San Juan County

East Orcas Water Budget Study

(April 2007 through March 2008)

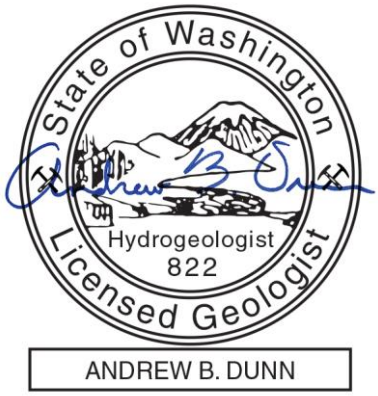
Prepared for
San Juan County

Prepared by
RH2 Engineering, Inc.

March 2015

East Orcas Water Budget Study

The information contained in this report was prepared by and under the direct supervision of the undersigned.



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SAN JUAN COUNTY
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EXECUTIVE SUMMARY

Washington State Department of Ecology (Ecology) staff undertook a water budget study of the Cascade Creek-Mountain Lake and Cascade Lake Watersheds from April 2007 through March 2008. During that study period the reservoir water levels were monitored, monthly streamflow measurements were made, and information was obtained from stakeholders on water diverted for beneficial use.

Precipitation measured during the study period at the Olga 2SE weather station was the 95th driest year on record, which means the amount of precipitation during the study period would only be less in 1 year out of 20.

Mountain Lake is 183 acres in surface area and there is approximately 10 feet of active storage for a total of 1,830 acre-feet (af) of storage. Mountain Lake has fully filled in each of the past 9 years, for which there are records, and has dropped below the principal spillway lip on average once every 2 years. There was still 8 feet of active storage remaining during the lowest water level measured over the past 9 years, which occurred during the Ecology study period. Weir equations were used to estimate the rate of flow over the Mountain Lake Dam principal and emergency spillways. Water, excluding evaporation, leaves Mountain Lake through diversion for municipal supply, flowing over the spillways, and by flow through the Mountain Lake Dam Outlet Pipe. Total inflow (minus evaporation) into Mountain Lake over the study period was 1,370 af. Of that water, 53 af was added to storage, 522 af was discharged through the outlet pipe, 743 af was lost over the spillways, and 51 af was diverted for municipal use.

The total volume of water discharging in Cascade Creek as measured upstream of the Olga Water Users diversion was 2,000 af, while the total discharge measured closer to Buck Bay, accounting for water diverted by Olga Water Users, was approximately 2,250 af. Cascade Creek gained flow downstream during the months of December through May during the study period, and was either neutral or lost flow downstream during the months of June through November. During the study period, no water was diverted from Cascade Creek to Cascade Lake through the Rosario Ditch. Diversions from the Cascade Creek watershed totaled 108.62 af during the study period with 51.38 af of that diverted from above the Mountain Lake Dam.

Total existing water rights issued in the Cascade Creek watershed equal 1,558.4 af. When the level of Mountain Lake is lower than the principal spillway lip, the only way to pass water from storage is through the outlet pipe. This pipe is not currently capable of passing the full water rights authorized by downstream appropriators during certain times of the year.

Cascade Lake is 169 acres in surface area and there is either 4 or 6 feet of active storage, depending on the amount of precipitation recorded at the Olga 2SE weather station, as specified by the adjudication. The active storage is either 676 af, or 1,014 af depending on whether there is 4 or 6 feet of active storage allowed. Cascade Lake has fully filled in each of the past 17 years, for which there are records. Over that period, the water level has never been within 1 foot of the minimum lake level. Weir equations were used to estimate the rate of flow over the Cascade Lake Dam principal spillway. Water, excluding evaporation, leaves Cascade Lake through diversion for municipal supply, diversion for hydropower supply, and flowing over the spillway. Total inflow (minus evaporation) into Cascade Lake over the study period was 1,326 af. Of that water, 8 af was

lost from storage, 110 af was diverted for municipal use, 596 af was diverted for hydropower use, and 628 af was lost over the spillway. Diversions for municipal and hydropower use from the Cascade Lake watershed were 718.02 af during the study period.

Existing water rights issued for natural water in the Cascade Lake watershed total 507 af. All water rights are for water use either within or upstream of Cascade Lake. This does not include the volume of water that can be used after being imported from Cascade Creek, which is an additional 1,098.1 af.

Recommendations to improve the long-term management of the water resources within the Cascade Creek and Cascade Lake Watersheds include: installing a meter on the Mountain Lake Dam Outlet Pipe; maintaining logbooms on both reservoirs to prevent debris from obstructing flow over the spillways, continuing to record water levels in the reservoirs; reconfiguring the Mountain Lake Dam Outlet Pipe to be able to pass enough water to meet downstream water right limits; improving the efficiency of the Rosario Ditch; and altering operation of the dams to take better advantage of available storage and to reduce the volume of water being lost to uncontrolled spill.

BACKGROUND

Study Area

This water resources study was undertaken on eastern Orcas Island. Orcas Island is part of San Juan County (County) and Water Resource Inventory Area (WRIA) 2. The study area encompasses the surface water drainage basins of Cascade Creek, which includes Mountain Lake, and Cascade Lake (**Figures 1** and **2**). These two watersheds are adjacent to each other and cover a combined total of approximately 5,220 acres. They range in elevation from sea level to just over 2,400 feet at the summit of Mount Constitution.

Study History

Ecology staff began to focus on processing new water right applications in WRIA 2 starting in approximately 2006 in cooperation with the County's participation in Watershed Planning under Chapter 90.82 of the Revised Code of Washington (RCW). As staff began assembling the applications that were to be processed, it was noted that the oldest of the pending applications were all located on the east side of Orcas Island. It became apparent after reviewing the water right files that the processing of water right applications in the Mountain Lake – Cascade Creek and Cascade Lake drainage basins could be contentious. The only adjudicated water right certificates within the Northwest Region of Ecology occur in these two watersheds. It was felt that the lack of available hydrologic information would make processing, and potentially defending the decisions in court, difficult. For this reason, it was decided that Ecology would conduct a year-long study of stream flow and reservoir levels in the watersheds to gain enough scientific knowledge of the hydrologic systems involved in order to make scientifically defensible decisions on the pending water right applications. The Ecology study was undertaken from April 2007 through March 2008 and was performed by Ecology staff, Mr. Buck Smith, Mr. Andy Dunn, Mr. Jeff Bash, Mr. Paul Fabiniak, and Mr. John Rose. Unfortunately, due to staffing changes and reductions in force, Ecology was not able to complete the analysis and report after concluding the field work. In 2014, the San Juan Water Resources Management Committee chose to budget money from a watershed planning grant to get the report finished. A request for proposal was advertised and RH2 Engineering, Inc., (RH2) was selected.

This report has been organized into four sections: the first dealing with aspects common to both watersheds; the second dealing with the monitoring of the Cascade Creek Watershed, the third dealing with the monitoring of the Cascade Lake Watershed; and the fourth providing recommendations. This organization is designed to allow the reader to quickly identify their area of interest without having to necessarily read the entire report.

SECTION 1 – ASPECTS COMMON TO BOTH WATERSHEDS

Study Plan

After the decision was made to create a water budget for the two watersheds, a study plan was developed. Existing studies were reviewed and a summary of previous hydrologic studies performed in these watersheds is contained in **Appendix A**. The local stakeholders were asked to provide data and support during the Ecology study, including San Juan County, Washington State Parks (State Parks), Washington Department of Fish and Wildlife, Doe Bay Water Users Association (Doe Bay), Olga Water Users (Olga), Rosario, and Washington Water Service Company (WWSC). Ecology, in conjunction with stakeholders, identified suitable monitoring locations during a reconnaissance site visit in late March 2007. Ecology then made monthly site visits to Orcas Island over the period of April 2007 through April 2008 to measure streamflow, record reservoir levels, and download data loggers. Precipitation data was obtained from the Olga 2SE station (**Figure 1**).

Instrumentation

A variety of instruments were used during the Ecology study for data collection. Existing staff gages were used for visually confirming the water level in reservoirs and the stream stage in creeks during the monthly site visits by Ecology staff, as well as when others visited the sites. Non-vented pressure transducer data loggers (Solinst Levelloggers) were utilized at some sites to record the absolute pressure once every hour. An atmospheric non-vented pressure transducer data logger (Solinst Barologger), located on Orcas Island in the Crow Valley area (Latitude 48.63267, Longitude -122.95743) was used to remove the barometric pressure fluctuation from the data produced by the data loggers that were being used to measure water level (**Figure 1**). The corrected water level data was then adjusted to correlate to available staff gages at each site. The data loggers were downloaded using a laptop computer during each site visit.

For stream discharge measurements, a Swoffer 2100 with a propeller-driven rotor and USGS-style top set wading rod was used. A tape measure was stretched across each stream transect location and was used to identify the station location on the cross section. Due to the shallow nature of the streams, velocity was measured at each station using the six-tenths depth method. Discharge was calculated using the midsection method.

To measure the discharge from the Mountain Lake Dam Outlet Pipe, the following procedure and equipment was used. A piece of 4-inch-diameter PVC sewer pipe was connected to an ABS elbow that was connected to a 4-inch-diameter ABS pipe. The 4-inch-diameter ABS pipe was inserted into the outlet pipe, while it was flowing. The outside diameter of the ABS pipe fit snuggly into the outlet pipe. The pipe section was then secured to prevent it from dislodging due to the force of the water flowing in the pipe. A Fuji Electric Portaflow X portable type ultrasonic flow meter was then installed on the PVC pipe and used to measure flow from the pipe.

Precipitation Data

Weather data has been collected at the Olga 2E station by the Willis Family since July 1891. Precipitation data was utilized to determine what the anticipated mean, minimum, and maximum precipitation would be for the watersheds. While it is likely that the higher elevations of the watersheds get more precipitation than where the weather station is located, it still allows for comparison from year to year. Any month that lacked data for 5 days or more was excluded along with any annual total calculated using the excluded month. Precipitation values were determined for a mean, minimum, and maximum calendar year (January 1 through December 31), water year (October 1 through September 30), and study period year (April 1 through March 31). The precipitation data was analyzed over the period of 1891 through 2014 (**Table 1**). All monthly precipitation data is contained in **Appendix B**.

Table 1. Olga 2 SE Annual Precipitation Statistics

Statistic	Calendar Year	Water Year	Ecology Study Year
Mean	28.84 inches	28.78 inches	28.82 inches
Standard Deviation	4.57 inches	4.97 inches	4.66 inches
Maximum	37.89 inches (1917)	38.99 inches (1894)	38.98 inches (1917)
Minimum	15.09 inches (1929)	15.95 inches (1929)	17.74 inches (1928)
Number of Recorded Years	115	113	114

Precipitation during the Ecology study yearwas equal to 24.51 inches, which is 85 percent of the mean (4.31 inches less than the mean) and, out of the 114 years of record, it was the 95th driest year, meaning that this amount of precipitation would be expected to be exceeded for Olga in 19 out of 20 years. **Figure 3** shows the breakdown in precipitation by month for the Ecology study period and the average over the period of record to allow comparison on a monthly basis.

As part of the Cascade Lake water right adjudication, any year with precipitation less than 29.22 inches was designated to be a dry year, which allowed for Cascade Lake to be drawn down to a lower level than during a normal year (precipitation greater than or equal to 29.22 inches). Applying this criteria to the 115 years of record, 55 of the years would have been classified as normal and 60 of these years would have been classified as dry (**Appendix B**).

SECTION 2 - MOUNTAIN LAKE AND CASCADE CREEK

The Cascade Creek watershed covers approximately 3,168 acres and extends from the southern flank of Mount Constitution to the marine water at Buck Bay, which is located in East Sound. Mountain Lake is a large dam-enhanced lake that forms the headwaters of Cascade Creek. According to Ecology in 1975, the surface area of Mountain Lake is 198 (or 100) acres. Ecology then indicated in 1976 that the surface area of Mountain Lake is 180 acres. RH2 (2005) calculated the surface area as approximately 198 acres. Mr. John Rose (Ecology GIS specialist) calculated the surface area of the lake to be 183 acres as part of this study. For this report the Mountain Lake surface area will be assumed to be 183 acres. The drainage basin upstream of the dam, including the Summit Lake watershed was calculated using GIS as approximately 1,450 acres. Tributaries to Cascade Creek below Mountain Lake all appear to be seasonal or intermittent in nature.

Summit Lake

Summit Lake covers approximately 10 to 12 acres (Ecology, 1975, and GIS analysis of 2006 aerial photo) and is located at an elevation of approximately 2,150 feet. A small concrete dam with wooden stoplogs, identified as Site S2, is located on the southeast corner of the lake (Latitude 48.6705, Longitude -122.8342, **Figure 2** and **Appendix C**). Gary Sale (State Parks) followed the channel of the water discharging over the concrete dam and determined that it eventually flows into the northwest side of Mountain Lake (email communication with Gary Sale, December 6, 2007). A permeable rip-rap rock structure, identified as Site S1, is located on the southwest corner of Summit Lake (Latitude 48.6702, Longitude -122.8363) (**Appendix C**). On occasion, water has been observed flowing through this "structure" to the south. Ecology employee Buck Smith followed the overflow downstream where it crossed through a culvert under Mount Constitution Road and appears to form the headwaters of Cold Springs Creek, which flows into Cascade Lake. Existing maps also show this area contributing to the headwaters of Paul Creek.

Due to the construction of the small concrete dam with wooden stoplogs and the location of the lake, it appears that operation of the dam can control whether water flows from Summit Lake into Cascade Lake or Mountain Lake. Increasing the number of stoplogs installed causes water to flow from the lake into the Cascade Lake basin. Reducing the number of stoplogs installed causes water to flow from the lake into the Mountain Lake basin. The drainage basin upstream of the dam is approximately 70 acres, and its area was included in the Mountain Lake drainage area described above.

Twin Lakes

Twin Lakes are located very close to the upper basin boundary of Mountain Lake. After discussion with multiple individuals, it became clear that there was some disagreement over whether these lakes were within the Mountain Lake drainage basin or outside of it. A field inspection conducted by Ecology employees Buck Smith and Jeff Bash determined that these lakes drain to the north into Rosario Strait with no surface water connection to the Mountain Lake watershed.

Cascade Creek Watershed Study Sites and Equipment

Numerous sites were selected within the watershed for measurement of water level and discharge as part of the Ecology study (**Figures 2** and **4**). The number of stations was intentional to better understand the gaining or losing reaches of the stream throughout the different seasons. Each site within the Cascade Creek watershed is described in the following subsections, listed in order from upstream to downstream.

M1 – Mountain Lake

Latitude 48.6499 Longitude -122.8125. There are three staff gages in Mountain Lake. Each one was placed so that a value of 900 could be added to any of the staff gage readings to give the water surface elevation in feet above mean sea level. So, if a staff gage reads 21.0 feet, the water surface elevation is at an elevation of 921.0 feet. One staff gage is located on the left abutment of the dam and can be used when the water level is high. The second is attached to the outside east side of the wet well on the upstream face of the dam. The third is attached to a piling near the boat launch on the northwest side of the lake. During the Ecology study, a data logger (Solinst Levellogger) was installed in a pipe on the north side of the wet well on the upstream face of the dam for recording the reservoir water level between site visits.

In addition to the reservoir water level monitoring equipment, the discharge being released from the reservoir through the Mountain Lake Outlet Discharge Pipe was measured using a portable ultrasonic flow meter (Fuji Electronic Portaflow X).

C1 – Cascade Creek below Mountain Lake Dam

Latitude 48.6496 Longitude -122.8125. This site is located just downstream of Mountain Lake Dam, approximately 10 feet upstream of the footbridge. At this location, all flow from the Mountain Lake Outlet Discharge Pipe and spillways have joined. The substrate at this location is cobbles and the gradient is steeper than desired. Streamflow measurements at this location are assumed to be fair with an error of approximately plus or minus 15 percent. Monthly streamflow measurements were taken at this site using a Swoffer flow meter.

P1 – Paul Creek above Confluence with Cascade Creek

Latitude 48.6296 Longitude -122.8260. This site is located approximately 20 feet upstream of where Paul Creek joins Cascade Creek. Paul Creek's channel is bedrock and very steep just upstream of this monitoring site. Once the creek reaches alluvial deposits, its gradient abruptly drops. Streamflow measurements at this location are assumed to be fair with an error of approximately plus or minus 15 percent. Monthly streamflow measurements were taken at this site using a Swoffer flow meter. Paul Creek is intermittent and did not flow for many months during the study.

C2 – Cascade Creek below Paul Creek

Latitude 48.6496 Longitude -122.8263. This site is located approximately 5 feet downstream of where Paul Creek enters Cascade Creek. The substrate consists of sand and gravel. Streamflow measurements at this location are assumed to be good with an error of approximately plus or minus 10 percent. Monthly streamflow measurements were taken at this site using a Swoffer flow meter. A pressure transducer data logger (Solinst Levellogger) was submerged in the alluvial gravels to collect stream stage information between site visits. After preparation of a rating curve, the stage information was correlated to discharge for those times between site visits. The total drainage basin above this point is approximately 1,986 acres.

C3 – Cascade Creek beneath Olga Road Bridge

Latitude 48.6450 Longitude -122.8362. This site is located underneath the Olga Road Bridge and just downstream from the current Olga diversion. This location was used in the Ecology (1975) study and was identified as site O-12 in that publication. Cascade Creek flows down a bedrock bounded chute and has created a plunge pool and pushed alluvial sediments downstream from the plunge. These sediments are coarse-grained gravel that likely lack any fine-grained material. The best monitoring transect was on top of these alluvial sediments. However, after multiple months of this site having consistently lower flows than both the upstream and downstream sites, it became apparent that much of the flow was subsurface at this location and was not being measured by the Swoffer flow meter. For this reason, monitoring of this site was terminated during the study and is not used in this analysis.

C-4 – Cascade Creek Downstream of Rosario Diversion

Latitude 48.6443 Longitude -122.8377. This site is located downstream of the Rosario diversion in an area where the creek substrate is bedrock and cobbles and the gradient is steep. Streamflow

measurements at this location are assumed to be fair with an error of approximately plus or minus 15 percent. Monthly streamflow measurements were taken at this site using a Swoffer flow meter.

C-11 – Cascade Creek near Kahboo Hill Road

Latitude 48.6375 Longitude 8372. This site is located on private property off of Kahboo Hill Road. The creek at this location flows straight, has a gentle gradient, has a well-defined channel, and a uniform gravel substrate. Streamflow measurements at this location are assumed to be excellent with an error of approximately plus or minus 5 percent. Monthly streamflow measurements were taken at this site using a Swoffer flow meter.

C-12 – Cascade Creek Downstream of Tributary near Kahboo Hill Road

This site was monitored briefly, but it was determined that the tributary was a backwater and was not contributing flow. Also, the flow measurements were repetitive to Site C-11, so it was discontinued.

C-5 – Cascade Creek at Old Olga Diversion

Latitude 48.6296 Longitude -122.8347. This site is located to the west of the Olga Road at the location of the old Olga diversion. A concrete structure from the diversion, including a weir that has been completely filled in with sediment, is located at this site. A staff gage (not correlated to elevation) and data logger stilling well were already affixed to one of the concrete walls in the creek channel upstream of the weir. The creek at this location has a sand and gravel substrate. Streamflow measurements at this location are assumed to be good with an error of approximately plus or minus 10 percent. Monthly streamflow measurements were taken at this site using a Swoffer flow meter. A pressure transducer data logger (Solinst Levellogger) was placed in the stilling well to collect stream stage information between site visits. After preparation of a rating curve, the stage information was correlated to discharge for those times between site visits. This site has been used by others in the past (Devine Tarbell and Associates, 2003 and 2004, **Appendix A**) as a discharge measurement location. This site is located downstream of all adjudicated diversions and allows for determination of how much water remains in the stream and likely to be discharging at the mouth of the creek. The total drainage basin above this point is approximately 2,966 acres.

Cascade Creek Watershed Water Right Points of Diversion

State Parks diverts water from a stream that is tributary to Mountain Lake. This water is removed from the hydrologic system before it has an opportunity to contribute to the storage in Mountain Lake. Doe Bay's point of diversion is in Mountain Lake, just upstream of the dam. Olga's point of diversion from Cascade Creek is located a short distance upstream from the Olga Road Bridge. The Rosario point of diversion from Cascade Creek is located just downstream from the Olga Road Bridge. This creates a situation where the senior water right holder (Rosario) is located downstream of a junior (Olga) (**Appendix D**). If Rosario was not able to divert its full water right from Cascade Creek, it could make a call for additional water to be released from Mountain Lake Dam so that both rights could be satisfied. If there was less than enough water for both water rights, then Rosario would have a right to make sure it can take all of its water before Olga would get any.

Mountain Lake Dam

Mountain Lake Dam was originally constructed in 1905 for Mr. Robert Moran. At the time of original construction, the dam consisted of a 60-foot-long arch-gravity structure founded on bedrock. The dam was about 5 feet thick at the base and about 1.5 feet thick at the top, with a total height of approximately 12 feet with the dam crest at 919.2 feet above mean sea level. In 1948, the dam crest was raised 3.5 feet to elevation 922.7 feet above mean sea level. In 1990, a stepped gravity buttress was constructed against the downstream side of the dam to cutoff seepage and provide structural support. Training walls were added to the dam to allow the dam crest to safely serve as an emergency spillway during periods of extreme flooding. In 1990 and 1991, the earthfill dikes located adjacent to either side of the dam were rehabilitated and raised to a top elevation of 925 feet (Washington State Parks, 1992).

Flow from the dam that enters Cascade Creek occurs either through the Mountain Lake Dam Outlet Pipe, which is controlled by a dam key, or via the principal or emergency spillways (**Figure 4**). The principal spillway, which was constructed in 1948, is located near the left abutment of the dam. The principal spillway consists of two 11.85 foot wide bays that can accommodate up to 3 stoplogs for water level management. These stoplogs are approximately 0.48 feet tall and 0.3 feet wide. The elevation of the surface of the stoplogs in each bay was measured during the Ecology study and found to be slightly different. **Table 2** identifies the elevation of the top of each spillway feature at the dam during the Ecology study.

Table 2. Mountain Lake Dam Spillway Elevations

Feature	Principal Spillway		Emergency Spillway
	Left Bay	Right Bay	
Emergency Spillway Crest	-	-	922.70
3 Stoplogs	922.53	922.46	-
2 Stoplogs	922.05	921.98	-
1 Stoplog	921.58	921.51	-
Principal Spillway Crest	921.00	921.00	-

If the discharge capacity of the principal spillway is exceeded, water then flows over the top of the entire length of the concrete portion of the dam, which is 60 feet across. The crest of the dam is 1.35 feet wide (measured perpendicular to flow). After cresting the dam, water then cascades down the steps of the gravity buttress on the downstream side of the dam before entering Cascade Creek.

Once the water level in Mountain Lake drops below the elevation of the principal spillway crest, the only way to move water into Cascade Creek from the reservoir is through the Mountain Lake Dam Outlet Pipe.

Dam Operating Rules (Washington State Parks, 1992)

The stoplogs are installed and removed by State Parks on a seasonal basis to manage the water resources of the basin. Operation of the dam and release of water is guided by the *Mountain Lake Dam Operations & Maintenance Manual* (May 1992) and governed by the water rights confirmed through the adjudication. **Table 3** shows the suggested schedules for installation and removal of the stoplogs. In the manual, stoplogs are generally recommended to be installed in March and removed in November.

Table 3. Mountain Lake Dam Stoplog Operating Curves

Schedule	Stoplog 1	Stoplog 2	Stoplog 3
Early Installation	Always Installed	March 1	March 1
Normal Installation		March 1	March 15
Late Installation		March 15	April 1
Early/Normal Removal		November 1	November 1
Late Removal		November 1	November 7

To provide reasonable assurance of a full reservoir pool by June 1 of each year, the manual states, "to provide reasonable assurance of a full reservoir pool by June 1, the installation of the third (highest) stoplog shall not, (with the exception of emergency or flood conditions), be delayed beyond May 1." The decision on whether to proceed with early, normal, or late installation and removal is based on the hydrology of each year and judgment of the operator.

Current practice deviates from **Table 3** in that only the third stoplog is ever removed, and the first and second stoplogs remain in place year round (Mr. Gary Sale, personal communication).

Mountain Lake Storage Estimate

Mountain Lake is 183 acres in surface area and its shoreline is relatively steep. From the top of the principal spillway with two stoplogs installed (rough elevation of 922 feet), to the top of the intake pipe elevation for the Doe Bay and the Mountain Lake Dam Outlet Pipe (elevation 912 feet – courtesy of Mr. Ted Wixom, Doe Bay) there is approximately 10 feet of active storage. By multiplying 10 feet of active storage by 183 acres, the maximum available active storage of water in the lake is 1,830 af.

Mountain Lake Dam Spillway Rating Tables

Rating tables were developed for the dam depending on how many stoplogs are installed in the principal spillway. These tables can be used to estimate the rate of water spilling from the lake as long as the number of stoplogs and water level are known. Two rating tables were created based on the situation where either two, or three stoplogs are installed in the principal spillway (**Appendix D**). The principal spillways were modeled as sharp-crested, contracted, rectangular weirs, while the emergency spillway was modeled as a broad-crested weir.

Mountain Lake Dam Outlet Pipe Discharge Measurements

The intake structure is the same pipe for Doe Bay and the Mountain Lake Dam Outlet Pipe. This pipe is located within a wet well on the upstream side of the dam with the top of the intake at roughly an elevation of 912 feet (Washington State Parks, 1992). The intake is a 12-inch pipe that wyes into two 8-inch pipes. One pipe is connected to the Doe Bay treatment facility, located downstream, and the second discharges into Cascade Creek on the downstream side of the dam. The Mountain Lake Dam Outlet Pipe has a constriction at the end that reduces the opening to approximately 5 inches. During the Ecology study, there was an attempt to create a rating table for the outlet pipe discharge based on reservoir water level and turns of the dam key. Through this investigation it was determined that while the curves are similar, this was not going to be an accurate way to determine how much water was moving through the pipe. Under all tests, it appeared that the maximum discharge rate from the current discharge pipe configuration would be around 2 cubic

feet per second (cfs) (**Figure 5**). Mr. Gary Sale (State Parks) has since opened the valve more turns and has been able to record a discharge of approximately 2.7 cfs from the outlet pipe (email correspondence, February 13, 2015).

Cascade Creek Watershed Monitoring Results

This section contains the monitoring results over the Ecology study period of April 2007 through March 2008.

Monthly Synoptic Streamflow Measurements

Figure 4 is a schematic showing the relative location of each measurement site with respect to prominent hydrologic and cultural features. The monthly measured discharge at each site is summarized in **Table 4** and shown graphically on **Figure 6**.

Table 4. Cascade Creek Watershed Study Flow Measurements

Cascade Creek Watershed (cfs)								
Date	Site ID							
	M1 - outlet pipe	Is M1 Spilling?	C1	P1	C2	C4	C11	C5
April 4, 2007	Not Measured	Yes	3.57	0.49	5.85	5.94	Not Measured	6.70
May 9, 2007	0.93	No	1.07	0.02	1.20	1.28	1.36	1.46
June 7, 2007	Not Measured	No	0.85	0.00	0.96	1.10	1.10	1.08
July 12, 2007	0.82	No	0.69	0.00	0.62	0.70	0.60	0.52
August 8, 2007	Not Measured	No	1.06	0.00	1.13	0.77	0.93	0.78
September 5, 2007	1.00	No	0.78	0.00	1.03	0.85	0.78	0.56
October 3, 2007	0.55	No	0.34	0.00	0.35	0.45	0.49	0.43
November 7, 2007	0.53	No	0.40	0.00	0.57	0.51	0.45	0.50
December 6, 2007	0.48	No	0.31	1.86	3.57	2.89	3.85	3.82
January 15, 2008	0.43	Yes	8.40	2.20	9.40	8.80	11.17	11.89
February 7, 2008	Not Measured	Yes	6.53	0.49	9.06	8.94	11.30	13.98
March 5, 2008	0.66	Yes	2.10	0.27	3.29	2.67	3.69	4.14
April 7, 2008	0.70	Yes	2.70	0.26	4.47	3.89	4.63	4.81

For the months of July through November, the flow in Cascade Creek is almost entirely supported by discharge from Mountain Lake. The streamflow measurements for these months show little to no increase, and often a slight decrease, in streamflow moving downstream in the basin (**Figure 6**). This observation is supported by the fact that Paul Creek, which is one of the larger tributaries, was dry during the months of June through November (**Table 4**). During the months of December through June, Cascade Creek gains water as it flows through the watershed. This gain is from intermittent tributary contributions, such as Paul Creek, overland flow, and also minor shallow groundwater seepage.

Diversion of Water under Existing Water Rights

During the study period, State Parks, Doe Bay, and Olga diverted water from the Cascade Creek Watershed under existing water rights. Rosario did not divert any water because their diversion structure was broken. The monthly and study year volume diverted for each entity is contained in **Table 5**.

Table 5. Water Diverted from Cascade Creek Watershed over Study Period

Month	Year	Mountain Lake and Tributaries		Cascade Creek	
		State Parks (af)	Doe Bay (af)	Olga (af)	Rosario (af)
April	2007	0.07	3.98	7.52	0
May	2007	0.09	4.19	4.43	0
June	2007	0.11	4.32	4.71	0
July	2007	0.09	5.45	***5.18***	0
August	2007	0.09	5.46	6.65	0
September	2007	0.08	4.49	***3.74***	0
October	2007	0.05	3.28	4.73	0
November	2007	0	3.40	4.27	0
December	2007	0	3.74	4.90	0
January	2008	0	3.88	5.21	0
February	2008	0	4.31	4.29	0
March	2008	0	4.30	1.61	0
Ecology Study Total		0.58	50.80	57.24	0
Watershed Total		108.62			

Notes:
af = acre-feet
Bold italics indicate estimated data

The cumulative total annual volume of the surface water rights issued in the Cascade Creek Watershed is equal to 1,558.4 acre-feet per year (afy) (**Appendix D**). So, during the Ecology study less than 10 percent of the water held under water rights was actually diverted. This is primarily due to the Rosario Diversion being damaged. Additional information on the rate and volume of water diverted from the Cascade Creek Watershed outside of the study period is contained in **Appendix D**.

Mountain Lake Dam

Based on data logger measurements and recorded observations, water was spilling over the principal spillway of the Mountain Lake Dam with two stoplogs installed when the study began in April 2007 and lasted through the end of that month. Water ceased to spill in May 2007 when the third stoplog was installed in the principal spillway of the dam. Water did not spill from May 2007 through December 2007. Water started spilling again in January 2008 through the end of the study (**Figure 7**). The highest water level elevation reached was 922.72 feet on February 15, 2008, and the lowest water level elevation was 920.07 feet on September 23, 2007. The lowest water level was still 8 feet above the Doe Bay and the Mountain Lake Dam Outlet pipe intake.

The fact that the water level of Mountain Lake remained relatively constant from September 15, 2007, through November 30, 2007, (**Figure 7**) suggests that inflow was balanced with outflow during this time period. There was no water spilling over the dam during this time period and the combined estimated average discharge from the outlet pipe and diversion by Doe Bay over this time period was 0.58 cfs. So, the inflow minus evaporation must have also been equal to approximately 0.58 cfs. Based on this, it is reasonable to anticipate approximately 0.5 cfs of useable inflow to Mountain Lake during the driest period of the year.

The Mountain Lake Dam rating tables were used to estimate spill rate from the lake every hour when water levels exceeded the installed stoplog elevation (**Appendix E**). One issue with using this method for calculation of spilling discharge over the study period is that it is unknown when the third stoplog was installed in spring 2008. The placement of the stoplog occurred before March 4, 2008, when noticed by Gary Sale (State Parks), but he is unsure who installed it and when it was installed. Based on the flow measured at the C2 and C5 sites, it is estimated that the third stoplog was placed at approximately 7:00 PM on February 12, 2008. Discharge from the Mountain Lake Dam Outlet Pipe was assumed to be the average of the two closest measurement points. Over the course of the study the discharge from this pipe ranged from 0.43 to 1.00 cfs, with the variability due to manipulation of the valve. The peak combined discharge from Mountain Lake occurred on approximately February 12, 2008, and was calculated as 42.5 cfs, while the minimum discharge is believed to have occurred during the month of December 2007 when discharge was solely from the outlet pipe, and was calculated as approximately 0.46 cfs (**Figure 7**).

Mountain Lake Dam Long-term Record

Figure 8 contains water level data for Mountain Lake spanning from December 2005 through December 2014. This graph shows that the lake level dropped lower during the Ecology study period than it has in any of the last 9 years. This chart also shows that management of the reservoir has allowed it to reach a water level equal to the top of the third stoplog in each of those years. In 5 out of the last 9 years the water level of the reservoir has dropped lower than the principal spillway lip, meaning that approximately once every 2 years, discharge through the outlet pipe will be required to maintain flows in Cascade Creek and to satisfy downstream water rights.

Mountain Lake Water Budget

Using the best information available collected during the study period, an estimate of the volume and rate of water passing through the Mountain Lake – Cascade Creek watershed was calculated. The total volume of water that entered Mountain Lake (minus evaporation from the lake) was equal to approximately 1,370 af over the duration of the study period. Fifty-three af was added to storage, 522 af was discharged through the outlet pipe, 743 af was lost over the spillways, and 51 af was diverted for municipal use. **Table 6** breaks down the volumes by month and **Figure 9** shows this graphically.

Table 6. Volumetric Fate of Water Entering Mountain Lake

Month	Year	Outlet Pipe Discharge	Spilling Discharge	Total Discharge to Creek	Doe Bay Diversion	Change in Storage	Reservoir Inflow minus Evaporation
		(af)	(af)	(af)	(af)	(af)	(af)
April	2007	-58	-85	-143	-4	-34	113
May	2007	-57	0	-57	-4	-36	25
June	2007	-54	0	-54	-4	-63	-5
July	2007	-59	0	-59	-5	-82	-18
August	2007	-61	0	-61	-5	-115	-48
September	2007	-37	0	-37	-4	-37	5
October	2007	-33	0	-33	-3	2	38
November	2007	-31	0	-31	-3	-5	29
December	2007	-29	0	-29	-4	320	353
January	2008	-31	-209	-241	-4	24	268
February	2008	-32	-424	-455	-4	71	531
March	2008	-41	-24	-65	-4	-7	62
Study Period Total:		**-522**	**-743**	**-1,265**	**-51**	**53**	**1,369**

Notes:
af = acre-feet
Negative volume indicates water leaving Mountain Lake
Total Discharge to Creek = Outlet Pipe Discharge + Spilling Discharge
Reservoir Inflow minus Evaporation = Change in Storage - Total Discharge to Creek - Doe Bay Diversion

Based on hourly data logger measurements the total spilling discharge rate and volume released from the dam into Cascade Creek was calculated and summarized monthly (**Tables 6** and **7**). Based on these calculations, approximately 424 af of water bypassed the Mountain Lake Dam by spilling in the month of February 2008. This represents 57 percent of the total volume spilled and approximately one-third of the reservoir inflow minus evaporation entering Mountain Lake over the study period.

For the study period, the average inflow into Mountain Lake minus evaporation was 1.89 cfs. **Table 7** breaks down the monthly inflow and outflow rates of the system.

Table 7. Flow Rate of Water Entering Mountain Lake

Month	Year	Outlet Pipe Discharge	Spilling Discharge	Total Discharge to Creek	Doe Bay Diversion	Change in Storage	Reservoir Inflow minus Evaporation
		(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
April	2007	-0.97	-1.44	-2.41	-0.04	-0.37	1.23
May	2007	-0.92	0.00	-0.92	-0.05	-0.39	0.41
June	2007	-0.90	0.00	-0.90	-0.05	-0.69	-0.08
July	2007	-0.96	0.00	-0.96	-0.06	-0.90	-0.29
August	2007	-1.00	0.00	-1.00	-0.06	-1.26	-0.79
September	2007	-0.63	0.00	-0.63	-0.05	-0.40	0.09
October	2007	-0.54	0.00	-0.54	-0.04	0.02	0.62
November	2007	-0.52	0.00	-0.52	-0.04	-0.06	0.48
December	2007	-0.47	0.00	-0.47	-0.04	3.50	5.74
January	2008	-0.51	-3.41	-3.91	-0.04	0.26	4.36
February	2008	-0.55	-7.36	-7.91	-0.05	0.78	9.23
March	2008	-0.66	-0.39	-1.05	-0.05	-0.08	1.00
Study Period Average:		**-0.72**	**-1.05**	**-1.77**	**-0.05**	**0.05**	**1.89**

Notes:
cfs = cubic feet per second
Negative rate indicates water leaving Mountain Lake
Total Discharge to Creek = Outlet Pipe Discharge + Spilling Discharge
Reservoir Inflow minus Evaporation = Change in Storage - Total Discharge to Creek - Doe Bay Diversion

Site C2 Discharge

Discharge at Site C2 was manually measured for the first 2 months of the study, then a data logger was installed that provided more detailed monitoring for the last 10 months of the study. The average discharge measured at this location was 2.76 cfs, which equals 1,999 af over the study period (**Table 8**). The peak discharge occurred on February 13, 2008, and was calculated as 21.63 cfs, while the minimum discharge occurred on September 8, 2007, and was calculated as 0.23 cfs (**Figures 6** and **10**). Flow at site C2 began to increase in December after being very low all summer and fall. This increase preceded when the reservoir started to spill and is related to tributary contribution, such as from Paul Creek (**Figure 6**).

Table 8. Monthly Average Discharge and Volume Past Site C2 and C5

Month	Year	Site C2		Site C5	
		Average Discharge (cfs)	Volume (af)	Average Discharge (cfs)	Volume (af)
April	2007	3.53	210	3.98	237
May	2007	1.20	74	1.20	74
June	2007	0.77	46	0.75	45
July	2007	0.78	48	0.56	34
August	2007	0.87	53	0.53	32
September	2007	0.49	29	0.41	24
October	2007	0.63	39	0.61	37
November	2007	0.94	56	0.57	34
December	2007	3.66	225	3.41	209
January	2008	8.13	500	8.50	522
February	2008	8.89	511	11.79	678
March	2008	3.37	207	3.44	211
Study Year Total:		**2.76**	**1,999**	**2.95**	**2,139**

Site C5 Discharge

Discharge at Site C5 was manually measured for the first 2 months of the study, then a data logger was installed that provided more detailed monitoring for the last 10 months of the study. The streambed at Site C5 appeared to maintain its structure over the course of Ecology's study. Discharge measurements were compared to staff gage elevations to produce a rating curve. This calculated rating curve, along with the measured points, can be seen in **Appendix F**. The average discharge measured at this location was 2.95 cfs, which equals 2,139 af over the study period (**Table 8**). The peak discharge occurred on February 13, 2008, and was calculated as 30.64 cfs, while the minimum discharge occurred on September 9, 2007, and was calculated as 0.17 cfs (**Figures 6** and **11**). The discharge measurement of 0.17 cfs was the lowest measured on Cascade Creek. This suggests that the stream during this time of year is wholly supported by release from Mountain Lake, and even then the stream loses water downstream during the late summer. This is expected since the Olga diversion is upstream of Site C5 (**Figure 4**).

A comparison of **Tables 6** and **8** suggests that there was over 874 af of tributary contribution between Mountain Lake Dam and Site C5 over the study period. Also, most (84 percent) of the tributary contribution occurs upstream of Site C2.

Cascade Creek Watershed Study Year Conclusions

During the Ecology study period, there was 1,369 af that entered Mountain Lake, 1,999 af that flowed past Site C2, and 2,139 af that flowed past Site C5. If the volume of water diverted under existing water rights over the study year (108.62 af) is added to this, then the total discharge from the Cascade Creek Watershed over the study period was approximately 2,250 af.

Total Annual Volume Compared with Other Studies

Total inflow minus evaporation from Mountain Lake was calculated to be 1,370 af over the study period. This number appears reasonable when compared to other studies that have been performed in the past, considering that the study period was a dry period.

- Department of Ecology (1975): 1,850 af for an average year
- RH2 (2005): 2,661 af in average year
  1,087 af in a 1 in 100 year drought

The total Cascade Creek watershed discharge past Site C2 was calculated to be equal to approximately 2,000 af over the study period. This number appears reasonable when compared to other studies that have been performed in the past, considering that the study period was a dry period.

- Department of Ecology (1975): 2,420 af for an average year

The total Cascade Creek watershed discharge past Site C5 was calculated to be equal to approximately 2,250 af over the study period. This number is much less than the volumes reported by Montgomery Water Group (2004).

- Montgomery Water Group (2004): 5,246 af in an average year
  3,599 af in a 1 in 10 drought year

Cascade Creek Comparison to Existing Water Rights

Surface water rights issued in the Cascade Creek watershed are currently equal to a total of 1,558.4 afy (**Appendix D**). This volume is less than the volume calculated to have flowed past Site C2 during the study year (2,000 af). While annual volume discharge estimates can be used for comparing water right annual volume with the water that flows through the Cascade Creek watershed, they do not address issues with timing. As was discussed previously, the spilling discharge from Mountain Lake was substantial in February 2008. Any water being spilled that is in excess of the downstream water right demand is lost and cannot be relied upon later in the year.

Olga, Rosario, and the Trust Water Right Program all have water rights on Cascade Creek below Site C2. The water needed to satisfy these water rights either comes from controlled release from Mountain Lake, uncontrolled spill from Mountain Lake, or tributary contributions. The total diversion rate allowed under these water rights varies throughout the year. **Table 9** compares the discharge measured during the Ecology study with the downstream water rights on Cascade Creek. This table shows that during the study period, there was not enough flow in Cascade Creek to fully satisfy the water right holders in the months of May through November. Also, the flow deficit in October and November exceeded the available additional capacity from the Mountain Lake Dam Outlet Pipe as currently configured, meaning that there would have been no way to actually meet the water right demand with the existing infrastructure.

Table 9. Comparison of Flow in Cascade Creek with Water Right Instantaneous Limits

Month	Year	Rate Discharging from Mountain Lake	Rate Discharging Past C2	Olga Water Rights	Water Rights at Rosario Diversion	Flow minus Water Rights
		(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
April	2007	2.41	3.53	-0.56	-1.00	1.97
May	2007	0.92	1.20	-0.56	-1.00	-0.36
June	2007	0.90	0.77	-0.56	-1.00	-0.79
July	2007	0.96	0.78	-0.56	-0.50	-0.28
August	2007	1.00	0.87	-0.56	-0.50	-0.19
September	2007	0.63	0.49	-0.56	-1.00	-1.07
October	2007	0.54	0.63	-0.56	-2.00	-1.93
November	2007	0.52	0.94	-0.56	-3.00	-2.62
December	2007	0.47	3.66	-0.56	-3.00	0.10
January	2008	3.91	8.13	-0.56	-3.00	4.57
February	2008	8.20	9.20	-0.56	-2.00	6.64
March	2008	1.05	3.37	-0.56	-2.00	0.81
Study Year Average		**1.75**	**2.76**			

Notes:
cfs = cubic feet per second
Flow minus Water Rights = Rate Discharging Past C2 + Olga Water Rights + Water Rights at Rosario Diversion
Water Rights at Rosario Diversion include Rosario Diversion to Cascade Lake and Trust Water Right remaining in Cascade Creek.

The flow limitation out of the Mountain Lake Dam Outlet Pipe means that if Mountain Lake is not spilling, the maximum flow rate that can be released from the dam is approximately 2.7 cfs. Since the instantaneous rate that can be diverted by downstream water rights can be as high as 3.649 cfs (in the months of November through January) there is currently no way that the current outlet pipe configuration can pass that rate of flow from Mountain Lake (**Appendix D**). In order for all water users to be satisfied without curtailment, either water has to be spilling from Mountain Lake, or there must be other flow into Cascade Creek below Mountain Lake but above the location of the diversions for Rosario, Olga, and Mr. Taylor. This situation is most likely to occur in the fall.

SECTION 3 - CASCADE LAKE

According to Ecology in 1975, the surface area of Cascade Lake is 172 (or 170) acres. Ecology then indicated in 1976 indicated that the surface area of Cascade Lake is 170 acres. RH2 in 2005 calculated the surface area as 170 acres. An Ecology GIS analysis of the 2006 aerial photos has the lake at 169 acres. The natural drainage basin upstream of the dam (not including the diversion from Cascade Creek) is approximately 2,053 acres. While the streamflow in Moran Creek and Cold Spring Creek was not measured during the Ecology study period, they are known to be the largest natural tributaries to Cascade Lake. Both of these creeks originate on the north and northeast side of the lake on the flank of Mount Constitution.

Cascade Lake Watershed Study Sites and Equipment

Limited sites were selected within the watershed for measurement of water level and discharge as part of the Ecology study. At the start of the study, it was unsure how long the Rosario diversion would be offline, so monitoring sites were picked assuming it would come back online during the study. As it turns out, the diversion was not reactivated during the study, so the monitoring locations

on the Rosario Ditch and Rosario Ditch Tributary are less useful than if the diversion had been in operation. Without the introduced Cascade Creek water, the primary focus has become the natural water budget of Cascade Lake and how it responded to municipal and hydropower demands. Each site within the Cascade Lake watershed is described in the following subsections, listed in order from upstream to downstream (**Figures 2** and **4**).

Site RDT1 – Rosario Ditch Tributary

Latitude 48.6453 Longitude -122.8391. This site is located just downstream of the foot trail bridge culvert and just upstream of where it enters Rosario Ditch. The Rosario Ditch Tributary is a natural intermittent water course that is captured by Rosario Ditch and diverted toward Cascade Lake. The creek bed has a sand and gravel substrate. Streamflow measurements at this location are assumed to be fair with an error of approximately plus or minus 15 percent. Measurement of flow often had to be estimated because it was too small for measurement. Monthly streamflow measurements were taken at this site using a Swoffer flow meter, when there was sufficient flow.

Site RD1 – Rosario Ditch

Latitude 48.6503 Longitude -122.8656. This site is located approximately 10 feet upstream of where a dirt road, which leads to campsites along the southern shore of Cascade Lake, crosses the Rosario Ditch. Rosario Ditch is the method of conveyance for water being diverted from Cascade Creek into Cascade Lake. However, during the study period, the diversion was broken and no water was diverted from Cascade Creek through the ditch. Streamflow measurements at this location are assumed to be fair with an error of approximately plus or minus 15 percent. Measurement of flow often had to be estimated because it was too small for measurement. Monthly streamflow measurements were taken at this site using a Swoffer flow meter, when there was sufficient flow.

Site CL1 – Cascade Lake

Latitude 48.6503 Longitude -122.8656. There are two staff gages in Cascade Lake located at the Cascade Lake Dam, off of Palisades Drive. Both staff gages are read through the principal spillway window and looking either to the right to see the original staff gage with the spillway lip equal to 351 feet, or looking to the left to see a newer staff gage with the spillway lip equal to 4.80 feet. The newer staff gage also has a data logger housing attached to it and that is where, during a portion of the Ecology study (August 8, 2007, through the end), a data logger (Solinst Levellogger) was installed for recording the reservoir water level between site visits. Lake water level was read monthly by Ecology staff and weekly by Rosario staff during the study.

Cascade Lake Dam

Cascade Lake Dam is a concrete dam located at the western end of Cascade Lagoon, which is an arm of the lake that extends west from the main body of the lake. The principal spillway for the dam is a rectangular window cut through the 0.8-foot-thick concrete of the dam and measuring 6.6 feet wide by 1.75 feet tall (**Appendix C**). A rating table was created for the principal spillway at Cascade Dam using the broad-crested weir equation (**Appendix G**). Based on the water right adjudication, the elevation of the spillway lip is 351 feet. Water spilling from the principal spillway is channeled on a sloped metal chute away from the back side of the dam and eventually cascades into a channel that passes under Palisades Drive in a culvert and then continues down a steep slope toward Cascade Bay in East Sound. In addition to the principal spillway, there are also pipes that extend through the dam and can discharge water when water level is very high. The invert of the lower of these two pipes is

approximately 351.58 feet. The invert of the upper pipe was not determined by Ecology during this study.

Rosario Ditch

Historically, water has been diverted from Cascade Creek, travels in an elevated corrugated pipe supported on a trestle before discharging into a partially lined ditch to flow overland for approximately 2,800 feet (0.5 miles) before dumping into Cascade Lake. During a storm in December 2006, a large limb fell and damaged a portion of the elevated corrugated pipe structure to the point that it was no longer able to convey water (**Appendix C**). The pipe remained unrepaired throughout the duration of the Ecology study. So, any water flowing in the Rosario Ditch did not come from Cascade Creek. One benefit of the damaged diversion was that it removed the need to estimate or measure how much water was being diverted from Cascade Creek and into Cascade Lake, which would have complicated the water budget calculations. This allowed Ecology to measure the natural streamflow without having to consider the intrabasin transfer of water.

Rosario Ditch location

On April 25, 2007, Mr. Andy Dunn, Mr. Buck Smith, and Mr. Jeff Bash (Ecology), along with Mr. Steve Boessow and Mr. Brendan Brokes (Washington Department of Fish and Wildlife (WDFW)), and Ms. Amanda Cronin (Washington Water Trust) walked the length of the Rosario diversion ditch. Geographic data points were taken using a Meridian Magellan GPS to identify the path of the ditch and also to identify prominent features. **Appendix H** contains a list of the latitude and longitude of the GPS points collected, along with the feature that existed at that location.

One tributary was observed flowing into the ditch in April of 2007. In order to determine how much water was entering the ditch from this watercourse, a stream gaging site was established for the stream and it was identified as Site RDT1.

Cascade Lake Watershed Study Year Monitoring Results

Water enters Cascade Lake through direct precipitation, through its major and minor tributaries, and through the introduction of water from Cascade Creek. Water losses from Cascade Lake are primarily limited to evaporative loss, water diverted for domestic use by Washington Water Service Company, water diverted for hydropower use by Rosario, and water leaving the lake by flowing out the principal spillway at the dam site and continuing down the steep slope into Cascade Bay within East Sound.

Table 10 contains a summary of the discharge measured or estimated at Sites RDT1 and RD1 over the study period.

Table 10. Measured Discharge in the Cascade Lake Watershed

Rosario Diversion Ditch (cfs)		
Date	Site ID	
	RDT1	RD1
April 4, 2007	0.32	0.09
May 9, 2007	0.04	0.00
June 7, 2007	0.02	0.00
July 12, 2007	0.00	0.00
August 8, 2007	0.00	0.00
September 5, 2007	0.00	0.00
October 3, 2007	0.00	0.00
November 7, 2007	0.00	0.00
December 6, 2007	0.01	0.00
January 15, 2008	0.31	0.00
February 7, 2008	0.42	0.01
March 5, 2008	0.11	0.01
April 7, 2008	0.09	0.01

As can be seen, the Rosario Ditch during the study period was not able to effectively convey the flow of the Rosario Ditch Tributary all the way to Cascade Lake. Also, the tributary is intermittent and flow was only observed during the months of December through June, similar to other intermittent streams in the area.

Assuming that that flow measured during the site visits persisted for the entire month measured, the total discharge over the study period passing RDT1 and RD1 was 78 af and 7 af, respectively. This data shows that with no flow in the Rosario Ditch, there is greater than 90 percent loss between where RDT1 enters the ditch and where Rosario Ditch enters Cascade Lake.

Diversion of Water from the Cascade Lake Watershed under Existing Water Rights

During the study period, Rosario Utilities (now Washington Water Service Company), Rosario, and State Parks diverted water from the Cascade Lake Watershed. The monthly volume diverted for each entity is shown in **Table 11**.

Table 11. Water Diverted from Cascade Lake Watershed over Study Period

Month	Year	Cascade Lake and Tributaries		
		State Parks (af)	WWSC Domestic (af)	Hydropower (af)
April	2007	1.11	7.57	66.84
May	2007	1.36	9.13	31.97
June	2007	1.63	10.49	16.74
July	2007	1.92	13.07	12.84
August	2007	1.76	13.28	13.02
September	2007	0.97	10.50	13.23
October	2007	0.61	7.61	38.88
November	2007	0.64	7.50	72.98
December	2007	0.60	7.30	75.42
January	2008	0.61	8.35	115.85
February	2008	0.60	7.34	71.01
March	2008	0.63	7.69	66.97
Ecology Study Total		12.44	109.83	595.75
Watershed Total		718.02		

Notes:
af = acre-feet
WWSC = Washington Water Service Company

Additional information on the rate and volume of water diverted from the Cascade Lake Watershed outside of the study period is contained in **Appendix D**.

Cascade Lake Storage Estimate

Since Cascade Lake is 169 acres in surface area and has a relatively steep shoreline, a simple calculation can be used to determine how much active storage is available behind the dam. From the top of the principal spillway (elevation 351 feet), to the top of the normal year minimum lake level (elevation 347 feet), there is 4 feet of active storage. By multiplying 4 feet of active storage by 169 acres it can be determined that the maximum controlled storage of water in the lake during a normal year is 676 af. In a dry year, the allowable minimum lake level is 345 feet. By multiplying 6 feet of active storage by 169 acres it can be determined that the maximum controlled storage of water in the lake during a dry year is 1,014 af.

Cascade Lake Level Fluctuation

As determined during the adjudication, the lip of the principal spillway is located at elevation 351 feet (staff gage 4.8 feet), average minimum lake level is at elevation 347 feet (staff gage 0.8 feet), and low minimum lake level is at elevation 345 feet (staff gage -1.2 feet).

During the Ecology study, the lake was spilling from April 2007 through June 2007. There was no spill from July 2007 until early January 2008. The lake then spilled from early January 2008 through the end of the Ecology study in April 2008 (**Figure 12**).

Cascade Lake Long-term Water Level Record

The adjudication required that if precipitation at Olga was equal to or above 29.22 inches, then the average minimum lake level limit is in effect. If precipitation was less than 29.22 inches, then the low minimum lake level limit is in effect.

In years 1998 through 2014, the lake has managed to fill completely each year and spill. During that period, the lake level never dropped below the normal year minimum lake level, even though 9 of those years qualified as dry years. The lowest lake level measured during this period occurred in September 2012, when the lake level was at elevation 348.17 feet (**Figure 13**).

Cascade Lake Study Year Water Budget

Using information available, an estimate of the volume and rate of water passing through the Cascade Lake watershed was calculated for the study period. The total volume of water that entered Cascade Lake (minus evaporation from the lake) was equal to approximately 1,326 af over the duration of the study period. Eight af was lost from storage, 110 af was diverted for municipal supply, 596 af was diverted for hydropower production, and 628 af was lost over the spillway. A total of 706 af was put to beneficial use during the study period. The largest use of water was for hydropower production. **Table 12** breaks down the volumes by month and **Figure 14** shows this graphically.

Table 12. Volumetric Fate of Water Naturally Entering Cascade Lake

Month	Year	WWSC Municipal Diversion	Rosario Hydropower	Spilling Discharge	Total Use and Discharge from Lake	Change in Storage	Reservoir Inflow minus Evaporation
		(af)	(af)	(af)	(af)	(af)	(af)
April	2007	-8	-67	-68	-142	-26	116
May	2007	-9	-32	-24	-65	-16	49
June	2007	-10	-17	-1	-29	-19	10
July	2007	-13	-13	0	-26	-29	-3
August	2007	-13	-13	0	-26	-29	-2
September	2007	-11	-13	0	-24	-27	-3
October	2007	-8	-39	0	-46	-4	42
November	2007	-8	-73	0	-80	-39	41
December	2007	-7	-75	0	-83	121	203
January	2008	-8	-116	-126	-250	92	342
February	2008	-7	-71	-260	-338	1	339
March	2008	-8	-67	-150	-225	-32	192
Study Period Total:		-110	-596	-628	-1,334	-8	**1,326**

Notes:
af = acre-feet
Negative volumes indicate water leaving Cascade Lake
Total Use and Discharge from Lake = WWSC Municipal Diversion + Rosario Hydropower + Spilling Discharge
Reservoir Inflow minus Evaporation = Change in Storage - Total Use and Discharge from Lake

Based on weekly manual observations and hourly data logger measurements, the total spilling discharge rate and volume released from the dam into the overflow creek was calculated and summarized monthly (**Tables 12** and **13**). Based on these calculations, a total of 628 af was lost due to spilling, which is equal to 45 percent of the total inflow minus evaporation. Approximately 260 af of water spilled from the Cascade Lake Dam in the month of February 2008. This represents 57

percent of the total volume spilled and approximately 20 percent of the reservoir inflow minus evaporation entering Cascade Lake over the study period.

For the study period, the average inflow into Cascade Lake minus evaporation was 1.83 cfs. **Table 13** breaks down the monthly inflow and outflow rates of the lake.

Table 13. Flow Rate of Water Naturally Entering Cascade Lake

Month	Year	WWSC Municipal Diversion	Rosario Hydropower	Spilling Discharge	Total Use and Discharge from Lake	Change in Storage	Reservoir Inflow minus Evaporation
		(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
April	2007	-0.13	-1.12	-1.14	-2.39	-0.44	1.95
May	2007	-0.15	-0.52	-0.39	-1.06	-0.27	0.79
June	2007	-0.18	-0.28	-0.02	-0.48	-0.31	0.17
July	2007	-0.21	-0.21	0.00	-0.42	-0.47	-0.05
August	2007	-0.22	-0.21	0.00	-0.43	-0.47	-0.04
September	2007	-0.18	-0.22	0.00	-0.40	-0.45	-0.05
October	2007	-0.12	-0.63	0.00	-0.76	-0.07	0.68
November	2007	-0.13	-1.23	0.00	-1.35	-0.66	0.70
December	2007	-0.12	-1.23	0.00	-1.35	1.96	3.31
January	2008	-0.14	-1.88	-2.04	-4.06	1.50	5.57
February	2008	-0.13	-1.28	-4.67	-6.08	0.02	6.10
March	2008	-0.13	-1.09	-2.44	-3.65	-0.53	3.13
Study Period Average:		-0.15	-0.82	-0.87	-1.84	-0.01	**1.83**

Notes:
cfs = cubic feet per second
Negative rates indicate water leaving Cascade Lake
Total Use and Discharge from Lake = WWSC Municipal Diversion + Rosario Hydropower + Spilling Discharge
Reservoir Inflow minus Evaporation = Change in Storage - Total Use and Discharge from Lake

The fact that there are no water rights located downstream of Cascade Lake reduces the operational constraints that are considered related to management of Mountain Lake.

Total Annual Volume Compared with Other Studies

Total inflow minus evaporation from Cascade Lake was calculated to be 1,326 af over the study period. This number is less than estimated by prior studies.

- Department of Ecology (1975): 2,700 af for an average year.
- RH2 (2005): 3,684 af in average year
  1,568 af in a 1 in 100 year drought

Even so, the volume calculated over the study period is more than double the annual volume of consumptive water rights issued in the Cascade Lake Watershed (507 afy) (**Appendix D**).

New Surface Water Right Applications on File

As of February 2015, there are no pending water right applications requesting additional water from either Mountain Lake, or Cascade Creek. There are three new surface water applications requesting water from Cascade Lake and its tributaries (**Table 14**).

Table 14. Cascade Lake Watershed Pending Water Right Applications

Application	Priority Date	Applicant	Purpose	Qi	Qa	Source
S1-28584	July 28, 2008	Washington Water Service Co.	Municipal	0.14 cfs	10 afy	Cascade Lake
S1-28618	April 27, 2009	Washington State Parks	Municipal	0.05 cfs	6 afy	Cold Creek
S1-28619	April 27, 2009	Washington State Parks	Municipal	0.05 cfs	6 afy	Moran Creek
Database searched February 10, 2015						

SECTION 4 - RECOMMENDATIONS

The following recommendations have been made to improve the long-term management of the water resources within the Cascade Creek and Cascade Lake Watersheds:

1. Install a meter on the outflow of water from the Mountain Lake Outlet Discharge Pipe. This will allow for the water users to know exactly how much water is being released from the lake when it is not spilling.
2. Maintain the logbooms on both Mountain Lake and Cascade Lake to prevent debris from obstructing flow over the principal spillways. This debris will invalidate the estimates of spilling discharge based on lake water levels using the tables provided in this report, which will interfere with efforts to account for the water discharging from the lakes.
3. Keep recording water levels in Mountain Lake and Cascade Lake, at least periodically, and share those readings with interested parties.
4. The Mountain Lake Dam Outlet Pipe end should be reconfigured to allow additional water to be discharged through the pipe in order to be able to meet downstream water right demand when reservoir levels are below the principal spillway elevation.
5. The efficiency of the Rosario Ditch should be improved to allow water to be efficiently conveyed from Cascade Creek to Cascade Lake.
6. Consider operating both Mountain Lake Dam and Cascade Lake Dam to take advantage of the water stored in order to be able to capture more of the water as the reservoirs fill. The goal should be to control as much of the discharge as possible and to reduce the volume of water being lost to uncontrolled spilling from both reservoirs.

SECTION 5 - REFERENCES

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Department of Ecology. 1976. Reconnaissance Data on Lakes in Washington Volume 1, Clallam, Island, Jefferson, San Juan, Skagit, and Whatcom Counties. Water-Supply Bulleting 43, Vol. 1

Montgomery Water Group, Inc. April 30, 2004. Multi-Purpose Surface Water Storage Assessment, WRIA 2, San Juan County, Washington. 22 pages. Appendix.

RH2 Engineering. June 2005. Rosario Water Budget Supply Analysis. Rosario Utilities and Eastsound Water Users Association, East Orcas Island, Washington, Preliminary Report.

San Juan County Water Resource Management Committee. October, 2005. The East Orcas Water Supply Report and Recommendations. 22 pages.

Washington State Parks. May 1992. Moran State Park Mountain Lake Dam Operation & Maintenance Manual.

Figures

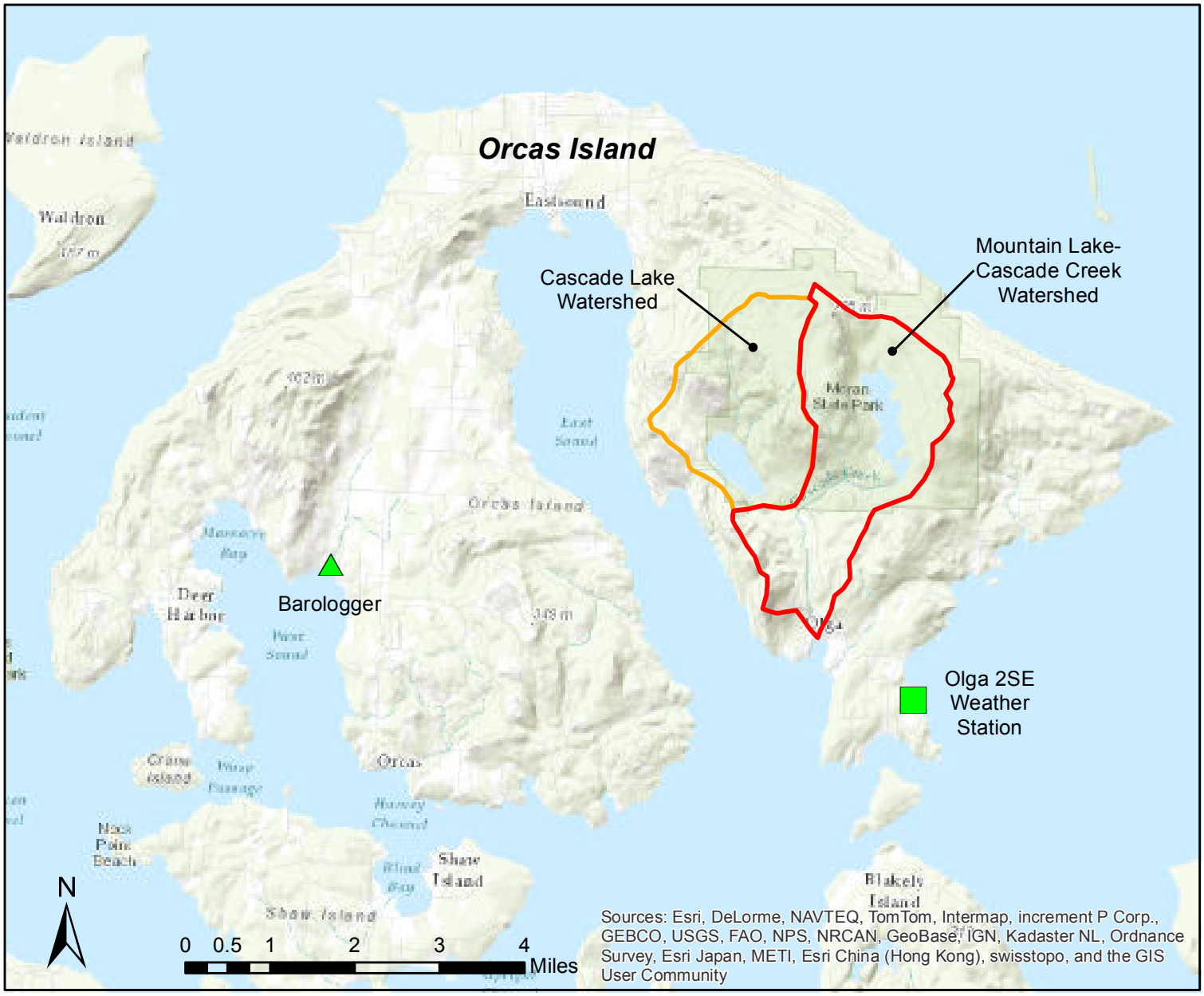
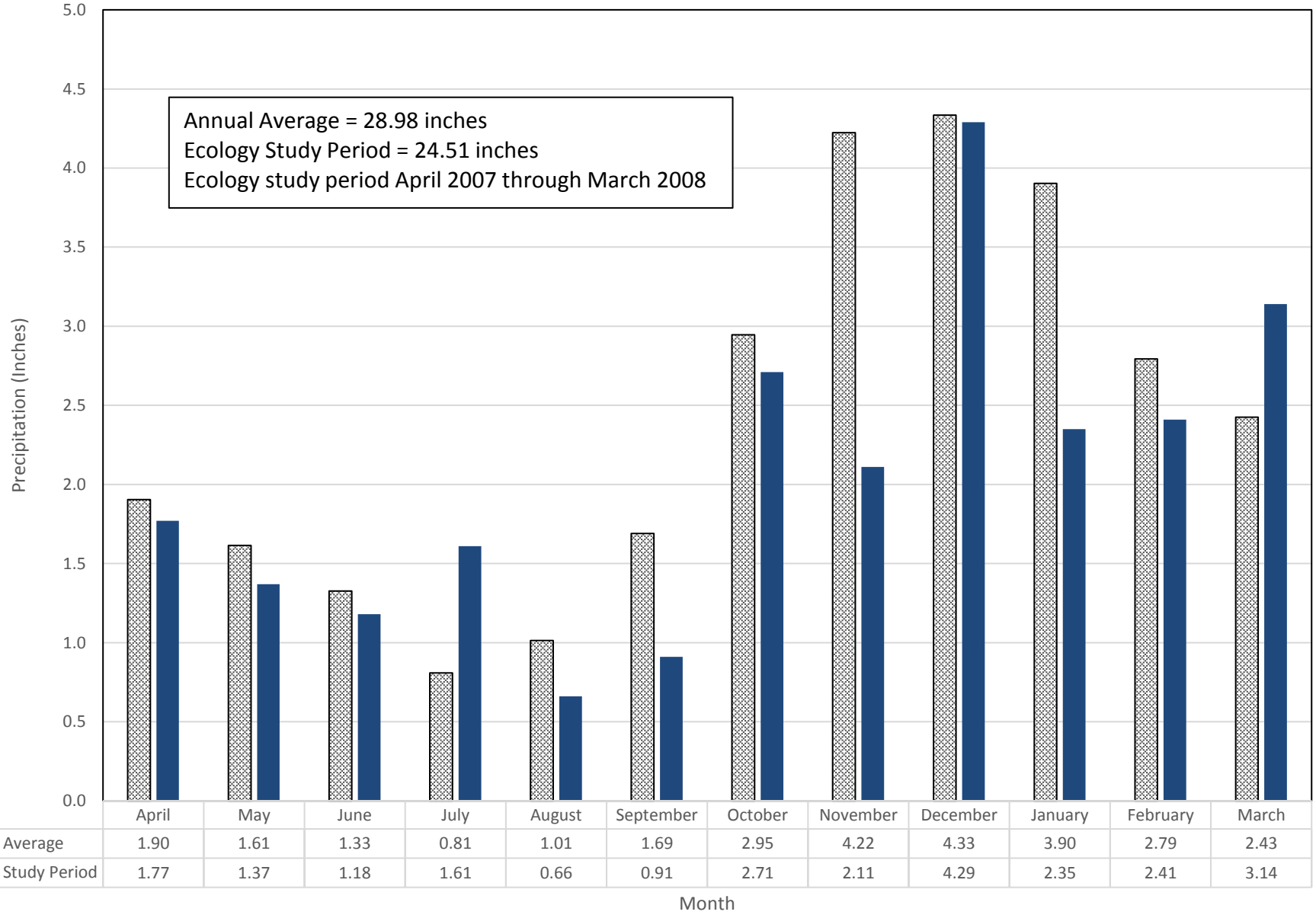


Figure 1. Study Area Map

Figure 2. Study Area with Monitoring Sites

Figure 3. Average vs. Ecology Study Period Precipitation (Olga 2SE Station)



	April	May	June	July	August	September	October	November	December	January	February	March
Average	1.90	1.61	1.33	0.81	1.01	1.69	2.95	4.22	4.33	3.90	2.79	2.43
Study Period	1.77	1.37	1.18	1.61	0.66	0.91	2.71	2.11	4.29	2.35	2.41	3.14

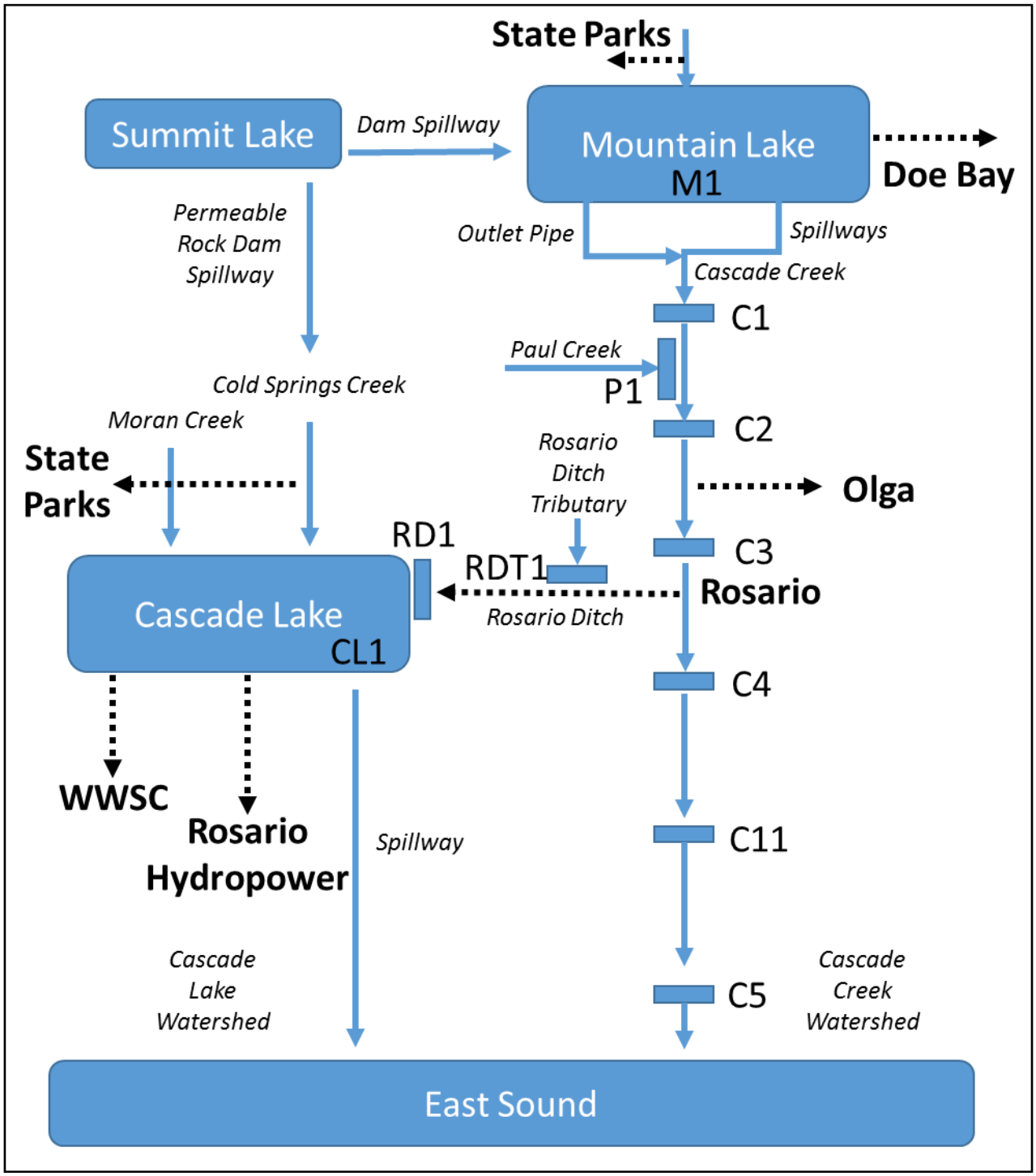


Figure 4. Schematic Diagram Showing Hydrology and Monitoring Sites

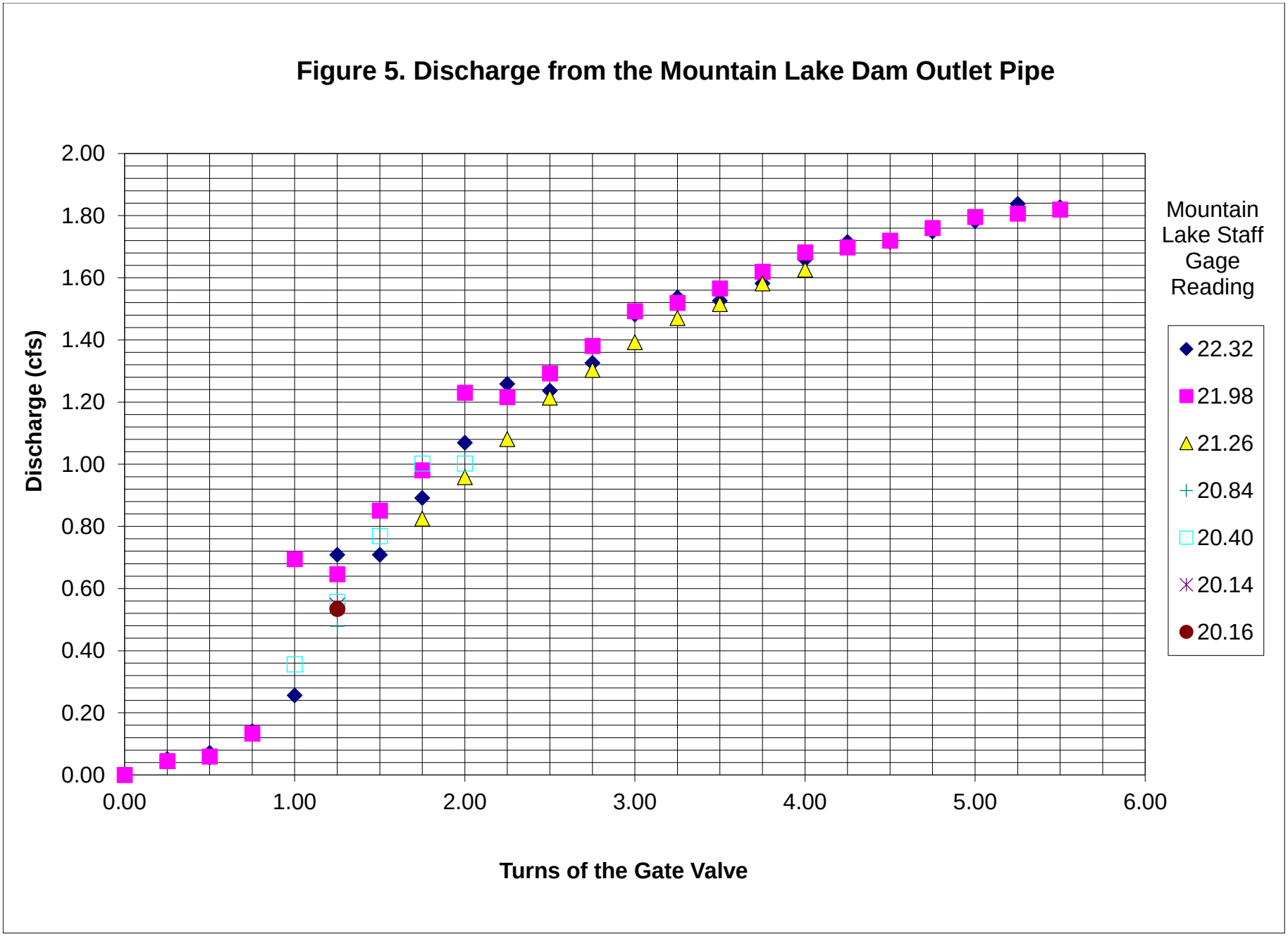


Figure 5. Discharge from the Mountain Lake Dam Outlet Pipe
Discharge (cfs)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Turns of the Gate Valve
Mountain Lake Staff Gage Reading
22.32
21.98
21.26
20.84
20.40
20.14
20.16

Figure 6. Cascade Creek Watershed Measured Discharge

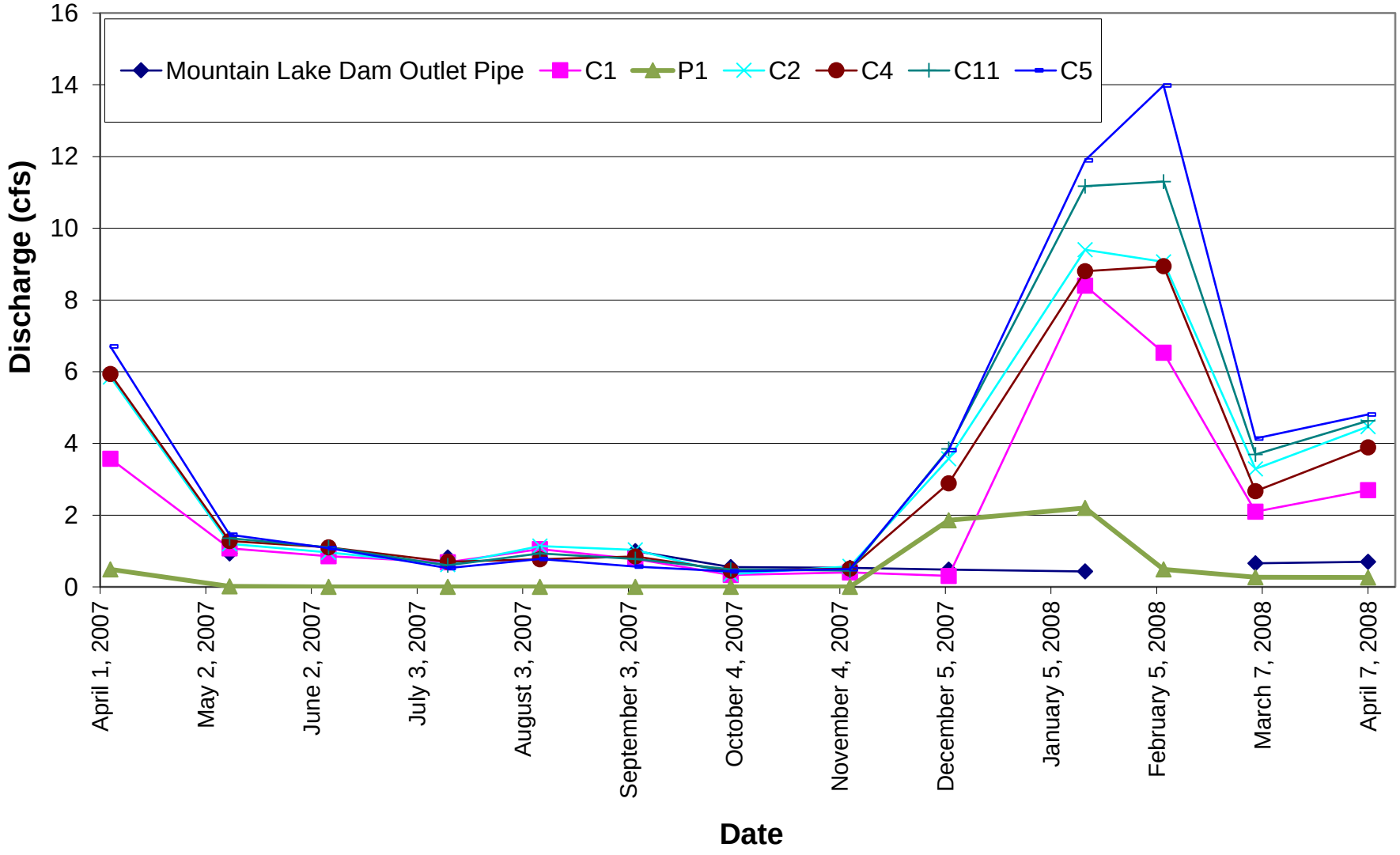
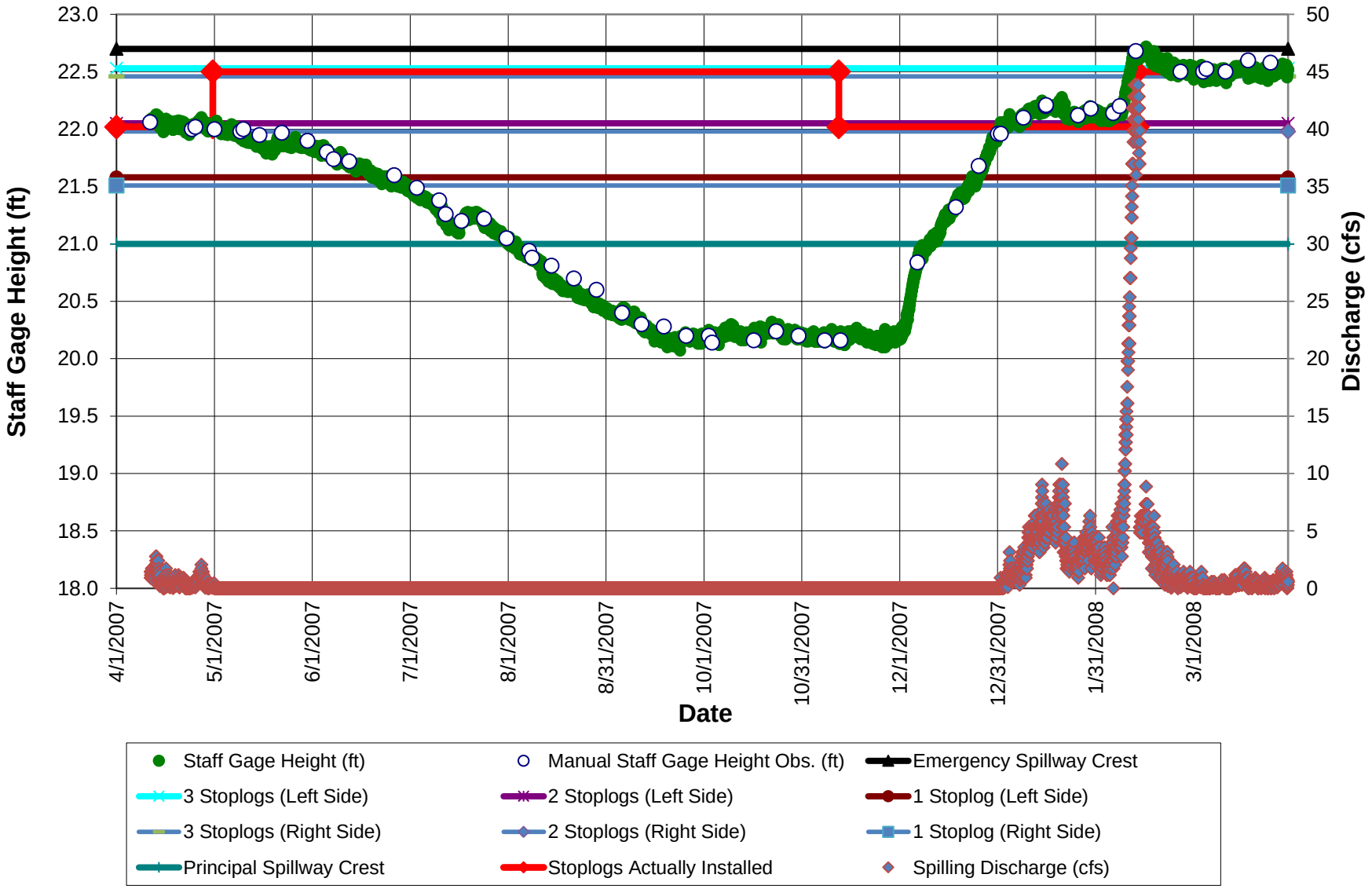


Figure 7. Mountain Lake Water Level and Calculated Spill Discharge



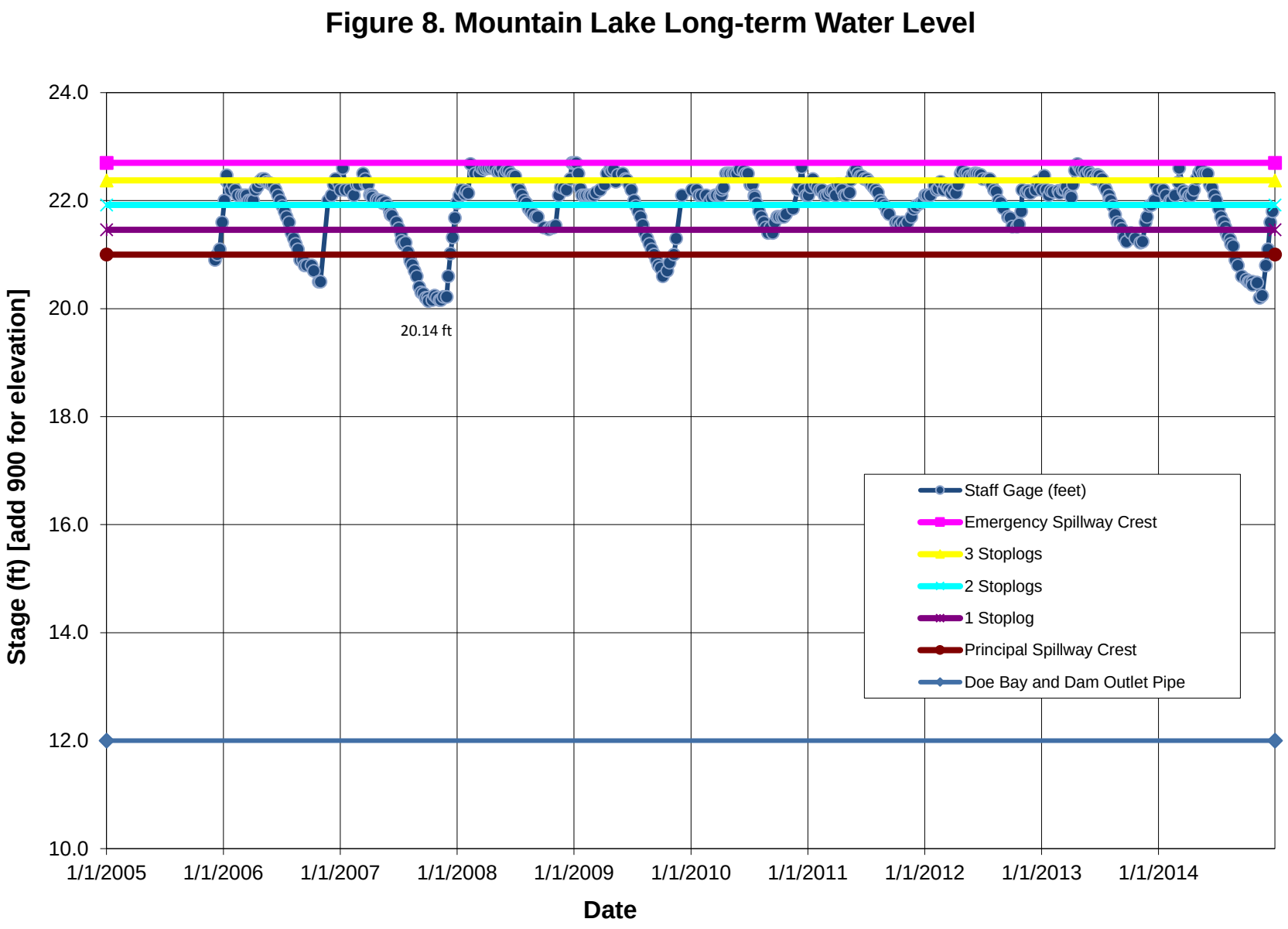


Figure 8. Mountain Lake Long-term Water Level
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
Stage (ft) [add 900 for elevation]
20.14 ft
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
1/1/2013
1/1/2014
Date
Staff Gage (feet)
Emergency Spillway Crest
3 Stoplogs
2 Stoplogs
1 Stoplog
Principal Spillway Crest
Doe Bay and Dam Outlet Pipe

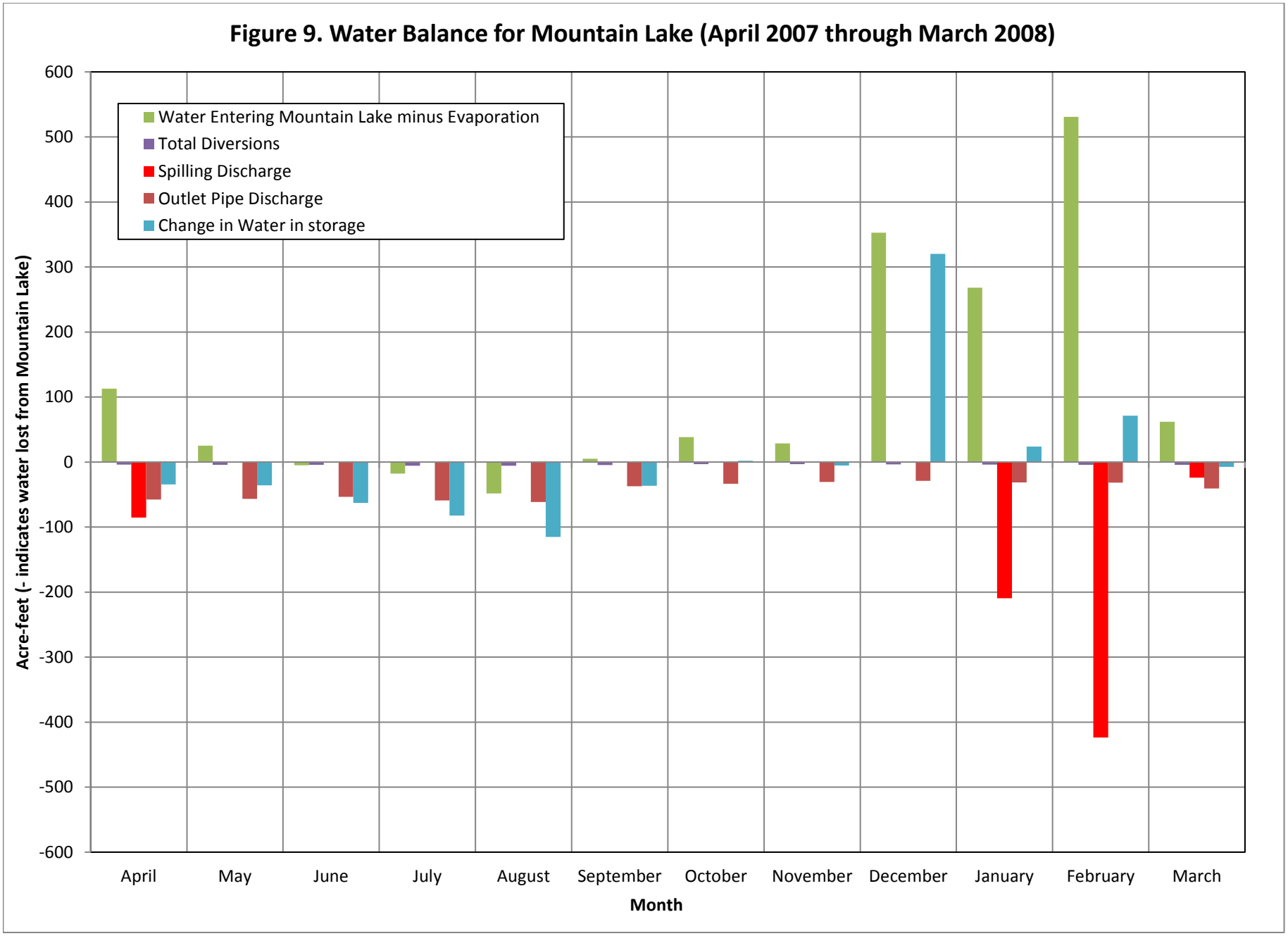


Figure 9. Water Balance for Mountain Lake (April 2007 through March 2008)
Water Entering Mountain Lake minus Evaporation
Total Diversions
Spilling Discharge
Outlet Pipe Discharge
Change in Water in storage
Acre-feet (- indicates water lost from Mountain Lake)
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
April
May
June
July
August
September
October
November
December
January
February
March
Month

Figure 10. Cascade Creek Discharge at Site C2
June 2007 to April 2008
Rating Curve -> Discharge = 2.9055 * (Barocorrected Logger Pressure $^{7.1279}$)
R^2 = 0.9735

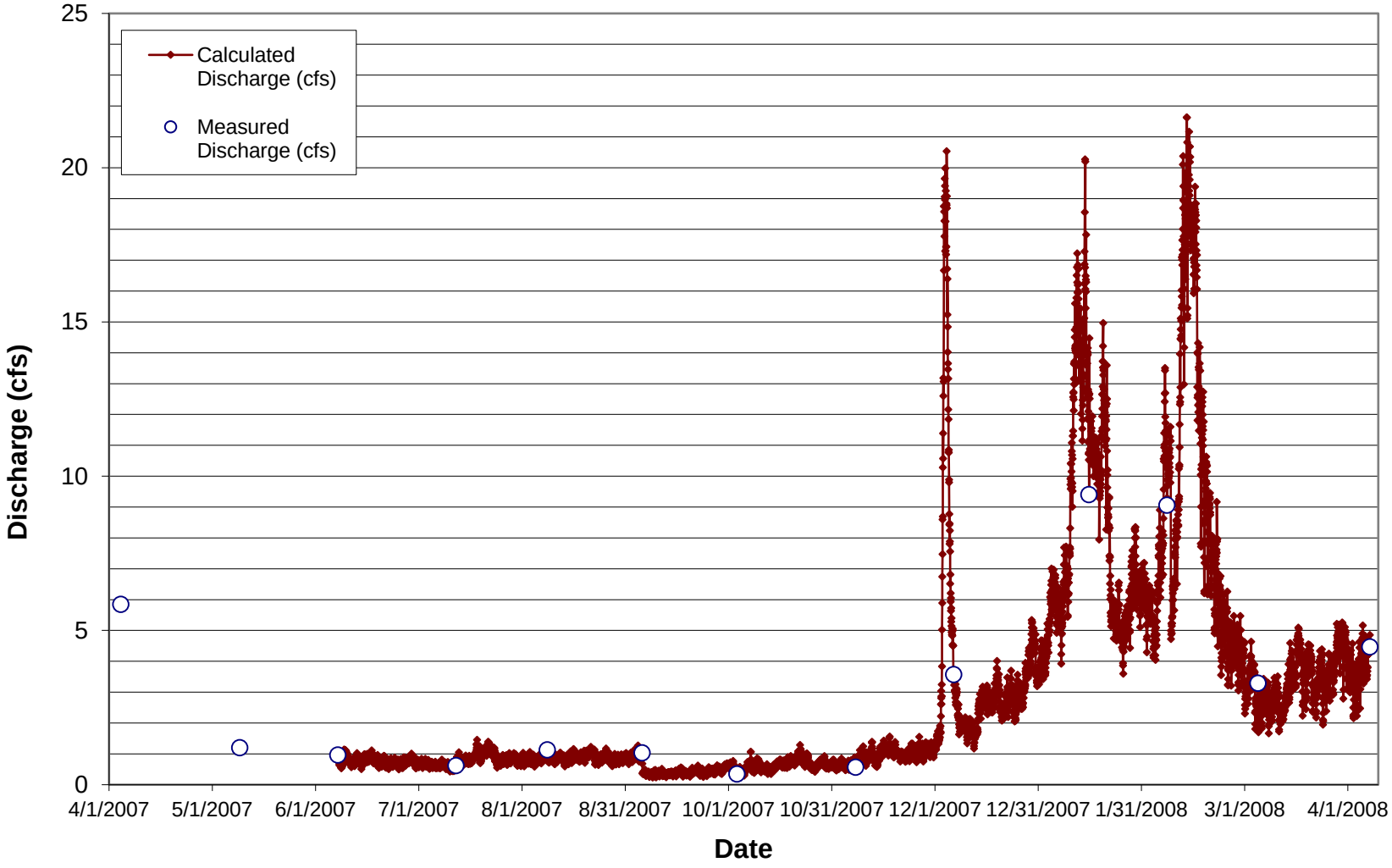
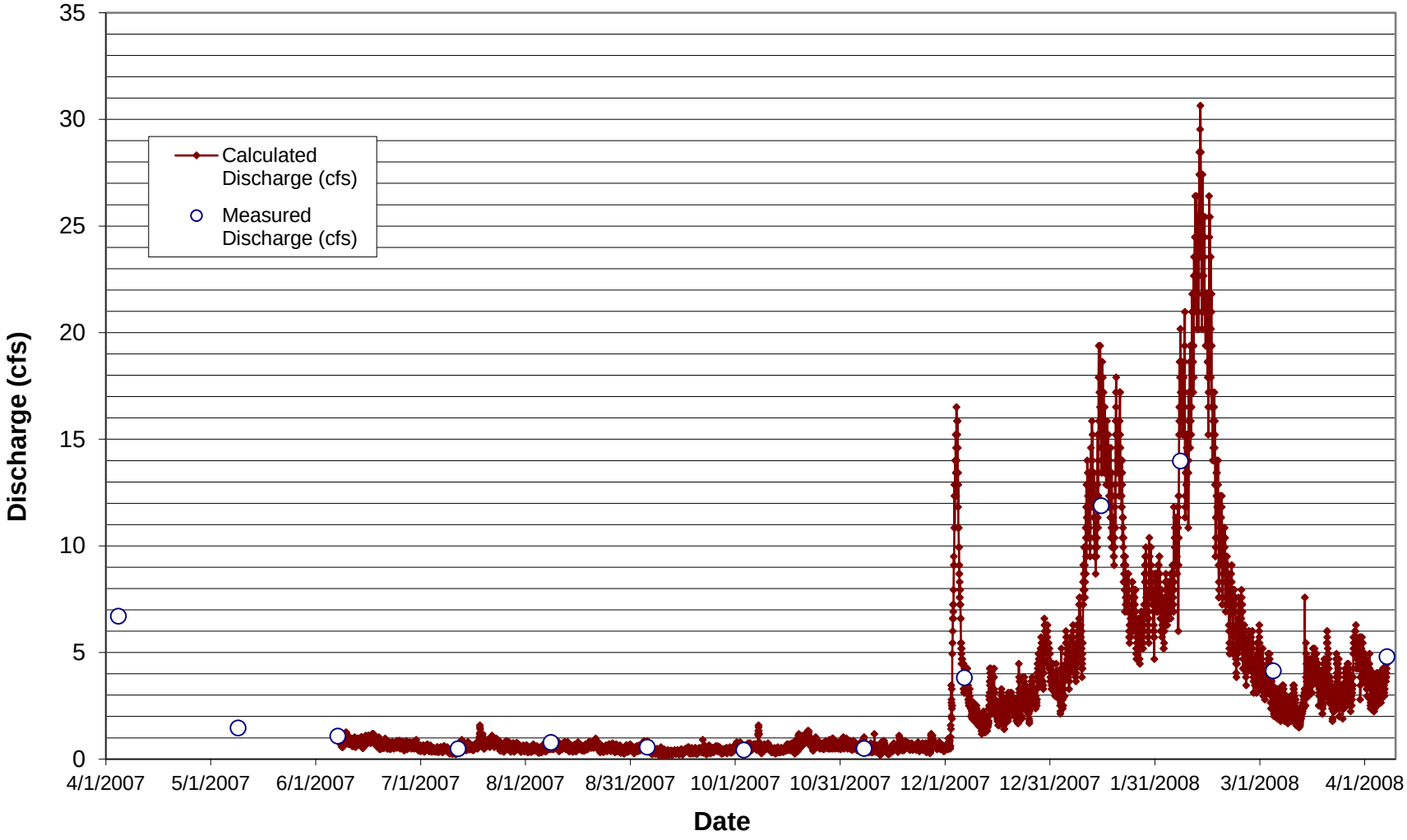


Figure 11. Cascade Creek Discharge at Site C5 (Old Olga Diversion Weir)
June 2007 to April 2008
Rating Curve -> Discharge in cfs = 1.1741 * (Stage Height in Feet $^{6.2164}$)
R^2 = 0.9903



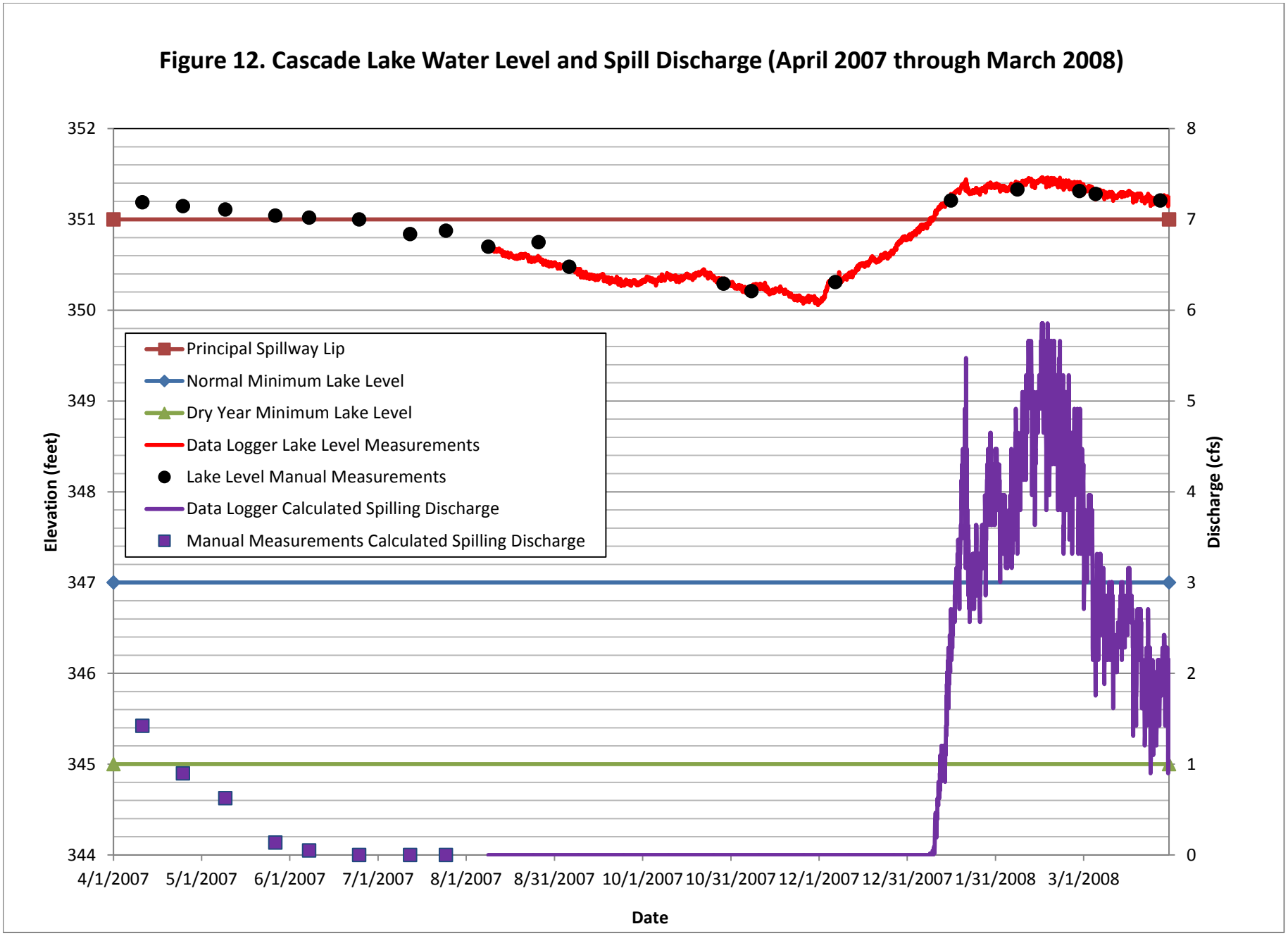


Figure 12. Cascade Lake Water Level and Spill Discharge (April 2007 through March 2008)
Elevation (feet)
Discharge (cfs)
Date
352
351
350
349
348
347
346
345
344
8
7
6
5
4
3
2
1
0
4/1/2007
5/1/2007
6/1/2007
7/1/2007
8/1/2007
8/31/2007
10/1/2007
10/31/2007
12/1/2007
12/31/2007
1/31/2008
3/1/2008
Principal Spillway Lip
Normal Minimum Lake Level
Dry Year Minimum Lake Level
Data Logger Lake Level Measurements
Lake Level Manual Measurements
Data Logger Calculated Spilling Discharge
Manual Measurements Calculated Spilling Discharge

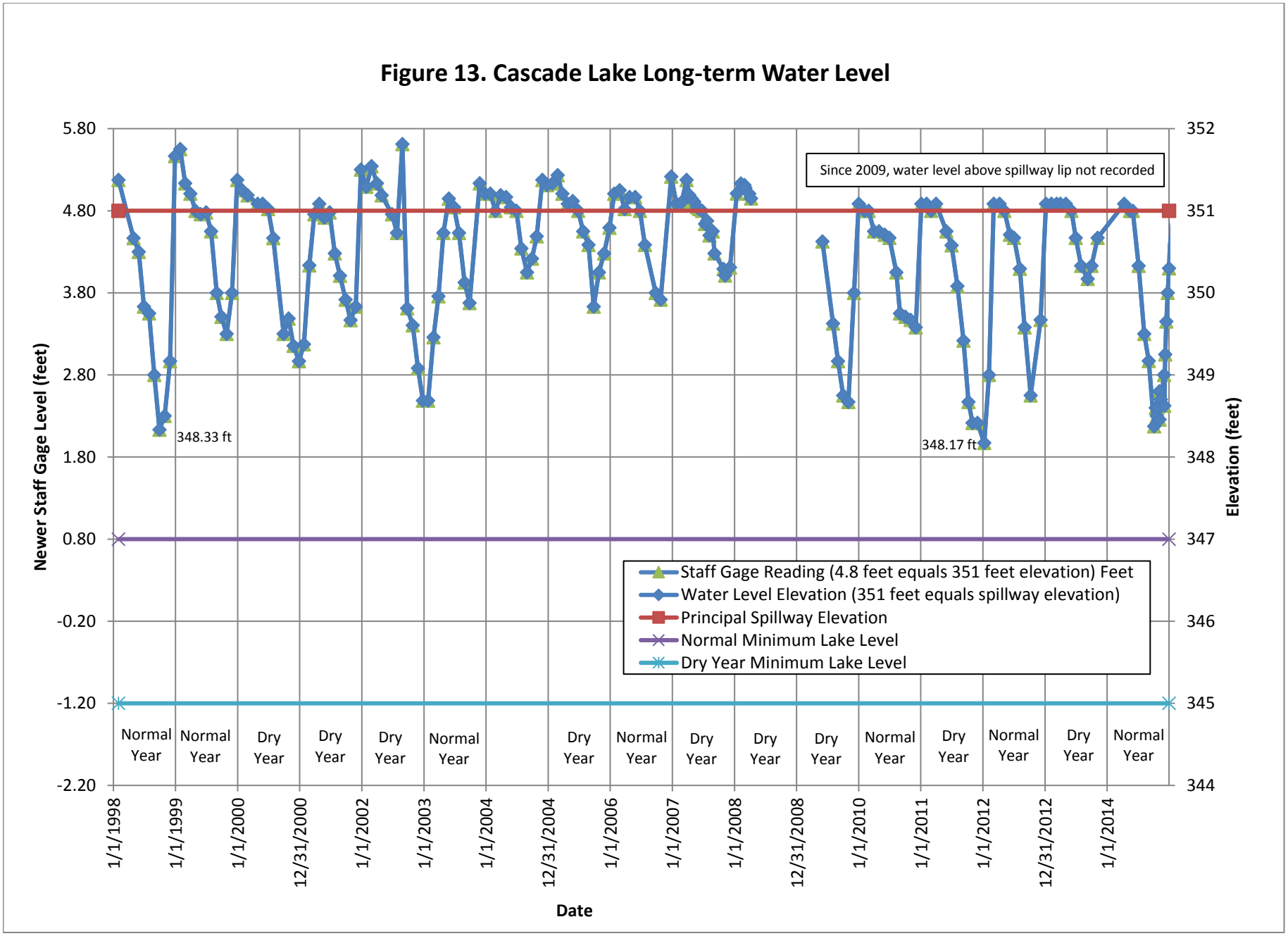


Figure 13. Cascade Lake Long-term Water Level
Since 2009, water level above spillway lip not recorded
348.33 ft
348.17 ft
Staff Gage Reading (4.8 feet equals 351 feet elevation) Feet
Water Level Elevation (351 feet equals spillway elevation)
Principal Spillway Elevation
Normal Minimum Lake Level
Dry Year Minimum Lake Level
Newer Staff Gage Level (feet)
Elevation (feet)
Date
5.80
4.80
3.80
2.80
1.80
0.80
-0.20
-1.20
-2.20
352
351
350
349
348
347
346
345
344
Normal Year
Normal Year
Dry Year
Dry Year
Dry Year
Normal Year
Dry Year
Normal Year
Dry Year
Dry Year
Dry Year
Normal Year
Dry Year
Normal Year
Dry Year
Normal Year
1/1/1998
1/1/1999
1/1/2000
12/31/2000
1/1/2002
1/1/2003
1/1/2004
12/31/2004
1/1/2006
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12/31/2012
1/1/2014

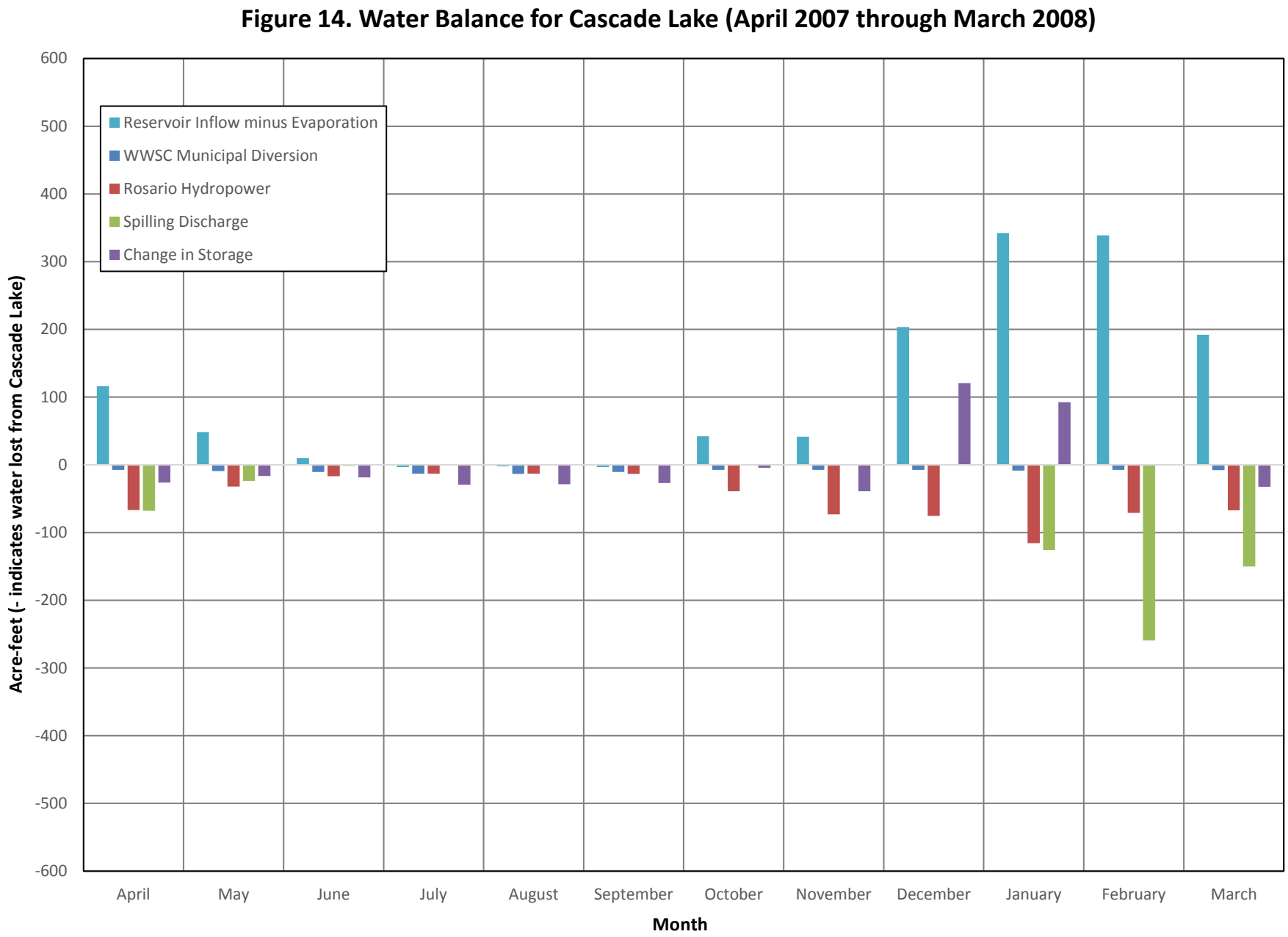


Figure 14. Water Balance for Cascade Lake (April 2007 through March 2008)
Reservoir Inflow minus Evaporation
WWSC Municipal Diversion
Rosario Hydropower
Spilling Discharge
Change in Storage
Acre-feet (- indicates water lost from Cascade Lake)
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
April
May
June
July
August
September
October
November
December
January
February
March
Month

Appendices

Appendix A
Summary of Previous Studies

APPENDIX A

Summary of Previous Studies

During the course of the study period, several other previous studies were identified that were prepared by earlier investigators. The conclusions of these reports are compared to the findings in the body of the main report. A short summary of each report is provided in this appendix.

Geology and Water Resources of the San Juan Islands, San Juan County Washington. 1975. Department of Ecology, Water Resources Bulletin 46.

This report has estimates of total average natural inflow into both Mountain and Cascade Lake, loss due to evaporation from those lakes, and discreet measurements of stream discharge on a monthly basis for the calendar year of 1974. Storage estimates are made for both Mountain Lake and Cascade Lake and rough water budgets are described (**Table A1** and **A2**).

Table A1. Mountain Lake Water Budget for Average Year

Hydrologic Component	Annual Volume
Total Inflow	2,200 afy
Evaporation	350 afy
Total Inflow minus Evaporation	**1,850 afy**
Discharge from Mountain Lake to Cascade Creek	1,820 afy
Tributary Contribution	600 afy
Total Flowing Past Approximately Site C2	**2,420 afy**

Table A2. Cascade Lake Natural Water Budget for Average Year

Hydrologic Component	Annual Volume
Total Inflow	3,000 afy
Evaporation	303 afy
Total Inflow – Evaporation	**2,697 afy**

Devine Tarbell and Associates (2003 and 2004)

Devine Tarbell and Associates (DTA) was hired by San Juan County to perform streamflow measurements in 2003 and 2004. DTA produced rating curves for their various sites, one of which the referred to as Cascade Creek at Olga, which corresponds to this study's Site C5. Data loggers were installed at certain locations as part of this study to allow for determination of stream flow between site visits. From their logger data and rating curves, they calculated average daily discharge for this site. **Table A3** shows calculated daily discharge from May 12 through April 1, 2004. The lowest average daily discharge was 1.1 cfs on a number of occasions in June 2003, while the highest average daily discharge was 91.9 cfs on November 19, 2003. This reported discharge of 91.9 cfs for Cascade Creek is the highest discharge that has been reported in the literature.

Table A3. DTA Measured Discharge at Site C5

Cascade Creek at Olga — **May 2003 - April 2004** — **Estimated Discharge In cfs***

*Discharges are estimated based on less than one year of records and are subject to change due to additional data and changes in rating curves.

Day

	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2003	May												2.9	2.5	2.3	2.1	2.1
	June	1.6	1.4	1.2	1.1	1.1	1.1	1.3	1.2	1.3	1.6	1.5	1.4	1.5	1.3	1.2	1.1
	July	1.5	1.5	1.5	1.6	1.6	1.5	1.6	1.6	1.4	1.4	1.6	1.6	1.8	1.7	1.6	1.7
	August	2.0	1.8	1.8	1.8	1.6	1.8	1.6	1.6	1.7	1.6	1.6	1.6	1.5	1.5	1.6	1.6
	September	1.3	1.4	1.5	1.5	1.5	1.5	1.7	1.5	1.2	1.3	1.3	1.2	1.2	1.3	1.3	1.5
	October	1.6	1.6	1.7	1.9	1.9	2.1	2.2	1.9	1.8	1.9	2.1	2.8	2.3	2.0	2.3	7.4
	November	5.0	4.4	4.0	3.6	3.6	3.5	3.3	3.0	3.0	4.8	5.4	4.6	4.3	4.3	4.5	5.0
	December	25.5	33.4	26.7	22.1	18.5	15.3	14.6	12.3	10.8	10.4	9.9	8.8	8.6	8.3	8.2	8.1
2004	January	2.8	2.4	3.0	2.8	1.5	1.7	3.8	4.6	5.3	5.3	5.4	5.9	6.1	6.1	6.0	5.3
	February	58.0	46.7	34.8	28.8	23.6	20.1	18.9	14.9	12.5	11.3	9.8	9.0	8.6	8.9	9.0	8.3
	March	2.4	2.2	3.3	3.5	3.8	3.5	6.4	6.1	6.2	5.2	5.0	4.8	2.9	3.0	2.6	2.9
	April	2.1	1.8	1.9	1.8	1.8	1.7	1.8	1.5	1.4	1.3	1.3	1.5	1.5	1.5	1.4	1.4

Day

	Month	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Avg. Monthly
2003	May	1.9	1.9	1.7	1.8	1.8	1.9	1.9	1.9	1.9	1.6	1.6	1.6	1.4	1.5	1.6	--
	June	1.1	1.3	1.2	1.3	1.5	1.4	1.3	1.1	1.1	1.1	1.3	1.5	1.7	1.9		**1.3**
	July	1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.5	1.5	1.6	1.4	1.4	1.6	1.8	2.0	**1.6**
	August	1.6	1.6	1.5	1.5	1.5	1.7	1.7	1.6	1.6	1.7	1.6	1.5	1.5	1.5	1.5	**1.6**
	September	1.5	1.7	1.5	1.3	1.2	1.3	1.3	1.2	1.3	1.2	1.2	1.6	1.7	1.6		**1.4**
	October	17.3	10.3	6.5	24.5	55.0	24.5	14.3	9.6	7.9	6.7	6.1	8.5	6.4	6.5	5.7	**8.0**
	November	5.1	22.9	91.9	31.0	18.5	13.8	12.7	13.1	11.4	9.5	8.6	19.4	27.8	17.5		**12.3**
	December	6.6	4.5	4.3	3.9	3.7	3.4	3.4	3.3	3.0	3.0	3.6	4.0	3.9	3.6	3.6	**9.7**
2004	January	4.8	4.7	5.0	4.8	4.6	5.3	6.5	6.4	6.1	7.8	9.4	11.2	21.1	56.5	59.0	**9.1**
	February	7.6	7.8	8.0	8.3	9.7	8.0	7.0	6.8	5.7	5.1	4.1	3.4	3.0			**14.1**
	March	2.9	3.0	3.4	2.6	2.5	2.5	2.7	2.9	2.9	2.9	2.4	2.2	2.4	2.9	2.4	**3.4**
	April	1.3															

Multi-purpose Surface Water Storage Assessment WRIA 2 – April 30, 2004. Montgomery Water Group and Devine Tarbell and Associates

Using the DTA data collected in 2003 and 2004, an analysis was performed to try to determine what water might be available in excess of existing water rights in the County. Using data from the Cascade Creek at Olga (Site C5) average monthly discharge rates were calculated for June 2003 through March 2004. Flow exceedance estimates for the 10 percent, 50 percent, and 90 percent exceedances were prepared using correlations to Samish River data. This report assumed that Rosario had been consumptively diverting their full instantaneous water right limit from Cascade Creek over the course of the study. It is unknown if this is a reasonable assumption for the period studied. **Table A4** summarizes the findings from the report.

Table A4. Table from Montgomery Water Group (2004) Report

Table 2-3. 10, 50 and 90% exceedance for Cascade Creek before and after diversions, based on data collected from Cascade Creek May 2003 – April 2004. Units are in cfs.

	% Exceedance before diversions			% Exceedance after diversions		
Month	**10**	**50**	**90**	**10**	**50**	**90**
January	24.7	11.2	7.0	21.8	9.1	5.2
February	22.5	10.9	7.2	19.7	8.9	5.3
March	18.0	10.3	6.9	15.4	8.2	5.1
April	15.0	8.6	6.3	12.7	6.7	4.5
May	10.5	6.2	4.8	8.4	4.5	3.1
June	7.6	4.7	3.9	5.7	3.1	2.3
July	5.2	3.9	3.4	3.5	2.2	1.8
August	4.0	3.4	3.1	2.4	1.8	1.5
September	5.3	3.4	3.0	3.5	1.8	1.4
October	9.6	4.5	3.1	7.6	2.8	1.5
November	19.2	9.1	4.5	16.6	7.2	2.8
December	22.4	11.0	6.6	19.6	8.9	4.8

The discharge rates in **Table 4A**, even for the 90 percent exceedance flow, are much higher than was recorded during this study at Site C5. If the discharge rates in **Table 4A** are extrapolated over each month, then the calculated volumetric discharge before diversions is 9,857 af, 5,246 af, and 3,599 af for the 10, 50 and 90 percent exceedance flows. These volumes are much higher than calculated by the other studies.

Rosario Water Budget Supply Analysis. Preliminary Report June 2005. RH2 Engineering, Inc.

RH2 was hired by Rosario Utilities and Eastsound Water Users Association to create a water balance for the same basins being studied by Ecology. In this report estimates are made for average year and a 100-year drought year runoff occurring into Mountain Lake and Cascade Lake (**Table 5A**). It summarizes that even during a 100-year drought, there will be enough water in the combined Cascade Creek and Cascade Lake systems to allow for an additional diversion of 100 million gallons (307 afy) over the course of a year. However, in reviewing the water budget calculations there is an assumption made that the only water leaving Mountain Lake is the water necessary to satisfy the Rosario and Trust Water Rights at the diversion to Cascade Lake. The analysis appears to neglect to include the 0.56 cfs Olga water right on Cascade Creek, does not take into account the diversion of water from Mountain Lake by Doe Bay, and it does not appear to take into account the use of water from Cascade Lake for hydropower production.

Table A5. Mountain Lake and Cascade Lake Water Budget

Lake	Average Year	1 in 100 Drought Year
Mountain Lake	2,661 afy	1,087 afy
Cascade Lake	3,684 afy	1,568 afy

Appendix B
Precipitation Data from Olga 2 SE Station

OLGA 2 SE, WASHINGTON Station

Precipitation in inches

Months with greater than 5 days missing. Not included in monthly average or annual total.

YEAR(S)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	Dry or Normal Year
1891							0.38	3.26	4.24		5.32	9.41		
1892	3.11	1.55	1.55	1.65	2.86	1.01	1.76	0.68	2.52	2.68				
1893	2.04	4.42	1.54	4.18	4.06	1.73	1.12	0.21	1.69	2.6	6.12	6.49	36.2	Normal
1894	4.34	2.1	3.78	4.94	2.83	2.33	0.54	0.13	2.79	3.94	5.89	1.76	35.37	Normal
1895	2.84	2.96	0.91	1.45	1.56	1.07	0.17	0.23	1.62	0.69	4.21	6.97	24.68	Dry
1896	3.54	3.95	1.79	2.17	1.63	1.29	0	0.43	1.03	3.32	7.13	7.13	33.41	Normal
1897	2.92	2.58	2.47	1.65	2.29	1.29	1.38	0.64	2.77	1.2	4.92	7.32	31.43	Normal
1898	1.33	3.93	3.22	1.22	0.96	2.15	0.46	0.3	2.45	3.33	4.32	3.42	27.09	Dry
1899	4.15	3.9	2.13	2.14	2.5	0.38	0.6	2.31	1.02	3.78	5.95	4.85	33.71	Normal
1900	4.25	3.08	2.95	1.88	2.56	2.47	0.64	1.37	1.87	2.76	2.28	4.52	30.63	Normal
1901	2.84	3.38	2.04	4.04	1.49	1.83	0.39	0	1.67	2.11	6.72	2.42	28.93	Dry
1902	2.4	1.86	3.36	2.03	1.69	0.55	0.98		1.69	1.8	6.26	6.69		
1903	4.6	3.36	3.5	1.36	1.59	0.98	1.36	1.2	4.27	2.12	5.75	2.52	32.61	Normal
1904	4.92	4.45	3.52	1.46	0.63	1.37	0.4	0.49	0.98	1.97	5.17	4.1	29.46	Normal
1905	2.95	1.69	1.8	0.58	3.01	1.56	0.56	1.13	5.73	3.23	1.3	3.12	26.66	Dry
1906	2.87	3.1	1.05	0.75	4.27	1.35	0.23	1.13	3.59	4.8	5.62	5.34	34.1	Normal
1907	2.29	5.04	1.58	2.22	0.3	0.79	0.95	1.22	1.91	0.79	4.46	4.9	26.45	Dry
1908	3.81	3.67	3.57	1.06	1.7	0.8	0.55	0.93	0.16	3.31	2.62	3.18	25.36	Dry
1909	3.18	3.16	2.21	0.67	1.35	0.65	2.03	0.9	1.59	2.48	9.45	2.47	30.14	Normal
1910	5.47	3.74	2.54	1.93	1.5	1.31	0	0.5	1.16	4.96	5.72	6.95	35.78	Normal
1911	4.2	1.5	1.13	1.88	3.1	0.99	0.4	1.17	2.9		6.41	5.05		
1912	3.85	2.74	1.4	2.09	2.35	1.73	1.28	3.62	1.14	3.38	5.17	5.05	33.8	Normal
1913	6.06	2.25	1.69	1.95	1.75	2.58	0.59	0.51	1.99	5.28	2.82	1.46	28.93	Dry
1914	5.17	2.52	1.44	2.44	0.35	3.86	0.03	0.22	4.51	2.04	6.35	1.29	30.22	Normal
1915	3.34	1.79	2.76	1.19	1.19	0.53	0.91	0.03	0.71	4.47	5.81	5.43	28.16	Dry
1916	2.61	4.86	6.09	1.89	1.06	0.86	2.16	0.13	0.99	1.51	2.53	4.19	28.88	Dry
1917	4.62	2.09	2.5	3.72	1.05	3.52	0.29	0.5	1.31	1.33	3.08	13.88	37.89	Normal
1918	4.86	3.04	2.4	0.57	0.63	0.25	1.49	2.13	0.27	4.11	3.83	5.64	29.22	Normal
1919	5.24	3.05	3.33	3.12	1.57	0.62	0.42	0.41	1.88	1.19	4.63	3.45	28.91	Dry
1920	6.19	0.66	3.11	2.8	1.16	2.12	0.55	1.24	3.73	5.58	3.6	5.18	35.92	Normal
1921	4.59	3.31	1.53	1.63	1.89	1.87	0.12	1.04	3.14	4.58	6.25	4.47	34.42	Normal
1922	1.91	1.68	2.38	2.02	1.17	0.02	0	1.15	2.6	3.34	1.88	5.7	23.85	Dry
1923	5.76	1.89	2.56	1.25	2.9	0.95	1.05	1.37	1.69	2.14	2.52	7.19	31.27	Normal
1924	2.56	5.48	1.03	1.97	0.12	0.76	0.65	0.82	1.29	2.14	4.15	6.89	27.86	Dry
1925	4.59	2.55	2.66	2.44	0.94	0.11	0.63	0.87	0.81	1.81	2.46	5.27	25.14	Dry
1926	3.32	3.07	0.82	1.11	2.77	0.26	0	1.51	1.17	2.91	3.19	4.39	24.52	Dry
1927	3.21	2.12	2.33	1.25	0.97	0.68	0.52	2.21	2.18	4.01	5.53	3.42	28.43	Dry
1928	4.19	0.87	2.36	2.21	0.1	0.95	0.38	0.4	0.84	4.21	1.77	2.35	20.63	Dry
1929	1.11	0.85	2.57	0.95	0.68	0.51	0.13	0.51	0.31	1.38	2.01	4.08	15.09	Dry
1930	1.32	3.61	2.7	1.75	0.88	1.08	0	0	1.13	5.31	1.26	1.22	20.26	Dry
1931	4.13	2.58	3.31	0.76	0.92	2.92	0.81	0.17	3.43	0.85	4.24	2.63	26.75	Dry
1932	3.73	4.93	4.68	2.06	0.34	0.82	3.3	0.75	0.94	3.27	7.71	3.51	36.04	Normal
1933	5.51	1.85	2.75	0.36	2.06	1.15	1.3	0.6	2.8	4.02	3.48	8.75	34.63	Normal
1934	5.92	1.35	2.96	1.07	0.78	0.07	0.58	0.95	1.4	1.77	4.3	4.32	25.47	Dry
1935	13.04	1.01	3.75	0.47	0.29	0.45	1.14	0.61	1.35	2.52	2.21	1.61	28.45	Dry
1936	5.65	3.46	2.29	1.19	2.67	1.74	0.8	0.31	2.04	0.98	1.37	6.42	28.92	Dry
1937	1.52	3.65	1.9	2.2	1.16	3.96	0	1.56	0.9	2.47	4.05	6.08	29.45	Normal
1938	2.95	1.47	2.11	2.2	0.94	0.01	0.42	0.19	1.32	2.83	2.92	6.13	23.49	Dry
1939	5.28	3.53	1.07	1.07	1.17	2.26	1.34	0.58	0.26	3.19	4.36	4.51	28.62	Dry
1940	2.2	4.19	3.77	1.08	1.81	0.1	0.82	0.47	1.45	2.8	3.4	3.95	26.04	Dry
1941	2.75	1.88	1.12	1.97	2.2	1.2	0.37	1.32	2.94	2.37	4.54	3.43	26.09	Dry
1942	1.23	1.63	1.47	2.08	1.53	3.4	1.46	0.22	0.32	1.81	4.91	4.86	24.92	Dry
1943	1.45	2.8	1.92	2.56	0.86	0.96	0.57	1.77	0.49	3.03	1.21	1.83	19.45	Dry
1944	2.39	2.04	1.7	2.16	0.93	1.56	0.42	1.03	1.56	1.94	2.78	1.57	20.08	Dry
1945	4.47	2.67	2.08	2.55	1.13	0.52	0.26	0.67	3.56	6.42	5.11	3.48	32.92	Normal
1946	4.16	2.93	3.71	1.88	0.76	3.27	0.74	0.24	0.6	3.5	1.88	3.04	26.71	Dry
1947	5.12	2.84	2.58	2.38	1.12	1.5	0.51	0.87	1.22	5.15	3.77	5.09	32.15	Normal
1948	2.96	5.28	2.5	1.69	4.2	2.61	1.09	2.71	1.53	2.5	5.18	5.22	37.47	Normal
1949	0.62	4.66	2.15	1.22	0.59	1.25	1.32	0.61	1.76	2.85	5.2	7.33	29.56	Normal
1950	2.88	3.34	3.82	1.56	1.05	0.41	1.15	1.77	0.63	5	4.23	4.24	30.08	Normal
1951	5.86	4.79	3.18	0.47	1.79	0.24	0.17	0.53	1.75	4.93	2.41	3.29	29.41	Normal
1952	2.63	2.06	3.4	1.63	1.86	1.45	0.65	0.37	0.68	1.76	0.68	2.73	19.9	Dry
1953	8.41	2.96	1.49	2.46	1.06	1.73	0.99	0.71	1.83	2.47	4.92	6.49	35.52	Normal
1954	5.74	3.37	0.83	1.93	1.33	1.49	1.49	2.17	2.31	1.22	6.49	2.36	30.73	Normal
1955	2.29	4.35	2.48	1.87	1.82	2.4	2.34	0.34	1.09	4.29	5.99	5.32	34.58	Normal
1956	3.14	1.83	2.89	0.2	0.31	2.91	0.3	1.62	2.99	5.81	2.19	6.57	30.76	Normal
1957	1.96	2.73	3.76	1.83	0.63	1.49	1.35	0.61	0.47	2.02	1.95	4.22	23.02	Dry
1958	3.27	2.88	1.05	1.87	1.15	1.26	0	0.48	1.76	4.24	6.74	3.77	28.47	Dry
1959	5.28	2.5	2.01	2.65	1.4	1.36	0.57	1.69	3.68	3.11	4.74	4.62	33.61	Normal
1960	4.62	2.49	2.68	2.1	2.67	0.74	0	2.43	1.18	2.14	4.22	2.2	27.47	Dry
1961	4.14	5.51	2.84	1.99	2.25	0.84	1.07	0.62	1.1	3.09	2.72	4.33	30.5	Normal
1962	2.05	1.32	2.39	1.89	1.57	0.78	0.19	3.29	1.52	2.85	5.14	3.34	26.33	Dry

OLGA 2 SE, WASHINGTON Station

Precipitation in inches

Months with greater than 5 days missing. Not included in monthly average or annual total.

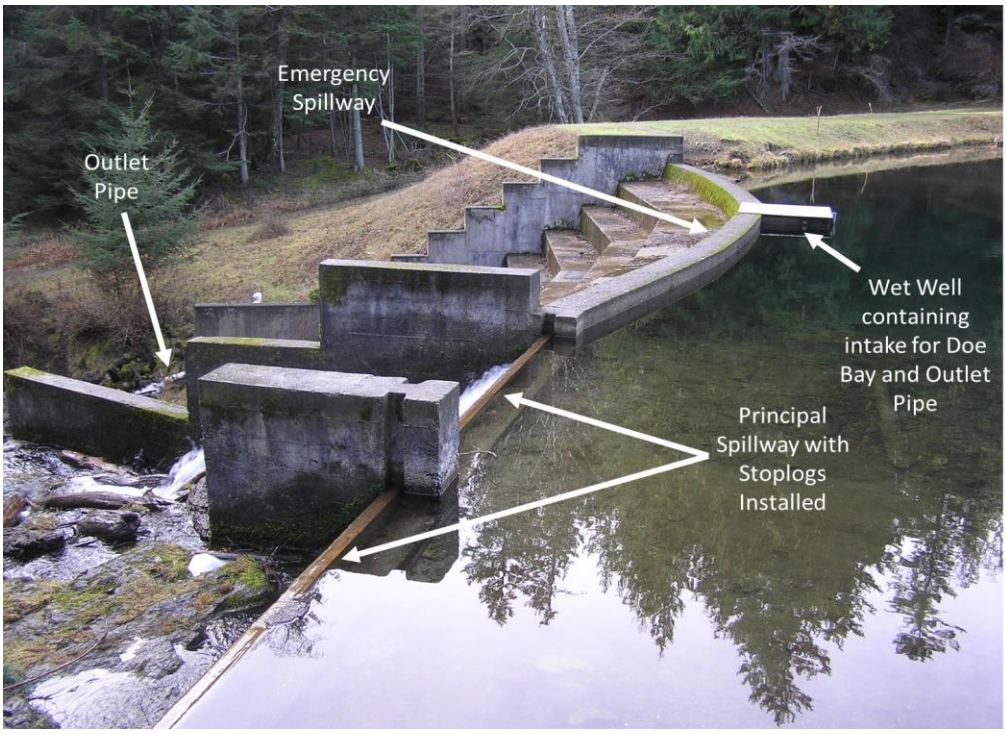
YEAR(S)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	Dry or Normal Year
1963	1.63	2.57	1.46	2.31	1.08	1.31	1.4	1.15	1.63	4.34	4.78	5.92	29.58	Normal
1964	5.5	2.78	3.84	1.67	1.64	1.91	1.81	1.61	2.96	1.54	3.63	3.65	32.54	Normal
1965	5.96	4.95	0.44	2.38	1.81	0.6	0.33	2.61	1.5	3.26	4.61	4.29	32.74	Normal
1966	3.24	1.62	2.79	1.52	1.78	1.21	3.62	0.59	1.19	4.02	3.45	4.82	29.85	Normal
1967	7.64	3.64	2.4	2.15	1.96	1.09	0.32	0.02	1	7.61	1.99	6.08	35.9	Normal
1968	3.98	3.15	3.57	1.97	1.67	1.62	0.85	1.97	2.62	3.82	4.14	5.17	34.53	Normal
1969	4.02	0.74	1.99	3.78	1.15	0.59	0.86	0.74	3.66	2.18	2.19	2.84	24.74	Dry
1970	5.01	2.13	1.65	3.21	0.96	0.43	0.71	0.09	2.38	2.84	3.59	3.19	26.19	Dry
1971	7.75	3.47	3.22	0.55	1.16	2.49	0.86	0.53	2.53	2.08	5.67	6.9	37.21	Normal
1972	4.69	4.65	4	3.53	0.61	1.59	1.53	1.02	1.71	1.25	2.59	6.16	33.33	Normal
1973	2.33	1.6	1.76	0.66	1.1	1.6	0.25	0.76	0.95	3.95	5.62	4.56	25.14	Dry
1974	7	3.27	2.5	2.42	1.97	1.05	1.93	0.07	0.26	1.34	4.38	4.8	30.99	Normal
1975	4.44	3.23	1.13	1.22	1.51	0.95	1.48	3.07	0.58	3.62	5	6.49	32.72	Normal
1976	5.35	4.28	1.67	1.85	1.59	1.35	0.84	2.26	1	2.3	1.13	3.12	26.74	Dry
1977	2.49	1.27	3.13	1.32	2.04	0.29	0.75	1.42	1.75	1.52	3.49	4.08	23.55	Dry
1978	2.99	2.79	2.42	2.25	1.65	0.78	0.83	1.93	2.21	1.53	3.35	1.88	24.61	Dry
1979	1.76	2.36	1.31	2.04	0.52	1.27	0.59		1.95	1.65	1.73	7.65		
1980	1.36	2.56	2.99	1.44	1.48	2.89	0.68	0.5	2.3	0.62	5.98	4.46	27.26	Dry
1981	1.43	4.53	2.04	2.8	2.32	2.13	0.75	0.27	1.31	4.2		5.2		
1982	6.44	6.36	1.97	0.96	0.49	1.15	2.97	0.64	1.26	2.11	2.11	4.42	30.88	Normal
1983	5.18	1.56	1.93	1.72	2.8	1.08	1.05	0.54	3.03	2.36	5.62	2.51	29.38	Normal
1984	7.42	2.64	2.17		2.63	1.36	0	1.09	2.03	2.59	5.41	2.77		
1985	0.62	1.31	1.13	1.98	1.24	1.6	0.15	0.42	1.16	5.54	2.94	0.6	18.69	Dry
1986	3.81	3.53	3.05	2.2	2.61	1.23	1.19	0	1.44	0.85	6.53	2.21	28.65	Dry
1987	1.86	2.42	1.73	1.99	1.33	0.45	0.6	0.62	0.2	0.22	1.6	4.05	17.07	Dry
1988	2.03	1.33	3.39	1.75	3.27	1.01	0.61	0.73	1.32	3.32	4.54	4.05	27.35	Dry
1989	4.17	1.41	3.83	1.84	1.44	0.7	0.54	1.39	0.15	1.5	7.27	3.11	27.35	Dry
1990	4.58	3.22	1.53	2.61	1.56	2.48	0.3	2.07	0.2	3.38		4.42		
1991	3.95	2.68	1.67	2.84	0.87	1.12	1.04	2.58	0.05	0.91	5.24	2.51	25.46	Dry
1992	4.37	2.83	1.41	2.99	0.58	1.93	1.48	0.96	2.72	1.97	4.59	2.46	28.29	Dry
1993	2.66	0.42	2.04	1.61	3.28	1.7	1.62	0.55	0.73	1.67	1.58	3.17	21.03	Dry
1994	1.39	2.84	1.46	1.53	0.64	1.51	0.39	0.34	1.39	3.39	4.42	3.71	23.01	Dry
1995	3.02	3.62	1.63	1.72	0.39	0.85	1.37	2.81	0.55	4.28	8.79	3.65	32.68	Normal
1996	4.96	2.8	1.13	2.81	1.94	0.38	0.43	0.84	2.82	3.85	4.86	5.33	32.15	Normal
1997	4.94	3.75	3.6	2.14	2.11	1.88	1.25	0.71	2.14	3.77	2.58	3.29	32.16	Normal
1998	4.12	1.19	3.17	0.48	2.5	1.51	0.9	0.03	0.22	1.88	8.22	6.16	30.38	Normal
1999	5.48	3.52	2.94	1.2	2.35	2.27	0.99	1.65	0.29	2.92	4.47	5.48	33.56	Normal
2000	2.94	2.24	2.11	2.16	3.68	1.01	0.92	1.21	1.97	2.01	2.24	2.83	25.32	Dry
2001	2.61	1.13	2.96	1.61	0.89	2.08	0.53	1.38	0.73	4.32	3.64	5.82	27.7	Dry
2002	5.47	2.7	2.49	2.25	1.56	1.05	0.51	0.51	1.11	0.93	1.96	3	23.54	Dry
2003	4.28	1.6	2.21	2.88	0.67	0.85	0.16	0.3	0.94	8.16	6.38	1.79	30.22	Normal
2004	3.25		2.75	0.32	1.65	0.65	0.53	3.6	2.23	2.94	5.61	3.96		
2005	4.66	1.4	2.2	1.8	1.38	1.5	0.56	1.71	1.14	4.33	3.38	3.02	27.08	Dry
2006	6.34	1.46	1.11	2.37	1.15	1.1	0.43	0.34	1.53	2.09	9	3.55	30.47	Normal
2007	5.78	2.46	3.91	1.77	1.37	1.18	1.61	0.66	0.91	2.71	2.11	4.29	28.76	Dry
2008	2.35	2.41	3.14	1.07	1.98	1.64	0.35	2.09	0.49	2.04	5.34	2.53	25.43	Dry
2009	3.92	1.68	2.06	1.58	2.29	0.32	0.55	0.62	1.73	5.2	5.56	2	27.51	Dry
2010	4.18	1.7	2.82	2.25	3.01	1.5	0.08	1.24	4.12	1.59	3.34	5.45	31.28	Normal
2011	5.53	2.1	2.88	3.24	3.57	0.35	0.71	0.31	0.71	1.79	3.74	1.7	26.63	Dry
2012	2.34	4.46	3.49	2.56	0.97	2.62	1.49	0.07	0.09	5.69	3.38	4.37	31.53	Normal
2013	3.59	1.91	2.5	3.66	2.32	1.13	0.02	0.97	4.22	1.07	3.91	3.08	28.38	Dry
2014	3.31	3.83	4.71	2.34	2.33	0.84	0.94	0.9	2.28	4.49	3.8	4.19	33.96	Normal

Period of Record Statistics

MEAN	3.90	2.79	2.43	1.90	1.61	1.33	0.81	1.01	1.69	2.95	4.22	4.33	28.84	
S.D.	1.81	1.19	0.95	0.84	0.89	0.82	0.65	0.83	1.10	1.49	1.81	1.92	4.57	
SKEW	1.18	0.44	0.55	0.60	0.77	0.95	1.58	1.23	0.95	0.78	0.35	1.20	-0.41	
MAX	13.04	6.36	6.09	4.94	4.27	3.96	3.62	3.62	5.73	8.16	9.45	13.88	37.89	
MIN	0.62	0.42	0.44	0.20	0.10	0.01	0.00	0.00	0.05	0.22	0.68	0.60	15.09	
NO YRS	123	122	123	122	123	123	124	122	124	122	121	123	115	115

Adjudication defined a dry year as any year in which the annual precipitation was less than 29.22 inches.

Appendix C
Photos



Mountain Lake Dam

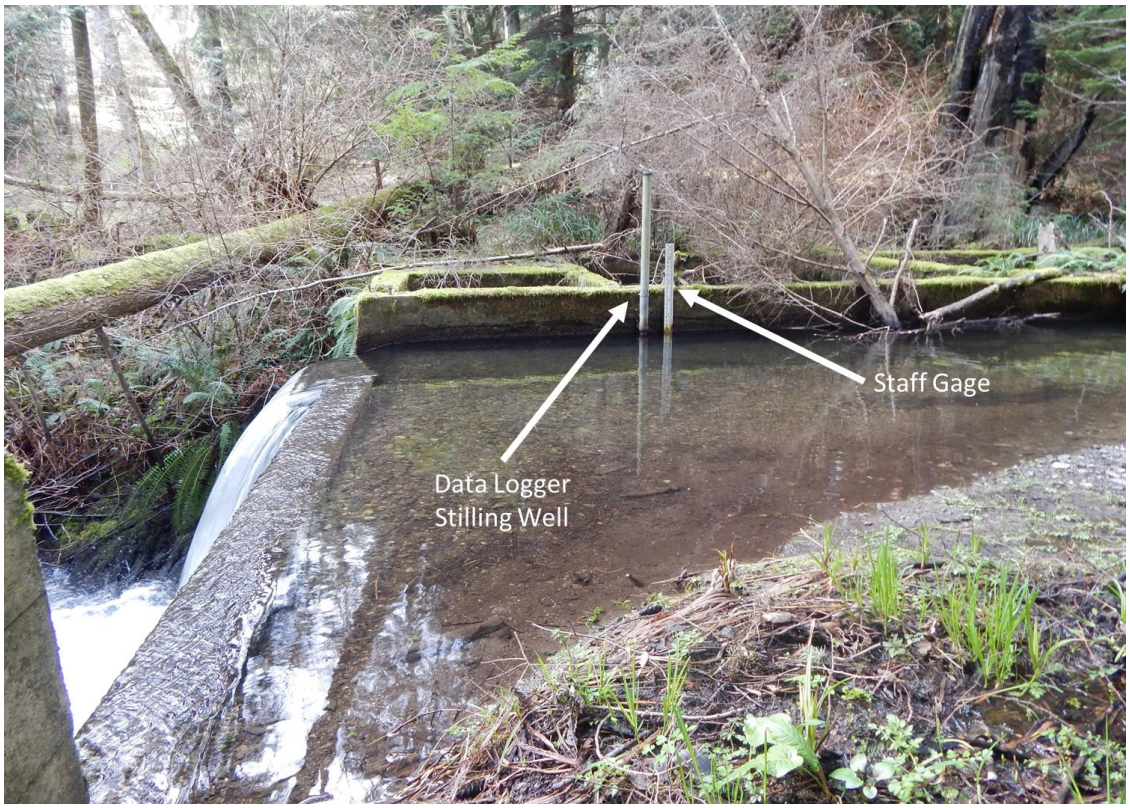
Metering Discharge from the Mountain Lake Dam Outlet Pipe (March 21, 2007)

Olga Point of Diversion from Cascade Creek

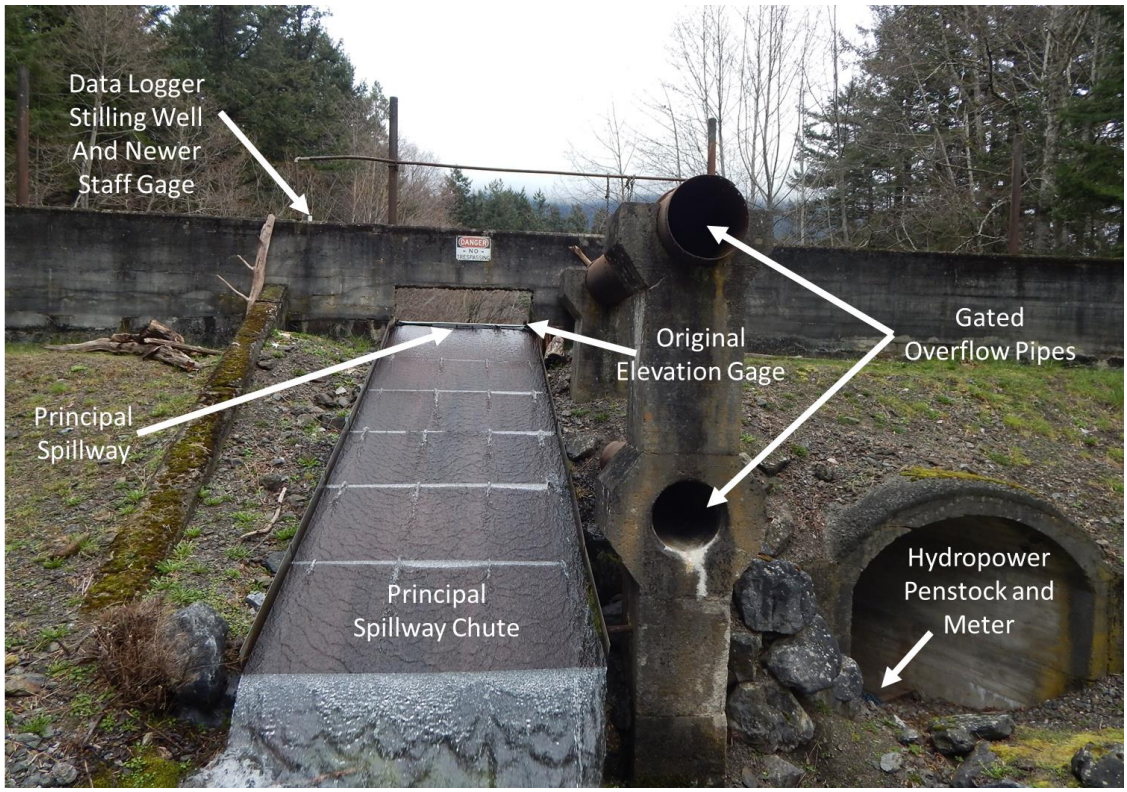
Rosario Point of Diversion from Cascade Creek (2007)

Broken Rosario Diversion During Ecology Study

Rosario Point of Diversion from Cascade Creek with New Fish Screen (2014)



Cascade Creek Site C5 (Old Olga Diversion) (2015)



Cascade Lake Dam (2015)

Appendix D
Water Rights and Water Use

APPENDIX D

Water Rights in the Mountain Lake Watershed

Doe Bay and State Parks hold three water rights for diversion out of Mountain Lake and its tributaries. These are the only water rights for diversion of water above the Mountain Lake Dam. Their certificates add up to a total of 189.4 af per year.

Table D1. Water Rights Diverted Above Mountain Lake Dam

Water Right Number	Water Right Holder	Priority Date	Purpose	Qi (cfs)	Qa (afy)	Source
Volume XI, of Adjudicated Certificates, at page 87	Washington State Parks and Recreation Commission	1920	Moran State Park	0.02	8.4	Unnamed Stream, tributary to Mountain Lake
Volume XI, of Adjudicated Certificates, at page 88	Doe Bay Water Users Association	November 3, 1945	Municipal Supply	0.05	12	Mountain Lake
Volume XI, of Adjudicated Certificates, at page 89	Doe Bay Water Users Association	August 22, 1946	Municipal Supply	0.35	82	Mountain Lake
S1-22996C	Doe Bay Water Users Association	November 2, 1977	Municipal Supply	0.5	87	Mountain Lake
			Total	**0.92**	**189.4**	-
In addition, Doe Bay Water Users Association also holds a reservoir permit that authorizes storage of 181 afy of water for municipal supply in Mountain Lake. Reservoir permit R1-26574P has a priority date of March 23, 1992.						

Water Use in the Mountain Lake Watershed

Water meter records were obtained from both Doe Bay and State Parks for their systems that divert water out of the Mountain Lake watershed.

State Parks diverts its water from a tributary to the lake. Over the period of 2003 through 2014, the average annual diversion volume was 0.50 afy with a minimum of 0.21 afy in 2003 and a maximum of 0.72 afy in 2010 (**Table D2**). Over the Ecology study period, State Parks diverted 0.58 afy from the Mountain Lake watershed. This diversion is very small with respect to the lake water balance and since the water is diverted before it water reaches the lake, it is not accounted for in the Mountain Lake water budget.

Table D2. State Parks Mountain Lake System Water Use

Year	Acre-feet
2003	0.21
2004	0.23
2005	0.50
2006	0.32
2007	0.58
2008	0.48
2009	0.59
2010	0.72
2011	0.55
2012	0.63
2013	0.58
2014	0.64

Doe Bay provided meter records for water entering its treatment plant. They divert water directly from Mountain Lake. Over the period of 1982 through 2014, the average annual diversion volume was 51.98 afy with a minimum of 15.46 afy in 1983 and a maximum of 74.84 afy in 1990. Since the mid-1990s the metered water use for Doe Bay has been reduced to an average of between 45 and 60 afy over the period of 2006 through 2014 (**Table D3**). Over the Ecology study period, Doe Bay diverted 50.8 af from Mountain Lake. Since the service area of Doe Bay lies outside of the Cascade Creek watershed, it is assumed that all water that flowed through the meter was consumptive to the watershed and did not return to Cascade Creek. Since Doe Bay's water rights are for a combined 181 afy, over the study period they only diverted 28 percent of their water right annual limit. According to the Water Facilities Inventory form, the current diversion rate by Doe Bay is 0.31 cfs. This is 0.59 cfs lower than the certificated limit of 0.90 cfs.

Table D3. Doe Bay Water Users Water Diverted from Mountain Lake

Year	Acre-feet
1982	15.55
1983	15.46
1984	17.72
1985	22.71
1986	15.97
1987	36.67
1988	40.62
1989	62.05
1990	74.84
1991	67.91
1992	57.94
1993	63.48
1994	65.63
1995	71.20
1996	69.00
1997	62.52
1998	69.43
1999	63.60
2000	60.66
2001	55.43
2002	56.45
2003	57.56
2004	61.47
2005	61.75
2006	59.09
2007	48.75
2008	52.23
2009	55.39
2010	51.05
2011	49.40
2012	48.65
2013	48.41
2014	56.58

Water Rights on Cascade Creek

Table D4 describes the water rights that have been issued on Cascade Creek in the reach extending from Mountain Lake Dam to Buck Bay.

Table D4. Water Rights Diverted From Cascade Creek Below Mountain Lake Dam

Water Right Number	Water Right Holder	Priority Date	Purpose	Qi (cfs)	Qa (afy)	Source
Volume XI, of Adjudicated Certificates, at page 85 Record A	Orcas Water Holdings and Washington Water Service Company	1884	Municipal and Hydropower	3.0 – January, November, December 2.0 – February and March 1.5 – October 1.0 – April and May 0.75 – June 0.50 – September 0.25 – July and August	1,098.1 124 (municipal) 974.1 (hydropower)	Cascade Creek
Volume XI, of Adjudicated Certificates, at page 85, Record B	State of Washington	1884	Instream Flow	0.25 – June, July, and August 0.50 – September and October	105.9	Cascade Creek
Volume XI, of Adjudicated Certificates, at page 86	Olga Water Users	1908	Municipal Supply	0.56	94	Cascade Creek
S1-23175C	Olga Water Users	July 31, 1978	Municipal Supply	Non-additive	34	Cascade Creek
S1-28144P	Alexander Taylor	July 11, 2002	Fish Propagation	0.089 – October through April	37 Non-consumptive	Cascade Creek
				Total	1,369	-
In addition, Doe Bay Water Users Association also holds a reservoir permit that authorizes storage of 181 afy of water for municipal supply in Mountain Lake. Reservoir permit R1-26574P has a priority date of March 23, 1992.						

Table D5 shows how the water right instantaneous rights vary over the course of the year.

Table D5. Total Instantaneous Diversion Rate from Cascade Creek below Mountain Lake Dam Permitted Under Existing Water Rights

Month	Olga (cfs)	Rosario (cfs)	Trust (cfs)	Taylor (non-consumptive) (cfs)	Diversion Rate (cfs)
January	0.56	3.0	0	0.089	3.649
February	0.56	2.0	0	0.089	2.649
March	0.56	2.0	0	0.089	2.649
April	0.56	1.0	0	0.089	1.649
May	0.56	1.0	0	0	1.56
June	0.56	0.75	0.25	0	1.56
July	0.56	0.25	0.25	0	1.06
August	0.56	0.25	0.25	0	1.06
September	0.56	0.5	0.5	0	1.56
October	0.56	1.5	0.5	0.089	2.649
November	0.56	3.0	0	0.089	3.649
December	0.56	3.0	0	0.089	3.649

Rosario diverts water from Cascade Creek into Cascade Lake. The diversion consists of a concrete structure to pool water, and water is conveyed in a pipe that is supported by a trestle located along the right bank of the creek. Eventually the pipe turns into a partially-lined ditch that conveys the water to Cascade Lake. The Rosario trestle and pipe were damaged during a storm in December 2006 and remained inoperable throughout the duration of the Ecology study. With the assistance of the WDFW, Rosario installed a fish screen to exclude fish from entering the diversion ditch. Recently Rosario has installed a 9-inch Montana Flume for measuring flow diverted from Cascade Creek into the Rosario Ditch.

Olga provided partial year data for the years of 1993, 1994, 2000, and 2007, and full year data for the years of 2001, 2003, 2004, and 2005 (**Table D6**). For the full years of data, the average water volume measured was 36.07 af. The highest volume was 43.73 af and the lowest volume was 28.47 af. It is assumed that all water metered is fully consumptive to Cascade Creek. Over the course of the study, Olga diverted an estimated 57.26 af from Cascade Creek. This value is estimated because there was no metering data provided for July and September of 2007. For the months with missing data, the average volume diverted for those months over the period of record was used. According to the Water Facilities Inventory form, the current diversion rate by Olga is 0.45 cfs. This is 0.11 cfs lower than the certificated limit.

Table D6. Olga Water Diverted from Cascade Creek

Year	Acre-feet	Notes
1993	44.28	Partial year (Missing data from January and February)
1994	55.56	Partial year (Missing data from December 2nd through the end of the year)
2000	13.01	Partial year (Missing data from April 2nd through the end of the year)
2001	43.73	Full Year
2003	38.75	Full Year
2004	33.34	Full Year
2005	28.47	Full Year
2007	47.66	Partial Year (Missing data from July and September)
2008	12.44	Partial Year (Missing data from May through December)

Water Rights Diverting from Cascade Lake Watershed

Water rights within the Cascade Lake Watershed are held by Rosario, Washington Water Service Company, and State Parks (**Table D7**).

Table D7. Consumptive Water Rights Diverted from above Cascade Lake Dam

Water Right Number	Water Right Holder	Priority Date	Purpose	Qi (cfs)	Qa (afy)	Source
Volume XI, of Adjudicated Certificates, at page 85 Record A	Orcas Water Holdings and Washington Water Service Company	1884	Municipal and Hydropower	2.443 0.359 (municipal) 2.084 (hydropower)	1,098.1 124 (municipal) 974.1 (hydropower)	Stored Water in Cascade Lake from Cascade Creek
Volume XIII, of Adjudicated Certificates, at page 2	Orcas Water Holdings	1910	Municipal and Hydropower	2.31 0.606 (municipal) 1.704 (hydropower)	499 159 (municipal) 340 (hydropower)	Cascade Lake Natural Water
			Subtotal From Lake	*4.753* *0.965 (municipal)* *3.788 (hydropower)*	*1,597.1* *283 (municipal)* *1,314.1 (hydropower)*	-
Volume XIII, of Adjudicated Certificates, at page 3	State Parks	4/17/1968	Domestic supply and public park purposes.	0.156	8	A spring, Moran Creek, and Cold Spring Creek.
			Total	4.909	1,605.1	-
			Total from Natural Water in Cascade Lake Basin	*2.466*	*507*	-

All domestic use from the Cascade Lake watershed by State Parks and Washington Water Supply Company and all hydropower water used by Rosario are fully consumptive to Cascade Lake. All of the domestic water is taken to a wastewater treatment facility, which is located outside of the basin. Rosario's hydropower plant is located near sea level and takes advantage of the 340-foot drop from Cascade Lake for power production. Rosario's hydropower facility historically produced DC power using pelton wheel and generator. The power was used in the immediate vicinity for lighting and heating of the Rosario Resort buildings. Recently, a new AC power plant was installed. This new facility now provides power to the electrical grid for use not only at Rosario Resort, but anywhere else that is connected to the grid.

Rosario diverts both their domestic (now operated by Washington Water Service Company) and hydropower water directly from Cascade Lake. Over the period of 1997 through 2014, the average annual diversion volume for domestic use was 106.11 afy with a minimum of 76.62 afy in 2009 and a maximum of 160.88 afy in 1999. Over the period of 1998 through 2014, the average annual diversion volume for hydropower use was 780.23 afy with a minimum of 408.60 afy in 2013 and a maximum of 1,170.79 afy in 2000. The highest year of combined domestic and hydropower use was 2000 with a total use of 1,290.27 afy (**Table D8**). During the study period, the domestic diversion was 109.86 af, the hydropower diversion was 595.75 af, for a total of 705.60 af diverted from the lake. Since there was not water imported from Cascade Creek during the Ecology study, the hydropower use from Cascade Lake should have been limited to no more than 340 af.

Table D8. Domestic and Hydropower Water Diverted from Cascade Lake

Year	Domestic Acre-feet	Hydropower Acre-feet	Combined Total Acre-feet
1998	158.81	966.83	1,125.64
1999	160.88	808.27	969.15
2000	119.48	1,170.79	1,290.27
2001	125.97	848.64	974.61
2002	116.42	812.96	929.37
2003	115.76	568.69	684.45
2004	109.08	547.41	656.50
2005	106.44	514.81	621.24
2006	112.45	572.22	684.67
2007	107.64	546.85	654.48
2008	79.24	Unknown	Unknown
2009	76.62	Unknown	Unknown
2010	79.00	979.37	1,058.37
2011	80.16	1,041.45	1,121.61
2012	83.17	1,047.88	1,131.05
2013	83.71	408.60	492.31
2014	89.13	868.66	957.79

State Parks diverts its water from a spring, Moran Creek, and Cold Spring Creek, which are all tributary to Cascade Lake. Over the period of 2000 through 2014, the average annual diversion volume was 11.52 af with a minimum of 7.94 af in 2014 and a maximum of 14.49 af in 2010 (**Table 9D**). During the study period, the diversion was 12.44 af. The water right limit is 8 af, so the diversion has been in excess of the water right for most years.

Table D9. State Parks Water Diverted from Cascade Lake Watershed

Year	Acre-feet
2000	10.76
2001	12.33
2002	11.40
2003	12.49
2004	11.18
2005	10.38
2006	13.20
2007	13.12
2008	11.45
2009	12.73
2010	14.49
2011	11.33
2012	10.35
2013	9.70
2014	7.94

Appendix E
Mountain Lake Spillway Rating Tables

Mountain Lake Dam Calculated Spilling Discharge with 2 Stoplogs Installed					
Staff Gage (ft)	***Elevation (ft)***	***Q Left Principal (cfs)***	***Q Right Principal (cfs)***	***Q Emergency (cfs)***	***Q Spilling Total (cfs)***
21.98	921.98	0.00	0.00	0.00	0.0
21.99	921.99	0.00	0.04	0.00	0.0
22.00	922.00	0.00	0.11	0.00	0.1
22.01	922.01	0.00	0.20	0.00	0.2
22.02	922.02	0.00	0.31	0.00	0.3
22.03	922.03	0.00	0.43	0.00	0.4
22.04	922.04	0.00	0.57	0.00	0.6
22.05	922.05	0.00	0.72	0.00	0.7
22.06	922.06	0.04	0.88	0.00	0.9
22.07	922.07	0.11	1.05	0.00	1.2
22.08	922.08	0.20	1.23	0.00	1.4
22.09	922.09	0.31	1.42	0.00	1.7
22.10	922.10	0.43	1.62	0.00	2.1
22.11	922.11	0.57	1.83	0.00	2.4
22.12	922.12	0.72	2.05	0.00	2.8
22.13	922.13	0.88	2.27	0.00	3.2
22.14	922.14	1.05	2.51	0.00	3.6
22.15	922.15	1.23	2.75	0.00	4.0
22.16	922.16	1.42	2.99	0.00	4.4
22.17	922.17	1.62	3.25	0.00	4.9
22.18	922.18	1.83	3.51	0.00	5.3
22.19	922.19	2.05	3.78	0.00	5.8
22.20	922.20	2.27	4.06	0.00	6.3
22.21	922.21	2.50	4.34	0.00	6.8
22.22	922.22	2.74	4.63	0.00	7.4
22.23	922.23	2.99	4.92	0.00	7.9
22.24	922.24	3.25	5.22	0.00	8.5
22.25	922.25	3.51	5.53	0.00	9.0
22.26	922.26	3.78	5.85	0.00	9.6
22.27	922.27	4.05	6.17	0.00	10.2
22.28	922.28	4.33	6.49	0.00	10.8
22.29	922.29	4.62	6.82	0.00	11.4
22.30	922.30	4.92	7.16	0.00	12.1
22.31	922.31	5.22	7.50	0.00	12.7
22.32	922.32	5.53	7.85	0.00	13.4
22.33	922.33	5.84	8.21	0.00	14.0
22.34	922.34	6.16	8.57	0.00	14.7
22.35	922.35	6.48	8.93	0.00	15.4
22.36	922.36	6.82	9.30	0.00	16.1
22.37	922.37	7.15	9.68	0.00	16.8
22.38	922.38	7.50	10.06	0.00	17.6
22.39	922.39	7.84	10.44	0.00	18.3
22.40	922.40	8.20	10.84	0.00	19.0
22.41	922.41	8.56	11.23	0.00	19.8
22.42	922.42	8.92	11.63	0.00	20.6
22.43	922.43	9.29	12.04	0.00	21.3
22.44	922.44	9.66	12.45	0.00	22.1
22.45	922.45	10.04	12.87	0.00	22.9

Mountain Lake Dam Calculated Spilling Discharge with 2 Stoplogs Installed					
Staff Gage (ft)	***Elevation (ft)***	***Q Left Principal (cfs)***	***Q Right Principal (cfs)***	***Q Emergency (cfs)***	***Q Spilling Total (cfs)***
22.46	922.46	10.43	13.29	0.00	23.7
22.47	922.47	10.82	13.71	0.00	24.5
22.48	922.48	11.21	14.15	0.00	25.4
22.49	922.49	11.62	14.58	0.00	26.2
22.50	922.50	12.02	15.02	0.00	27.0
22.51	922.51	12.43	15.47	0.00	27.9
22.52	922.52	12.85	15.92	0.00	28.8
22.53	922.53	13.27	16.37	0.00	29.6
22.54	922.54	13.69	16.83	0.00	30.5
22.55	922.55	14.12	17.29	0.00	31.4
22.56	922.56	14.55	17.76	0.00	32.3
22.57	922.57	14.99	18.23	0.00	33.2
22.58	922.58	15.44	18.71	0.00	34.1
22.59	922.59	15.89	19.19	0.00	35.1
22.60	922.60	16.34	19.68	0.00	36.0
22.61	922.61	16.80	20.17	0.00	37.0
22.62	922.62	17.26	20.66	0.00	37.9
22.63	922.63	17.72	21.16	0.00	38.9
22.64	922.64	18.20	21.67	0.00	39.9
22.65	922.65	18.67	22.17	0.00	40.8
22.66	922.66	19.15	22.69	0.00	41.8
22.67	922.67	19.64	23.20	0.00	42.8
22.68	922.68	20.12	23.72	0.00	43.8
22.69	922.69	20.62	24.25	0.00	44.9
22.70	922.70	21.11	24.78	0.00	45.9
22.71	922.71	21.62	25.31	0.16	47.1
22.72	922.72	22.12	25.85	0.44	48.4
22.73	922.73	22.63	26.39	0.81	49.8
22.74	922.74	23.15	26.94	1.25	51.3
22.75	922.75	23.66	27.49	1.74	52.9
22.76	922.76	24.19	28.04	2.29	54.5
22.77	922.77	24.71	28.60	2.89	56.2
22.78	922.78	25.25	29.16	3.53	57.9
22.79	922.79	25.78	29.73	4.21	59.7
22.80	922.80	26.32	30.30	4.93	61.6
22.81	922.81	26.86	30.87	5.69	63.4
22.82	922.82	27.41	31.45	6.48	65.3
22.83	922.83	27.96	32.03	7.31	67.3
22.84	922.84	28.52	32.62	8.17	69.3
22.85	922.85	29.08	33.21	9.06	71.4
22.86	922.86	29.64	33.81	9.98	73.4
22.87	922.87	30.21	34.40	10.93	75.5
22.88	922.88	30.78	35.01	11.91	77.7
22.89	922.89	31.36	35.61	12.92	79.9
22.90	922.90	31.94	36.22	14.17	82.3
22.91	922.91	32.52	36.84	15.32	84.7
22.92	922.92	33.11	37.45	16.43	87.0
22.93	922.93	33.70	38.08	17.57	89.3

Mountain Lake Dam Calculated Spilling Discharge with 2 Stoplogs Installed					
Staff Gage (ft)	***Elevation (ft)***	***Q Left Principal (cfs)***	***Q Right Principal (cfs)***	***Q Emergency (cfs)***	***Q Spilling Total (cfs)***
22.94	922.94	34.30	38.70	18.73	91.7
22.95	922.95	34.90	39.33	19.92	94.1
22.96	922.96	35.50	39.97	21.13	96.6
22.97	922.97	36.11	40.60	22.36	99.1
22.98	922.98	36.72	41.24	23.62	101.6
22.99	922.99	37.33	41.89	24.90	104.1
23.00	923.00	37.95	42.54	26.21	106.7
23.01	923.01	38.57	43.19	27.53	109.3
23.02	923.02	39.20	43.85	28.88	111.9
23.03	923.03	39.83	44.51	30.26	114.6
23.04	923.04	40.46	45.17	31.65	117.3
23.05	923.05	41.10	45.84	33.06	120.0
23.06	923.06	41.74	46.51	34.50	122.7
23.07	923.07	42.39	47.19	35.95	125.5
23.08	923.08	43.04	47.86	37.43	128.3
23.09	923.09	43.69	48.55	38.92	131.2
23.10	923.10	44.35	49.23	40.44	134.0
23.11	923.11	45.01	49.92	42.06	137.0
23.12	923.12	45.67	50.62	43.61	139.9
23.13	923.13	46.34	51.31	45.18	142.8
23.14	923.14	47.01	52.01	46.77	145.8
23.15	923.15	47.68	52.72	48.37	148.8
23.16	923.16	48.36	53.43	50.00	151.8
23.17	923.17	49.04	54.14	51.64	154.8
23.18	923.18	49.73	54.86	53.30	157.9
23.19	923.19	50.42	55.57	54.98	161.0
23.20	923.20	51.11	56.30	56.67	164.1
23.21	923.21	51.81	57.02	58.38	167.2
23.22	923.22	52.51	57.75	60.11	170.4
23.23	923.23	53.21	58.49	61.86	173.6
23.24	923.24	53.92	59.23	63.62	176.8
23.25	923.25	54.63	59.97	65.40	180.0
23.26	923.26	55.35	60.71	67.19	183.3
23.27	923.27	56.07	61.46	69.01	186.5
23.28	923.28	56.79	62.21	70.83	189.8
23.29	923.29	57.51	62.97	72.68	193.2
23.30	923.30	58.24	63.73	74.54	196.5
23.31	923.31	58.97	64.49	77.67	201.1
23.32	923.32	59.71	65.25	79.61	204.6
23.33	923.33	60.45	66.02	81.57	208.0
23.34	923.34	61.19	66.80	83.54	211.5
23.35	923.35	61.94	67.57	85.53	215.0
23.36	923.36	62.69	68.35	87.53	218.6
23.37	923.37	63.44	69.14	89.55	222.1
23.38	923.38	64.20	69.92	91.59	225.7
23.39	923.39	64.96	70.71	93.64	229.3
23.40	923.40	65.72	71.51	95.71	232.9
23.41	923.41	66.49	72.31	97.80	236.6

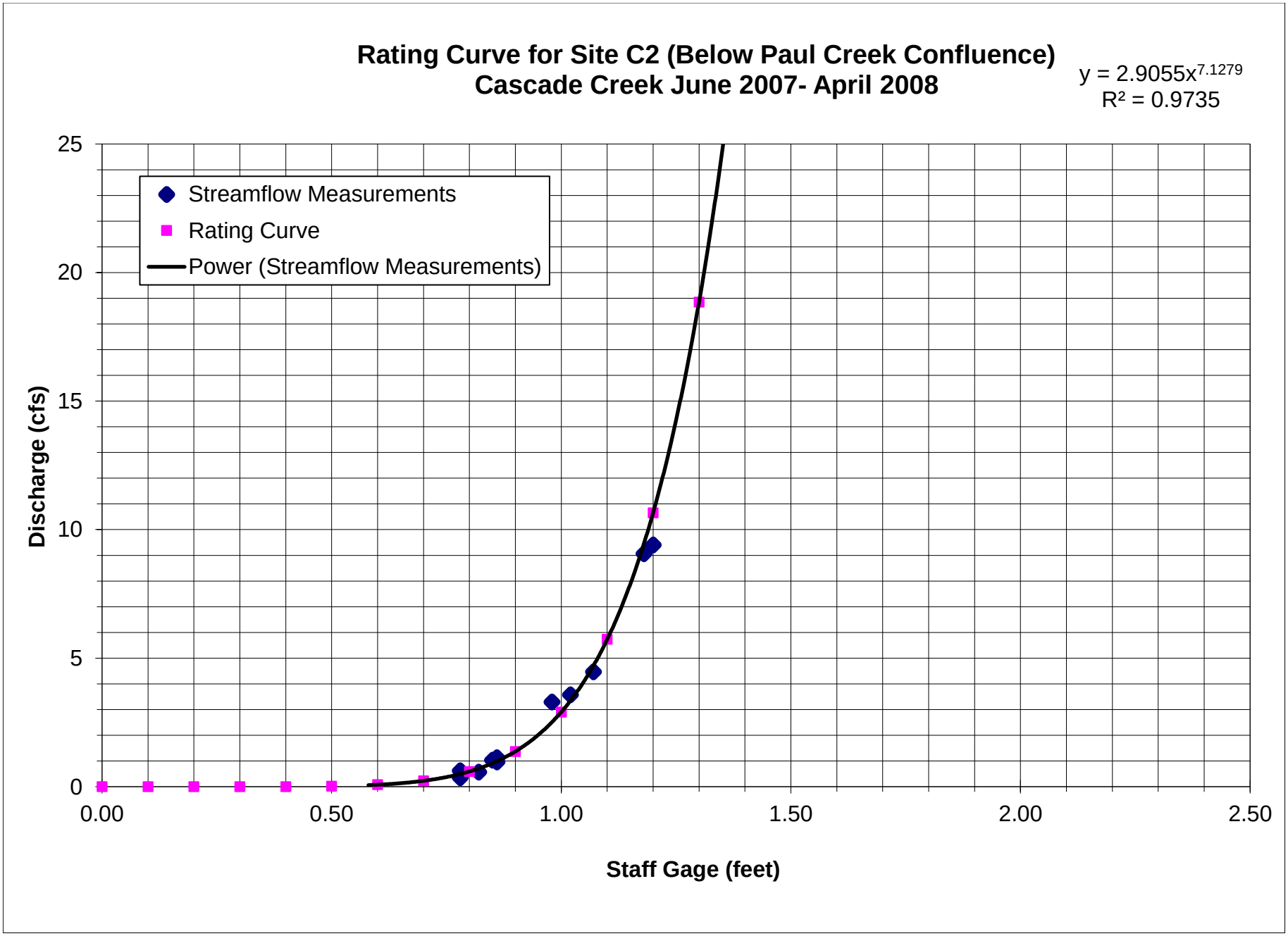
Mountain Lake Dam Calculated Spilling Discharge with 2 Stoplogs Installed					
Staff Gage (ft)	***Elevation (ft)***	***Q Left Principal (cfs)***	***Q Right Principal (cfs)***	***Q Emergency (cfs)***	***Q Spilling Total (cfs)***
23.42	923.42	67.26	73.11	99.90	240.3
23.43	923.43	68.04	73.91	102.01	244.0
23.44	923.44	68.81	74.72	104.14	247.7
23.45	923.45	69.60	75.53	106.29	251.4
23.46	923.46	70.38	76.35	108.45	255.2
23.47	923.47	71.17	77.17	110.63	259.0
23.48	923.48	71.96	77.99	112.82	262.8
23.49	923.49	72.76	78.81	115.03	266.6
23.50	923.50	73.55	79.64	117.25	270.4
23.51	923.51	74.36	80.47	122.57	277.4
23.52	923.52	75.16	81.31	124.89	281.4
23.53	923.53	75.97	82.15	127.22	285.3
23.54	923.54	76.78	82.99	129.57	289.3
23.55	923.55	77.60	83.84	131.93	293.4
23.56	923.56	78.42	84.69	134.30	297.4
23.57	923.57	79.24	85.54	136.70	301.5
23.58	923.58	80.07	86.40	139.10	305.6
23.59	923.59	80.90	87.26	141.53	309.7
23.60	923.60	81.73	88.12	143.96	313.8
23.61	923.61	82.56	88.99	146.42	318.0
23.62	923.62	83.40	89.86	148.88	322.1
23.63	923.63	84.25	90.73	151.36	326.3
23.64	923.64	85.09	91.61	153.86	330.6
23.65	923.65	85.94	92.49	156.37	334.8
23.66	923.66	86.79	93.37	158.90	339.1
23.67	923.67	87.65	94.26	161.43	343.3
23.68	923.68	88.51	95.15	163.99	347.6
23.69	923.69	89.37	96.04	166.56	352.0
23.70	923.70	90.24	96.94	169.14	356.3

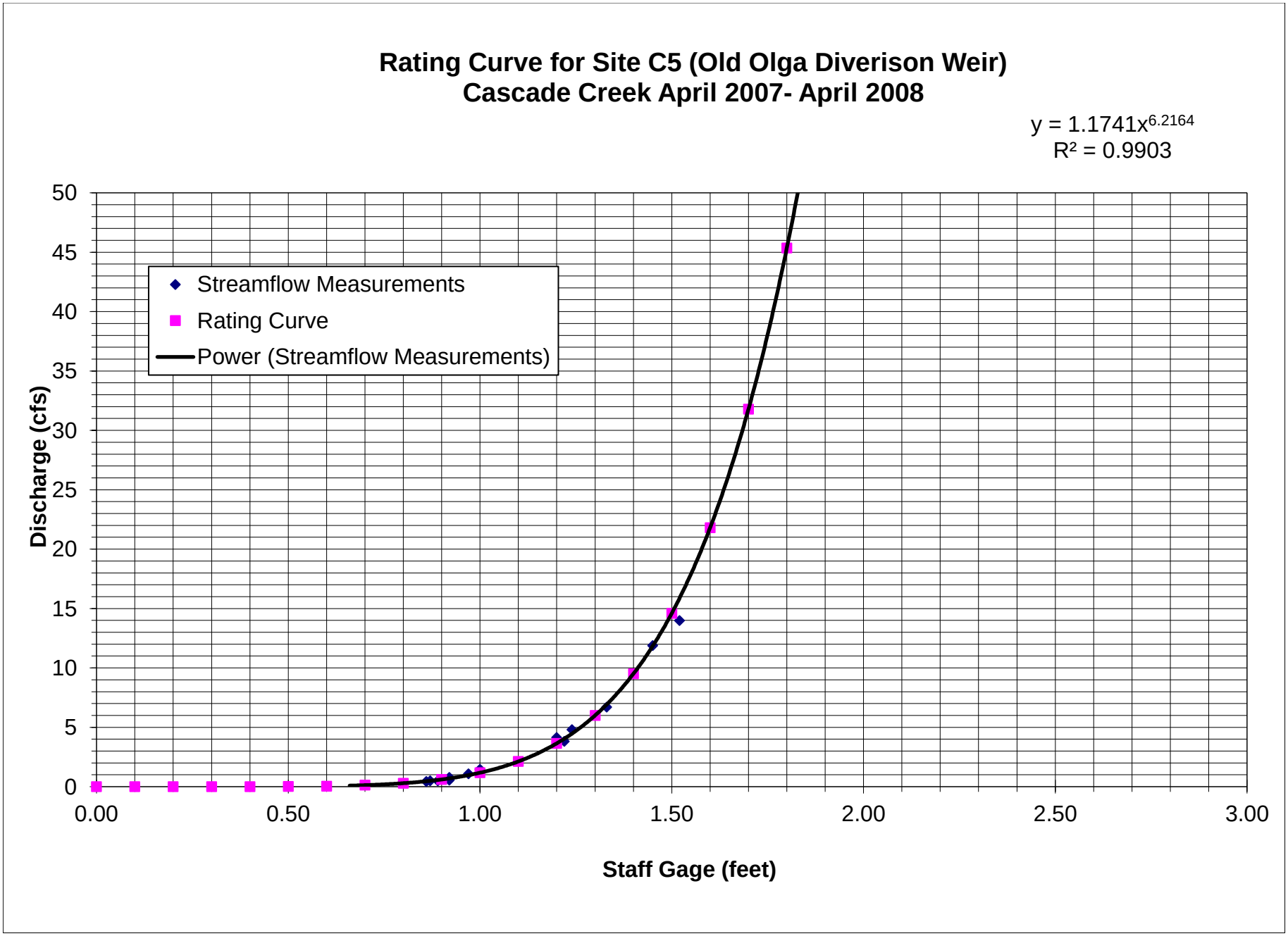
Mountain Lake Dam Calculated Spilling Discharge with 3 Stoplogs Installed						
Staff Gage (ft)	***Elevation (ft)***	***Q Left Principal (cfs)***	***Q Right Principal (cfs)***	***Q Emergency (cfs)***		***Q Spilling Total (cfs)***
22.45	922.45	0.00	0.00	0.00		0.0
22.46	922.46	0.00	0.00	0.00		0.0
22.47	922.47	0.00	0.04	0.00		0.0
22.48	922.48	0.00	0.11	0.00		0.1
22.49	922.49	0.00	0.20	0.00		0.2
22.50	922.50	0.00	0.31	0.00		0.3
22.51	922.51	0.00	0.43	0.00		0.4
22.52	922.52	0.00	0.57	0.00		0.6
22.53	922.53	0.00	0.72	0.00		0.7
22.54	922.54	0.04	0.88	0.00		0.9
22.55	922.55	0.11	1.05	0.00		1.2
22.56	922.56	0.20	1.23	0.00		1.4
22.57	922.57	0.31	1.42	0.00		1.7
22.58	922.58	0.43	1.62	0.00		2.1
22.59	922.59	0.57	1.83	0.00		2.4
22.60	922.60	0.72	2.04	0.00		2.8
22.61	922.61	0.88	2.27	0.00		3.1
22.62	922.62	1.05	2.50	0.00		3.5
22.63	922.63	1.23	2.74	0.00		4.0
22.64	922.64	1.42	2.98	0.00		4.4
22.65	922.65	1.62	3.24	0.00		4.9
22.66	922.66	1.83	3.50	0.00		5.3
22.67	922.67	2.04	3.76	0.00		5.8
22.68	922.68	2.27	4.04	0.00		6.3
22.69	922.69	2.50	4.32	0.00		6.8
22.70	922.70	2.74	4.61	0.00		7.3
22.71	922.71	2.98	4.90	0.16		8.0
22.72	922.72	3.24	5.20	0.44		8.9
22.73	922.73	3.50	5.50	0.81		9.8
22.74	922.74	3.76	5.81	1.25		10.8
22.75	922.75	4.04	6.13	1.74		11.9
22.76	922.76	4.32	6.45	2.29		13.1
22.77	922.77	4.60	6.78	2.89		14.3
22.78	922.78	4.90	7.12	3.53		15.5
22.79	922.79	5.19	7.46	4.21		16.9
22.80	922.80	5.50	7.80	4.93		18.2
22.81	922.81	5.81	8.15	5.69		19.7
22.82	922.82	6.13	8.51	6.48		21.1
22.83	922.83	6.45	8.87	7.31		22.6
22.84	922.84	6.78	9.23	8.17		24.2
22.85	922.85	7.11	9.60	9.06		25.8
22.86	922.86	7.45	9.98	9.98		27.4
22.87	922.87	7.79	10.36	10.93		29.1
22.88	922.88	8.14	10.75	11.91		30.8
22.89	922.89	8.50	11.14	12.92		32.6
22.90	922.90	8.86	11.53	14.17		34.6
22.91	922.91	9.23	11.93	15.32		36.5
22.92	922.92	9.60	12.34	16.43		38.4

Mountain Lake Dam Calculated Spilling Discharge with 3 Stoplogs Installed						
Staff Gage (ft)	***Elevation (ft)***	***Q Left Principal (cfs)***	***Q Right Principal (cfs)***	***Q Emergency (cfs)***		***Q Spilling Total (cfs)***
22.93	922.93	9.97	12.75	17.57		40.3
22.94	922.94	10.35	13.16	18.73		42.2
22.95	922.95	10.74	13.58	19.92		44.2
22.96	922.96	11.13	14.01	21.13		46.3
22.97	922.97	11.52	14.44	22.36		48.3
22.98	922.98	11.92	14.87	23.62		50.4
22.99	922.99	12.33	15.31	24.90		52.5
23.00	923.00	12.74	15.75	26.21		54.7
23.01	923.01	13.15	16.20	27.53		56.9
23.02	923.02	13.57	16.65	28.88		59.1
23.03	923.03	13.99	17.10	30.26		61.4
23.04	923.04	14.42	17.56	31.65		63.6
23.05	923.05	14.85	18.03	33.06		65.9
23.06	923.06	15.29	18.49	34.50		68.3
23.07	923.07	15.73	18.97	35.95		70.6
23.08	923.08	16.18	19.44	37.43		73.0
23.09	923.09	16.63	19.92	38.92		75.5
23.10	923.10	17.08	20.41	40.44		77.9
23.11	923.11	17.54	20.90	42.06		80.5
23.12	923.12	18.00	21.39	43.61		83.0
23.13	923.13	18.47	21.89	45.18		85.5
23.14	923.14	18.94	22.39	46.77		88.1
23.15	923.15	19.42	22.90	48.37		90.7
23.16	923.16	19.90	23.41	50.00		93.3
23.17	923.17	20.38	23.92	51.64		95.9
23.18	923.18	20.87	24.44	53.30		98.6
23.19	923.19	21.36	24.96	54.98		101.3
23.20	923.20	21.86	25.48	56.67		104.0
23.21	923.21	22.36	26.01	58.38		106.8
23.22	923.22	22.86	26.55	60.11		109.5
23.23	923.23	23.37	27.08	61.86		112.3
23.24	923.24	23.88	27.62	63.62		115.1
23.25	923.25	24.40	28.17	65.40		118.0
23.26	923.26	24.92	28.72	67.19		120.8
23.27	923.27	25.44	29.27	69.01		123.7
23.28	923.28	25.97	29.83	70.83		126.6
23.29	923.29	26.50	30.39	72.68		129.6
23.30	923.30	27.04	30.95	74.54		132.5
23.31	923.31	27.58	31.52	77.67		136.8
23.32	923.32	28.12	32.09	79.61		139.8
23.33	923.33	28.67	32.67	81.57		142.9
23.34	923.34	29.22	33.24	83.54		146.0
23.35	923.35	29.78	33.83	85.53		149.1
23.36	923.36	30.34	34.41	87.53		152.3
23.37	923.37	30.90	35.00	89.55		155.5
23.38	923.38	31.46	35.60	91.59		158.7
23.39	923.39	32.03	36.19	93.64		161.9
23.40	923.40	32.61	36.79	95.71		165.1

Mountain Lake Dam Calculated Spilling Discharge with 3 Stoplogs Installed						
Staff Gage (ft)	***Elevation (ft)***	***Q Left Principal (cfs)***	***Q Right Principal (cfs)***	***Q Emergency (cfs)***		***Q Spilling Total (cfs)***
23.41	923.41	33.18	37.40	97.80		168.4
23.42	923.42	33.76	38.01	99.90		171.7
23.43	923.43	34.35	38.62	102.01		175.0
23.44	923.44	34.94	39.23	104.14		178.3
23.45	923.45	35.53	39.85	106.29		181.7
23.46	923.46	36.12	40.47	108.45		185.0
23.47	923.47	36.72	41.10	110.63		188.4
23.48	923.48	37.33	41.73	112.82		191.9
23.49	923.49	37.93	42.36	115.03		195.3
23.50	923.50	38.54	43.00	117.25		198.8
23.51	923.51	39.15	43.64	122.57		205.4
23.52	923.52	39.77	44.28	124.89		208.9
23.53	923.53	40.39	44.93	127.22		212.5
23.54	923.54	41.01	45.58	129.57		216.2
23.55	923.55	41.64	46.23	131.93		219.8
23.56	923.56	42.27	46.89	134.30		223.5
23.57	923.57	42.91	47.55	136.70		227.2
23.58	923.58	43.54	48.21	139.10		230.9
23.59	923.59	44.19	48.88	141.53		234.6
23.60	923.60	44.83	49.55	143.96		238.3
23.61	923.61	45.48	50.22	146.42		242.1
23.62	923.62	46.13	50.90	148.88		245.9
23.63	923.63	46.78	51.58	151.36		249.7
23.64	923.64	47.44	52.27	153.86		253.6
23.65	923.65	48.10	52.95	156.37		257.4
23.66	923.66	48.77	53.64	158.90		261.3
23.67	923.67	49.44	54.34	161.43		265.2
23.68	923.68	50.11	55.04	163.99		269.1
23.69	923.69	50.78	55.74	166.56		273.1
23.70	923.70	51.46	56.44	169.14		277.0

Appendix F
Rating Curves for Sites C2 and C5


Rating Curve for Site C2 (Below Paul Creek Confluence)
Cascade Creek June 2007- April 2008
y = 2.9055x^7.1279
R² = 0.9735
Streamflow Measurements
Rating Curve
Power (Streamflow Measurements)
Discharge (cfs)
Staff Gage (feet)
0
5
10
15
20
25
0.00
0.50
1.00
1.50
2.00
2.50


Rating Curve for Site C5 (Old Olga Diverison Weir)
Cascade Creek April 2007- April 2008
y = 1.1741x^6.2164
R² = 0.9903
Streamflow Measurements
Rating Curve
Power (Streamflow Measurements)
Discharge (cfs)
Staff Gage (feet)
0
5
10
15
20
25
30
35
40
45
50
0.00
0.50
1.00
1.50
2.00
2.50
3.00

Appendix G
Cascade Lake Spillway Rating Table

Cascade Lake Dam Spillway Discharge Rating Table

Estimate as a broad-crested, contracted, rectangular weir
Flow only calculated for spillway window, not higher discharge pipes.

Brater and King, 1976
Knox County Tennessee Stormwater Management Manual

Q = C*L*H^(1.5)

Q = Discharge (cfs)
C = Broad-crested weir coefficient extrapolated from the table from Brater and King, 1976)
L = Broad-crested weir length perpendicular to flow (ft)
H = Head of water above weir crest (ft)

Height of spillway opening:
21 inches (1.75 feet)

Approx. Invert Elevation of lowest discharge pipe:
351.58 feet

Feature	**Staff Gage (ft)**	**Elevation (ft)**
Window Spillway Crest	4.80	351.00
L in feet	6.6	
B in feet	0.8	

Coefficient (C) is an extrapolation of Brater and King, 1976 table

Calculated
Primary Window Spillway Only

H (ft)	***Staff Gage (ft)***	***Elevation (ft)***	***C***	***Q (cfs)***
0	**4.80**	**351.00**	**0.000**	**0.00**
0.01	4.81	351.01	2.600	0.02
0.02	4.82	351.02	2.600	0.05
0.03	4.83	351.03	2.600	0.09
0.04	4.84	351.04	2.600	0.14
0.05	4.85	351.05	2.600	0.19
0.06	4.86	351.06	2.600	0.25
0.07	4.87	351.07	2.600	0.32
0.08	4.88	351.08	2.600	0.39
0.09	4.89	351.09	2.600	0.46
0.1	4.9	351.10	2.600	0.54
0.11	4.91	351.11	2.600	0.63
0.12	4.92	351.12	2.600	0.71
0.13	4.93	351.13	2.600	0.80
0.14	4.94	351.14	2.600	0.90
0.15	4.95	351.15	2.600	1.00
0.16	4.96	351.16	2.600	1.10
0.17	4.97	351.17	2.600	1.20
0.18	4.98	351.18	2.600	1.31
0.19	4.99	351.19	2.600	1.42
0.2	**5**	**351.20**	**2.738**	**1.62**
0.21	5.01	351.21	2.762	1.75
0.22	5.02	351.22	2.763	1.88
0.23	5.03	351.23	2.764	2.01
0.24	5.04	351.24	2.766	2.15
0.25	5.05	351.25	2.767	2.28
0.26	5.06	351.26	2.768	2.42
0.27	5.07	351.27	2.769	2.56
0.28	5.08	351.28	2.770	2.71
0.29	5.09	351.29	2.771	2.86
0.3	5.1	351.30	2.773	3.01
0.31	5.11	351.31	2.774	3.16
0.32	5.12	351.32	2.775	3.32
0.33	5.13	351.33	2.776	3.47
0.34	5.14	351.34	2.777	3.63
0.35	5.15	351.35	2.778	3.80
0.36	5.16	351.36	2.779	3.96
0.37	5.17	351.37	2.781	4.13
0.38	5.18	351.38	2.782	4.30
0.39	5.19	351.39	2.783	4.47
0.4	**5.2**	**351.40**	**2.784**	**4.65**
0.41	5.21	351.41	2.837	4.92
0.42	5.22	351.42	2.839	5.10
0.43	5.23	351.43	2.840	5.29
0.44	5.24	351.44	2.841	5.47
0.45	5.25	351.45	2.843	5.66

Cascade Lake Dam Spillway Discharge Rating Table

Estimate as a broad-crested, contracted, rectangular weir
Flow only calculated for spillway window, not higher discharge pipes.

Brater and King, 1976
Knox County Tennessee Stormwater Management Manual

Q = C*L*H^(1.5)

Q = Discharge (cfs)
C = Broad-crested weir coefficient extrapolated from the table from Brater and King, 1976)
L = Broad-crested weir length perpendicular to flow (ft)
H = Head of water above weir crest (ft)

Height of spillway opening:
21 inches (1.75 feet)

Approx. Invert Elevation of lowest discharge pipe:
351.58 feet

Feature	**Staff Gage (ft)**	**Elevation (ft)**
Window Spillway Crest	4.80	351.00
L in feet	6.6	
B in feet	0.8	

Coefficient (C) is an extrapolation of Brater and King, 1976 table

Calculated
Primary Window Spillway Only

H (ft)	***Staff Gage (ft)***	***Elevation (ft)***	***C***	***Q (cfs)***
0.46	5.26	351.46	2.844	5.86
0.47	5.27	351.47	2.845	6.05
0.48	5.28	351.48	2.846	6.25
0.49	5.29	351.49	2.848	6.45
0.5	5.3	351.50	2.849	6.65
0.51	5.31	351.51	2.850	6.85
0.52	5.32	351.52	2.852	7.06
0.53	5.33	351.53	2.853	7.27
0.54	5.34	351.54	2.854	7.48
0.55	5.35	351.55	2.856	7.69
0.56	5.36	351.56	2.857	7.90
0.57	5.37	351.57	2.858	8.12
0.58	5.38	351.58	2.859	8.34
0.59	5.39	351.59	2.861	8.56
0.6	**5.4**	**351.60**	**2.862**	**8.78**
0.61	5.41	351.61	2.969	9.33
0.62	5.42	351.62	2.971	9.57
0.63	5.43	351.63	2.972	9.81
0.64	5.44	351.64	2.974	10.05
0.65	5.45	351.65	2.976	10.29
0.66	5.46	351.66	2.978	10.54
0.67	5.47	351.67	2.979	10.78
0.68	5.48	351.68	2.981	11.03
0.69	5.49	351.69	2.983	11.28
0.7	5.5	351.70	2.985	11.54
0.71	5.51	351.71	2.986	11.79
0.72	5.52	351.72	2.988	12.05
0.73	5.53	351.73	2.990	12.31
0.74	5.54	351.74	2.992	12.57
0.75	5.55	351.75	2.993	12.83
0.76	5.56	351.76	2.995	13.10
0.77	5.57	351.77	2.997	13.36
0.78	5.58	351.78	2.999	13.63
0.79	5.59	351.79	3.000	13.90
0.8	**5.6**	**351.80**	**3.002**	**14.18**
0.81	5.61	351.81	3.088	14.86
0.82	5.62	351.82	3.089	15.14
0.83	5.63	351.83	3.090	15.42
0.84	5.64	351.84	3.091	15.71
0.85	5.65	351.85	3.092	15.99
0.86	5.66	351.86	3.093	16.28
0.87	5.67	351.87	3.094	16.57
0.88	5.68	351.88	3.095	16.86
0.89	5.69	351.89	3.096	17.16
0.9	5.7	351.90	3.097	17.45
0.91	5.71	351.91	3.098	17.75

Cascade Lake Dam Spillway Discharge Rating Table

Estimate as a broad-crested, contracted, rectangular weir
Flow only calculated for spillway window, not higher discharge pipes.

Brater and King, 1976
Knox County Tennessee Stormwater Management Manual

Q = C*L*H^(1.5)

Q = Discharge (cfs)
C = Broad-crested weir coefficient extrapolated from the table from Brater and King, 1976)
L = Broad-crested weir length perpendicular to flow (ft)
H = Head of water above weir crest (ft)

Height of spillway opening:
21 inches (1.75 feet)

Approx. Invert Elevation of lowest discharge pipe:
351.58 feet

Feature	**Staff Gage (ft)**	**Elevation (ft)**
Window Spillway Crest	4.80	351.00
L in feet	6.6	
B in feet	0.8	

Coefficient (C) is an extrapolation of Brater and King, 1976 table

Calculated
Primary Window Spillway Only

H (ft)	***Staff Gage (ft)***	***Elevation (ft)***	***C***	***Q (cfs)***
0.92	5.72	351.92	3.100	18.05
0.93	5.73	351.93	3.101	18.35
0.94	5.74	351.94	3.102	18.66
0.95	5.75	351.95	3.103	18.96
0.96	5.76	351.96	3.104	19.27
0.97	5.77	351.97	3.105	19.58
0.98	5.78	351.98	3.106	19.89
0.99	5.79	351.99	3.107	20.20
1	**5.8**	**352.00**	**3.108**	**20.51**

Shaded where higher discharge pipes could also be spilling water.

Appendix H
Rosario Ditch GPS Points and Features

Rosario Ditch		
Ditch walked and data obtained on April 25, 2007		
Latitude Decimal Degrees	Longitude Decimal Degrees	Description
48.6446	-122.8378	Diversion point from Cascade Creek
48.6446	-122.8373	Start of open unlined ditch
48.6448	-122.8378	Sandbags on left side of ditch. Also, limit of backwater from RDT 1 entering ditch
48.6451	-122.8385	Spring on downhill side of left bank. Appears to be water seeping from ditch
48.6453	-122.8391	Confluence of RDT1 and ditch
48.6452	-122.8394	Start of concrete lined section of ditch
48.6450	-122.8398	Spring on downhill side of left bank.
48.6450	-122.8401	Break in concrete with approximately 20 feet of plastic tarp and sandbags creating temporary patch. Leaking under plastic on upstream side and flowing back toward Cascade Creek drainage. At least losing half of the ditch flow at this location.
48.6451	-122.8424	Still concrete lined
48.6447	-122.8430	End of concrete lined stretch and back to unlined
48.6447	-122.8435	Start of approximately 30 foot long concrete lined stretch
48.6447	-122.8447	Start of another concrete lined stretch
48.6449	-122.8452	Trail bridge going over ditch
48.6457	-122.8459	Roughly the divide between the Cascade Creek and Cascade Lake drainage basins. Either unlined at this location or concrete buried under sediment.
48.6460	-122.8461	Incised ditch
48.6465	-122.8465	Culvert crossing under road going to Cascade Lake

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