soil origin is from Mazama ash-flow and glacial till deposits. The soil size consists predominantly of sand and larger particle sizes. Finer soil size particles such as clay and silt have a tendency to remain suspended in turbulent water (creating turbidity) whereas sand and larger particles settle out more rapidly and therefore produce negligible amounts of turbidity.

There are four stream crossings[28] of Lake Creek within the project boundary. Starting at Diamond Lake, there is a double-culvert crossing of Forest road 4795-000 at the outlet. Roads 4700-710 and 4700-000 (Highway 138) also have double culverts downstream of the outlet

[27] Fluvial action refers to the physical action of rivers and streams.
[28] Road 4700710 and 4700000 (Hwy 138) were evaluated in 2001 as part of the Forest Fish Passage at Road Crossings Assessment

about 6.6 and 6.7 miles respectively. The last crossing is a pipe-arch at road 2614-000 near the mouth of Lake Creek at Lemolo Reservoir.

The double culverts at Road 4700-710 and Highway 138 crossings show evidence of being too small or undersized. The total diameters of these culverts are about 35-40% of bankfull width, which indicates that the combined culvert widths are narrower than the natural channel at bankfull flow and does not simulate natural channel flow through the crossings. Both sets of culverts have rust lines that are nearly half the height of each structure at the inlet, which suggests that these culverts are hydraulically undersized. The crossing of Road 4700-710 exhibits over-steepened fill slope, fill sloughing, and undercutting of the toe of the fill between the culverts. This crossing likely experiences annual fill erosion, which indicates a risk of failure. However, a geo-technical field review did not find this site to be a high risk for erosional failure of the fill in the crossing (Hanek, 2004). The crossing of Highway 138 shows better fill integrity and likely less risk of failure. All of the double pipes are circular pipes. Photos 1, 2, 3, and 4 (Figure 10) illustrate summer flow condition at these crossings and identify a rust line on each culvert.

A fourth crossing is on Road 2614-000 just upstream of Lemolo Reservoir. This crossing is a pipe-arch with a span that is about 50% of bankfull width. At this pipe span, the crossing is less likely to impede the flow and is closer to natural channel width and flow simulation.

Photo 1. Inlet at Highway 138 Crossing. Photo 2. Outlet at Highway 138 Crossing.

Photo 3. Inlet at Road 4700-710 Crossing. Photo 4. Outlet at Road 4700-710 Crossing.

Figure 10. Summer Flow Condition for the Lake Creek Double Culvert Crossings of Highway 138 and Road 4700-710.

ENVIRONMENTAL EFFECTS

Direct Effects: (Lake Creek at the Diamond Lake Outlet)
Alternatives 1 and 4 would not affect channel morphology since streamflow is not altered; therefore no direct, indirect or cumulative effects would occur.

Alternatives 2, 3, and 5 are the only proposed actions that would potentially affect the channel morphology of Lake Creek. During the draw down period, the bankfull and runoff flows would not directly affect the immediate channel outlet segment. After the outlet is dewatered, all bankfull and runoff flows would be routed down the canal. The canal is through bedrock providing a stable, resistive setting to fluvial changes.

The road 4795-000 crossing at the outlet would not experience the prolonged draw down flow since most of the flow would by-pass the outlet through the canal.

Indirect Effects: (Lake Creek and Downstream)
For Alternatives 2, 3 and 5, bankfull flow over the draw down period would likely accelerate erosion at the three erosional landslide features (Geology sites 3, 4, and 5) identified along Lake Creek and at occasional bank undercutting sites. Most of the delivered sediment would be sand size. The amount of sediment is expected to be limited because of the characteristics of bankfull flow for Lake Creek (see Streams and Streamflow section). At the Lake Creek Stream Gaging Station, bankfull flow would have a narrow depth of flow range from 0.3 to 1.0 feet above the long-term monthly average stream stage (depth) from September to April (not including winter or spring runoff flows). This illustrates the limited range of flow and related energy increase that bankfull flow has over the average, which is typical of High Cascade stream systems. In comparison to post-Mazama eruption, when the stream started eroding the ash-flow deposit and forming the current stream valley, the size and duration of erosion would be orders of magnitude smaller. In more recent time, the substantially greater 1954 draw down flow did not change the channel location or appear to degrade the channel. Therefore, the bankfull flow proposed in these alternatives also would not be expected to either.

Lake Creek bankfull flow also lacks the energy to transport large amounts of woody debris significant distances. If woody debris is moved, it is more likely to be transported short distances and reorganized into numerous debris dams. Smaller size woody debris may possibly become mobilized and accumulate in existing debris dams or at other points of constriction along Lake Creek such as culvert inlets.

Persistent stream energy would have the potential to sort finer substrate and improve pool depth where large wood directs flows to scour. This process appears to be absent per the Diamond Lake/Lemolo Lake Watershed Analysis (1998) and would be a benefit, but would not last indefinitely.

Under the draw down phase of Alternatives 2, 3, and 5, the canal would be opened when fall flows normally are starting to increase in response to precipitation. Fall flow increases generally cause turbidity in perennial streams from the natural flushing of stored sediments in intermittent tributaries and adjacent banks. When the canal is opened, the accumulated loose material from 50-years of non-use would be flushed causing turbid water for about a day. A temporary turbidity/sediment response from the canal would likely occur during the time of fall sediment flush making it difficult to distinguish the sources farther downstream from the canal. Turbid water from the canal would also become less noticeable farther downstream in Lake Creek because the larger soil size (i.e.; sand and larger) from the canal would likely settle in the downstream lower gradient segments. Once the canal sediment is flushed, the bedrock bottom of the canal would not be a sediment source during the draw down flow.

The upper extent of the Wild & Scenic section of the North Umpqua River is about 26 stream miles downstream from the mouth of Lake Creek. This distance includes three in-river storage structures (Lemolo Reservoir, Toketee Reservoir, and Soda Springs Reservoir) that change the timing and ability of the river to deliver turbid water to the Wild & Scenic section. If turbid water from Lake Creek is delivered to Lemolo Reservoir, it would not be distinguishable from natural fall turbidity response in the downstream river segments or the Wild & Scenic section.

Flow restriction at the 4700-710 and 4700-000 crossings would occur for the duration of the draw down period. Under bankfull flow, there is a concern for fluvial erosion of the fill and floatable wood blocking the inlet at the road 4700-710 crossing. Road 4700-000 crossing would have less concern for fill erosion, but floatable blockage is a potential concern for this public highway. These potential effects would be reduced through monitoring of the crossings especially when additional flow above bankfull would occur during winter storms and spring runoff. Equipment capable of removing mobile wood that would lodge at the culvert inlets would be available. These mitigative measures would reduce the risk of culvert failure.

No effect is expected at road crossing 2614-000 near the mouth of Lake Creek.

Cumulative Effects: (Lake Creek Combined with Other Actions)
Past timber harvest and road building have been limited in spatial extent within the Lake Creek Sub-watershed, which includes the total length of Lake Creek. Because of the low road density (1.13 miles per square mile) and the few total acres harvested (about 4% of the sub-watershed), no resulting effect on the streamflow regime has likely occurred to affect the channel condition. Therefore, the lack of past activity effects to streamflow and the lack of long-term (longer than project lifetime) direct and indirect alternative effects would result in no expected cumulative channel morphology effects from streamflow changes.

There are no proposed or planned actions along Lake Creek or downstream that would combine with any of the alternatives to create an additive effect on channel morphology by influencing streamflow. Therefore, no cumulative effects would occur.

Conclusions:

Only under Alternatives 2, 3, and 5 would there be any potential affect on channel morphology. Since the higher flows from the 1954 lake draw down did not appear to impact the channel integrity, the lower proposed flows for these alternatives also would not be expected to impact Lake Creek or the area downstream. Lemolo Reservoir would absorb and transfer the additional flow downstream within the existing streamflow regime.

Road crossings 4700-000 and 4700-710 would have some risk of plugging because of small size culverts and potential floatable wood. Road crossing 4700-710 also would have the risk of fill failure with the prolonged bankfull flow. Both of these potential conditions would be addressed through project monitoring and mitigation.

No effect is expected at road crossings 4795-000 at the outlet and 2614-000 near the mouth of Lake Creek.

Aquatic Conservation Strategy:

Under Alternatives 1 and 4, Lake Creek and downstream would not experience short-or long-term effects that would alter physical channel integrity or sediment regime. These two alternatives would have a neutral contribution to Aquatic Conservation Strategy (ACS) objectives 3[29] and 5[30] at the sub-watershed and watershed levels.

Alternatives 2, 3, and 5 would have a short-term affect on the channel. Short-term accelerated bank erosion along Lake Creek would likely occur at three distinct locations during the draw down phase. However, the amount of erosion would be orders of magnitude smaller in comparison to the development of the current stream valley after the eruption of Mazama. Within a few years following draw down, the bank erosion rate would return to the pre-draw down rate. Therefore, the long-term physical channel integrity and sediment regime would be maintained and these alternatives would have a neutral contribution to ACS objective 3 and 5 at the sub-watershed and watershed levels.

Table 2 provides a summary of important conclusions and a comparison of the alternatives effects on stream morphology.

[29] ACS objective 3: "Maintain and restore the physical integrity of the aquatic system, including shorelines, banks, and bottom configurations."

[30] ACS objective 5: "Maintain and restore the sediment regime under which aquatic ecosystems evolved. Elements of the sediment regime include the timing, volume, rate, and character of sediment input, storage, and transport."

Table 2. Comparison of Alternative Effects on Channel Morphology

Summary of alternative effects on Channel Morphology in Lake and North Umpqua River					
Stream/Water Body	**Alternative 1 - No Action**	**Alternative 2 -Rotenone with Put, Grow and Take Fishery**	**Alternative 3 – Rotenone with Put and Take Fishery**	**Alternative 4 - Mechanical & Biological**	**Alternative 5- Modified Rotenone and Fish Stocking**
Lake Creek (near outlet)	**Short-term** No effect on channel morphology because streamflow is not changed.	**Short-term** From years 1-3, no effect on channel morphology because most of the draw down flow bypasses the outlet.	**Short-term** From years 1-3, no effect on channel morphology because most of the draw down flow bypasses the outlet.	**Short-term** No effect on channel morphology because streamflow is not changed	**Short-term** From years 1-3, no effect on channel morphology because most of the draw down flow bypasses the outlet.
	Long-term No effect on channel morphology because streamflow is not changed.	**Long-term** After 3 years, no effect on channel morphology because the outlet post-project flow returns to the natural flow regime.	**Long-term** After 3 years, no effect on channel morphology because the outlet post-project flow returns to the natural flow regime.	**Long-term** No effect on channel morphology because streamflow is not changed.	**Long-term** After 3 years, no effect on channel morphology because the outlet post-project flow returns to the natural flow regime.
Lake Creek (downstream)	**Short-term** No effect on channel morphology because streamflow is not changed.	**Short-term** From years 1-3, during the draw down phase, temporary bank erosion at three specific sites and sorting of finer substrate and improving pool depth at large wood sites under continuous bankfull flow or higher winter or spring flows.	**Short-term** From years 1-3, during the draw down phase, temporary bank erosion at three specific sites and sorting of finer substrate and improving pool depth at large wood sites under continuous bankfull flow or higher winter or spring flows.	**Short-term** No effect on channel morphology because streamflow is not changed.	**Short-term** From years 1-3, during the draw down phase, temporary bank erosion at three specific sites and sorting of finer substrate and improving pool depth at large wood sites under continuous bankfull flow or higher winter or spring flows.
	Long-term No effect on channel morphology because streamflow is not changed	**Long-term** After 3 years, no effect on channel morphology because streamflow returns to the natural flow regime.	**Long-term** After 3 years, no effect on channel morphology because streamflow returns to the natural flow regime.	**Long-term** No effect on channel morphology because streamflow is not changed	**Long-term** After 3 years, no effect on channel morphology because streamflow returns to the natural flow regime.

Summary of alternative effects on Channel Morphology in Lake and North Umpqua River					
Stream/Water Body	**Alternative 1 - No Action**	**Alternative 2 -Rotenone with Put, Grow and Take Fishery**	**Alternative 3 - Rotenone with Put and Take Fishery**	**Alternative 4 - Mechanical & Biological**	**Alternative 5- Modified Rotenone and Fish Stocking**
North Umpqua River	**Short-term** No effect on channel morphology because streamflow is not changed	**Short-term** From years 1-3, during the initial months of the draw down phase, additional flow released to equal bankfull flow would only be potentially detectable immediately below Lemolo Reservoir but no effect on channel morphology would be expected because of the limited flow.	**Short-term** From years 1-3, during the initial months of the draw down phase, additional flow released to equal bankfull flow would only be potentially detectable immediately below Lemolo Reservoir but no effect on channel morphology would be expected because of the limited amount.	**Short-term** No effect on channel morphology because streamflow is not changed	**Short-term** From years 1-3, during the initial months of the draw down phase, additional flow released to equal bankfull flow would only be potentially detectable immediately below Lemolo Reservoir but no effect on channel morphology would be expected because of the limited amount.
	Long-term No effect on channel morphology because streamflow is not changed	**Long-term** After 3 years, no effect on channel morphology because streamflow returns to natural flow	**Long-term** After 3 years, no effect on channel morphology because streamflow returns to natural flow	**Long-term** No effect on channel morphology because streamflow is not changed	**Long-term** After 3 years, no effect on channel morphology because streamflow returns to natural flow

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Appendix A

Snowpack Data

At

Diamond Lake SNOTEL Site

/cdbs /or/ snow 41

DIAMOND LAKE	22F18	5320'	43º 11'	-122º 08'	NORTH UMPQUA 2E+07	KLAMATH

Station 22F 18, DIAMOND LAKE
----- --
Unit = inches

year/	January			February			March			April			May			June		
card	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe
	----	---	-----	----	---	-----	----	---	-----	----	---	-----	----	---	-----	----	---	-----
37-1	K/31	24	4.6	31-Jan	65	15.6	28-Feb	61	21.2	27-Mar	57	23.2	16-Apr	57	26.3			
38-1	K/30	12	3.6	29-Jan	31	7.9	24-Feb	63	18.2	30-Mar	91	33.1	30-Apr	48	22.5			
39-1	K/31	17	5.4	31-Jan	48	12.2	28-Feb	63	18.2	31-Mar	45	19.8						
40-1	K/30	3	1	31-Jan	12	3.1	Feb-29	32	9.6	30-Mar	29	9.8						
41-1	K/31	18	3.5	31-Jan	38	10.5	27-Feb	36	12.8	28-Mar	18	6.7						
42-1	K/30	21	5.6	29-Jan	21	6.8	26-Feb	45	14.6	31-Mar	30	12.1						
43-1	K/31	66	19.9	29-Jan	100	31.5	27-Feb	83	32.9	30-Mar	69	31.3						
44-1	K/30	9	2.6	30-Jan	27	7.4	28-Feb	35	10.6	30-Mar	27	10.6						
45-1	K/30	23	4.8	30-Jan	14	4.5	27-Feb	34	9.7	29-Mar	49	17.6						
46-1	K/31	50	18.8	31-Jan	81	26.1	28-Feb	84	31.8	31-Mar	85	35.9	30-Apr	55	26.7			
47-1	K/31	18	6.2	29-Jan	33	9.3	27-Feb	27	10.1	31-Mar	36	12.7	30-Apr	5	1.8			
48-1	1-Jan	26	8.9	28-Jan	30	11.8	Feb-29	60	21.9	26-Mar	68	25.6	28-Apr	54	21			
49-1	K/31	55	15.5	31-Jan	57	19.1	28-Feb	77	29.8	30-Mar	77	30.9	30-Apr	34	15.4			
50-1	K/31	32	6.2	31-Jan	74	23.5	28-Feb	54	21.5	28-Mar	82	30	30-Apr	45	18.9			
51-1	K/31	22	6.9	30-Jan	55	19.2	28-Feb	63	24	28-Mar	68	27.7	29-Apr	30	12.8			
52-1	K/31	79	20.8	1-Feb	86	31.1	28-Feb	92	38.4	29-Mar	90	40.7	30-Apr	48	26			
53-1	6-Jan	47	15.7	4-Feb	62	22.3	25-Feb	73	27.4	27-Mar	77	32.5	28-Apr	51	24			
54-1	1-Jan	23	5.5	4-Feb	69	25.6	27-Feb	67	26.3	31-Mar	66	28	1-May	32	14.3			
55-1	4-Jan	38	9.7	31-Jan	42	12.2	24-Feb	44	14.5	4-Apr	63	23.2	28-Apr	65	25.5			
56-1	12-Jan	49	15.8	1-Feb	60	20.3	1-Mar	106	33.7	30-Mar	86	34.7	29-Apr	52	24.8			

57-1	1-Jan	12	5.3	1-Feb	34	10.1	28-Feb	29	11.7	31-Mar	46	18.8	29-Apr	26	11.4			
58-1	K/27	43	11.4	22-Jan	50	17	24-Feb	56	22.9	21-Mar	63	25.2	24-Apr	58	24.6			
59-1	K/30	12	2.8	23-Jan	10	3	23-Feb	42	11.8	23-Mar	32	11.9	27-Apr	6	2.5			
60-1	K/24	15	2.2	23-Jan	36	10.1	21-Feb	43	14.9	22-Mar	48	19.8	26-Apr	42	19.3			
61-1	K/28	22	7.5	24-Jan	22	8.5	20-Feb	36	11	27-Mar	65	22.1	26-Apr	37	14.9			
62-1	K/27	44	15.2	24-Jan	53	16.9	21-Feb	53	18.8	26-Mar	74	27.6	28-Apr	36	14.7			
63-1	K/27	9	3.2	24-Jan	9	4.1	25-Feb	3	1.2	26-Mar	4	1.6	30-Apr	18	7.3			
64-1	K/30	13	4.6	23-Jan	69	14.7	20-Feb	61	18.8	24-Mar	77	26	29-Apr	45	17.4			
65-1	K/30	70	16.5	22-Jan	62	21.6	26-Feb	58	23.3	24-Mar	49	21.8	29-Apr	24	12.1			
66-1	K/20	5	1.6	26-Jan	63	20.7	25-Feb	69	24	28-Mar	72	29.1	26-Apr	35	16.6	24-May	2	0.8
67-1	K/29	24	5.8	23-Jan	54	12.6	24-Feb	51	16.8	29-Mar	60	20	24-Apr	63	23.3	26-May	10	4.4
68-1	K/26	26	7.2	23-Jan	26	9.8	20-Feb	34	12.6	20-Mar	34	12.6	24-Apr	18	8.3	27-May	0	0
69-1	K/26	33	7.6	27-Jan	69	17.2	24-Feb	73	24	24-Mar	70	27.4	23-Apr	46	21.8	26-May	2	1.3
70-1	K/29	28	5.4	22-Jan	22	8.8	27-Feb	36	14.4	23-Mar	40	16.6	24-Apr	36	14.6	26-May	4	1.9
71-1	K/23	37	9.2	22-Jan	48	18.9	22-Feb	58	20.7	29-Mar	79	31	28-Apr	72	27.5	28-May	23	11.9
72-1	K/30	50	14.4	28-Jan	66	21.6	23-Feb	78	23.5	29-Mar	60	25.6	24-Apr	58	26.1	30-May	5	2.3
73-1	K/29	19	3.8	29-Jan	30	8	23-Feb	31	10.2	27-Mar	32	11.6	30-Apr	10	3.8	31-May	0	0
74-1	K/27	48	16.9	31-Jan	66	21.4	28-Feb	95	27.9	25-Mar	84	31.6	30-Apr	78	33.9	30-May	35	15.7
75-1	K/30	34	8.5	29-Jan	48	16	25-Feb	72	24.6	25-Mar	115	33	28-Apr	89	34.9	E/ST		10.8
76-1	K/29	26	9.2	30-Jan		16	25-Feb		24.9	25-Mar	83	24.9	27-Apr	62	24.8	25-May	19	8.8
77-1	K/29	2	0.6	E/ST		1.8	24-Feb	11	2.3	29-Mar	26	6.8	25-Apr	1	0.7	31-May	0	0
78-1	K/29	20	5.9	E/ST		8.1	E/ST		11	27-Mar	27	11.2	26-Apr	20	8.4	31-May	0	0
79-1	K/21	11	2.7	29-Jan	11	2.6	23-Feb	39	9.7	26-Mar	23	9.2	25-Apr	22	9.6	23-May	0	0
80-1	K/27	15	3.7	28-Jan	20	6.2	25-Feb	19	7.6	25-Mar	33	10.8	28-Apr	13	5.6	29-May	0	0
81-1	K/29	3	0.7	27-Jan	6	1.1	25-Feb	5	0.9	25-Mar	3	1.2	28-Apr	0	0	27-May	0	0
82-1	K/21	28	7.3	26-Jan	76	20.9	23-Feb	56	20.1	26-Mar	51	21.4	28-Apr	52	22.4	26-May	12	6.1
83-1	K/28	44	12.6	25-Jan	46	14.5	22-Feb	54	20.4	30-Mar	66	23.7	28-Apr	51	22	26-May	17	7.4
84-1	K/28	43	11.4	25-Jan	38	12.8	E/ST		18.2	27-Mar	50	18.3	E/ST		15.1	E/ST		3.3

85-1	K/27	41	12.7	31-Jan	40	13.6	27-Feb	50	19.4	25-Mar	57	18.6	E/ST	15.4	E/ST	3.4
86-1	K/30	25	8.1	30-Jan	23	8.7	27-Feb	42	16.6	24-Mar	34	14.1				
87-1	K/30	18	4.9	28-Jan	40	9.2	27-Feb	43	13.9	31-Mar	36	15.6				
88-1	K/28	18	4.7	27-Jan	28	8.4	25-Feb	22	8.2	28-Mar	17	6.1				
89-1	K/29	43	11.6	31-Jan	51	16.9	27-Feb	54	20	30-Mar	55	22.1				

Appendix B

Air Temperature Data

Station: OR22F18S, DIAM OND LAKE

Daily max mean

YR	Jun	Jul	Aug
1989	20	21	21
1990	17	24	23
1991	16	24	24
1992	21	22	26
1993	16	16	17
1994	18	26	24
1995	16	22	22
1996	18	26	26
1997	16	22	24
1998	18	26	26
1999	17	23	22
2000	20	22	25
2001	17	23	25
2002	20	27	24
ave C	**18**	**23**	**24**
Ave F	64	73	75

YR	Dec	Jan	Feb
1988	2	4	11
1989	6	5	2
1990	10	4	4
1991	1	7	10
1992	6	7	8
1993	2	1	4
1994	5	8	4
1995	3	3	10
1996	4	3	6
1997	3	5	6
1998	5	3	3
1999	3	5	2
2000	6	3	5
2001	7	6	5
2002	2	3	8
ave C	4	4	6
Ave F	39	39	43

Station:	OR22F18S,	DIAM	OND	LAKE
daily min mean				
	Dec	Jan	Feb	
1988	-7	-7	-6	
1989	-6	-7	-11	
1990	-4	-5	-8	
1991	-11	-7	-2	
1992	-5	-5	-3	
1993	-7	-9	-9	
1994	-5	-5	-7	
1995	-7	-3	-3	
1996	-3	-5	-5	
1997	-4	-7	-6	
1998	-7	-3	-4	
1999	-8	-6	-7	
2000	-4	-6	-3	
2001	-5	-6	-8	
2002	-5	-8	-6	
ave C	-6	-6	-6	
ave F	21	21	21	

Appendix C

Mean Monthly Flow

In

Lake Creek

Monthly Streamflow Statistics for Oregon
USGS 14312500 LAKE CREEK NEAR DIAMOND LAKE,OREG.

YEAR	Monthly mean streamflow, in ft^3/s											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1922										43.3		
1923					46	63.5	46.5	31.5	23.8			
1925				44.1	72.3	94.5	39.4	21.4	22.7			
1926										16.5	32.2	88.7
1927	71.9	91.3	85.3	58.1	59.5	82	66.5	35	37			
1928				74.9	74.2	58	38.1	17.7	18.9			
1929				60.5	54.9	55.3	36	23.6	12.4			
1930							21.7			17		
1931					35.6			11.2	12.4			
1933										34.8	36.8	56.7
1934	71.2	60.8	35.9	28.4	30.4	23.1	23	24.2	20.6	43.8	36.7	67.6
1935	84.3	61.5	57.4	56.5	38.3	40.6	32.8	31.9	29.8	27.8	27.8	33.2
1936	65.2	54.6	64.6	53.4	50.1	57.4	41.9	27.6	21.1	24.9	14.7	33.2
1937	56.4	61.9	51.8	63.7	47.1	34.5	21.9	18	16.2	35.5	46.1	84
1938	89.6	95	78.7	64.4	65.6	73.8	45.5	35.1	23	18.1	56.9	61.6
1939	57.5	72.6	73.5	29	49.4	39.6	29.1	26	25.3	20.3	28.2	54.6
1940	70	58.4	70.8	71.3	52.8	44.9	24.2	24.3	25	25.9	28.9	49.4
1941	64.6	57.2	28.5	24	50.2	47.1	33	34.2	23.4	11.8	37.2	64.9
1942	79.7	74	45.4	5	42.4	38.2	30.9	25.9	11.7	17.7	51.2	107
1943	98.5	59.7	46.5	74.5	107	97.8	46.8	36	32.3	50.4	73.9	72.7
1944	70.6	49.7	50.8	55.3	50	51.1	41	33.2	16.9	26	61.4	53.4
1945	55	69.8	65.3	56.4	66.6	54.6	31.1	29.6	32.4	17.8	36.5	93.6
1946	94.4	70.3	65.9	69.6	68	60.2	42.6	31.2	30	48.3	68.9	76.7
1947	49.2	57.9	63.6	61	67	35	52.9	27	26.2	51.4	62	53.6
1948	80.1	70.9	70.9	63.7	56	84	59	36.5	35.9	16.5	39.9	85.5

1949	73.4	78.3	62.1	34.4	92.5	82.5	33.6	27.9	26.8	56.5	59.1	62.3
1950	109	112	97.8	79.4	57.6	94.8	49.2	32.6	47.8	78.2	104	98.7
1951	113	123	104	82.3	91.3	94.6	57.1	35.9	34.3	92.8	86.9	107
1952	99.7	96.9	85.4	78.5	93.8	119	70.1	48.6	44	35.1	26.8	139
1953	142	140	101	75.1	83.3	149	81.1	59.7	58.2			
1971										93.5	85.3	106
1972	96.3	88.2	134	106	96.1	109	29.5	46.3	55.6	77.3	77	88.7
1973	102	81.1	64.4	39.9	54.7	40	27.1	18.9	31.3	74.3	133	110
1974	124	93.3	85.5	80.9	38.7	146	77.5	15.9	35.5	49	67.9	75.6
1975	96.3	91.5	94.3	78.6	72.9	97.2	72.5	39.6	14.2	76.1	117	99.4
1976	101	76.4	74.9	67.3	59.5	73.5	54.3	49.5	26.8	28.9	72.6	38.4
1977	33.7	33.9	63.1	46	57.1	42.5	20.7	19.5	56.3	61.5		
1978		70	55.2	53.4	55.8	43.3	32	11	21.3	33.7	58.8	56.7
1979	47.4	67.1	61.5	46.6	44.2	26.3	9.53	9.2	25	45	62.1	64.4
1980	78.4	62.2	60.7	47.3	54.4	39.4	11.4	6.19	10.6	28.6	63	71
1981	53	54.7	49	44.9	35	26.1	17.1	10.1	7.41	21.7	109	130
1982	109	88.2	80.1	66.5	43.2	106	69.6	16	22.1	63.3	111	103
1983	77.6	83.1	86.8	84.7	64	120	68.6	38.9	35.4	32.2	126	107
1984	84.7	80.1	80.4	78.6	93	127	55.3	31.5	41.3			
1999										55.5	104	83.3
2000	73.5	89.9	80.3	47.9	97.4	57.5	45.3	25.2	38	45	88.9	72.4
2001	62.7	58.3	47.1	23.6	31.3	30.9	23.8	12.1	19.6	45.2	82.3	96.2
2002	78.9	64.5	53.3	35.9	26.5	27.5	21.5	7.5	16.4			
Mean of monthly streamflows	80.9	75.6	69.6	57.8	60.1	68	41.2	27.2	27.7	42.1	65.9	79

Yr-Mean 58

Appendix D

Cumulative Draw Down Volume

By Month

USGS 14312500 LAKE CREEK NEAR DIAMOND LAKE,OREG.
Bankfull mean = 110 - mean_value

	Water	Year	cfs	cfs	cfs	cfs			Ac-ft	
month_nu	month_nu	day_nu	mean_value	max_value	min_value	bkfl-mean	ac-ft/sec	ac-ft/day	Accum Vol	Draw Down
Sep	9	1	26.1	67	4	83.9	0.001926	166.4132		
Sep	9	2	26.2	67	4.5	83.8	0.001924	166.2149		
Sep	9	3	26.1	65	4.8	83.9	0.001926	166.4132		
Sep	9	4	25.5	64	5.5	84.5	0.00194	167.6033		
Sep	9	5	26.2	67	5.5	83.8	0.001924	166.2149		
Sep	9	6	25.7	64	2	84.3	0.001935	167.2066		
Sep	9	7	25.2	62	6	84.8	0.001947	168.1983		
Sep	9	8	25.8	62	6	84.2	0.001933	167.0083		
Sep	9	9	25.8	59	6	84.2	0.001933	167.0083		
Sep	9	10	25.8	59	6	84.2	0.001933	167.0083		
Sep	9	11	25.5	59	6	84.5	0.00194	167.6033		
Sep	9	12	25.6	57	6	84.4	0.001938	167.405		
Sep	9	13	26.7	57	6	83.3	0.001912	165.2231		
Sep	9	14	26.2	59	6	83.8	0.001924	166.2149		
Sep	9	15	26.6	57	6	83.4	0.001915	165.4215		
Sep	9	16	26.8	57	6	83.2	0.00191	165.0248	165	Start
Sep	9	17	27.5	59	6	82.5	0.001894	163.6364	329	
Sep	9	18	27.9	99	5	82.1	0.001885	162.843	492	
Sep	9	19	28.1	97	5	81.9	0.00188	162.4463	654	
Sep	9	20	29.2	95	5	80.8	0.001855	160.2645	814	
Sep	9	21	29.7	121	3	80.3	0.001843	159.2727	973	
Sep	9	22	29.5	116	2	80.5	0.001848	159.6694	1133	
Sep	9	23	29.4	116	1	80.6	0.00185	159.8678	1293	
Sep	9	24	30.4	130	1	79.6	0.001827	157.8843	1451	
Sep	9	25	31.5	135	1	78.5	0.001802	155.7025	1607	
Sep	9	26	30.8	128	1	79.2	0.001818	157.0909	1764	
Sep	9	27	31.2	121	7	78.8	0.001809	156.2975	1920	
Sep	9	28	31.3	140	5	78.7	0.001807	156.0992	2076	

Sep	9	29	31.1	138	3	78.9	0.001811	156.4959	2233
Sep	9	30	31.6	128	3	78.4	0.0018	155.5041	2388
Oct	10	1	33.6	121	1	76.4	0.001754	151.5372	2540
Oct	10	2	33	116	1	77	0.001768	152.7273	2692
Oct	10	3	32.8	113	2	77.2	0.001772	153.124	2845
Oct	10	4	32	113	2	78	0.001791	154.7107	3000
Oct	10	5	33	105	3	77	0.001768	152.7273	3153
Oct	10	6	33.9	98	4	76.1	0.001747	150.9421	3304
Oct	10	7	34.3	103	4	75.7	0.001738	150.1488	3454
Oct	10	8	34.8	108	4	75.2	0.001726	149.157	3603
Oct	10	9	36	103	7.1	74	0.001699	146.7769	3750
Oct	10	10	37.6	117	7.5	72.4	0.001662	143.6033	3894
Oct	10	11	37.1	114	6	72.9	0.001674	144.595	4038
Oct	10	12	38.6	110	11	71.4	0.001639	141.6198	4180
Oct	10	13	38.9	108	9	71.1	0.001632	141.0248	4321
Oct	10	14	39.2	105	11	70.8	0.001625	140.4298	4461
Oct	10	15	38.3	103	13	71.7	0.001646	142.2149	4603
Oct	10	16	38.3	99	13	71.7	0.001646	142.2149	4746
Oct	10	17	39.3	103	5	70.7	0.001623	140.2314	4886
Oct	10	18	39.4	103	5	70.6	0.001621	140.0331	5026
Oct	10	19	40.7	99	5	69.3	0.001591	137.4545	5163
Oct	10	20	41.8	109	4	68.2	0.001566	135.2727	5299
Oct	10	21	43.6	109	4	66.4	0.001524	131.7025	5430
Oct	10	22	45	109	4	65	0.001492	128.9256	5559
Oct	10	23	45.9	112	4	64.1	0.001472	127.1405	5686
Oct	10	24	49.6	116	4	60.4	0.001387	119.8017	5806
Oct	10	25	49.6	107	4	60.4	0.001387	119.8017	5926
Oct	10	26	51.5	105	5	58.5	0.001343	116.0331	6042
Oct	10	27	52.2	119	5	57.8	0.001327	114.6446	6157
Oct	10	28	53.3	131	5	56.7	0.001302	112.4628	6269
Oct	10	29	54.5	159	8	55.5	0.001274	110.0826	6379
Oct	10	30	55.3	172	10	54.7	0.001256	108.4959	6488
Oct	10	31	57.8	159	6	52.2	0.001198	103.5372	6591
Nov	11	1	58.4	159	4	51.6	0.001185	102.3471	6694
Nov	11	2	57.6	151	10	52.4	0.001203	103.9339	6798
Nov	11	3	57.5	138	16	52.5	0.001205	104.1322	6902

Nov	11	4	59.1	136	16	50.9	0.001169	100.9587	7003
Nov	11	5	59.9	135	15	50.1	0.00115	99.3719	7102
Nov	11	6	63.3	160	15	46.7	0.001072	92.6281	7195
Nov	11	7	63.9	160	13	46.1	0.001058	91.43802	7286
Nov	11	8	62.4	160	5	47.6	0.001093	94.41322	7380
Nov	11	9	64.3	160	13	45.7	0.001049	90.64463	7471
Nov	11	10	63.9	150	14	46.1	0.001058	91.43802	7563
Nov	11	11	62.9	150	13	47.1	0.001081	93.42149	7656
Nov	11	12	62.9	150	14	47.1	0.001081	93.42149	7749
Nov	11	13	64	150	14	46	0.001056	91.23967	7841
Nov	11	14	64.5	150	15	45.5	0.001045	90.24793	7931
Nov	11	15	64.8	153	5	45.2	0.001038	89.65289	8021
Nov	11	16	66.8	184	14	43.2	0.000992	85.68595	8106
Nov	11	17	69.6	205	7.2	40.4	0.000927	80.13223	8186
Nov	11	18	68.6	200	8.7	41.4	0.00095	82.1157	8268
Nov	11	19	67.9	194	9	42.1	0.000966	83.50413	8352
Nov	11	20	67.6	201	9.4	42.4	0.000973	84.09917	8436
Nov	11	21	68.9	213	9.9	41.1	0.000944	81.52066	8518
Nov	11	22	66.1	205	5	43.9	0.001008	87.07438	8605
Nov	11	23	67.5	213	9.4	42.5	0.000976	84.29752	8689
Nov	11	24	65.8	164	8	44.2	0.001015	87.66942	8777
Nov	11	25	65.5	167	9	44.5	0.001022	88.26446	8865
Nov	11	26	65.1	142	9	44.9	0.001031	89.05785	8954
Nov	11	27	65.9	139	7	44.1	0.001012	87.47107	9041
Nov	11	28	64.9	129	7	45.1	0.001035	89.45455	9131
Nov	11	29	64.9	135	2	45.1	0.001035	89.45455	9220
Nov	11	30	65.5	133	11	44.5	0.001022	88.26446	9309
Dec	12	1	68.5	132	18	41.5	0.000953	82.31405	9391
Dec	12	2	70.3	127	19	39.7	0.000911	78.7438	9470
Dec	12	3	71.6	121	19	38.4	0.000882	76.16529	9546
Dec	12	4	71.8	134	19	38.2	0.000877	75.7686	9622
Dec	12	5	72.8	145	18	37.2	0.000854	73.78512	9695
Dec	12	6	73.3	121	10	36.7	0.000843	72.79339	9768
Dec	12	7	76.5	150	21	33.5	0.000769	66.44628	9835
Dec	12	8	80.5	212	21	29.5	0.000677	58.5124	9893
Dec	12	9	78.3	165	22	31.7	0.000728	62.87603	9956

Dec	12	10	77.5	176	18	32.5	0.000746	64.46281	10020
Dec	12	11	77	165	18	33	0.000758	65.45455	10086
Dec	12	12	75	150	6	35	0.000803	69.42149	10155
Dec	12	13	74.9	127	21	35.1	0.000806	69.61983	10225
Dec	12	14	78.2	201	24	31.8	0.00073	63.07438	10288
Dec	12	15	80.7	232	28	29.3	0.000673	58.1157	10346
Dec	12	16	80	216	35	30	0.000689	59.50413	10406
Dec	12	17	80.2	200	30	29.8	0.000684	59.10744	10465
Dec	12	18	80.2	186	33	29.8	0.000684	59.10744	10524
Dec	12	19	80.1	179	32	29.9	0.000686	59.30579	10583
Dec	12	20	77.9	172	23	32.1	0.000737	63.66942	10647
Dec	12	21	79.1	165	32	30.9	0.000709	61.28926	10708
Dec	12	22	79.6	159	32	30.4	0.000698	60.29752	10768
Dec	12	23	80.2	153	32	29.8	0.000684	59.10744	10828
Dec	12	24	80.4	148	32	29.6	0.00068	58.71074	10886
Dec	12	25	80.1	144	33	29.9	0.000686	59.30579	10946
Dec	12	26	79.6	145	34	30.4	0.000698	60.29752	11006
Dec	12	27	79.7	146	26	30.3	0.000696	60.09917	11066
Dec	12	28	81.4	168	17	28.6	0.000657	56.72727	11123
Dec	12	29	83.5	175	17	26.5	0.000608	52.56198	11175
Dec	12	30	84	166	18	26	0.000597	51.57025	11227
Dec	12	31	83.4	230	19	26.6	0.000611	52.76033	11280
Jan	1	1	83.5	250	19	26.5	0.000608	52.56198	11332
Jan	1	2	81.3	210	19	28.7	0.000659	56.92562	11389
Jan	1	3	80	180	20	30	0.000689	59.50413	11449
Jan	1	4	78.5	155	11	31.5	0.000723	62.47934	11511
Jan	1	5	80.8	144	21	29.2	0.00067	57.91736	11569
Jan	1	6	79.6	136	21	30.4	0.000698	60.29752	11629
Jan	1	7	79	133	22	31	0.000712	61.4876	11691
Jan	1	8	79.3	128	23	30.7	0.000705	60.89256	11752
Jan	1	9	79	134	25	31	0.000712	61.4876	11813
Jan	1	10	78.6	131	35	31.4	0.000721	62.28099	11875
Jan	1	11	78.1	128	15	31.9	0.000732	63.27273	11939
Jan	1	12	80.7	128	36	29.3	0.000673	58.1157	11997
Jan	1	13	81.8	131	36	28.2	0.000647	55.93388	12053
Jan	1	14	82	131	36	28	0.000643	55.53719	12108

Jan	1	15	81.7	135	44	28.3	0.00065	56.13223	12164
Jan	1	16	83.3	167	44	26.7	0.000613	52.95868	12217
Jan	1	17	83.6	165	44	26.4	0.000606	52.36364	12270
Jan	1	18	82.5	166	20	27.5	0.000631	54.54545	12324
Jan	1	19	83.3	179	45	26.7	0.000613	52.95868	12377
Jan	1	20	82.7	182	45	27.3	0.000627	54.14876	12431
Jan	1	21	82.9	179	45	27.1	0.000622	53.75207	12485
Jan	1	22	82.2	168	28	27.8	0.000638	55.1405	12540
Jan	1	23	82.1	162	7.1	27.9	0.00064	55.33884	12596
Jan	1	24	81.5	156	6.8	28.5	0.000654	56.52893	12652
Jan	1	25	79.2	153	5.7	30.8	0.000707	61.09091	12713
Jan	1	26	80.5	153	4.6	29.5	0.000677	58.5124	12772
Jan	1	27	79.4	150	4.8	30.6	0.000702	60.69421	12832
Jan	1	28	78.3	148	5	31.7	0.000728	62.87603	12895
Jan	1	29	78.4	145	27	31.6	0.000725	62.67769	12958
Jan	1	30	77	139	28	33	0.000758	65.45455	13023
Jan	1	31	75.9	137	25	34.1	0.000783	67.63636	13091
Feb	2	1	74.1	137	26	35.9	0.000824	71.20661	13162
Feb	2	2	75	136	27	35	0.000803	69.42149	13232
Feb	2	3	75.4	156	25	34.6	0.000794	68.6281	13300
Feb	2	4	75.9	156	28	34.1	0.000783	67.63636	13368
Feb	2	5	76.4	162	28	33.6	0.000771	66.64463	13435
Feb	2	6	76.4	165	29	33.6	0.000771	66.64463	13501
Feb	2	7	76.2	159	29	33.8	0.000776	67.04132	13568
Feb	2	8	75.1	162	30	34.9	0.000801	69.22314	13638
Feb	2	9	75.7	159	31	34.3	0.000787	68.03306	13706
Feb	2	10	74.9	150	33	35.1	0.000806	69.61983	13775
Feb	2	11	73.9	150	33	36.1	0.000829	71.60331	13847
Feb	2	12	74.3	150	34	35.7	0.00082	70.80992	13918
Feb	2	13	76.1	140	33	33.9	0.000778	67.23967	13985
Feb	2	14	75.1	140	35	34.9	0.000801	69.22314	14054
Feb	2	15	74.8	140	35	35.2	0.000808	69.81818	14124
Feb	2	16	75.6	140	37	34.4	0.00079	68.2314	14192
Feb	2	17	76.8	140	37	33.2	0.000762	65.85124	14258
Feb	2	18	76.8	130	39	33.2	0.000762	65.85124	14324
Feb	2	19	75.9	130	39	34.1	0.000783	67.63636	14391

Feb	2	20	76.3	130	33	33.7	0.000774	66.84298	14458
Feb	2	21	75.4	130	27	34.6	0.000794	68.6281	14527
Feb	2	22	74.4	130	32	35.6	0.000817	70.61157	14598
Feb	2	23	75.5	137	35	34.5	0.000792	68.42975	14666
Feb	2	24	74.6	120	37	35.4	0.000813	70.21488	14736
Feb	2	25	74.6	120	39	35.4	0.000813	70.21488	14806
Feb	2	26	74.5	120	41	35.5	0.000815	70.41322	14877
Feb	2	27	74.8	120	41	35.2	0.000808	69.81818	14947
Feb	2	28	74.4	120	41	35.6	0.000817	70.61157	15017
Feb	2	29	77.9	113	45	32.1	0.000737	63.66942	15081
Mar	3	1	73.5	121	40	36.5	0.000838	72.39669	15153
Mar	3	2	75.2	147	40	34.8	0.000799	69.02479	15222
Mar	3	3	75	153	39	35	0.000803	69.42149	15292
Mar	3	4	74	150	38	36	0.000826	71.40496	15363
Mar	3	5	73.4	147	38	36.6	0.00084	72.59504	15436
Mar	3	6	72.7	147	38	37.3	0.000856	73.98347	15510
Mar	3	7	72	141	39	38	0.000872	75.3719	15585
Mar	3	8	70.6	135	39	39.4	0.000904	78.14876	15663
Mar	3	9	70.7	132	39	39.3	0.000902	77.95041	15741
Mar	3	10	70.7	132	38	39.3	0.000902	77.95041	15819
Mar	3	11	70.6	135	38	39.4	0.000904	78.14876	15897
Mar	3	12	70	141	38	40	0.000918	79.33884	15977
Mar	3	13	69.6	147	37	40.4	0.000927	80.13223	16057
Mar	3	14	68.8	144	29	41.2	0.000946	81.71901	16139
Mar	3	15	68.5	144	18	41.5	0.000953	82.31405	16221
Mar	3	16	69	141	17	41	0.000941	81.32231	16302
Mar	3	17	67.9	141	11	42.1	0.000966	83.50413	16386
Mar	3	18	69.2	141	13	40.8	0.000937	80.92562	16467
Mar	3	19	69.1	138	13	40.9	0.000939	81.12397	16548
Mar	3	20	70.1	135	15	39.9	0.000916	79.1405	16627
Mar	3	21	70	129	18	40	0.000918	79.33884	16706
Mar	3	22	68.6	135	19	41.4	0.00095	82.1157	16788
Mar	3	23	68.5	132	19	41.5	0.000953	82.31405	16871
Mar	3	24	69.4	132	14	40.6	0.000932	80.52893	16951
Mar	3	25	68.9	126	14	41.1	0.000944	81.52066	17033
Mar	3	26	67.2	123	7.7	42.8	0.000983	84.89256	17118

Mar	3	27	65.3	121	11	44.7	0.001026	88.66116	17206
Mar	3	28	64.6	116	8	45.4	0.001042	90.04959	17296
Mar	3	29	64.8	113	5	45.2	0.001038	89.65289	17386
Mar	3	30	66.1	108	2	43.9	0.001008	87.07438	17473
Mar	3	31	66	111	1	44	0.00101	87.27273	17560
Apr	4	1	65.1	109	4	44.9	0.001031	89.05785	17649
Apr	4	2	63.9	110	5	46.1	0.001058	91.43802	17741
Apr	4	3	63.9	108	5	46.1	0.001058	91.43802	17832
Apr	4	4	63.6	105	5	46.4	0.001065	92.03306	17924
Apr	4	5	62.5	116	5	47.5	0.00109	94.21488	18018
Apr	4	6	61.8	132	5	48.2	0.001107	95.60331	18114
Apr	4	7	61.5	126	9	48.5	0.001113	96.19835	18210
Apr	4	8	61.1	121	5	48.9	0.001123	96.99174	18307
Apr	4	9	60.5	118	3	49.5	0.001136	98.18182	18405
Apr	4	10	59.5	113	3	50.5	0.001159	100.1653	18506
Apr	4	11	59.3	110	3	50.7	0.001164	100.562	18606
Apr	4	12	58.2	118	3	51.8	0.001189	102.7438	18709
Apr	4	13	58.9	118	3	51.1	0.001173	101.3554	18810
Apr	4	14	59.6	118	3	50.4	0.001157	99.96694	18910
Apr	4	15	58.5	113	3	51.5	0.001182	102.1488	19012
Apr	4	16	56.8	108	6	53.2	0.001221	105.5207	19118
Apr	4	17	56	105	4	54	0.00124	107.1074	19225
Apr	4	18	55	100	4	55	0.001263	109.0909	19334
Apr	4	19	54.6	98	4	55.4	0.001272	109.8843	19444
Apr	4	20	54.5	96	4	55.5	0.001274	110.0826	19554
Apr	4	21	53.5	94	4	56.5	0.001297	112.0661	19666
Apr	4	22	53	94	5	57	0.001309	113.0579	19779
Apr	4	23	53.2	94	5	56.8	0.001304	112.6612	19892
Apr	4	24	54.6	94	4	55.4	0.001272	109.8843	20002
Apr	4	25	54.6	94	5	55.4	0.001272	109.8843	20112
Apr	4	26	53.4	94	5	56.6	0.001299	112.2645	20224
Apr	4	27	54.7	94	4	55.3	0.00127	109.686	20334
Apr	4	28	54.9	99	6	55.1	0.001265	109.2893	20443
Apr	4	29	55	99	6	55	0.001263	109.0909	20552
Apr	4	30	54.9	96	7	55.1	0.001265	109.2893	20661
May	5	1	55.6	102	9	54.4	0.001249	107.9008	20769

May	5	2	56.5	118	9.9	53.5	0.001228	106.1157	20875
May	5	3	57.3	111	10	52.7	0.00121	104.5289	20980
May	5	4	56.7	110	11	53.3	0.001224	105.719	21085
May	5	5	58.4	154	12	51.6	0.001185	102.3471	21188
May	5	6	57.4	148	13	52.6	0.001208	104.3306	21292
May	5	7	58	142	11	52	0.001194	103.1405	21395
May	5	8	57.3	139	12	52.7	0.00121	104.5289	21500
May	5	9	56.6	134	14	53.4	0.001226	105.9174	21606
May	5	10	56	131	15	54	0.00124	107.1074	21713
May	5	11	58.7	128	10	51.3	0.001178	101.7521	21815
May	5	12	58	126	7.6	52	0.001194	103.1405	21918
May	5	13	58	125	9.4	52	0.001194	103.1405	22021
May	5	14	57.8	123	12	52.2	0.001198	103.5372	22124
May	5	15	58.4	118	15	51.6	0.001185	102.3471	22227
May	5	16	60	119	18	50	0.001148	99.17355	22326
May	5	17	61.9	117	21	48.1	0.001104	95.40496	22421
May	5	18	62.3	117	24	47.7	0.001095	94.61157	22516
May	5	19	62.9	118	25	47.1	0.001081	93.42149	22609
May	5	20	60.1	115	27	49.9	0.001146	98.97521	22708
May	5	21	59.5	121	27	50.5	0.001159	100.1653	22809
May	5	22	61.7	121	26	48.3	0.001109	95.80165	22904
May	5	23	62.7	129	26	47.3	0.001086	93.81818	22998
May	5	24	64.5	126	26	45.5	0.001045	90.24793	23088
May	5	25	65.1	124	26	44.9	0.001031	89.05785	23177
May	5	26	65.8	126	26	44.2	0.001015	87.66942	23265
May	5	27	66.7	126	27	43.3	0.000994	85.8843	23351
May	5	28	67.7	126	27	42.3	0.000971	83.90083	23435
May	5	29	68.4	142	27	41.6	0.000955	82.5124	23517
May	5	30	68.2	140	19	41.8	0.00096	82.90909	23600
May	5	31	67.1	144	5.7	42.9	0.000985	85.09091	23685
Jun	6	1	68.7	158	6	41.3	0.000948	81.91736	23767
Jun	6	2	71.1	173	6.3	38.9	0.000893	77.15702	23844
Jun	6	3	69.8	170	6.8	40.2	0.000923	79.73554	23924
Jun	6	4	70.1	165	7.5	39.9	0.000916	79.1405	24003
Jun	6	5	71.3	160	7.8	38.7	0.000888	76.76033	
Jun	6	6	75.8	181	9.1	34.2	0.000785	67.83471	

Jun	6	7	73.9	177	17	36.1	0.000829	71.60331
Jun	6	8	74.5	174	26	35.5	0.000815	70.41322
Jun	6	9	74.7	176	23	35.3	0.00081	70.01653
Jun	6	10	75.3	174	26	34.7	0.000797	68.82645
Jun	6	11	74.5	184	22	35.5	0.000815	70.41322
Jun	6	12	75.5	181	27	34.5	0.000792	68.42975
Jun	6	13	74.7	182	22	35.3	0.00081	70.01653
Jun	6	14	73	179	26	37	0.000849	73.38843
Jun	6	15	72.5	176	21	37.5	0.000861	74.38017
Jun	6	16	71.9	176	26	38.1	0.000875	75.57025
Jun	6	17	68.5	170	22	41.5	0.000953	82.31405
Jun	6	18	69.5	168	22	40.5	0.00093	80.33058
Jun	6	19	67.3	168	19	42.7	0.00098	84.69421
Jun	6	20	68.3	165	19	41.7	0.000957	82.71074
Jun	6	21	64.8	162	17	45.2	0.001038	89.65289
Jun	6	22	64.8	159	20	45.2	0.001038	89.65289
Jun	6	23	63.1	153	16	46.9	0.001077	93.02479
Jun	6	24	62.9	150	20	47.1	0.001081	93.42149
Jun	6	25	61.5	138	16	48.5	0.001113	96.19835
Jun	6	26	60.3	132	9.1	49.7	0.001141	98.57851
Jun	6	27	57.8	126	9.5	52.2	0.001198	103.5372
Jun	6	28	58	124	10	52	0.001194	103.1405
Jun	6	29	54.5	123	11	55.5	0.001274	110.0826
Jun	6	30	54.3	122	10	55.7	0.001279	110.4793

Appendix E

Annual Snow Water Equivalent

At

Diamond Lake SNOTEL Site

Station SNOTEL # OR22F18S DIAM OND LAKE
(inches of water)

YR	NOV	DEC	JAN	FEB	MAR	APR		TOTAL	AVE
1981	0.14	1.05	0.62	1.32	1.13	1.2		5.46	0.91
1982									
1983	1.45	7.08	7.47	20.97	21.27	22.61		80.85	13.48
1984	1.91	9.93	2.11	14.84	17.13	18.95		64.87	10.81
1985	3.95	12.3	4.11	16.99	20.13	13.49		70.97	11.83
1986	1.83	6.95	9.86	13.87	11.55	0.82		44.88	7.48
1987	1.09	5.04	9.72	15.75	14.88	4.74		51.22	8.54
1988	0.29	1.98	6.17	7.62	2.86	0		18.92	3.15
1989	2.79	8.22	6.79	20.95	20.05	11.92		70.72	11.79
1990	0.35	0.69	0.71	6.92	7.55	0.44		16.66	2.78
1991	0.22	2.15	3.37	1.85	5.51	5.43		18.53	3.09
1992	0.84	2.3	4.59	4.21	0.16	0.02		12.12	2.02
1993	0.55	6.46	7.69	22.85	22.21	16.61		76.37	12.73
1994	0.22	4.37	7.47	8.97	6.59	0.47		28.09	4.68
1995	4.93	9.75	2.44	8.62	7.04	3.13		35.91	5.99
1996	0.03	1.42	4.89	7.53	4.09	0.08		18.04	3.01
1997	0.15	8.77	2.84	13.82	15.88	5.8		47.26	7.88
1998	0.17	1.88	9.05	13.69	14.97	10.09		49.85	8.31
1999	2.34	11.2	6.95	29.07	38.68	37.49		125.73	20.96
2000	0.16	4	1.47	17.03	20.94	9.04		52.64	8.77
2001	0.55	3.55	7.34	9.75	8.45	1.41		31.05	5.18
2002	0.63	9.24	0.4	15.08	17.31	6.56		49.22	8.20
2003	1.11	1.44	7.27	3.1	3.86	1.51		18.29	3.05
AVE	1.17	5.44	5.15	12.49	12.83	7.81		44.89	
							Min-Yr	5.46	
							Max-Yr	125.73	

Appendix F

Water Quality Data

By J. Eilers

Water Quality Data for Lake Creek and Downstream Sites (Eilers, 2001)

Sample ID	Site	Date	Unfilter Total-N mg/L	Dslvd Total-N mg/L	Unfilter Total-P mg/L	Dslvd PO4-P mg/L	pH	Alkal HCO3-C mg/L	Cond us/cm	NO3-N+NO2-N mg/L	NH3-N mg/L	Dslvd Si mg/L
BSODAR	BSODA	9/5/2001									0.002	
BSODAR	BSODA	9/5/2001			0	0.055	8.6		61	0.003	0.002	
INLETR	INLET	9/5/2001			0	0.067	8.1		56.5	0.006	0.001	
INLETR	INLET	8/20/2001			0	0.072				0.009	0.004	14.4
INLET	INLET	8/6/2001	0.02	0.01	0	0.073				0.007	0	14.61
INLET010723R	INLET	7/23/2001	0.07	0.13	0							
INLET010723R	INLET	7/23/2001	0.07	0.12	0	0.07				0.006	0.007	14.72
INLET0621R	INLET	6/21/2001	0.02	0.02	0	0.066	7.8	6.44	56.3	0.006	0	
L138FS	L138FS	8/6/2001			0							
L138FS	L138FS	8/6/2001	0.27	0.26	0	0.013				0.162	0.005	8.94
LAKEFSR	LAKEFS	9/5/2001									0.17	
LAKEFSR	LAKEFS	9/5/2001			0	0.003	8.3		43.1	0.009	0.168	
LAKEFSR	LAKEFS	8/20/2001			0	0.008				0.007	0.156	7.94
LAKEFS	LAKEFS	8/6/2001	0.76	0.53	0	0.008				0.002	0.015	7.61
LAKEMR	LAKEM	9/5/2001			0	0.014	7.9		43.7	0.095	0.005	
LAKEMR	LAKEM	8/20/2001			0	0.02				0.176	0.007	10.12
LAKEM	LAKEM	8/6/2001	0.29	0.19	0	0.011				0.139	0.006	9.56
LAKEM010723R	LAKEM	7/23/2001				0.012						
LAKEM010723R	LAKEM	7/23/2001	0.33	0.23	0	0.011				0.073	0.007	9.17
LAKEM0621R	LAKEM	6/21/2001	0.24	0.17	0	0.009	7.7	5.08	41.4	0.011	0.001	
LCBSFS	LCBSFS	8/6/2001									0.021	7.61
LCBSFS	LCBSFS	8/6/2001	0.44	0.32	0	0.009				0.15	0.022	7.61

INLET -- inlet to Lemolo Lake at the bridge crossing on the North Umpqua River
LAKEM -- inlet to Lemolo Lake from Lake Creek at USFS road crossing near mouth
LAKEFS -- outlet from Diamond Lake to Lake Creek
SPRINGR -- Spring River above confluence with North Umpqua River
BSODA -- Below Soda Springs Dam at USGS monitoring site
L138FS -- Lake Creek at HWY 138 crossing (upstream)
LCBSFS -- Lake Creek below confluence with Sheep Creek
CLR2 -- Clearwater Water River