PHOENIX LAKE IRWM RETROFIT

Attachment 3 - Work Plan

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Phoenix Lake Photos

1.0 Introduction

1.1 Goals and Objectives

The Phoenix Lake IRWM Retrofit is an important component of the greater Ross Valley Flood Reduction and Watershed Management Program. The Program goal is to substantially reduce the flood hazard in Ross Valley. Program objectives integrate restoration of creek ecological function and other public riparian resource enhancements with the primary objective of flood protection. Specific objectives of the Program include providing a 100-year level flood protection throughout Ross Valley; improve riparian and aquatic habitat, particularly to aid in the recovery of special-status anadromous salmonids; and, enhance access and public enjoyment of the creek.

Funding for Program projects and activities will partially derive from a drainage fee that was approved by voters of Ross Valley (Marin County Flood Control and Water Conservation District, Flood Zone 9 (**FZ9**)) in 2007 following the disastrous flood of December 31, 2005 (an approximate 100-year flood). The drainage fee will generate about $40 million over the next 20 years. Additional sources of funding, such as grants, will be needed to implement all Program projects and activities.

The guiding planning document for the Program is the Ross Valley Flood Reduction and Creek Management Capital Improvement Plan Study (Stetson Engineers, et al, April, 2011 (draft)).[1] The Capital Improvement Plan Study identifies five flood detention basins for capturing and attenuating flood flows and over 160 in-channel improvements aimed at increasing flood conveyance capacity while simultaneously improving the ecological function of Corte Madera Creek and its tributaries (see Figure 1). These detention basins and in-channel capacity improvements work together to provide 100-year flood protection to homes and businesses in flood-prone Ross Valley.

Phoenix Lake, an existing water supply reservoir owned and operated by Marin Municipal Water District (**MMWD**), is the keystone of the Program owing to its sizable attenuation capacity and substantial effect in reducing flood flows. Originally built in 1906 on Ross Creek (a tributary to Corte Madera Creek) for municipal water supply, the 100-year old Phoenix Lake Dam requires major retrofit in order to function as a duel-purpose water supply-flood detention basin. The earthen embankment dam needs structural strengthening to improve seismic stability; the spillway crest needs to be raised six feet for added water supply and flood attenuation capacity; and the intake/outlet works of the low-level drain pipeline need modification to enable rapid lake drawdown in advance of a forecasted flood.

Concomitant with the above-described retrofit of the dam are other physical and operational improvements that are needed to better utilize this valuable, multi-purpose public asset in ways that are compatible, and even synergistic, with flood damage

[1] Document can be viewed and downloaded from the website, http://www.marinwatersheds.org/.

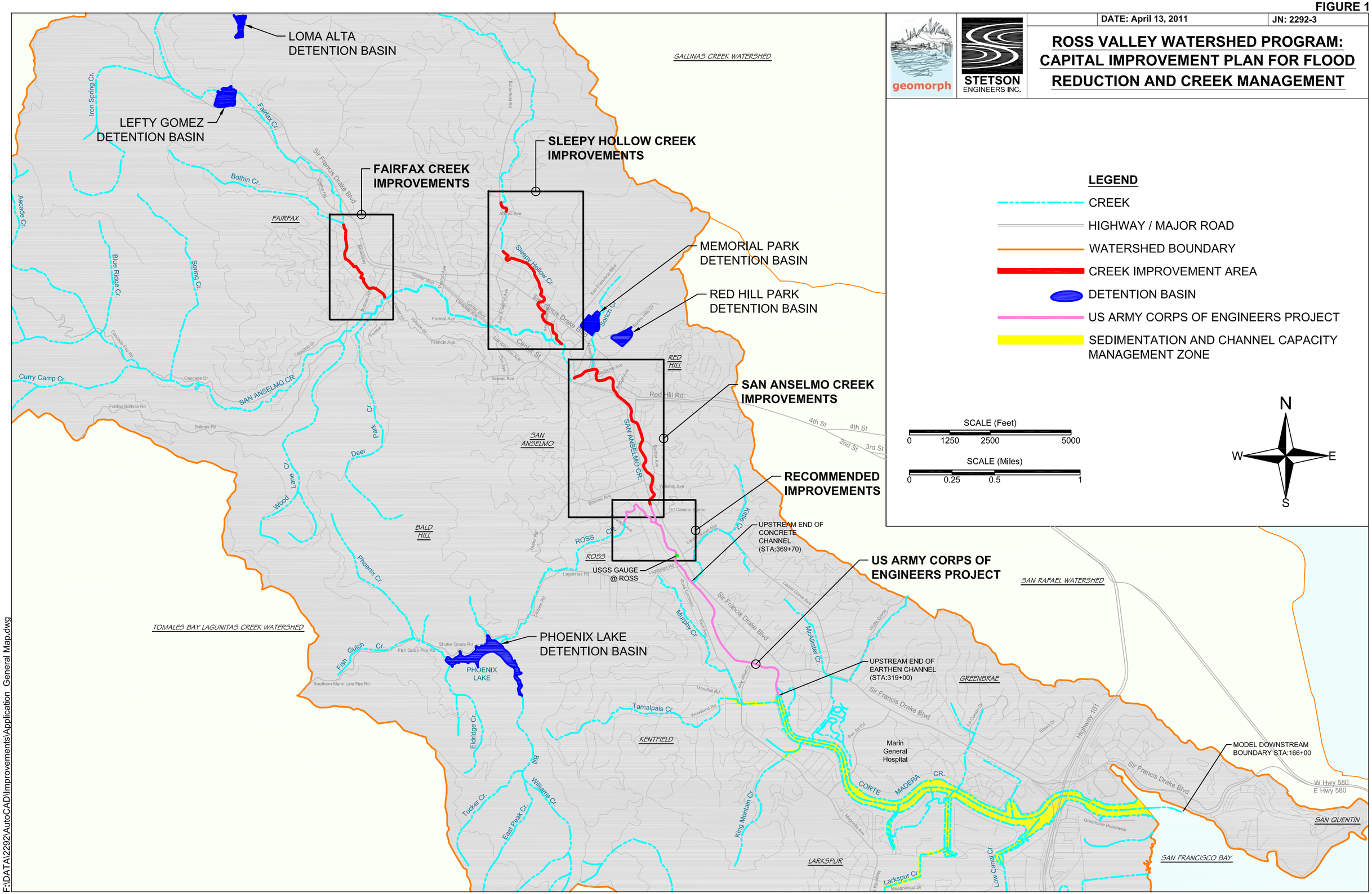
FIGURE 1

geomorph

STETSON ENGINEERS INC.

DATE: April 13, 2011 | JN: 2292-3

ROSS VALLEY WATERSHED PROGRAM: CAPITAL IMPROVEMENT PLAN FOR FLOOD REDUCTION AND CREEK MANAGEMENT



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reduction and water supply functions. Installation of two lake circulation devices aims to improve lake water quality (reduce algal growth in the epilimnion and improve lake clarity; increase dissolved oxygen concentrations and reduce iron and manganese and other metals concentrations in the hypolimnion); instream flow release of cooler water withdrawn from the lake hypolimnion by way of the modified intake of the low-level outlet aims to improve downstream water quality and aquatic habitat for target anadromous salmonids and other cold freshwater fish; and improvements to trails aim to improve public access and enjoyment of the lake and reduce erosion in tributaries and sediment delivery to the lake. The Capital Improvement Plan Study provides engineering analysis, preliminary designs, and costs for several of the component projects of the Phoenix Lake IRWM Retrofit.

1.2 Purpose and Need

There is a need to reduce the frequency and severity of flooding in Ross Valley for the protection of property and public safety. The current capacity of Corte Madera Creek (below Phoenix Lake and the Ross Creek confluence) is about 3,600 cfs, which corresponds to about the 17-percent-annual-chance flood (i.e., 6-year recurrence flood). Several times in recent history Corte Madera Creek has flooded Ross Valley with varying degrees of severity. Prior to establishment in 1951 of the USGS streamflow gaging station on Corte Madera Creek in Ross, flooding was reported in calendar years 1914, 1925, 1937, and 1942. Since 1951 flood flows have been recorded in calendar years 1951, 1955, 1958, 1967, 1969, 1970, 1982, 1983, 1986, 1994 , and 2005. Of these, the two most severe floods occurred in 1982 and 2005, with peak discharges of approximately 7,200 cfs and 6,800 cfs; the annual-chances of which were approximately 0.6-percent and 1-percent, respectively. Historical flooding has caused extensive property damage and economic hardship to residents, businesses, and local governments, and has threatened the lives of those living in the floodplain, with at least one recorded death occurring in the 1955 flood and at least one rescue by Urban Search and Rescue personnel during the 2005 flood.

In accordance with its Congressional authorization for flood control along the lower reach of Corte Madera Creek, the Army Corps of Engineers has plans to increase creek conveyance capacity below the Ross Creek confluence to about 5,400 cfs (about the 4-percent-annual-chance or 25-year recurrence flood). Although this is clearly a major improvement the Ross Valley community desires a higher level of protection. In order to increase the effectiveness of the Corps' design and achieve the desired 1-percent-annual-chance level of flood protection (i.e., 100-year recurrence flood protection), the 100-year flood discharge at the Ross Creek confluence needs to be reduced by 1,400 cfs, from 6,800 cfs down to 5,400 cfs. This reduction is achievable through detention basins, and retrofit of Phoenix Lake, the largest of the five basins, is critical because it can reduce the 100-year flood discharge by about 650 cfs, or nearly half of the total amount needed.

The Phoenix Lake IRWM Retrofit includes seismic upgrade of the dam to enable storage of floodwater to a the higher water level; stabilization of two landslides along the northern side of the lake to prevent further slope failure and rapid deposition of soil into

the lake during flood detention operations; modification of the intake/outlet works of the low-level drain pipeline to enable rapid lake drawdown in advance of a forecasted flood to provide additional storage and floodwater attenuation; and, excavation of the lake bottom to provide an adequate refugia pool for fish and other aquatic wildlife and to prevent entrainment and discharge of sediment when the lake is fully drawndown. Without the Phoenix Lake IRWM Retrofit, the lower reach of Corte Madera Creek will be limited to about the 4-percent-annual chance level of flood protection. Public safety and property downstream of the Ross Creek confluence in the communities of Ross, Kentfield, Larkspur and Greenbrae will remain at an unacceptably high risk of flooding.

There is a need to provide more reliability and flexibility to MMWD's water supply. MMWD reliable water supply is less than the current water demand. MMWD supplies come from local sources and imported water from the Russian River purchased from the Sonoma County Water Agency. If Marin County experiences another drought similar to that of 1976–77, water supplies may not be adequate to meet current demands. MMWD has begun to implement an aggressive water conservation program, investing $3.3 million in 2008–09 to support a wide range of conservation program activities. In combination with implementation of the California Plumbing Code, these activities are projected to save enough water to meet the needs of the projected future MMWD customers until 2025. Increasing its local supply would provide MMWD with much needed water supply reliability and flexibility, particularly during droughts. The Phoenix Lake IRWM Retrofit will restore the spillway crest to its pre-1985 elevation 180 ft, thereby increasing the storage capacity of the lake by about 120 acre-feet. Also included is modification to MMWD’s raw water piping that will provide flexibility to MMWD water production operations reducing the cost of using Phoenix Lake water and opening up more opportunities for its use. Preliminary analysis based on available hydrologic data shows that this added lake storage capacity would increase average long-term yield of the lake by about 107 acre-feet per year and the yield during shortages by about 50 acre-feet per year for supply to the MMWD system. Further analysis based on a longer period of hydrologic record that includes shortage years is needed to confirm these preliminary figures. Lands draining to Phoenix Lake are situated within the Mt. Tamalpais Watershed, which is owned and managed by MMWD for water supply as well as public use and resource management. There are no significant diversions above Phoenix Lake. MMWD holds pre-1914 water rights to Phoenix Lake.

There is a need to improve the water quality of Phoenix Lake. The lake is afflicted with floating algae blooms, particularly during summertime, and low dissolved oxygen in the lake hypolimnion reduces available cold freshwater habitat in the lake and creates a potential for dissolution of sediment-bound metals (e.g., iron and manganese). Algae blooms can contribute to taste and odor problems in drinking water. These water quality problems can impair the beneficial uses of the lake, particularly for drinking water supply. To address these water quality issues, Phoenix Lake IRWM Retrofit includes installation of an epilimnetic circulation device and a hypolimnetic circulation device. The eplimnetic circulation device aims to reduce the growth of floating algae, thereby improving the water quality, lake clarity, and reducing treatment costs during the summertime when lake supply is most needed. The hypolimnetic circulation device aims

to oxygenate the hypolimnion and prevent dissolution of sediment-bound metals. Without the Phoenix Lake IRWM Retrofit, MMWD will continue to explore other, more costly, options to achieve its water supply reliability and flexibility goals.

There is a need to restore the ecological health and function of Corte Madera Creek and its tributaries. The Basin Plan for the San Francisco Bay Region (2010) designates beneficial uses for Ross Creek and Corte Madera Creek, which include COLD, MIGR, RARE, SPWN and others. The creek provides important habitat for threatened and endangered species and is considered an "anchor stream" in the NMFS recovery plans for coho salmon and steelhead trout. Although overall ecosystem functions of the creek are still essentially intact, the freshwater aquatic and creek riparian habitats have been reduced and degraded by human activities and the ongoing presence of development. By the late 1800s, cattle grazing, deforestation, and dredging for navigation began directly modifying creek corridors and increasing the severity of rainfall and sediment-laden runoff. Railroad prisms, bridges, and other permanent infrastructure were installed flanking and spanning the creeks, often creating grade breaks or otherwise altering the creek bed making it difficult for native fish to pass through. In the 1900s, encroachment by urban development gradually filled in along the edges of the creek corridors eliminating portions of the riparian canopy and natural creek bank vegetation and encouraging invasion by non-native vegetation. With construction of Phoenix Lake in 1906, baseflow water temperatures in Ross Creek and farther downstream were warmed as historical seepage of cool groundwater into upper Ross Creek was replaced by spillway overflow from the warmer (and lighter) upper layer of the newly formed lake. All of these factors have contributed to today's sub-optimal aquatic and riparian habitat conditions below Phoenix Lake. The Phoenix Lake IRWM Retrofit includes modification of the intake/outlet works of the low-level drain pipeline. This modification will enable instream flow release of cooler water from the lake hypolimnion and improved downstream water quality and aquatic habitat for target anadromous salmonids and other coldwater species. Without the Phoenix Lake IRWM Retrofit, recovery of target anadromous salmonids and other species will continue to be challenged by sub-optimal riparian and aquatic habitat conditions.

Finally, there is a need to enhance opportunities for public enjoyment of the lake. Phoenix Lake and its associated trails and watershed land provide fishing, hiking, mountain biking, and other enjoyment opportunities to the public. Phoenix Lake is one of its most heavily used recreational areas in the MMWD watershed. Improvements to these trails are needed to keep up with the growing demand and maintain adequate access and safe conditions. Reduction in lake sedimentation is also needed. Comparison of the original lake bathymetric contours with recent contours surveyed in 2009 indicates that the lake has lost about 100 acre-feet to sedimentation, or about 25% of its original storage capacity, since 1906. Much of the sediment comes from erosion along creeks that are tributary to the lake. The Phoenix Lake IRWM Retrofit will implement necessary improvements to roads and trails, as well as culverts where these features cross over tributary drainages. These improvements will aim to enhance public access, safety, and reduce erosion and the delivery of sediment to lake. Without the Phoenix Lake IRWM

Retrofit, lake sedimentation will continue at historical rates and opportunities for public enjoyment of the lake will remain at current levels.

1.3 Project List [and Elements]

The Phoenix Lake IRWM Retrofit consists of five projects; Flood Damage Reduction Project, Water Supply Project, Water Quality Project, Ecosystem Restoration Project, and Recreation and Public Access Project. All five projects are located at Phoenix Lake or in the immediate vicinity (see Figure 3a). Each project has one or more physical elements, which is a new facility or improvement to an existing lake facility. The table below provides an overview of the five component Projects comprising the Retrofit. All Projects have been assessed and evaluated and are currently at the Concept (30%) Design stage. No environmental review or permitting work has been completed.

Phoenix Lake IRWM Retrofit Overview			
Component Projects	**Project Elements**	**Abstract**	**Status**
Flood Damage Reduction Project	Dam Seismic Upgrade	Stabilization of the dam, including construction of a compacted earthen buttress fill and drain on the downstream face and rows of reinforced concrete displacement piles along the dam crest and upstream face.	At Concept (30%) Design stage: Geotechnical studies have been completed based on existing data; initial informal consultation with DSOD has been completed; concept designs and costs have been completed. Further geotechnical investigation, including exploratory drilling, is needed. Final design to be performed based on results of further geotechnical investigation and consultation with DSOD.
	Dam Face Erosion Protection and Crest Raising	Placement of a 3 ft thick rip-rap facing on the upstream face to prevent sloughing during rapid drawdown; placement of 2 ft thick compacted fill over the dam crest to provide added freeboard; stabilization of two landslides to prevent further failure and rapid deposition of sediment into lake during flood detention operations.	
	Low-Level Drain Pipe Intake	Installation of two new low level intakes, at el. 140 ft and el. 160 ft, on the low-level drain pipe to enable rapid drawdown and water level control for flood detention and cool water release to Ross Creek.	At Concept (30%) Design stage Hydraulic studies analyzing reservoir flood routing and new intake hydraulics have been completed; lake water quality studies confirming cool water pool have been completed.
	Lake Bottom Excavation	Excavation of about 30,000 cubic yards of deposited sediment to restore dead pool for aquatic wildlife refugia and reducing sediment in discharge during full lake drawdown.	At Concept (30%) Design stage Lake bathymetric survey has been completed establishing current lake bottom topography and historical sedimentation.

Water Supply Project	Spillway Crest Gate	Installation of a 6-ft high pneumatic spillway gate to add 120 acre-feet of storage capacity for flood attenuation (wet season) and water supply (dry season).	At Concept (30%) Design stage Hydraulic studies analyzing reservoir flood routing, potential water supply yield (preliminary), and engineering feasibility have been completed.
	Phoenix Lake to Bon Tempe Lake Transfer Piping	Modifications to delivery system from Phoenix Lake to enable pumping to Bon Tempe Lake thereby providing flexibility and new opportunities to use Phoenix Lake water in the MMWD system.	At Concept (30%) Design stage Engineering design study analyzing needed piping system modifications and engineering feasibility has been completed.
Water Quality Project	Epilimnetic Circulation Device	Installation of a self contained solar-powered device that circulates water in the lake epilimnion to reduce algae and improve lake clarity.	At Concept (30%) Design stage Preliminary layout of devices has been completed showing one epilimnetic device and one hypolimnetic device.
	Hypolimnetic Circulation Device	Installation of a self contained solar-powered device that circulates water in the lake hypolimnion to add oxygen and thereby reduce iron and manganese and enlarge the pool suitable for coldwater fish.	
Ecosystem Restoration Project	Low-Level Drain Pipe Intake Control Valve	Installation of a small sliding gate on the new low level intakes at el. 140 ft to enable precise control of cool water release to Ross Creek for aquatic habitat restoration.	At Concept (30%) Design stage Lake water quality studies confirming available in-lake cool water pool and benefits of release on Ross Creek water temperatures have been completed.
Recreation and Public Access Project	Bill Williams Creek Arch Culvert Replacement		At Concept (30%) Design stage Watershed assessments identifying source sites contributing sediment to streams and lake and describing restoration/remediation plans for the sites has been completed.
	Phoenix Lake Watershed Trail Improvements		
	Visitor Use Facility Upgrades		
	Road-Related Sediment Reduction Improvements		

1.3.1 Flood Damage Reduction Project

The goal of the Flood Damage Reduction Project is to enable Phoenix Lake to function as a flood detention basin. The objective of flood detention operations is to attenuate flows produced in the upper Ross Creek watershed sufficiently to reduce the peak discharge to lower Ross Creek, and hence lower Corte Madera Creek, during the 1-percent-chance-annual flood (or 100-year flood) by about 650 cfs[2]. In order to achieve this objective, Phoenix Lake needs to provide about 460 acre-feet of flood storage capacity for floodwater attenuation, including surcharge storage above the spillway crest. To provide this storage capacity, flood detention operations call for rapid drawdown of the lake level to elevation 140 ft ahead of a forecasted heavy storm event and storage of floodwaters up to elevation 180 ft, plus surcharge storage.

These flood detention operations require improvements and modifications to the dam, spillway, reservoir and inlet/outlet works. The earthen embankment dam needs structural strengthening to improve seismic stability at the higher water level, elevation 180 ft; the intake of the inlet/outlet works of the low-level drain pipeline needs modification to enable rapid lake drawdown in advance of a forecasted flood; and, the lake bottom needs to be excavated to provide an adequate refugia pool for fish and other aquatic wildlife and to prevent entrainment and discharge of sediment when the lake is fully drawn down to el. 140 ft.[3]

The Flood Damage Reduction Project has four elements that address the four above-described needs: (1) dam seismic upgrade element, (2) dam face erosion protection and dam crest raising element, (3) low-level drain pipeline intake element, and (4) lake bottom excavation element. Section 3.1 provides details on these elements, including the underlying need and rationale, design, and costs.

The dam seismic upgrade element consists of a compacted earthen buttress and drain on the downstream face of the dam and three rows of reinforced concrete displacement piles along both the dam crest and the upstream face of the dam.

The dam face erosion protection and dam crest raising element consists of 3 ft thick of rip-rap facing on the upstream face of the dam and 2 ft of compacted fill over the entire dam crest, which spans 350 ft in length and 22 ft in width. This element also includes stabilization of two landslides that are evident along the northern side of the lake. These landslides require stabilization to prevent further slope failure and rapid deposition of

[2] Phoenix Lake can also reduce peak flows for smaller floods. The amounts of peak flow reduction at the Ross streamflow gage for the 50-year, 25-year, 10-year, and 5-year floods are estimated to be approximately 600 cfs, 510 cfs, 370 cfs, and 270 cfs, respectively.

[3] In addition, the spillway crest, currently at el. 174 ft, needs to be raised six feet to el. 180 ft for the added storage and attenuation capacity. However, the added storage and attenuation capacity is an *enhancement* to the flood reduction project; while it is *essential* to the water supply project. For this reason, the element of raising the spillway crest is included in the water supply project and, accordingly, is described in section 1.3.2 below.

large amounts of sediment into the lake during flood detention operations. Stabilization requires retaining wall and drilled pier and grade beam stabilization structures.

The low-level drain pipeline intake modification element consists of installation of a two-level, motor-controlled, gated intake structure connected to the existing low-level intake structure and extending along the side of the lake opposite the dam. The existing low-level drain pipeline intake was installed in the late 1960s**.** The intake has a 20-inch manually-operated hydraulic slide gate**.** It was designed to enable slow, gradual draining of the lake in the unlikely or rare case that draining was needed. It was not designed for frequent opening and closing and rapid lake drawdown that is required for flood detention operations. Further, there is concern that frequent operation of the gate for flood detention would be difficult, given its manual operation, and would place significant stress on the plate and open/close mechanism which could result in damage or failure of the slide gate mechanism. The modified two-level gated intake will be designed for frequent operations and will enable rapid drawdown of the lake ahead of a forecasted heavy storm and maintenance of the lake water surface at the el. 160 ft (referred to as “step 1 drawdown”) or el. 140 ft level (referred to as “step 2 drawdown”). The gate will be electric motor-controlled. A diesel-powered electric-generator facility is included in this element to ensure a reliable source of power in case there is a disruption in the regional electrical power distribution system.

The lake bottom excavation element consists of excavating the lake bottom in the vicinity of the low-level drain pipeline intake. The existing low-level drain pipeline intake is set at approximately el. 133 ft. Examination of the 2009 bathymetric survey of the lake bottom reveals that much of the dead pool below el. 140 ft has been filled with sediment. The area of excavation will cover about 2.5 acres and the volume of excavated sediment will be about 30,000 cubic yards. The excavation will aim to recover much of the original dead pool volume of the lake. The recovered dead pool will provide adequate refugia for fish and other aquatic wildlife and to prevent entrainment and discharge of sediment through the low-level drain pipe when the lake is drawndown to el. 140 ft.

1.3.2 Water Supply Project

The goal of the Water Supply Project is to increase the yield of Phoenix Lake and thereby provide more reliability and flexibility to MMWD's water supply. The Phoenix Lake IRWM Retrofit will restore the spillway crest to its pre-1985 elevation 180 ft, thereby increasing the storage capacity of the lake by 120 acre-ft. The added storage capacity could potentially increase the long-term average lake yield by up to 107 acre-ft per year and up to 50 acre-ft per year during shortage years for supply to the MMWD system. Accordingly, water supply operations require operating the lake at el. 180 ft for extended periods, particularly during the dry season.

Water supply operations require modification of the spillway. The spillway crest needs to be raised to its pre-1985 elevation, 180 ft. In addition, modifications to the piping system from Phoenix Lake to Bon Tempe Lake will be needed to create separate potable and lake water transfer systems for more flexible utilization of the increased yield of

Phoenix Lake water. Accordingly, the Water Supply Project has two elements: (1) spillway gate; and (2) Phoenix Lake to Bon Tempe Lake transfer piping. Section 3.2 provides details on these elements, including the underlying need and rationale, design, and cost.

The spillway gate element consists of installing a gate within the 14-ft wide by 6 ft high "notch" of the existing concrete spillway. The spillway gate will be an Obermeyer or similar type of pneumatically-operated spillway gate which can be raised and lowered over a range of levels. This type of gate operates by inflating/deflating "bladders" placed beneath spillway panels. The spillway gate will raise the spillway crest by six feet and thereby enable capture and active storage of up to an additional 120 acre-feet of runoff from the MMWD watershed. The added active storage capacity could potentially increase the long term average annual yield of the lake by as much as 107 acre-feet per year and during shortage years by about 50 acre-feet per year for municipal supply to MMWD. Further hydrologic analysis is needed to confirm these estimates of yield using a longer period of historical record that includes extended shortage periods.

1.3.3 Water Quality Project

The goal of the Water Quality Project is to improve the quality of water in Phoenix Lake for municipal water supply and public recreation. The lake experiences floating algae blooms, particularly during summertime. This reduces water clarity and the overall aesthetic appeal of the lake to fishermen and other recreationalists who visit the lake. Algae also affect the filtration process and increase MMWD's treatment costs at its Bon Tempe Water Treatment Plant. Low dissolved oxygen in the lake hypolimnion creates a potential for dissolution of sediment-bound metals. The algae and low dissolved oxygen can lead to taste and odor problems in the treated drinking water.

The Water Quality Project has two elements that address the water quality issues in the lake: (1) epilimnetic circulation device and (2) hypolimnetic circulation device. Section 3.3 provides details on these two elements, including the underlying need and rationale, design, and cost. The two circulation devices will be SolarBee© or similar type of self-contained, independently solar powered, and automated devices. The devices will be supplied and delivered to the site, and installed by the manufacturer.

The eplimnetic circulation device is designed to reduce the growth of floating algae and thereby improve water quality, lake clarity, and reduce treatment costs, particularly during the summertime when lake supply is most needed. The hypolimnetic circulation device aims to oxygenate the hypolimnion and prevent dissolution of sediment-bound metals (e.g., iron and manganese). Higher oxygen concentrations in the hypolimnion will enlarge the pool in the lake that is suitable for coldwater fish, including trout. This is expected to improve the lake's trout fishery.

1.3.4 Ecosystem Restoration Project

The goal of the Ecosystem Restoration Project is to improve aquatic habitat conditions below the dam in Ross Creek and lower Corte Madera Creek by cooling water temperatures in these creeks during the dry season. Cooling of water temperatures requires augmenting the design of the Flood Damage Reduction Project's low-level drain pipeline intake to allow precisely controlled low flow release from the 140 ft level intake.

The Ecosystem Restoration Project has one element that addresses this single need: (1) low-level drain pipe intake low-flow control gate. Section 3.4 provides details on this element, including the underlying need and rationale, design, and cost.

The low-level drain pipe intake low-flow control gate element consists of installing an additional gate on the 140 ft level intake. This gate will be a small sliding gate which can be adjusted over a range of levels to allow for precise control of low flow releases to Ross Creek over a range of low, summer base flows; preliminarily estimated to be 1 to 5 cfs. The gate will be electric motor-controlled. Release flow will be measured at the outlet of the low-level drain pipe where it overflows from a concrete vault below the dam. Water level and water temperature sensors will be placed in the bottom of the vault and a v-notch weir will be cut into one of the vault sides for measurement of outflow. A water level vs. discharge rating curve will be developed for the v-notch weir and a recorder installed nearby to enable continuous measurement and recording of low-flow discharges and temperatures. Instream flow release of cooler water from the lake hypolimnion will improve downstream water quality and aquatic habitat for target anadromous salmonids and other coldwater species.

1.3.5 Recreation and Public Access Project

The goal of the Recreation and Public Access Project is to enhance public access, safety, and reduce erosion and the delivery of sediment to Phoenix Lake. This requires improvements to roads and trails, as well as culverts where these features cross over tributary drainages of Phoenix Lake.

The Recreation and Public Access Project has four elements that address public access, safety, and reduce erosion and the delivery of sediment to Phoenix Lake: (1) Bill Williams Creek arch culvert replacement; (2) Phoenix Lake Watershed trail improvements; (3) visitor use facility upgrades; and, (4) road-related sediment reduction improvements. Section 3.5 provides details on these elements, including the underlying need and rationale, design, and cost.

The Bill Williams Creek culvert replacement will prevent further erosion from occurring at the site, ensure that emergency and visitor access is maintained on Bill Williams Road, and re-establish fish passage in Bill Williams Creek. Phoenix Lake Watershed trail improvements to the trail network around Phoenix Lake will prevent ongoing chronic erosion from occurring on the trail surfaces, reduce sedimentation to Phoenix Lake and its tributaries, and improve visitor access and safety. Upgrading visitor use facilities will

provide benches, bathrooms, and educational kiosks that will enhance the visitor experience, add a public outreach, stewardship, and educational component, and reduce user impacts to the Phoenix Lake watershed. Finally, road-related sediment reduction projects will significantly reduce the amount of erosion and sediment generation taking place in the watershed. This will provide safe and sustainable access for visitor use, watershed maintenance and emergency access vehicles, improve water quality and aquatic habitats in Phoenix Lake and its tributaries, and reduce sedimentation and maintain lake storage capacity for flood attenuation and water supply.

1.4 Integrated Elements of Projects

The component projects comprising the Phoenix Lake IRWM Retrofit work synergistically to enhance function and add value to each other. For example, the spillway gate element of the Water Supply Project increases the yield of Phoenix Lake while simultaneously enhancing the function and adding value to the Flood Damage Reduction Project by increasing the lake's ability to store floodwater and attenuate peak flood flows. Similarly, the low-level drain pipe intake modification element of the Flood Damage Reduction project enables drawdown and maintenance of lake level at el. 140 ft while simultaneously enhancing the Ecosystem Restoration Project by enabling withdrawal of cool water from the lake hypolimnion for release to Ross Creek. There are numerous similar examples of multiple project synergies. The table below explains how each element provides a benefit to its primary project (in red) as well as enhanced function and added value to other projects (in black).

Element	Project					
	Flood Damage Reduction	**Water Supply**	**Water Quality**	**Ecosystem Restoration**	**Recreation /Public Access**	**Explanation**
Dam Seismic Upgrade	X	X			X	Enables storage to a higher water level (el. 180 ft) for peak flow attenuation and flood reduction; enhances water supply by enabling increased storage and lake yield; adds to lake's recreational value by expanding lake area thereby improving the aesthetic appeal, and enlarging the lake coldwater habitat volume thereby improving the trout fishery.
Dam Face Erosion Protection and Dam Crest Raising	X	X				Enables rapid drawdown by preventing sloughing of dam face (erosion protection) and enables storage to a higher water level (el. 180 ft; raising) for peak flow attenuation and flood reduction; enhances water supply by providing necessary freeboard for storage to a higher water level (raising) thereby increasing lake yield.
Low-Level Drain Pipe Intake	X		X	X		Enables lake drawdown by discharge through low-level drain pipeline and lake level control for flood reduction; enhances ecosystem restoration and improves downstream water quality by enabling withdrawal of deep, cool water for downstream release thereby improving fresh coldwater beneficial use.
Low-Level Drain Pipe Intake Control Valve			X	X		Enables precisely controlled low-flow discharge through the low-level drain pipeline for cool water instream flow release during dry season; enhances downstream water quality by improving fresh coldwater beneficial use.
Spillway Gate	X	X			X	Enables storage to a higher water level (el. 180 ft) for increased storage and lake yield; enhances flood damage reduction by enabling increased storage for peak flow attenuation and flood reduction; adds to lake's recreational value by expanding lake area thereby improving the aesthetic appeal, and enlarging the lake coldwater habitat volume thereby improving the trout fishery.
Phoenix Lake to Bon Tempe Lake Transfer Piping		X				Enables more flexible utilization and new opportunities to use the increased yield of Phoenix Lake water by creating completely separate potable and lake water transfer systems.
Lake Bottom Excavation	X	X				Enables lake drawdown by providing adequate dead pool storage during flood detention drawdown; enhances water supply by providing adequate dead pool storage during water supply drawdown.
Epilimnetic Circulation Device		X	X	X	X	Improves lake water quality/clarity by reduce floating algae; enhances water supply by improving lake water quality for drinking water use; enhances ecosystem restoration and public recreation by reducing invasive aquatic vegetation and adding to lake's aesthetic appeal.
Hypolimnetic Circulation Device		X	X	X	X	Improves lake water quality by increasing dissolved oxygen and reducing dissolution of anaerobic chemicals in the lake hypolimnion water quality; enhances water supply by improving lake water quality for drinking water use; enhances ecosystem restoration by increasing dissolved oxygen in low-level outlet instream releases; enhances public recreation by increasing dissolved oxygen in the hypolimnion and enlarging the lake's suitable coldwater habitat volume thereby improving the trout fishery.
Public Trails and Visitor Use Improvements	X	X	X		X	Improves public recreation and access by enhancing trail safety; improves lake water quality and maintains lake storage capacity for flood damage reduction (flood attenuation capacity) and water supply by reducing erosion and sediment delivery/sedimentation in the lake.

X (red) denotes primary project benefit; X (black) denotes enhanced function and added value and other secondary project benefit.

1.5 Regional Map

Figure 2 is a regional map showing the location of the Phoenix Lake IRWM Retrofit, major drainages, water bodies, and flood infrastructure, and relevant active faults. The location of the Retrofit relative to the State Plan of Flood Control (SPFC) is also shown.

1.6 Project Specifics

The tables in sections 1.3 and 1.4 above describe the various component projects comprising the Phoenix Lake IRWM Retrofit. The Retrofit's function and relation to the greater Ross Valley Flood Reduction and Watershed Management Program is explained in Section 1.9 below.

The Phoenix Lake IRWM Retrofit is not a part of the SPFC as shown in Figure 2b, which shows the location of the Phoenix Lake IRWM Retrofit in relation to the SPFC. The figure shows that the Retrofit and the SPFC are located more than 50 miles apart in different hydrologic regions and otherwise not related.

1.7 Completed Work and Existing Data and Studies

Completed work, i.e., work that has been completed or is expected to be completed prior to grant award, will be limited to the data that has been collected and the studies, designs, and cost estimates that have already been completed. Completed work that is related to the five projects is tabulated and described in Sections 3.1 through 3.5. No further work will be completed prior to grant award.

1.8 Project Map

Figure 3a is a local map of Phoenix Lake and the immediate vicinity showing the locations of all projects and project elements comprising the Phoenix Lake IRWM Retrofit. Figure 3b shows a monitoring system that will be used to evaluate the performance of the projects.

1.9 Project Timing and Phasing

Although it is considered the keystone of the greater Ross Valley Flood Reduction and Watershed Management Program, the Phoenix Lake IRWM Retrofit is geographically and physically isolated, so it can be implemented and operated as a stand-alone project with independent utility, function, and benefits. Acting alone, the Retrofit can substantially reduce flooding in Ross, Kentfield, Greenbrae, and Larkspur; improve water supply reliability and water quality of the MMWD system; deliver cooler instream flows to Ross Creek and lower Corte Madera Creek and thereby improve downstream aquatic and riparian habitat during the dry season; improve lake water quality; reduce growth of lake algae; reduce lake sedimentation; and, enhance overall public access and enjoyment of the lake.

FIGURE 2a

J:\n2367\Regionalmap.mxd

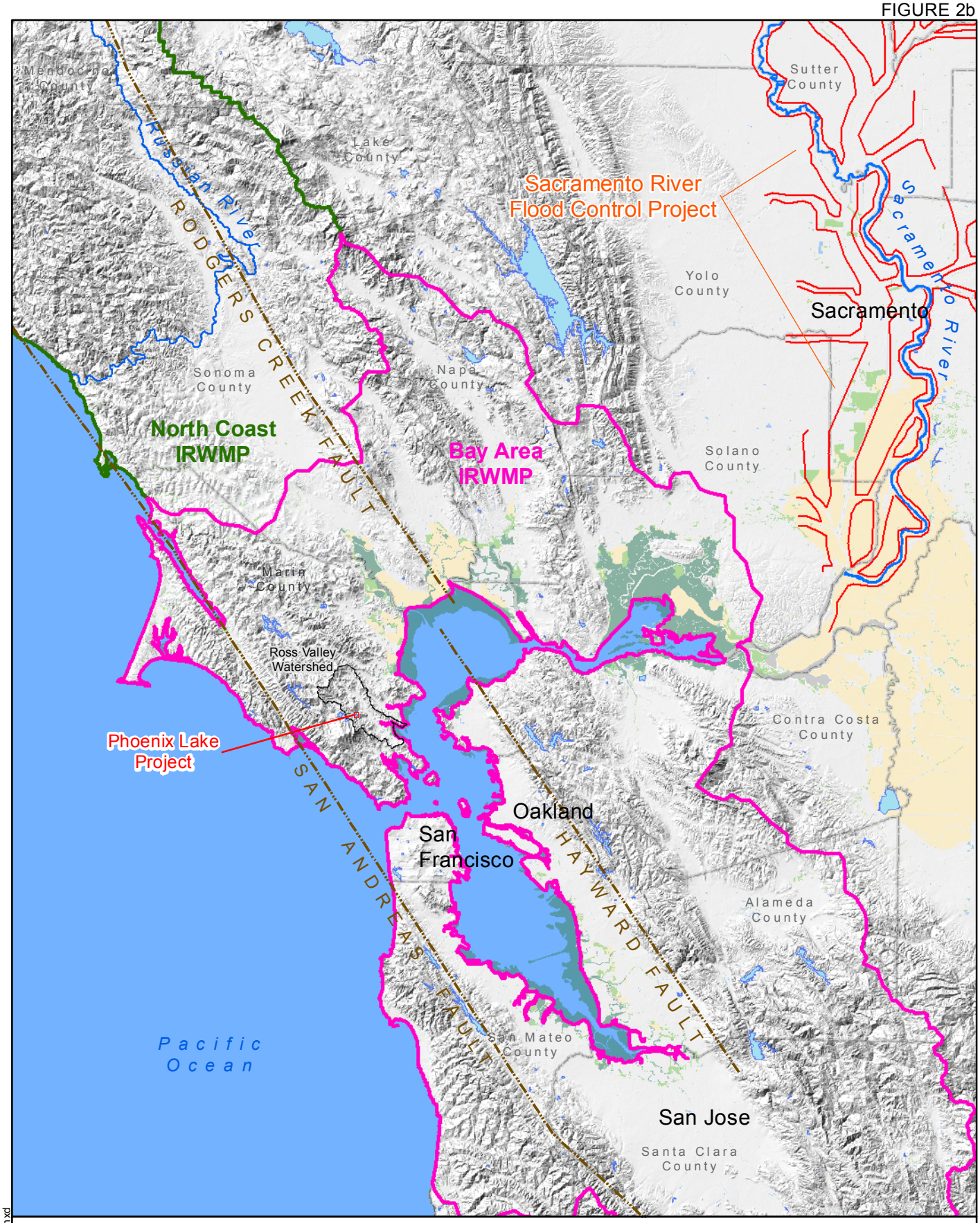
STETSON ENGINEERS INC.

REGIONAL MAP SHOWING THE LOCATION OF THE PHOENIX LAKE IRWM RETROFIT, MAJOR WATER BODIES, AND THE ARMY CORPS FLOOD CONTROL CHANNEL

N

0 0.5 1 Miles

FIGURE 2b



STETSON ENGINEERS INC.

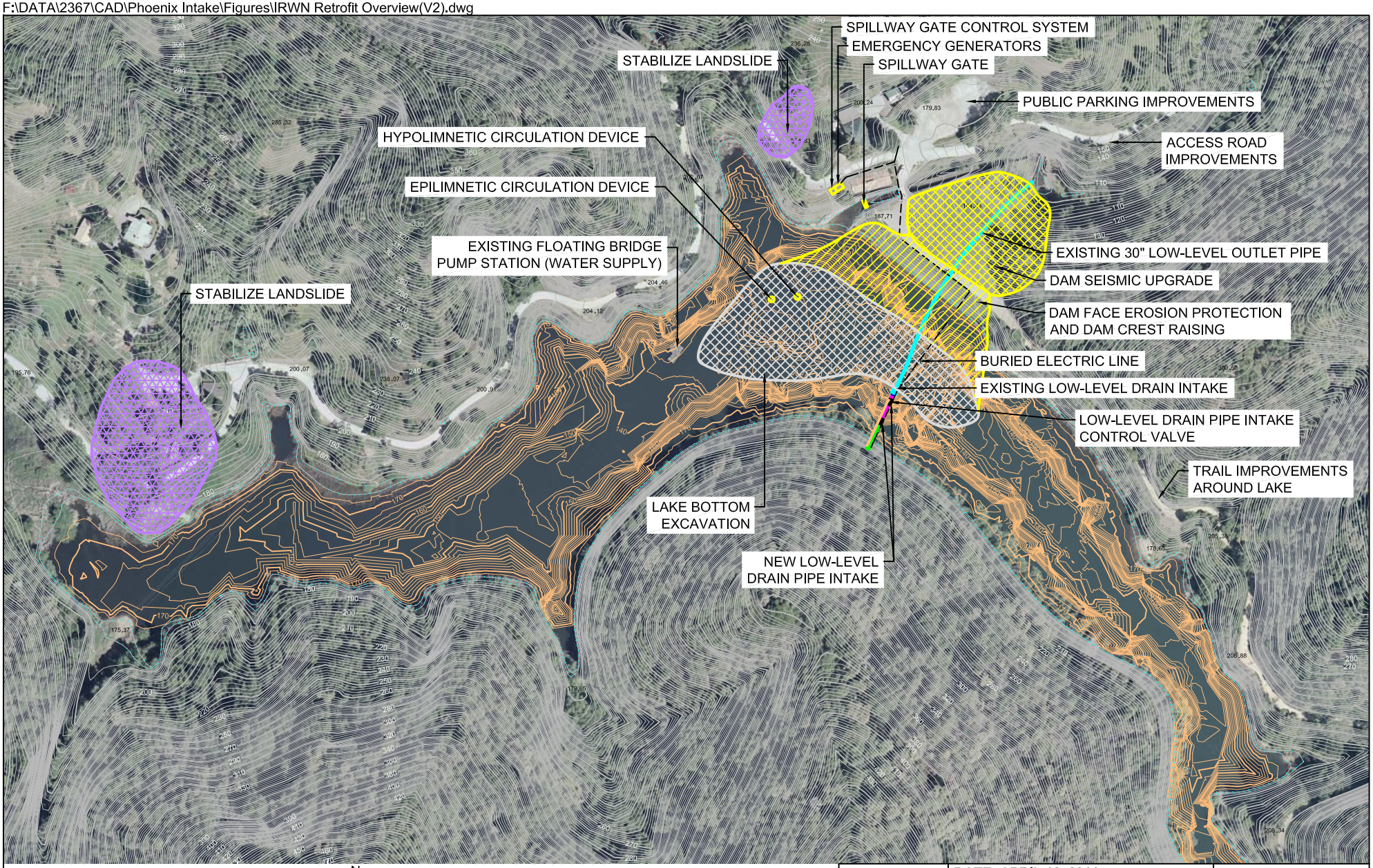
REGIONAL MAP SHOWING THE LOCATION OF THE PHOENIX LAKE IRWM RETROFIT, BAY AREA IRWMP BOUNDARY, RELEVANT ACTIVE FAULTS, AND THE LOCATION OF THE RETROFIT RELATIVE TO THE SPFC

N

0 5 10 Miles

J:\n2367\Regionalmap2.mxd

F:\DATA\2367\CAD\Phoenix Intake\Figures\IRWN Retrofit Overview(V2).dwg



LEGEND

CONTOUR LINES (2 FOOT INTERVAL)

BATHYMETRIC CONTOUR LINES (2 FOOT INTERVAL)

179.16 SPOT ELEVATION

N
W E
S

SCALE (FEET)
0 125 250

Notes:

1. This drawing is in California State Plane NAD 83, zone 3 and vertical datum NGVD 29.
2. Bathymetry data points source is XYZ file data received from Environmental Data Solutions in November 2009.
3. 2' Interval Contourlines and Spot Elevations are based on the 2004 aerial survey contour data received from Marin County.

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DATE: APRIL 12, 2011 | JN: 2367

PHOENIX LAKE IRWM RETROFIT FACILITY LAYOUT

FIGURE 3a

Summary of Monitoring Stations and Monitoring Activities

Project	Monitoring Stations	Monitoring Activities	Continuous or Periodic?
Flood Damage Reduction Project	Trib1	Stream Flow (wet season)	Continuous
	Trib2	Stream Flow (wet season)	Continuous
	PL_S	Lake Stage (wet season)	Continuous
Water Supply Project	PL_S	Lake Stage (dry season)	Continuous
Water Quality Project	PL_WQ	Water Quality	Periodic
	PL_T	Water Temperature	Continuous
Ecosystem Restoration Project	Trib1	Stream flow (dry season)	Continuous
	Trib2	Stream Flow (dry season)	Continuous
	RC1	Stream Flow; Water Temperature; Dissolved Oxygen	Continuous; Continuous; Periodic
	RC1.5	Dissolved Oxygen	Periodic
	RC2	Water Temperature	Continuous
	RC3	Water Temperature	Continuous
	RC4	Stream Flow; Water Temperature	Continuous; Continuous
	CMC1	Water Temperature	Continuous
	CMC2	Water Temperature	Continuous
Recreation and Public Access Project	-	-	

Cost assignment of installation of permanent monitoring stations:

- **Flood Damage Reduction Project**: Trib1, Trib2, and PL_S, and development of rating curves for streamflow gages at Trib1 and Trib2.
- **Water Supply Project**: None
- **Water Quality Project**: PL_T
- **Ecosystem Restoration Project**: RC1, RC2, RC3, RC4, CMC1, and CMC2, and development of rating curves for streamflow gages at RC1 and RC4.
- **Recreation and Public Access Project**: None

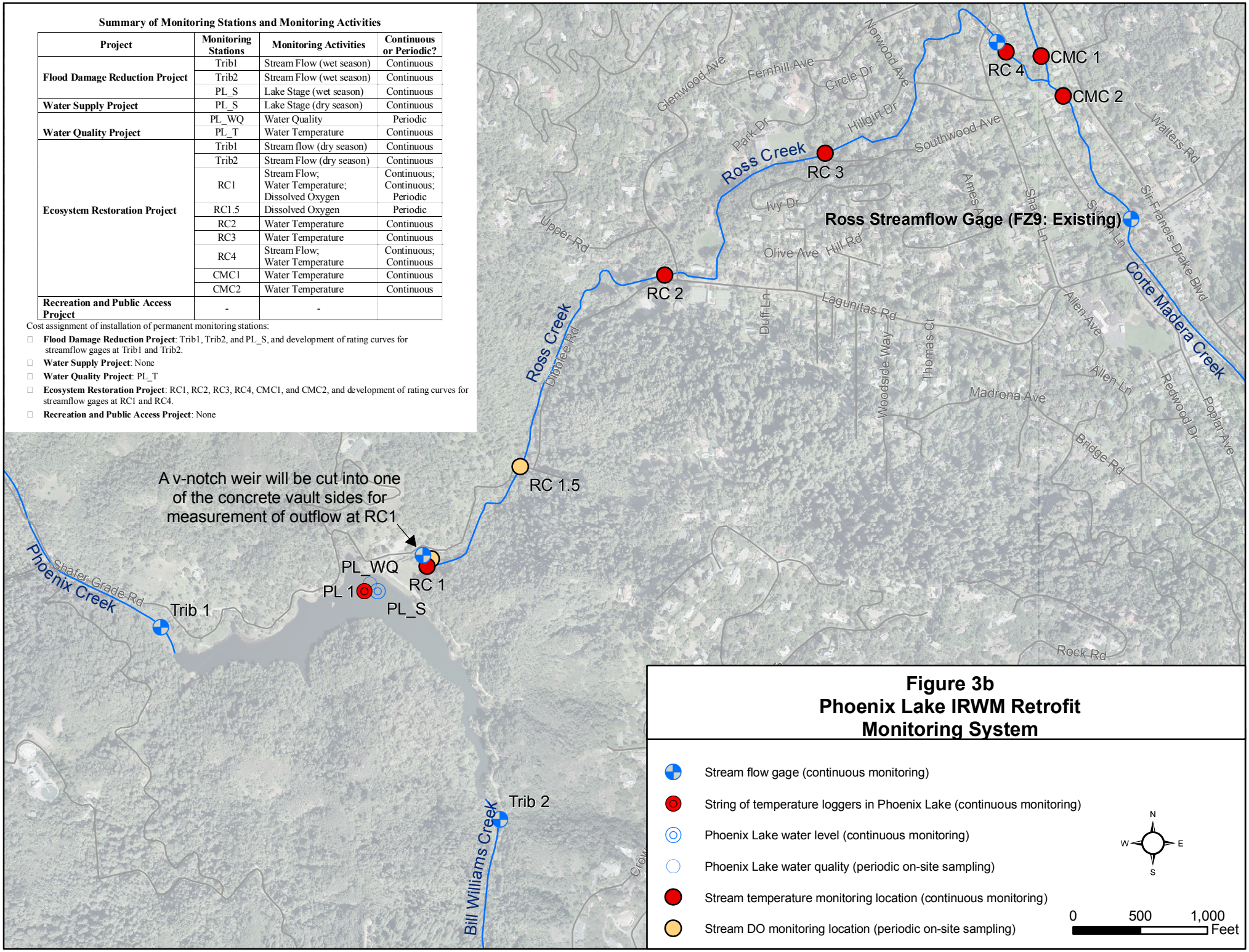


Figure 3b
Phoenix Lake IRWM Retrofit Monitoring System

- Stream flow gage (continuous monitoring)
- String of temperature loggers in Phoenix Lake (continuous monitoring)
- Phoenix Lake water level (continuous monitoring)
- Phoenix Lake water quality (periodic on-site sampling)
- Stream temperature monitoring location (continuous monitoring)
- Stream DO monitoring location (periodic on-site sampling)

N W E S

0 500 1,000 Feet

However, it should be pointed out that the benefits of the Retrofit will be enhanced, synergistically, through completion of the Army Corps of Engineers' project farther downstream in Corte Madera Creek. The Army Corps project is scheduled for completion in 2014. The Army Corps project is planned to include, at a minimum, removal of an existing timber bulkhead/fish ladder, which historically has acted as an impediment to fish passage and migration, and other in-channel improvements aimed at increasing the capacity of Corte Madera Creek to 5,400 cfs. These improvements will enhance fish passage and allow migrating Coho and steelhead better access into Ross Creek below Phoenix Lake. Working in concert, projects identified in the Ross Valley Flood Reduction and Watershed Management Program, including the keystone Phoenix Lake IRWM Retrofit, and the Army Corps project can provide a 100-year level of flood protection to Ross Valley and substantially restore the ecological function of Corte Madera Creek and its tributaries.

The Phoenix Lake IRWM Retrofit will be implemented as a stand-alone project. Due to the synergies between its component projects, all of the component projects will be implemented in concert, including environmental review and regulatory permitting, design, and construction. Attachment 5, Schedule, provides details on timing of implementation. Once construction of the Retrofit is completed in 2015[4], Phoenix Lake will be operated for flood damage reduction, water supply, ecosystem restoration, and public recreation in a coordinated fashion. A Coordinated Operations Plan (COP), establishing the rules and criteria for operating the lake in a manner that achieves the lake's new multi-use benefits, will be developed that is mutually acceptable for MMWD and Flood Zone 9 (FZ9). Monitoring, assessment, and performance measurements will also be conducted in a coordinated fashion as well.

1.10 Relationship of the Phoenix Lake IRWM Retrofit to the Adopted Bay Area IRWMP

The Phoenix Lake IRWM Retrofit advances many of the goals and objectives of the adopted Bay Area IRWMP. The table below, which is derived from the adopted Bay Area IRWMP, identifies specific goals and objectives advanced by the five component Projects comprising the Retrofit.

[4] All component projects will be completed in 2015, except for the Water Quality Project which will be completed in 2016.

Goals and Objectives of the Bay Area IRWMP Advanced by the Phoenix Lake IRWM Retrofit						
		Flood Reduction	Water Supply	Water Quality	Ecosystem Restoration	Public Recreation
Regional Goal	**Objectives**					
A. Contribute to the promotion of economic, social,and environmental sustainability	**Contribute to:**					
	1. Avoiding, minimizing, and mitigating net impacts to environment	x	x	x	x	x
	2. Maintaining and promoting economic and environmental sustainability through sound water resources management practices	x	x	x	x	x
	3. Maximizing external support and partnerships	x	x	x	x	x
	4. Maximizing ability to get outside funding	x	x	x	x	x
	5. Maximizing economies of scale and governmental efficiencies	x	x	x	x	x
	6. Providing trails and recreation opportunities					x
	7. Protecting cultural resources	x				
	8. Increasing community outreach and education for watershed health					x
	9. Maximizing community involvement and stewardship					x
	10.Reducing energy use and/or use renewable resources where appropriate		x	x	x	
	11.Minimizing solid waste generation/maximize reuse			x		
	12.Engaging public agencies, businesses, and the public in stormwater pollution prevention and watershed management, including decision -making					
	13.Achieving community awareness of local flood risks, including potential risks in areas protected by existing projects					
	14.Considering and addressing disproportionate community impacts					
	15.Balancing needs for all beneficial uses of water	x	x	x	x	x
	16.Securing funds to implement solutions	x	x	x	x	x
B. Contribute to improved supply reliability	**Contribute to:**					
	1. Meeting future and dry year demands		x	x		
	2. Maximizing water use efficiency		x	x	x	
	3. Minimizing vulnerability of infrastructure to catastrophes and security breaches	x				
	4. Maximizing control within the Bay Area region					
	5. Preserving highest quality supplies for highest use		x	x	x	
	6. Protecting against overdraft		x	x		
	7. Providing for groundwater recharge while maintaining groundwater resources					
	8. Increasing opportunities for recycled water use consistent with health and safety					
	9. Maintaining a diverse portfolio of water supplies to maximize flexibility		x	x		
	10.Securing funds to implement solutions	x	x	x	x	x
C. Contribute to the protection and improvement of	**Contribute to:**					
	1. Protecting, restoring, and rehabilitating natural watershed processes					x
	2. Controlling excessive erosion and managing sedimentation	x				x
	3. Maintaining or improving in-stream flow conditions		x		x	x
	4. Improving floodplain connectivity					

hydrologic function	5. Preserving land perviousness and infiltration capacity					
	6. Securing funds to implement solutions	x	x	x	x	x
D. Contribute to the protection and improvement of the quality of water resources	**Contribute to:**					
	1. Minimizing point and non-point source pollution					x
	2. Reducing salinity-related problems					
	3. Reducing mass loading of pollutants to surface waters		x		x	
	4. Minimizing taste and odor problems			x		
	5. Preserving natural stream buffers and floodplains to improve filtration of point and non-point source pollutants					
	6. Maintaining health of whole watershed, upland vegetation and land cover to reduce runoff quantity and improve runoff quality					x
	7. Protecting surface and groundwater resources from pollution and degradation			x		x
	8. Anticipating emerging contaminants					
	9. Eliminating non-stormwater pollutant discharges to storm drains					
	10.Reducing pollutants in runoff to the maximum extent practicable					x
	11.Periodically evaluating beneficial uses					
	12.Continuously improving stormwater pollution prevention methods					
	13.Securing funds to implement solutions	x	x	x	x	x
E. Contribute to the protection of public health, safety, and property	**Contribute to:**					
	1. Providing clean, safe, reliable drinking water		x	x		
	2. Minimizing variability for treatment		x	x		
	3. Advancing technology through feasibility studies/demonstrations			x		
	4. Meeting promulgated and expected drinking water quality standards					
	5. Managing floodplains to reduce flood damages to homes, businesses, schools, and transportation					
	6. Minimizing health impacts associated with polluted waterways					
	7. Achieving effective floodplain management by encouraging wise use and management of flood-prone areas					
	8. Maintaining performance of flood protection and stormwater facilities	x				
	9. Partnering with municipalities to prepare mitigation action plans that reduce flood risks to the community					
	10.Coordinating resources and mutual aid between agencies to enhance agency effectiveness	x	x	x	x	x
	11.Securing funds to implement solutions	x	x	x	x	x
F. Contribute to the creation, protection, enhancement, and maintenance of environmental resources and habitats	**Contribute to:**					
	1. Providing net benefits to environment	x	x	x	x	x
	2. Conserving and restoring habitat for species protection		x	x	x	
	3. Acquiring, protecting and/or restoring wetlands, streams, and riparian areas				x	
	4. Enhancing wildlife populations and biodiversity (species richness)			x	x	x
	5. Providing lifecycle support (shelter, reproduction, feeding)			x	x	
	6. Protecting and recovering fisheries (natural habitat and harvesting)			x	x	
	7. Protecting wildlife movement/wildlife corridors				x	
	8. Managing pests and invasive species			x		
	9. Recovering at-risk native and special status species			x	x	
	10.Improving structural complexity (riparian and channel)					
	11.Designing and constructing natural flood protection and stormwater facilities					
	12.Securing funds to implement solutions	x	x	x	x	x

1.11 Data Management and Deliverables

As part of the Bay Area IRWMP implementation, data will be collected to support assessment of the performance of Phoenix Lake IRWM Retrofit, as well as in meeting the regional goals and objectives identified in the Bay Area IRWMP. Details on the monitoring program, including the data that will be collected under the Phoenix Lake IRWM Retrofit, are described in Attachment 6, Monitoring, Assessment, and Performance Measures. To facilitate the data management and deliverables, FZ9 will assign a database coordinator to oversee the collection, storage, and dissemination of data and to ensure that the data management and deliverables are consistent with the Bay Area IRWMP standards.

Data collection will be ensured to be comparable with the statewide data collection programs, such as the Surface Water Ambient Monitoring Program (SWAMP). Upon completion of the performance assessment, the collected data, along with its associated quality assurance/quality control information, will be provided to the State in a format that can be easily integrated into statewide data collection and tracking programs. As appropriate, the collected data will be contributed to the following statewide data programs:

- California Environmental Resources Evaluation System (CERES), an information system developed by the California Resources Agency to facilitate access to natural resource data; and,
- California Environmental Data Exchange Network (CEDEN), a website developed by the State for coordinated data sharing.

2.0 Tasks

This chapter describes tasks that will be performed to implement the five component projects comprising the Phoenix Lake IRWM Retrofit. These tasks are consistent with those used in Attachment 4, Budget, and Attachment 5, Schedule.

As the biggest (by far) of the five component Projects, the Flood Damage Reduction Project tasks are described first. Some of the task descriptions are the same across all projects. So, for sake of brevity, these tasks are described just once in the Flood Damage Reduction Project, and the sameness is noted in the task descriptions of other projects. Although these task descriptions are the same, the level of effort and cost will differ across the five component projects and will be split approximately according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

Given that the five component Projects comprising the Phoenix Lake IRWM Retrofit are linked geographically, functionally and institutionally (i.e., between FZ9 and MMWD) as one project, it is anticipated that the approach to environmental review will be a combined environmental document (e.g., Environmental Impact Report/Environmental Impact Statement (EIR/EIS) or Initial Study/Environmental Assessment (IS/EA)). This combined environmental document will analyze the environmental impacts and provide mitigation measures for the whole Phoenix Lake IRWM Retrofit. The level of effort and cost for Task 6, Environmental Documentation, will be split according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

Since all activities of the Retrofit will be located on property owned by MMWD, there will not be a need for land purchases, easements, or other form of right-of-way acquisition.

It is anticipated that the work will be primarily performed using contractors under several contracts, with administration and oversight performed by FZ9 and MMWD. The contact work is summarized in the table below.

Summary of Contractors for Phoenix Lake IRWM Retrofit			
Phase	**Task**	**Projects**	**Contractor**
Pre-Construction	Geotechnical Pre-Design Report	Flood Damage Reduction Project	Geotechnical engineering consultant-contractor
	Design	Flood Damage Reduction Project, Ecosystem Restoration Project	Engineering consultant-contractor
	Combined CEQA/NEPA Documentation	All Projects	Environmental consultant-contractor
	Permitting	All Projects	Environmental consultant-contractor
	Environmental Compliance Workplan	All Projects	Environmental consultant-contractor
	Long term hydrologic analysis of reoperation of Phoenix Lake for flood detention and water supply	Flood Damage Reduction Project, Water Supply Project	Engineering consultant-contractor
	Coordinated Operations Plan	Flood Damage Reduction Project, Water Supply Project	Engineering consultant-contractor
	Design	Water Supply Project – Spillway gate	Engineering consultant-contractor
	Design	Water Supply Project – Phoenix Lake to Bon Tempe Lake transfer piping	Engineering consultant-contractor
	Baseline Water Quality Report for Phoenix Lake	Water Quality Project	Hydrographer consultant-contractor
	Design	Water Quality Project	Engineering consultant-contractor
	Baseline Water Quality Report for Ross Creek/Corte Madera Creek	Ecosystem Restoration Project	Hydrographer consultant-contractor
	Design	Recreation and Public Access Project – Trails Improvements	Engineering/erosion control consultant-contractor
	Design	Recreation and Public Access Project – Visitor Use Facilities	Engineering consultant-contractor
Construction	Construct	Flood Damage Reduction Project, Ecosystem Restoration Project	Construction contractor
	Construct	Water Supply Project – Spillway gate	Engineering construction contractor
	Construct	Water Supply Project – Phoenix Lake to Bon Tempe Lake transfer piping	Engineering construction contractor
	Furnish and Install Circulation Devices	Water Quality Project	Vendor-contractor
	Construct	Recreation and Public Access Project – Trails Improvements	Construction contractor
	Construct	Recreation and Public Access Project – Visitor Use Facilities	Construction contractor
	Furnish and install streamflow gages, lake level gage, water level sensor at outlet vault; develop discharge rating curves; furnish and install water temperature sensors	Flood Damage Reduction Project, Water Supply Project, Ecosystem Restoration Project	Hydrographer consultant-vendor

2.1 Flood Damage Reduction Project Tasks

2.1.1 Task 1: Administration

This task consists of administration of all Flood Damage Reduction Project-related activities that will be performed by FZ9, FZ9 contractors, and FZ9's partner agency, MMWD. Activities will primarily include, but will not be limited to, planning and design work and construction and testing work. FZ9 will be the lead agency under CEQA and will be the contracting agency on all work performed by contractors. MMWD, as owner of the Phoenix Lake property and facilities, will participate in all activities in a "review-and-comment" and "inspect-and-approve" capacity.

Administration will cover work performed by FZ9 and MMWD that is incidental but directly related to the above-described Project-related activities. Administration will also involve Grant Agreement-related administrative work.

Administration will also cover preparation of a Memorandum of Agreement (MOA) between FZ9 and MMWD concerning cost sharing and joint operation of Phoenix Lake for flood control, water supply, ecosystem restoration, and recreation. It is anticipated that the Coordinated Operations Plan (see section 2.2.4 below) for Phoenix Lake will be incorporated into the MOA. Preparation of the MOA will involve FZ9 and MMWD engineering, management, and legal staff.

Deliverables: Submission of invoices and other deliverables as required; Memorandum of Agreement[5]

2.1.2 Task 2: Labor Compliance Program

This task consists of preparation, submission, and implementation of a Labor Compliance Program. FZ9 will prepare and submit a written Labor Compliance Program which will satisfy all requirements of the Labor Code. FZ9 will implement the Labor Compliance Program in all contracts the FZ9 enters into for the Phoenix Lake IRWM Retrofit. Implementation will involve FZ9 preparing and inserting provisions in all contracts requiring contractors to comply with the Labor Code, including paying prevailing wage rates, overtime, holidays, and other special provisions. Implementation will also involve FZ9 enforcing these contract provisions by reviewing contractors' invoices and payroll records for compliance.

Deliverable: Submission of a written Labor Compliance Program

[5] Since the MOA primarily addresses joint use of Phoenix Lake for flood control and water supply, it has been included under both the Flood Damage Reduction Project and the Water Supply Project. The cost to prepare the MOA has been split 50/50 between these two projects, as reflected in Attachment 4, Budget.

2.1.3 Task 3: Reporting

This task consists of preparing quarterly, annual, and final progress reports for the whole Phoenix Lake IRWM Retrofit.[6] The progress reports will describe all grant-funded activities, expenditures vs. budget, and other information for the reporting period as specified in the Grant Agreement. As detailed in Attachment 5, Schedule, the Project is planned to occur over a 55 month period, from September 1, 2011 to March 31, 2016. Accordingly, it is anticipated that that 17 quarterly reports, 4 annual reports, and one final progress report will be prepared.

Deliverable: Submission of quarterly, annual, and final reports as specified in the Grant Agreement.

2.1.4 Task 4: Assessment and Evaluation

Completed work on the Flood Damage Reduction Project is summarized in Section 3.1. The completed work includes a Project Assessment and Evaluation Memorandum, Concept (30%) Design Memorandum, and prior hydrologic, hydraulic, and geotechnical studies. The completed hydrologic and hydraulic studies have adequately verified the feasibility and viability of these aspects of the Project; therefore, no further assessment and evaluation hydrology and hydraulics work is needed. However, further assessment and evaluation work is needed in geotechnical engineering to verify the feasibility and viability of the geotechnical aspect of the Project. In particular, additional field data is needed on the engineering properties of the soil and rock that comprise the dam and to characterize the two landslides on the northern side of the lake that require stabilization (refer to Miller Pacific, May 2010; p. 10). This field data will support further assessment and evaluation of seismic upgrade and other geotechnical aspects of this Project, as well as provide the geotechnical information needed for final design.

Further assessment and evaluation work in geotechnical engineering will have three main elements: (1) consultation with DWR/DSOD to determine the project-specific field exploratory drilling, testing and geotechnical engineering analyses that will be required; (2) perform the required field exploratory drilling and testing; and (3) perform the required geotechnical engineering analyses.

For purposes of this grant application, it is anticipated that the required field exploratory drilling and testing work will include six (6) borings in the dam and two (2) borings in the two landslides and laboratory testing of the boring materials, including moisture density, strength (TXCU/pp), PI, and grain size. It is anticipated that the required geotechnical engineering analyses will include more refined (i.e., more refined than the previously completed analyses) stability and deformation analyses based on the new field data. All work, including field data, testing, and analyses, findings, and conclusions verifying feasibility and viability of the geotechnical aspect of the Project will be documented in a Geotechnical Pre-Design Report.

[6] The cost for reporting has been split across all five component projects comprising the Retrofit according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

A Coordinated Operations Plan (COP), establishing the rules and criteria for operating the lake in a manner that achieves the lake's new multi-use benefits, will be developed that is mutually acceptable for MMWD and FZ9. Details on the COP are provided in section 2.2.4 below.[7]

It is anticipated that this work will be performed by geotechnical engineering consultant-contractors with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment services.

Deliverables: Geotechnical Pre-Design Report

2.1.5 Task 5: Final Design

For purposes of this grant application and based on information in Section 3.1, the Flood Damage Reduction Project is currently at the Concept (30%) design stage. Further work will be needed to complete Final Design. This further work is divided into two groups based on the four elements of the Project as described in more detail in Section 3.1: (1) Low-Level Drain Pipe Intake, which will require civil, structural, mechanical, and electrical design, and (2) Dam Seismic Upgrade, Dam Face Erosion Protection and Dam Crest Raising, Lake Bottom Excavation, which will require geotechnical design.

Design plans for these two engineering groups will be prepared at three stages, based on the design stage definitions given in the PSP, p. 33, for review, comment, and approval by FZ9 and MMWD: 60% design, 90% (Pre-final) design, and 100% (Final) design. The 100% (Final) design will include the design package and contract that will be advertised for award for construction. It is anticipated that a single design package and contract, combining all four elements of the Flood Damage Reduction Project, will be advertised and awarded for construction to a single contractor. It is anticipated that the design work will be performed by an engineering consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment and approval of all designs.

Deliverables: 60% design, 90% (Pre-final) design, and 100% (Final) design package

2.1.6 Task 6: Environmental Documentation

The Phoenix Lake IRWM Retrofit will be subject to environmental review under the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA). It is anticipated FZ9 and the U.S. Army Corps of Engineers will be the lead agencies under CEQA and NEPA, respectively. Given that the five component Projects comprising the Phoenix Lake IRWM Retrofit are linked geographically, functionally and institutionally (i.e., between FZ9 and MMWD) as one project, it is anticipated that the

[7] Since the COP primarily addresses joint use of Phoenix Lake for flood control and water supply, the cost for the COP has been split 50/50 between the Flood Damage Reduction Project and the Water Supply Project, as indicated in Attachment 4, Budget.

approach to environmental review will be a combined Environmental Impact Report/Environmental Impact Statement (EIR/EIS) or Initial Study/Environmental Assessment (IS/EA). This combined environmental document will analyze the environmental impacts and provides mitigation measures for the whole Phoenix Lake IRWM Retrofit, including the Flood Damage Reduction Project and the other four component Projects.

It is anticipated that environmental review will proceed concurrently with regulatory permitting (see section 2.1.7 below). This approach offers flexibility and expands opportunities for mitigating impacts associated with individual Projects and Project elements. Conceivably, impacts in one location within the geographic footprint of the Retrofit can be mitigated elsewhere in the geographic footprint. It can also streamline and reduce the overall costs (e.g., special studies) associated with the environmental review and permitting processes.

It is anticipated that this work will be performed by an environmental consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment.

Deliverables: Approved and adopted combined CEQA/NEPA documentation

2.1.7 Task 7: Permitting

The Flood Damage Reduction Project will be subject to the regulatory permitting authority of several federal and state agencies. The table below identifies the permits that are expected to be required.

It is anticipated that environmental regulatory permitting will proceed concurrently with environmental review. This approach offers flexibility and expands opportunities for mitigating impacts associated with individual Projects and Project elements. Conceivably, impacts in one location within the geographic footprint of the Retrofit can be mitigated elsewhere in the geographic footprint. It can also streamline and reduce the overall costs (e.g., special studies) of the environmental review and permitting processes.

It is anticipated that DSOD permitting will proceed concurrently with Final (100%) Design (see section 2.1.5 above).

It is anticipated that special technical studies will be required to support the applications identified in the table above, including delineations of waters of the U.S. and State; vegetation surveys at affected areas; biological surveys for special-status species; and an instream flow study of aquatic habitat in Ross Creek. These studies will be used to support both the environmental review and permitting processes.

It is anticipated that permitting work in connection with the applications to DSOD and Marin County will be performed by an engineering consultant-contractor and the remaining environmental regulatory permitting work will be performed by environmental

consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment.

Approvals and Permits Required for the Phoenix Lake IRWM Retrofit

Agency	Trigger	Approval	Submittal
US Army Corps of Engineers (USACE)	Discharge of fill within ordinary high water mark in creek, lake, or adjacent wetlands	Section 404/10 Permit (Nationwide Permit or an Individual Permit)	Application
National Marine Fisheries Service (NOAA Fisheries) US Fish and Wildlife Service	Effects on federally listed threatened or endangered species	Biological Opinion through a Section 7 Consultation with USACE	Biological Assessment
San Francisco Bay Regional Water Quality Control Board (RWQCB)	Section 404 Permit through USACE	Section 401 Water Quality Certification through Section 404 Permit with USACE	Application
California Department of Fish and Game (DFG)	Work in waters of the State Effects on federally listed threatened or endangered species	Lake and Streambed Alteration Agreement	CEQA document
State Historic Preservation Officer (SHPO)	Effects on cultural or archeological resources	SHPO review and concurrence of inventory/evaluation report	CEQA/NEPA document
Department of Water Resources/Division of Safety of Dams (DSOD)	Modification of dam, spillway, or low-level drain pipe	Approval of Plans and Specifications for modification	Application
Marin County	Construction, earthwork, work in a watercourse	Grading Permit, Building Permit, Watercourse Permit	Application; CEQA document

Deliverables: Permit applications for Army Corps 404, Regional Board 401 Certification, and Fish and Game Stream/Lake Alteration, including requisite supporting technical studies; application for DSOD approval of plans and specifications; application to Marin County for grading/building/watercourse permit

2.1.8 Task 8: Construction Contracting

This task covers activities associated with construction contracting, including advertisement for bids; answering questions from contractors and preparing addendums to the design package during the bidding period; pre-bid contractors meeting; evaluation of bids; and award of contract. FZ9 will carry out the advertisement and award of contract work, and will be assisted by an engineering consultant-contractor in the other work.

Deliverables: Bid advertisement; written answers to questions during bidding; addendums to contract, if/as needed; meeting notes from pre-bid meeting with contractors; documented evaluation of bids and recommendation for award.

2.1.9 Task 9: Construction

As indicated above in section 2.1.5, it is anticipated that a single design package and contract, combining all four elements of the Flood Damage Reduction Project (Low-Level Drain Pipe Intake, Dam Seismic Upgrade, Dam Face Erosion Protection and Dam Crest Raising, Lake Bottom Excavation), will be advertised and awarded for construction. Construction is divided into three categories: mobilization and site preparation; project construction; and performance testing and demobilization.

Following major construction work, further work will be performed on the monitoring system. It is anticipated that this work will be performed by a consulting hydrographer-contractor.

2.1.9.1 Mobilization and Site Preparation

This category of work includes several items as described in the table below.

Mobilization and Site Preparation Work	
Staging area	Establish the on-site work staging area and support facilities (e.g., water tank, electric power)
Stockpile area	Establish stockpile area for temporary storage of excavated material
Mobilization	Mobilize equipment to the site
Erosion Control	Set up erosion control
Access roads	Trim, grade, and make other improvements (widen road, modify culverts, etc.) to the existing access road leading to the staging area needed to accommodate large construction equipment; create new access road(s) to the reservoir bottom, as needed
Dewatering and water management	Gravity drain the lake using existing low-level drain pipe; dewater the dead pool using temporary pumps; construct cofferdam(s) to collect tributary and groundwater inflow and maintain dewatered condition during construction using temporary pumps; install sediment controls and discharge pipeline to Ross Creek
Wildlife protection	Set up exclusionary fencing as required by the Environmental Compliance Workplan (ECW; see section 2.1.10 below)
Wildlife relocation	Collect fish and other aquatic wildlife from lake after gravity draining and relocate

2.1.9.2 Project Construction

This category of work includes several items as described in the table below.

Project Construction Work	
Filter Fabric	Stabilize and place filter fabric on upstream dam face
Rip-rap facing	Placed 3 ft thick rip-rap on upstream dam face
Piles	Construct auger cast displacement piles in upstream face; 18-in dia, 60-ft deep, 6 rows at 10 ft o.c.
Excavate and stockpile	Excavate and stockpile material from downstream face
Drainage blanket	Place and install drainage blanket on downstream dam face
Buttress fill	Place compacted buttress fill, using lake bottom material, on downstream dam face
Excavate lake bottom	Excavate lake bottom
Stabilize landslides	Construct retaining wall using soldier pile and timber lagging; install drilled pier and grade beam structure; finish site grading and install erosion control
Construct Intake	Install intakes on low-level drain pipe at el. 140 ft and 160 ft
Mechanical	Install slide gates and motor controls on intakes
Emergency Generators	Construct housing for emergency generators; install emergency generators and appurtenances
Electrical	Install power lines; hook-up motor-controlled slide gates to power supply sources
Monitoring	Install gages at lake tributaries (2) and lake level gage (1)

2.1.9.3 Performance Testing and Demobilization

This category of work includes several items as tabulated below relating to the construction contract.

Performance Testing and Demobilization Work (Construction Contract)	
Performance testing	Test performance of mechanical and electrical systems, including emergency generators, motor-controlled gates, and monitoring components
Demobilization	Demobilize equipment and remove support facilities and temporary hookups from the site
Site restoration	Finish grade disturbed areas; hydroseed and install erosion control; plant other vegetation in disturbed areas as needed
Wildlife Replacement	Collect temporarily stored fish and other aquatic wildlife and replace into lake

2.1.9.4 Monitoring System Work

This category of work includes several items as described in the table below relating to the monitoring system.

Post-Construction Monitoring System Work	
Monitoring	Develop creek water level vs. discharge rating curves for gages (2) at the creek tributaries to lake
Monitoring	Install temporary flow measurement device at low-level outlet pipe; perform lake drawdown tests to assess lake drawdown capability and rate and to develop lake water level vs. discharge relationship for the new intakes (2)

2.1.10 Task 10: Environmental Compliance, Mitigation, Enhancement

It is anticipated that an outcome of environmental review under CEQA and NEPA and regulatory permitting will be various environmental compliance, mitigation, and enhancement measures that will be required pre-, during, and post-construction. Since the environment review has not been initiated, it is impossible at this time to predict exactly what measures will be required but, for purposes of this grant application, the following measures are anticipated.

Environmental Compliance, Mitigation and Enhancement	
Environmental Compliance Workplan	Preparation of an written Environmental Compliance Workplan (ECW) for the Phoenix Lake IRWM Retrofit[8] which will identify special-status species and other sensitive biological resources occurring in the Project area; describe pre-construction biological surveys and avoidance measures (e.g., exclusionary fencing); describe construction avoidance measures (e.g., construction season, exclusionary fencing) and monitoring; describe post-construction restoration and mitigation measures; and describe post-construction mitigation monitoring
Pre-construction biological surveys	Perform pre-construction biological surveys as required in the ECW
Restoration and mitigation (in addition to normal construction site restoration req'd by construction contractor)	Re-create five (5) acres of lake-fringe wetland habitat
Initial monitoring (initial verification monitoring only – not long term)	Perform initial monitoring to verify and document initial installation of restoration and mitigation as required in the ECW

[8] It is anticipated that the ECW will cover the whole Phoenix Lake IRWM Retrofit. The cost for the ECW has been split according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

It is anticipated that this work will be performed by environmental consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment.

Deliverables: Environmental Compliance Workplan Report; pre-construction biological survey report; construction monitoring reports; initial monitoring (initial verification) report.

2.1.11 Task 11: Construction Administration

This task covers activities associated with administering and managing construction of the Project. Specifically this task includes collecting, reviewing, and filing all documentation, bonding, and certifications required from the contractor before work can begin; holding a pre-construction meeting with the contractor; field-inspecting the work of the contractor, including review of required materials certifications and earthwork testing; monitoring of construction activities to ensure compliance with the ECW; review of contractors submittals, including shop drawings; preparation of change orders; review of contractors progress invoices and recommendations for payment of progress invoices; inspection of performance testing; review of contractors final invoice and recommendation for payment.

Also included is construction inspection and monitoring, which will consist of performing continuous, on-site inspection and monitoring on construction activities by an on-site resident engineer and biologist during all phases of construction to ensure conformance with the contract plans and specifications and compliance with the ECW.

FZ9 will carry out collecting, reviewing, and filing all documentation, insurance and bonding, and certifications as required from the contractor; and payment of invoices. FZ9 anticipates that the other work described above will be performed by an engineering consultant-contractor and environmental consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also perform review-and-comment and inspection-and-approval functions during construction.

Deliverables: Meeting notes on pre-construction meeting; field-inspection reports; field monitoring reports; documented materials certifications and earthwork testing results; review/approved shop drawings, if/as needed; change orders, if/as needed; documented review and recommendations for progress and final payments to contractors.

2.2 Water Supply Project Tasks

The Water Supply Project has two elements, spillway gate and Phoenix Lake to Bon Tempe Lake transfer piping. Although the descriptions of some of the tasks that follow are similar to the Flood Damage Reduction Project, the level of effort to complete the tasks as well as the cost, as reflected in Attachment 4, Budget, will be substantially less.

As indicated in section 2.2.5 below, FZ9 anticipates awarding a single, separate contract to and engineering construction contractor to furnish and install the spillway gate.

2.2.1 Task 1: Administration

Same as Task 1 in Flood Damage Reduction Project (see section 2.1.1 above).

Deliverables: Submission of invoices and other deliverables as required; Memorandum of Agreement[9]

2.2.2 Task 2: Labor Compliance Program

Same as Task 2 in Flood Damage Reduction Project (see section 2.1.2 above).

Deliverable: Submission of a written Labor Compliance Program

2.2.3 Task 3: Reporting

Same as Task 3 in Flood Damage Reduction Project (see section 2.1.3 above).[10]

Deliverable: Submission of quarterly, annual, and final reports as specified in the Grant Agreement.

2.2.4 Task 4: Assessment and Evaluation

Completed work on the Water Supply Project is summarized in Section 3.2. The completed work includes a Project Assessment and Evaluation Memorandum, Concept (30%) Design Memorandum, and prior hydrologic studies. The Concept (30%) Design Memorandum has adequately verified the engineering feasibility and viability of the spillway gate and the Phoenix Lake to Bon Tempe Lake transfer piping; therefore, no further engineering assessment and evaluation work is needed. However, further hydrologic assessment and evaluation is needed.

One of the completed hydrologic studies was a long-term hydrologic analysis of re-operation of Phoenix Lake for flood detention and water supply. The purpose of the analysis was to assess and evaluate the long term yield of the Water Supply Project if Phoenix Lake is operated for both flood detention and water supply. The analysis was based on the best available hydrologic data covering the period 1986 to 2010. Unfortunately, there were years in this period with missing data (1989-1992 and 1996)

[9] Since the MOA primarily addresses joint use of Phoenix Lake for flood control and water supply, it has been included under both the Flood Damage Reduction Project and the Water Supply Project. The cost to prepare the MOA has been split 50/50 between these two projects, as reflected in Attachment 4, Budget.
[10] The cost for reporting has been split across all five component projects comprising the Retrofit according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

which included some shortage years. In order to more thoroughly assess and evaluate the long term yield of the Water Supply Project, further long-term hydrologic analysis covering shortage years is needed. One approach is to synthesis the data that are missing for 1989-1992 and 1996. Another approach is to extend the period of analysis further back it time to cover the 1976-77 drought years if the data are available. Whatever approach(s) is taken, the Phoenix Lake operations model previously developed will be used again for this further analysis.

A Coordinated Operations Plan (COP), establishing the rules and criteria for operating the lake in a manner that achieves the lake's new multi-use benefits, will be developed that is mutually acceptable for MMWD and FZ9. The operating rules and criteria will govern lake levels, withdrawals for water supply, and operation of the spillway gate. The COP will also describe instream flow releases for ecosystem restoration in Ross Creek below the dam and lake levels for public recreational uses of the lake. The Phoenix Lake operations model and findings of the instream flow study of Ross Creek and lower Corte Madera Creek (see section 2.4.7) will be used in developing the COP. It is anticipated that the COP will be incorporated into the MOA (see section 2.1.1 above).[11]

It is anticipated that the above-described work will be performed by an engineering consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment services.

Deliverables: Report on Long-Term Hydrologic Analysis of Re-operation of Phoenix Lake for Flood Detention and Water Supply; Coordinated Operations Plan

2.2.5 Task 5: Final Design

For purposes of this grant application and based on information in Section 3.2, the Water Supply Project is currently at the Concept (30%) design stage. Further work will be needed to complete Final Design of the spillway gate installation and the Phoenix Lake to Bon Tempe Lake transfer piping. This further work will require civil, structural, mechanical, and electrical design.

Design plans for the spillway gate installation and the transfer piping will be prepared at three stages, based on the design stage definitions given in the PSP, p. 33, for review, comment, and approval by FZ9 and MMWD: 60% design, 90% (Pre-final) design, and 100% (Final) design. The 100% (Final) design will include the design package and contract that will be advertised for award for construction. It is anticipated that separate two design packages and contracts will be advertised and awarded to two separate contractors for construction of the spillway gate and transfer piping.

[11] Since the COP primarily addresses joint use of Phoenix Lake for flood control and water supply, it has been included under both the Flood Damage Reduction Project and the Water Supply Project. The cost to prepare the COP has been split 50/50 between these two projects, as reflected in Attachment 4, Budget.

It is anticipated that the design work will be performed by an engineering consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment and approval of all designs.

Deliverables: 60% design, 90% (Pre-final) design, and 100% (Final) design package, two of each.

2.2.6 Task 6: Environmental Documentation

Same as Task 6 in Flood Damage Reduction Project (see section 2.1.6 above).

Deliverables: Approved and adopted combined CEQA/NEPA documentation[12]

2.2.7 Task 7: Permitting

The Water Supply Project will be subject to the regulatory permitting authority of state and local agencies. The table below identifies the permits that are expected to be required.

Approvals and Permits Required for the Phoenix Lake IRWM Retrofit

Agency	Trigger	Approval	Submittal
Department of Water Resources/Division of Safety of Dams (DSOD)	Modification of dam, spillway, or low-level drain pipe	Approval of Plans and Specifications for modification	Application
Marin County	Construction	Building Permit	Application; CEQA document

It is anticipated that the above-described permitting will proceed concurrently with Final (100%) Design (see section 2.2.5 above).

It is anticipated that the above-described permitting work will be performed by an engineering consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment and approval of applications.

Deliverables: Applications for DSOD approval of plans and specifications for spillway gate; application to Marin County for building permit

[12] Since it is anticipated that the approach to environmental review will be a combined CEQA/NEPA document covering the whole Phoenix Lake IRWM Retrofit, Task 6, Environmental Documentation is the same for all five component projects of the Retrofit. The cost for Task 6 has been split according to each projects pro-rata construction cost, as reflected in Attachment 4, Budget.

2.2.8 Task 8: Construction Contracting

Same as Task 8 in Flood Damage Reduction Project (see section 2.1.8 above).

Deliverables: Bid advertisement; written answers to questions during bidding; addendums to contract, if/as needed; meeting notes from pre-bid meeting with contractors; documented evaluation of bids and recommendation for award.

2.2.9 Task 9: Construction

As indicated above in section 2.2.5, it is anticipated that two separate design packages and contracts will be advertised and awarded to two separate contractors for construction of the spillway gate and transfer piping. Construction is divided into three categories: mobilization and site preparation; project construction; and performance testing and demobilization.

2.2.9.1 Mobilization and Site Preparation

This category of work includes several items as described in the table below.

Mobilization and Site Preparation Work	
Staging area	Establish the on-site work staging area and support facilities (e.g., electric power)
Mobilization	Mobilize equipment to the site
Wildlife protection	Set up exclusionary fencing as required by the ECW

2.2.9.2 Project Construction

This category of work includes several items as described in the table below.

Project Construction Work	
Mechanical	Furnish and install spillway gate
Equipment House	Construct housing for spillway gate inflation blower and controls
Electrical (spillway gate)	Install power lines; hook-up spillway gate controls to power supply sources

2.2.9.3 Performance Testing and Demobilization

This category of work includes several items as tabulated below relating to the construction contract.

Performance Testing and Demobilization Work (Construction Contracts)	
Performance testing	Test operations of spillway gate and electrical systems, including spillway gate control and monitoring components
Performance testing	Test operations of the transfer piping
Demobilization	Demobilize equipment and remove support facilities and temporary hookups from the site
Site restoration	Clean-up site as needed

2.2.9.4 Monitoring System Work

No monitoring system work is anticipated.

2.2.10 Task 10: Environmental Compliance, Mitigation, Enhancement

Since the Water Supply Project footprint will be limited to the existing concrete spillway and upland staging and equipment house areas, no environmental compliance, mitigation, or enhancement is anticipated.

2.2.11 Task 11: Construction Administration

Same as Task 11 in Flood Damage Reduction Project (see section 2.1.11 above).

Deliverables: Meeting notes on pre-construction meeting; field-inspection reports; documented materials certifications and earthwork testing results; review/approved shop drawings, if/as needed; change orders, if/as needed; documented review and recommendations for progress and final payments to contractors.

2.3 Water Quality Project Tasks

The Water Quality Project has only two elements; epilimnetic circulation device and hypolimnetic circulation device. Although the descriptions of some of the tasks that follow are similar to the Flood Damage Reduction Project, the level of effort to complete the tasks as well as the cost, as reflected in Attachment 4, Budget, will be substantially less.

As indicated in section 2.3.5 below, FZ9 anticipates awarding a single, separate contract to an equipment vendor to furnish and install the two circulation devices in the lake.

2.3.1 Task 1: Administration

This task consists of administration of all Water Quality Project-related activities that will be performed by FZ9, FZ9 contractors, and FZ9's partner agency, MMWD. Activities will primarily include, but will not be limited to, planning and design work and

construction and testing work. FZ9 will be the lead agency under CEQA and will be the contracting agency on all work performed by contractors. MMWD, as owner of the Phoenix Lake property and existing facilities, will participate in all activities in a "review-and-comment" and "inspect-and-approve" capacity.

Administration will cover work performed by FZ9 and MMWD that is incidental but directly related to the above-described Project-related activities. Administration will also involve Grant Agreement-related administrative work.

Deliverables: Submission of invoices and other deliverables as required

2.3.2 Task 2: Labor Compliance Program

Same as Task 2 in Flood Damage Reduction Project (see section 2.1.2 above).

Deliverable: Submission of a written Labor Compliance Program

2.3.3 Task 3: Reporting

Same as Task 3 in Flood Damage Reduction Project (see section 2.1.3 above).[13]

Deliverable: Submission of quarterly, annual, and final reports as specified in the Grant Agreement.

2.3.4 Task 4: Assessment and Evaluation

Completed work on the Water Quality Project is summarized in Section 3.3. The completed work includes a Project Assessment and Evaluation Memorandum and Concept (30%) Design Memorandum. The Concept (30%) Design Memorandum has adequately verified the engineering feasibility and viability of the two circulation devices; therefore, no further engineering assessment and evaluation work is needed. However, further assessment and evaluation of baseline (existing, or pre-construction) water quality conditions in the lake is needed.

Further assessment and evaluation of existing water quality conditions will include pre-construction water quality monitoring summarized in the table below.

It is anticipated that this work will be performed by a hydrographer-consultant contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment services.

Deliverables: Report on Baseline Water Quality Conditions in Phoenix Lake

[13] The cost for reporting has been split across all five component projects comprising the Retrofit according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

Monitoring Plan for Baseline (Existing) Conditions

	Description
What	• Water quality (Secchi depth and vertical profiles of Chlorophyll-*a*, dissolved oxygen, and iron and manganese) • Water temperature (vertical profiles of water temperature)
Why	• Provide data to establish baseline conditions for evaluating project performance
When	• Monthly sampling of water quality in the months from April through October: o *Pre-construction* • Continuous monitoring of water temperature in the months from April through October: o *Pre-construction*
Where	• Near the dam and near the proposed circulation devices
Who	• FZ9 contractor

2.3.5 Task 5: Final Design

For purposes of this grant application and based on information in Section 3.3, the Water Quality Project is currently at the Concept (30%) design stage. Further work will be needed to complete the installations of the circulation devices, including final determination of the depth settings of the devices and design of the tethering systems. The contract to furnish and install the devices will require the contractor to review the Baseline Water Quality Report for the lake to determine the depth of settings and provide shop drawings showing the installations of the circulation devices.

Final Design work for the Water Quality Project will be limited to preparation of the specification package and contract that will be advertised for award for furnishing and installing the two devices. It is anticipated that a single specification package and contract will be advertised and awarded to a single equipment vendor-contractor.

It is anticipated that preparation of the specification package and contract will be performed by an engineering consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment and approval of all specifications.

2.3.6 Task 6: Environmental Documentation

Same as Task 6 in Flood Damage Reduction Project (see section 2.1.6 above).

Deliverables: Approved and adopted combined CEQA/NEPA documentation[14]

[14] Since it is anticipated that the approach to environmental review will be a combined CEQA/NEPA document covering the whole Phoenix Lake IRWM Retrofit, Task 6, Environmental Documentation is the

2.3.7 Task 7: Permitting

It is not anticipated that the Water Quality Project will be subject to regulatory permitting authority. Therefore, no work is anticipated under this task.

2.3.8 Task 8: Construction Contracting

Same as Task 8 in Flood Damage Reduction Project (see section 2.1.8 above).

Deliverables: Bid advertisement; written answers to questions during bidding; addendums to contract, if/as needed; meeting notes from pre-bid meeting with contractors; documented evaluation of bids and recommendation for award.

2.3.9 Task 9: Construction

As indicated above in section 2.3.5, it is anticipated that a single specification package and contract to furnish and install the two circulation devices will be advertised and awarded for construction. Construction is divided into two categories: project construction and performance testing.

2.3.9.1 Mobilization and Site Preparation

There is no work planned for this category.

2.3.9.2 Project Construction

This category of work includes two items as described in the table below.

Project Construction Work	
Mechanical	Furnish and install two circulation devices in the lake
Tethering System	Furnish and install tethering systems for two circulation devices

2.3.9.3 Performance Testing and Demobilization

This category of work includes one item as tabulated below relating to the construction contract.

Performance Testing and Demobilization Work (Construction Contract)	
Performance testing	Test operation of the two circulation devices

same for all five component projects of the Retrofit. The cost for Task 6 has been split according to each projects pro-rata construction cost, as reflected in Attachment 4, Budget.

2.3.9.4 Monitoring System Work

No monitoring system work is anticipated.

2.3.10 Task 10: Environmental Compliance, Mitigation, Enhancement

No environmental compliance, mitigation, or enhancement is anticipated for this project.

2.3.11 Task 11: Construction Administration

Same as Task 11 in Flood Damage Reduction Project (see section 2.1.11 above).

Deliverables: Meeting notes on pre-construction meeting; field-inspection reports; review/approved shop drawings, if/as needed; change orders, if/as needed; documented review and recommendations for progress and final payments to vendor-contractor.

2.4 Ecosystem Restoration Project Tasks

The Ecosystem Restoration Project has only one element, low-level drain pipe intake low-flow control gate. Although the descriptions of some of the tasks that follow are similar to the Flood Damage Reduction Project, the level of effort to complete the tasks as well as the cost, as reflected in Attachment 4, Budget, will be substantially less.

As indicated in section 2.4.5 below, FZ9 anticipates incorporating the low-flow control gate in the Final (100%) design package and contract that is award for Flood Damage Reduction Project. The reason is that the low-flow control gate will be physically attached to and made part of the new intake at el. 140 ft that will be constructed as part of the Flood Damage Reduction Project. It is logical to have the low-flow control gate installed at the same time and by the same contractor responsible for the Flood Damage Reduction Project work. Nonetheless, the activities associated with installation of the low-flow control gate are described in this section and the associated costs are allocated to the Ecosystem Restoration Project, as indicated in Attachment 4, Budget.

2.4.1 Task 1: Administration

Same as Task 1 in the Water Quality Project (see section 2.3.1 above).

Deliverables: Submission of invoices and other deliverables as required

2.4.2 Task 2: Labor Compliance Program

Same as Task 2 in Flood Damage Reduction Project (see section 2.1.2 above).

Deliverable: Submission of a written Labor Compliance Program

2.4.3 Task 3: Reporting

Same as Task 3 in Flood Damage Reduction Project (see section 2.1.3 above).[15]

Deliverable: Submission of quarterly, annual, and final reports as specified in the Grant Agreement.

2.4.4 Task 4: Assessment and Evaluation

Completed work on the Ecosystem Restoration Project is summarized in Section 3.4. The completed work includes a Project Assessment and Evaluation Memorandum and Concept (30%) Design Memorandum. The Concept (30%) Design Memorandum has adequately verified the engineering feasibility and viability of the low-flow control gate; therefore, no further engineering assessment and evaluation work is needed. However, further assessment and evaluation is needed of baseline (existing, or pre-construction) water quality conditions below Phoenix Lake in Ross Creek and Corte Madera Creek.

Further assessment and evaluation of existing conditions will include pre-construction monitoring summarized in the table below.

It is anticipated that this work will be performed by a hydrographer-consultant contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment services.

Deliverables: Report on Baseline Water Quality Conditions below Phoenix Lake in Ross Creek and Corte Madera Creek

[15] The cost for reporting has been split across all five component projects comprising the Retrofit according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

Monitoring Plan for Baseline (Existing) Conditions

	Description
What	• Water temperature • Water quality (dissolved oxygen) • Hydrology (stream flow)
Why	• Provide data to establish baseline conditions for evaluation of project performance
When	• Continuous monitoring of water temperature for the period of April through October: o *Pre-construction* • Monthly sampling of dissolved oxygen in the months of April through October: o *Pre-construction* • Continuous stream flow for the period of April through October: o *Pre-construction*
Where	• Four water temperature locations along Ross Creek and two water temperature locations in Corte Madera Creek with one above the Ross Creek confluence and another below the confluence • Two dissolved oxygen locations in Ross Creek; one immediately below Phoenix lake dam and another 1,500 ft below the dam • Two stream flow locations in Ross Creek to measure accretion flow; one immediately below Phoenix Lake dam and another at the mouth of Ross Creek • The same two stream flow locations as the Flood Damage Reduction Project to measure lake inflows in the dry season
Who	• FZ9 contractor

2.4.5 Task 5: Final Design

For purposes of this grant application and based on information in Section 3.4, the Ecosystem Restoration Project is currently at the Concept (30%) design stage. Further work will be needed to complete Final Design of the low-flow control gate installation. This further work will require civil, mechanical, and electrical design.

It is anticipated that the design of low-flow control gate will be incorporated into the overall design of the low-level drain pipe intake modifications, which are part of the Flood Damage Reduction Project. As such, the low-flow control gate will be included in the Final (100%) design package and contract that is awarded for the Flood Damage Reduction Project. Nonetheless, the design of the low-flow control gate is described in this section and the associated costs are allocated to the Ecosystem Restoration Projects, as indicated in Attachment 4, Budget.

Design plans for the low-flow control gate will be included in the design submittals for the Flood Damage Reduction Project at three stages, based on the design stage definitions given in the PSP, p. 33, for review, comment, and approval by FZ9 and MMWD: 60% design, 90% (Pre-final) design, and 100% (Final) design.

It is anticipated that the design work will be performed by an engineering consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment and approval of all designs.

Deliverables: 60% design, 90% (Pre-final) design, and 100% (Final) design package

2.4.6 Task 6: Environmental Documentation

Same as Task 6 in Flood Damage Reduction Project (see section 2.1.6 above).

Deliverables: Approved and adopted combined CEQA/NEPA documentation[16]

2.4.7 Task 7: Permitting

The Ecosystem Restoration Project will be subject to the regulatory permitting authority of state and local agencies. The table below identifies the permits that are expected to be required.

It is anticipated that environmental regulatory permitting for the Ecosystem Restoration Project will be integrated with the permitting for the Flood Damage Reduction Project. It is anticipated that an instream flow study of aquatic habitat in Ross Creek and lower Corte Madera Creek will be needed to support preparation of the Biological Assessment and Section 7 Consultation process. This study will be used to support both the environmental review and permitting processes for the two projects.

It is anticipated that DSOD permitting will proceed concurrently with Final (100%) Design (see section 2.4.5 above).

It is anticipated that work in connection with the applications to DSOD and Marin County will be performed by an engineering consultant-contractor and the remaining environmental regulatory permitting work will be performed by environmental consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment on all applications and approval of applications to DSOD and Marin County.

[16] Since it is anticipated that the approach to environmental review will be a combined CEQA/NEPA document covering the whole Phoenix Lake IRWM Retrofit, Task 6, Environmental Documentation is the same for all five component projects of the Retrofit. The cost for Task 6 has been split according to each projects pro-rata construction cost, as reflected in Attachment 4, Budget.

Approvals and Permits Required for the Ecosystem Restoration Project

Agency	Trigger	Approval	Submittal
National Marine Fisheries Service (NOAA Fisheries) US Fish and Wildlife Service	Effects on federally listed threatened or endangered species	Biological Opinion through a Section 7 Consultation with USACE	Biological Assessment
San Francisco Bay Regional Water Quality Control Board (RWQCB)	Section 404 Permit through USACE	Section 401 Water Quality Certification through Section 404 Permit with USACE	Application
California Department of Fish and Game (DFG)	Effects on federally listed threatened or endangered species	Lake and Streambed Alteration Agreement	CEQA document
Department of Water Resources/Division of Safety of Dams (DSOD)	Modification of dam, spillway, or low-level drain pipe	Approval of Plans and Specifications for modification	Application
Marin County	Construction	Building Permit	Application; CEQA document

Deliverables: Biological Assessment; Permit applications for Regional Board 401 Certification, and Fish and Game Stream/Lake Alteration, including requisite supporting instream flow study; application for DSOD approval of plans and specifications; application to Marin County for building permit

2.4.8 Task 8: Construction Contracting

Same as Task 8 in Flood Damage Reduction Project (see section 2.1.8 above).

Deliverables: Bid advertisement; written answers to questions during bidding; addendums to contract, if/as needed; meeting notes from pre-bid meeting with contractors; documented evaluation of bids and recommendation for award.

2.4.9 Task 9: Construction

As indicated above in section 2.4.5, FZ9 anticipates incorporating the design of low-flow control gate into the overall design of the low-level drain pipe intake modifications, which are part of the Flood Damage Reduction Project. As such, the low-flow control gate will be included in the Final (100%) design package and contract that is awarded for the Flood Damage Reduction Project. Nonetheless, the construction of the low-flow control gate is described in this section and the associated costs are allocated to the Ecosystem Restoration Projects, as indicated in Attachment 4, Budget.

Construction is divided into two categories: project construction and performance testing.

2.4.9.1 Mobilization and Site Preparation

There is no work in this category

2.4.9.2 Project Construction

This category of work includes several items as described in the table below.

Project Construction Work	
Mechanical	Furnish and install low-flow slide gate
Electrical	Furnish and hook-up motor-control for low-flow slide gate to power supply sources
Monitoring	Furnish and install stream flow gages at lake tributaries (2) and lake level gage (1); water level senor at low-level outlet discharge vault (1); streamflow gage at mouth of Ross Creek(1); install temperature sensors along Ross Creek (4) and Corte Madera Creek (2)

2.4.9.3 Performance Testing and Demobilization

This category of work includes several items as tabulated below relating to the construction contract.

Performance Testing and Demobilization Work (Construction Contract)	
Performance testing	Test operation of low-flow control gate and monitoring components

2.4.9.4 Monitoring System Work

This category of work includes several items as described in the table below relating to the monitoring system.

Post-Construction Monitoring System Work	
Monitoring	Develop creek water level vs. discharge rating curves for streamflow gages (3); develop water level vs. discharge rating curve at low-level outlet discharge vault (1)

2.4.10 Task 10: Environmental Compliance, Mitigation, Enhancement

No environmental compliance, mitigation, or enhancement associated with the low-flow control gate is anticipated.

2.4.11 Task 11: Construction Administration

Same as Task 11 in Flood Damage Reduction Project (see section 2.1.11 above).

Deliverables: Meeting notes on pre-construction meeting; field-inspection reports; documented materials certifications and earthwork testing results; review/approved shop drawings, if/as needed; change orders, if/as needed; documented review and recommendations for progress and final payments to contractors.

2.5 Recreation and Public Access Project Tasks

2.5.1 Task 1: Administration

Same as Task 1 in the Water Quality Project (see section 2.3.1 above).

Deliverables: Submission of invoices and other deliverables as required

2.5.2 Task 2: Labor Compliance Program

Same as Task 2 in Flood Damage Reduction Project (see section 2.1.2 above).

Deliverable: Submission of a written Labor Compliance Program

2.5.3 Task 3: Reporting

Same as Flood Damage Reduction Project (see section 2.1.3 above).[17]

Deliverable: Submission of quarterly, annual, and final reports as specified in the Grant Agreement.

2.5.4 Task 4: Assessment and Evaluation

Completed work on the Recreation and Public Access Project is summarized in Section 3.5. The completed work includes a Project Assessment and Evaluation Memorandum, Concept (30%) Design Memorandum, and the following two prior watershed studies:

- Summary Report, Road and Trail Inventory and Assessment, Erosion Prevention Implementation Plan, Mt. Tamalpais Watershed, Marin Municipal Water District, Marin County, California, Pacific Watershed Associates. 2003

[17] The cost for reporting has been split across all five component projects comprising the Retrofit according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

- Mount Tamalpais Road and Trail Management Plan. Marin Municipal Water District. 2005. http://marinwater.org/controller?action=menuclick&id=249. Last accessed 04/08/2011.

The completed work has adequately assessed and evaluated the Recreation and Public Access Project and verified its feasibility and viability; therefore, no further assessment and evaluation work is needed.

2.5.5 Task 5: Final Design

For purposes of this grant application and based on information in Section 3.5, the Recreation and Public Access Project is currently at the Concept (30%) design stage. Further work will be needed to complete Final Design. This further work is divided into two groups based on the four elements of the Project as described in more detail in Section 3.5: (1) Bill Williams Creek Culvert Replacement; Phoenix Lake Watershed Trail Improvements; and Road-Related Sediment Reduction Projects, which will require civil, geotechnical, and erosion-control design, and (2) Visitor Use Facility Upgrades, which will require civil design.

Design plans for these two engineering groups will be prepared at three stages, based on the design stage definitions given in the PSP, p. 33, for review, comment, and approval by FZ9 and MMWD: 60% design, 90% (Pre-final) design, and 100% (Final) design. The 100% (Final) design will include the design package and contract that will be advertised for award for construction. It is anticipated that two separate design packages and contracts, corresponding to the two groups of elements described above, will be advertised and awarded for construction to two contractors. FZ9 anticipates that the design work for the road and trail elements will be performed by an engineering/erosion control consultant-contractor and the design work for the visitor use element will be performed by an engineering consultant-contractor with review and oversight by FZ9 staff/ MMWD staff will also provide review-and-comment and approval of all designs.

Deliverables: 60% design, 90% (Pre-final) design, and 100% (Final) design package, two of each.

2.5.6 Task 6: Environmental Documentation

Same as Task 6 in Flood Damage Reduction Project (see section 2.1.6 above).

Deliverables: Approved and adopted combined CEQA/NEPA documentation

2.5.7 Task 7: Permitting

The Recreation and Public Access Project will be subject to the regulatory permitting authority of several federal and state agencies. The table below identifies the permits that are expected to be required.

Approvals and Permits Required for the Phoenix Lake IRWM Retrofit

Agency	Trigger	Approval	Submittal
US Army Corps of Engineers (USACE)	Discharge of fill within ordinary high water mark in creek, lake, or adjacent wetlands	Section 404/10 Permit (Nationwide Permit or an Individual Permit)	Application
National Marine Fisheries Service (NOAA Fisheries) US Fish and Wildlife Service	Effects on federally listed threatened or endangered species	Biological Opinion(s) through a Section 7 Consultation with USACE	Biological Assessment(s)
San Francisco Bay Regional Water Quality Control Board (RWQCB)	Section 404 Permit through USACE	Section 401 Water Quality Certification through Section 404 Permit with USACE	Application
California Department of Fish and Game (DFG)	Discharge of fill within waters of the State Effects on federally listed threatened or endangered species	Lake and Streambed Alteration Agreement	CEQA document
State Historic Preservation Officer (SHPO)		SHPO review and concurrence of inventory/evaluation report	CEQA/NEPA document
Marin County	Construction, earthwork, work in creeks	Grading Permit, Building Permit, Watercourse Permit	Application(s); CEQA document

It is anticipated that environmental regulatory permitting will proceed concurrently with environmental review. This approach offers flexibility and expands opportunities for mitigating impacts associated with individual Projects and Project elements. Conceivably, impacts in one location within the geographic footprint of the Retrofit can be mitigated elsewhere in the geographic footprint. It can also streamline and reduce the overall costs (e.g., special studies) of the environmental review and permitting processes.

It is anticipated that special technical studies will be required to support the applications identified in the table above, including delineations of waters of the U.S. and State; vegetation surveys at affected areas; and biological surveys for special-status species. These studies will be used to support both the environmental review and permitting processes.

FZ9 anticipates that work in connection with the application to Marin County will be performed by an engineering consultant-contractor, and the remaining work will be performed by environmental consultant-contractor with review and oversight by FZ9 staff. MMWD staff will also provide review-and-comment and approval of all work.

Deliverables: Permit applications for Army Corps 404, Regional Board 401 Certification, and Fish and Game Stream/Lake Alteration, including requisite supporting technical studies; applications to Marin County for grading/building permit and watercourse permit

2.5.8 Task 8: Construction Contracting

Same as Task 8 in Flood Damage Reduction Project (see section 2.1.8 above).

Deliverables: Bid advertisement; written answers to questions during bidding; addendums to contract, if/as needed; meeting notes from pre-bid meeting with contractors; documented evaluation of bids and recommendation for award.

2.5.9 Task 9: Construction

As indicated above in section 2.5.5, it is anticipated that two separate design packages and contracts, corresponding to the two groups of elements of the Recreation and Public Access Project ((1) Bill Williams Creek Culvert Replacement; Phoenix Lake Watershed Trail Improvements; and Road-Related Sediment Reduction Projects, and (2) Visitor Use Facility Upgrades), will be advertised and awarded for construction. Construction is divided into three categories: mobilization and site preparation; project construction; and demobilization.

2.5.9.1 Mobilization and Site Preparation

This category of work includes several items as described in the table below.

Mobilization and Site Preparation Work	
Staging area	Establish the on-site work staging area and support facilities (e.g., water tank, electric power)
Stockpile area	Establish stockpile area for temporary storage of excavated material, building materials
Mobilization	Mobilize equipment to the site
Wildlife protection	Set up exclusionary fencing as required by the ECW (see section 2.5.10 below)

2.5.9.2 Project Construction

This category of work includes several items as described in the table below.

Project Construction Work	
Trails	Construct trail improvements
Road Improvements	Construct road improvements
Culverts	Furnish and install arch and pipe culverts
Erosion protection	Install erosion protection
Facilities (Visitor Use Facilities contract only)	Furnish and install kiosks, benches, and restrooms

2.5.9.3 Performance Testing and Demobilization

This category of work includes several items as tabulated below relating to the construction contract.

Performance Testing and Demobilization Work (Construction Contract)	
Demobilization	Demobilize equipment and remove support facilities and temporary hookups from the site
Site restoration	Finish grade disturbed areas; hydroseed and install erosion control; plant other vegetation in disturbed areas as needed

2.5.9.4 Monitoring System Work

No work is anticipated in this category

2.5.10 Task 10: Environmental Compliance, Mitigation, Enhancement

It is anticipated that an outcome of environmental review under CEQA and NEPA and regulatory permitting will be various environmental compliance, mitigation, and enhancement measures that will be required during and post-construction. Since the environmental review has not been initiated, it is impossible at this time to predict exactly what measures will be required but, for purposes of this grant application, the following measures are anticipated.

Environmental Compliance, Mitigation and Enhancement	
Environmental Compliance Workplan	Preparation of an written Environmental Compliance Workplan (ECW)[18] which will identify special-status species and other sensitive biological resources occurring in the Project area; describe pre-construction biological surveys and avoidance measures (e.g., exclusionary fencing); describe construction avoidance measures (e.g., construction season, exclusionary fencing) and monitoring; describe post-construction restoration and mitigation measures; and describe post-construction mitigation monitoring
Pre-construction biological surveys	Perform pre-construction biological surveys as required in the ECW
Monitoring (initial verification monitoring only – not long term)	Perform initial monitoring to verify and document initial installation of restoration and mitigation as required in the ECW

Deliverables: Environmental Compliance Workplan Report; pre-construction biological survey report; construction monitoring report; monitoring (initial verification) report.

[18] It is anticipated that the ECW will cover the whole Phoenix Lake IRWM Retrofit, as described in section 2.1.10. The cost for the ECW has been split according to each project's pro-rata construction cost, as reflected in Attachment 4, Budget.

2.5.11 Task 11: Construction Administration

Same as Task 11 in Flood Damage Reduction Project (see section 2.1.11 above).

Deliverables: Meeting notes on pre-construction meeting; field-inspection reports; field monitoring reports; documented materials certifications and earthwork testing results; review/approved shop drawings, if/as needed; change orders, if/as needed; documented review and recommendations for progress and final payments to contractors.

3.0 Supporting Documents

3.1 Flood Damage Reduction Project

3.1.1 Project Assessment and Evaluation Memorandum

3.1.2 Project Concept (30%) Design and Cost Memorandum

- Dam Seismic Upgrade
- Dam Face Erosion Protection and Raising
- Low-Level Drain Pipeline Intake
- Lake Bottom Excavation

Appendices

Appendix 1: HEC-HMS Hydrologic Modeling Analysis of Phoenix Lake in Peak Flow Reduction

Appendix 2: Preliminary Coordinated Operations Plan for Phoenix Lake

Appendix 3: Phoenix Lake Spillway Hydraulic Evaluation

Appendix 4: Geotechnical Evaluations (2) of Phoenix Lake Dam

3.2 Water Supply Project

3.2.1 Project Assessment and Evaluation Memorandum

3.2.2 Project Concept (30%) Design and Cost Memorandum

- Spillway Gate
- Phoenix Lake to Bon Tempe Lake Transfer Piping

Appendices

Appendix 5: Long-Term Hydrologic Analysis of Re-operating Phoenix Lake for Flood Detention and Water Supply

3.3 Water Quality Project

3.3.1 Project Assessment and Evaluation Memorandum

3.3.2 Project Concept (30%) Design and Cost Memorandum

- Epilimnetic and Hypolimnetic Circulation Device

Appendices

Appendix 6: Phoenix Lake Water Quality Issues and Solutions

Appendix 7: SolarBee's Proposal for Phoenix Lake

3.4 Ecosystem Restoration Project

3.4.1 Project Assessment and Evaluation Memorandum

3.4.2 Project Concept (30%) Design Memorandum

- Low-level Drain Pipeline Intake Control Valve

Appendices

Appendix 8: Ross Creek Water Temperature Issues and Solutions

Appendix 9: Ross Creek Water Temperature Monitoring Report (Friends of Corte Madera Creek Watershed, 2008)

3.5 Recreation and Public Access Project

3.5.1 Project Assessment and Evaluation Memorandum

3.5.2 Project Concept (30%) Design Memorandum

- Public Use Facility, Road, and Trail Improvements

3.1 Flood Damage Reduction Project

3.1.1 Project Assessment and Evaluation Memorandum

Project Name:
Flood Damage Reduction Project

Project Element(s):
Dam Seismic Upgrade; Dam Face Erosion Protection and Dam Crest Raising; Low-Level Drain Pipeline Intake; Lake Bottom Excavation; Monitoring System

Project Purpose and Need:
There is a need to reduce the frequency and severity of flooding in Ross Valley for the protection of property and public safety. The current capacity of Corte Madera Creek (below Phoenix Lake and the Ross Creek confluence) is about 3,600 cfs, which corresponds to about the 17 percent-annual-chance flood (i.e., 6-year flood).

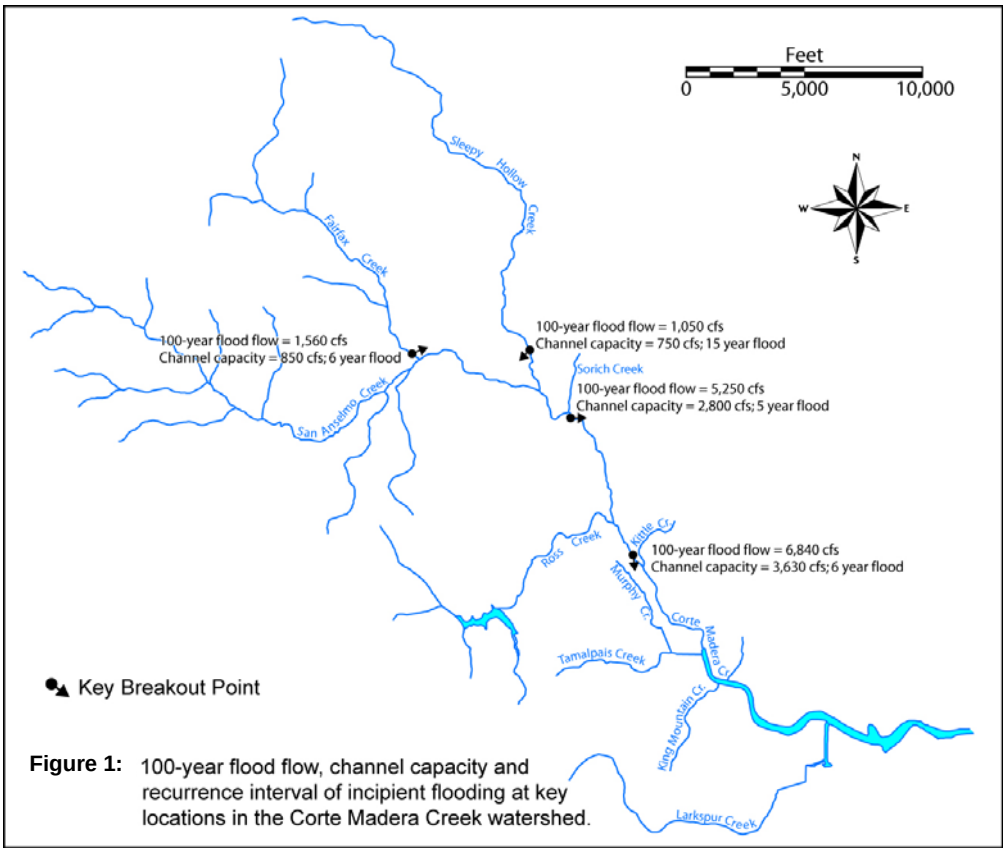


Figure 1: 100-year flood flow, channel capacity and recurrence interval of incipient flooding at key locations in the Corte Madera Creek watershed.

Several times in recent history the Ross Valley has been flooded by overflow from Corte Madera Creek with varying degrees of severity. Prior to establishment in 1951 of the USGS streamflow gaging station on Corte Madera Creek in Ross, flooding was reported in calendar years 1914, 1925, 1937, and 1942. Since the Corte Madera Creek streamflow gage in Ross has been in operation, flood flows have been recorded in calendar years

1951, 1955, 1958, 1967, 1969, 1970, 1982, 1983, 1986, 1994 , and 2005. Of these, the two most severe floods occurred in 1982 and 2005, with peak discharges of approximately 7,200 cfs and 6,800 cfs; the percent-annual-chances of which were approximately 0.6 percent and 1 percent, respectively. Historical flooding has caused extensive property damage and economic hardship to residents, businesses, and local governments, and has threatened the lives of those living in the floodplain, with at least one recorded death occurring in the 1955 flood and at least one rescue by Urban Search and Rescue personnel during the 2005 flood.

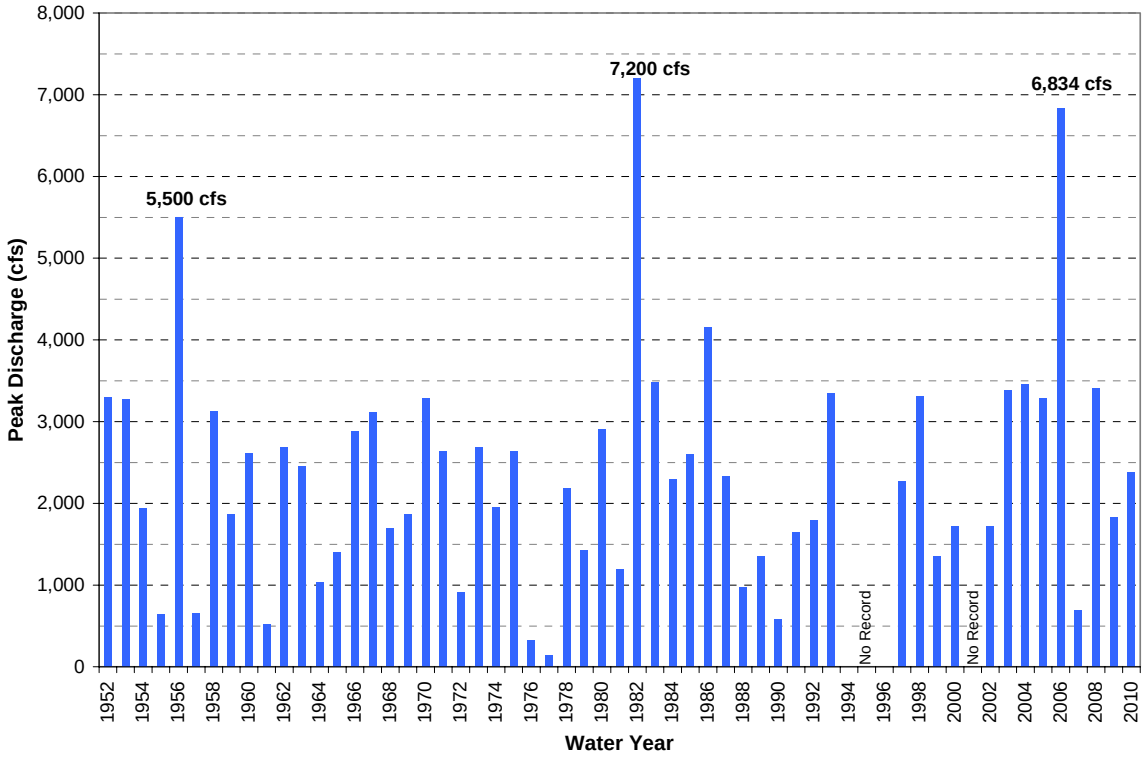


Figure 2 Historical Annual Peak Discharges Recorded at the Flood Zone 9 Streamflow Gage in Ross, Corte Madera Creek

In accordance with its Congressional authorization, the Army Corps of Engineers has plans to increase creek conveyance capacity below the Ross Creek confluence to about 5,400 cfs, or about the 4 percent-annual-chance flood (i.e., 25-year flood). This is considered a major improvement but the Ross Valley community desires a further reduction in the flood hazard. In order to increase the effectiveness of the Corps' design and achieve a more appropriate 1 percent-annual-chance level of flood protection (i.e., 100-year flood protection), the 100-year flood discharge at the Ross Creek confluence needs to be reduced by 1,400 cfs, from 6,800 cfs down to 5,400 cfs. This reduction is achievable through detention basins, and retrofit of Phoenix Lake is key since this basin could reduce the 100-year flood discharge by about 650 cfs, or nearly half of the total amount needed. Without the Phoenix Lake IRWM Retrofit, public safety and property downstream of the Ross Creek confluence in the communities of Ross, Kentfield, Larkspur and Greenbrae would remain at-risk of flooding.

Summary of Completed Work, Existing Data and Studies:

	Description	Reference	Purpose
Completed Work	Concept (30%) designs of all facility elements of the Flood Damage Reduction Project	Project Concept (30%) Design Memorandum	• Investigate the engineering feasibility of the flood damage reduction project. • Design project layout; size project facilities/components • Provide design information for estimating construction costs.
Existing Data	1) Hydrologic Data	Stetson in-house database; Marin County website; USGS database; DSOD Inspection Report	• Observed rainfall runoff data were used to develop and calibrate the HEC-HMS hydrologic model for the entire Corte Madera Creek watershed. • Observed annual peak discharge data the streamflow gage in Ross were used to develop flood frequency curve. • The DSOD-developed 30,000-year flood hydrograph for Phoenix Lake were used to evaluate the spillway hydraulic capacity. • Surveyed bathymetric data of Phoenix Lake were used to develop an elevation-storage curve for use in HEC-HMS hydrologic routing.
	2) Hydraulic Data	Stetson in-house database; Marin County website	• Observed stage-discharge data were used to update the rating curve of the Ross streamflow gage in Corte Madera Creek. • Surveyed channel geometry and bridge/culvert geometry data were used to develop the in-channel MIKE 11 hydraulic model. • Surveyed topographic data of the Ross Valley floodplain were used to develop the floodplain MIKE 21 hydraulic model. • Surveyed high water marks data for the 1982 and 2005 floods were used to calibrate the MIKE FLOOD hydraulic model.
	3) Geotechnical Data	Miller Pacific database	• Historical earthquakes data were used to demonstrate that the project is located within the seismic active region. • Historical subsurface exploration data were used to understand the soil type and geotechnical conditions of the earthen dam.
Existing Studies	1) HEC-HMS Hydrologic Modeling Analysis of Phoenix Lake in Peak Flow Reduction	Appendix 1	• To identify the best physical and operational modification alternatives for flood detention at Phoenix Lake. • To evaluate the alternatives' effectiveness at reducing peak flows.
	2) Preliminary Coordinated Operations Plan for Phoenix Lake	Appendix 2	• To provide an operations plan for Phoenix Lake to achieve flood detention during the wet season, water supply during the dry season, and other beneficial uses.
	3) Phoenix Lake Spillway Hydraulic Evaluation	Appendix 3	• To analyze the peak water surface in the lake during the 30,000-year design flood through reservoir routing to determine whether there is an adequate residual freeboard. • To compute the peak water surface profile along the spillway and chute during the 30,000-year design flood to determine whether the spillway has an adequate capacity.
	4) Geotechnical Evaluations (2) of Phoenix Lake Dam and Reservoir	Appendix 4	• To evaluate the seismic conditions of the dam, demonstrate the need for seismic retrofit, and provide engineering methods for seismic retrofit. • To investigate the geotechnical feasibility of operating the lake at a higher water level (el. 180 ft). • To evaluate slope stability and identify the need for dam face erosion protection under rapid drawdown.

Finding(s):

1) HEC-HMS hydrologic modeling analysis of Phoenix Lake peak flow reduction (see Appendix 1) indicated that drawing the lake level down ahead of a forecasted storm to el.140 ft (NGVD29), in concert with installing a 6-foot high inflatable/deflatable rubber dam across the spillway, would provide sufficient storage space in the lake to detain floodwaters and effectively reduce 100-year peak flows (by about 650 cfs from 6,840 cfs to 6,190 cfs at the Ross streamflow gage) along Ross Creek and Corte Madera Creek, including key breakout points in Ross.
2) Analysis of routing winter baseflows through the Phoenix Dam with the existing 30-inch low-level outlet open (see Appendix 1, Section 4.0) indicated that it would take about 23 hours for the 30" low-level outlet to drain the lake from the spillway crest level (174 ft) down to elevation 160 ft, and an additional 24 hours from elevation 160 ft down to elevation 140 ft. In order to achieve rapid drain-down for evacuating the lake under winter baseflow conditions within 24 hours of impending heavy storm, a two-step drawdown procedure was developed (see Appendix 2). The first step is initial drawdown of the lake (from elevation 174 ft down to elevation 160 ft) and the second step is final drawdown of the lake (from elevation 160 ft down to elevation 140 ft). Accordingly, the existing low-level outlet structure (a 30" pipe with an intake elevation at 130 ft NGVD29) will be modified to have two level gates, one at elevation 140 ft and the other at elevation 160 ft.
3) The Phoenix Lake spillway hydraulic evaluation (see Appendix 3) indicated that the spillway has adequate capacity to pass the routed 30,000-year peak discharge. However, in order for the Phoenix Lake Flood Damage Reduction Project to meet the DSOD minimum requirement of 1.5 ft residual freeboard, the existing Phoenix Lake dam (el. 189 ft) needs to be raised by at least 1.1 ft.
4) The geotechnical evaluation (see Appendix 4) indicated that:
    - The proposed use of Phoenix Lake dam and reservoir as a flood detention basin is feasible. However, localized, shallow instability is likely during rapid drawn. Erosion protection is needed for the identified areas where are potentially instable during rapid drawdown.
    - Deformation of the dam will likely occur during strong seismic shaking. Seismic retrofit of the dam may be needed.
    - Exploratory drilling and lab testing of the existing earthen embankment dam are needed to determine strength properties, verify the need for seismic retrofit, and, if verified, develop design parameters for the retrofit.

3.1.2 Project Concept (30%) Design Memorandum

Project Name:
Flood Damage Reduction Project

Project Element(s):
Dam Seismic Upgrade; Dam Face Erosion Protection and Dam Crest Raising; Low-Level Drain Pipeline Intake; Lake Bottom Excavation; Monitoring System

Design Objective:
The goal of the Flood Damage Reduction Project is to enable Phoenix Lake to function as a flood detention basin. The objective of flood detention operations is to attenuate flows produced in the upper Ross Creek watershed sufficiently to reduce the peak discharge to lower Ross Creek, and hence lower Corte Madera Creek, during the 1-percent-chance-annual flood by about 650 cfs[19]. In order to achieve this objective, Phoenix Lake needs to provide about 460 acre-feet of flood storage capacity[20] for floodwater attenuation. Accordingly, flood detention operations call for rapid drawdown of the lake level to elevation 140 ft ahead of a forecasted heavy storm event and storage of floodwaters up to elevation 180 ft.

Design Criteria and Other Design Considerations:
Meeting the design objective requires improvements and modifications to the dam, spillway, reservoir and inlet/outlet works. The earthen embankment dam needs structural strengthening to improve seismic stability at the higher water level, elevation 180 ft; the dam face needs to be stabilized to enable rapid drawdown by preventing sloughing of dam face (erosion protection) and enables storage to a higher water level (el. 180 ft; raising) for peak flow attenuation and flood reduction; the intake/outlet works of the low-level drain pipeline need modification to enable rapid lake drawdown in advance of a forecasted flood; and, the lake bottom needs to be excavated to provide an adequate refugia pool for fish and other aquatic wildlife and to prevent entrainment and discharge of sediment when the lake is drawn down to el. 140 ft.

Design Description:
The designed improvements include 1) constructing seismic retrofit of the dam; 2) stabilizing the dam embankment and raising the dam crest by at least 1.1 ft; 3) modifying the existing low-level outlet structure (a 30” pipe with an intake elevation at 130 ft NGVD29) to have two water level-control gates, one at elevation 140 ft and the other at elevation 160 ft; 4) creating about 20 acre-ft of additional (dead) storage below elevation 140 ft by excavating the lake bottom near the existing low-level intake; 5) installing emergency generators; and 6) installing monitoring, flood warning, and control systems. The improvement #2 also includes stabilization of two landslides that are evident along

[19] Phoenix Lake can also reduce peak flows for smaller floods. The amounts of peak flow reduction at the Ross streamflow gage for the 50-year, 25-year, 10-year, and 5-year floods are estimated to be approximately 600 cfs, 510 cfs, 370 cfs, and 270 cfs, respectively.

[20] Including the storage of about 410 acre-ft between elevations 140 ft and 180 ft and a surcharge storage of about 50 acre-ft).

the northern side of the lake. These landslides require stabilization to prevent deposition of large amounts of sediment into the lake during flood detention operations. Stabilization requires retaining wall and drilled pier and grade beam stabilization structures.

List of Design Drawing(s):

- Figure 1: Project Layout
- Figure 2: Plan View of the Low-Level Drain Pipe Intake
- Figure 3: Profile View of the Low-Level Drain Pipe Intake
- Figure 4: Cross Section of the New Inlet Structure
- Figure 5: Lake Bottom Excavation

Engineers Cost Estimate:

Total Construction Cost = 8,212,000

Flood Damage Reduction Project - Construction Cost Estimation

Item	Description	Quantity	Unit	Unit Price	Total Cost
General Requirements:					**$ 530,000**
01	Mobilization	1	LS	$ 200,000	$ 200,000
02	Access Road Improvements	1	LS	$ 100,000	$ 100,000
03	Clearing and Grubbing	1	LS	$ 30,000	$ 30,000
04	Temporary Construction Facilities:				
04.1	Dewatering / Coffer Dam / Pumping	1	LS	$ 100,000	$ 100,000
04.2	Wildlife Relocation	1	LS	$ 100,000	$ 100,000
Dam Seismic Upgrade:					**$ 2,731,000**
05	Seismic Retrofit of Dam	1	LS	$ 2,731,000	$ 2,731,000
Dam Face Erosion Protection and Crest Raising:					**$ 3,265,000**
06	Dam Face Erosion Protection and Crest Raising	1	LS	$ 2,550,000	$ 2,550,000
07	Landslide Stabilization Elsewhere	1	LS	$ 715,000	$ 715,000
Low-Level Drain Pipe Intake:					**$ 698,000**
08	Inlet/Outlet Works Modification:				
08.1	Earthworks	1,000	CY	$ 80	$ 80,000
08.2	Rip-Rap Slope Protection	600	Ton	$ 140	$ 84,000
08.3	Concrete (Gate Structures)	15	CY	$ 2,200	$ 33,000
08.4	Concrete (Slab)	40	CY	$ 1,000	$ 40,000
08.5	36" Steel Pipe	100	LF	$ 330	$ 33,000
08.6	6" Air Release Pipe	100	LF	$ 20	$ 2,000
08.7	Pipe Connection	1	LS	$ 5,000	$ 5,000
08.8	36" Sluice Gates	2	Each	$ 20,000	$ 40,000
08.9	Trash Racks	2	Each	$ 10,000	$ 20,000
08.10	Outlet Modification	1	LS	$ 32,000	$ 32,000
09	Concrete (Control Station)	5	CY	$ 1,800	$ 9,000
10	Hydraulic Control System	1	LS	$ 50,000	$ 50,000
11	Emergency Generators for the Gates Control System	1	LS	$ 250,000	$ 250,000
12	Revegetation	1	LS	$ 20,000	$ 20,000
Lake Bottom Excavation:					**$ 937,500**
13	Lake Bottom Excavation	31,250	CY	$ 30	$ 937,500
Monitoring System:					**$ 50,000**
14	Monitoring System	1	LS	$ 50,000	$ 50,000
				Total Construction	**$ 8,212,000**

3.2 Water Supply Project

3.2.1 Project Assessment and Evaluation Memorandum

Project Name:
Water Supply Project

Project Element(s):
Spillway Gate; Phoenix Lake to Bon Tempe Lake Water Transfer Piping

Project Purpose and Need:

There is a need to provide more reliability and flexibility to MMWD's water supply. The Water Supply Project will restore the spillway crest to its pre-1985 elevation 180 ft, thereby increasing the storage capacity of the lake by about 120 acre-ft. The added storage capacity could potentially increase the long-term average lake yield by up to 107 acre-ft per year and up to 50 acre-ft per year during shortage years for supply to the MMWD system.

Currently water from Phoenix Lake is pumped to the Bon Tempe Water Treatment Plant. In order for MMWD to more flexibly utilize the increased yield of Phoenix Lake water, it is necessary to install a new piping system from Phoenix Lake to Bon Tempe Lake to create completely separate potable and lake water transfer systems.

Summary of Completed Work, Existing Data and Studies:

	Description	Reference	Purpose
Completed Work	Concept (30%) designs of all facility elements of the Water Supply project	Project Concept (30%) Design Memorandum	• Investigate the engineering feasibility of the water supply project. • Design project layout; size project facilities/components. • Provide design information for estimating construction costs.
Existing Data	1) Water Demand and Supply Data and Historical Water Use Data of Phoenix Lake	MMWD website	• Water demand and supply data demonstrate that additional water supply is needed. • Historical water use data of Phoenix Lake demonstrate that the lake is an important water supply in the summer season of dry years, particularly during shortages.
	2) Lake Bathymetry Data	Stetson in-house database	• Surveyed bathymetric data of Phoenix Lake were used to analyze storage curve and volume reduction due to historical sedimentation.
Existing Studies	1) MMWD Desalination Project EIR; MMWD Urban Water Management Plan	MMWD website	• To demonstrate the need of additional water supply.
	2) Long-Term Hydrologic Analysis of Re-operating Phoenix Lake for Flood Detention and Water Supply	Appendix 5	• To analyze and verify whether natural inflow to the lake during the spring refilling period is sufficient to refill the lake for dry season water supply in case wet season drawdown for flood detention.

Finding(s):

1) Additional water supply is needed for MMWD to meet the water demand. For a variety of reasons, the current MMWD reliable water supply is close to the current water demand and there is little, if any, surplus supply.

2) The long-term hydrologic analysis of re-operating Phoenix Lake for flood detention and water supply (see Appendix 5) indicated that, in most years, inflow into Phoenix Lake during the spring would be sufficient to refill the lake from the wet season flood operations drawdown level, el. 160 ft, to the raised spillway crest, el. 180 ft. In very dry years, complete refill may not occur. However, under the Preliminary Coordinated Operations Plan for Phoenix Lake (see Appendix 2), the initial drawdown will not happen during very dry years when the water supply of Phoenix Lake is needed most.

3.2.2 Project Concept (30%) Design Memorandum

Project Name:
Water Supply Project

Project Element(s):
Spillway Gate; Phoenix Lake to Bon Tempe Lake Water Transfer Piping

Design Objective:
The objective of the Water Supply Project is to increase the yield of Phoenix Lake and thereby provide more reliability and flexibility to MMWD's water supply. The Water Supply Project will restore the spillway crest to its pre-1985 elevation 180 ft, thereby increasing the storage capacity of the lake by 120 acre-ft. The added storage capacity could potentially increase the long-term average lake yield by up to 107 acre-ft per year and up to 50 acre-ft per year during shortage years for supply to the MMWD system. Accordingly, water supply operations require operating the lake at el. 180 ft for extended periods, particularly during the dry season.

Design Criteria and Other Design Considerations:
Water supply operations require modification the spillway. The spillway crest needs to be raised from current elevation 174 ft to its pre-1985 elevation, 180 ft. In addition, a new piping system from Phoenix Lake to Bon Tempe Lake will be installed to create completely separate potable and lake water transfer systems to more flexibly utilize the increased yield of Phoenix Lake water (see the attached MMWD Memorandum dated March 17, 2011). Accordingly, the Water Supply Project has two elements that address these needs: (1) spillway gate; and (2) Phoenix Lake to Bon Tempe Lake transfer piping.

Design Description:
The spillway gate element consists of installing a gate within the 14-ft wide by 6-ft high "notch" of the existing concrete spillway. The spillway gate will be an Obermeyer or similar type of pneumatically-operated spillway gate which can be raised and lowered over a range of levels. Obermeyer gates operate by inflating/deflating "bladders" placed beneath spillway panels. The spillway gate will raise the spillway crest by six feet and thereby enable capture and active storage of up to an additional 120 acre-feet of runoff from the MMWD watershed. The added active storage capacity will increase the long term average annual yield of the lake by 107 acre-feet per year and during shortage years by about 50 acre-feet per year for municipal supply to MMWD.

Design Drawing(s):
- Figure 1: Project Layout
- Figure 2: Spillway Gate Detail

Engineers Cost Estimate:

Total Construction Cost = $257,000

Water Supply Project - Construction Cost Estimation

Item	Description	Quantity	Unit	Unit Price	Total Cost
General Requirements:					**$ 20,000**
01	Mobilization	1	LS	$ 15,000	$ 15,000
02	Clearing and Grubbing	1	LS	$ 5,000	$ 5,000
Spillway Gate:					**$ 160,000**
03	Obermeyer Spillway Gate (14' wide × 6' high)	1	LS	$ 60,000	$ 60,000
04	Spillway Gate Installation	1	LS	$ 50,000	$ 50,000
05	Spillway Gate Control System	1	LS	$ 20,000	$ 20,000
06	Control System Building	1	LS	$ 30,000	$ 30,000
Phoenix Lake to Bon Tempe Lake Transfer Piping:					**$ 77,000**
07	Move Floating Barge Pump Station	400	FT	$ 100	$ 40,000
08	Material, Labor, and Fabrication	1	LS	$ 37,000	$ 37,000
				Total Construction	**$ 257,000**

MMWD MEMORANDUM

DATE: March 17, 2011 File No.: D09058

TO: **Jon LaHaye**

FROM: **Carl A. Gowan**

SUBJECT: Phoenix Lake to Bon Tempe Lake Transfer

Recommendation

Install new piping in and around the Phoenix Lake/Transfer Pump Station to create completely separate potable and lake water systems.

Benefits:

- Eliminates costly change over from one system to the other: estimated at $10,000.
- Eliminates four (4) confined spaces.
- Eliminates use of chemicals for chlorination and dechlorination and the associated environmental impact.
- Increases ease of operation: more likely to use systems.

Cost:

- $37,000 capital project cost for labor, materials and fabrication.

Background

Last year a 100 hp vertical turbine pump was installed on a barge in Phoenix Lake and a new 250 hp horizontal centrifugal booster pump was installed in the Phoenix Lake Pump Station (D09058.) This allows transfer of lake water from Phoenix Lake to Bon Tempe. In addition, last year a 24" water line was installed from the base of Fish Grade to Ross Reservoir paralleling an existing 18" potable water line (F09001.) Project D09058 cost $450,000 and Project F09001 cost $1,550,000 million.

Operation

Placing the lake system in operation requires the relocation of two bypass sections: one set of two spools located near the inlet to the Phoenix Lake/Transfer Pump Station and the second set of two spools at the top of the hill near the intersection of the 33" and 24" lines going to and from the Bon Tempe Treatment Plant. This reconfiguration also requires the dechlorniation (when emptying) and treatment (when refilling) of 2700 feet of the 18" discharge line: 35,000 gallons. The cost for reconfiguration the system is estimated at $10,000.

Proposed Design

Install piping, valves, spools and appurtenances as shown on the attached figures. See List of Figures.

The system schematic shows the complete separation of the piping and the two pumps in the Phoenix Lake/Transfer Pump Station. No changes are required for the electrical system.

The 18" potable line at the top of the hill is located in a 78" x 132" x 92" redwood box pit. After reconfiguration, the redwood pit would be demolished and the pipes buried. The 18" lake water line at the top of the hill would be reconfigured with the spool; after reconfiguration, the pit would be filled and the pipes buried.

The 18" lake inlet line near the pump station would be reconfigured with the installation of the existing spool. The 12" potable water inlet line would be disconnected from the 18" lake water line and the spool removed. Both of these pits would be filled in with native soil.

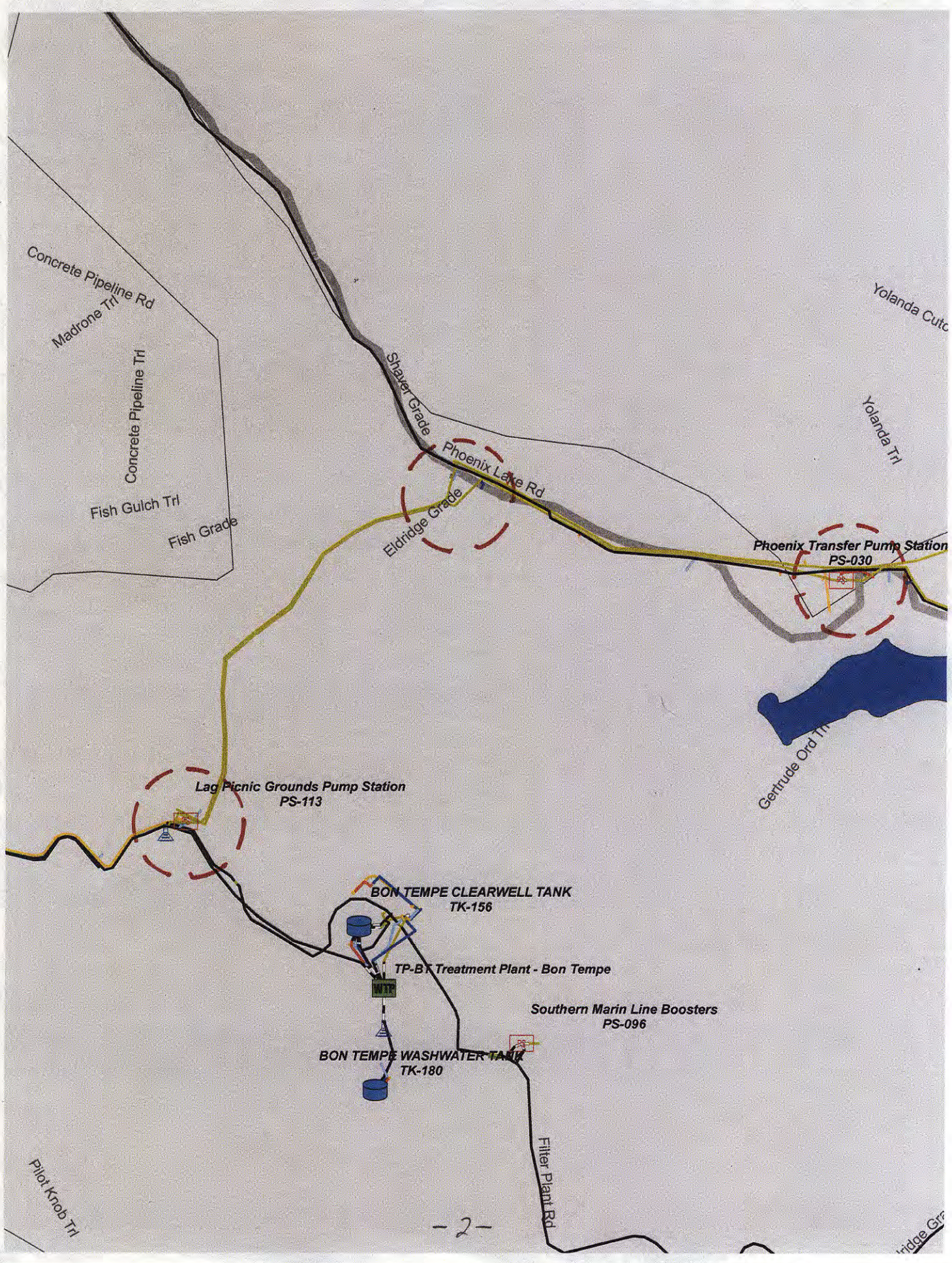
The inlet line to the potable water pump would be connected to the 12" line off of the 18" potable water line. To separate the suction and discharge sides of the potable water pump, the 18" line would be cut and a tee, a 12" BTFY VA and 18" BTFY VA would be installed. Then the outlet line from the potable water pump would be connected to the 18" potable water line through the 12" FE BTFY VA.

The piping inside the pump station would be reconfigured to completely separate the lake water line from the potable water line. The inlet to the potable pump would continue through the wall, under the existing outlet of the lake water pump and to the inlet side of the pump. The outlet from the potable pump would continue under the outlet from the lake water outlet line, through a check valve and through the wall.

The lake water pump inlet line would be reconfigured using the existing 12" "Y" located in the pump station. The outlet line would be reconfigured by removing the concrete support, supporting the existing check valve, and installing a 4' section of 12" WSP.

The inlet lines would be color coded "blue" and the outlet lines color coded "green".

Attachments: List of Figures and Figures


Concrete Pipeline Rd
Madrone Trl
Concrete Pipeline Trl
Fish Gulch Trl
Fish Grade
Shaver Grade
Phoenix Lake Rd
Eldridge Grade
Yolanda Trl
Phoenix Transfer Pump Station
PS-030
Gertrude Ord Trl
Lag Picnic Grounds Pump Station
PS-113
BON TEMPE CLEARWELL TANK
TK-156
TP-BT Treatment Plant - Bon Tempe
Southern Marin Line Boosters
PS-096
BON TEMPE WASHWATER TANK
TK-180
Filter Plant Rd
Pilot Knob Trl

3.3 Water Quality Project

3.3.1 Project Assessment and Evaluation Memorandum

Project Name:
Water Quality Project

Project Element(s):
Epilimnetic Circulation Device; Hypolimnetic Circulation Device; Monitoring System

Project Purpose and Need:

There is a need to improve the water quality of Phoenix Lake. The lake is afflicted with floating algae blooms, particularly during summertime, which can reduce lake clarity and contribute to taste and odor problems. Low dissolved oxygen in the lake hypolimnion reduces suitable cold freshwater habitat and creates a potential for dissolution of sediment-bound metals. These water quality problems can impair the beneficial uses of the lake. To address these water quality issues, Phoenix Lake IRWM Retrofit includes installation of a "SolarBee©" epilimnetic circulation device and a hypolimnetic circulation device or similar type of circulation devices. The eplimnetic circulation device aims to reduce the growth of floating algae, thereby improving the water quality, lake clarity, and reducing treatment costs during the summertime when lake supply is most needed for drinking water supply. The hypolimnetic circulation device aims to oxygenate the hypolimnion and prevent dissolution of sediment-bound metals.

Summary of Completed Work, Existing Data and Studies:

	Description	Reference	Purpose
Completed Work	Concept (30%) designs of all facility elements of the Water Quality Project	Project Concept (30%) Design Memorandum	• Investigate the engineering feasibility of the water quality project. • Design project layout; size project facilities/components. • Provide design information for estimating construction costs.
Existing Data	Lake Water Quality Data	Stetson in-house database	• Observed lake water quality data (algae, dissolved oxygen, and water temperature) were used to identify water quality issues of the lake. • Observed thermal structure data were used to determine the feasibility and deployment of epilimnetic and hypolimnetic circulation devices.
	Lake Bathymetry Data	Stetson in-house database	• Surveyed bathymetric data of Phoenix Lake were used to provide information (volume, area, depth) for the deployment of epilimnetic and hypolimnetic circulation devices.
Existing Studies	1) Water Temperature/ Water Quality Issues in Phoenix Lake and Recommended Solutions for Improving Water Quality and Cold Freshwater Habitat	Appendix 6	• To identify water quality issues in Phoenix Lake and recommend solutions.
	2) Evaluation of Applying SolarBee Circulation Devices in Phoenix Lake	Appendix 7	• To evaluate the feasibility of applying SolarBee circulation devices in Phoenix Lake

Finding(s):

1) Phoenix Lake has a strong stratification during summertime with low dissolved oxygen in the hypolimnion. The phonetic zone (i.e., epilimnion) of Phoenix Lake is about 15-20 ft in depth.

2) The lake is afflicted with floating algae blooms, particularly during summertime.

3) It is feasible to improve the lake water quality by deploying two SolarBee circulation devices, one in the epilimnion to prevent algae blooms and another in the hypolimnion to increase dissolved oxygen.

3.3.2 Project Concept (30%) Design Memorandum

Project Name:
Water Quality Project

Project Element(s):
Epilimnetic Circulation Device; Hypolimnetic Circulation Device; Monitoring System

Design Objective:
The objective of the Water Quality Project is to improve the quality of water in Phoenix Lake for municipal water supply and public recreation. The lake experiences floating algae blooms, particularly during summertime. This reduces water clarity and the overall aesthetic appeal of the lake to fishermen and other recreationalists who visit the lake. Algae also affect the filtration process and increase MMWD's treatment costs at its Bon Tempe Treatment Plant. Algae, particularly blue-green algae, can create taste and odor problems in the treated drinking water. Low dissolved oxygen in the lake hypolimnion creates a potential for dissolution of sediment-bound metals.

Design Criteria and Other Design Considerations:
Design of the Water Quality Project needs to meet the following requirements:

- Prevent algae blooms in the epilimnion;
- Increase dissolved oxygen in the hypolimnion; and,
- Have little effects on the lake's thermal structure (i.e., stratification).

Design Description:
The Water Quality Project has two elements that address the water quality issues in the lake: (1) epilimnetic circulation device and (2) hypolimnetic circulation device. The two circulation devices are self-contained, independently powered by solar power, and automated. The two devices will be carefully designed so that little effects on the lake's thermal structure will be created. The devices will be furnished and installed by the manufacturer.

The eplimnetic circulation device is designed to reduce the growth of floating algae and thereby improve water quality, lake clarity, and reduce treatment costs, particularly during the summertime when lake supply is most needed. The hypolimnetic circulation device aims to oxygenate the hypolimnion and prevent dissolution of sediment-bound metals. Higher oxygen concentrations in the hypolimnion will enlarge the pool in the lake that is suitable for coldwater fish, including trout. This is expected to improve the lake's trout fishery.

Design Drawing(s):

- Figure 1: Project Layout
- Figure 2: Typical Tethering System

Engineers Cost Estimate:
Total Construction Cost = $123,000

Water Quality Project - Construction Cost Estimation

Item	Description	Quantity	Unit	Unit Price	Total Cost
General Requirements:					**$ 5,000**
01	Mobilization	1	LS	$ 5,000	$ 5,000
Epilimnetic Circulation Device:					**$ 53,000**
02	SB10000 v18 with 10 Feet of Hose	1	LS	$ 45,000	$ 45,000
03	Factory Delivery, Installation and Startup	1	LS	$ 8,000	$ 8,000
Hypolimnetic Circulation Device:					**$ 55,000**
04	SB7500 v18 with 50 Feet of Hose	1	LS	$ 47,000	$ 47,000
05	Factory Delivery, Installation and Startup	1	LS	$ 8,000	$ 8,000
Monitoring System:					**$ 10,000**
06	Monitoring System	1	LS	$ 10,000	$ 10,000
				Total Construction	**$ 123,000**

3.4 Ecosystem Restoration Project

3.4.1 Project Assessment and Evaluation Memorandum

Project Name:
Ecosystem Restoration Project

Project Element(s):
Low-Level Drain Pipe Intake Control Valve; Monitoring System

Project Purpose and Need:

There is a need to restore the ecological health and function of Corte Madera Creek and its tributaries. The creek provides important habitat for threatened and endangered species and is considered an "anchor stream" in the NMFS recovery plans for coho salmon and steelhead trout. Although overall ecosystem functions of the creek are still essentially intact, the freshwater aquatic and creek riparian habitats have been reduced and degraded by human activities and the ongoing presence of development. By the late 1800s, cattle grazing, deforestation, and dredging for navigation began directly modifying creek corridors and increasing the severity of rainfall and sediment-laden runoff. Railroad prisms, bridges, and other permanent infrastructure were installed flanking and spanning the creeks, often creating grade breaks or otherwise altering the creek bed making it difficult for native fish to pass through. In the 1900s, encroachment by urban development gradually filled in along the edges of the creek corridors eliminating portions of the riparian canopy and natural creek bank vegetation and encouraging invasion by non-native vegetation. With construction of Phoenix Lake in 1906, baseflow water temperatures in Ross Creek and farther downstream were warmed as historical seepage of cool groundwater into upper tributaries above Ross Creek was replaced by spillway overflow from the warmer (and lighter) upper layer of the newly formed Phoenix Lake. All of these factors have contributed to today's sub-optimal aquatic and riparian habitat conditions below Phoenix Lake.

The Ecosystem Restoration Project component of the Phoenix Lake IRWM Retrofit includes modification of the intake/outlet works of the low-level drain pipeline. This modification will enable instream flow release of cooler water from the lake hypolimnion and improve downstream water quality and aquatic habitat for target salmonids and other coldwater species. Without the Ecosystem Restoration Project component of the Phoenix Lake IRWM Retrofit, recovery of target salmonids and other species will continue to be challenged by sub-optimal riparian and aquatic habitat conditions.

Summary of Completed Work, Existing Data and Studies:

	Description	Reference	Purpose
Completed Work	Concept (30%) designs of all facility elements of the Ecosystem Restoration Project	Project Concept (30%) Design Memorandum	• Investigate the engineering feasibility of the water quality project. • Design project layout; size project facilities/components. • Provide design information for estimating construction costs.
Existing Data	Ross Creek Water Temperature and Dissolved Oxygen Data	Stetson in-house database	• Observed stream water temperature and dissolved oxygen data were used to identify water quality issues of the creek.
Existing Studies	1) Water Temperature/ Water Quality Issues in Ross Creek below the Dam and Recommended Solutions for Improving Water Quality and Cold Freshwater Habitat	Appendix 8	• To identify water quality issues in Ross Creek and recommend solutions.
	2) Water Temperature Report by Friends of Corte Madera Creek Watershed	Appendix 9	• Assess water temperature in Ross Creek below the dam and the influence of Phoenix Lake on stream temperature; Also, • To provide more detailed information about the monitoring program and water temperature monitoring results.

Finding(s):

1) The water temperatures in Ross Creek below the dam and farther downstream in Corte Madera Creek could be improved to better support steelhead rearing habitat if the water is released from the hypolimnion of Phoenix Lake, instead of from the spillway overflow.

2) The released water from the hypolimnion of Phoenix Lake will have relatively low dissolved oxygen concentration. However, this relatively low DO will be quickly increased by re-aeration within a short distance.

3.4.2 Project Concept (30%) Design Memorandum

Project Name:
Ecosystem Restoration Project

Project Element(s):
Low-Level Drain Pipe Intake Control Valve; Monitoring System

Design Objective:
The objective of the Ecosystem Restoration Project is to improve aquatic habitat conditions below the dam in Ross Creek and lower Corte Madera Creek by cooling water temperatures in these creeks during the dry season.

Design Criteria and Other Design Considerations:
The Ecosystem Restoration Project has just one element that addresses this single need: (1) low-level drain pipe intake low-flow control gate. Cooling of water temperatures requires augmenting the design of the Flood Damage Reduction Project's low-level drain pipeline intake to allow precisely controlled low flow release from the 140 ft level intake.

Design Description:
The low-level drain pipe intake low-flow control gate element consists of installing an additional gate on the 140 ft level intake. The gate will be a small sliding gate (6") which can be adjusted over a range of levels to allow for precise control of low flow releases to Ross Creek over a range of low, summer baseflows; preliminarily estimated to be 1 to 5 cfs. The gate will be electric motor controlled. Release flow will be measured at the outlet of the low-level drain pipe where it overflows from a concrete vault. Water level sensor and water temperature sensors will be place in the bottom of the vault and a v-notch weir will be cut into one of the vault sides. A water level discharge rating curve will be developed and a recorder installed nearby to enable continuous measurement and recording of low-flow discharges and temperatures. Instream flow release of cooler water from the lake hypolimnion will improve downstream water quality and aquatic habitat for target salmonids and other coldwater species.

Design Drawing(s):
- Figure 1: Project Layout
- Figure 2: Low-Level Drain Pipe Control Valve

Engineers Cost Estimate:

Total Construction Cost = $128,000

Ecosystem Restoration Project - Construction Cost Estimation

Item	Description	Quantity	Unit	Unit Price	Total Cost
General Requirements:					**$ 11,000**
01	Mobilization	1	LS	$ 6,000	$ 6,000
02	Clearing and Grubbing	1	LS	$ 5,000	$ 5,000
Low-Level Drain Pipe Intake Control Valve:					**$ 12,000**
03	6" Gate	1	Each	$ 2,000	$ 2,000
04	Hydraulic Control System	1	LS	$ 10,000	$ 10,000
Monitoring System:					**$ 105,000**
05	Monitoring System	1	LS	$ 100,000	$ 100,000
06	V-notch Weir Cut Into One of the Concrete Vault Sides	1	LS	$ 5,000	$ 5,000
				Total Construction	**$ 128,000**

3.5 Recreation and Public Access Project

3.5.1 Project Assessment and Evaluation Memorandum

Project Name:
Recreation and Public Access Project

Project Element(s):
Bill Williams Creek Culvert Replacement; Phoenix Lake Watershed Trail Improvements; Visitor Use Facility Upgrades; Road-Related Sediment Reduction Projects

Project Purpose and Need:

There is a need to enhance opportunities for public enjoyment of the lake. Phoenix Lake and its associated trails and watershed land provide fishing, hiking, mountain biking, and other enjoyment opportunities to the public. MMWD records show that Phoenix Lake is one of its most heavily used recreational areas in the MMWD Watershed. Improvements to these trails are needed to keep up with the growing demand and maintain adequate access and safe conditions. Reduction in lake sedimentation is also needed. Comparison of the original lake bathymetric contours with recent contours surveyed in 2009 indicates that the lake has lost about 100 acre-feet to sedimentation, or about 25% of its original storage capacity, since 1906. The Phoenix Lake IRWM Retrofit will implement necessary improvements to roads and trails, as well as culverts where these features cross over tributary drainages of Phoenix Lake. These improvements will aim to enhance public access, safety, and reduce erosion and the delivery of sediment to lake. Without the Phoenix Lake IRWM Retrofit, lake sedimentation will continue at historical rates and opportunities for public enjoyment of the lake will remain at current levels.

1) Bill Williams Creek Arch Culvert Replacement - Bill Williams Creek is a major class 1 tributary to Ross Creek upstream of Phoenix Lake Dam. The Bill Williams Creek Arch Culvert Project will remove a fish passage barrier on this class 1 stream, prevent future erosion and sediment delivery at a failing stream crossing, and improve emergency and public access by replacing a non-functioning culverted stream crossing with a multi-plate arch culvert.

Currently, a non-functioning, 80% plugged, double-culvert crossing on Bill Williams Road prohibits the migration of fish and other aquatic species in Bill Williams Creek. A 2003 assessment of this stream crossing found that due to its extremely diminished capacity, it had a high likelihood to fail catastrophically during a large magnitude storm event. It was estimated that such a failure would deliver approximately 485 cubic yards of sediment to Bill Williams Creek.

By removing and replacing the current crossing with a multi-plate arch culvert designed to pass the 100 year flood, the possibility of future erosion and sediment delivery at the

site will be addressed, emergency and visitor access will be improved, and fish and other aquatic species will be able to pass freely up and downstream.

2) **Phoenix Lake Watershed Trail Improvements** - The Marin Municipal Water District (MMWD) recognizes several miles of trails in the Phoenix Lake watershed for public use and enjoyment. Many of these trails date to the 1930's and are in need of restoration to reduce erosion, improve public safety, and lessen trail impacts on the natural environment. Approximately 4.11 miles of trails in the watershed have been identified by MMWD as requiring attention. Work along these reaches of trail include improving drainage to reduce erosion, trail re-routing to avoid problem and/or sensitive habitat areas, constructing or rebuilding minor structures, such as crib walls, puncheons, and bridges, and installing trail signage to improve user safety and enjoyment.

3) **Visitor Use Facility Upgrades** - The Phoenix Lake area provides multiple recreational benefits to the citizens of Marin County and the Bay Area, including hiking, cycling, horseback riding, bird watching, and fishing. However, the infrastructure to support visitor use in the immediate area surrounding Phoenix Lake is in need of upgrading to meet the growing population of visitors that enjoy the watershed. The purpose of the Phoenix Lake Public Use Facility Upgrades is to provide visitors with clean bathrooms, park benches, and information kiosks to enhance the user experience. This project is needed to lessen the impacts on the surrounding environment, and to educate the public of the importance to respect the watershed while at the same time enjoying its recreational opportunities.

4) **Road-Related Sediment Reduction Projects** – MMWD manages tens of miles of unpaved service and fire protection roads in the Phoenix Lake watershed. These roads are necessary for carrying out maintenance and repairs to the MMWD's water supply infrastructure, providing emergency access for fire, law enforcement and medical personnel, and providing the public with hiking, biking and other recreational opportunities. While unpaved road networks provide multiple benefits, if they are not properly constructed and maintained, they can lead to increased erosion and sediment delivery to streams and lakes, aquatic and terrestrial habitat degradation, and user safety concerns. Storm proofing roads is a proven method used to address all of these potential issues and is widely used by the US Forest Service, National Park Service, California State Parks, the California Department of Fish and Game, and other large public and private land managing agencies to minimize the impact of roads on the environment and improve watershed function.

   Storm proofing includes upgrade and decommissioning treatments, as well as site specific and contributing road length treatments. Site specific treatments focus on treating the point of sediment generation and delivery, such as replacing a currently undersized stream crossing culvert to prevent stream crossing failure, or removing unstable fill along the outer edge of a road that may potentially catastrophically erode into a stream. Contributing road length treatments focus on reducing chronic sediment generation and delivery from the road surfaces. The target of theses treatments is to

produce the smallest flow length possible for any road-borne runoff. By reducing the runoff length through upgrade treatments like road outsloping, installing ditch relief culverts and rolling dips, and through decommissioning treatments, such as total recontouring, installing crossroad drains, and in-place outsloping, surface runoff generated on, or intercepted by the road is quickly conveyed from the road prism to the natural hillslope. These treatments are designed to create the smallest drainage area and produce the shortest contact time of surface runoff with the road, thus limiting the amount of potential hydraulic energy that can be generated at each road drainage structure, and producing the least hydrologic impact to the watershed. Through such treatments, sediment generation is minimized, and the delivery of surface flows and entrained sediments transported from the road to identified sediment delivery sites is effectively reduced.

An assessment of Bill Williams Road and Filter Plant/Lower Eldridge Grade Road revealed that 23 identified sediment delivery sites would deliver over 5,300 cubic yards of sediment to Phoenix Lake and its tributaries. Sediment reduction through storm proofing techniques are needed on these roads to reduce erosion, protect terrestrial and aquatic habitats, ensure that access is maintained and that conditions are safe for public use and enjoyment.

Summary of Completed Work, Existing Data and Studies:

	Description	Reference	Purpose
Completed Work	Assessment, conceptual (30%) design and project planning for trail improvements, road related sediment reduction, and visitor use facilities	Project Concept (30%) Design Memorandum	• Assess road and trail-related environmental degradation • Evaluate erosion and sedimentation impacts from roads and trails • Design project layout and size project facilities/components • Provide design information for estimating construction costs to improve roads and trails, and provide visitor use facilities
Existing Data	GIS and tabular databases of sediment delivery sites	Stetson in-house database	• Provide comprehensive data of every road and trail related sediment delivery site in the Phoenix Lake watershed
Existing Studies	• Summary Report, Road and Trail Inventory and Assessment, Erosion Prevention Implementation Plan, Mt. Tamalpais Watershed, Marin Municipal Water District, Marin County, California, Pacific Watershed Associates. 2003 • Mount Tamalpais Road and Trail Management Plan. Marin Municipal Water District. 2005. http://marinwater.org/controller?action=menuclick&id=249. Last accessed 04/08/2011.	MMWD Website	• To identify, quantify, and provide restoration implementation planning to address surface water quality pollution stemming from road and trail-related erosion and sediment delivery.

Finding(s):

The Phoenix Lake watershed provides visitors with multiple recreational opportunities; however the current road and trail network and visitor use facilities are in need of repair and modification to ensure that recreation impacts do not negatively affect the surrounding environment. The Bill Williams Creek culvert replacement will prevent further erosion from occurring at the site, ensure that emergency and visitor access is maintained on Bill Williams Road, and re-establish fish passage in Bill Williams Creek. Improvements to the trail network around Phoenix Lake will prevent ongoing chronic erosion from occurring on the trail surfaces, reduce sedimentation to Phoenix Lake and its tributaries, and improve visitor access and safety. Upgrading visitor use facilities will provide benches, bathrooms, and educational kiosks that will enhance the visitor experience, add an educational component, and reduce user impacts to the Phoenix Lake watershed. Finally, road-related sediment reduction projects will significantly reduce the amount of erosion and sediment generation taking place in the watershed. This will provide safe and sustainable access for visitor use, watershed maintenance and emergency access vehicles, improve water quality and aquatic habitats in Phoenix Lake and its tributaries, and reduce sedimentation and maintain lake storage capacity for flood damage reduction in the wet season and water supply in the dry season.

3.5.2 Project Concept (30%) Design Memorandum

Project Name:
Recreation and Public Access Project

Project Element(s):
Bill Williams Creek Culvert Replacement; Phoenix Lake Watershed Trail Improvements; Visitor Use Facility Upgrades; Road-Related Sediment Reduction Projects

Design Objective:
The goal of the Recreation and Public Access Project is to improve public access and recreational opportunities, while at the same time lessening user impacts on the natural environment and improving watershed function. Phoenix Lake and its associated trails and watershed land provide fishing, hiking, mountain biking, and other enjoyment opportunities to the public. MMWD records show that Phoenix Lake is one of its most heavily used recreational areas in the MMWD Watershed. Improvements to these trails are needed to keep up with the growing demand and maintain adequate access and safe conditions. Reduction in lake sedimentation is also needed to maintain the lake storage capacity for flood damage reduction and water supply.

Design Criteria and Other Design Considerations:

- The design flood for removal and replacement of the current Bill Williams Creek culvert crossing will be the 100-year flood. The possibility of future erosion and sediment delivery at the site will need to be addressed, and improvement to emergency and visitor access will need to be considered.
- Improving Phoenix Lake watershed trails will include improving drainage to reduce erosion, trail re-routing to avoid problem and/or sensitive habitat areas, constructing or rebuilding minor structures, such as crib walls, puncheons, and bridges, and installing trail signage to improve user safety and enjoyment.

Design Description:
The designed improvements include:

- Replacing the non-functioning stream crossing on Bill Williams Creek with a multi-plate arch culvert to reduce erosion, improve access, and provide fish passage;
- Improving trail conditions around Phoenix Lake to reduce erosion and sediment delivery, and to improve access and visitor safety;
- Upgrading visitor facilities, such as bathrooms, benches, and informational kiosks around Phoenix Lake to enhance the user experience, provide public education, and lessen user impacts to the surrounding environment;
- Constructing road-related sediment reduction projects to reduce erosion and sediment impacts to Phoenix Lake and its tributaries by storm proofing watershed maintenance and emergency access roads.

Design Drawing(s):

- Figure 1: Project Layout

- Figure 2: Bill Williams Creek Culvert Replacement Typical Details

Engineers Cost Estimate:

Total construction cost = $1,085,000

Recreation and Public Access Project - Construction Cost Estimation

Item	Description	Quantity	Unit	Unit Price	Total Cost
Bill Williams Culvert Replacement:					**$ 182,800**
1.1	Mobilization/Demobilization	1	LS	$ 40,000	$ 40,000
1.2	Clearing and Grubbing	160	CY	$ 80	$ 12,800
1.3	Clearing and Grubbing	40	LF	$ 60	$ 2,400
1.4	Earth Excavation W/O Backfill	200	CY	$ 80	$ 16,000
1.5	Bedrock Excavation W/O Backfill	40	CY	$ 400	$ 16,000
1.6	Furnish Arch Culvert	30	LF	$ 500	$ 15,000
1.7	Install and Backfill	50	LF	$ 60	$ 3,000
1.8	Install and Backfill	150	CY	$ 80	$ 12,000
1.9	Structural Concrete Footing	16	CY	$ 1,000	$ 16,000
1.10	Structural Concrete Headwall and Wing	15	CY	$ 1,800	$ 27,000
1.11	Class II Aggregate Base	30	Ton	$ 120	$ 3,600
1.12	1.5(H):1(V) Slope Protection Rip Rap	60	Ton	$ 200	$ 12,000
1.13	Erosion Control and Revegetation	1	LS	$ 7,000	$ 7,000
Trail Improvements:					**$ 39,935**
2.1	Ross Trail	1	mi	$ 24,500	$ 13,965
2.2	Gertrude-Ord Trail	1	mi	$ 24,500	$ 25,970
2.3	Bill Williams Trail	0	mi	$ 24,500	$ 11,760
2.4	Tucker Trail	2	mi	$ 24,500	$ 39,445
2.5	Harry Allan Trail	0	mi	$ 24,500	$ 9,555
Visitor Use Facilities:					**$ 58,500**
3.1	Kiosks	2	Each	$ 13,000	$ 26,000
3.2	Benches	4	Each	$ 1,000	$ 4,000
3.3	Self-contained Serviceable Restroom	1	Each	$ 28,500	$ 28,500
Road-Related Sediment Control (Stormproofing):					**$ 804,190**
4.1	Outsloping	4,941	LF	$ 15	$ 74,115
4.2	Rolling Dips	13	Each	$ 2,250	$ 29,250
4.3	Earth Excavation and Backfill	4,346	CY	$ 150	$ 651,900
4.4	Road Rock	378	CY	$ 30	$ 11,340
4.5	Rock Armor	97	CY	$ 30	$ 2,910
4.6	18" Diam. Culvert	205	LF	$ 15	$ 3,075
4.7	24" Diam. Culvert	390	LF	$ 25	$ 9,750
4.8	30" Diam. Culvert	380	LF	$ 35	$ 13,300
4.9	36" Diam. Culvert	80	LF	$ 45	$ 3,600
4.10	42" Diam. Culvert	90	LF	$ 55	$ 4,950
				Total Construction	**$ 1,085,000**

Appendices

Appendices to the Flood Damage Reduction Project Assessment and Evaluation Memorandum:

Appendix 1: HEC-HMS Hydrologic Modeling Analysis of Phoenix Lake in Peak Flow Reduction

Appendix 2: Preliminary Coordinated Operations Plan for Phoenix Lake

Appendix 3: Phoenix Lake Spillway Hydraulic Evaluation

Appendix 4: Geotechnical Evaluations (2) of Phoenix Lake Dam

Appendices to the Water Supply Project Assessment and Evaluation Memorandum:

Appendix 5: Long-Term Hydrologic Analysis of Re-operating Phoenix Lake for Flood Detention and Water Supply

Appendices to the Water Quality Project Assessment and Evaluation Memorandum:

Appendix 6: Phoenix Lake Water Quality Issues and Solutions

Appendix 7: SolarBee's Proposal for Phoenix Lake

Appendices to the Ecosystem Restoration Project Assessment and Evaluation Memorandum:

Appendix 8: Ross Creek Water Temperature Issues and Solutions

Appendix 9: Ross Creek Water Temperature Monitoring Report (Friends of Corte Madera Creek Watershed, 2008)

Appendix 1 to Attachment 3

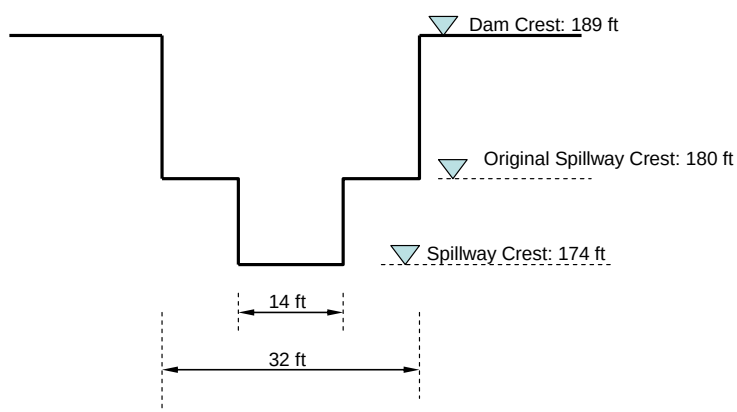
HEC-HMS Hydrologic Modeling Analysis of Phoenix Lake in Peak Flow Reduction

Stetson Engineers Inc.
May 11, 2010

The purpose of this analysis was to identify the best physical and operational modification alternative of flood detention by Phoenix Lake and to evaluate its effectiveness at reducing peak flows. The Stetson-developed and calibrated HEC-HMS model for the Ross Valley watershed was used as a tool to conduct the analysis. The December 31, 2005 flood event, an estimated 100-year flood event, was used as the design flood. It was found from the analysis that drawing the lake level down ahead of a forecasted storm to el.140 ft (NGVD29), in concert with installing a 6-foot high inflatable/deflatable rubber dam across the spillway, would provide sufficient storage space in the lake to detain floodwaters and effectively reduce 100-year peak flows (by about 650 cfs from 6,840 cfs to 6,190 cfs at the Ross streamflow gage) along Ross Creek and Corte Madera Creek, including key breakout points in Ross.

1.0 Description of Phoenix Lake

Phoenix Lake is located on Ross Creek, a major tributary of Corte Madera Creek. The watershed area of Phoenix Lake is about 2.22 square miles. The lake has a gated 30" diameter low-level outlet and an ungated spillway at the dam. The elevations of the low-level outlet inlet invert, the spillway crest, and the dam crest are 130 ft, 174 ft, and 189 ft (NGVD29), respectively. The existing spillway has two crest levels (see the graph below), one at elevation 174 ft and the other at elevation 180 ft. The existing low-level outlet is normally kept closed and has been used infrequently since it was built.



Sketch of Existing Phoenix Lake Spillway

Figure 1 shows the storage curve of Phoenix Lake based on the 2009 bathymetric survey the historical storage curves provided by MMWD. During the last 100 years, the lake storage was reduced by about 118 acre-ft (from 420 acre-ft to 302 acre-ft) at the spillway crest elevation of 174 ft. Based on the 2009 bathymetric survey, the lake currently has a storage volume of 0.2 acre-ft, 302 acre-ft, and 637 acre-ft corresponding to the elevations of 130 ft, 174 ft, and 189 ft, respectively.

2.0 HEC-HMS Modeling Scenarios and Results

Phoenix Lake functions as a de facto detention basin. Currently the lake was not operated for flood control and the low-level outlet is normally kept closed. Its detention benefit on peak flow reduction would be increased if the lake was operated for flood control. In order to test the flood control ability of the lake, the calibrated HEC-HMS hydrologic model for the Corte Madera Creek watershed was used to simulate the following scenarios for the December 31, 2005 flood event (see Table 1 also). The simulation period started at December 30, 2005, 0:00am and ended at January 1, 2006, 12:00pm. A time interval of 10 minutes was used in the model computation.

- Baseline Scenario: As operated.
- Scenario 1: Modify the existing low-level outlet intake to raise its invert elevation from 130 ft to 140 ft; open the low-level outlet to drawdown the lake prior to the storm event and keep the outlet open during the storm event[1].
- Scenario 2: Modify the existing low-level outlet intake to raise its invert elevation from 130 ft to 140 ft; open the low-level outlet to drawdown the lake prior to the storm event but close the outlet at the time of incipient flooding (t_1) and keep the outlet closed.
- Scenario 3: Modify the existing low-level outlet intake to raise its invert elevation from 130 ft to 140 ft; open the low-level outlet to drawdown the lake prior to the storm event and keep the outlet open during the storm event; and install an inflatable/deflatable rubber dam across the spillway to raise the spillway crest from 174 ft to 180 ft.

[1] The current storage volume of Phoenix Lake below elevation 130 ft is only 0.2 acre-ft based on the 2009 bathymetric survey. Opening the existing low-level outlet would empty the lake since the lake level would be drawdown to the same elevation as the intake invert. Raising the intake invert elevation from 130 ft to 140 ft would create a dead storage of about 11 acre-ft (see Figure 1 for Phoenix Lake storage curve). Dredging the lake to create additional dead storage may be needed.

Table 1 Summary of Phoenix Lake Operating Scenarios That Were Simulated Using the HEC-HMS Model of the Corte Madera Creek Watershed

Operating Scenario	Initial Water Level Elevation (ft above MSL)	Low-Level Outlet Operations	Modification to Spillway?
Baseline (As Operated)	174	Closed all time.	No
Scenario 1	140* (lake drawn down)	Open all time.	No
Scenario 2	140* (lake drawn down)	Open prior to storm event; Closed starting at time of d/s incipient flooding during the storm event (t_1).	No
Scenario 3	140* (lake drawn down)	Open all time.	Raise spillway crest from 174 ft to 180 ft by installing an inflatable/deflatable rubber dam across the spillway.

* The existing low-level outlet is a 500 ft long 30-inch metal pipe with an inlet invert elevation at 130 ft (NGVD29). The current storage volume of Phoenix Lake below elevation 130 ft is only 0.2 acre-ft based on the 2009 bathymetric survey. Opening the existing low-level outlet would empty the lake since the lake level would be drawdown to the same elevation as the intake invert. Raising the intake invert elevation from 130 ft to 140 ft would create a dead storage of about 11 acre-ft. Dredging the lake to create additional dead storage may be needed.

Baseline Scenario – As operated

Under Baseline Scenario (i.e., as operated), the existing low-level outlet would be kept closed. The initial water level for Baseline Scenario would be the spillway crest elevation, i.e., 174 ft above MSL. Figure 2 shows the simulated inflows to the lake, outflows from the lake, and lake water surface elevations (WSE). The results show that, under Baseline Scenario, the detention effect of the lake reduced the Ross Creek peak flow from about 956 cfs to 880 cfs during the December 31, 2005 flood event, and the lake water surface elevation peaked at 181.1 ft.

Scenario 1 – Modify the existing low-level outlet intake to raise its invert elevation from 130 ft to 140 ft, open the low-level outlet to drawdown the lake prior to the storm event and keep the outlet open during the storm event.

Under Scenario 1, the modified low-level outlet would be open all time during the wet season. This scenario requires minimal operations to the modified low-level outlet: open the low-level outlet prior to the wet season and close the low-level outlet after the wet season to fill the lake. In terms of flood detention modeling, the initial water level for Scenario 1 would be the modified intake invert elevation, which is at 140 ft (NGVD29).

Figure 3 shows the simulated inflows to the lake, total outflows from the lake, and lake water surface elevations. The results show that, under Scenario 1, the detention effect of the lake would reduce the Ross Creek peak flow from about 956 cfs to 738 cfs during the December 31, 2005 flood event, and the lake water surface elevation would peak at 180.0 ft. The simulated outflows show that at about 5:00am of December 31, 2005, the lake water surface elevation would reach the spillway crest (i.e., 174 ft) and spillway overflows would occur thereafter.

Scenario 2 – Modify the existing low-level outlet intake to raise its invert elevation from 130 ft to 140 ft, open the low-level outlet to drawdown the lake prior to the storm event but close the outlet at the time of incipient flooding (t_1) and keep the outlet closed.

Under Scenario 2, the modified low-level outlet would be open to evacuate the lake prior to the storm event and then kept open until the time of incipient flooding (t_1). At the time of t_1 the low-level outlet is closed and kept closed thereafter. This scenario requires real-time operation of the low-level outlet based on the real-time stage measurements at the Ross streamflow gage and the weather forecasts. In terms of flood detention modeling, the difference between Scenario 2 and Scenario 1 is that in Scenario 2 the low-level outlet is open until time t_1 but in Scenario 1 it is open during the entire storm event. The initial water level for Scenario 2 would be the modified intake invert elevation of 140 ft.

HEC-HMS is able to directly simulate the conditions that the low-level outlet is either open or closed during the entire storm event, but is unable to directly simulate the operational condition of Scenario 2. In order to simulate Scenario 2, the following three steps were taken:

(1) Run model with the modified low-level outlet open all time.

This was done in the simulation of Scenario 1. The simulated results for the time period from the beginning of the storm event to the time t_1 are the desired status prior to the close of the low-level outlet for Scenario 2. The simulated outflow hydrograph for the low-level outlet was exported to Excel and the outflows after t_1 were set to 0. This revised hydrograph would be the desired outflow hydrograph of the low-level outlet for Scenario 2. The outflow volume through the 30" low-level outlet from the beginning of the storm event to the time t_1 was calculated to be approximately 106 acre-ft.

(2) Run model with the modified low-level outlet closed during the entire storm event.

During the simulation in this step, the outflow volume computed in step (1) above would be detained in the lake. This would cause a higher water surface elevation at time t_1 in the lake than expected in Scenario 2. In addition, the flows in the Ross Creek below Phoenix Dam would be zero during the simulation for the time period from the beginning of the storm to time t_1. This is not the desired result for Scenario 2 because it would be expected that the flows for the time period for Scenario 2 would be the outlet outflows computed in step (1). Without correctly simulating the flows in the Ross Creek below Phoenix Dam, the computed hydrographs for all the reaches downstream of the Phoenix Dam would be incorrect.

The way to have the model achieve the expected water surface elevation at time t_1 is to create a hypothetical elevation-storage curve of the lake by adding the additional volume of 106 acre-ft to the actual storage curve.

The way to have the model achieve the desired flows is to add a source element to the Ross Creek below Phoenix Dam in the HEC-HMS model. This source flow would be the low-level outlet outflow hydrograph generated in step (1).

(3) Generate final results by combining the results from step (1) and step (2).

The final outflow hydrograph from the lake dam would be the combination of the low-level outlet outflow hydrograph generated in step (1) and the outflow hydrograph simulated in step (2). The final lake level hydrograph would be the combination of the lake level hydrograph simulated in step (1) for the time period from the beginning of the storm to time t_1 and the lake level hydrograph simulated in step (2) thereafter.

Figure 4 shows the simulated inflows to the lake, final outflows from the lake, and final lake water surface elevations. The results show that, under Scenario 2, the detention effect of the lake would reduce the Ross Creek peak flow from about 956 cfs to 767 cfs during the December 31, 2005 flood event, and the lake water surface elevation would peak at 180.6 ft. The simulated outflows show that at about 5:00am of December 31,

2005, the lake water surface elevation would reach the spillway crest (i.e., 174 ft) and spillway overflows would occur thereafter.

Scenario 3 – Modify the existing low-level outlet intake to raise its invert elevation from 130 ft to 140 ft, open the low-level outlet to drawdown the lake prior to the storm event and keep the outlet open during the storm event, and install an inflatable/deflatable rubber dam across the spillway to raise the spillway crest from 174 ft to 180 ft.

Scenario 3 requires the same operations for the modified low-level outlet as Scenario 1. Scenario 3 may also require additional operations for the inflatable/deflatable rubber dam across the spillway. In terms of HEC-HMS modeling analysis, the difference between the two scenarios is that they have different spillway crest elevations.

Figure 5 shows the simulated inflows to the lake, final outflows from the lake, and final lake water surface elevations. The results show that, under Scenario 3, the detention effect of the lake would reduce the Ross Creek peak flow from about 956 cfs to 686 cfs during the December 31, 2005 flood event, and the lake water surface elevation would peak at 182.8 ft. The simulated outflows show that at about 7:00am of December 31, 2005, the lake water surface elevation would reach the gated spillway crest (i.e., 180 ft) and spillway overflows would occur thereafter.

3.0 Comparison of Modeling Results for Different Scenarios

Figure 6 shows a comparison of simulated outflows from Phoenix Lake for various scenarios. For the given available flow from Ross Creek, Scenario 3 would have the greatest reduction in peak flow and overbank flow volume for the downstream reaches. Scenarios 1 and 2 would have similar reduction in peak flow and overbank flow volume for the downstream reaches.

Figure 7 shows a comparison of simulated flows at the Ross gage for different scenarios. Scenarios 1, 2, and 3 reduce the December 31, 2005 peak flow at the Ross gage by 264 cfs, 261 cfs, and 646 cfs, respectively. All three scenarios would shorten the period of overbank flow and reduce overbank flow volume.

Since Scenarios 1 and 2 have similar reduction in peak flow and overbank flow volume for the downstream reaches, there would be no need to close the low-level outlet at the time t_1 once the outlet is open for flood control purpose. In other words, Scenario 2 offers little benefit and requires more operating effort.

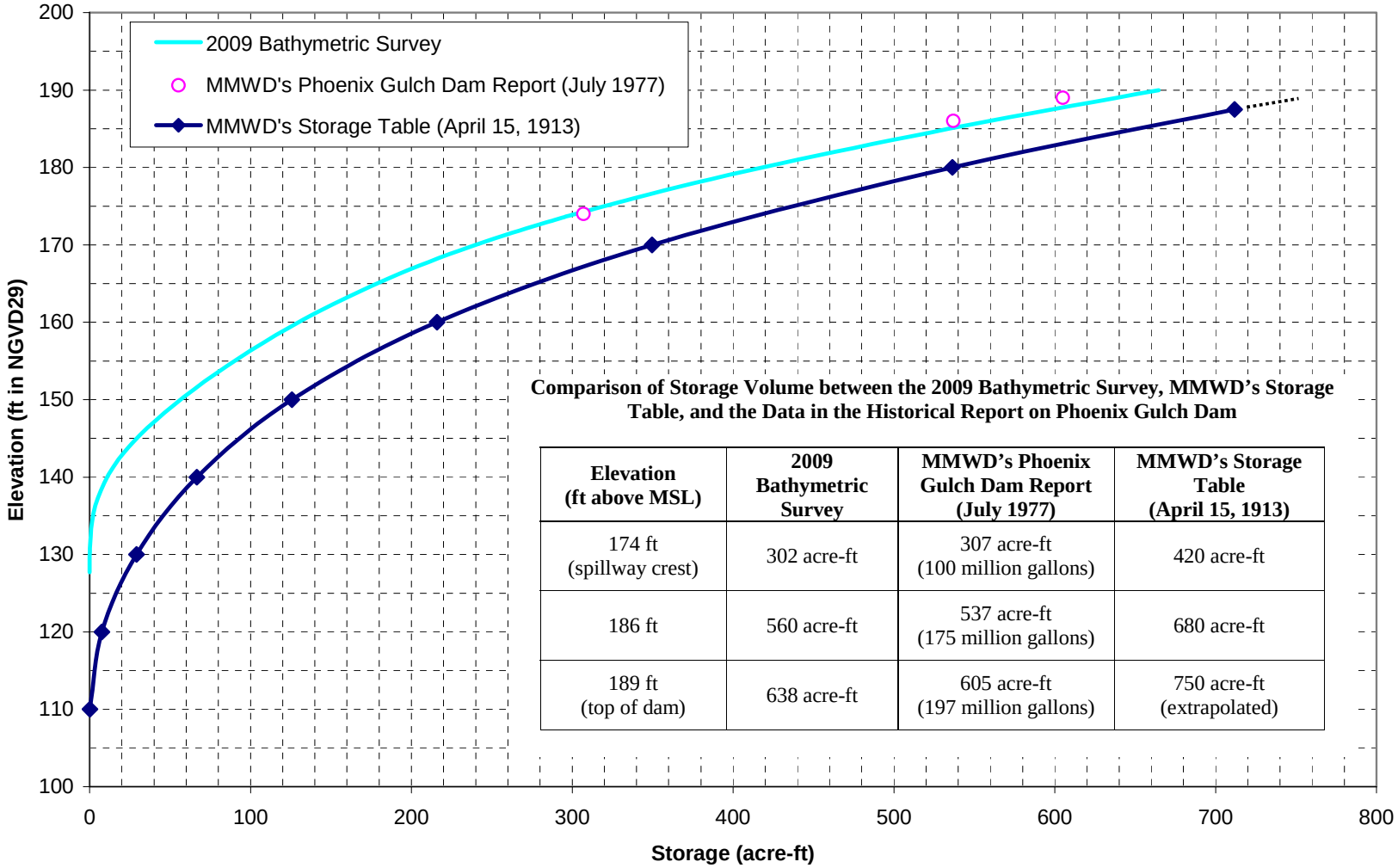
4.0 Analysis of Routing Winter Baseflows (Inflow) through the Dam with the Existing 30-inch Low-Level Outlet Open

This analysis determined whether the existing 30” low-level outlet has adequate capacity to achieve rapid drain-down for evacuating the lake from the spillway crest level under winter baseflow conditions within 24 hours of impending heavy storm.

Figure 8 shows the analysis results of routing winter baseflow through the dam with the 30” low-level outlet open. The results indicate that it would take about two days (48 hours) for the 30” low-level outlet to drain the lake from the spillway crest level (174 ft) down to elevation 140 ft.

According to the lake storage curve, the lake has a storage of about 291 acre-ft between the modified low-level outlet inlet invert (140 ft) and the spillway crest (174 ft). The low-level outlet has a discharge capacity of about 115 cfs when the lake level is at the spillway crest of 174 ft. Apparently, the existing 30” low-level outlet does not have adequate capacity to evacuate the lake from the spillway crest level within 24 hours because it can only drain 230 acre-ft within 24 hours at the discharge rate of 115 cfs.

Figure 1 Phoenix Lake Storage Curve
(Note: The storage curve based on the 2009 bathymetric survey was used in the modeling analyses)



Comparison of Storage Volume between the 2009 Bathymetric Survey, MMWD's Storage Table, and the Data in the Historical Report on Phoenix Gulch Dam

Elevation (ft above MSL)	2009 Bathymetric Survey	MMWD's Phoenix Gulch Dam Report (July 1977)	MMWD's Storage Table (April 15, 1913)
174 ft (spillway crest)	302 acre-ft	307 acre-ft (100 million gallons)	420 acre-ft
186 ft	560 acre-ft	537 acre-ft (175 million gallons)	680 acre-ft
189 ft (top of dam)	638 acre-ft	605 acre-ft (197 million gallons)	750 acre-ft (extrapolated)

Figure 2 Simulated Results for Phoenix Lake – Baseline Scenario (As Operated)

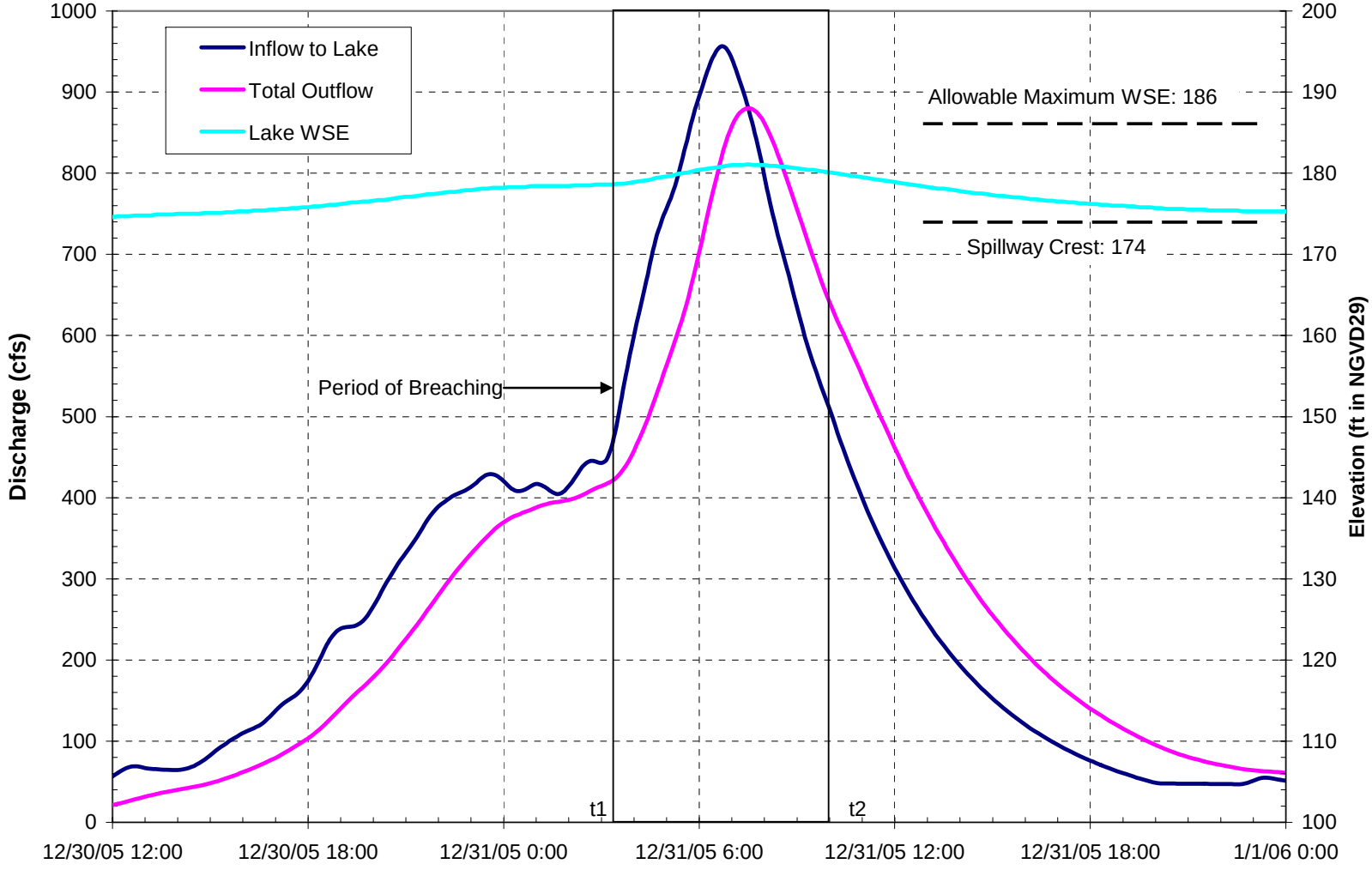


Figure 3 Simulated Results for Phoenix Lake – Scenario 1

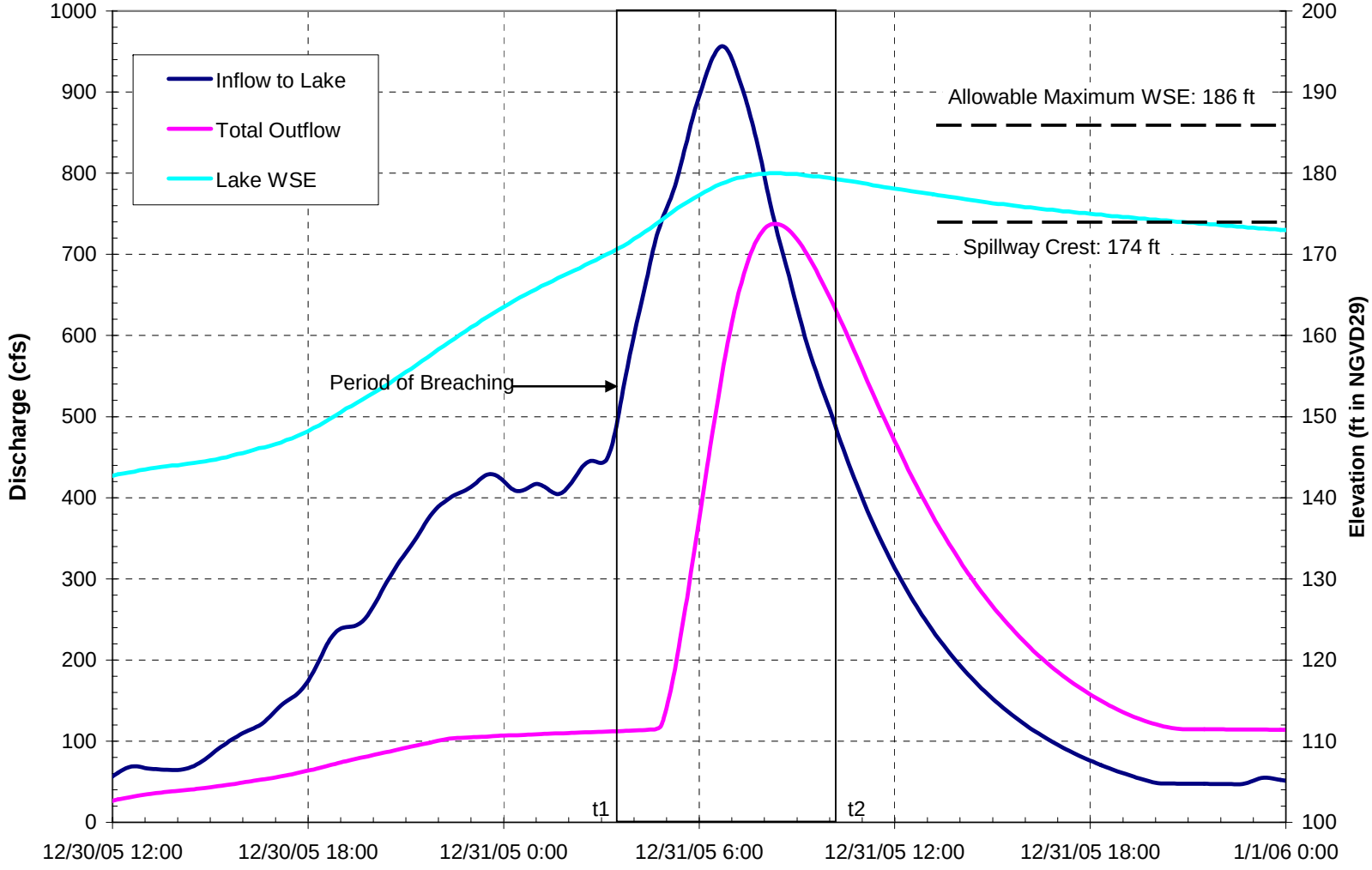


Figure 4 Simulated Results for Phoenix Lake – Scenario 2

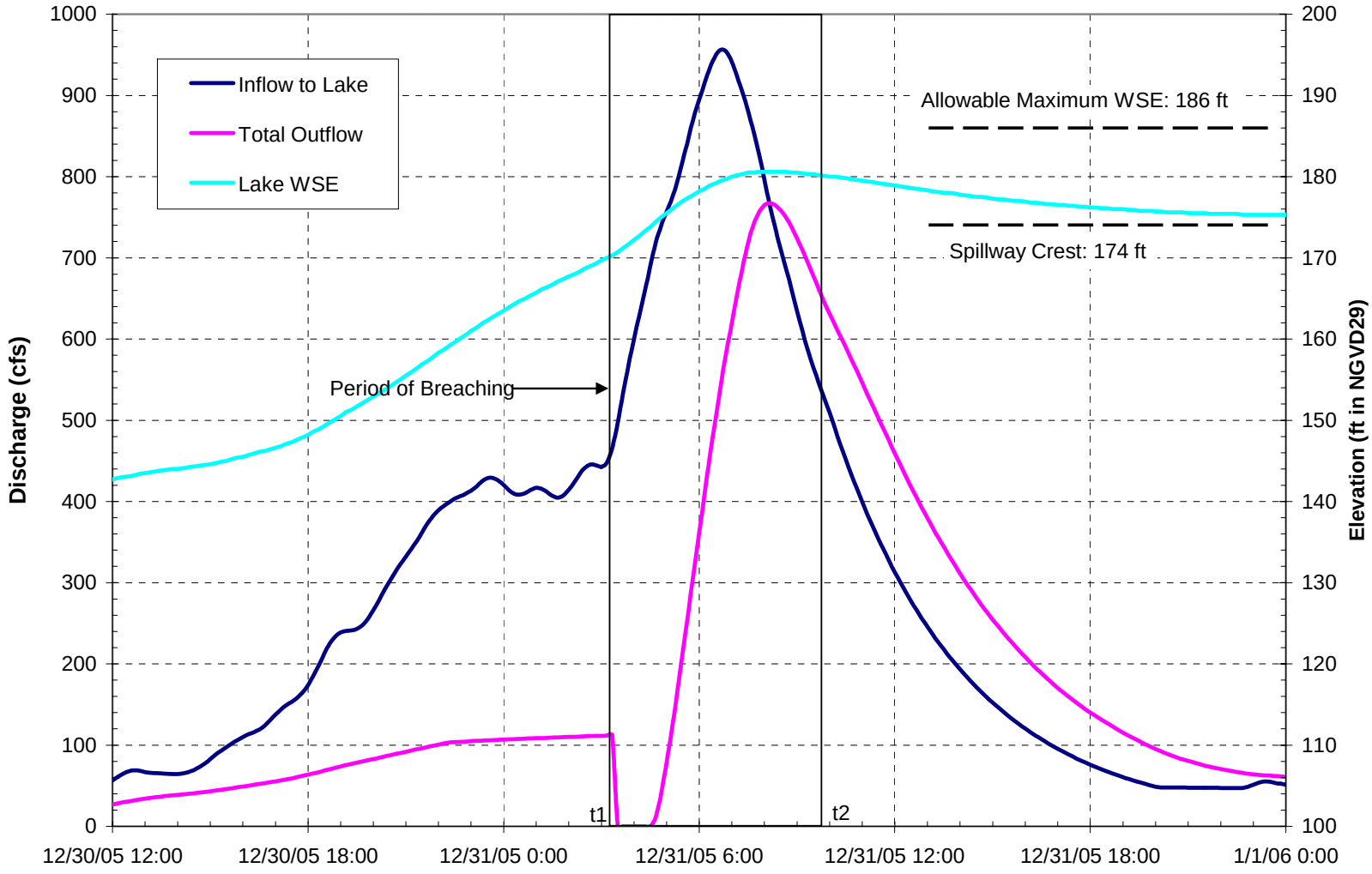


Figure 5 Simulated Results for Phoenix Lake – Scenario 3
(Spillway Crest Raised from 174 ft to 180 ft)

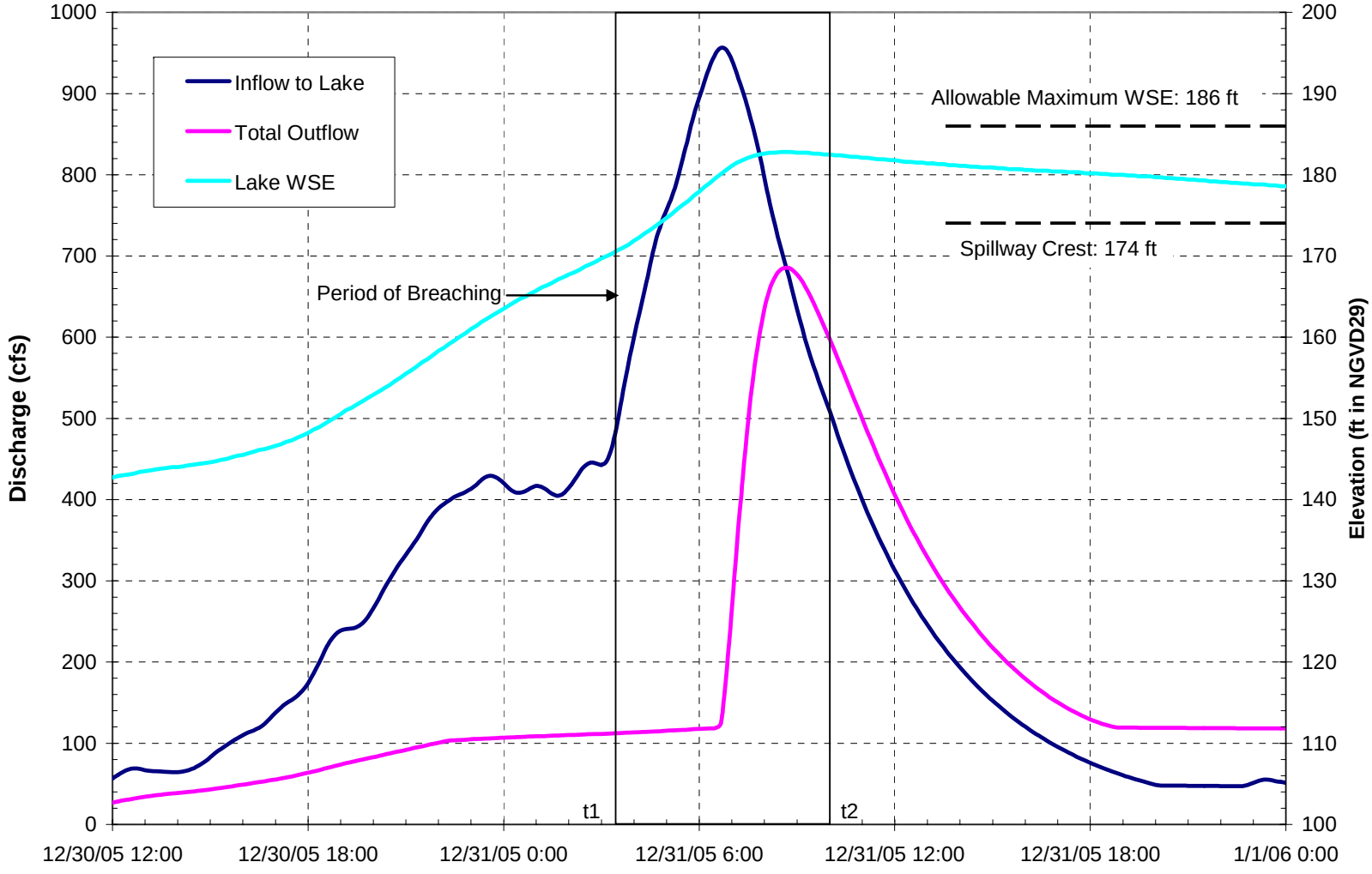


Figure 6 Comparison of Simulated Outflows from Phoenix Lake for Different Scenarios

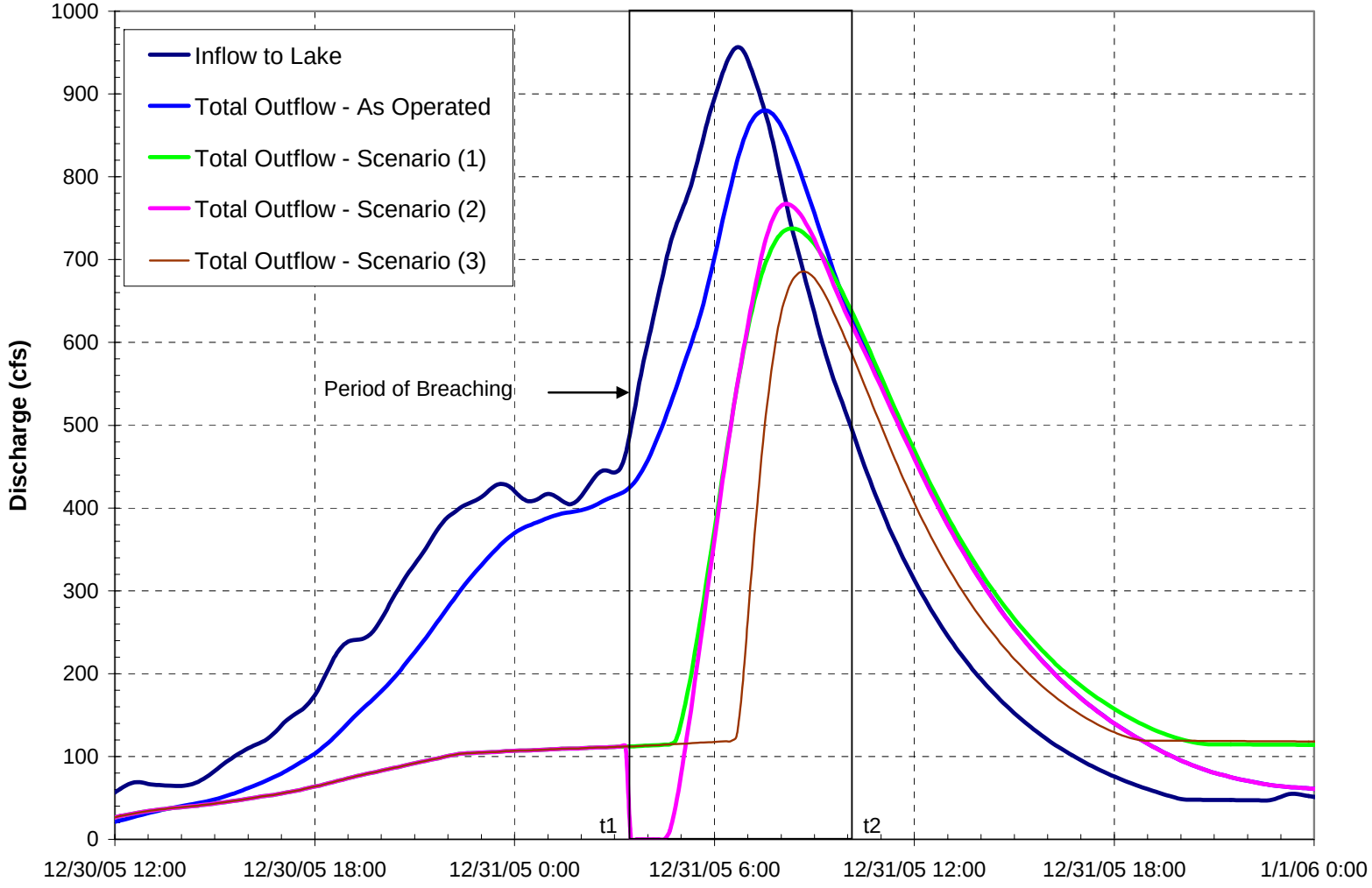


Figure 7 Comparison of Simulated Flows at Ross Gage for Different Scenarios of Phoenix Lake

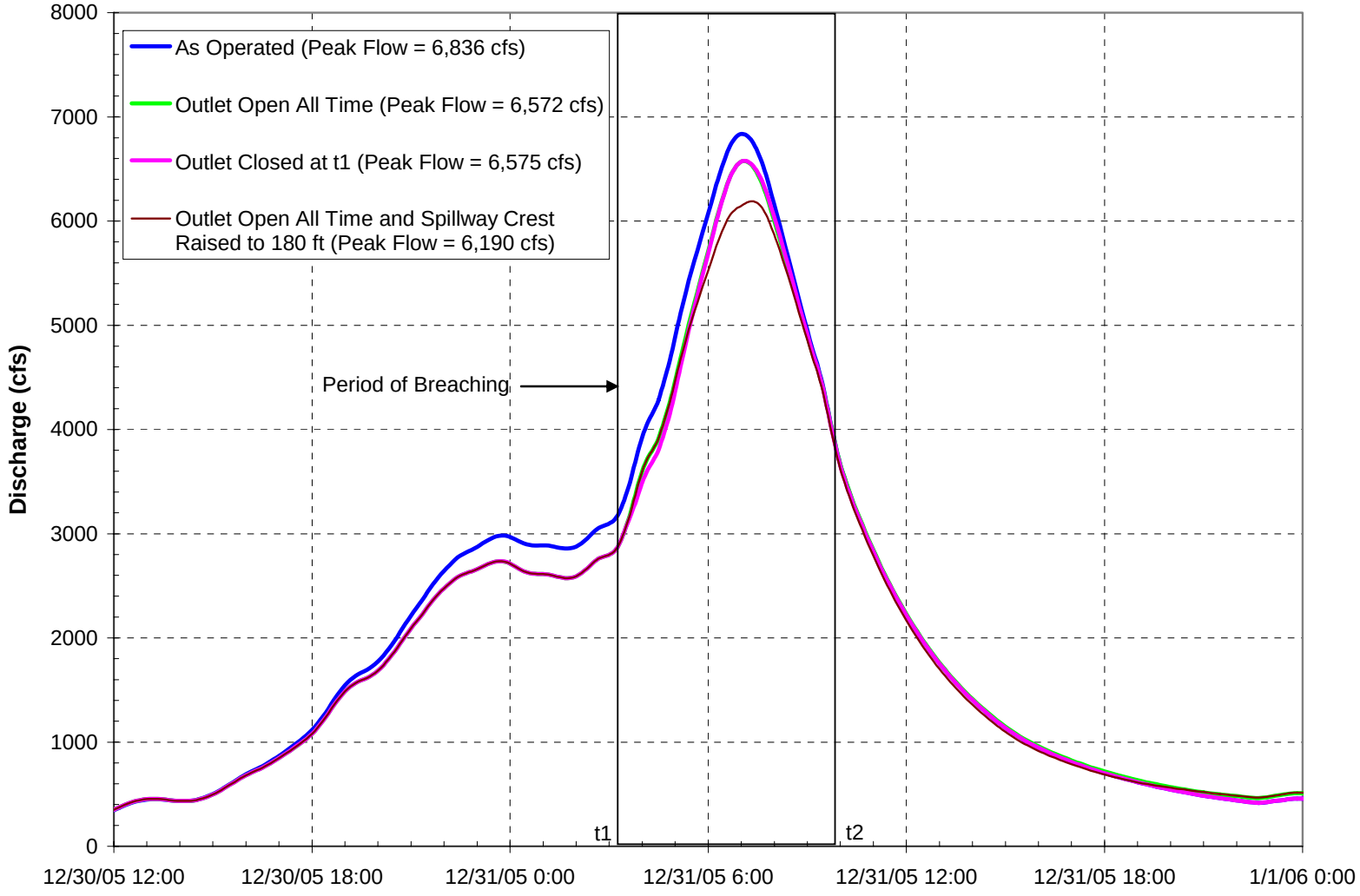
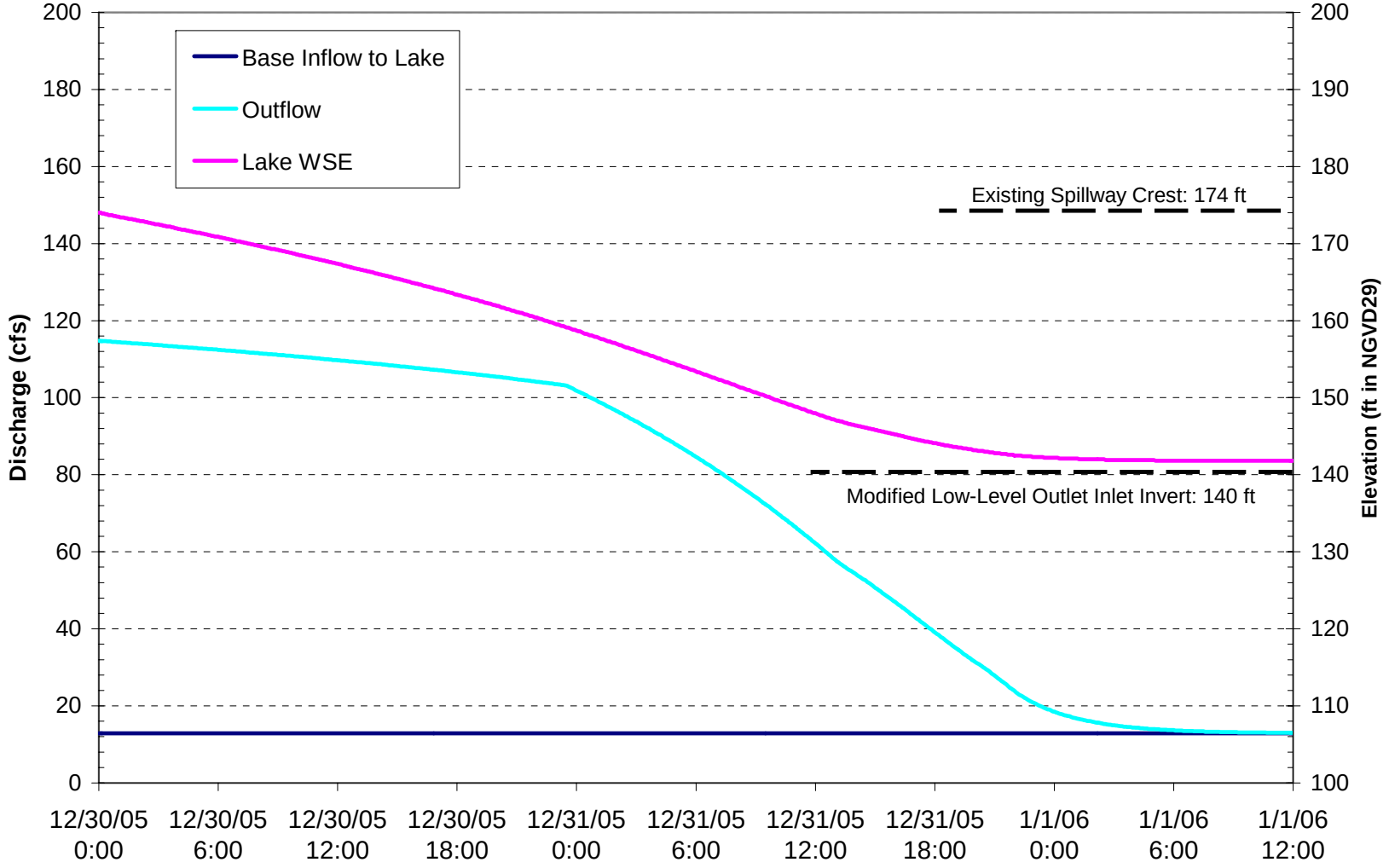


Figure 8 Analysis Results of Routing Winter Baseflow through the Phoenix Lake Dam with the 30" Low-Level Outlet Open



Appendix 2 to Attachment 3

<u>Preliminary</u> Coordinated Operations Plan of Phoenix Lake

Stetson Engineers Inc.
January 26, 2011

This *Preliminary* Coordinated Operations Plan provides general rules and criteria for operating Phoenix Lake to achieve its multi-purpose objectives. The objectives include dry season water supply to MMWD, flood damage reduction, ecosystem restoration, water quality enhancement, and public recreation and enjoyment. A Final Coordinated Operations Plan will be developed that is mutually acceptable to MMWD and FZ9.

Phoenix Lake currently functions as a de facto detention basin. During heavy storms, the lake water level rises above the spillway crest. This resulting "surcharge" storage attenuates stormflow and reduces the peak flow in the creek downstream. In order to enhance the attenuation effect for peak flow reduction purposes, the existing low-level outlet structure (a 30" pipe with an intake elevation at 130 ft NGVD29) will be modified to have two level gates, one at elevation 140 ft and the other at elevation 160 ft, and a 6-foot high inflatable/deflatable rubber dam installed across the spillway. By installing a 6-foot high inflatable/deflatable rubber dam across the spillway, the lake level will be raised to its pre-1985 elevation of 180 feet during floods when additional storage capacity and attenuation are needed. The lake level will also be raised in the spring after the flood season has passed to capture additional water available for dry season water supply.

Phoenix Lake will be generally operated according to the "rule curve" (see Figure 1) which was developed to meet the needs of both flood detention in the wet season and water supply and public recreation in the dry season. During the dry season, the lake water level will normally be maintained at elevation around 180 ft. In the fall, the lake water level will be gradually drawing down to elevation 174 ft through the low-flow gate of the new intake structure to prepare for flood detention in the upcoming wet season. By late fall, when the lake water level is down to its normal wet season level at elevation 174 ft, the low-flow gate will be closed and the rubber dam will be deflated.

Normal Operations Levels	
Wet Season	El. 174 ft
Dry Season	El. 180 ft

Wet season flood detention operations in Phoenix Lake basin will be primarily triggered by forecasts of potential flooding in Ross Creek and Corte Madera Creek in Ross. Phoenix Lake will be operated prior to a forecasted potential flood; during a flood, it will operate passively, i.e., on its own. Flood detention operations will follow a two-step procedure. The first step is initial drawdown of the lake and the second step is final drawdown of the lake and maintained opening of the low-level outlet. The first step can

occur at any time during the wet season. Watershed moisture conditions will be continually monitored by tracking soil moisture content, groundwater levels, discharges from seeps and springs, and base flows in creeks. When this monitoring indicates watershed moisture approaching saturation, then the lake will be gradually drawn down to elevation 160 ft, 14 ft below the existing spillway crest (Note: 23-hours is required for Step 1 drawdown; see Figure 2), and maintained at that level using the newly modified 160 ft-elevation lake level-control intake. (Note: It is possible that the initial drawdown will not happen during very dry years when the water supply of Phoenix Lake is needed most). The second step will be triggered by a forecast of potential flooding issued by the National Weather Service, in which case the low level outlet will be opened and the lake will be further drawn down 20 ft (Note: 24-hours is required for Step 2 drawdown; see Figure 2), to elevation 140 ft and maintained at that level using the newly modified 140 ft-elevation lake level control intake. The low-level outlet will remain open thereafter, continuing on its own to pass lake to Ross Creek below. The lake will begin to fill, passively, during the storm as inflow into the lake exceeds outflow through the low-level outlet. As the lake level rises and approaches the spillway the rubber dam will be inflated raising the spillway level by 6 ft and adding 120 acre-feet of attenuation capacity to the lake. During an extreme flood event, if the lake level rises above the rubber dam, water will flow over the rubber dam and through the spillway.

After the storm passes and flows in the creek subside, floodwaters temporarily stored in the detention basins will be released back to the creek, safely and in a controlled and coordinated fashion, at a rate that, when combined with the natural creek flow, is contained in the channel. As soon as is safe and practical Phoenix Lake will be drawn back down to its pre-flood, ready, condition at elevation 160 ft. Several days following a heavy storm event, if monitoring indicates watershed moisture returns to normal, the low level outlet will be closed and the lake will be refilled to its normal wet season operating level of 174 ft.

The wet season flood detention operations will generally occur between December 1st and March 15th. After March 15th, refilling the lake for dry season water supply will be the focus. As baseflows and freshet flows refill the lake in the spring, the rubber dam will be inflated and the lake will be refilled to elevation 180 ft, which is 6 ft higher that its existing full pool level and 120 acre-ft greater in terms of storage. The added storage will be available to MMWD for municipal use during the dry season.

Figure 1 Phoenix Lake Operations Rule Curve

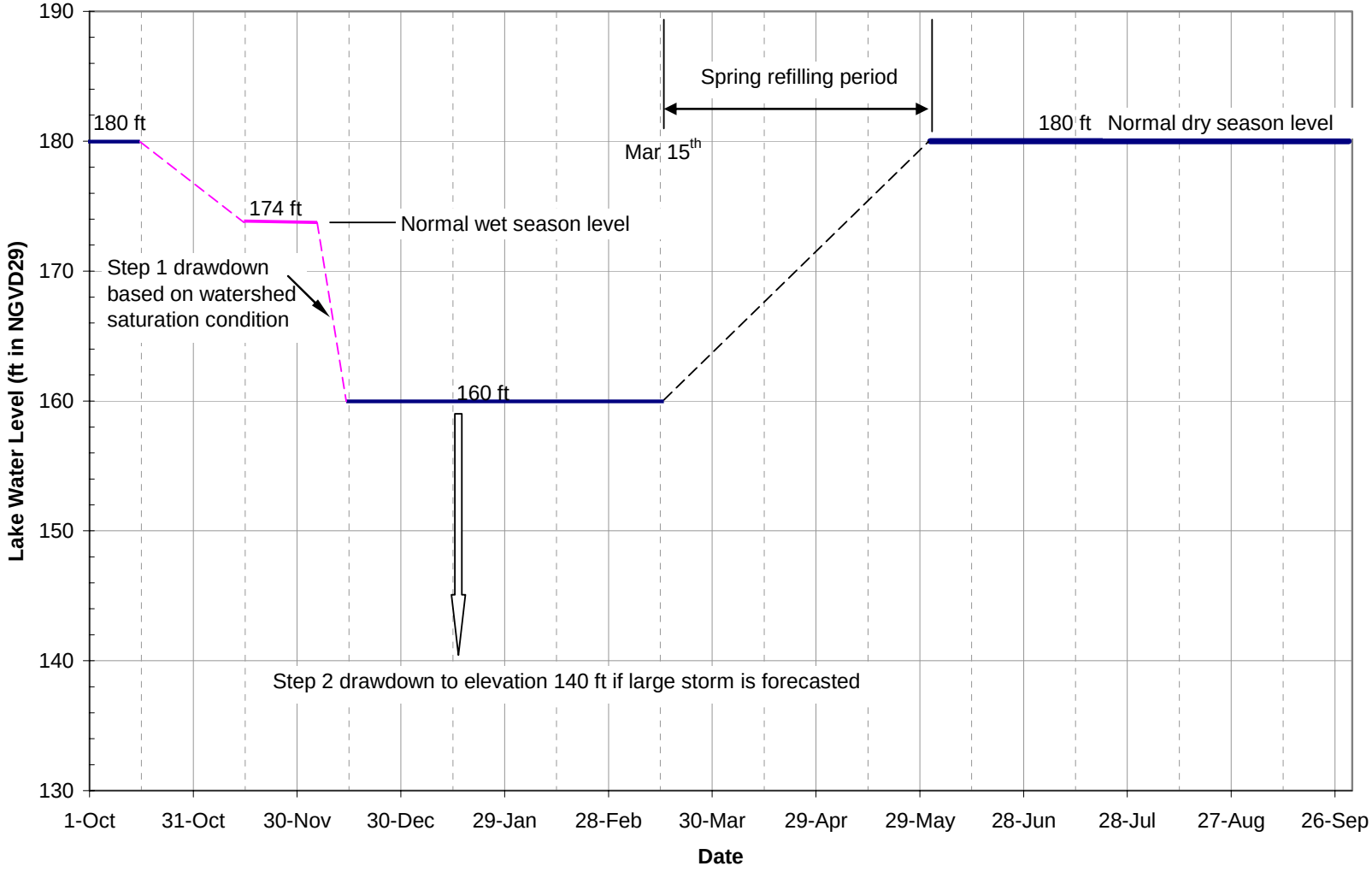
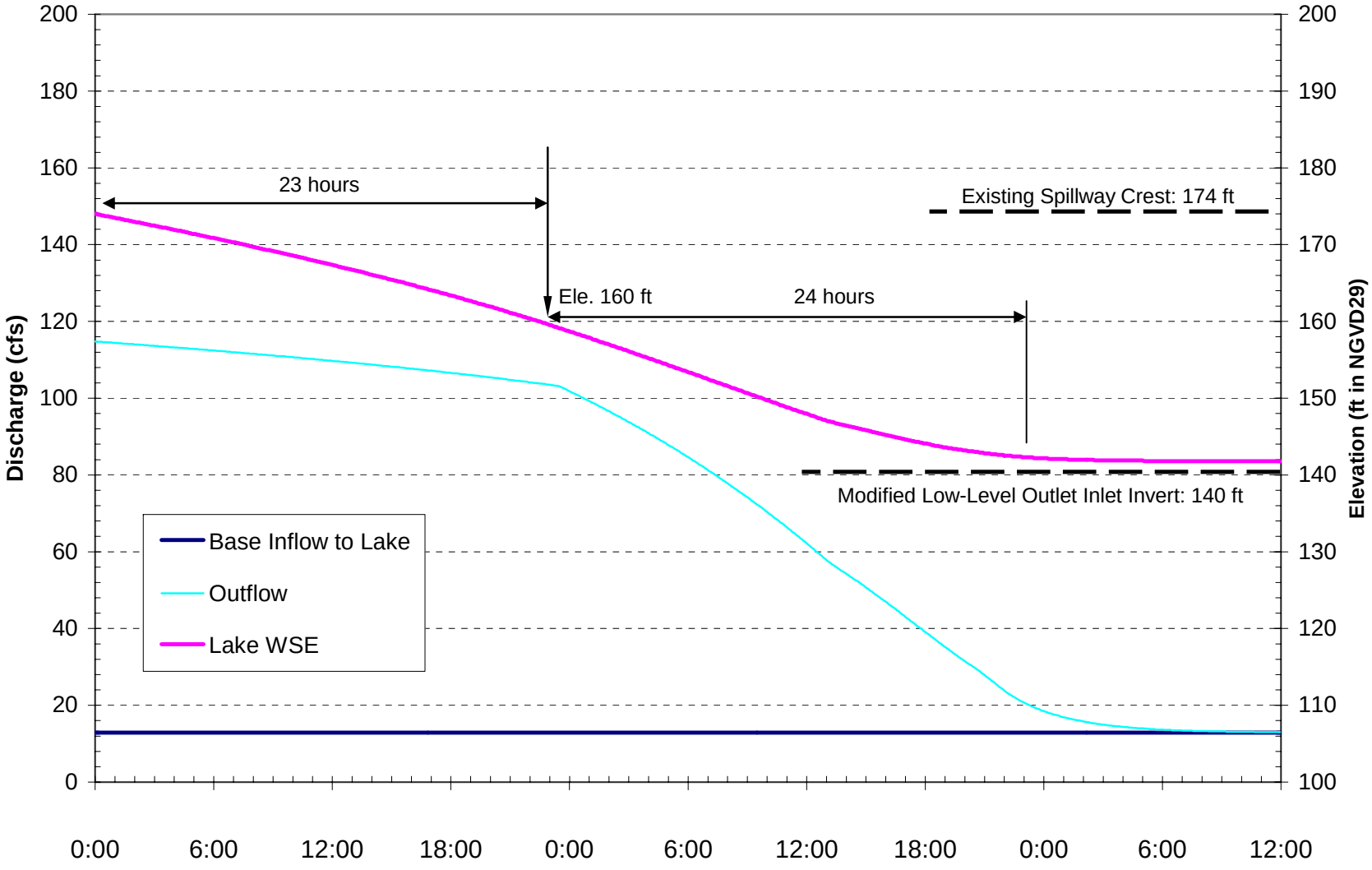


Figure 2 Winter Baseflow Routing Analysis through Phoenix Lake Dam with the 30" Low-Level Outlet Open Indicates That 23 Hours are Needed to Drawdown the Lake from Elevation 174 ft to 160 ft, and 24 Hours are Needed to Further Drawdown the Lake from Elevation 160 ft to 140 ft



Appendix 3 to Attachment 3

Phoenix Lake Spillway Hydraulic Evaluation

Stetson Engineers Inc.
February 22, 2011

Introduction

In 1979, the Division of Safety of Dams (DSOD) made an investigation of the original spillway of Phoenix Lake (which had a crest elevation of 180 feet). A design flood with an estimated 30,000-year return period was used in the investigation[1]. As a result, DSOD concluded that the original spillway was insufficiently sized to carry the 30,000-year design flood[2]. MMWD was requested by DSOD to modify the spillway so that it can 1) carry a suitable design flood, and 2) lower the normal water surface of the lake six feet below the original spillway crest to provide for an additional degree of seismic safety. In 1985 MMWD modified the spillway by lowering the crest by six feet, from elevation 180 feet down to elevation 174 feet (see the photo below).

Photo of Existing Phoenix Lake Spillway

[1] The DSOD-estimated 30,000-year flood hydrograph in 1979 (which has a peak flow of about 3,000 cfs) was verified by Sierra Hydrotech Engineering Consultants (1980). The current DSOD-used design flood, which was prepared in 1984, is for a 35,000-year return period producing a peak flow of about 2,660 cfs. To be conservative, the 30,000-year flood hydrograph prepared by DSOD in 1979, which has a higher peak flow, was directly used in this hydraulic evaluation.

[2] The problem of the original spillway capacity was not related to the spillway crest itself, but rather to the inability of the water to accelerate rapidly enough to pass through the narrower transition farther downstream along the spillway at the chute at a depth which would not cause overtopping or damage to the spillway roof or cover.

Phoenix Lake currently functions as a de facto detention basin. During heavy storms, the lake water level rises above the spillway crest. This resulting "surcharge" storage attenuates stormflow and reduces the peak flow in the creek downstream. In order to enhance the attenuation effect for peak flow reduction purposes, the existing low-level outlet structure will be modified and a 6-foot high inflatable/deflatable rubber dam installed across the spillway. By installing a 6-foot high inflatable/deflatable rubber dam across the spillway, the lake level will be raised to its pre-1985 elevation of 180 feet during floods when additional storage capacity and attenuation are needed.

The following analyses were conducted to evaluate the spillway hydraulic capacity under existing and the proposed project conditions:

- Flood routing analysis through the lake for the 30,000-year design flood using HEC-HMS hydrologic modeling to determine peak water level in the lake and peak discharge through the spillway.
- Peak water surface profile analysis along the spillway and chute using HEC-RAS steady-state hydraulic modeling to determine whether the spillway has an adequate capacity to pass the peak discharge analyzed from the flood routing analysis.

Flood Routing Analysis through the Lake Using HEC-HMS

The DSOD-developed 30,000-year flood hydrograph was routed through the lake and spillway to obtain the time-history of lake level and spillway discharge. This is essentially a process of accounting for inflow, storage, and outflow throughout the duration of the design flood. It was assumed that the lake is full at the beginning of the design flood. This assumption represents the worst case for the proposed project condition, in which the low-level outlet is supposed to be open prior to a forecasted flood.

Figure 1 shows the spillway discharge curves used in the modeling analysis. Figures 2 and 3 show the HEC-HMS simulated lake levels and outflows under the 30,000-year flood hydrograph for the existing and project conditions, respectively. Under existing conditions, the routed 30,000-year peak outflow is about 2,438 cfs, and the lake water surface elevation peaks at 185.8 ft. Under project conditions, the routed peak outflow is about 2,428 cfs, and the lake water surface elevation peaks at 188.6 ft. In order for the proposed project to meet the DSOD minimum requirement of 1.5 ft residual freeboard, the existing dam (el. 189 ft) needs to be raised by at least 1.1 ft.

Peak Water Surface Profile Analysis Using HEC-RAS

A HEC-RAS steady-state hydraulic model was developed to analyze the water surface profile at the peak discharge over the spillway. As-built designs of the existing spillway (Figure 4) were used to prepare geometry data for the model. A site visit was made on February 25, 2011 to verify the as-built designs and to provide field observations for the hydraulic modeling. The roughness coefficients or Manning's n of 0.018 were used in the model for the concrete spillway.

Figure 5 compares the HEC-RAS simulated water surface profiles between existing and project conditions. Also shown in this figure are the top of bank profiles on both sides of the spillway and simulated critical depth. The results show that the spillway has adequate capacity to pass the routed peak discharge. The results also show that there is little difference in water surface profile below the inflated rubber dam between existing and project conditions. This is expected because the inflated rubber dam would not have any effects on the downstream hydraulics.

Figure 1 Phoenix Lake Spillway Discharge Curves Under Existing and Project Conditions

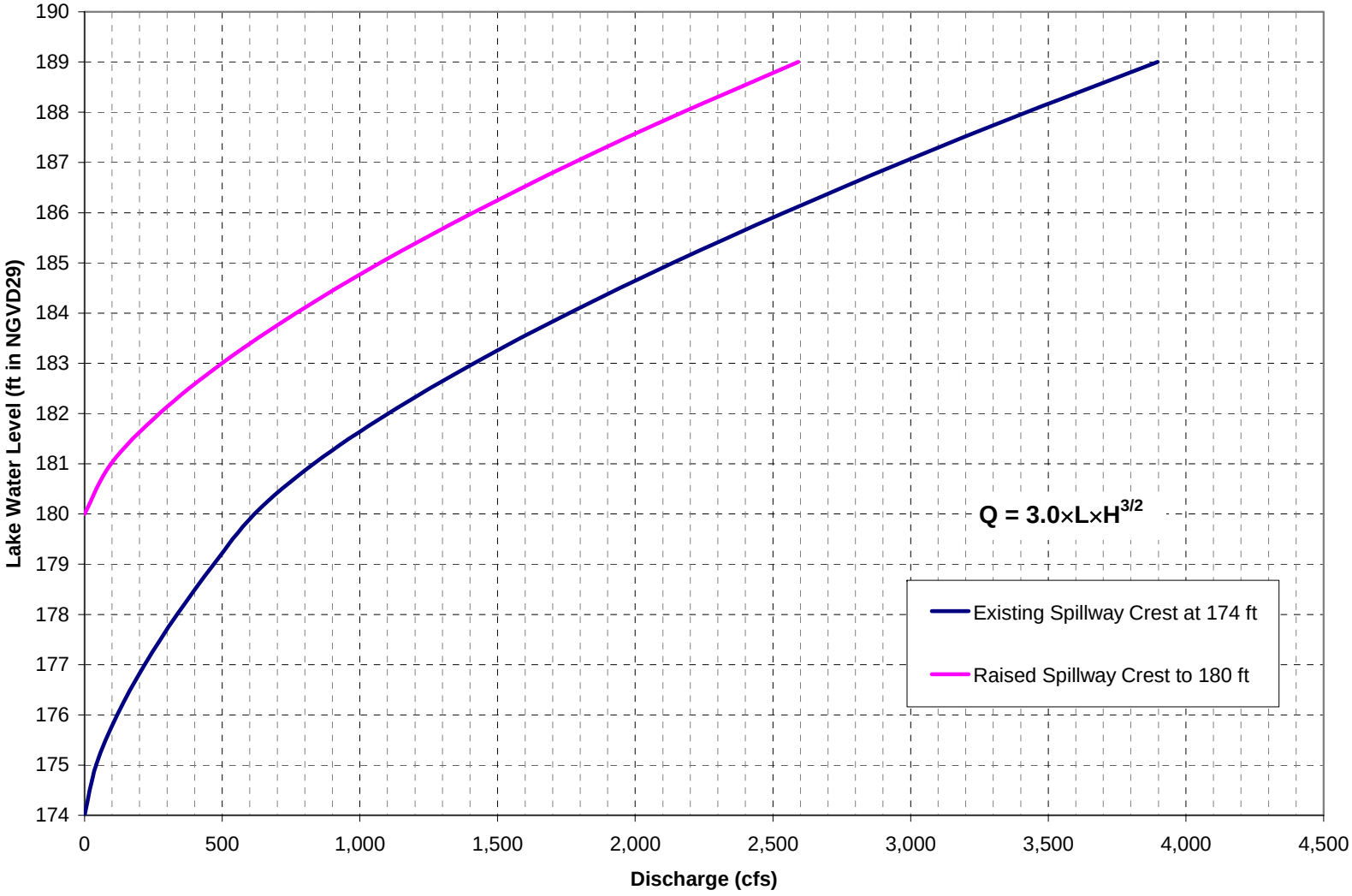


Figure 2 HEC-HMS Simulated Lake Levels and Outflows Under the 30,000-Year Design Hydrograph – Existing Condition

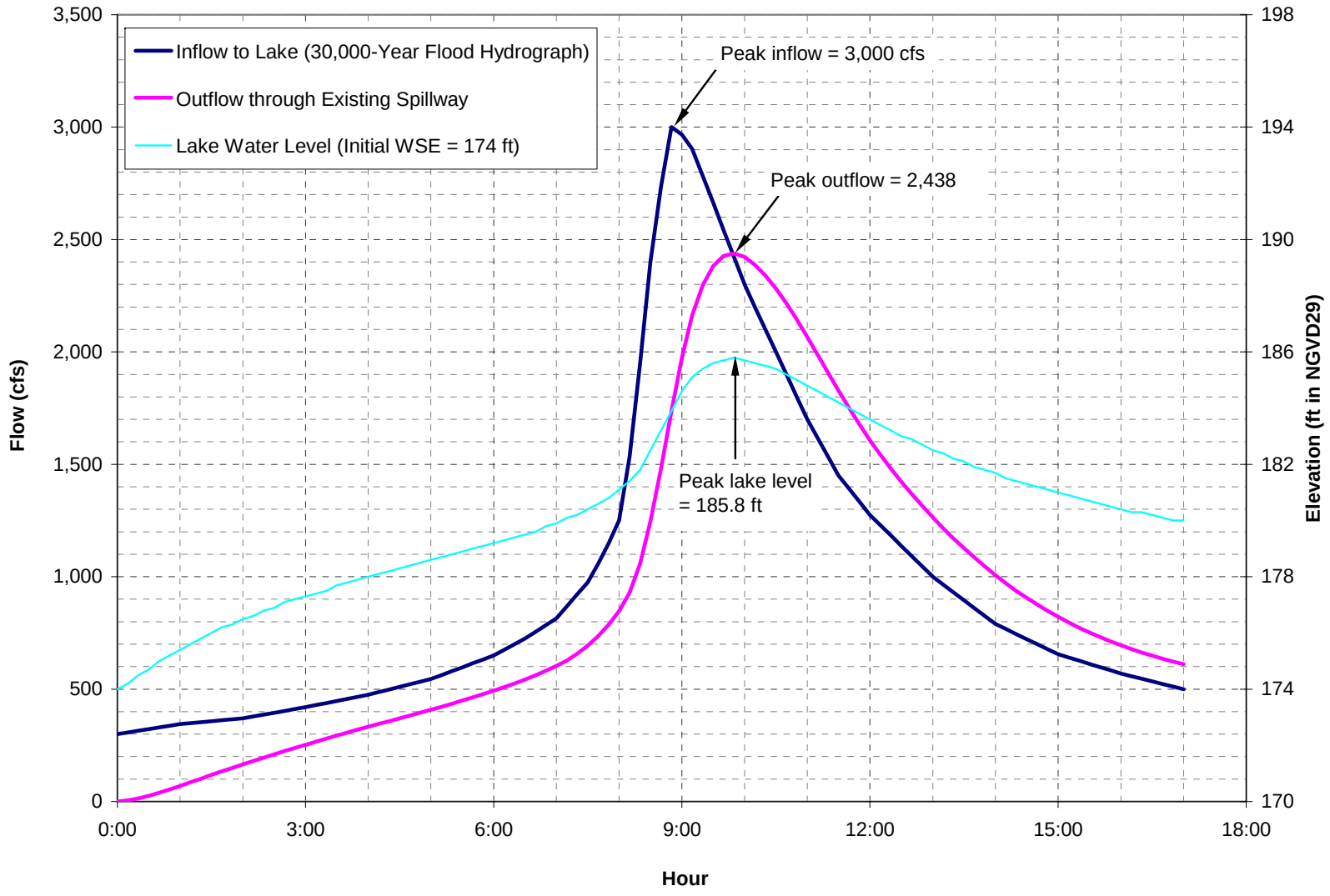
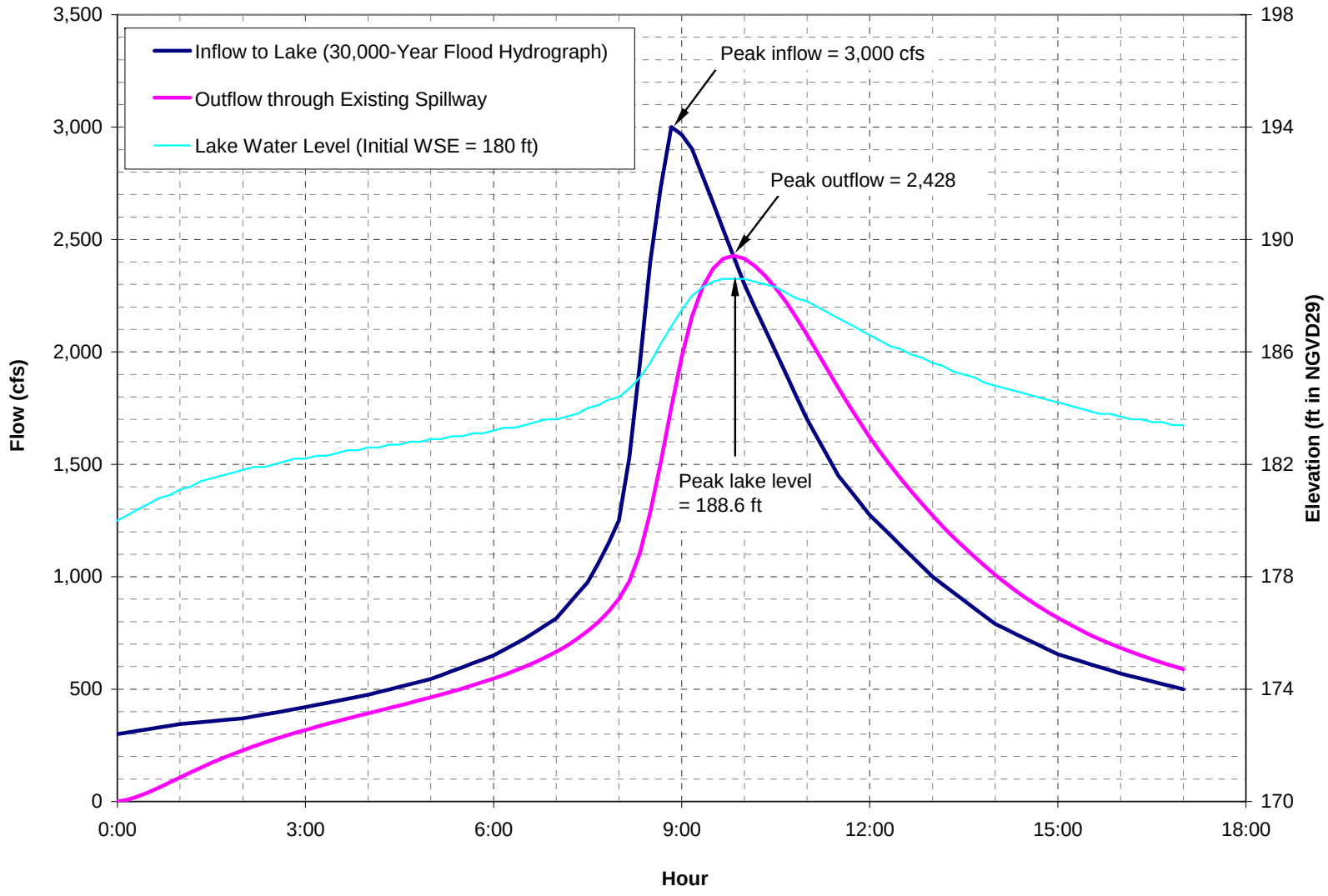


Figure 3 HEC-HMS Simulated Lake Levels and Outflows Under the 30,000-Year Design Hydrograph – Project Condition



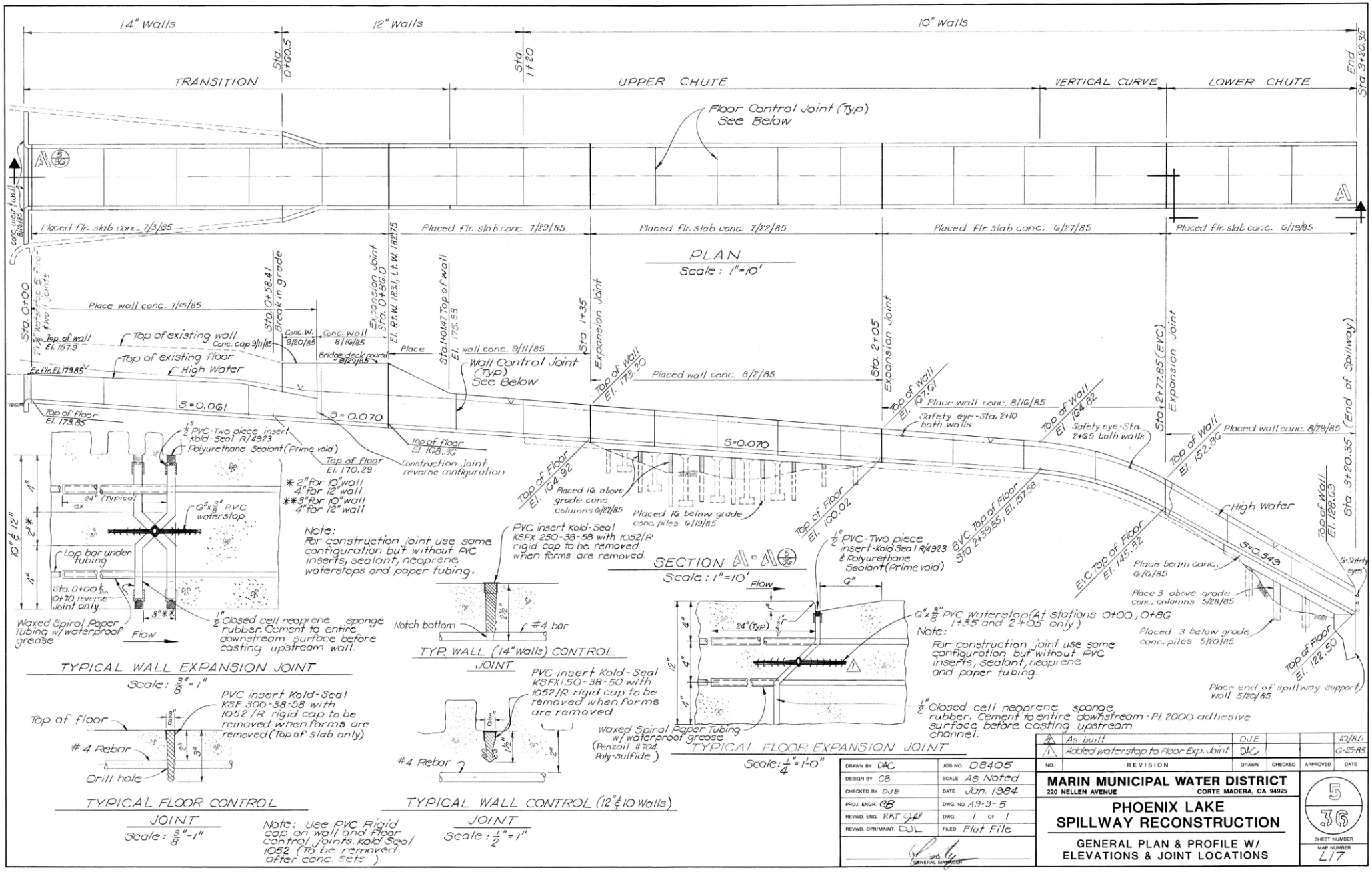
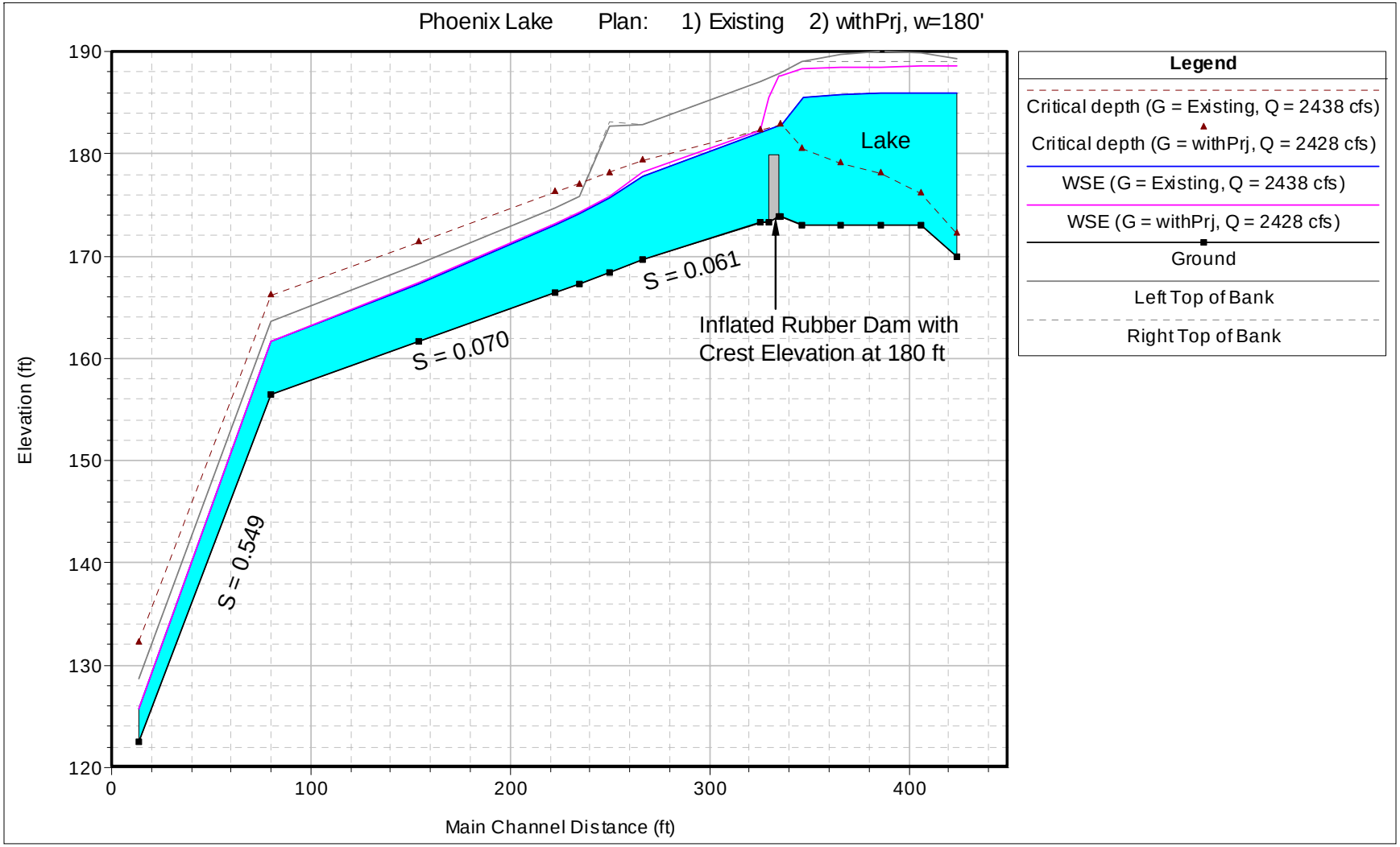


FIGURE 4 - As-Built Designs of Phoenix Lake Spillway and Chute

Figure 5 Comparison of HEC-RAS Simulated Water Surface Profiles between Existing and Project Conditions



Appendix 4 to Attachment 3

Geotechnical Evaluations (2) of Phoenix Lake Dam and Reservoir

1) **Preliminary Study**

2) **Sensitivity Analysis**

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PRELIMINARY GEOTECHNICAL EVALUATION
DB5 – PHOENIX LAKE DAM & RESERVOIR
WATERSHED FLOOD DAMAGE REDUCTION & CREEK MANAGEMENT STUDY
MARIN COUNTY, CALIFORNIA

May 6, 2010

Project 960.05

Prepared For:
Marin County Flood Control and
Water Conservation District, Zone 9
c/o Stetson Engineers
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San Rafael, CA 94901

CERTIFICATION

This document is an instrument of service, prepared by or under the direction of the undersigned professionals, in accordance with the current ordinary standard of care. The service specifically excludes the investigation of radon, asbestos or other hazardous materials. The document is for the sole use of the client and consultants on this project. No other use is authorized. If the project changes, or more than two years have passed since issuance of this report, the findings and recommendations must be reviewed by the undersigned.

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PRELIMINARY GEOTECHNICAL EVALUATION
DB5 – PHOENIX LAKE DAM & RESERVIOR
WATERSHED FLOOD DAMAGE REDUCTION &
CREEK MANAGEMENT STUDY
MARIN COUNTY, CALIFORNIA

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APPENDIX A – PREVIOUS BORING LOGS

PRELIMINARY GEOTECHNICAL EVALUATION
DB5 – PHOENIX LAKE DAM & RESERVIOR
WATERSHED FLOOD DAMAGE REDUCTION &
CREEK MANAGEMENT STUDY
MARIN COUNTY, CALIFORNIA

I INTRODUCTION

This report presents the results of our preliminary geotechnical evaluation for Detention Basin 5 (Phoenix Lake Dam and Reservoir) as part of the Watershed Flood Damage Reduction and Creek Management Study, Marin County, California. The location of the project site is shown on Figure 1, Site Location Map. This report is intended for the exclusive use of Marin County Flood Control and Water Conservation District, Stetson Engineers and their consultants on this project. No other use is authorized without the express written consent of Miller Pacific Engineering Group. The purpose of our current services is to review available data, evaluate geologic and geotechnical conditions, and provide our opinion regarding the feasibility of using of Phoenix Lake as a flood control reservoir.

In accordance with our agreement dated January 5, 2010, the scope of our geotechnical services includes the following:

- Review of geologic and geotechnical data available from the design team and local government sources (County of Marin, Marin Municipal Water District, local city files and Division of Safety of Dams (DSOD)), as well as, review of published USGS and state geologic data, and relative Miller Pacific Engineering Group reference data,

- Site reconnaissance to observe the site conditions, project features, constraints and site access. Examination of the slopes and general reservoir area for existing landslides, rock outcrops, structure and stratigraphy,

- Air photo examination for evaluation of geologic surface features suggestive of instability, faulting or shear zones,

- Review topographic mapping provided by the design team,

- Attendance at project meetings to consult with project team regarding project status, detention basin storage capacity, drawdown rates and reservoir levels,

- Opinion of rim slope stability associated with use of the reservoir as a detention basin during flood events,

- Consult with DSOD regarding design requirements and determine probabilistic ground shaking accelerations at the project site for use in pseudo-static slope stability,

- Develop a model of the dam from information available in the project files and from the previous geotechnical exploration and laboratory testing performed at the site. This may include some estimated soil properties based on the soil type and construction practices,

- Perform preliminary static and pseudo-static stability analyses using a cross-section near the center of the dam. We will evaluate dam stability for various reservoir levels, sudden drawdown conditions and potential seismic deformations using procedures published by Bray and Travasarou, and

- Prepare technical memorandum describing the geologic and geotechnical evaluation, site seismicity, dam stability and geotechnical feasibility of using Phoenix Lake as a flood control reservoir.

Our current scope of services did not include any subsurface exploration or laboratory testing. Theses services may be performed as part of a more detailed investigation and design of the flood control improvements at Phoenix Lake Dam.

II. PROJECT DESCRIPTION

Phoenix Lake is a recreational reservoir in southern Marin County owner by Marin Municipal Water District. We understand the Marin County Flood Control and Water Conservation District would like to utilize this reservoir for short term storage of storm water to aid in flood management of Corte Madera and San Anselmo Creek. Phoenix Lake Dam is an earth fill dam constructed in 1907 utilizing the construction techniques of that time. The existing Phoenix Dam is approximately 94-feet in height (crest elevation 189-feet), 350-feet in length and has a crest width of approximately 22-feet with slopes varying between approximately 1.5:1 (horizontal:vertical) to 3:1. From the early 1900's until the mid 1980's the reservoir water level was maintained at approximately elevation +180 feet[1]. The dam was modified in the late 1960's to improve performance during future seismic events.

As part of the spillway retrofit work performed in the 1980's, the spillway elevation was lowered to elevation + 174-feet. The purpose of this study is to evaluate the potential to temporarily increase the water level for storm water storage. In consultation with the project team, we have evaluated the potential for temporary increases in the reservoir level to elevations of +180 and +184 to allow greater water storage during significant rain events to reduce the potential for flooding of downstream properties.

[1] All elevations given in this report are relative to the NGVD29 datum.

III. REFERENCE DATA

We reviewed various geotechnical reports and data on file at the Division of Safety of Dams (DSOD) that have been performed regarding Phoenix Lake Dam. The relevant reports reviewed are listed below:

- Dames & Moore "Stability Evaluation Phoenix Lake Dam," October 1959,
- Leeds, Hill & Jewett, Inc., "Methods of Strengthening Phoenix Lake Dam," March 1966,
- Marin Municipal Water District, "Specifications for the Rehabilitation of Phoenix Lake Dam," Undated (1968?),
- Earth Sciences Associates, "1977-78 Evaluation of Seismic Stability Phoenix Lake Dam," March 1978,
- Marin Municipal Water District, "Phoenix Dam Spillway Seismic Analysis," March 1980,
- Division of Safety of Dams, Department of Water Resources, "Phase 1 Inspection Report for Phoenix Lake Dam," May 1981, and
- Earth Sciences Associates, "Phoenix Lake Spillway Reconstruction Geotechnical Report," February 1984.

The Dames & Moore (1959), Leeds, Hill & Jewett, Inc. (1966), and Earth Sciences Associates (1978) reports analyzed various stability conditions of Phoenix Dam including seismic and rapid drawdown conditions. The remaining reference reports included design specifications, seismic analysis of the spillway structure, DSOD inspection report, geotechnical report for the spillway structure reconstruction, and various general correspondences. The three pertinent geotechnical analysis reports are outlined below:

Dames & Moore – The 1959 report was issued prior to the retrofit of Phoenix Dam. Dames & Moore analyzed seismic conditions utilizing a seismic load of "10% gravity", or 0.10 g, and rapid drawdown conditions (completely draining the reservoir) on both the upstream and downstream slopes. Based on the results of the slope stability analyses, Dames & Moore concluded the downstream seismic and static factors of safety were 1.2 and were "adequate". Additionally, Dames & Moore concluded the computed upstream factor of safety of 1.15 during rapid drawdown was "not high" and the drawdown of the dam should be controlled.

Leeds, Hill, & Jewett – The 1966 report prepared by Leeds, Hill, & Jewett, Inc. (LHJ) provided Marin Municipal Water District (MMWD) with three conceptual options to retrofit the existing dam to strengthen the dam. The conceptual plans included:

Plan I – Repair Plan I was originally developed by MMWD that included flattening the slopes by adding an impervious "blanket" on the upstream bank, buttressing the downstream side with a semi-impervious material on the downstream bank, constructing a new outlet tunnel, and extending the existing spillway.

Plan II – Repair Plan II included flattening the upstream bank by excavation, flattening the downstream bank by filling, construction of a hydraulically operated gate controlled inlet, and the construction of a new spillway.

Plan III – Repair Plan III included flattening the upstream bank by adding an impervious "blanket", constructing a drain on the downstream toe of the dam, and constructing an earth buttress on the downstream toe to confine the drain and provide additional support.

Leeds, Hill, & Jewett performed seismic slope stability analyzes utilizing a peak ground acceleration (PGA) of 0.15 g on two of the conceptual plans (Plans II and III), LHJ did not analyze Plan I due to the relatively high costs of implementing Plan I. The results of the stability analyses performed on Plan II indicate the upstream and downstream factors of safety were approximately 1.70 and 1.20, respectively. LHJ concluded the factors of safety for Plan II indicated "ample stability". The results of the stability analyses for Plan III indicated the upstream factor of safety was approximately 1.25 and downstream factor of safety was lower. However, LHJ concluded that the downstream results were "not believed valid" due to the implementation of a drain at the toe of the dam and the placement of impervious blanket on the upstream slope. They concluded the phreatic surface would be "significantly lowered" with Plan III and therefore would "be much more effective in stabilizing the existing stratified, somewhat pervious dam than simply by the addition of a pervious stabilizing fill downstream only, as in Plan II". Therefore, LHJ ultimately recommended that MMWD construct Plan III and based on the current configuration of the Phoenix Dam it appears that Plan III was designed and constructed.

Earth Sciences Associates – The report prepared by Earth Sciences Associates (ESA) was performed after Phoenix Dam was retrofitted as described in the report issued by LHJ (Plan III). ESA performed a SHAKE analysis utilizing a design earthquake event of the San Andreas Fault rupturing with magnitude 8.4. The results of ESA's SHAKE analyses provided the predicted seismic acceleration throughout the height to the dam (0.56 g at the base to 1.0+ g at the crest). These accelerations were utilized to conservatively estimate the potential upslope deformation during the design seismic event and concluded a potential crest settlement of 5.3-feet and down slope movement of 11-feet.

IV. SITE CONDITIONS

A. Regional and Local Geology

The site is located within the Coast Range Geomorphic Province of California. The regional bedrock geology mostly consists of complexly folded, faulted, sheared, and altered sedimentary, igneous, and metamorphic rock of the Jurassic-Cretaceous age (65-190 million years ago) Franciscan Complex. The Franciscan is characterized by a diverse assemblage of greenstone, sandstone, shale, chert, and mélange, with lesser amounts of conglomerate, calc-silicate rock, schist and other metamorphic rocks.

The regional topography is characterized by northwest-southeast trending mountain ridges and intervening valleys that were formed by compressive movement between the North American and the Pacific Plates. Continued deformation and erosion during the late Tertiary and Quaternary Age (the last several million years) formed the prominent coastal ridges and the inland depression that is now the San Francisco Bay. The more recent seismic activity within the Coast Range Geomorphic Province is concentrated along the San Andreas Fault zone, a complex group of generally north to northwest trending faults.

Additional geologic mapping was performed by Earth Sciences Associates (1978) and indicate Phoenix Lake is predominately surrounded by greywacke sandstone. Minor inclusions of serpentinite, chert, and greenstone are mapped within the greywacke. The drainage swales surrounding Phoenix Lake contain colluvial and alluvial deposits. The mapping also indicates three landslides are located on the surrounding rim of Phoenix Lake. The largest mapped landslide is located on the northwestern tip of Phoenix Lake. A Site Geology Map is presented on Figure 2.

B. Seismicity

1. Active Faults in the Region – The project property is located within the seismically active California Coast region and will therefore experience the effects of future earthquakes. Such earthquakes could occur on any of several active faults within the region. The California Geological Survey (CGS)–formerly California Division of Mines and Geology (2000)–has mapped various active and inactive faults in the region. Active faults are defined by the CGS as those that show evidence of movement in the past 11,000 years and have reported slip rates of >0.1 mm/year.

   Based on the CGS information (1999) there are no known active faults passing through or in the immediate proximity of the property. The closest known active fault is the San Andreas Fault, which is located about 6.4 miles (10.3 kilometers) to the west. The locations of the

active faults relative to the project site are shown on Figure 3.

2. Historical Fault Activity - Numerous earthquakes have occurred in the region within historical times. The results of our computer database search indicate that 70 earthquakes (Richter Magnitude 5.0 or larger) have occurred within 100 kilometers (62 miles) of the site between 1735 and 2010. Significant earthquakes to affect the project site are summarized in Table A.

TABLE A
SIGNIFICANT EARTHQUAKE ACTIVITY
PHOENIX LAKE DAM
ROSS, CALIFORNIA

Epicenter (Latitude, Longitude)	Magnitude	Fault	Year	Distance
37.80, -122.20	6.8	Hayward	1836	37 km
37.60, -122.40	7.0	San Andreas	1838	42 km
37.70, -122.10	6.8	Hayward	1868	50 km
38.20, -122.40	6.2	Rodgers Creek	1898	31 km
		Post Construction		
37.70, -122.50	8.2	San Andreas	1906	29 km
37.67, -122.48	5.3	San Andreas	1957	32 km
38.46, -122.69	5.7	Hayward	1969	56 km
37.85, -121.82	5.8	San Gregorio	1980	67 km
37.91, -121.69	4.5	San Andreas	1999	10 km
37.43, -121.77	5.6	Calaveras	2007	91 km

Reference: USGS (2010)

Probability of Future Earthquakes – The historical records do not directly indicate either the maximum credible earthquake or the probability of such a future event. To evaluate earthquake probability in this region, the USGS has assembled a group of researchers into the "Working Group on California Earthquake Probabilities" to estimate the probabilities of earthquakes on active faults. Potential sources were analyzed considering fault geometry, geologic slip rates, geodetic strain rates, historic activity, and micro-seismicity, to arrive at estimates of probabilities of earthquakes with a Moment Magnitude greater than 6.7 by 2037.

The probability studies focused on seven "fault systems" within the Bay Area. Fault systems are composed of different, interacting fault segments capable of producing earthquakes within the individual segment or in combination with other segments of the same fault system. The probabilities for a magnitude 6.7 or greater earthquake before 2032 on fault segments within the

San Francisco Bay Area are presented on Figure 3.

In addition to the seven fault systems, the studies included probabilities of "background earthquakes." These earthquakes are not associated with the identified fault systems and may occur on lesser faults (i.e., West Napa) or previously unknown faults (i.e., the 1989 Loma Prieta and 2000 Napa/Mt. Veeder Earthquake). When the probabilities on all seven fault systems and the background earthquakes are combined mathematically, there is a 62 percent chance for a magnitude 6.7 or larger earthquake to occur in the Bay Area by the year 2032. Smaller earthquakes (between magnitudes 6.0 and 6.7), capable of considerable damage depending on proximity to urban areas, have about an 80 percent chance of occurring in the Bay Area by 2032 (USGS, 2002). Additional studies by the USGS regarding the probability of large earthquakes in the Bay Area are on going. These current evaluations include data from additional active faults and updated geological data.

C. Aerial Photograph Review

We reviewed several aerial photographs obtained from Pacific Aerial Surveys of Oakland, California. The photographs reviewed are summarized below:

- September 06, 1946, AV9-2-1 (1:23,600) – This aerial photograph is the earliest available that shows Phoenix Lake and Phoenix Lake Dam. At the time of the photograph, Phoenix Lake Dam appears to be operating at a relatively high water elevation. The dam is highly vegetated with grasses. A significant number of trees have encroached onto the southwestern abutment and toe of the dam.

- July 02, 1970, AV957-03-25 (1:12,000) – This areal photograph was taken in the summer of 1970 and the vegetation on the dam appears to be dead/dormant and lighter in color. The light color and bright summer sun caused the photo to "wash-out", concealing the finer details of the dam. However, it appears trees have been removed from the southeastern abutment. It also appears the additional buttress and bench has been constructed on the downstream side of the dam.

- April 01, 1980, AV1840-03-29 (1:12,000) – The aerial photograph is relatively unchanged from the previous photograph. The spillway is more detailed in the 1980 photograph and it appears to be a covered structure.

- May 03, 1982, AV2140-03-25 (1:12,000) – The aerial photograph is relatively unchanged from the previous photograph. However, it appears some erosion has occurred at the spillway outlet.

- April 19, 1986, AV2860-10-18 (1:12,000) – The aerial photograph is relatively unchanged from the previous photograph However the water level of Phoenix Lake has reached capacity and the spillway is operating.

- March 15, 1990, AV3766-8-29 (1:12,000) – The aerial photograph is relatively unchanged from the previous photograph. However, it appears the erosion at the spillway outlet has been repaired.
- August 14, 1995, AV4890-16-54 (1:12,000) – The aerial photograph is relatively unchanged from the previous photograph.

- March 06, 2005, KAV9010-19-1 (1:12,000) – The aerial photograph is relatively unchanged from the previous photograph.

D. Site Reconnaissance and Surface Conditions

We performed a site inspection on February 17, 2010 to observe existing conditions and identify any significant visual threats that could preclude use of Phoenix Lake as a flood-control detention basin. Our geologic and geotechnical site reconnaissance is summarized below with our observations noted on the attached Figure 2, Geologic Map.

The reservoir is surrounded by rugged terrain, characterized by steep slopes and deeply incised drainage channels. Bedrock typically is composed of Franciscan sandstone and shale, often interbedded in discontinuous layers, are visible in outcrops along most of the shoreline and adjacent trails. Bedrock typical of this portion of Mount Tamalpais is especially well-exposed just east of the dam along the shoreline, and in a large cut slope along the rim trail approximately ¼ miles west of the dam. Locally, bedrock may be thin- to thick-bedded and relatively fresh. In general, bedrock is massive and highly altered through physical and chemical weathering processes.

The slopes surrounding the lake are generally steep, with inclinations ranging from 0.5:1 (horizontal:vertical) to 3:1 or shallower. In general, slopes consist of a few feet of colluvial and residual soil over relatively competent bedrock. On slopes where colluvial deposits are present, some soil creep is suspected due to the overall “terraced” appearance. On slopes where vegetation is more prevalent and soil deposits are thicker, small landslides and debris flows are common. Drainage channels are typically filled with debris, including soil, rock, and vegetation. Cut slopes along adjacent hiking trails commonly exhibit evidence of instability, including sloughing, raveling, and debris flows.

Two larger landslides were noted during our reconnaissance. Both are on the north shore of the lake, and have been mapped previously by Rice (1976). The main rim trail has been graded across both slides. One slide toes into the lake near its western end, while the other toes into a tributary which discharges at the north end of the dam. Both landslides deposited soil and rock debris into the reservoir which has likely reduced the storage capacity.

Phoenix Lake Dam appears to be in good condition. We observed erosion channels at various locations along the downstream edges the dam, incised to depths of less than 1 foot. Some surface rills were present on both upstream and downstream faces of the dam to a maximum depth of approximately 3-inches, though they were uncommon. We did not observe any signs of seepage through the dam or visible damage to the spillway walls, floor, or piers.

E. Interpreted Subsurface Conditions and Laboratory Testing

Our scope of services did not include performing a subsurface exploration. However, subsurface explorations were performed by Dames & Moore (1959) and Earth Sciences Associates (1978). The approximate boring locations of the previous subsurface explorations are shown on Figure 4. The subsurface explorations performed by the aforementioned firms observed silty sands (SM) and silty clays (CL) within the upper 20-feet of the embankment. The lower portions of the embankment consisted of gravely sandy clay (CL) and clayey sandy gravels (GC). The observed bedrock below the earth dam is graywacke sandstone with minor inclusions of shale and metagraywacke. The boring logs performed by Dames & Moore and Earth Sciences Associates are presented in Appendix A.

Both Dames & Moore and Earth Sciences Associates performed laboratory testing on select soil samples to determine the pertinent engineering soil properties. The tests performed included moisture content, dry density, unconfined compression, and consolidated undrainded triaxial tests with pore pressure measurements (TXCU-pp). The test results were utilized to develop a strength profile for Phoenix Dam. The summarized results of the laboratory tests and outlined the strength data developed by Dames & Moore and Earth Sciences Associates are presented on Figure 5.

We plotted the existing laboratory shear strength data versus depth to identify trends in strength values versus depth of the dam. Considering the variability of the laboratory data, we developed a shear strength versus depth profile for use in our analyses, as shown on Figure 6. For comparison, we also plotted the shear strength profiles developed and utilized by Dames & Moore and Earth Sciences Associates.

V. GEOLOGIC HAZARDS EVALUATION

A. General

This section identifies potential geologic hazards at the project site, their significant adverse impacts, and recommended mitigation measures. The significant geologic hazards at the project site are strong seismic ground shaking, potential slope instability, and erosion. We judge that other geologic/seismic hazards are of lesser concern.

B. Fault Surface Rupture

Pursuant to the Alquist-Priolo Special Studies Zone Act of 1972, the California Geological Survey (CGS) (formerly California Division of Mines and Geology (CDMG)) produced 1:24,000 scale maps showing all known active faults and delineating boundaries to either side of these faults called "Special Studies Zones." Within these zones, the Act requires that a fault investigation be undertaken. The intent of the Act and required investigation is to assure that structures for human habitation are not located astride an active fault trace. Our review of the Special Studies maps (CGS, 2000) and our aerial photograph interpretation indicate that the closest active fault trace is the San Andreas Fault is located about 10 km west of the site. The site is not within the special studies zone and the potential for surface fault rupture through the property is low.

No mitigation measures anticipated.

C. Seismic Shaking

The site will likely experience seismic ground shaking from future earthquakes in the San Francisco Bay Area. Earthquakes along several active faults in the region, as shown on Figure 3, could cause moderate to strong ground shaking at the site.

Deterministic Seismic Hazard Analysis – Deterministic Seismic Hazard Analysis (DSHA) predicts the intensity of earthquake ground motions by analyzing the characteristics of nearby faults, distance to the faults and rupture zones, earthquake magnitudes, earthquake durations, and site-specific geologic conditions. Empirical relations (Abrahamson and Silva, Boore and Atkinson, Campbell and Borzognia, Chiou and Youngs, and Idriss (2008)) for bedrock were utilized to provide approximate estimates of median peak site accelerations. A summary of the principal active faults affecting the site, their closest distance, moment magnitude of characteristic earthquake and probable peak ground accelerations (PGA), which an earthquake on the fault could generate at the site are shown in Table B.

TABLE B
DETERMINISTIC PEAK GROUND ACCELERATION
PHOENIX LAKE DAM
ROSS, CALIFORNIA

Fault	Moment Magnitude	Distance	Median PGA	84th% PGA
San Andreas	7.8	10 km	0.31 g	0.53 g
San Gregorio	7.2	21 km	0.16 g	0.29 g
Hayward	6.9	19 km	0.16 g	0.28 g
Point Reyes	6.9	22 km	0.13 g	0.25 g

References: Sources: USGS (2009), Abrahamson and Silva (2008), Boore and Atkinson (2008), Campbell and Borzognia (2008), Chiou and Youngs (2008), Idriss (2008)

Probabilistic Seismic Hazard Analysis – Probabilistic Seismic Hazard Analysis (PSHA) analyzes all possible earthquake scenarios while incorporating the probability of each individual event to occur. The probability is determined in the form of the recurrence interval, which is the average time for a specific earthquake acceleration to be exceeded. The design earthquake is not solely dependent on the fault with the closest distance to the site and/or the largest magnitude, but rather the probability of given seismic events occurring on both know and unknown faults.

Probabilistic seismic hazard analyses (PSHA) ground motions are determined in the form of recurrence intervals such as 10% chance of exceedance in 100 years. Each recurrence interval converts to a return period, for instance the return period for a probabilistic ground motion with a 10% chance of exceedance in 100 years is 949 years. Common PSHA recurrence intervals are 2% chance exceedance in 50 years (2,475 year return period) and 10% chance of exceedance in 50 years (475 year return period). Predicted accelerations for the common recurrence intervals are given below on Table C.

TABLE C
PROBABILISTIC PEAK GROUND ACCELERATION
PHOENIX LAKE DAM
ROSS, CALIFORNIA

Recurrence Interval	Return Period	PGA, g
10% in 50 years	475 years	0.42
2% in 50 years	2,475 years	0.72

References: National Seismic Hazard Map Program (USGS, 2008)

The potential for strong seismic shaking at the project site is high. Due to their close proximity and historical seismic activity, the San Andreas and Hayward Faults present the highest potential for severe ground shaking. The most significant adverse impact associated with strong seismic shaking is embankment or slope instability, seismic displacements, and potential damage to structures and improvements.

Evaluation: *Less than significant with mitigation.*

Mitigation: *Embankment slopes shall be stable under static conditions and provide acceptable levels of deformation during the anticipated levels of strong ground shaking. Preliminary slope stability analyses indicate the performance of the dam during strong seismic shaking may be better than previously estimated. Mitigation measures include checking the dam stability and calculated displacements using various water level and seismic ground motions to confirm appropriate levels of safety are maintained. Any dam modification or ancillary structures for the project should be designed and constructed in accordance with the seismic provisions of the most recent version of the California Building Code (CBC). Consultation, review and approval of the any dam modifications need to be performed by the California Division of Safety of Dams.*

D. Liquefaction Potential

Liquefaction refers to the sudden, temporary loss of soil shear strength during strong ground shaking. Liquefaction-related phenomena include liquefaction-induced settlement, flow failure, and lateral spreading. These phenomena can occur where there are saturated, loose, granular (non-clayey) deposits. These conditions have not been identified at the project site. Therefore, the potential for liquefaction to occur appears low.

No mitigation measures anticipated.

E. Seismic Induced Ground Settlement

Ground shaking can induce settlement of loose granular soils above the water table. Based on previous explorations, the dam is primarily composed of clayey gravel and gravelly clay. Loose granular deposits were not observed. Therefore, the potential for seismic induced ground settlement is low.

No mitigation measures anticipated.

F. Lurching, Lateral Spreading, and Ground Cracking

Lurching and associated ground cracking can occur during strong ground shaking. Ground

cracking generally occurs along the tops of slopes where stiff soils are underlain by soft deposits or along essentially flat terrain that is fronted by a free face, such as a channel bank. These conditions are not present at the project site. Lurching and ground cracking can damage structures or utilities located close to the top of slopes.

No mitigation measures anticipated.

G. Slope Stability

Active and dormant landslides exist around the reservoir as shown on Figure 2. These landslides range in size from small "pop-outs" to large dormant features. There is the potential for re-activation of existing landslides due to seismic shaking or significant saturation. We did not observe any landslide features that could significantly impact the dam. However, surficial sloughing was reported when the reservoir was drained to perform the 1960's improvements. Based on our preliminary slope stability analyses, Phoenix Lake Dam is most susceptible to slope instability and deformation during large seismic events. The results of our analyses indicate deformation during a strong seismic event would be less than calculated deformation from the previous reports. A more detailed discussion of slope instability of Phoenix Lake Dam is presented later in this report. Given the steep slopes and erosive nature of colluvial soil deposits, the potential for landsliding and slope instability around the reservoir is moderate to high.

Evaluation: *Potentially Significant.*

Mitigation: *Phoenix Lake Dam has been in place for nearly a century and has reportedly not experienced any significant instability or displacements over its lifetime. Mitigation measures performed in the 1960's and 1980's included lowering the spillway to account for displacements and crest settlement. New analyses indicate less displacement. Planned modification to dam should be analyzed to confirm adequate dam safety and freeboard are maintained after potential seismic deformation.*

H. Erosion

Sandy soils on moderate slopes or clayey soils on steep slopes are susceptible to erosion and gullying when exposed to concentrated surface water flow. Erosion is increased on slopes subjected to concentrated runoff by outfall from drainage facilities and on long slopes without surface drainage control. Currently the inboard slope of Phoenix Dam is covered in a "blanket" of rip-rap to reduce the erosion caused by wave action. The existing downstream slopes are significantly covered with low grasses. Additionally, we did not observe any evidence of excess erosion during our site visit. Therefore, the potential for significant erosion is low.

Evaluation: *Less than significant with mitigation.*

Mitigation: *The vegetation and rip-rap on the slopes of the dam should be maintained. Re-establishing vegetation on disturbed areas will minimize erosion. Erosion control measures during and after construction should conform to the most recent version of the Erosion and Sediment Control Field Manual (San Francisco Branch, Regional Water Quality Control Board, 2002).*

I. Seiche and Tsunami

Seiches and tsunamis are short duration earthquake or landslide generated water waves in large, enclosed bodies of water and the open ocean, respectively. The extent and severity of a seiche would be dependent upon the ground motion and the fault offset from nearby active faults. There is some potential for seiches to occur after an earthquake, especially when water levels are high. Additionally, there are landslides mapped around the reservoir. Based on the topography surrounding this area, it appears that landslides have impacted the reservoir in the past. If a landslide were to remobilize and flow into the reservoir, it could displace a sizable volume of water that could create a seiche. It is not likely that an earthquake or landslide induced seiche will damage the dam provided adequate freeboard is maintained and the spillway can release the excess water. Given the low risk of damage, mitigation measures do not appear warranted.

Evaluation: *Less than significant with mitigation.*

Mitigation: *Maintain adequate dam freeboard above the lake water level to prevent a seiche from over-topping Phoenix Dam. For preliminary design, we recommend that a minimum 4-foot freeboard should be maintained.*

J. Flooding

The adverse impact from flooding is water overtopping the earthen dam creating excess erosion of the dam. Phoenix Lake is surrounded by a watershed that will divert surface water runoff into the reservoir raising the water surface elevation. However, the existing dam is equipped with a spillway that can release excess water as it approaches its maximum elevation. Additionally, reservoir water can be released prior to storms to provide additional storage capacity during heavy rain events. Therefore, provided flood management procedure are developed, the spillway is operating and Phoenix Dam is monitored during heavy rain events, flooding is not considered a significant geologic hazard. A detailed flood management study including the Phoenix Lake is being prepared by Stetson Engineers.

No mitigation measures anticipated.

K. Settlement

New surface loads can cause consolidation of soft clays or compression of loose soils. These conditions do not appear to exist at the dam site. Since the dam has been in place for nearly 100 years and construction of new heavy structures or fills is not expected as part of this project, settlement does not appear to be an issue.

No mitigation measures anticipated.

L. Expansive Soil

Expansive soil conditions occur when clay particles interact with water, causing volume changes in the clay with a resultant reduction in strength. The clayey soils swell when saturated and shrink when dry. Such physical changes may damage lightly loaded foundations, flatwork, and pavement. Expansive soil problems generally decrease in magnitude with increased confinement pressure at depth. Highly expansive soils most likely do not exist at the site, and do not play a role in the pertinent issues of this report.

No mitigation measures anticipated.

VI. DISCUSSION AND EVALUATION

A. General

Based on our research, geologic reconnaissance and initial investigation, we conclude that the proposed use of Phoenix Lake Dam and Reservoir as a flood control detention basin is feasible. Based on our analyses, increasing the water level within the dam during short term storm events has a minor impact on the overall stability. The primary geologic and geotechnical issues include verification of the preliminary slope stability analyses and deformation estimates based on additional exploration and lab data.

B. DSOD Jurisdictional Determination

We have consulted with the California Department of Water Resources, Division of Safety of Dams (DSOD) regarding the potential to utilize Phoenix Lake as a storm water storage detention basin for flood management. Based on our conversation, DSOD would allow Phoenix Lake to be utilized as a storm water detention basin. Phoenix Lake is currently certified for operation at reservoir level +174. Without submitting supplemental analyses, the reservoir could be utilized for flood management by drawing down the reservoir prior to storm events. Temporary impoundment of storm water at higher reservoir levels is feasible provided that supplemental analyses are performed and documentation provided showing adequate stability and freeboard is maintained. For pseudo-static (seismic) analyses, recommended ground motions are the higher of the 84th percentile of the deterministic motions or probabilistic analyses with a reasonable return period. The analyses do not need to consider a worst case earthquake and worst case storm occurring at the same time. DSOD requires a 4-foot minimum freeboard to be maintained for the dam.

C. Stability Analyses

We performed slope stability analyses for static, pseudo-static, and rapid draw down conditions using Spencer's Method with the computer program Slide version 6.0, produced by RocScience. We evaluated an idealized cross section that corresponded to the differing geometries of Phoenix Dam. Strength parameters for the materials were determined from a compilation of all available data, as shown on Figure 7.

We performed slope stability analyses on various scenarios including static, pseudo-static (seismic), and rapid drawdown. The static and seismic analyses were performed on the downstream slopes only. The additional weight of Phoenix Lake increases the stability of the upstream slope; therefore the downstream slopes are more critical than the upstream. The rapid drawdown analyses were performed on the upstream slopes because the water level within the dam would be higher in the upstream slopes subsequently causing higher pore pressure when the reservoir is lowered.

Based on deterministic analyses (NGA 2008), the seismic response of the site due to a seismic event on the San Andreas Fault is 0.53g for the 84th percentile. We utilized the probabilistic peak ground accelerations (0.49 and 0.78 g's) for our seismic slope stability analyses. The results of our analyses are summarized below on Table E and are presented on Figures 7 through 9.

Minor sloughs may occur on the downstream side during a rapid drawdown conditions. It is difficult to determine the stability of minor sloughs.

TABLE E
SLOPE STABILITY FACTORS OF SAFETY
PHOENIX LAKE DAM
ROSS, CALIFORNIA

	Static Conditions		Rapid Drawdown	
Water Level	Downstream	Upstream	Half	Full
174 feet	1.37	2.22	1.55	1.40
180 feet	1.36	2.28	1.58	1.38
184 feet	1.36	2.41	1.76	1.38

Pseudo-Static (Seismic) Analyses

	DSHA[1]		PSHA[2]			
	84th Percentile (0.53g)		10% in 50 years (0.49g)		2% in 50 yrs (0.78g)	
Water Level	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream
174 feet	0.63	0.62	0.66	0.66	0.48	0.46
180 feet	0.61	0.62	0.65	0.65	0.47	0.47
184 feet	0.61	0.62	0.65	0.66	0.46	0.49

Notes:
1) Deterministic Seismic Hazard Analyses
2) Probabilistic Seismic Hazard Analyses

As shown in Table E, raising the water level from 174 feet to 184 feet does not significantly influence the calculated factors of safety. Additionally, the global stability factors of safety under static and rapid drawdown conditions are above 1.3. However, some localized surficial instability may occur during rapid drawdown. The factors of safety under seismic conditions are below 1.0 which indicates deformation of the dam may occur during strong seismic shaking. A slope stability output file is presented in Appendix B.

D. Seismic Slope Displacement

Due to factors of safety below 1.0 under seismic conditions, the slopes of Phoenix Lake Dam will likely deform during the strong seismic shaking. The previous 1978 deformation analyses by Earth Science estimated 11 feet of elastic deformation along the slip plane which results in 5.3 feet of vertical settlement of the crest. We analyzed the potential slope displacement based on the procedures outlined by Bray & Travasarou (2007). The results of our analyses indicate that the anticipated range of displacements along the slip plane between 1 and 35 inches, depending on the seismic acceleration used in the analyses. The calculated potential dam displacements are shown on Table F.

TABLE F
PREDICTED DAM DISPLACEMENT
PHOENIX LAKE DAM
ROSS, CALIFORNIA

	Predicted Slope Displacement		
Water Level	DSHA[1] 84th Percentile	PSHA[2] 10% in 50 yrs.	PSHA[3] 2% in 50 yrs.
174 feet	1.2 – 5.7 inches	1.9 – 7.7 inches	7.8 – 29.1 inches
180 feet	1.7 – 7.0 inches	2.4 – 9.3 inches	9.1 – 33.9 inches
184 feet	1.7 – 7.2 inches	2.5 – 9.6 inches	9.3 – 34.7 inches

Notes: 1. DSHA – Deterministic Seismic Hazard Analysis, spectral acceleration = 0.58g
2. PSHA – Probabilistic Seismic Hazard Analysis, spectral acceleration = 0.65g
3. PSHA – Probalistic Seismic Hazard Analysis, spectral acceleration = 1.15g

The predicted displacement listed above is considered the total displacement along the slope of the dam. The total displacement can be broken down into horizontal and vertical components based on the existing slope inclination and basic geometric principles. For example an 18-inch displacement on the dam's 2:1 (26.6°) slope would break down to 16-inches of horizontal displacement and 8-inches of vertical displacement.

At all reservoir levels analyzed (+174, +180 and +184), the estimated displacements are significantly less than the previous estimates. Based on the preliminary analyses, overtopping of the dam should not occur during a strong earthquake event when the water level in the reservoir is elevated (up to elev. +184) during temporary storage of storm waters. Supplemental exploration, laboratory testing and more sophisticated deformation analyses should be performed to confirm the preliminary results. Supplemental services should be performed in consultation DSOD.

E. Operating Constraints

From a geotechnical and geologic standpoint there appear to be only a few operating constraints. As mentioned above, the factors of safety during strong seismic conditions are below 1.0 and therefore the dam may experience seismic displacements. Following a seismic event, a thorough inspection of the dam and reservoir should be performed.

Minor sloughing may continue to be an occurrence during a drawdown event. When possible, drawdown should be performed at a slow rate (i.e., 1-foot/day) to reduce the potential for upstream slope failures. Higher rates of drawdown (i.e., 10 to 15-ft/day) will increase the potential for minor sloughing to occur. Placement of additional rip-rap and a seepage collection system on the upstream face of the dam would reduce the potential for shallow sloughing during sudden drawdown.

As with all earth fill dams, inspection of the slopes and surrounding area should be performed on a periodic basis to identify and remediate geotechnical conditions that can lead to larger slope instability problems. Some of these conditions are expected to include signs of wave erosion, surface “rilling”, piping, seepage areas or ground cracking.

VII. SUPPLEMENTAL SERVICES

Provided that the concept of using Phoenix Lake Dam and Reservoir as a flood control measure is approved for use by the owner/operators, our supplemental services should include exploration and laboratory testing to provide additional data on the engineering properties of the soil and rock that comprise the dam. This phase of work will involve consultation with the Division of Safety of Dams (DSOD) to determine project specific analyses to be performed. More refined stability and deformation analyses should be performed utilized the additional data collected. In addition, we recommend consultation with an independent geotechnical peer reviewer during the design level investigation regarding the planned dam improvements.

We should review the plans and specifications for the project when they near completion to review the geotechnical aspects, confirm that the intent of our geotechnical recommendations has been incorporated and provide supplemental recommendations, if needed. During construction, inspection and testing of the geotechnical portions of the project should be performed under the direction of a registered geotechnical engineer.

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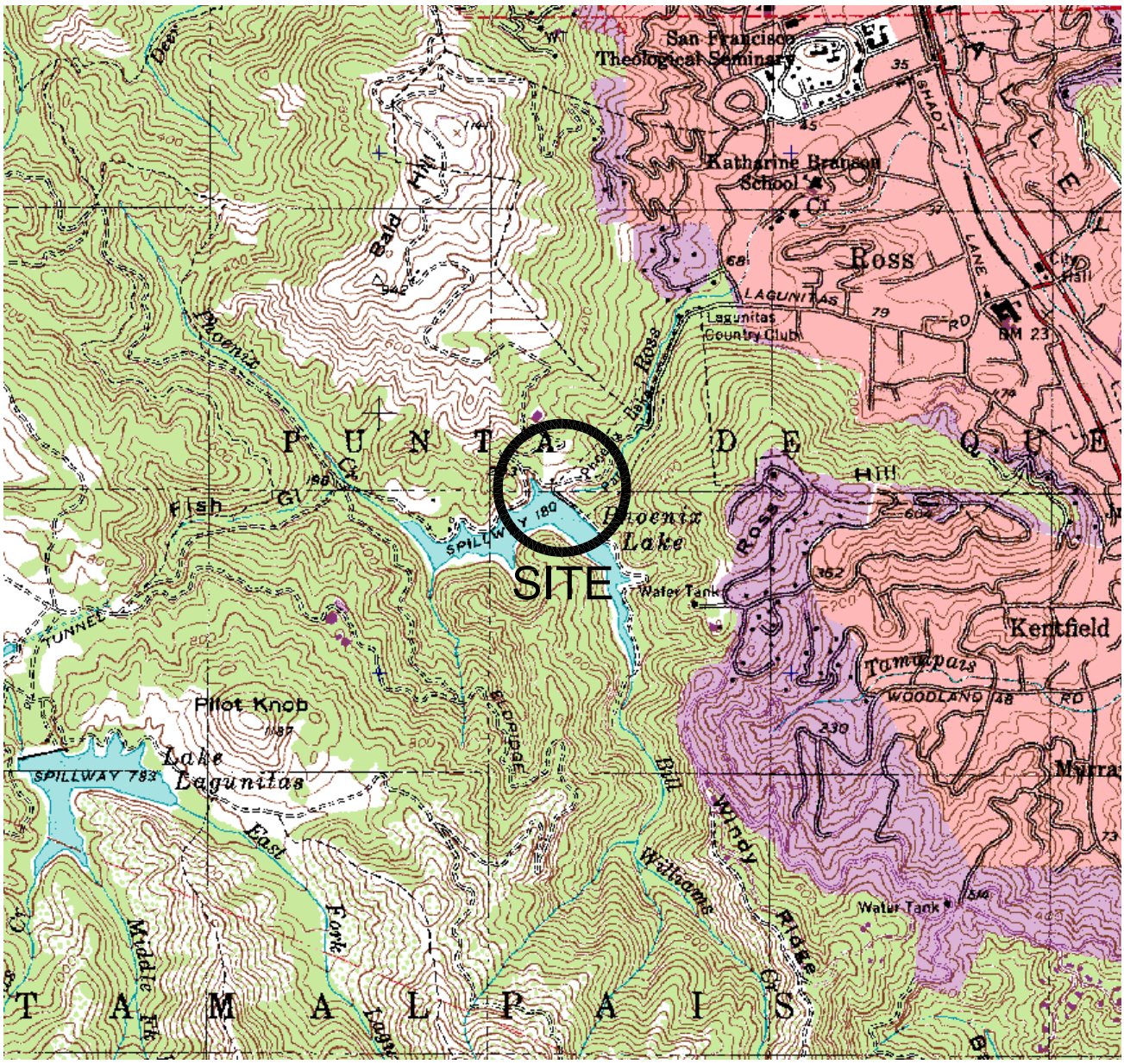

SITE LOCATION

SCALE

0 1000 2000 4000 FEET

0 500 1000 METERS

NORTH

REFERENCE: DeLorme 3D TopoQuads, 1999

Miller Pacific ENGINEERING GROUP	504 Redwood Blvd.	SITE LOCATION MAP		
	Suite 220	Stetson - MC Flood Protection Phoenix Lake Dam Marin County, California	Drawn JSC Checked	1
	Novato, CA 94947			
	T 415 / 382-3444			
	F 415 / 382-3450			
	www.millerpac.com	Project No. 960.05 Date: 1/4/10		FIGURE

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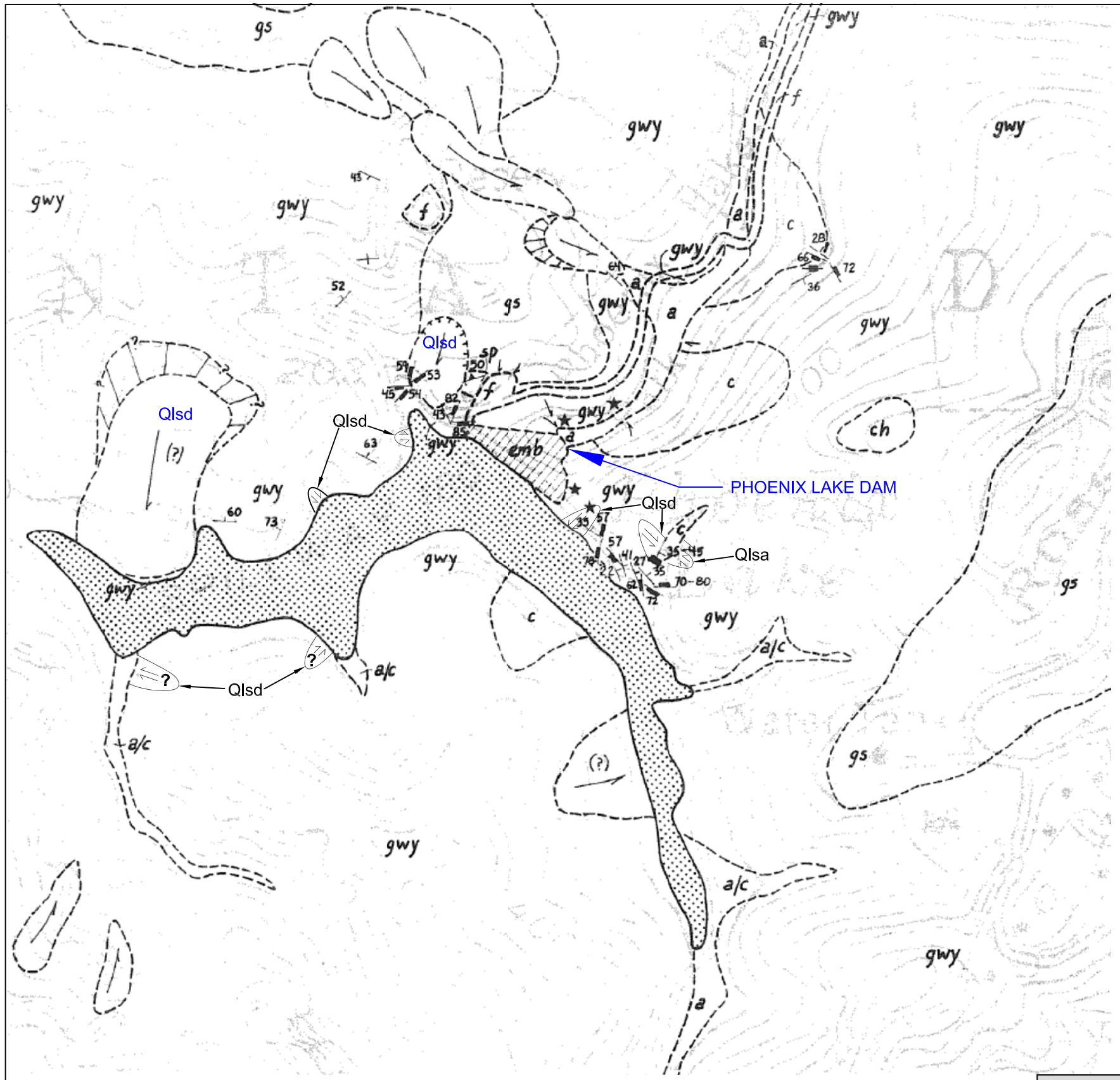

GEOLOGIC UNITS

f/emb	Fill; emb- embankment fill
a	Alluvial deposits
c	Colluvial deposits
gwy	Graywacke-type sandstone, shale and some metagraywacke
gs	Greenstone
ch	Chert
sp	Serpentinite and sheared rock

SYMBOLS

Geologic contact, dashed where approximate, dotted where concealed, queried where inferred or uncertain

source area or high head scarp — arrow shows direction of movement

low head scarp

head scarp not apparent

Landslide; boundaries dashed where approximate, queried where uncertain; relatively deep failures involving bedrock

Shallow landslide involving mainly surficial deposits

Spring

Strike and dip of bedding

Vertical bedding

Strike and dip of joints

Vertical joint

Strike and dip of shear foliation

Numerous attitudes at single outcrop located at center of symbols

Attitudes at outcrops marked with star are shown on Fig. 3

Qlsa - Active landslide or debris flow showing evidence of recent movement

Qlsd - Dormant landslide or debris flow, no evidence observed suggesting recent movement

Reference: Earth Sciences Associates, "Phoenix Dam 1977-78 Evaluation of Seismic Stability," March 1978.

SCALE

0 250 500 1000 FEET

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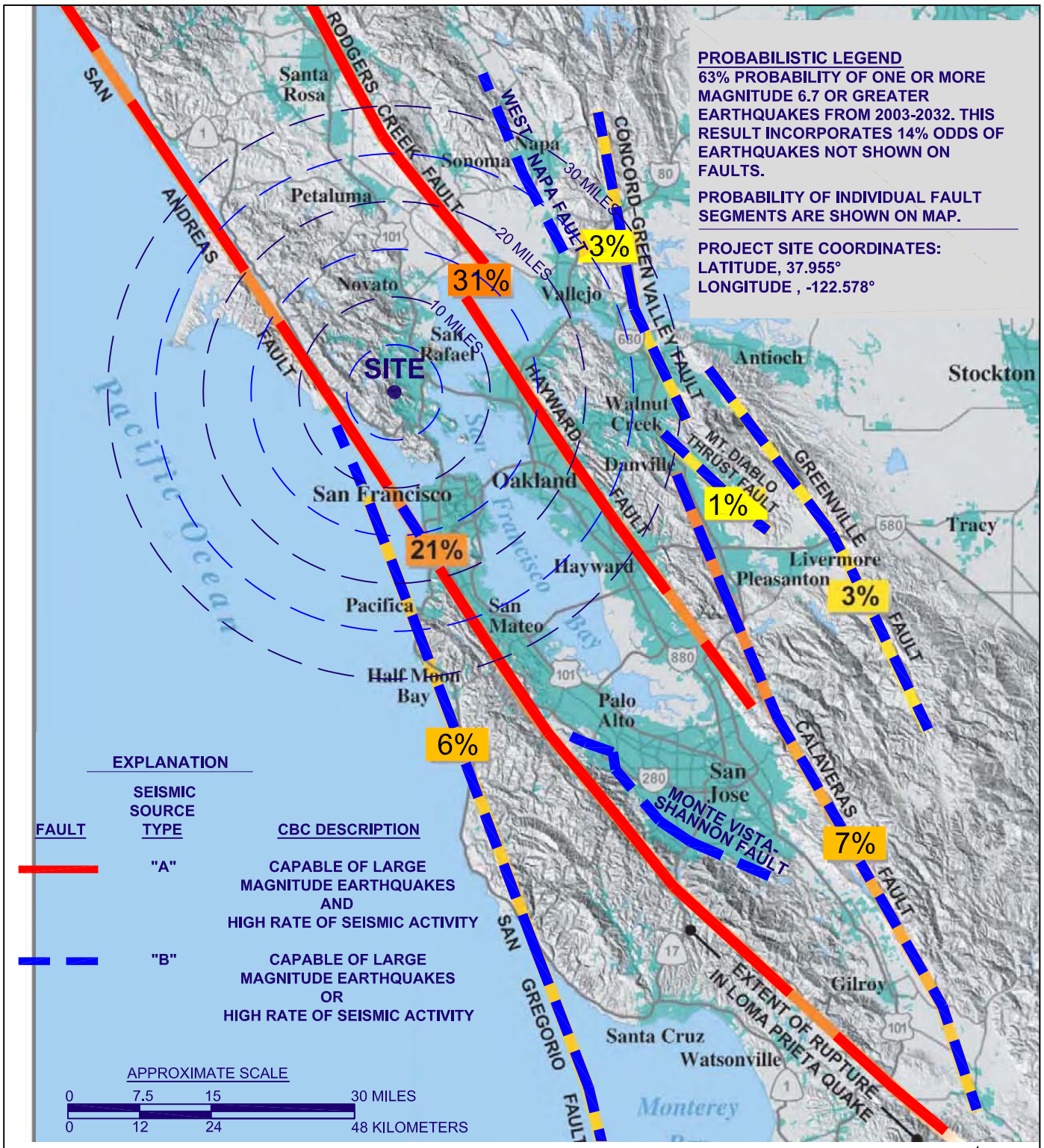
GEOLOGIC MAP

Stetson - MC Flood Protection
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 2/23/10

Designed
Drawn JTO
Checked

2
FIGURE



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Miller Pacific ENGINEERING GROUP	504 Redwood Blvd. Suite 220 Novato, CA 94947 T 415 / 382-3444 F 415 / 382-3450 www.millerpac.com	ACTIVE FAULT MAP		
		Stetson - MC Flood Protection Phoenix Lake Dam Marin County, California Project No. 960.05 Date: 1/4/10	Drawn JSC Checked	3 FIGURE

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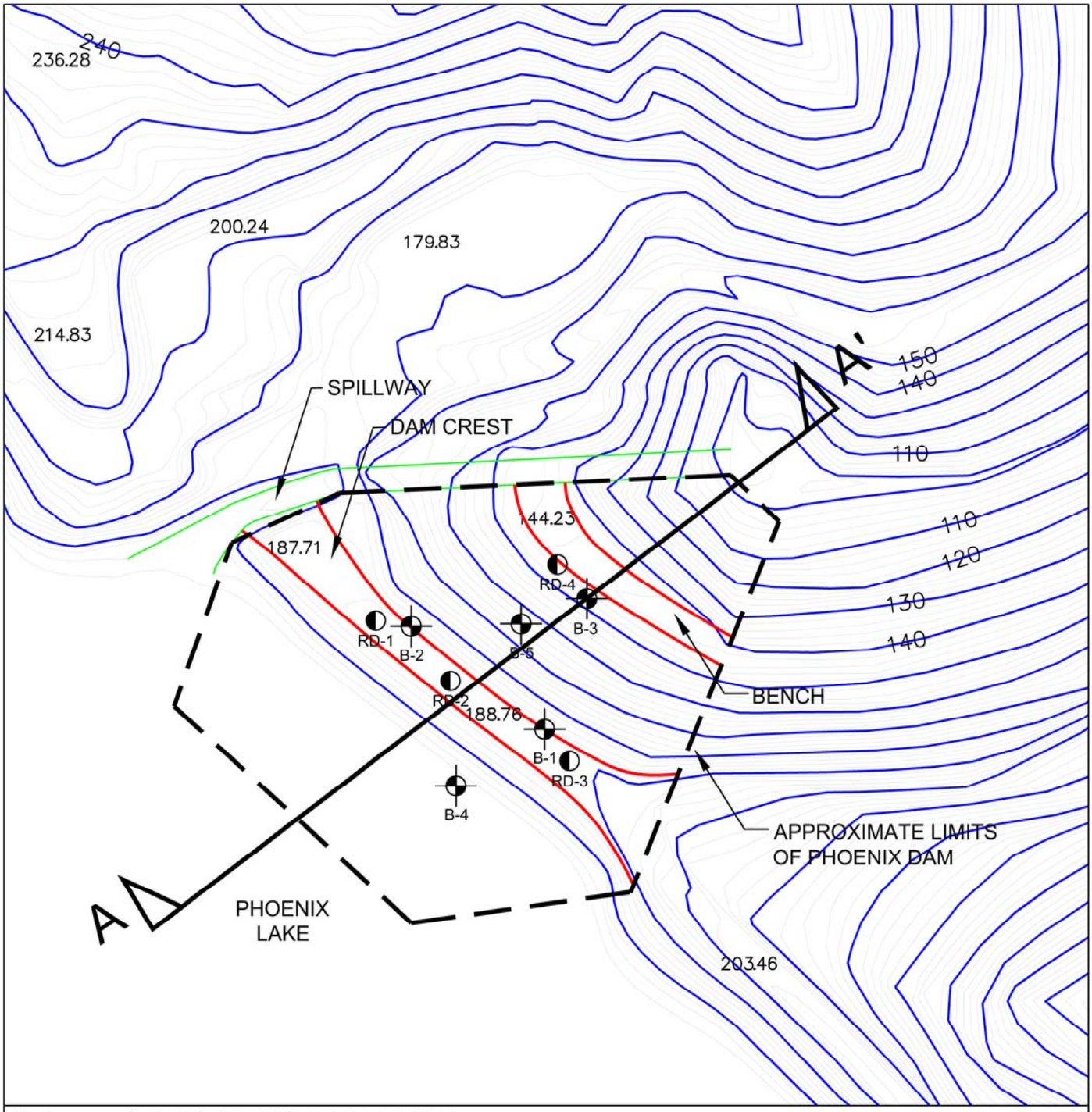

Reference: Marin Municipal Water District, 2004

RD-4 Boring by Earth Sciences Associates, 1977

B-2 Boring by Dames & Moore, 1958

SCALE

0 50 100 200 FEET

NORTH

Miller Pacific ENGINEERING GROUP	504 Redwood Blvd. Suite 220 Novato, CA 94947 T 415 / 382-3444 F 415 / 382-3450 www.millerpac.com	BORING LOCATIONS		
		Stetson - MC Flood Control Phoenix Lake Dam Marin County, California	Drawn JSC Checked	4 FIGURE
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PREVIOUS LABORATORY TEST RESULTS

Firm	Boring	Elev. (ft)	Elev. (ft)	Soil Type	γ_D (pcf)	MC (%)	TXUU UC (psf)	TXCU-pp ϕ' (deg)	TXCU-pp c' (psf)	P200 (%)	LL	PI
D&M	B-3	146	2	CL	111	17.2	1100					
D&M	B-3	132	16	SC	115		1200					
D&M	B-3	126	22	SC			3400					
D&M	B-3	116	32	SC-GC	114	17.1	500					
D&M	B-4	158	6	SC	130	11.5	1500					
D&M	B-4	152	12	SC	117	15.1	2100					
D&M	B-4	147	17	SC	120	14.6	1200					
D&M	B-4	147	17	SC	117	10.5	1800					
D&M	B-4	133	31	SC	128	14.1	2750					
D&M	B-4	133	31	SC	111	19.6	3300					
D&M	B-5	162	1	SC	121	14.7	990					
D&M	B-5	156	7	SC	115	19.5	2200					
D&M	B-5	145	18	SC	120	14.4	2800					
D&M	B-5	141	22	GP-GC	110	22.3	4100					
D&M	B-5	132	31	CL	112	22.6	1400					
ESA	RD-3	158	27	CL	108.8	17.2						
ESA	RD-3	147	38	GC-CL	115.6	17.0	1700			34.9		
ESA	RD-3	143	42	GC-CL	120.7	13.1						
ESA	RD-3	138	47	GC-CL	114.5	15.9						
ESA	RD-3	130	55	GC-CL	124.2	13.6	3600			26.0	40	21
ESA	RD-3	125	60	GC-CL	117.1	16.3	3900			43.5	38	19
ESA	RD-3		(remolded sample)		111.0	12.8		31	144			
				Average Properties =	**116.8**	**16.0**	**2196.7**	**31**	**144**	**34.8**	**39**	**20**

VALUES UTILIZED IN PREVIOUS ANALYSES

DAMES & MOORE

Levee Strength

γ_{SAT} (pcf)	γ_{SUB} (pcf)	Static ϕ' (deg)	Static c' (psf)	Seismic ϕ'	Seismic c' (psf)
137.4	75.0	25	500	30	650

Rock Strength

γ_T (pcf)	ϕ' (deg)	c' (psf)
150	84.3	10000

EARTH SCIENCE

UPPER 25 FEET: Estimated Ultimate Shear Strength = 1500 psf

UPPER 25 FEET: Estimated Cyclic Shear Strength = 1000 psf

BELOW 25 FEET: Ultimate Shear Strength $\tau/\sigma'_{vo} = 0.5$

BELOW 25 FEET: Cyclic $\tau/\sigma'_{vo} = 0.33$

Undrained Shear Strength 25-50 feet = 2200 (@25 ft. depth) + 52pcf/foot

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LABORAATORY DATA SUMMARY

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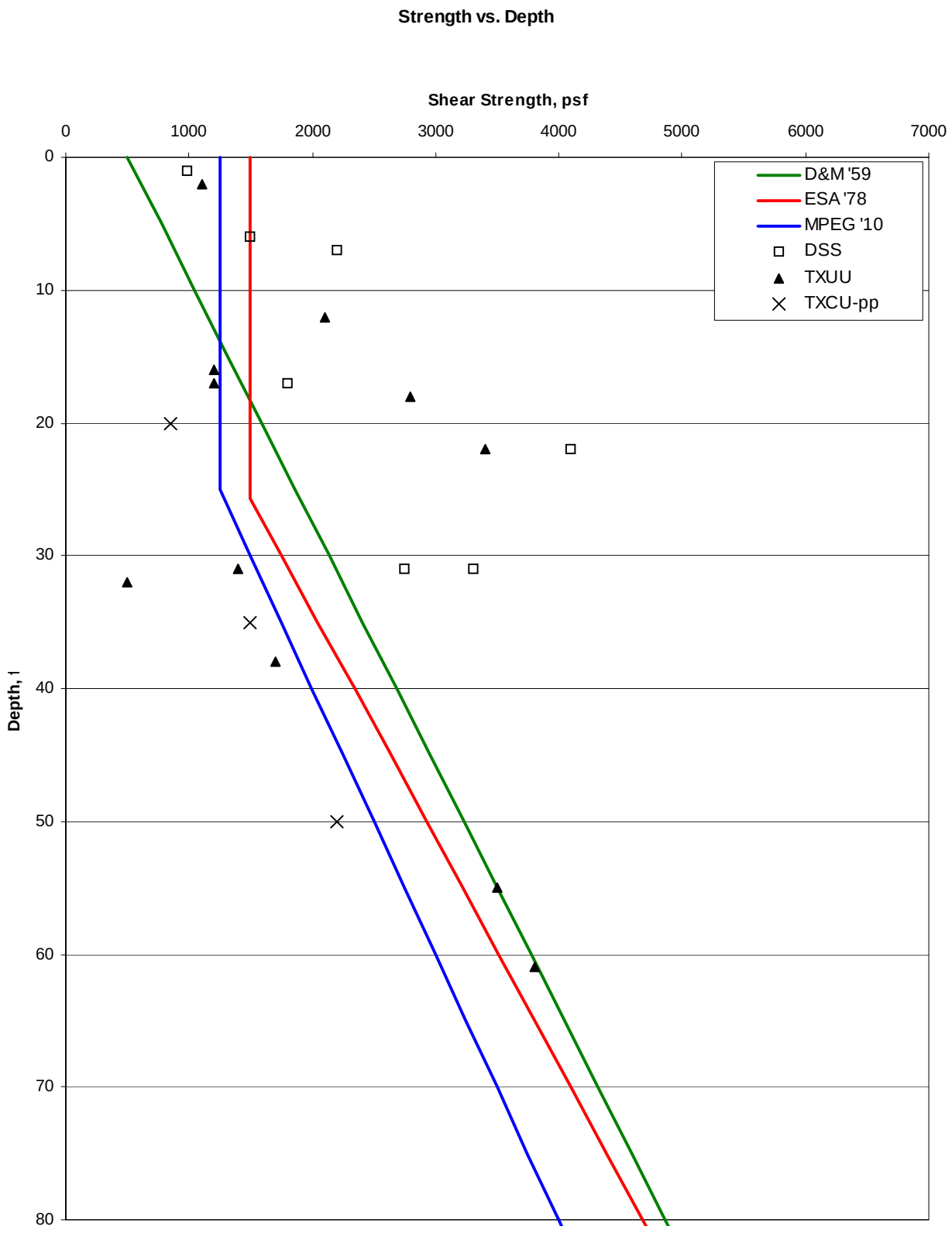
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 2/04/10

Drawn BSP
Checked

FIGURE 5



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SHEAR STRENGTH vs. DEPTH PROFILE

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 2/04/10

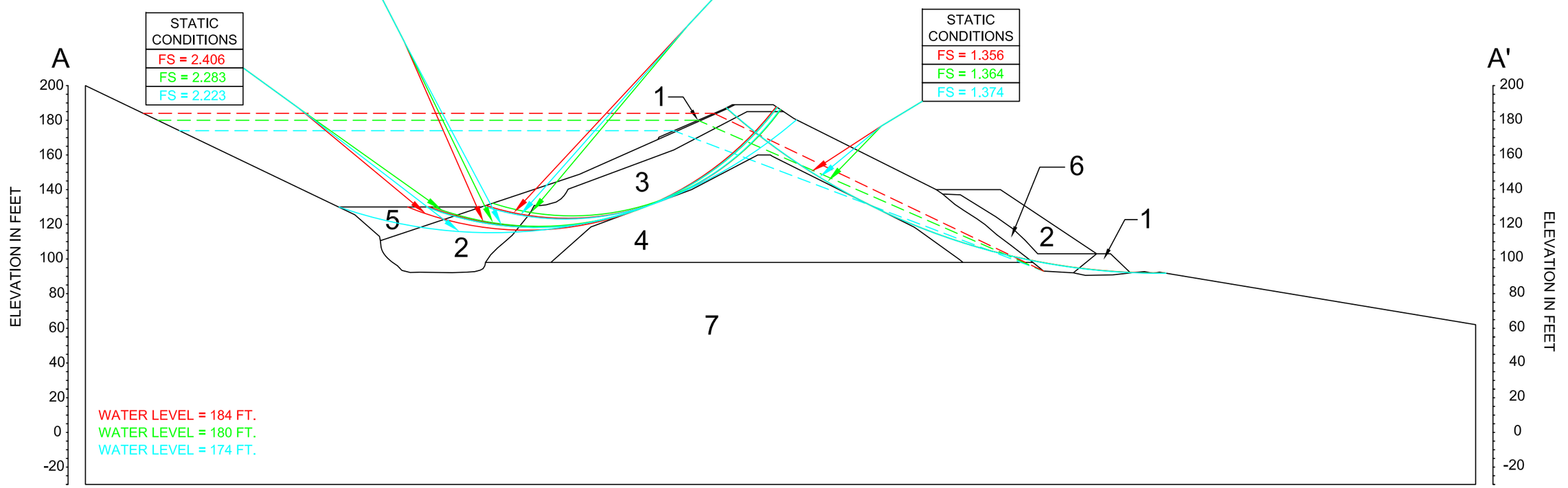
Drawn BSP
Checked

6
FIGURE

PHOENIX LAKE DAM
STATIC CONDITIONS

RAPID DRAWDOWN TO EMPTY RESERVOIR		
INITIAL WATER LEVEL	FINAL WATER LEVEL	FACTOR OF SAFETY
184 FT.	130 FT.	1.376
180 FT.	130 FT.	1.384
174 FT.	130 FT.	1.398

RAPID DRAWDOWN TO HALF RESERVOIR		
INITIAL WATER LEVEL	FINAL WATER LEVEL	FACTOR OF SAFETY
184 FT.	157 FT.	1.592
180 FT.	155 FT.	1.576
174 FT.	152 FT.	1.551



MATERIAL PROPERTIES

LAYER	MATERIAL TYPE	γ_{TOTAL} (pcf)	γ_{SAT} (pcf)	FRICTION ANGLE	COHESION (psf)	τ/σ
1	Rock Fill	135.0	145.0	40°	200	---
2	Dam Butress	125.0	140.0	0°	1500	---
3	Dam 0 - 25 ft	130.0	137.4	0°	1250	---
4	Dam 25+ ft	130.0	137.4	0°	0	0.427
5	Silt Deposits	100.0	100.0	0°	100	---
6	Drain Blanket	135.0	130.0	35°	0	---
7	Bedrock	140.0	145.0	38°	2000	---

SCALE
0 30 60 120 FEET

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SLOPE STABILITY ANALYSES RESULTS

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 02/03/2010

Drawn MFJ
Checked

7
FIGURE

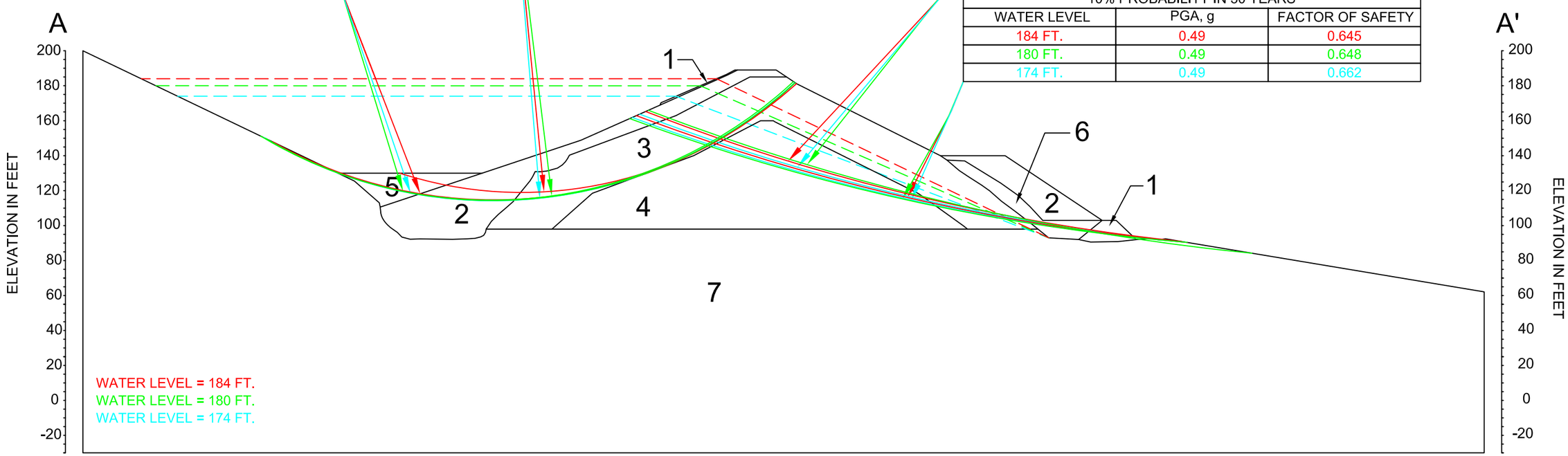
PHOENIX LAKE DAM
SEISMIC CONDITIONS
PROBABILISTIC ANALYSIS

2% PROBABILITY IN 50 YEARS		
WATER LEVEL	PGA, g	FACTOR OF SAFETY
184 FT.	0.78	0.486
180 FT.	0.78	0.467
174 FT.	0.78	0.461

10% PROBABILITY IN 50 YEARS		
WATER LEVEL	PGA, g	FACTOR OF SAFETY
184 FT.	0.49	0.664
180 FT.	0.49	0.652
174 FT.	0.49	0.659

2% PROBABILITY IN 50 YEARS		
WATER LEVEL	PGA, g	FACTOR OF SAFETY
184 FT.	0.78	0.464
180 FT.	0.78	0.468
174 FT.	0.78	0.477

10% PROBABILITY IN 50 YEARS		
WATER LEVEL	PGA, g	FACTOR OF SAFETY
184 FT.	0.49	0.645
180 FT.	0.49	0.648
174 FT.	0.49	0.662



MATERIAL PROPERTIES

LAYER	MATERIAL TYPE	γ_{TOTAL} (pcf)	γ_{SAT} (pcf)	FRICTION ANGLE	COHESION (psf)	τ/σ
1	Rock Fill	135.0	145.0	40°	200	---
2	Dam Butress	125.0	140.0	0°	1500	---
3	Dam 0 - 25 ft	130.0	137.4	0°	1250	---
4	Dam 25+ ft	130.0	137.4	0°	0	0.427
5	Silt Deposits	100.0	100.0	0°	100	---
6	Drain Blanket	135.0	130.0	35°	0	---
7	Bedrock	140.0	145.0	38°	2000	---

SCALE
0 30 60 120 FEET

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FILE: 960.05F8.dwg

SLOPE STABILITY ANALYSES RESULTS

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 02/03/2010

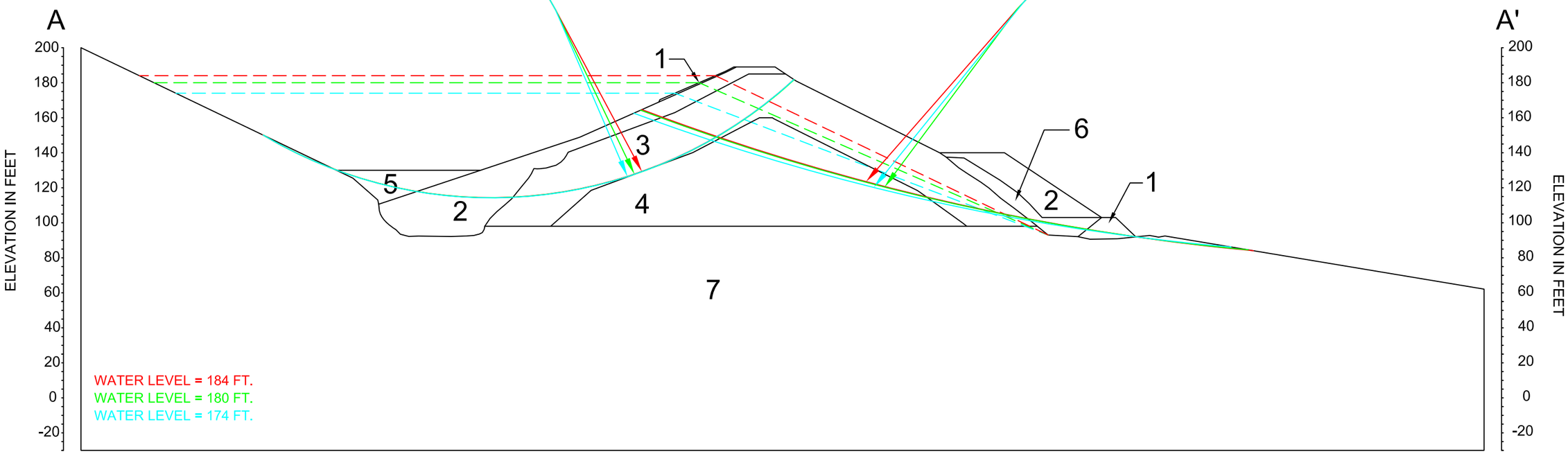
Drawn MFJ
Checked

8
FIGURE

PHOENIX LAKE DAM
SEISMIC CONDITIONS
DETERMINISTIC ANALYSIS

DSHA 84th PERCENTILE		
WATER LEVEL	PGA, g	FACTOR OF SAFETY
184 FT.	0.53	0.623
180 FT.	0.53	0.620
174 FT.	0.53	0.621

DSHA 84th PERCENTILE		
WATER LEVEL	PGA, g	FACTOR OF SAFETY
184 FT.	0.53	0.605
180 FT.	0.53	0.611
174 FT.	0.53	0.626



MATERIAL PROPERTIES

LAYER	MATERIAL TYPE	γ_{TOTAL} (pcf)	γ_{SAT} (pcf)	FRICTION ANGLE	COHESION (psf)	τ/σ
1	Rock Fill	135.0	145.0	40°	200	---
2	Dam Butress	125.0	140.0	0°	1500	---
3	Dam 0 - 25 ft	130.0	137.4	0°	1250	---
4	Dam 25+ ft	130.0	137.4	0°	0	0.427
5	Silt Deposits	100.0	100.0	0°	100	---
6	Drain Blanket	135.0	130.0	35°	0	---
7	Bedrock	140.0	145.0	38°	2000	---

SCALE
0 30 60 120 FEET

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SLOPE STABILITY ANALYSES RESULTS

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 02/03/2010

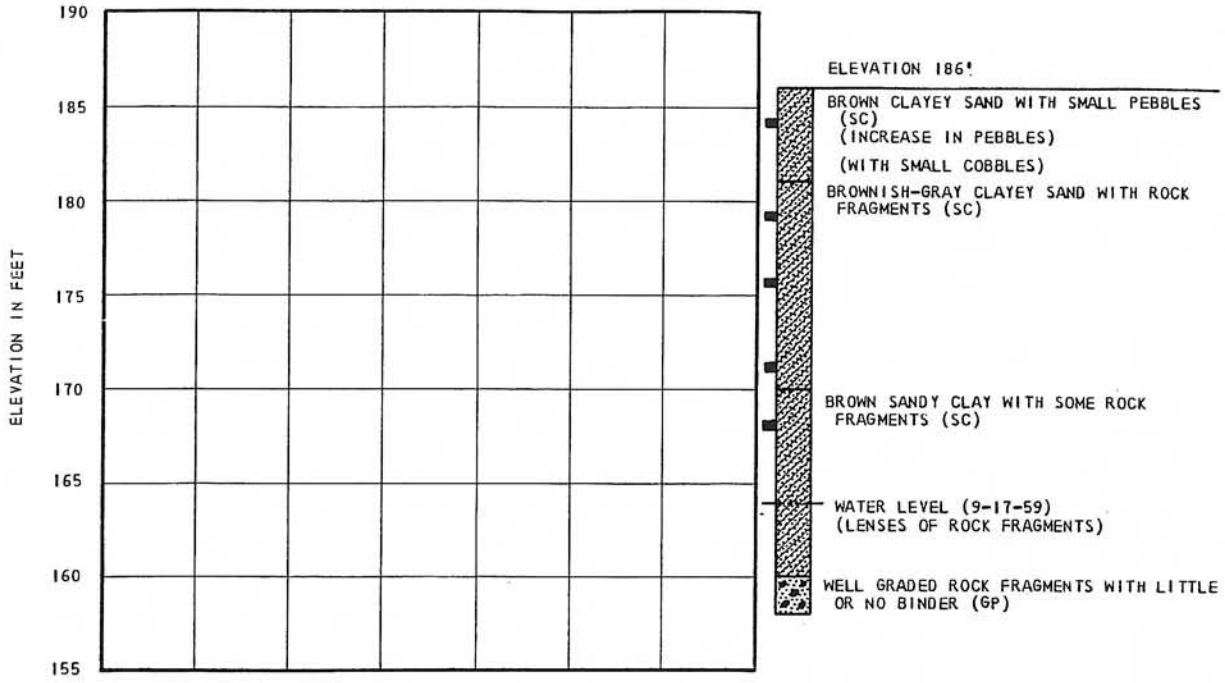
Drawn MFJ
Checked

9
FIGURE

APPENDIX A
PREVIOUS BORING LOGS

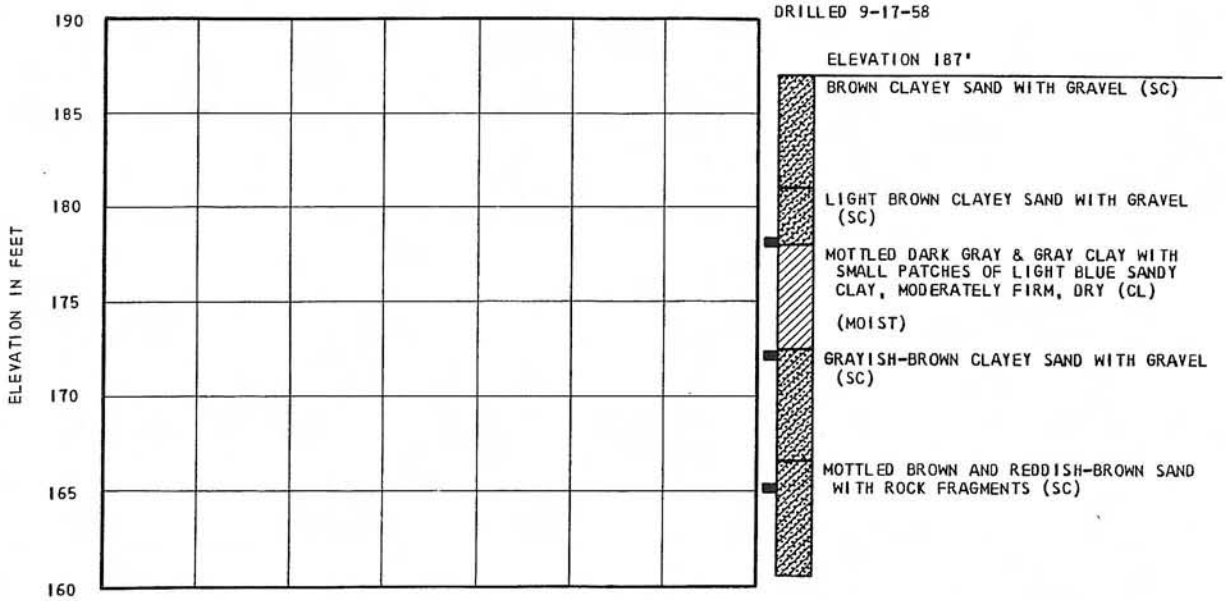
BORING 1

DRILLED 9-17-58



BORING 2

DRILLED 9-17-58



NOTE:
BORINGS 1 & 2, 16" DIAM, DRILLED WITH AUGER TYPE DRILLING EQUIPMENT.
BORINGS 3,4 & 5, 4" DIAM, DRILLED WITH ROTARY-WASH DRILLING EQUIPMENT.
ELEVATIONS REFER TO GROUND SURFACE CONTOURS SHOWN ON PLOT PLAN.

LOG OF BORINGS

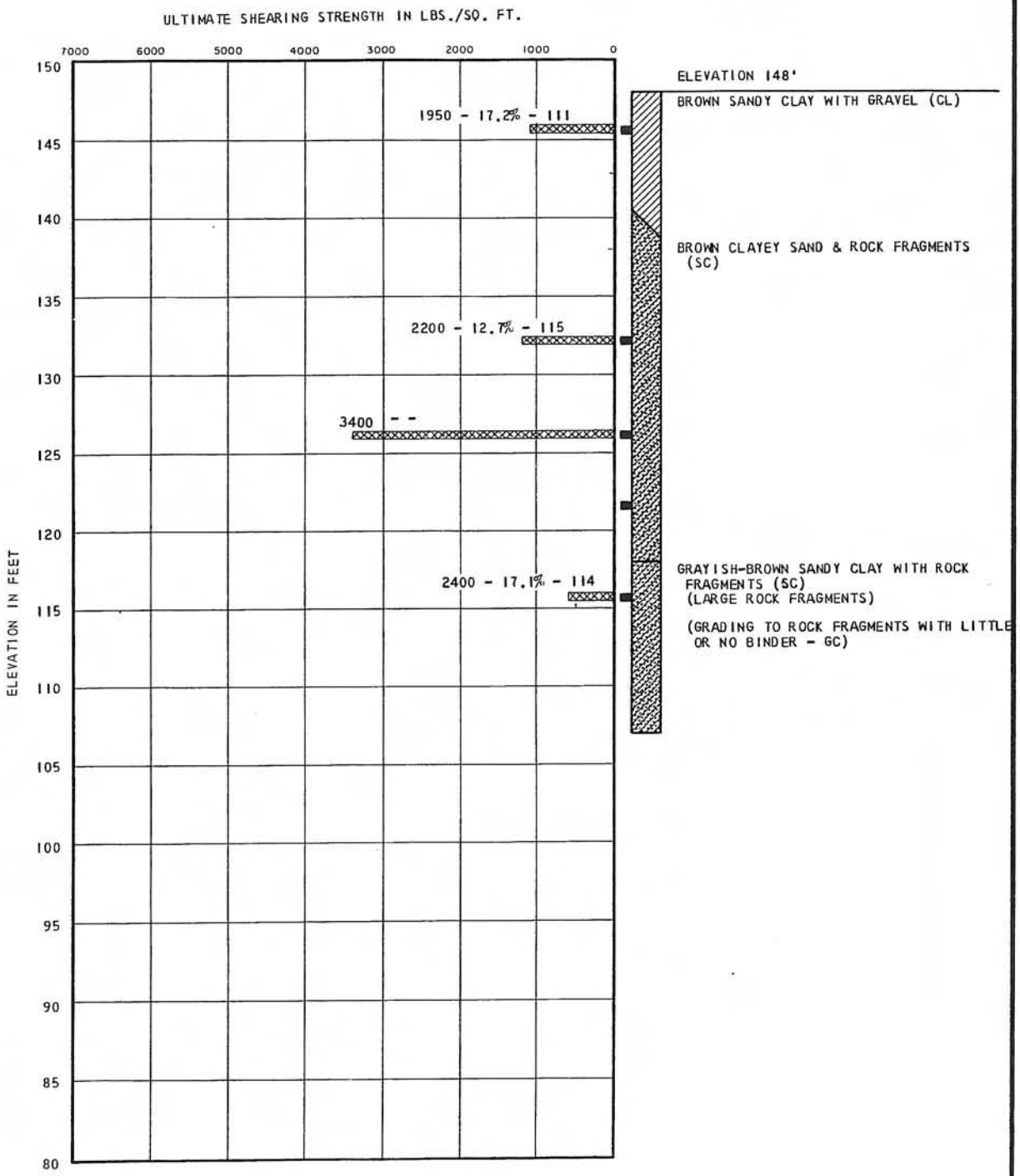
REVISIONS
BY ____ DATE ____
BY ____ DATE ____
PLATE ____ OF ____

FILE 1185-1
BY ____ DATE ____
CHECKED BY ____ DATE ____

DAMES & MOORE
SOIL MECHANICS ENGINEERS

BORING 3

DRILLED 4-20-59 TO 4-24-59



LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

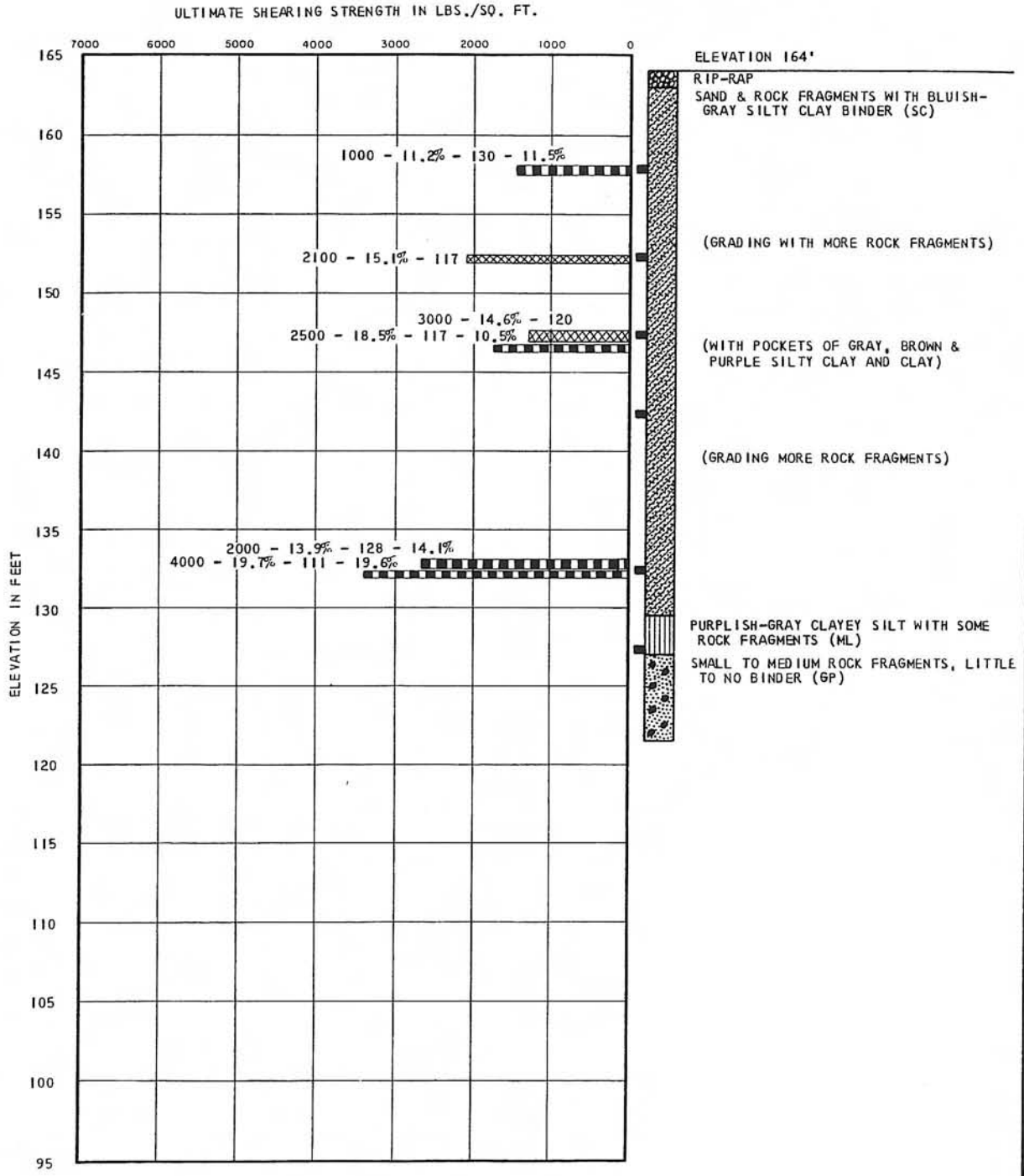
PLATE 3B

REVISIONS
BY_____ DATE_____
BY_____ DATE_____
PLATE_____ OF_____

FILE 1164.E
M.M.W.D.
BY HST. KJT DATE 11-21-59
CHECKED BY GSM DATE 10/20/59

BORING 4

DRILLED 4-23-59 TO 4-24-59



LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

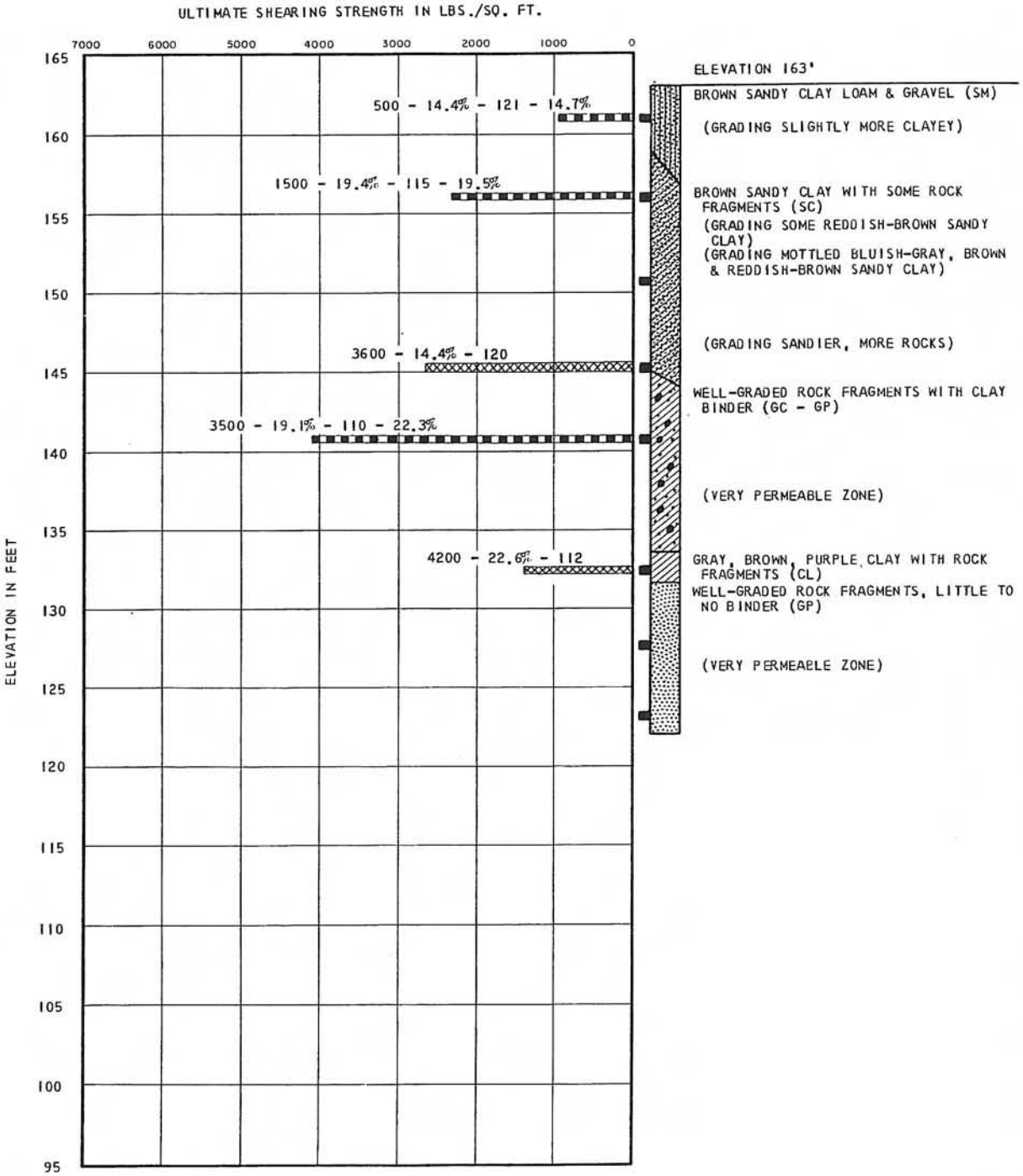
PLATE 3C

REVISIONS
BY _____ DATE _____
BY _____ DATE _____
PLATE _____ OF _____

FILE 1184.E
BY M.P.N.D. K.T. DATE 10-21-59
CHECKED BY C.Z. DATE 10/28/59

BORING 5

DRILLED 4-24-59 TO 4-28-59



LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

PLATE 3D

REVISIONS
BY_____ DATE_____
BY_____ DATE_____
PLATE_____ OF_____

FILE 184-E
N.M.W.P.
BY HCT - ET DATE 10-21-59
CHECKED BY 10/60 DATE 10/10/59

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT PHOENIX DAM 1890 DATE DRILLED 11:22 HOLE NO. RD-1

LOCATION _____ GROUND SURFACE ELEV. 1897±

DRILLING CONTRACTOR J.N. PITCHER LOGGED BY MTD DEPTH TO GROUND WATER _____

TYPE OF RIG FAILING 750 HOLE DIAMETER 4 7/8" HAMMER WEIGHT AND FALL 140 lb - 30 in.

SURFACE CONDITIONS BASE ROCK WEATHER CLOUDY - COOL

Piezometer Installation

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer Tons / Torvane Tsf)	MODE	REMARKS
0.0	SM	0.0-5.0 GRAVELLY SAND: Blue; 10-20% predominantly silt fines; fine to medium sand; fine angular gravel; dense; moist. Base Rock. 0.5 color grades to light moderate brown. ~2 small lense of soft, wet clayey silt.		AD	
2.0					
4.0				AD	
	SM			DR	Drove Standard split Spoon 4.0 – 5.5 12/0.5 19/0.5 18/0.5
	CL	5.0-22.5 SILT CLAY: Light olive gray and light gray; medium plasticity; contains scattered rounded gravel; scattered roots and wood; firm; moist.		0.5 / 1.5	
6.0				RD	Hit rock at 5' with auger. 5.0 Set 6" g. casing - begin rotary drilling.
8.0				PB	Pitcher Barrel 7.0 – 9.4
				0 / 2.4	Rocks block tube.
10.0				RD	
12.0				PB	Pitcher Barrel 11.0 – 13.5
				0 / 2.5	
14.0				DR	Drove California Sampler 13.5 – 15.0 12/1.5
			J-1 0.39 0.26 0.38	1.0 / 1.5	0.8 0.7 2.0
16.0				PB	Pitcher Barrel 15.0 – 17.5
				0 / 2.5	Took barrel apart to see if ball was in place - it was, no replacement.
18.0				RD	
				PB	2.30 stopped for day. Pitcher Barrel 18.0 – 20.5
				0 / 2.5	
20.0	CL				

SHEET 1 OF 4

PROJECT 1890 DATE DRILLED 11:23 HOLE NO. RD-1

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer TSF)	MODE	REMARKS
20.0	CL	5.0-22.5 SILTY CLAY: cont.	Torvane TSF	PB	
				RD	Appear to be pushing rock in front of bit - Tried to push it aside with drag bit.
22.0		22.5-38.0 GRAVELLY SANDY CLAY: Purple with numerous olive green and yellowish brown mottles; low plasticity clay; fine to coarse sand; 20% fine-coarse gravel (serpentine?); firm to stiff; moist			
	CL			PS	Pushed Shelby Tube 23.0-25.5
24.0	(GC)			0.6 / 2.5	300 psi
			>0.45 / 1.45		Tube bent at end.
			J-2		
26.0				RD	
				PB	Pitcher Barrel 26.0-28.0
				1.5 / 2.5	
28.0			J-3		
		clay binder appears to get softer.		PB	Pitcher Barrel 28.0-30.5
				1.7 / 2.5	Samples when extruded are generally broken into 4-6" lengths
30.0			J-4		
		clay binder has strengths from drive sample 0.7 → 1.5 TSF		DR	Drove Standard Split Spoon 30.5-32.0
				0.8 / 1.5	
32.0			J-5		
				RD	3/0.5 3/0.5 5/0.5
				PB	Pitcher Barrel 33.0-35.5
34.0	CL	34.4-34.3 blue grey silty clay; contains scattered gravel		1.4 / 2.5	
	CL-CH		J-6 0.6 0.6		
	CL	34.3-36.0 Moderate brown sandy clay; contains some 10-15% gravel.	1.2 1.0 1.4		
			J-7		3" serpentine gravel in bottom of tube
36.0	GC-CL	grades back to same as 22.5-38.0 except gravel content increases.	2.5 2.7	PB	
					Pitcher Barrel 35.5-38.0
				0.9 / 2.5	Clay binder washes out unless sample is frozen.
38.0	GC	38.0-57.0 CLAYEY GRAVEL: Moderate brown with purple discolorations clay binder; 5-20% low plasticity clay; some sand; angular to subrounded gravel up to 2"; dense; moist to wet. Clay binder is soft to firm.	J-8	DR	Drove Standard Split Spoon 38.0-39.5
				0.7 / 1.5	5/0.5 8/0.5 11/0.5
40.0				RD	Sample broken up - impossible to test.
Piezometer #1					Pitcher Barrel 41.0-41.5 (Refusal)
			J-9	PB 0.4/0.5	
42.0		(Sample J-10, includes loose "clean" gravel that are probably cuttings)		DR	Drove Standard Split Spoon 41.5-43.0
			J-10	0.3 / 1.5	9/0.5 11/0.5 15/0.5
				RD	
44.0	GC	clay content increases			

Piezo Seal

Sand Back Fill

SHEET 2 OF 4

PROJECT 1290 DATE DRILLED 11:23 HOLE NO. RD-1

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
44.0	GC (CL)	33.0-67.0 CLAYEY GRAVEL cont.		DR 0.6/1.5	Drove Standard Split Spoon 44.0-45.5
	CL		J-11	RD	15/0.5 12/0.5 13/0.5
46.0					
	GC-SP			PB 0/2.5	Pitcher Barrel 46.5-49.0
48.0	GC	clay binder moderate brown and purple.			47-48 Rig chatters strongly. Sample washed out?
				RD	
50.0				PB 0.6/2.5	Pitcher Barrel 50.0-52.5
52.0			J-12		Rig chatters sporadically. Large rock in bottom
				DR 0.5/1.5	Drove Standard Split Spoon 52.5-54.0
54.0			J-13	RD	5/0.5 15/0.5 13/0.5
					54.5 Rig chatters violently. →55.0
56.0					
58.0					
60.0				RD	
				DR 0.0/1.5	Drove Standard Split Spoon 60.0-61.5
					7/0.5 9/0.5 11/0.5
62.0				RD	Stopped for Day 11:28:78 Hole caved to 31.5 ft.
	(SC-GC)	clay content decreases.			
64.0				PB 0.4/2.5	Pitcher Barrel 64.0-66.0 Continuous loss of water
66.0			J-14		
Piezometer #2		67.0- BED ROCK:		DR 0.5/1.5	Drove Standard Split Spoon 66.0-67.5
			J-15		15/0.5 15/0.5 50/0.5
68.0				RD	

Sand backfill

Pea Gravel

Sand backfill

Piezometer #2

SHEET 3 OF 4

PROJECT 1890 DATE DRILLED 11:28:77 HOLE NO. BD-1

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
68.0		67.0 – BEDROCK: cont. Dark olive green shale and Franciscan melange; contains some roots in top 5 feet of unit; varying quantities of clay, decreasing with depth; hard.		RD	Big chattering continuously
70.0					
72.0					
74.0			J-16	RD DR 0.7/0.5	Drove Standard Split Spoon 74.0 – 74.5 50/0.5
				RD	
78.0					
80.0				RD	Drove Standard Split Spoon 80.0 – 80.2. 30/0.2 Rods bouncing
		B.H. 80.2			
82.0					Backfilled with: sand – 80.2 – 55 piezoseal – 55 – 50 piezometer @ 69'.
84.0					sand 50 – 36 piezoseal 36 – 31 piezometer 43' (graphical display of piezometer installations in left-hand CLASS. column of log)
86.0					
88.0					
90.0					
92.0					
94.0					SHEET 4 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT PHOENIX DAM 1890 DATE DRILLED 11:29- HOLE NO. RD-2

LOCATION DAM CREST NR. MAXIMUM SECTION. GROUND SURFACE ELEV. 1895±

DRILLING CONTRACTOR J.N. PITCHER LOGGED BY MTD DEPTH TO GROUND WATER

TYPE OF RIG FAILING 750 HOLE DIAMETER 4 7/8" HAMMER WEIGHT AND FALL 140 lb - 30 inch.

SURFACE CONDITIONS DAM CREST ROAD - BARE ROCK WEATHER CLEAR - COOL.

Piezometer Installation

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
0.0	GP	0.0-1.0 BASE ROCK:	Torvane TSF	AD	Augered to 5 ft.
	SM	Greyish blue; less than 5% fines; fine to coarse sand; fine gravel; moist; dense.			Set 7'. 6"ϕ casing.
2.0		1.0-5.5 (8/1968 FILL:			
	CL	Moderate yellowish brown with dark olive green and purple discolorations; generally a silty sand with layers of silty and gravelly clay; silty sand generally med. yell. brown; moist; dense to very dense.		AD	
4.0			J-1	DR 0.3/1.5	Drove Standard Split Spoon 3.5-5.0
	CL			RD	7/0.5 24/0.5 26/0.5 Rock in bottom of shoe.
6.0	CL-GC	5.5-11.5 CLAYEY GRAVEL TO GRAVELLY CLAY: Purple and dark olive grey; variable amount of clay fines; some sand; fine to coarse angular gravel; some cobbles; moist; dense.	J-2	PB 1.7/2.5	Pitcher Barrel 6.0-8.5 Bottom of tube badly bent.
8.0			J-3	PB 0.5/0.5	Pitcher Barrel 8.5-9.0 Refusal - losing all circulation. Tube Bent, rock in Bottom.
10.0			J-4	DR 0.2/1.5	Drove Standard Split Spoon 9.0-10.5
	CL-GC	11.5-19.4 SILTY CLAY:		RD	15/0.5 8/0.5 7/0.5 Rocks in shoe, some clay binder.
12.0	CL	Olive green and light grey; low to moderate plasticity; contains scattered roots; firm; moist to wet.		PB 1.2/2.5	10.0 Added half a bag of revert, could not get circulation. Mixed up ½ bag of bentonite.
14.0		some black organic discoloration. contains scattered gravel up to 2".	J-5	PB	Drove another 5' of casing. Pitcher Barrel 12.0-14.5
16.0			J-6	PB 1.0/2.5	Pitcher Barrel 14.5-17.0
18.0				PB	Pitcher Barrel 17.0-19.5
	CL	19.4-26.0 SANDY GRAVELLY CLAY:	J-7	PB 1.0/2.5	
20.0	CL				SHEET 1 OF 4

* Test on sample end.

PROJECT 1390 DATE DRILLED 11:29:77 HOLE NO. RD-2

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
20.0	CL	19.4-86.0 SANDY GRAVELLY CLAY: cont.		PB	Pitcher Barrel
		Reddish brown; medium plasticity clay; 20-30% predominantly coarse sand; up to 20% coarse gravel; medium dense to dense; moist to wet.		1.2 / 2.5	19.5 - 22.0
22.0			J-8		Tube Bent at bottom. Rock gouged side of sample.
				PB	Pitcher Barrel
				0.5 / 2.0	22.0 - 24.0
24.0			J-9		Steady loss of water.
				PB	Pitcher Barrel
				0.8 / 2.5	24.0 - 26.5
26.0			J-10		
				DR	Drove Standard Split Spoon
	(GC)			0.7 / 1.5	26.5 - 28.0
28.0			J-11		4/0.5 4/0.5 7/0.5
		28.5 Cuttings become cleaner, fines could be washing out or material is cleaner.		RD	Stopped for night 11:29:77
	CL / GC-GP	grades to clayey gravel; with lenses of clean gravel. Binder is medium plasticity clay.		PB	Pitcher Barrel
30.0				0 / 2.5	29.0 - 31.5
					Tube bent
32.0				PB	Pitcher Barrel
Piezometer #1				0 / 2.5	31.5 - 34.0
					Tube bent
34.0				RD	Loosing water continuously.
				DR	Drove Standard Split Spoon
36.0				0* / 1.5	35.0 - 36.5
			J-12.		5/0.5 4/0.5 8/0.5
				RD	* 6" of loose clean gravel in tube, could be cuttings or native.
	GC-GP / CL	36.7-38.5 lense of light olive grey sandy clay, contains scattered fine gravel; stiff to very stiff; moist.		DR	
38.0			J-13	0.5 / 1.5	Drove Standard Split Spoon
	GC			RD	37.0 - 38.5
		color grades to dark grey			9/0.5 8/0.5 12/0.5
40.0				PS PB	Pushed Shelby Tube 40.0-41.0
				0 / 1.0	Pitcher Barrel 40.0-42.5
42.0				0.5 / 2.5	
			J-14		Tube Bent.
				PB	Pitcher Barrel 42.5-45.0
44.0					

Bentonite seal

Sand backfill

Bentonite seal

SHEET 2 OF 4

PROJECT 1890 DATE DRILLED 11:30 HOLE NO. RD-2

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
44.0	GC / GC-SC	19.4-86.0 SANDY GRAVELLY CLAY: cont.	Torvane TSF	PB 1.0/1.3	Tube Bent.
		44.6 sand content increases. matrix becomes sandy clay.	J-15 TSF	DR 2.5/1.5	Drove Standard split spoon 45.0-46.5 9/0.5 19/0.5 22/0.5
46.0			J-16	RD	Rock in shoe.
48.0					
	GC-SC ? CL	~49.0 grades to sandy clay with up to 20% fine to coarse gravel in lenses and throughout unit. sand content 30%? variable.		RD	
50.0			J-17	DR 0.5/1.5	Drove Standard split spoon 50.0-51.5 11/0.5 7/0.5 13/0.5
52.0				RD	
54.0					
56.0				RD	
	CL	57.7-58.2 clayey silt to silty clay with some gravel and sand.	0.50	PB	Pitcher Barrel 57.0-59.5
58.0	CL-ML	58.2-58.6 Sandy silt to silty sand w. gravel.	J-18 1.7		
	SM-ML	58.6-59.0 silty sand w. gravel	J-19 0.75	1.3/2.5	
	SM (GP) CL	59.0-59.5 clayey silt to silty clay, w. gravel.	J-20 0.83		
	CL-ML		J-21 2.3		
60.0	CL (SC)			PB	Pitcher Barrel 59.5-62.0.
				0.7/1.5	
62.0			J-22	DR 0.5/2.5	Drove Standard split spoon 62.0-63.5 8/0.5 14/0.5 24/0.5
			J-23 1.2		
64.0				RD	
66.0	(SC) CL ? GC				67.0 Stopped for night 11:30
68.0					

Sea Straight

SHEET 3 OF 4

PROJECT 1890 DATE DRILLED 12:1 HOLE NO. RD-2

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
68.0	GC	19.4-68.0 SANDY GRAVELLY CLAY: cont.	TSF	PB	Pitcher Barrel 68.0-70.5
	Bentonite seal			0/2.5	12:1 Hole caved to 53' overnight.
70.0				RD	300 gal of water + 1½ sacks of mud to clean out and run tube - still losing circulation.
72.0	sand backfill			PB 0/2.5	Pitcher Barrel 72.0-74.5
74.0					Drove an extra 5' of casing to try and control water loss.
				DR 0/1.5	Drove standard split spoon 74.5-76.0 3/0.5 4/0.5 6/0.5
76.0				RD	
Piezometer #2		cleaned out for long time; cuttings of rock with bits of purple clay.		DR 2/1.5 *	sample of cuttings. Hole was well cleaned out no obvious reason for lack of sample. Pushing rock?
78.0			J-24		
		cuttings of sand and gravel; some clay.		RD †	Drove standard split spoon 77.0-78.5 3/0.5 3/0.5 12/0.5
80.0		hole caves below sampler gets back into hole, can't get thick mud because of leakage.		PB 0/2.5	* Cuttings. Pitcher Barrel 80.0-82.5
82.0				†	78.5-80.0 Rig chatters moderately.
	CL-SC	? 83.0 grey sandy clay to clayey sand.		RD	
84.0				DR 2.5/2.5	Drove Standard split spoon 84.0-86.5 5/0.5 6/0.5 12/0.5
			1.75 1.4 1.25 1.0 J-25		
86.0	CL-SC	86.0-88.4 BEDROCK Olive green shale with some clay binder, clay decreases with depth.		RD	86.0-87.5 Rig chatters violently.
88.0			J-26	DR 2.3/0.4	Drove standard split spoon 88.0-88.4 30/0.2 rods bouncing.
		B.H. 88.4			
90.0					Sand B.H.-71 Piezo 80 Bentonite Balls 71-63. Hole caved overnight 63-43. Bent. Balls 43-40 sand 40-30 piezo 30.35'. Bent. balls 30-27
92.0					SHEET 4 OF 4

(graphical display of piezometer installations in left-hand CLAS column of log)

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT PHOENIX DAM 1890 DATE DRILLED 12:5: HOLE NO. RD-3

LOCATION DAM CREST GROUND SURFACE ELEV. 189.1

DRILLING CONTRACTOR J.N. PITCHER LOGGED BY MTD DEPTH TO GROUND WATER

TYPE OF RIG FAILING 750 HOLE DIAMETER 9" HAMMER WEIGHT AND FALL 140 lb-30"

SURFACE CONDITIONS BASE ROCK WEATHER MISTY

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
0.0	GM	0.0-0.5 BASE ROCK:	Torque: ✓ TSF ✓ TSF	RD	Rotary Drill with 9" bit.
	CL	0.5-9.0 SILTY SANDY CLAY: Moderate yellowish brown with numerous dark olive green and purple discolorations; sandy clay with pockets of silty clay; contains gravel up to 2"; moist; stiff to very stiff.			
2.0					
4.0					
6.0				RD	
			B-1 74.5	PB 0.6 / 2.5	220 psi hydraulic pressure while cutting cored with 6" pitcher barrel most of sample dropped out near top of hole
		7.0 ground contact unconsolidated; color grades to purple.			cleaned out hole to 8.5'
8.0	(GC) CL	9.0-14.2 CLAYEY GRAVEL TO GRAVELLY CLAY: Dark olive green; varying amounts of sandy and silty clay;		PB 2.5 / 2.5	Pitcher Barrel 8.5-11.0 9.5 Rig chatters 10.5 Rig chatters.
	GC-CL				
10.0	GC-CL CL		B-2 11.1, 1.3 11.2, 1.5		
	GC-CL CL CL	11.4-11.6 light olive green silty clay. 11.6-11.8 purple sandy clay.	B-3	PB 0.8 / 2.0	losing circulation used 1½ bags of bentonite from first 11 feet. water stands at 9 feet.
12.0	GC-CL (?)				
	GC-GP	clay binder is purple, predominantly sandy clay; boulders up to 5"; mod. clean		PB 2.5 / 2.5	Pitcher Barrel 13.0-15.5 13.0-14.2 Rig chatters strongly, losing circulation.
14.0	GC-GP CL	14.2-21.6 SILTY CLAY: Light olive gray and light gray with rusted discolorations; medium plasticity; contains scattered gravel up to 2"; moist locally wet; firm.	B-4		
			B-5 0.73 0.65	2.3 1.0 1.75 1.9	
16.0				RD	
				PB 2.5 / 2.5	Pitcher Barrel 16.0-18.5
			0.37 0.43	0.5 0.70 0.75 1.0 0.85 0.8 0.75 1.75 0.9 1.9	
18.0			B-6 0.63 0.63		
				RD	
20.0				RD	

SHEET 1 OF 4

PROJECT 1890 DATE DRILLED 12:6:77 HOLE NO. RD-3

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
20	CL	14.2-21.6 SILTY CLAY: cont.	4 TSF	RD	
		21.6-70.5 GRAVELLY SANDY CLAY:			21.5 Stopped for night. Water dropped 3' overnight.
22	CL	Purple with rust brown and light olive green discolorations; sandy clay (soft to firm) matrix; fine to coarse sand; pred. fine gravel; 20-30% coarse sand and gravel; firm; moist to wet.		RD	
				PB	Pitcher Barrel 22.0-22.5
24			B-7	2.4/2.5	Continuous moderate chatter.
			1.25 1.3	RD	25.0 Plate loading Test.
26				RD	
				PB	Pitcher Barrel 26.5-27.8
	CL	27.5-28.5 Rig chattering violently; boulder(?)	B-8	0.5/1.3	Strong Chattering, Refusal.
28	GP			RD	Bottom of sample fell out of tube. Clean cuttings(?) in tube.
	CL			DR	Drove Standard Split Spoon 29.0-31.5
30	CL-GC-CL	30.0 Dark olive gray gravelly clay. 30.5 color grades to purple; gravel and sand content increases to 50-60%; clay binder is firm.	B-9	0.3/1.5	5/0.5 4/0.5 7/0.5
				PB	Pitcher Barrel
32			B-10	1.1/2.5	
				RD	
34		color grades to medium gray; with brick red and turquoise discolorations.			35.0 Plate Loading Test. 35.0 Stopped for Day 12:6:77
36					
		37.5 Pocket of turquoise silty clay; firm. 37.8-40.2 layer of yellowish brown gravelly sandy clay; appears less dense than surrounding material.		RD	
38			B-11	PB	Pitcher Barrel 37.5-40.0
		gravel content is about 25%	B-12	2.5/2.5	37.5-38.0 Rig chatters strongly 38.0-40.0 " " moderately
40				RD	40.0 Plate loading Test. DMY logging hole
		42.1-42.4 large grn. gray graywacke cobble; washed out void ~3" max.			
42		42.4-43.0 med. to dk. olive gray silty clay, scattered med. sand; small patches yel. brown clay; gravel content ~ 20-25%	B-13	RD	Cored w/ Pitcher barrel sampler
			1.7(?) 1.2 1.25 1.3(?)	PB 0.9/1.0	Have been coring w/ 200-300 psi down pressure. Swivel elbow on mud line broke—pulled sampler
44	GC-CL			RD	SHEET 2 OF 4
				RD	

sfa
dow
firm
10:
a.r
11:-
a.

PROJECT 1290-Phoenix Dam DATE DRILLED 12/7/77 HOLE NO. RD-3

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
44	GCL	21.6-70.5 GRAVELLY SANDY CLAY: cont.	4 TSF	RD	44.0 Plate loading test
		color grades dark greenish grey; gravel content 25-30%.		RD	
46			B-14	PB 0.5/0.5	Cored w/Pitcher barrel sampler
				RD	Barrel plugged up - no circulation. 12:50 p.m. - Line on pump blew; down 10 minutes
48		48-48.6 2-3 large graywacke cobbles, ~3" max. dimension		PB	Cored with Pitcher Barrel 48.0-50.5.
		48.5-49.5 - brn. gray gravelly clay	B-15	1.7/2.5	
50		49.5-50 purplish gray sandy silty clay, scattered gravel ~ 15-20%	1.25, 1.4, 1.25, 0.9, 1.1		
		49.6 - layer of clayey med. sand; ~1/2" thick		RD	
52		54.8 - 55.7 - greenish to med. grey gravelly sandy clay some stringers of purple clay, less well compacted			
54		55.7-56.5 - several pockets yel-grn. silty clay, clayey silt; also purple silty clay gravel ~35%	1.7	RD / PB 1.7/2.5	Cored with Pitcher Barrel 54 - 56.5
			B-16		
56		56.5 - small pocket of med. brown clay.	B-17	1.5, 1.7, 2.0, 1.5	PB / RD
58					
60			1.5, 1.3, 1.1	RD / PB 1.3/1.5	Cored with Pitcher Barrel 60 - 61.5
			B-18		61.5 - 62.8 hard, rig chattering
		62.8 - purple & grey brn clay in cuttings	2.3	PB / RD	62.8 - softer, drilling faster
62					
64		64 - lot of clay coming up in cuttings			
66		67 - high amount of clay in cuttings			67 - drilling smooth
68					

SHEET 3 OF 4

PROJECT 1890 - Phoenix Dam DATE DRILLED 12/7/77 HOLE NO. RD-3

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
68		21.6-70.5 GRAVELLY SANDY CLAY: con't.		RD	68.7 - bit of chattering
70		~70 - 60%-70% of cuttings is clay Bedrock			70.5 - heavy chattering
	B.H. 71.5'	70.5 - 71.5 - GRAYWACKE hard to very hard little to mod weathered judging by cuttings and drill rate			B.H. 71.5

SHEET 4 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1890 - Phoenix Dam DATE DRILLED 12/5-6/77 HOLE NO. RD-4

LOCATION Downstream berm between existing holes 3 & 4 GROUND SURFACE ELEV. 140 (Topo.)

DRILLING CONTRACTOR J.N. Pitcher Co. LOGGED BY DMY DEPTH TO GROUND WATER —

TYPE OF RIG Failing 250 HOLE DIAMETER 5" HAMMER WEIGHT AND FALL 140 lb., 30"

SURFACE CONDITIONS grassy embankment berm WEATHER clear, mild

(track mounted crawler rig)

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	Pocket Penetrom.	MODE	REMARKS
2, 4 (new toe berm)	CL	0.0-4.5' (GRAVELLY) SANDY CLAY: dk. yel. brn. (5 YR 3/4); mod. plastic, slow dilatancy silty-clay fines (75-85%); scattered (15-20%) fine to coarse qtz., lithic sand grains; fine gravel (5-10%), pred. Fran. qwy, some ch, qmst., sh., ang. to subrnd. frags, vary hd. to friable, weath. stained; firm to stiff (mod. dense); slightly moist.			AD	Spin augered to 3½' set up mud tub - 1½ sk. bentonite to seal collar, start circulation
					RD	Drilled down w/ drag bit set surface casing to 4.0'
6, 8 (chimney drain)	GP	4.5-9.0' GRAVEL: med. grn. gray (5 GY 5/1), some mod. brn. (5YR 4/2) weath. stains; v. minor fines (<< 5%); scattered coarse, ang. graywacke sand grains (1-3%); pred. med. gravel (½-4" avg), ang., fresh to little weathered, hd., strong frags. (Probably a drain chimney)	B-1		PB 0.4/2.5	Cored w/ Pitcher Bbl. Assem. (only clean gravel w/ some sand in tube, no clay binder)
					RD	Drilled down with drag bit Add 2½ sks. bentonite to maintain circulation
10, 12, 14, 16, 18, 20 (hole caved to here 12/5, after drilling to 19.0) (original embankment)	GC	9.0-22.0' CLAYEY GRAVEL: dk. yel. brn. (10 YR 4/2), mod brn. (5 YR 4/4); 10-15% mod plastic silty clay fines; 5-10% scattered coarse, ang. sandst., volc. sand grains; 75-85% fine to med. gravel, pred. ang. to subrnd. graywacke, meta graywacke, metavolc. frags. consistency uncertain, probably dense in-situ; moisture uncertain in-situ.				Set casing to 9.0' to reduce water loss, maintain circulation
			J-1		PB 1.5/2.5	Cored with Pitcher barrel assembly
					RD	Drilled down w/ drag bit
		14.0-15.0 grades more sandy (15-20%), more clayey (20-30%)	J-2	1.9(?)	PB 1.2/2.5	Cored with Pitcher barrel assembly 0.5' gravel cave on top of sample
	GP	16.5-19.0 amount of caving and appearance of sample indicate little clay binder	B-2		PB 0.3/2.5	Cored with Pitcher barrel assembly 0.5' cave on top of 3-4" diam. cobble wedged in end of tube
12/5	GC	17-20 cuttings suggest material similar to 14.0-15.0 interval			RD	Drilled down w/ tricone bit

SHEET 1 OF 2

RD to 19' 3 times, hole caves to 15' each time, add ½ sk bentonite, cave to 14'

PROJECT 1890 - Phoenix Dam DATE DRILLED 12/5-6/77 HOLE NO. RD-4

add 1/4 sack bentonite

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS (cased to 20', add 1/4 sk. bentonite, flush to 22' after RD)	N, blows/ft
	GC			DR 0.0/1.5	Drove standard split spoon 13/0.5 12/0.5 18/0.5	30
				RD	Drilled down with tricone bit	
22	GC (GP)	22.0-43.5' CLAYEY SANDY GRAVEL: mod. brn. (5 YR 4/4); generally 20-25% mod. plastic silty clay fines, locally to 40-45% in clayey pockets; sand (30-40%) fine to predom. coarse, mainly angular rock frags; 35-45% gravel, avg. size 3/4-1", pred. ang. to subang., chert, serpentinite, metavolc., graywacke, frags gen. hard, strong; gravel seems to be in loose (to soft) clayey sand matrix in places, blow counts suggest mod. dense material; probably moist in-situ.	J-3	PB 1.7/2.5	Cored with Pitcher barrel assembly. Tube had 2.7' sample + voids before extrusion	
24			cave	PB 0.3/2.5	Cored w/ Pitcher barrel assembly. minor slough/cave on top of 2 1/2" cobble in end of tube	
26			cave	RD	Drilled down w/ tricone bit	
			B-3	DR 0.9/1.5	Drove standard split spoon 16/0.5 12/0.5 17/0.5	2
28		29.0-29.9 grades more coarse sand (clayey gravelly sand to gravelly clayey sand)	B-4	RD	Drilled down w/ tricone bit add 3/4 sk. bentonite to flush cuttings	
	SC (GC)			DR 0.9/1.5	Drove standard split spoon 11/0.5 8/0.5 9/0.5	17
30		30.5-34.0' cuttings suggest more coarse-fine sand, less gravel, more fines		RD	Drilled down w/ tricone bit add 1 sk bentonite to flush cuttings; water loss not significant (have used total of ~5 sks. bentonite in hole to here)	
32						
34	GC (GP)	34.2-34.6 distinctive gray-brown clayey sandy gravel	J-4 J-5	PB 1.6/2.5	Cored w/ Pitcher barrel assembly. samples appear relatively undisturbed after extrusion	
36				RD	Drilled down w/ tricone bit	
	GP?	37.0-39.0' cuttings suggest relatively little clay binder				
38						
	GC (GP)			DR 0.0/1.5	Drove standard split spoon 11/0.5 11/0.5 11/0.5	2
40				RD	Drilled down w/ tricone bit	
		Bedrock				
42		43.5-44.0 METAGRAYWACKE: cuttings suggest dk. to gray grn meta-graywacke sandstone; little clayey binder in cuttings; hard drilling			mod. chatter, rig shows at 43.5'	
44	rock				SHEET 2 OF 2	

original embankment

B.H. - 44.0'

terminate hole at 44.0

Important Information About Your

Geotechnical Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

The following information is provided to help you manage your risks.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared *solely* for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. *Do not rely on a geotechnical engineering report* whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. *Always* contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are *Not* Final

Do not overrely on the construction recommendations included in your report. *Those recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual

subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.*

A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure contractors have sufficient time* to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a *geoenvironmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, a number of mold prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; ***none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.***

Rely, on Your ASFE-Member Geotechncial Engineer for Additional Assistance

Membership in ASFE/The Best People on Earth exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you ASFE-member geotechnical engineer for more information.

ASFE
The Best People on Earth

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GEOTECHNICAL SENSITIVITY ANALYSIS
DB5 – PHOENIX LAKE DAM & RESERVOIR
WATERSHED FLOOD DAMAGE REDUCTION & CREEK MANAGEMENT STUDY
MARIN COUNTY, CALIFORNIA

April 11, 2011

Project 960.05

Prepared For:
Marin County Flood Control and
Water Conservation District, Zone 9
c/o Stetson Engineers
2171 East Francisco Blvd., Suite K
San Rafael, CA 94901

CERTIFICATION

This document is an instrument of service, prepared by or under the direction of the undersigned professionals, in accordance with the current ordinary standard of care. The service specifically excludes the investigation of radon, asbestos or other hazardous materials. The document is for the sole use of the client and consultants on this project. No other use is authorized. If the project changes, or more than two years have passed since issuance of this report, the findings and recommendations must be reviewed by the undersigned.

MILLER PACIFIC ENGINEERING GROUP
(a California corporation)

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GEOTECHNICAL SENSITIVITY ANALYSIS
DB5 – PHOENIX LAKE DAM & RESERVIOR
WATERSHED FLOOD DAMAGE REDUCTION &
CREEK MANAGEMENT STUDY
MARIN COUNTY, CALIFORNIA

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APPENDIX A – PREVIOUS BORING LOGS

GEOTECHNICAL SENSITIVITY ANALYSIS
DB5 – PHOENIX LAKE DAM & RESERVIOR
WATERSHED FLOOD DAMAGE REDUCTION &
CREEK MANAGEMENT STUDY
MARIN COUNTY, CALIFORNIA

I INTRODUCTION

This report presents the results of our supplemental evaluation of Phoenix Lake Dam in Ross, California. Our work is performed as part of the Watershed Flood Damage Reduction and Creek Management Study, Marin County, California. This report is intended for the exclusive use of Marin County Flood Control and Water Conservation District, Stetson Engineers and their consultants on this project. No other use is authorized without the express written consent of Miller Pacific Engineering Group.

We previously prepared a preliminary geotechnical evaluation for Detention Basin 5 (Phoenix Lake Dam & Reservoir) dated May 6, 2010. The purpose of our supplemental evaluation is to vary the soil strength profile within the dam to determine the effect on stability and predicted seismic displacement. If seismic displacements using conservative strength profiles are excessive, then develop possible mitigation measures and associated cost estimates to improve stability and reduce seismic displacements. In accordance with our agreement dated February 3, 2011, the scope of our supplemental geotechnical services includes the following:

- Consult with Division of Safety of Dams (DSOD) regarding seismic ground shaking accelerations for use in pseudo-static slope stability and allowable deformation. Determine DSOD approved consultants for outside consultation and peer review.
- Develop various strength profiles for the dam based on the existing geotechnical exploration and laboratory testing performed at the site. This would include conservatively low strength profiles, as well as, best fit strength interpretation.
- Perform preliminary, two-dimensional, static and pseudo-static stability analyses using a cross-section near the center of the dam. We will evaluate dam stability for sudden drawdown conditions and calculate potential seismic deformations using procedures published by Makdisi / Seed or Bray.
- Develop and analyze potential mitigation measures, if needed, to improve stability and reduce deformations to DSOD acceptable levels. Provide rough cost estimates for the conceptual mitigation measures.
- Prepare technical memorandum describing the results of the supplemental geotechnical evaluation as described above

II. PROJECT DESCRIPTION

Phoenix Lake is a recreational reservoir in southern Marin County owner by Marin Municipal Water District. The location of the project site is shown on Figure 1. We understand Marin County Flood Control and Water Conservation District would like to utilize this reservoir for short term storage of storm water during larger, infrequent events, to aid in flood management of Corte Madera and San Anselmo Creek.

Phoenix Lake Dam is an earth fill dam originally constructed in 1905 utilizing the construction techniques of that time. The dam experienced the affects of the Great 1906 San Francisco Earthquake and remained intact with minor sloughing of the upstream face.

From the early 1900's until the mid 1980's the reservoir water level was maintained at approximately elevation +180 feet[1]. The dam was retrofitted in the late 1960's to improve performance during future seismic events and control seepage. The improvements included an upstream buttress fill and downstream berm underlain with a pervious drainage blanket and rip-rap toe. The existing Phoenix Dam is approximately 94 feet in height (crest elevation 189 feet), 350 feet in length and has a crest width of approximately 22 feet with slopes varying between approximately 1.5:1 (horizontal:vertical) to 3:1.

Additional work was performed on the spillway in about 1985 to account for potential seismic displacements and increase spillway capacity. A fourteen (14) feet wide by six (6) feet deep notch was constructed in the bottom of the existing spillway to lower the reservoir to elevation +174 feet and thus increase the total freeboard of the dam.

[1] All elevations given in this report are relative to the NGVD29 datum.

III. REFERENCE DATA

We reviewed various geotechnical reports and data on file at MMWD and the Division of Safety of Dams (DSOD) that pertain to the geotechnical aspects of Phoenix Lake Dam. The relevant reports reviewed are listed below:

- Dames & Moore "Stability Evaluation Phoenix Lake Dam," October 1959,
- Leeds, Hill & Jewett, Inc., "Methods of Strengthening Phoenix Lake Dam," March 1966,
- Marin Municipal Water District, "Specifications for the Rehabilitation of Phoenix Lake Dam," Undated (1968),
- Earth Sciences Associates, "1977-78 Evaluation of Seismic Stability Phoenix Lake Dam," March 1978,
- Marin Municipal Water District, "Phoenix Dam Spillway Seismic Analysis," March 1980,
- Division of Safety of Dams, Department of Water Resources, "Phase 1 Inspection Report for Phoenix Lake Dam," May 1981, and
- Earth Sciences Associates, "Phoenix Lake Spillway Reconstruction Geotechnical Report," February 1984.

The Dames & Moore (1959), Leeds, Hill & Jewett, Inc. (1966), and Earth Sciences Associates (1978) reports analyzed various stability conditions of Phoenix Dam including seismic and rapid drawdown conditions. The remaining reference reports included design specifications, seismic analysis of the spillway structure, DSOD inspection report, geotechnical report for the spillway structure reconstruction, and various general correspondences. The three pertinent geotechnical analysis reports are outlined below:

Dames & Moore – The 1959 report was issued prior to the retrofit of Phoenix Dam. Dames & Moore performed subsurface exploration and analyzed seismic conditions utilizing a seismic load of "10% gravity", or 0.10 g, and rapid drawdown conditions (completely draining the reservoir) on both the upstream and downstream slopes. Based on the results of their slope stability analyses, Dames & Moore concluded the downstream seismic and static factors of safety were 1.2 and were "adequate". Additionally, Dames & Moore concluded the computed upstream factor of safety of 1.15 during rapid drawdown was "not high" and the drawdown of the dam should be controlled.

Leeds, Hill, & Jewett – The 1966 report prepared by Leeds, Hill, & Jewett, Inc. (LHJ) provided Marin Municipal Water District (MMWD) with three conceptual options to retrofit and strengthen the dam. Conceptual Plan III was selected and included: flattening the upstream bank by adding an impervious "blanket" fill, constructing a drain on the downstream toe of the dam, adding an earth buttress on the downstream side to confine the drain, and placement of rip-rap for erosion

control at the toe of the dam.

Earth Sciences Associates – The 1978 report was performed after Phoenix Dam was retrofitted as described in the report issued by LHJ (Plan III). ESA performed a SHAKE analysis utilizing a design earthquake event of the San Andreas Fault rupturing with magnitude 8.4. The results of ESA's analyses provided the predicted seismic acceleration throughout the height to the dam (0.56 g at the base to 1.0+ g at the crest). These accelerations were utilized to conservatively estimate the potential deformation during the design seismic event and concluded a potential crest settlement of 5.3 feet and downslope movement of 11 feet.

IV. SITE CONDITIONS

A. Regional and Local Geology

The site is located within the Coast Range Geomorphic Province of California. The regional bedrock geology mostly consists of complexly folded, faulted, sheared, and altered sedimentary, igneous, and metamorphic rock of the Jurassic-Cretaceous age (65-190 million years ago) Franciscan Complex. The Franciscan is characterized by a diverse assemblage of greenstone, sandstone, shale, chert, and mélange, with lesser amounts of conglomerate, calc-silicate rock, schist and other metamorphic rocks.

The regional topography is characterized by northwest-southeast trending mountain ridges and intervening valleys that were formed by compressive movement between the North American and the Pacific Plates. Continued deformation and erosion during the late Tertiary and Quaternary Age (the last several million years) formed the prominent coastal ridges and the inland depression that is now the San Francisco Bay. The more recent seismic activity within the Coast Range Geomorphic Province is concentrated along the San Andreas Fault zone, a complex group of generally north to northwest trending faults.

Site geologic mapping was performed by Earth Sciences Associates (1978) and indicate Phoenix Lake is predominately surrounded by greywacke sandstone. Minor inclusions of serpentinite, chert, and greenstone are mapped within the greywacke. The drainage swales surrounding Phoenix Lake contain colluvial and alluvial deposits. The mapping also indicates three landslides are located on the surrounding rim of Phoenix Lake. The largest mapped landslide is located on the northwestern tip of Phoenix Lake.

B. Seismicity

1. Active Faults in the Region – The project property is located within the seismically active California Coast region and will therefore experience the effects of future earthquakes. Such earthquakes could occur on any of several active faults within the region. The California Geological Survey (CGS, 2000) has mapped various active and inactive faults in the region. Active faults are defined by the CGS as those that show evidence of movement in the past 11,000 years and have reported slip rates of >0.1 mm/year.

   Based on the CGS information, there are no known active faults passing through or in the immediate proximity of the property. The closest known active fault is the San Andreas Fault, which is located about 6.4 miles (10.3 kilometers) to the west. The locations of the active faults relative to the project site are shown on Figure 2.

2. Historical Fault Activity – Numerous earthquakes have occurred in the region within historical times. The results of our computer database search indicate that 70 earthquakes (Richter Magnitude 5.0 or larger) have occurred within 100 kilometers (62 miles) of the site between 1735 and 2010. Significant earthquakes to affect the project site are summarized in Table A.

TABLE A
SIGNIFICANT EARTHQUAKE ACTIVITY
Phoenix Lake Dam
Ross, California

Epicenter (Latitude, Longitude)	Magnitude	Fault	Year	Distance
37.80, -122.20	6.8	Hayward	1836	37 km
37.60, -122.40	7.0	San Andreas	1838	42 km
37.70, -122.10	6.8	Hayward	1868	50 km
38.20, -122.40	6.2	Rodgers Creek	1898	31 km
		Post Construction		
37.70, -122.50	8.2	San Andreas	1906	29 km
37.67, -122.48	5.3	San Andreas	1957	32 km
38.46, -122.69	5.7	Hayward	1969	56 km
37.85, -121.82	5.8	San Gregorio	1980	67 km
37.91, -121.69	4.5	San Andreas	1999	10 km
37.43, -121.77	5.6	Calaveras	2007	91 km

Reference: USGS (2010)

Probability of Future Earthquakes – The historical records do not directly indicate either the maximum credible earthquake or the probability of such a future event. To evaluate earthquake probability in this region, the USGS has assembled a group of researchers into the "Working Group on California Earthquake Probabilities" to estimate the probabilities of earthquakes on active faults. Potential sources were analyzed considering fault geometry, geologic slip rates, geodetic strain rates, historic activity, and micro-seismicity, to arrive at estimates of probabilities of earthquakes with a Moment Magnitude greater than 6.7 by 2037.

The probability studies focused on seven "fault systems" within the Bay Area. Fault systems are composed of different, interacting fault segments capable of producing earthquakes within the individual segment or in combination with other segments of the same fault system. The probabilities for a magnitude 6.7 or greater earthquake before 2032 on fault segments within the

San Francisco Bay Area are presented on Figure 2.

In addition to the seven fault systems, the studies included probabilities of "background earthquakes." These earthquakes are not associated with the identified fault systems and may occur on lesser faults (i.e., West Napa) or previously unknown faults (i.e., the 1989 Loma Prieta and 2000 Napa/Mt. Veeder Earthquake). When the probabilities on all seven fault systems and the background earthquakes are combined mathematically, there is a 62 percent chance for a magnitude 6.7 or larger earthquake to occur in the Bay Area by the year 2032. Smaller earthquakes (between magnitudes 6.0 and 6.7), capable of considerable damage depending on proximity to urban areas, have about an 80% chance of occurring in the Bay Area by 2032 (USGS, 2002). Additional studies by the USGS regarding the probability of large earthquakes in the Bay Area are on going. These current evaluations include data from additional active faults and updated geological data.

C. Interpreted Subsurface Conditions and Laboratory Testing

Our scope of services did not include performing a subsurface exploration. However, subsurface explorations were performed by Dames & Moore (1959) and Earth Sciences Associates (1978). The approximate locations of previous exploration are shown on Figure 3, Site Plan. Based on the construction records for the dam, we are aware that the dam was built during two primary phases of construction that took place in 1905 and 1968. The original 1905 dam fill can be generalized as consisting of interbedded gravelly clays and clayey gravels. The newer upstream buttress constructed in 1968 consists of compacted impervious clayey material. At the downstream side, a layer of well graded sand and gravel was placed as a drainage blanket that underlies non-specific general fill free of large amounts of clay and rocks exceeding 8-inches. The rip-rap toe at the downstream base of the dam consists of well graded rock fragments free of fine grained sediments. Deposits of saturated fine-grained sediments have been accumulating on the toe of the upstream face between 1968 to present. Interpreted geologic cross sections are presented on Figures 4 and 5.

The subsurface explorations performed by the aforementioned firms observed silty sands (SM) and silty clays (CL) within the upper 20 feet of the embankment. The lower portions of the embankment consisted of gravelly sandy clay (CL) and clayey sandy gravels (GC). The observed bedrock below the earth dam is graywacke sandstone with minor inclusions of shale and metagraywacke. The boring logs performed by Dames & Moore and Earth Sciences Associates are presented in Appendix A.

Both Dames & Moore and Earth Sciences Associates performed laboratory testing on select soil samples to determine the pertinent engineering soil properties. The tests performed included

moisture content, dry density, unconfined compression, down-hole bearing plate tests and consolidated undrained triaxial tests with pore pressure measurements (TXCU-pp). The test results were utilized to develop a strength profile for Phoenix Dam.

We plotted the existing laboratory shear strength data versus depth to identify trends in strength values versus depth of the dam. Considering the variability of the laboratory data, we developed three (3) soil shear strength versus depth profiles for use in our analyses, as shown on Figure 6. Strength Envelope 1 represents a conservative estimate of the average strength of the dam based on existing data. Strength Envelope 2 represents a 20% reduction to provide a more conservative profile or reduced cyclic strength during seismic loading. Strength Envelope 3 is another 20% reduction for an even more conservative estimate of average soil strength. For comparison, we also plotted the shear strength profiles developed and utilized by Dames & Moore and Earth Sciences Associates on Figure 6.

V. GEOLOGIC HAZARDS EVALUATION

A. General

This section identifies potential geologic hazards at the project site, their significant adverse impacts, and recommended mitigation measures. Geologic hazards considered include fault rupture, seismic shaking, liquefaction, seismic induced settlement, lurching, lateral spreading, ground cracking, slope stability, erosion, seiche, tsunami, flooding, settlement and expansive soils. The potentially significant geologic hazards at the project site are strong seismic ground shaking, seismic induced settlement, slope instability, seiche and flooding. We judge that other geologic/seismic hazards are of lesser concern as discussed in the preliminary geotechnical report. The evaluation and more detailed discussion of potentially significant geologic hazards are discussed in the following sections.

B. Seismic Shaking

The site will likely experience seismic ground shaking from future earthquakes in the San Francisco Bay Area. Earthquakes along several active faults in the region, as shown on Figure 2, could cause moderate to strong ground shaking at the site.

Deterministic Seismic Hazard Analysis – Deterministic Seismic Hazard Analysis (DSHA) predicts the intensity of earthquake ground motions by analyzing the characteristics of nearby faults, distance to the faults and rupture zones, earthquake magnitudes, earthquake durations, and site-specific geologic conditions. Empirical relations (Abrahamson and Silva, Boore and Atkinson, Campbell and Borzognia, Chiou and Youngs, and Idriss (2008) for bedrock were utilized to provide approximate estimates of median peak site accelerations. A summary of the principal active faults affecting the site, their closest distance, moment magnitude of characteristic earthquake and probable peak ground accelerations (PGA), which an earthquake on the fault could generate at the site, are shown in Table B.

TABLE B
DETERMINISTIC PEAK GROUND ACCELERATION
Phoenix Lake Dam
Ross, California

Fault	Moment Magnitude	Distance	Median PGA	84th% PGA
San Andreas	7.8	10 km	0.31 g	0.53 g
San Gregorio	7.2	21 km	0.16 g	0.29 g
Hayward	6.9	19 km	0.16 g	0.28 g
Point Reyes	6.9	22 km	0.13 g	0.25 g

References: Sources: USGS (2009), Abrahamson and Silva (2008), Boore and Atkinson (2008), Campbell and Borzognia (2008), Chiou and Youngs (2008), Idriss (2008)

Probabilistic Seismic Hazard Analysis – Probabilistic Seismic Hazard Analysis (PSHA) analyzes all possible earthquake scenarios while incorporating the probability of each individual event to occur. The probability is determined in the form of the recurrence interval, which is the average time for a specific earthquake acceleration to be exceeded. The design earthquake is not solely dependent on the fault with the closest distance to the site and/or the largest magnitude, but rather the probability of given seismic events occurring on both know and unknown faults.

Probabilistic seismic hazard analyses (PSHA) ground motions are determined in the form of recurrence intervals such as 10% chance of exceedance in 100 years. Each recurrence interval converts to a return period, for instance the return period for a probabilistic ground motion with a 10% chance of exceedance in 100 years is 949 years. Common PSHA recurrence intervals are 2% chance exceedance in 50 years (2,475 year return period) and 10% chance of exceedance in 50 years (475 year return period). Predicted accelerations for the common recurrence intervals are given below in Table C.

TABLE C
PROBABILISTIC PEAK GROUND ACCELERATION
Phoenix Lake Dam
Ross, California

Recurrence Interval	Return Period	PGA, g
10% in 50 years	475 years	0.42
2% in 50 years	2,475 years	0.72

References: National Seismic Hazard Map Program (USGS, 2008)

The potential for strong seismic shaking at the project site is high. Due to their close proximity and historical seismic activity, the San Andreas and Hayward Faults present the highest potential for severe ground shaking. The most significant adverse impact associated with strong seismic shaking is embankment or slope instability, seismic displacements, and potential damage to structures and improvements.

The spectral bedrock accelerations at the site for the 84% deterministic and probabilistic evaluations are shown on Figure 7. DSOD considers both deterministic and probabilistic accelerations. For the Phoenix Dam evaluation, the 84% deterministic was used. This level of acceleration corresponds with a roughly 500-year return period. If the return period is unreasonably low, DSOD recommends a probabilistic evaluation with a higher return period (i.e., 1000 year minimum). Therefore, we also evaluated the dam using the 2% in 50 years probabilistic earthquake with a return period of about 2,475 years.

Embankment slopes need to be stable under static conditions and provide acceptable levels of deformation during strong ground shaking. Preliminary slope stability analyses indicate the performance of the dam during strong seismic shaking may be better than the 1978 ESA evaluation. Mitigation measures include checking the dam stability and calculated displacements using various strength envelopes and seismic ground motions to confirm appropriate levels of safety are maintained. Consultation, review and approval of any dam modifications need to be performed by the California Division of Safety of Dams.

C. Seismic Induced Settlement

Ground shaking can induce settlement of loose granular soils above the water table. Based on previous explorations, the dam is primarily composed of clayey gravel and gravelly clay. Loose granular deposits were not often observed in the previous exploratory borings. In addition, the dam experienced seismic shaking during the 1906 earthquake, which would have densified loose granular deposits. Therefore, the potential for significant seismic induced ground settlement is low.

Some potential crest settlement from seismic densification should be incorporated into the seismic deformation analyses. For preliminary evaluation, we recommend 0.5 foot of potential crest settlement during a strong seismic event due to densification be added to crest settlement induced from slope deformation associated with seismic slope instability.

D. Dam Slope Stability

Based on our preliminary slope stability analyses, Phoenix Lake Dam is most susceptible to slope

instability and deformation during large seismic events. The results of our analyses indicate deformation during a strong seismic event would be less than calculated deformation from the previous reports. A more detailed discussion of slope instability of Phoenix Lake Dam is presented later in this report.

Phoenix Lake Dam has been in place for over a century and has reportedly not experienced any significant instability or displacements over its lifetime. Mitigation measures performed in the 1980's included lowering the spillway to account for displacements and crest settlement. Our new analyses indicate less displacement. Planned modification to dam should be analyzed to confirm adequate dam safety and freeboard are maintained after potential seismic deformation.

E. Seiche

Seiches are short duration earthquake or landslide generated water waves in large, enclosed bodies of water. The extent and severity of a seiche would be dependent upon the ground motion and the fault offset from nearby active faults. There is some potential for seiches to occur after an earthquake, especially when water levels are high. Additionally, if a landslide were to remobilize and suddenly flow into the reservoir, it could displace a sizable volume of water that could create a seiche.

It is not likely that an earthquake or landslide induced seiche will damage the dam provided adequate freeboard is maintained and the spillway can release the excess water. For preliminary design, we recommend that a minimum of 4-feet of freeboard should be maintained.

F. Flooding

The adverse impact from flooding is water overtopping the earthen dam causing excessive erosion and potential instability. Phoenix Lake is surrounded by a watershed that will divert surface water runoff into the reservoir raising the water surface elevation during storm events. The existing dam and spillway is designed to pass a 35,000 year storm and maintain with a residual freeboard of about 3.4 feet.

The intent of the project is to utilize the existing reservoir for flood control. This would include lowering the reservoir water prior to predicted flood events and increasing the storage capacity of the reservoir by raising the spillway from elevation +174 to +180. Modifications to the Dam and spillway may be required to maintain the DSOD required 1.5 feet of freeboard during the 35,000 year storm event. Stetson Engineers is preparing a more detailed study of the Phoenix Lake reservoir and spillway for flood management.

VI. DISCUSSION AND EVALUATION

A. General

Based on our supplemental evaluation, we conclude that the proposed use of Phoenix Lake Dam and Reservoir as a flood control detention basin is feasible. Based on our analyses, reducing the estimated strength of the soils that comprise the dam reduces stability and increase estimated seismic deformations. However, the calculated displacements using the lowest soil strength profile and maximum seismic accelerations are still less than the estimated displacements presented in the 1978 ESA report that are the basis for the 1985 spillway modifications and DSOD maximum reservoir level of +174.

Factors of safety are above 1.09 for most of the sudden drawdown conditions and strength profiles. The exception is full drawdown from +180 to +140 for the weakest estimated soil profile (Strength Envelope 3) where the calculated factor of safety is near 1.0.

Dam stability, estimated seismic displacements and sudden drawdown stability appear to be acceptable using a reservoir level at +180 for both Strength Envelopes 1 and 2. For Strength Envelope 3, estimated seismic displacements may exceed 5 feet and full drawdown conditions have marginal stability. For this reason, mitigation measures have been developed to improve stability and reduce seismic deformations.

B. DSOD Jurisdictional Determination

We have consulted with the California Department of Water Resources, Division of Safety of Dams (DSOD) regarding the potential to utilize Phoenix Lake as a storm water storage detention basin for flood management. Based on our conversation, DSOD may allow Phoenix Lake to be utilized as a storm water detention basin. Phoenix Lake is currently certified for operation at reservoir level +174. Without submitting supplemental analyses, the reservoir could be utilized for flood management by drawing down the reservoir prior to storm events. Temporary impoundment of storm water at higher reservoir levels is feasible provided that supplemental analyses are performed and documentation provided showing adequate stability and freeboard is maintained. For pseudo-static (seismic) analyses, ground motions are the higher of the 84th percentile deterministic motions or probabilistic analyses with a reasonable return period. For Phoenix Lake dam, DSOD will likely utilize the 2% in 50 years (2475 yr return period) probabilistic acceleration of about 0.72g for evaluation of the dam. Minimum factors of safety are 1.5 for static conditions, 1.0 for post-seismic conditions, 1.1 for sudden drawdown, and predicted seismic deformations ideally less than 5 feet. The analyses do not need to consider a worst case earthquake and worst case storm occurring at the same time. DSOD also requires a 4-foot minimum freeboard be maintained

for the dam.

C. Stability Analyses

We performed slope stability analyses for static, pseudo-static and rapid draw down conditions using Spencer's Method with the computer program Slide version 6.0, produced by RocScience. We evaluated an idealized cross section through the central portion of Phoenix Dam. We varied the strength envelope profile with the dam to evaluate the effect on factor of safety and seismic displacement. The three strength envelopes analyzed are shown on Figure 6.

For pseudo-static analyses, we evaluated deterministic and probabilistic seismic accelerations. For deterministic analyses (NGA 2008), the seismic peak bedrock acceleration of the site due to a seismic event on the San Andreas Fault is 0.53g for the 84th percentile. We also evaluated the 2% in 50 years probabilistic peak ground acceleration (0.72 g's) in our seismic slope stability analysis. The factors of safety under pseudo-static (seismic) conditions are below 1.0, which indicates deformation of the dam will likely occur during strong seismic shaking.

For our analyses, a reservoir water level of +180 was used. As previously discussed in the preliminary geotechnical report, varying the water level from +174 feet to +184 feet does not significantly influence the calculated factors of safety. We also calculated stability factors of safety under two rapid drawdown conditions. Condition 1 is rapid drawdown from reservoir elevation +180 down to +160, and Condition 2 is rapid drawdown from +180 to +140. The results indicate factors of safety at or above 1.0. However, localized, shallow instability is likely during rapid drawdown, and has occurred during previous rapid drawdown of the reservoir.

The results of our analyses are summarized below in Table D and are presented on Figures 8 through 10.

TABLE D
SLOPE STABILITY FACTORS OF SAFETY
Phoenix Lake Dam
Ross, California

	Static Analyses			
	Static Conditions		Rapid Drawdown	
Soil Profile	Downstream	Upstream	+180 to +160	+180 to +140
Effective Stress Envelope	1.64	2.35		
Strength Envelope #1	1.30	2.21	1.46	1.21
Strength Envelope #2	1.11	1.82	1.31	1.09
Strength Envelope #3	0.96	1.51	1.18	0.99

	Pseudo-Static (Seismic) Analyses			
	DSHA		PSHA	
	84th Percentile (0.53 g)		2% in 50 years (0.72 g)	
Soil Profile	Downstream	Upstream	Downstream	Upstream
Strength Envelope #1	0.54	0.59	0.45	0.47
Strength Envelope #2	0.46	0.50	0.39 - 0.48	0.39
Strength Envelope #3	0.36	0.42	0.32 - 0.44	0.33

D. Seismic Slope Displacement

Due to brief factors of safety below 1.0 under seismic conditions, the slopes of Phoenix Lake Dam will likely deform during strong seismic shaking. The previous 1978 deformation analyses by Earth Science estimated 11 feet of elastic deformation along the slip plane which results in 5.3 feet of vertical settlement of the crest. We analyzed the potential slope displacement based on the procedures outlined by Makdisi Bray & Travasarou (2007). The results of our analyses indicate that the anticipated range of displacements along the slip plane is strongly influenced by the soil strength profile and seismic acceleration used in the analyses. The calculated potential dam displacements rounded up to the nearest inch are shown in Table E.

TABLE E
PREDICTED SEISMIC DAM DISPLACEMENT
Phoenix Lake Dam
Ross, California

	DSHA PGA = 0.53 g						PSHA PGA = 0.72 g					
	Upstream Displacement (in.)			Downstream Displacement (in.)			Upstream Displacement (in.)			Downstream Displacement (in.)		
Strength Envelope #1	2	**5**	9	5	**10**	19	4	**8**	15	10	**19**	37
Strength Envelope #2	5	**9**	17	7	**13**	26	7	**13**	25	13	**24**	47
Strength Envelope #3	8	**15**	29	17	**32**	63	10	**20**	38	27	**51**	99

7 **13** 25 – Upper range (16% chance of exceedance) of estimated displacement.
I I--- Median of estimated displacement range.
I---- Low range (84% chance of exceedance) of estimated displacement.

The predicted displacements listed above are along the potential failure mode within the dam. The total displacement can be broken down into horizontal and vertical components based on inclination and geometric principles. Since most of the calculated failure surfaces roughly correspond with the average inclination of the dam slopes (26 degrees), the horizontal displacement is about 90% of the total and the vertical component is about 45% of the total. For example, 50 inches of total displacement would break down to about 45 inches of horizontal displacement and 22 inches of vertical displacement.

For all strength envelopes analyzed, the estimated displacements are significantly less than the 1978 Earth Science Associates estimates. For the worst case scenario with the higher PSHA seismic acceleration, weakest soil profile (Strength Envelope 3), and upper part of the displacement range, crest settlement is estimated at 44 inches plus 6 inches seismic densification settlement results in 50 inches. With the spillway elevation at +180, this would leave more than 4 feet of freeboard following a strong earthquake. Based on the preliminary analyses, overtopping of the dam should not occur during or following a strong earthquake event when the water level in the reservoir is elevated (up to elev. +180).

If supplemental exploration and laboratory testing indicated low soil strength values, mitigation measure can be performed to improve dam stability and reduce seismic displacements.

E. Potential Mitigation Measures

Based on our preliminary evaluation, some mitigation may be required to improve stability and reduce displacements if the actual strength of the dam is as low as Strength Envelope 3. Possible mitigation measures include: additional buttress fill, internal drainage, soil cement columns, rock anchors, and auger cast displacement piles. For strengthening with embedded structural members, the auger cast piles appear to have the highest benefit:cost ratio. We have performed stability analyses using Strength Envelope 3 with a rebuilt downstream embankment, 3 rows of auger cast displacement piles through the center of the dam and on the upstream face. The static stability, pseudo-static stability, seismic displacement and rapid drawdown stability results are shown on Figure 11. Each reinforced concrete displacement pile is expected to be about 18-inches in diameter and spaced roughly 10 feet on center. The combination of rebuilt downstream embankment, internal drainage and displacement piles reduce seismic displacements and improve stability during full rapid drawdown.

As noted previously, the dam is also susceptible to surficial sloughing of the dam face during sudden drawdown conditions. Options considered to reduce surficial sloughing include: (1) placement of a rip-rap layer and a seepage collection system on the upstream face of the dam; (2) installation of shallow trench drains on the face to collect water seepage and then cement treatment of the upper 18-inches of soil to increase strength and sloughing resistance; or (3) repairing sloughs as they occur with a rip-rap rock pack. We have utilized a 3 foot thick rip-rap layer on the dam face for our conceptual cost estimating. The rough cost estimate for this option is presented on Figure 11. When possible, drawdown should be performed at a slow rate (i.e., 1-foot/day) to reduce the potential for upstream slope failures.

As with all earth fill dams, inspection of the slopes and surrounding area should be performed on a periodic basis to identify and remediate geotechnical conditions that can lead to larger slope instability problems. Some of these conditions are expected to include signs of wave erosion, surface “rilling”, piping, seepage areas or ground cracking.

As mentioned above, the factors of safety during strong seismic conditions are below 1.0 and therefore the dam may experience seismic displacements. Following a seismic event, a thorough inspection of the dam and reservoir should be performed to evaluate performance and provide recommendations for any required repair work.

VII. SUPPLEMENTAL SERVICES

Provided that the concept of using Phoenix Lake Dam and Reservoir as a flood control measure is approved for use by the owner/operators, our supplemental services should include exploration and laboratory testing to provide additional data on the engineering properties of the soil and rock that comprise the dam. This phase of work will involve consultation with the Division of Safety of Dams (DSOD) to determine project specific analyses to be performed. More refined stability and deformation analyses should be performed utilizing the additional data collected. In addition, we recommend consultation with an independent geotechnical peer reviewer during the design level investigation regarding the planned dam improvements.

We should review the plans and specifications for the project when they near completion to review the geotechnical aspects, confirm that the intent of our geotechnical recommendations has been incorporated and provide supplemental recommendations, if needed. During construction, inspection and testing of the geotechnical portions of the project should be performed under the direction of a registered Geotechnical Engineer.

Supplemental exploration, laboratory testing and more sophisticated deformation analyses should be performed to confirm the preliminary results. Supplemental services should be performed in consultation DSOD.

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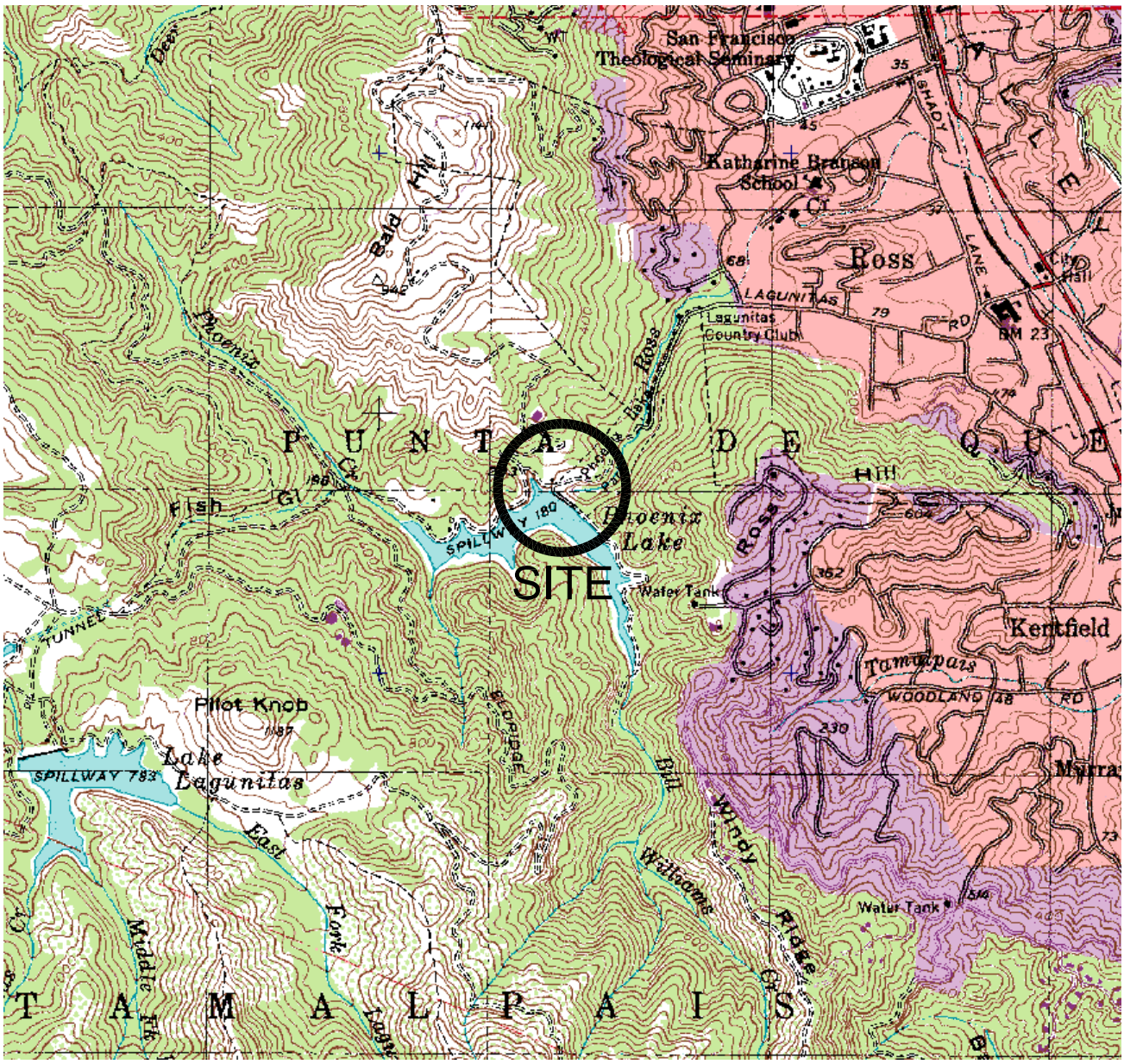

SITE: LATITUDE, 38.9557°
LONGITUDE, -122.5752°

SITE LOCATION

SCALE

0 1000 2000 4000 FEET

0 500 1000 METERS

NORTH

REFERENCE: DeLorme 3D TopoQuads, 1999

Miller Pacific ENGINEERING GROUP	504 Redwood Blvd.	SITE LOCATION MAP		
	Suite 220	Stetson - MC Flood Protection Phoenix Lake Dam Marin County, California	Drawn JSC Checked	1
	Novato, CA 94947			
	T 415 / 382-3444			
	F 415 / 382-3450			
	www.millerpac.com	Project No. 960.05 Date: 3/8/11		FIGURE

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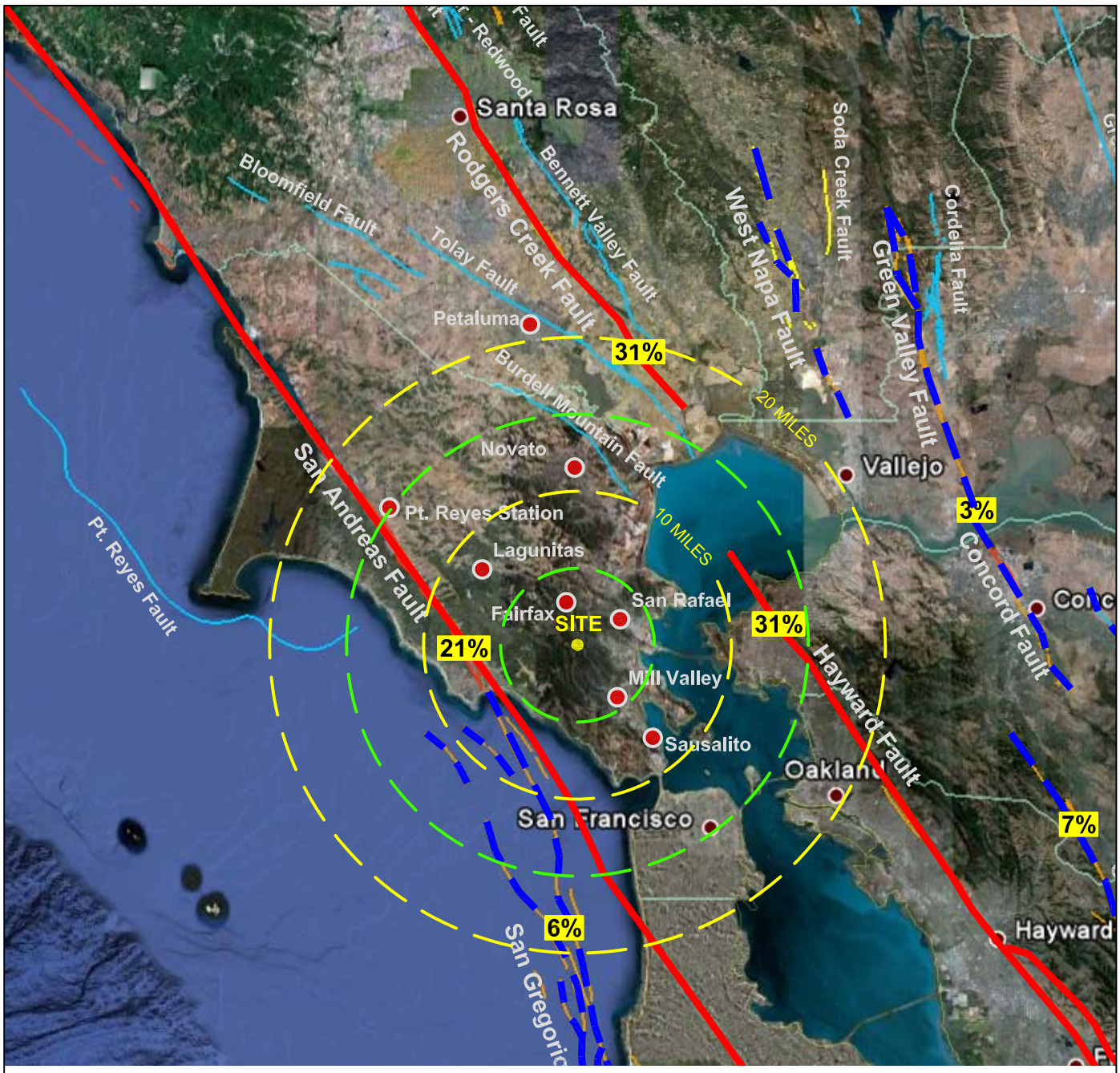
FILE: 960.05SP.dwg



LEGEND

SITE: LATITUDE, 38.9557°
LONGITUDE, -122.5752°

NORTH

FAULT	TYPE	CBC DESCRIPTION
	"A"	CAPABLE OF LARGE MAGNITUDE EARTHQUAKES AND HIGH RATE OF SEISMIC ACTIVITY
	"B"	CAPABLE OF LARGE MAGNITUDE EARTHQUAKES OR HIGH RATE OF SEISMIC ACTIVITY

21% PROBABILITY OF M≥6.7 BETWEEN 2008-2038 FOR FAULTS SHOWN. OVERALL PROBABILITY OF 63% IN BAY AREA OF ONE OR MORE M≥6.7 EARTHQUAKES FROM 2008-2038.

REFERENCES:

1) ACTIVE FAULT MAP MODIFIED FROM SUMMARY OF EARTHQUAKE PROBABILITIES IN THE S.F. BAY REGION, 2008-2038, THE 2007 WORKING GROUP ON CALIFORNIA EARTHQUAKE PROBABILITIES, 2008.

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FILE: 960.05 FM.dwg

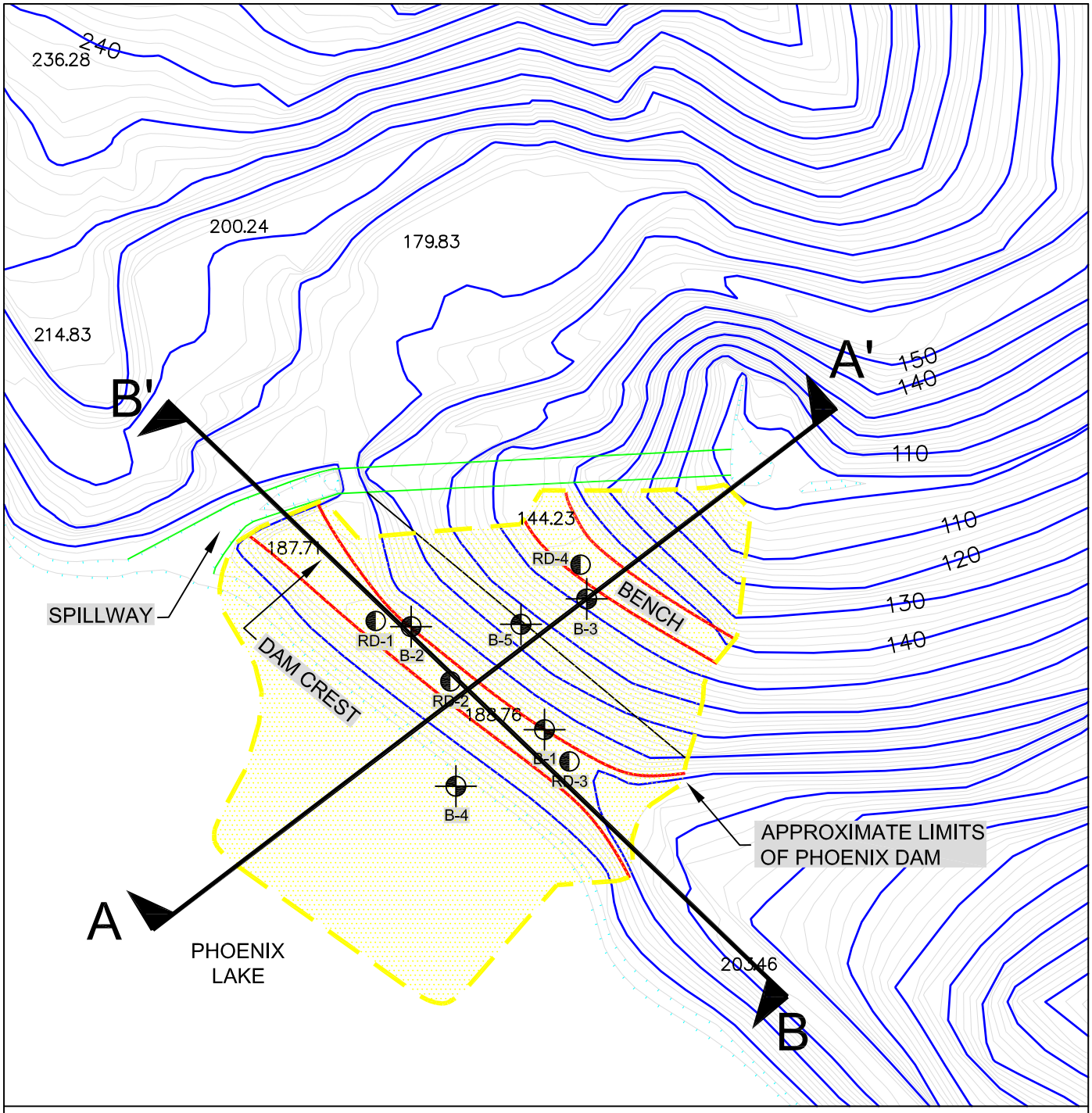
ACTIVE FAULT MAP

Stetson MC - Flood Protection
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 3-8-11

Drawn JTO
Checked

2
FIGURE



RD-4 Boring by Earth Sciences Associates, 1977

B-2 Boring by Dames & Moore, 1958

SCALE

0 50 100 200 FEET

NORTH

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FILE: 960.05F2.dwg

SITE PLAN AND BORING LOCATIONS

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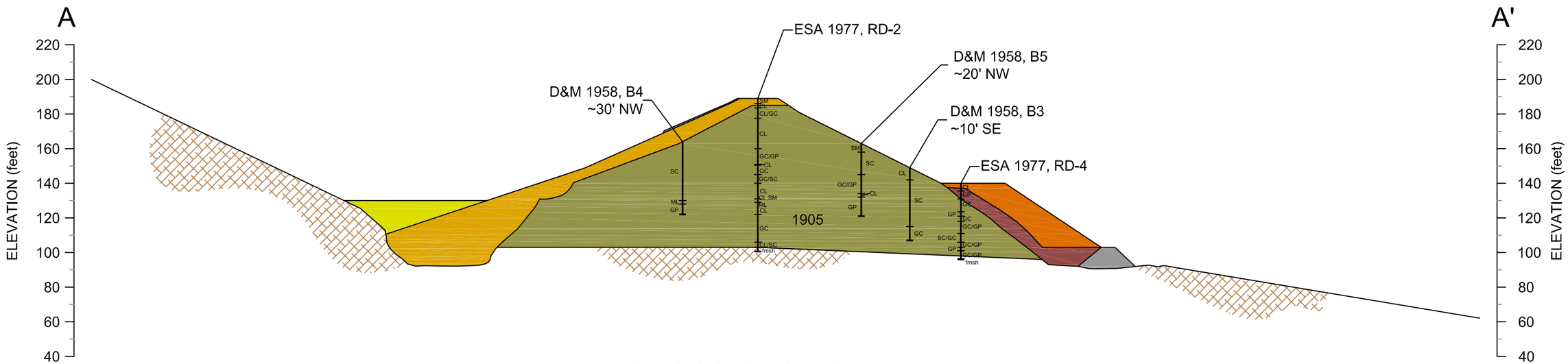
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 3-8-11

Drawn JSC
Checked

3
FIGURE



CROSS SECTION A - A'

SCALE 1" = 60'

LOW PERMEABILITY BUTTRESS FILL
- 1968 construction
compacted impervious
clayey material

GENERAL BUTTRESS FILL
- 1968 construction
on-site materials without large
amounts of clay or rocks exceeding 8"

ORIGINAL DAM FILL
- 1905 construction
interbedded gravelly
clay/clayey gravel

- FRANCISCAN GRAYWACKE SANDSTONE

SILT SEDIMENT
- accumulated from post 1968
construction to present
saturated fine grained sediments

DRAINAGE BLANKET
- 1968 construction
well graded sand and gravel (1/2" max.)

RIP-RAP
1968 construction
- highly pervious well graded
rock fragments free of soil
and and fines

SCALE
0 30 60 120 FEET

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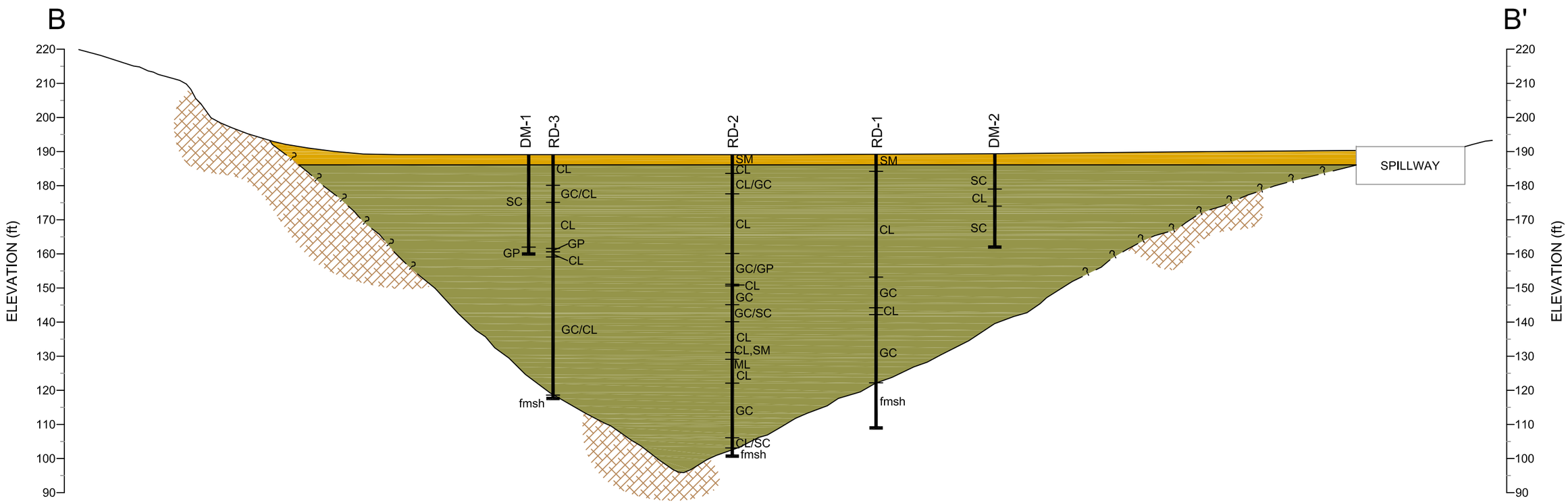
CROSS SECTION A - A'

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 3-8-11

Drawn BSP
Checked

4
FIGURE



LOW PERMEABILITY BUTTRESS FILL
- 1968 construction
compacted impervious
clayey material

ORIGINAL DAM FILL
- 1905 construction
interbedded gravelly
clay/clayey gravel

- FRANCISCAN GRAYWACKE SANDSTONE

CROSS SECTION B - B'

1" = 30'

SCALE

0 15 30 60 FEET

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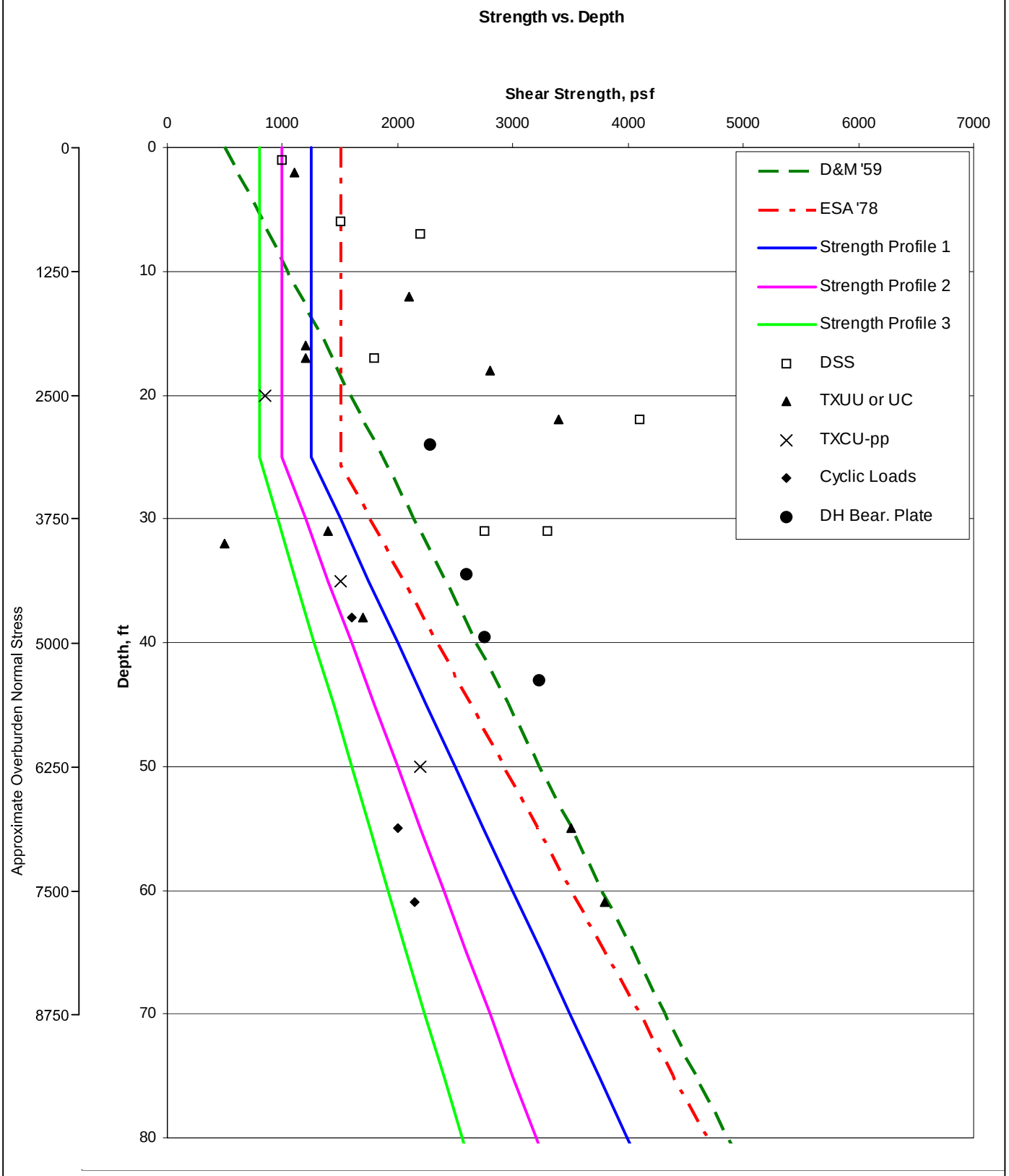
CROSS SECTION B - B'

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 3-8-11

Drawn BSP
Checked

5
FIGURE



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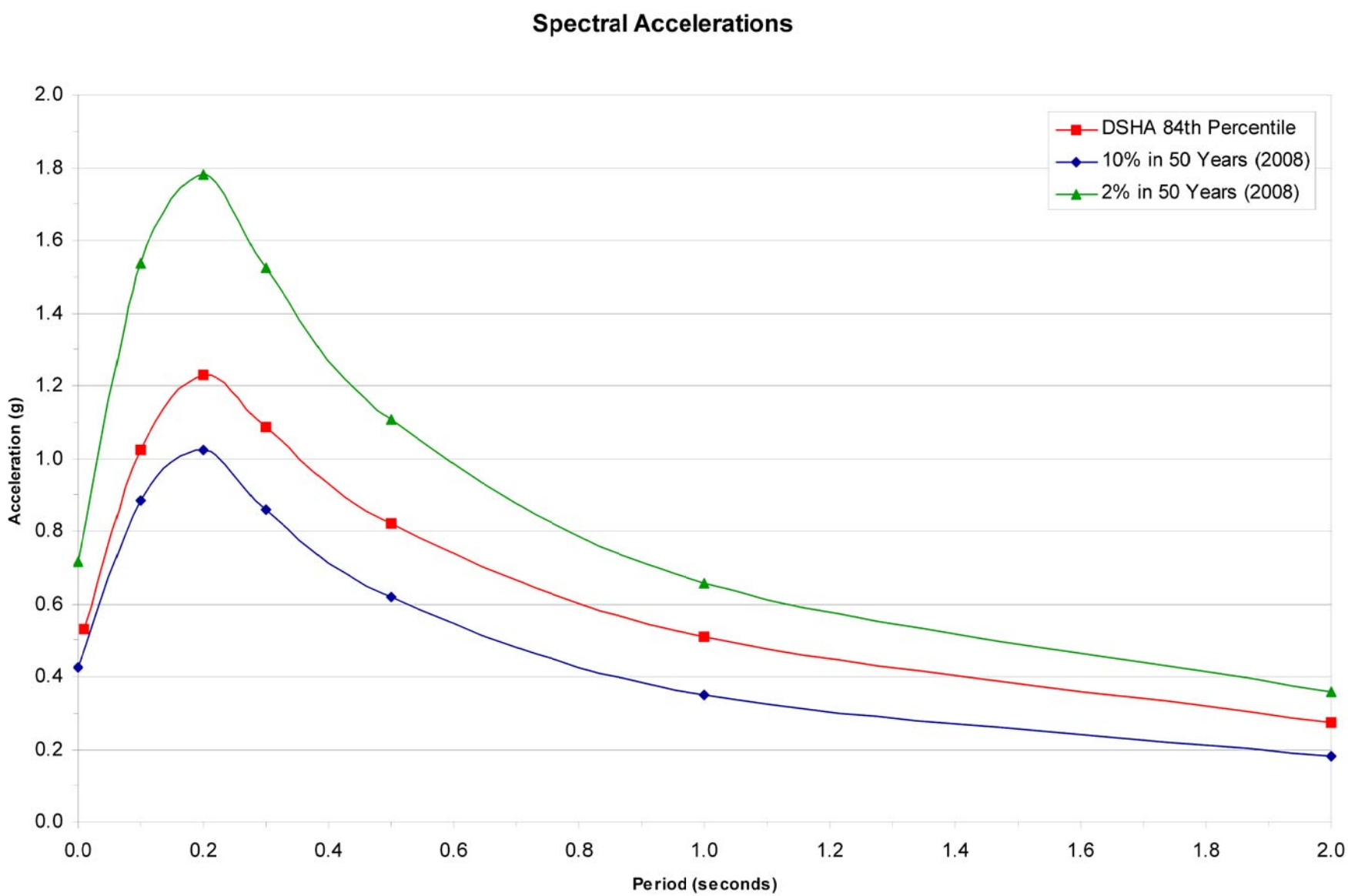
SHEAR STRENGTH vs. DEPTH PROFILE

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 3-8-11

Drawn BSP
Checked

6
FIGURE



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FILE: 960.05SA.dwg

SPECTRAL ACCELERATIONS

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, Califoria

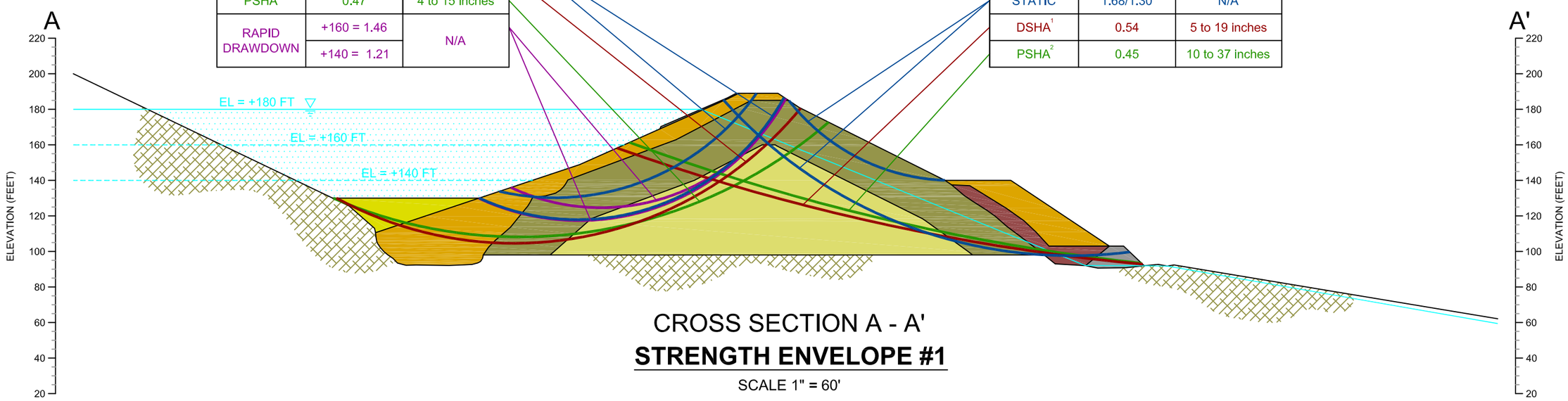
Project No. 960.05 Date: 3-8-11

Drawn JTO
Checked

7
FIGURE

CONDITIONS	FACTOR OF SAFETY	SEISMIC DISPLACEMENT
STATIC	2.44/2.21	N/A
DSHA	0.59	2 to 9 inches
PSHA	0.47	4 to 15 inches
RAPID DRAWDOWN	+160 = 1.46	N/A
	+140 = 1.21	

CONDITIONS	FACTOR OF SAFETY	SEISMIC DISPLACEMENT
STATIC	1.68/1.30	N/A
DSHA[1]	0.54	5 to 19 inches
PSHA[2]	0.45	10 to 37 inches



CROSS SECTION A - A'

STRENGTH ENVELOPE #1

SCALE 1" = 60'

LEGEND

- NEW DAM/BUTTRESS FILL
  γ = 125 pcf, γ_{SAT} = 140 pcf
  c = 1500 psf
- ORIGINAL DAM FILL
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 1250 psf
- ORIGINAL DAM FILL
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 1250 psf + 50 psf/ft
- SILT SEDIMENT
  γ = 100 pcf, γ_{SAT} = 100 pcf
  c = 100 psf
- RIP-RAP
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 1500 psf, ϕ = 40°
- DRAINAGE BLANKET
  γ = 130 pcf, γ_{SAT} = 135 pcf
  c = 200 psf, ϕ = 35°
- FRANCISCAN GRAYWACKE SANDSTONE
  γ = 140 pcf, γ_{SAT} = 145 pcf
  c = 2000 psf, ϕ = 38°

SCALE

0 30 60 120 FEET

NOTE:

1. EFFECTIVE STRESS VALUES WERE ALSO UTILIZED FOR STATIC CONDITIONS AS FOLLOWS:
   ORIGINAL DAM FILL: c' = 140 psf; ϕ' = 31°
   PROPOSED EARTH BUTRESS: c' = 500 psf; ϕ' = 35°
2. DSHA - DETERMINISTIC SEISMIC HAZARD ANALYSIS
   84TH PERCENTILE
   PGA = 0.53 g
3. PSHA - PROBABLISTIC SEISMIC HAZARD ANALYSIS
   2% CHANCE OF EXCEEDANCE IN 50 YEARS
   PGA = 0.72 g
4. 2.61/1.78
   - FACTOR OF SAFETY BASED ON TOTAL STRESS ANALYSIS
   - FACTOR OF SAFETY BASED ON EFFECTIVE STRESS ANALYSIS

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FILE: 960.05StabilityResults.dwg

SE#1 SLOPE STABILITY ANALYSES RESULTS

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

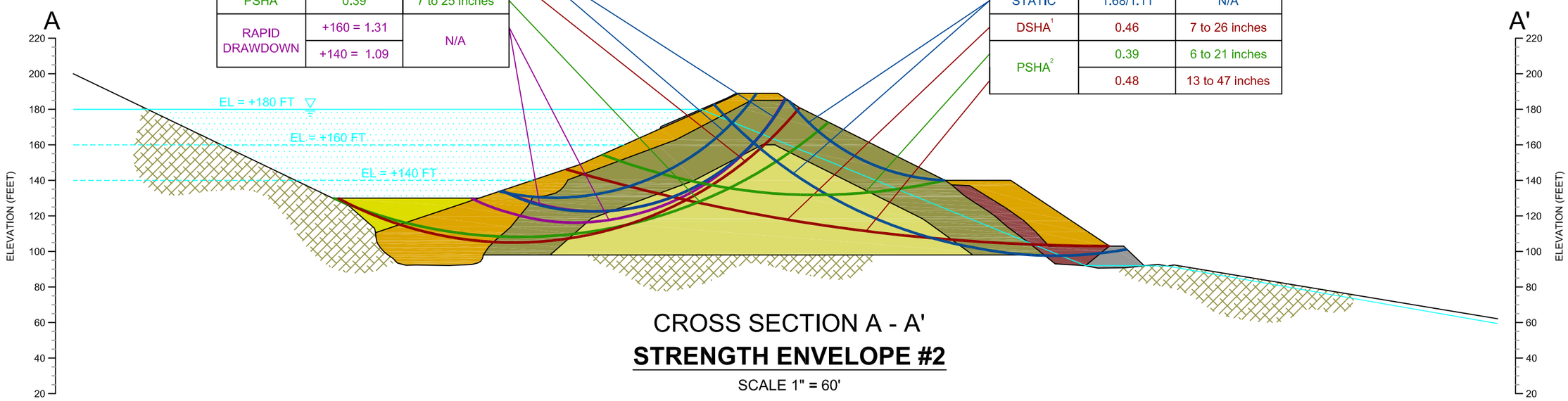
Project No. 960.05 Date: 3-8-11

Drawn BSP
Checked

8
FIGURE

CONDITIONS	FACTOR OF SAFETY	SEISMIC DISPLACEMENT
STATIC	2.44/1.82	N/A
DSHA	0.50	5 to 17 inches
PSHA	0.39	7 to 25 inches
RAPID DRAWDOWN	+160 = 1.31	N/A
	+140 = 1.09	

CONDITIONS	FACTOR OF SAFETY	SEISMIC DISPLACEMENT
STATIC	1.68/1.11	N/A
DSHA[1]	0.46	7 to 26 inches
PSHA[2]	0.39	6 to 21 inches
	0.48	13 to 47 inches



CROSS SECTION A - A'

STRENGTH ENVELOPE #2

SCALE 1" = 60'

LEGEND

- NEW DAM/BUTTRESS FILL — γ = 125 pcf, γ_{SAT} = 140 pcf, c = 1500 psf
- ORIGINAL DAM FILL — γ = 130 pcf, γ_{SAT} = 137.4 pcf, c = 1000 psf
- ORIGINAL DAM FILL — γ = 130 pcf, γ_{SAT} = 137.4 pcf, c = 1000 psf + 40 psf/ft
- SILT SEDIMENT — γ = 100 pcf, γ_{SAT} = 100 pcf, c = 100 psf
- RIP-RAP — γ = 130 pcf, γ_{SAT} = 137.4 pcf, c = 1500 psf, ϕ = 40°
- DRAINAGE BLANKET — γ = 130 pcf, γ_{SAT} = 135 pcf, c = 200 psf, ϕ = 35°
- FRANCISCAN GRAYWACKE SANDSTONE — γ = 140 pcf, γ_{SAT} = 145 pcf, c = 2000 psf, ϕ = 38°

SCALE

0 30 60 120 FEET

NOTE:

1. EFFECTIVE STRESS VALUES WERE ALSO UTILIZED FOR STATIC CONDITIONS AS FOLLOWS:
   ORIGINAL DAM FILL: c' = 140 psf; ϕ' = 31°
   PROPOSED EARTH BUTRESS: c' = 500 psf; ϕ' = 35°
2. DSHA - DETERMINISTIC SEISMIC HAZARD ANALYSIS
   84TH PERCENTILE
   PGA = 0.53 g
3. PSHA - PROBABLISTIC SEISMIC HAZARD ANALYSIS
   2% CHANCE OF EXCEEDANCE IN 50 YEARS
   PGA = 0.72 g
4. 2.61/1.78
   - FACTOR OF SAFETY BASED ON TOTAL STRESS ANALYSIS
   - FACTOR OF SAFETY BASED ON EFFECTIVE STRESS ANALYSIS

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SE#2 SLOPE STABILITY ANALYSES RESULTS

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

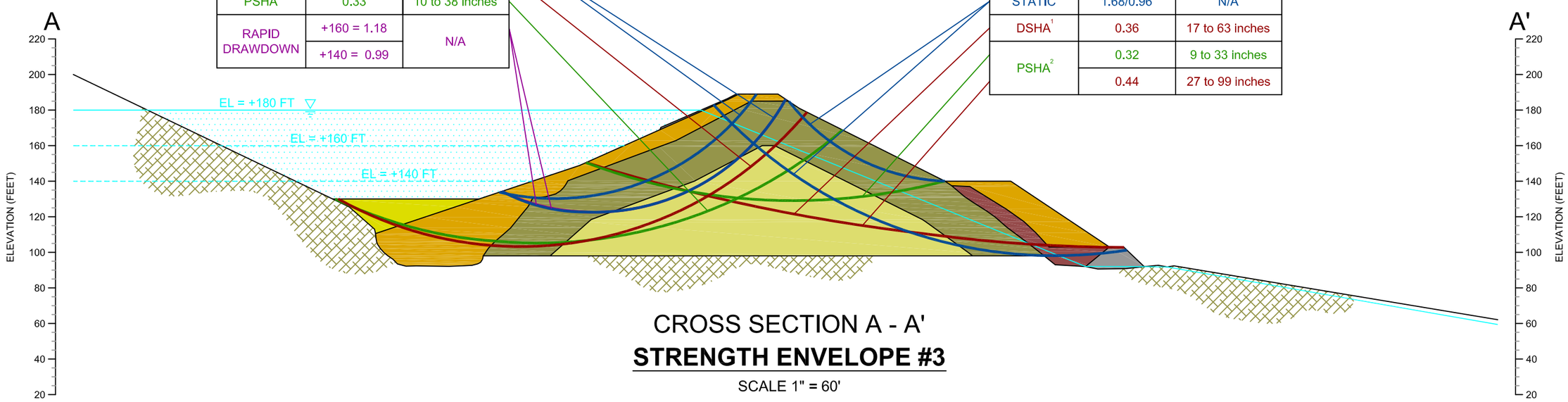
Project No. 960.05 Date: 3-8-11

Drawn BSP
Checked

9
FIGURE

CONDITIONS	FACTOR OF SAFETY	SEISMIC DISPLACEMENT
STATIC	2.44/1.51	N/A
DSHA	0.42	8 to 29 inches
PSHA	0.33	10 to 38 inches
RAPID DRAWDOWN	+160 = 1.18	N/A
	+140 = 0.99	

CONDITIONS	FACTOR OF SAFETY	SEISMIC DISPLACEMENT
STATIC	1.68/0.96	N/A
DSHA[1]	0.36	17 to 63 inches
PSHA[2]	0.32	9 to 33 inches
	0.44	27 to 99 inches



CROSS SECTION A - A'

STRENGTH ENVELOPE #3

SCALE 1" = 60'

LEGEND

- NEW DAM/BUTTRESS FILL
  γ = 125 pcf, γ_{SAT} = 140 pcf
  c = 1500 psf
- ORIGINAL DAM FILL
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 800 psf
- ORIGINAL DAM FILL
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 800 psf + 32 psf/ft
- SILT SEDIMENT
  γ = 100 pcf, γ_{SAT} = 100 pcf
  c = 100 psf
- RIP-RAP
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 1500 psf, ϕ = 40°
- DRAINAGE BLANKET
  γ = 130 pcf, γ_{SAT} = 135 pcf
  c = 200 psf, ϕ = 35°
- FRANCISCAN GRAYWACKE SANDSTONE
  γ = 140 pcf, γ_{SAT} = 145 pcf
  c = 2000 psf, ϕ = 38°

SCALE

0 30 60 120 FEET

NOTE:

1. EFFECTIVE STRESS VALUES WERE ALSO UTILIZED FOR STATIC CONDITIONS AS FOLLOWS:
   ORIGINAL DAM FILL: c' = 140 psf; ϕ' = 31°
   PROPOSED EARTH BUTRESS: c' = 500 psf; ϕ' = 35°
2. DSHA - DETERMINISTIC SEISMIC HAZARD ANALYSIS
   84TH PERCENTILE
   PGA = 0.53 g
3. PSHA - PROBABLISTIC SEISMIC HAZARD ANALYSIS
   2% CHANCE OF EXCEEDANCE IN 50 YEARS
   PGA = 0.72 g
4. 2.61/1.78
   - FACTOR OF SAFETY BASED ON TOTAL STRESS ANALYSIS
   - FACTOR OF SAFETY BASED ON EFFECTIVE STRESS ANALYSIS

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FILE: 960.05StabilityResults.dwg

SE#3 SLOPE STABILITY ANALYSES RESULTS

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

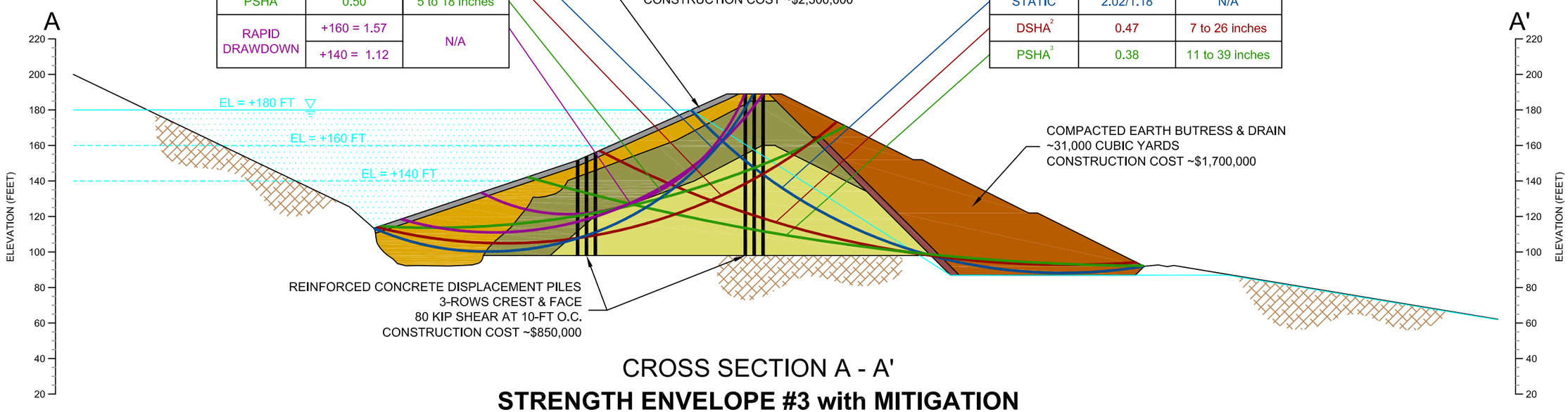
Project No. 960.05 Date: 3-8-11

Drawn BSP
Checked

10
FIGURE

CONDITIONS	FACTOR OF SAFETY	SEISMIC DISPLACEMENT
STATIC[1]	2.61/1.78[4]	N/A
DSHA[2]	0.57	2 to 8 inches
PSHA[3]	0.50	5 to 18 inches
RAPID DRAWDOWN	+160 = 1.57	N/A
	+140 = 1.12	

CONDITIONS	FACTOR OF SAFETY	SEISMIC DISPLACEMENT
STATIC[1]	2.02/1.18[4]	N/A
DSHA[2]	0.47	7 to 26 inches
PSHA[3]	0.38	11 to 39 inches



CROSS SECTION A - A'

STRENGTH ENVELOPE #3 with MITIGATION

SCALE 1" = 60'

LEGEND

- NEW DAM/BUTTRESS FILL
  γ = 125 pcf, γ_{SAT} = 140 pcf
  c = 1500 psf
- ORIGINAL DAM FILL
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 800 psf
- ORIGINAL DAM FILL
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 800 psf + 32 psf/ft
- PROPOSED EARTH BUTTRESS
  γ = 120 pcf, γ_{SAT} = 130 pcf
  c = 2000 psf
- RIP-RAP
  γ = 130 pcf, γ_{SAT} = 137.4 pcf
  c = 1500 psf, ϕ = 40°
- DRAINAGE BLANKET
  γ = 130 pcf, γ_{SAT} = 135 pcf
  c = 200 psf, ϕ = 35°
- FRANCISCAN GRAYWACKE SANDSTONE
  γ = 140 pcf, γ_{SAT} = 145 pcf
  c = 2000 psf, ϕ = 38°

SCALE

0 30 60 120 FEET

NOTE:

1. EFFECTIVE STRESS VALUES WERE ALSO UTILIZED FOR STATIC CONDITIONS AS FOLLOWS:
   ORIGINAL DAM FILL: c' = 140 psf; ϕ' = 31°
   PROPOSED EARTH BUTRESS: c' = 500 psf; ϕ' = 35°
2. DSHA - DETERMINISTIC SEISMIC HAZARD ANALYSIS
   84TH PERCENTILE
   PGA = 0.53 g
3. PSHA - PROBABLISTIC SEISMIC HAZARD ANALYSIS
   2% CHANCE OF EXCEEDANCE IN 50 YEARS
   PGA = 0.72 g
4. 2.61/1.78
   - FACTOR OF SAFETY BASED ON TOTAL STRESS ANALYSIS
   - FACTOR OF SAFETY BASED ON EFFECTIVE STRESS ANALYSIS

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FILE: 960,05RepairStability.dwg

SE#3 with MITIGATION SLOPE STABILITY ANALYSES

Stetson - MC Flood Control
Phoenix Lake Dam
Marin County, California

Project No. 960.05 Date: 02/03/2010

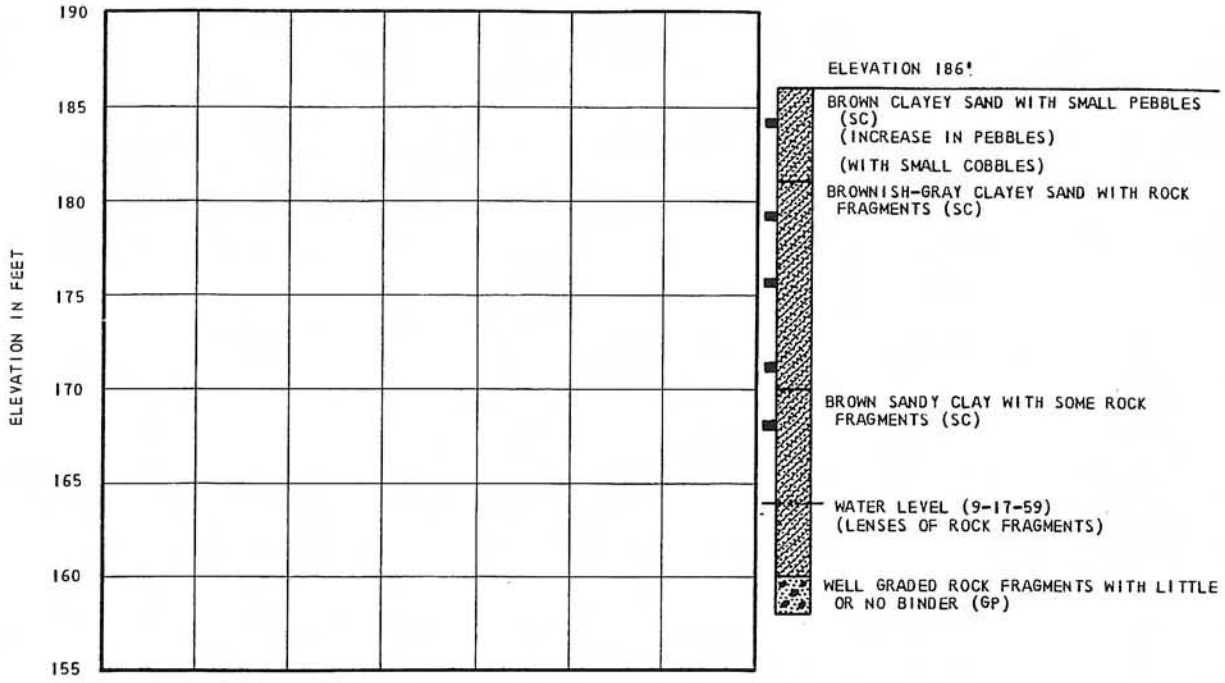
Drawn BSP
Checked

11
FIGURE

APPENDIX A
PREVIOUS BORING LOGS

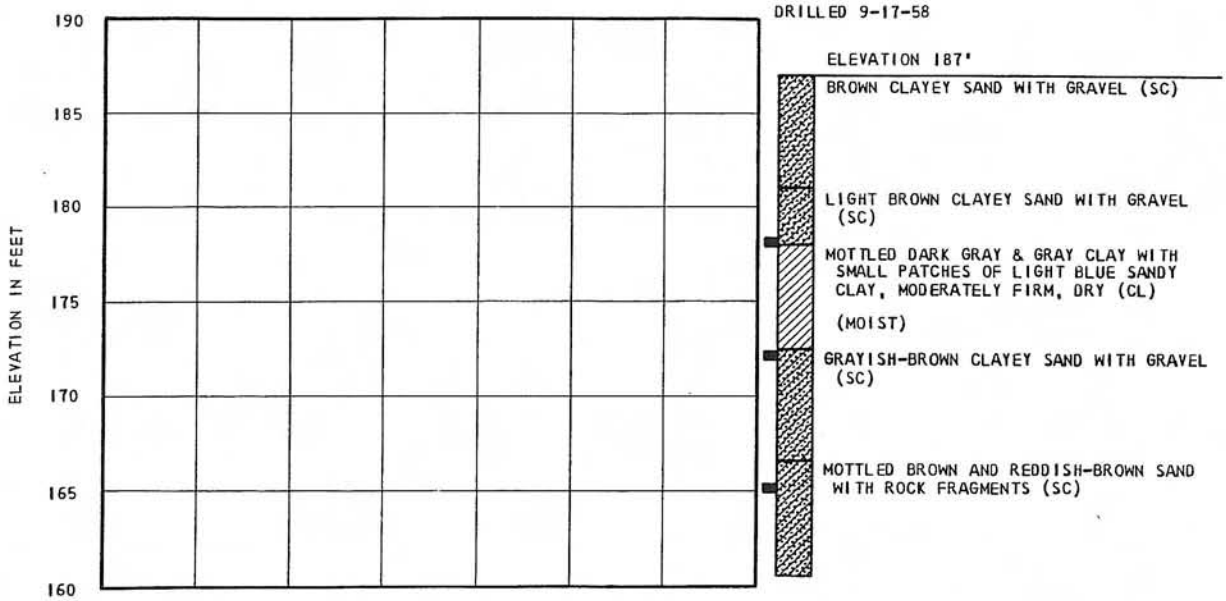
BORING 1

DRILLED 9-17-58



BORING 2

DRILLED 9-17-58



NOTE:
BORINGS 1 & 2, 16" DIAM, DRILLED WITH AUGER TYPE DRILLING EQUIPMENT.
BORINGS 3,4 & 5, 4" DIAM, DRILLED WITH ROTARY-WASH DRILLING EQUIPMENT.
ELEVATIONS REFER TO GROUND SURFACE CONTOURS SHOWN ON PLOT PLAN.

LOG OF BORINGS

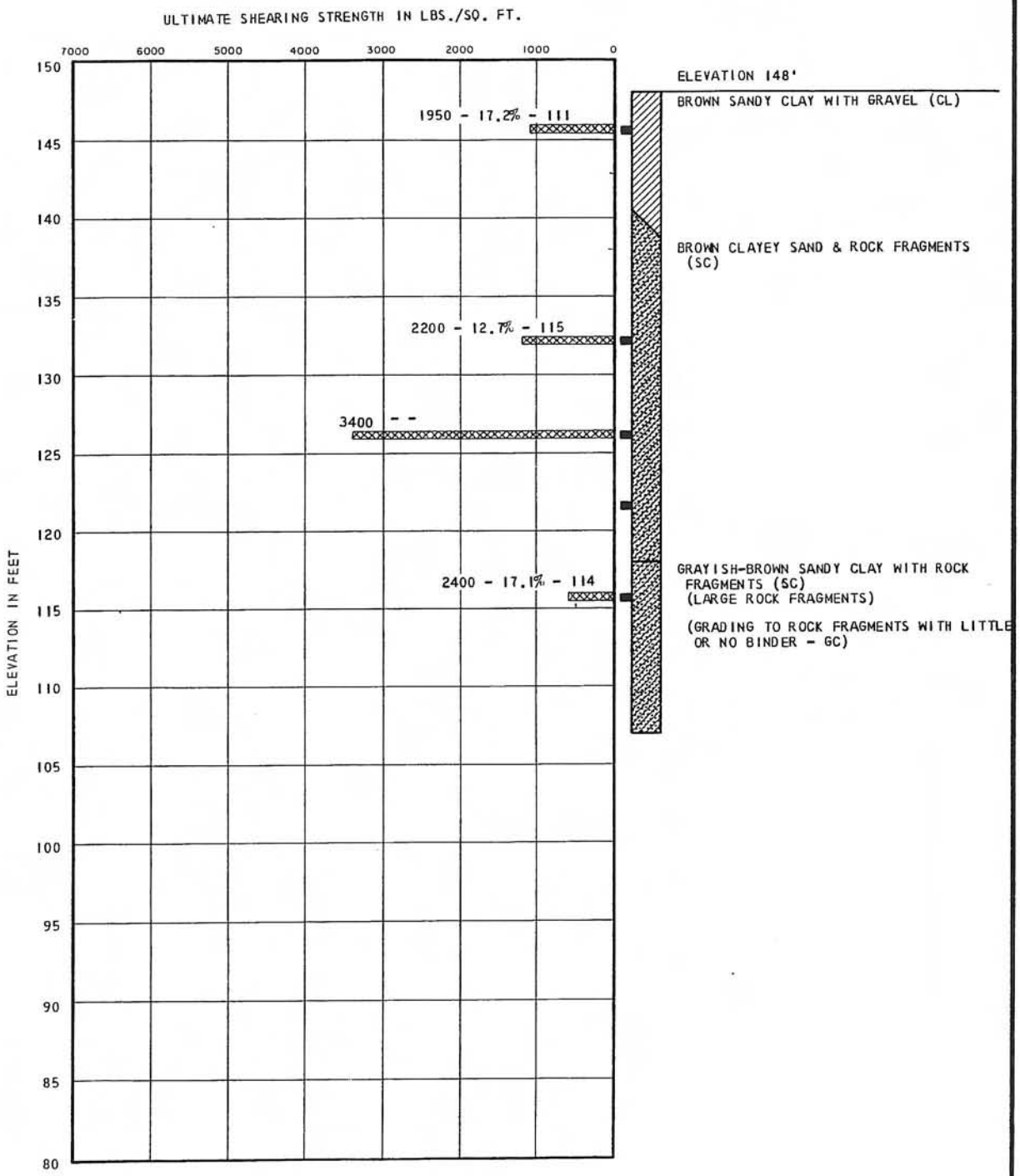
REVISIONS
BY ____ DATE ____
BY ____ DATE ____
PLATE ____ OF ____

FILE 1185-1
BY ____ DATE ____
CHECKED BY ____ DATE ____

DAMES & MOORE
SOIL MECHANICS ENGINEERS

BORING 3

DRILLED 4-20-59 TO 4-24-59



LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

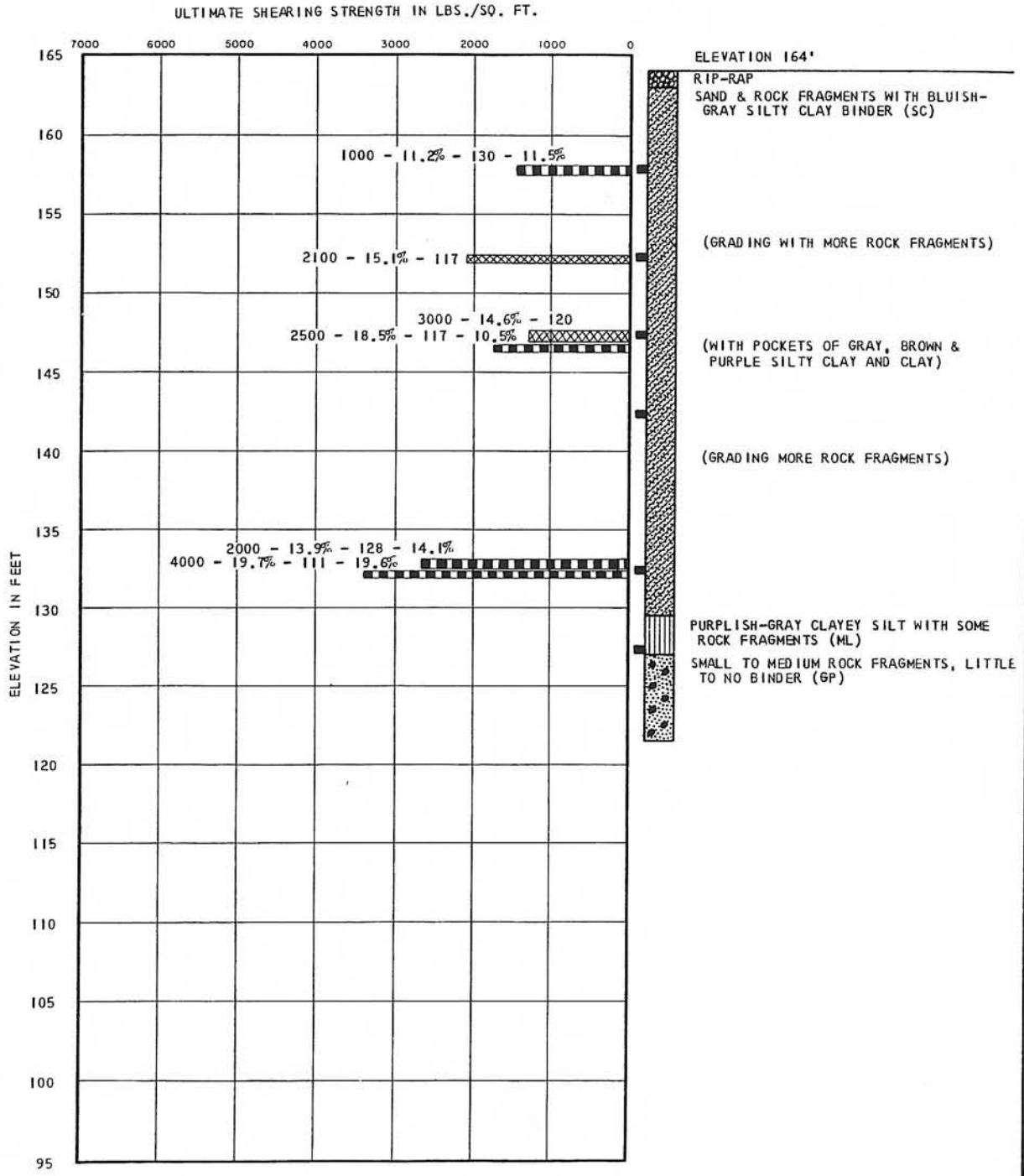
PLATE 3B

REVISIONS
BY_____ DATE_____
BY_____ DATE_____
PLATE_____ OF_____

FILE 1164.E
M.M.W.D.
BY HST. KJT DATE 11-21-59
CHECKED BY GSM DATE 10/20/59

BORING 4

DRILLED 4-23-59 TO 4-24-59



LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

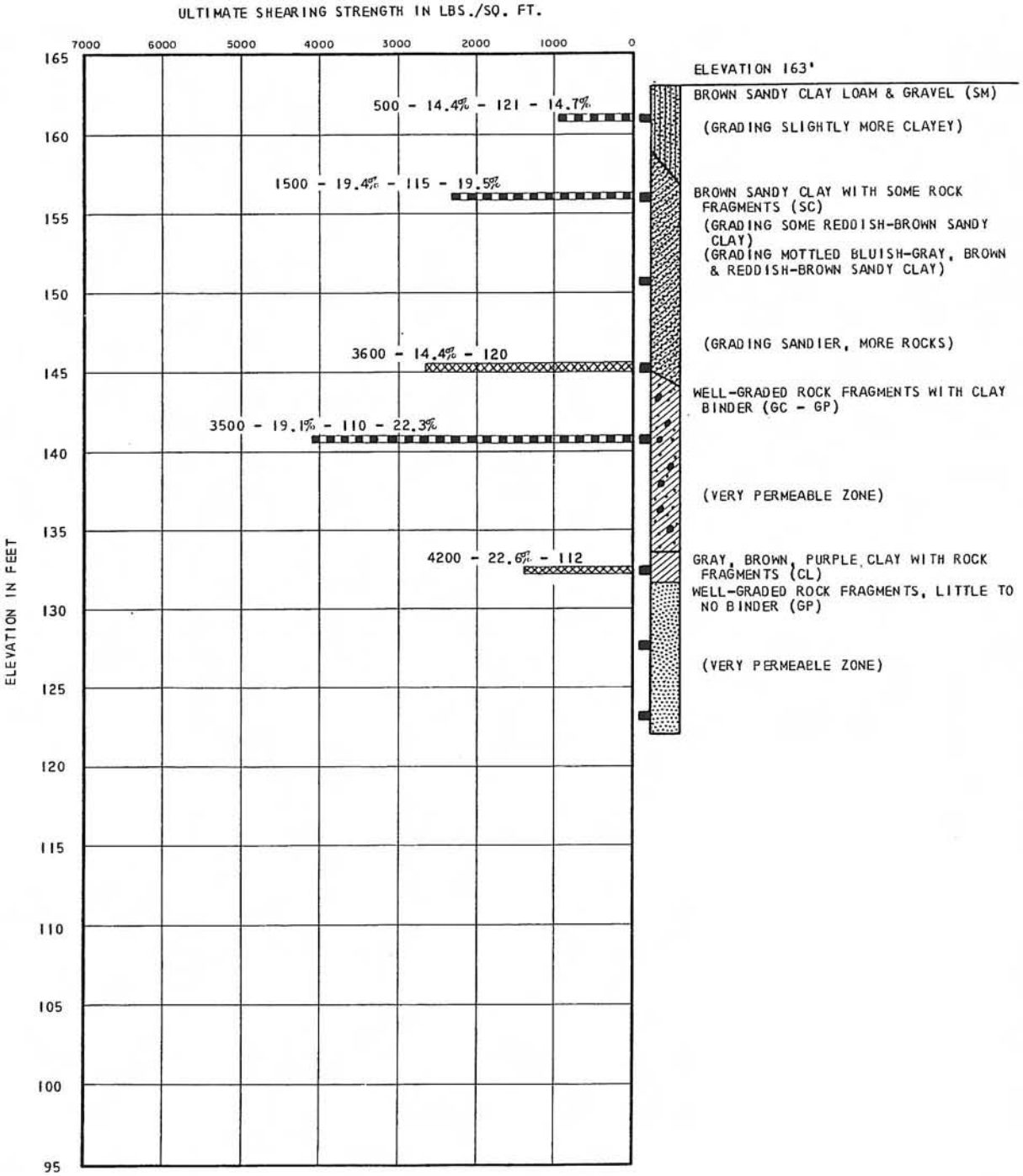
PLATE 3C

REVISIONS
BY _____ DATE _____
BY _____ DATE _____
PLATE _____ OF _____

FILE 1184.E
BY M.P.N.D. K.T. DATE 10-21-59
CHECKED BY C.Z. DATE 10/28/59

BORING 5

DRILLED 4-24-59 TO 4-28-59



LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

PLATE 3D

REVISIONS
BY_____ DATE_____
BY_____ DATE_____
PLATE_____ OF_____

FILE 184-E
N.M.W.P.
BY HCT - ET DATE 10-21-59
CHECKED BY 10/60 DATE 10/10/59

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT PHOENIX DAM 1890 DATE DRILLED 11:22 HOLE NO. RD-1

LOCATION _____ GROUND SURFACE ELEV. 1897±

DRILLING CONTRACTOR J.N. PITCHER LOGGED BY MTD DEPTH TO GROUND WATER _____

TYPE OF RIG FAILING 750 HOLE DIAMETER 4 7/8" HAMMER WEIGHT AND FALL 140 lb - 30 in.

SURFACE CONDITIONS BASE ROCK WEATHER CLOUDY - COOL

Piezometer Installation

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer Tons / Torvane Tsf)	MODE	REMARKS
0.0	SM	0.0-5.0 GRAVELLY SAND: Blue; 10-20% predominantly silt fines; fine to medium sand; fine angular gravel; dense; moist. Base Rock. 0.5 color grades to light moderate brown. ~2 small lense of soft, wet clayey silt.		AD	
2.0					
4.0				AD	
	SM			DR	Drove Standard split Spoon 4.0 – 5.5 12/0.5 19/0.5 18/0.5
	CL	5.0-22.5 SILT CLAY: Light olive gray and light gray; medium plasticity; contains scattered rounded gravel; scattered roots and wood; firm; moist.		0.5 / 1.5	
6.0				RD	Hit rock at 5' with auger. 5.0 Set 6" g. casing - begin rotary drilling.
8.0				PB	Pitcher Barrel 7.0 – 9.4
				0 / 2.4	Rocks block tube.
10.0				RD	
12.0				PB	Pitcher Barrel 11.0 – 13.5
				0 / 2.5	
14.0				DR	Drove California Sampler 13.5 – 15.0 12/1.5
			J-1 0.39 0.26 0.38	1.0 / 1.5	0.8 0.7 2.0
16.0				PB	Pitcher Barrel 15.0 – 17.5
				0 / 2.5	Took barrel apart to see if ball was in place - it was, no replacement.
18.0				RD	
				PB	2.30 stopped for day. Pitcher Barrel 18.0 – 20.5
				0 / 2.5	
20.0	CL				

SHEET 1 OF 4

PROJECT 1890 DATE DRILLED 11:23 HOLE NO. RD-1

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer TSF)	MODE	REMARKS
20.0	CL	5.0-22.5 SILTY CLAY: cont.	Torvane TSF	PB	
				RD	Appear to be pushing rock in front of bit - Tried to push it aside with drag bit.
22.0		22.5-38.0 GRAVELLY SANDY CLAY: Purple with numerous olive green and yellowish brown mottles; low plasticity clay; fine to coarse sand; 20% fine-coarse gravel (serpentine?); firm to stiff; moist			
	CL			PS	Pushed Shelby Tube 23.0-25.5
24.0	(GC)			0.6 / 2.5	300 psi
			>0.45 / 1.45		Tube bent at end.
			J-2		
26.0				RD	
				PB	Pitcher Barrel 26.0-28.0
				1.5 / 2.5	
28.0			J-3		
		clay binder appears to get softer.		PB	Pitcher Barrel 28.0-30.5
				1.7 / 2.5	Samples when extruded are generally broken into 4-6" lengths
30.0			J-4		
		clay binder has strengths from drive sample 0.7 → 1.5 TSF		DR	Drove Standard Split Spoon 30.5-32.0
				0.8 / 1.5	
32.0			J-5		
				RD	3/0.5 3/0.5 5/0.5
				PB	Pitcher Barrel 33.0-35.5
34.0	CL	34.4-34.3 blue grey silty clay; contains scattered gravel		1.4 / 2.5	
	CL-CH		J-6 0.6 0.6		
	CL	34.3-36.0 Moderate brown sandy clay; contains some 10-15% gravel.	1.2 1.0 1.4		
			J-7		3" serpentine gravel in bottom of tube
36.0	GC-CL	grades back to same as 22.5-38.0 except gravel content increases.	2.5 2.7	PB	
					Pitcher Barrel 35.5-38.0
				0.9 / 2.5	Clay binder washes out unless sample is frozen.
38.0	GC	38.0-57.0 CLAYEY GRAVEL: Moderate brown with purple discolorations clay binder; 5-20% low plasticity clay; some sand; angular to subrounded gravel up to 2"; dense; moist to wet. Clay binder is soft to firm.	J-8	DR	Drove Standard Split Spoon 38.0-39.5
				0.7 / 1.5	5/0.5 8/0.5 11/0.5
40.0				RD	Sample broken up - impossible to test.
Piezometer #1					Pitcher Barrel 41.0-41.5 (Refusal)
			J-9	PB 0.4/0.5	
42.0		(Sample J-10, includes loose "clean" gravel that are probably cuttings)		DR	Drove Standard Split Spoon 41.5-43.0
			J-10	0.3 / 1.5	9/0.5 11/0.5 15/0.5
				RD	
44.0	GC	clay content increases			

Piezo Seal

Sand Back Fill

SHEET 2 OF 4

PROJECT 1290 DATE DRILLED 11:23 HOLE NO. RD-1

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
44.0	GC (CL)	33.0-67.0 CLAYEY GRAVEL cont.		DR 0.6/1.5	Drove Standard Split Spoon 44.0-45.5
	CL		J-11	RD	15/0.5 12/0.5 13/0.5
46.0					
	GC-SP			PB 0/2.5	Pitcher Barrel 46.5-49.0
48.0	GC	clay binder moderate brown and purple.			47-48 Rig chatters strongly. Sample washed out?
				RD	
50.0				PB 0.6/2.5	Pitcher Barrel 50.0-52.5
52.0			J-12		Rig chatters sporadically. Large rock in bottom
				DR 0.5/1.5	Drove Standard Split Spoon 52.5-54.0
54.0			J-13	RD	5/0.5 15/0.5 13/0.5
					54.5 Rig chatters violently. →55.0
56.0					
58.0					
60.0				RD	
				DR 0.0/1.5	Drove Standard Split Spoon 60.0-61.5
					7/0.5 9/0.5 11/0.5
62.0				RD	Stopped for Day 11:28:78 Hole caved to 31.5 ft.
	(SC-GC)	clay content decreases.			
64.0				PB 0.4/2.5	Pitcher Barrel 64.0-66.0 Continuous loss of water
66.0			J-14		
Piezometer #2		67.0- BED ROCK:		DR 0.5/1.5	Drove Standard Split Spoon 66.0-67.5
			J-15		15/0.5 15/0.5 50/0.5
68.0				RD	

Sand backfill

Pea Gravel

Sand backfill

Piezometer #2

SHEET 3 OF 4

PROJECT 1890 DATE DRILLED 11:28:77 HOLE NO. BD-1

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
68.0		67.0 – BEDROCK: cont. Dark olive green shale and Franciscan melange; contains some roots in top 5 feet of unit; varying quantities of clay, decreasing with depth; hard.		RD	Big chattering continuously
70.0					
72.0					
74.0			J-16	RD DR 0.7/0.5	Drove Standard Split Spoon 74.0 – 74.5 50/0.5
				RD	
78.0					
80.0				RD	Drove Standard Split Spoon 80.0 – 80.2. 30/0.2 Rods bouncing
		B.H. 80.2			
82.0					Backfilled with: sand – 80.2 – 55 piezoseal – 55 – 50 piezometer @ 69'.
84.0					sand 50 – 36 piezoseal 36 – 31 piezometer 43' (graphical display of piezometer installations in left-hand CLASS. column of log)
86.0					
88.0					
90.0					
92.0					
94.0					SHEET 4 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT PHOENIX DAM 1890 DATE DRILLED 11:29- HOLE NO. RD-2

LOCATION DAM CREST NR. MAXIMUM SECTION. GROUND SURFACE ELEV. 1895±

DRILLING CONTRACTOR J.N. PITCHER LOGGED BY MTD DEPTH TO GROUND WATER

TYPE OF RIG FAILING 750 HOLE DIAMETER 4 7/8" HAMMER WEIGHT AND FALL 140 lb - 30 inch.

SURFACE CONDITIONS DAM CREST ROAD - BARE ROCK WEATHER CLEAR - COOL.

Piezometer Installation

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
0.0	GP	0.0-1.0 BASE ROCK:	Torvane TSF	AD	Augered to 5 ft.
	SM	Greyish blue; less than 5% fines; fine to coarse sand; fine gravel; moist; dense.			Set 7'. 6"ϕ casing.
2.0		1.0-5.5 (8/1968 FILL:			
	CL	Moderate yellowish brown with dark olive green and purple discolorations; generally a silty sand with layers of silty and gravelly clay; silty sand generally med. yell. brown; moist; dense to very dense.		AD	
4.0			J-1	DR 0.3/1.5	Drove Standard Split Spoon 3.5-5.0
	CL			RD	7/0.5 24/0.5 26/0.5 Rock in bottom of shoe.
6.0	CL-GC	5.5-11.5 CLAYEY GRAVEL TO GRAVELLY CLAY: Purple and dark olive grey; variable amount of clay fines; some sand; fine to coarse angular gravel; some cobbles; moist; dense.	J-2	PB 1.7/2.5	Pitcher Barrel 6.0-8.5 Bottom of tube badly bent.
8.0			J-3	PB 0.5/0.5	Pitcher Barrel 8.5-9.0 Refusal - losing all circulation. Tube Bent, rock in Bottom.
10.0			J-4	DR 0.2/1.5	Drove Standard Split Spoon 9.0-10.5
	CL-GC	11.5-19.4 SILTY CLAY:		RD	15/0.5 8/0.5 7/0.5 Rocks in shoe, some clay binder.
12.0	CL	Olive green and light grey; low to moderate plasticity; contains scattered roots; firm; moist to wet.		PB 1.2/2.5	10.0 Added half a bag of revert, could not get circulation. Mixed up ½ bag of bentonite.
14.0		some black organic discoloration. contains scattered gravel up to 2".	J-5	PB	Drove another 5' of casing. Pitcher Barrel 12.0-14.5
16.0			J-6	PB 1.0/2.5	Pitcher Barrel 14.5-17.0
18.0				PB	Pitcher Barrel 17.0-19.5
	CL	19.4-26.0 SANDY GRAVELLY CLAY:	J-7	PB 1.0/2.5	
20.0	CL				SHEET 1 OF 4

* Test on sample end.

PROJECT 1390 DATE DRILLED 11:29:77 HOLE NO. RD-2

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
20.0	CL	19.4-86.0 SANDY GRAVELLY CLAY: cont.		PB	Pitcher Barrel
		Reddish brown; medium plasticity clay; 20-30% predominantly coarse sand; up to 20% coarse gravel; medium dense to dense; moist to wet.		1.2 / 2.5	19.5 - 22.0
22.0			J-8		Tube Bent at bottom. Rock gouged side of sample.
				PB	Pitcher Barrel
				0.5 / 2.0	22.0 - 24.0
24.0			J-9		Steady loss of water.
				PB	Pitcher Barrel
				0.8 / 2.5	24.0 - 26.5
26.0			J-10		
				DR	Drove Standard Split Spoon
	(GC)			0.7 / 1.5	26.5 - 28.0
28.0			J-11		4/0.5 4/0.5 7/0.5
		28.5 Cuttings become cleaner, fines could be washing out or material is cleaner.		RD	Stopped for night 11:29:77
	CL / GC-GP	grades to clayey gravel; with lenses of clean gravel. Binder is medium plasticity clay.		PB	Pitcher Barrel
30.0				0 / 2.5	29.0 - 31.5
					Tube bent
32.0				PB	Pitcher Barrel
Piezometer #1				0 / 2.5	31.5 - 34.0
					Tube bent
34.0				RD	Loosing water continuously.
				DR	Drove Standard Split Spoon
36.0				0* / 1.5	35.0 - 36.5
			J-12.		5/0.5 4/0.5 8/0.5
				RD	* 6" of loose clean gravel in tube, could be cuttings or native.
	GC-GP / CL	36.7-38.5 lense of light olive grey sandy clay, contains scattered fine gravel; stiff to very stiff; moist.		DR	
38.0			J-13	0.5 / 1.5	Drove Standard Split Spoon
	GC			RD	37.0 - 38.5
		color grades to dark grey			9/0.5 8/0.5 12/0.5
40.0				PS PB	Pushed Shelby Tube 40.0-41.0
				0 / 1.0	Pitcher Barrel 40.0-42.5
42.0				0.5 / 2.5	
			J-14		Tube Bent.
				PB	Pitcher Barrel 42.5-45.0
44.0					

Bentonite seal

Sand backfill

Bentonite seal

SHEET 2 OF 4

PROJECT 1890 DATE DRILLED 11:30 HOLE NO. RD-2

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
44.0	GC / GC-SC	19.4-86.0 SANDY GRAVELLY CLAY: cont.	Torvane TSF	PB 1.0/1.3	Tube Bent.
		44.6 sand content increases. matrix becomes sandy clay.	J-15 TSF	DR 2.5/1.5	Drove Standard split spoon 45.0-46.5 9/0.5 19/0.5 22/0.5
46.0			J-16	RD	Rock in shoe.
48.0					
	GC-SC ? CL	~49.0 grades to sandy clay with up to 20% fine to coarse gravel in lenses and throughout unit. sand content 30%? variable.		RD	
50.0			J-17	DR 0.5/1.5	Drove Standard split spoon 50.0-51.5 11/0.5 7/0.5 13/0.5
52.0				RD	
54.0					
56.0				RD	
	CL	57.7-58.2 clayey silt to silty clay with some gravel and sand.	0.50	PB	Pitcher Barrel 57.0-59.5
58.0	CL-ML	58.2-58.6 Sandy silt to silty sand w. gravel.	J-18 1.7		
	SM-ML	58.6-59.0 silty sand w. gravel	J-19 0.75	1.3/2.5	
	SM (GP) CL	59.0-59.5 clayey silt to silty clay, w. gravel.	J-20 0.83		
	CL-ML		J-21 2.3		
60.0	CL (SC)			PB	Pitcher Barrel 59.5-62.0.
				0.7/1.5	
62.0			J-22	DR 0.5/2.5	Drove Standard split spoon 62.0-63.5 8/0.5 14/0.5 24/0.5
			J-23 1.2		
64.0				RD	
66.0	(SC) CL ? GC				67.0 Stopped for night 11:30
68.0					

Sea Straight

SHEET 3 OF 4

PROJECT 1890 DATE DRILLED 12:1 HOLE NO. RD-2

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
68.0	GC	19.4-68.0 SANDY GRAVELLY CLAY: cont.	TSF	PB	Pitcher Barrel 68.0-70.5
	Bentonite seal			0/2.5	12:1 Hole caved to 53' overnight.
70.0				RD	300 gal of water + 1½ sacks of mud to clean out and run tube - still losing circulation.
72.0	sand backfill			PB 0/2.5	Pitcher Barrel 72.0-74.5
74.0					Drove an extra 5' of casing to try and control water loss.
				DR 0/1.5	Drove standard split spoon 74.5-76.0 3/0.5 4/0.5 6/0.5
76.0				RD	
Piezometer #2		cleaned out for long time; cuttings of rock with bits of purple clay.		DR 2/1.5 *	sample of cuttings. Hole was well cleaned out no obvious reason for lack of sample. Pushing rock?
78.0			J-24		
		cuttings of sand and gravel; some clay.		RD †	Drove standard split spoon 77.0-78.5 3/0.5 3/0.5 12/0.5
80.0		hole caves below sampler gets back into hole, can't get thick mud because of leakage.		PB 0/2.5	* Cuttings. Pitcher Barrel 80.0-82.5
82.0				†	78.5-80.0 Rig chatters moderately.
	CL-SC	? 83.0 grey sandy clay to clayey sand.		RD	
84.0				DR 2.5/2.5	Drove Standard split spoon 84.0-86.5 5/0.5 6/0.5 12/0.5
			1.75 1.4 1.25 1.0 J-25		
86.0	CL-SC	86.0-88.4 BEDROCK Olive green shale with some clay binder, clay decreases with depth.		RD	86.0-87.5 Rig chatters violently.
88.0			J-26	DR 2.3/0.4	Drove standard split spoon 88.0-88.4 30/0.2 rods bouncing.
		B.H. 88.4			
90.0					Sand B.H.-71 Piezo 80 Bentonite Balls 71-63. Hole caved overnight 63-43. Bent. Balls 43-40 sand 40-30 piezo 30.35'. Bent. balls 30-27
92.0					SHEET 4 OF 4

(graphical display of piezometer installations in left-hand CLAS column of log)

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DRILLING AND SAMPLING LOG

PROJECT PHOENIX DAM 1890 DATE DRILLED 12:5: HOLE NO. RD-3

LOCATION DAM CREST GROUND SURFACE ELEV. 189.1

DRILLING CONTRACTOR J.N. PITCHER LOGGED BY MTD DEPTH TO GROUND WATER

TYPE OF RIG FAILING 750 HOLE DIAMETER 9" HAMMER WEIGHT AND FALL 140 lb-30"

SURFACE CONDITIONS BASE ROCK WEATHER MISTY

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
0.0	GM	0.0-0.5 BASE ROCK:	Torque: ✓ TSF ✓ TSF	RD	Rotary Drill with 9" bit.
	CL	0.5-9.0 SILTY SANDY CLAY: Moderate yellowish brown with numerous dark olive green and purple discolorations; sandy clay with pockets of silty clay; contains gravel up to 2"; moist; stiff to very stiff.			
2.0					
4.0					
6.0				RD	
			B-1 74.5	PB 0.6 / 2.5	220 psi hydraulic pressure while cutting cored with 6" pitcher barrel most of sample dropped out near top of hole
		7.0 ground contact unconsolidated; color grades to purple.			cleaned out hole to 8.5'
8.0	(GC) CL	9.0-14.2 CLAYEY GRAVEL TO GRAVELLY CLAY: Dark olive green; varying amounts of sandy and silty clay;		PB 2.5 / 2.5	Pitcher Barrel 8.5-11.0 9.5 Rig chatters 10.5 Rig chatters.
	GC-CL				
10.0	GC-CL CL		B-2 11.1, 1.3 11.2, 1.5		
	GC-CL CL CL	11.4-11.6 light olive green silty clay. 11.6-11.8 purple sandy clay.	B-3	PB 0.8 / 2.0	losing circulation used 1½ bags of bentonite from first 11 feet. water stands at 9 feet.
12.0	GC-CL (?)				
	GC-GP	clay binder is purple, predominantly sandy clay; boulders up to 5"; mod. clean		PB 2.5 / 2.5	Pitcher Barrel 13.0-15.5 13.0-14.2 Rig chatters strongly, losing circulation.
14.0	GC-GP CL	14.2-21.6 SILTY CLAY: Light olive gray and light gray with rusted discolorations; medium plasticity; contains scattered gravel up to 2"; moist locally wet; firm.	B-4		
			B-5 0.73 0.65	2.3 1.0 1.75 1.9	
16.0				RD	
				PB 2.5 / 2.5	Pitcher Barrel 16.0-18.5
			0.37 0.43	0.5 0.70 0.75 1.0 0.85 0.8 0.75 1.75 0.9 1.9	
18.0			B-6 0.63 0.63		
				RD	
20.0				RD	

SHEET 1 OF 4

PROJECT 1890 DATE DRILLED 12:6:77 HOLE NO. RD-3

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
20	CL	14.2-21.6 SILTY CLAY: cont.	4 TSF	RD	
		21.6-70.5 GRAVELLY SANDY CLAY:			21.5 Stopped for night. Water dropped 3' overnight.
22	CL	Purple with rust brown and light olive green discolorations; sandy clay (soft to firm) matrix; fine to coarse sand; pred. fine gravel; 20-30% coarse sand and gravel; firm; moist to wet.		RD	
				PB	Pitcher Barrel 22.0-22.5
24			B-7	2.4/2.5	Continuous moderate chatter.
			1.25 1.3	RD	25.0 Plate loading Test.
26				RD	
				PB	Pitcher Barrel 26.5-27.8
	CL	27.5-28.5 Rig chattering violently; boulder(?)	B-8	0.5/1.3	Strong Chattering, Refusal.
28	GP			RD	Bottom of sample fell out of tube. Clean cuttings(?) in tube.
	CL			DR	Drove Standard Split Spoon 29.0-31.5
30	CL-GC-CL	30.0 Dark olive gray gravelly clay. 30.5 color grades to purple; gravel and sand content increases to 50-60%; clay binder is firm.	B-9	0.3/1.5	5/0.5 4/0.5 7/0.5
				PB	Pitcher Barrel
32			B-10	1.1/2.5	
				RD	
34		color grades to medium gray; with brick red and turquoise discolorations.			35.0 Plate Loading Test. 35.0 Stopped for Day 12:6:77
36					
		37.5 Pocket of turquoise silty clay; firm. 37.8-40.2 layer of yellowish brown gravelly sandy clay; appears less dense than surrounding material.		RD	
38			B-11	PB	Pitcher Barrel 37.5-40.0
		gravel content is about 25%	B-12	2.5/2.5	37.5-38.0 Rig chatters strongly 38.0-40.0 " " moderately
40				RD	40.0 Plate loading Test. DMY logging hole
		42.1-42.4 large grn. gray graywacke cobble; washed out void ~3" max.			
42		42.4-43.0 med. to dk. olive gray silty clay, scattered med. sand; small patches yel. brown clay; gravel content ~ 20-25%	B-13	RD	Cored w/ Pitcher barrel sampler
			1.7(?) 1.2 1.25 1.3(?)	PB 0.9/1.0	Have been coring w/ 200-300 psi down pressure. Swivel elbow on mud line broke—pulled sampler
44	GC-CL			RD	SHEET 2 OF 4
				RD	

sfa
dow
firm
10:
a.r
11:-
a.

PROJECT 1290-Phoenix Dam DATE DRILLED 12/7/77 HOLE NO. RD-3

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE (Penetrometer)	MODE	REMARKS
44	GCL	21.6-70.5 GRAVELLY SANDY CLAY: cont.	4 TSF	RD	44.0 Plate loading test
		color grades dark greenish grey; gravel content 25-30%.		RD	
46			B-14	PB 0.5/0.5	Cored w/Pitcher barrel sampler
				RD	Barrel plugged up - no circulation. 12:50 p.m. - Line on pump blew; down 10 minutes
48		48-48.6 2-3 large graywacke cobbles, ~3" max. dimension		PB	Cored with Pitcher Barrel 48.0-50.5.
		48.5-49.5 - brn. gray gravelly clay	B-15	1.7/2.5	
50		49.5-50 purplish gray sandy silty clay, scattered gravel ~ 15-20%	1.25, 1.4, 1.25, 0.9, 1.1		
		49.6 - layer of clayey med. sand; ~1/2" thick		RD	
52		54.8 - 55.7 - greenish to med. grey gravelly sandy clay some stringers of purple clay, less well compacted			
54		55.7-56.5 - several pockets yel-grn. silty clay, clayey silt; also purple silty clay gravel ~35%	1.7	RD / PB 1.7/2.5	Cored with Pitcher Barrel 54 - 56.5
			B-16		
56		56.5 - small pocket of med. brown clay.	B-17	1.5, 1.7, 2.0, 1.5	PB / RD
58					
60			1.5, 1.3, 1.1	RD / PB 1.3/1.5	Cored with Pitcher Barrel 60 - 61.5
			B-18		61.5 - 62.8 hard, rig chattering
		62.8 - purple & grey brn clay in cuttings	2.3	PB / RD	62.8 - softer, drilling faster
62					
64		64 - lot of clay coming up in cuttings			
66		67 - high amount of clay in cuttings			67 - drilling smooth
68					

SHEET 3 OF 4

PROJECT 1890 - Phoenix Dam DATE DRILLED 12/7/77 HOLE NO. RD-3

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
68		21.6-70.5 GRAVELLY SANDY CLAY: con't.		RD	68.7 - bit of chattering
70		~70 - 60%-70% of cuttings is clay Bedrock			70.5 - heavy chattering
	B.H. 71.5'	70.5 - 71.5 - GRAYWACKE hard to very hard little to mod weathered judging by cuttings and drill rate			B.H. 71.5

SHEET 4 OF 4

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DRILLING AND SAMPLING LOG

PROJECT 1890 - Phoenix Dam DATE DRILLED 12/5-6/77 HOLE NO. RD-4

LOCATION Downstream berm between existing holes 3 & 4 GROUND SURFACE ELEV. 140 (Topo.)

DRILLING CONTRACTOR J.N. Pitcher Co. LOGGED BY DMY DEPTH TO GROUND WATER —

TYPE OF RIG Failing 250 HOLE DIAMETER 5" HAMMER WEIGHT AND FALL 140 lb., 30"

SURFACE CONDITIONS grassy embankment berm WEATHER clear, mild

(track mounted crawler rig)

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	Pocket Penetrom.	MODE	REMARKS
2, 4 (new toe berm)	CL	0.0-4.5' (GRAVELLY) SANDY CLAY: dk. yel. brn. (5 YR 3/4); mod. plastic, slow dilatancy silty-clay fines (75-85%); scattered (15-20%) fine to coarse qtz., lithic sand grains; fine gravel (5-10%), pred. Fran. qwy, some ch, qmst., sh., ang. to subrnd. frags, vary hd. to friable, weath. stained; firm to stiff (mod. dense); slightly moist.			AD	Spin augered to 3½' set up mud tub - 1½ sk. bentonite to seal collar, start circulation
					RD	Drilled down w/ drag bit set surface casing to 4.0'
6, 8 (chimney drain)	GP	4.5-9.0' GRAVEL: med. grn. gray (5 GY 5/1), some mod. brn. (5YR 4/2) weath. stains; v. minor fines (<< 5%); scattered coarse, ang. graywacke sand grains (1-3%); pred. med. gravel (½-4" avg), ang., fresh to little weathered, hd., strong frags. (Probably a drain chimney)	B-1		PB 0.4/2.5	Cored w/ Pitcher Bbl. Assem. (only clean gravel w/ some sand in tube, no clay binder)
					RD	Drilled down with drag bit Add 2½ sks. bentonite to maintain circulation
10, 12, 14, 16, 18, 20 (hole caved to here 12/5, after drilling to 19.0) (original embankment)	GC	9.0-22.0' CLAYEY GRAVEL: dk. yel. brn. (10 YR 4/2), mod brn. (5 YR 4/4); 10-15% mod plastic silty clay fines; 5-10% scattered coarse, ang. sandst., volc. sand grains; 75-85% fine to med. gravel, pred. ang. to subrnd. graywacke, meta graywacke, metavolc. frags. consistency uncertain, probably dense in-situ; moisture uncertain in-situ.				Set casing to 9.0' to reduce water loss, maintain circulation
			J-1		PB 1.5/2.5	Cored with Pitcher barrel assembly
					RD	Drilled down w/ drag bit
		14.0-15.0 grades more sandy (15-20%), more clayey (20-30%)	J-2	1.9(?)	PB 1.2/2.5	Cored with Pitcher barrel assembly 0.5' gravel cave on top of sample
	GP	16.5-19.0 amount of caving and appearance of sample indicate little clay binder	B-2		PB 0.3/2.5	Cored with Pitcher barrel assembly 0.5' cave on top of 3-4" diam. cobble wedged in end of tube
12/5	GC	17-20 cuttings suggest material similar to 14.0-15.0 interval			RD	Drilled down w/ tricone bit

SHEET 1 OF 2

RD to 19' 3 times, hole caves to 15' each time, add ½ sk bentonite, cave to 14'

PROJECT 1890 - Phoenix Dam DATE DRILLED 12/5-6/77 HOLE NO. RD-4

add 1/4 sack bentonite

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS (cased to 20', add 1/4 sk. bentonite, flush to 22' after RD)	N, blows/ft
	GC			DR 0.0/1.5	Drove standard split spoon 13/0.5 12/0.5 18/0.5	30
				RD	Drilled down with tricone bit	
22	GC (GP)	22.0-43.5' CLAYEY SANDY GRAVEL: mod. brn. (5 YR 4/4); generally 20-25% mod. plastic silty clay fines, locally to 40-45% in clayey pockets; sand (30-40%) fine to predom. coarse, mainly angular rock frags; 35-45% gravel, avg. size 3/4-1", pred. ang. to subang., chert, serpentinite, metavolc., graywacke, frags gen. hard, strong; gravel seems to be in loose (to soft) clayey sand matrix in places, blow counts suggest mod. dense material; probably moist in-situ.	J-3	PB 1.7/2.5	Cored with Pitcher barrel assembly. Tube had 2.7' sample + voids before extrusion	
24			cave	PB 0.3/2.5	Cored w/ Pitcher barrel assembly. minor slough/cave on top of 2 1/2" cobble in end of tube	
26			cave	RD	Drilled down w/ tricone bit	
			B-3	DR 0.9/1.5	Drove standard split spoon 16/0.5 12/0.5 17/0.5	2
28		29.0-29.9 grades more coarse sand (clayey gravelly sand to gravelly clayey sand)	B-4	RD	Drilled down w/ tricone bit add 3/4 sk. bentonite to flush cuttings	
	SC (GC)			DR 0.9/1.5	Drove standard split spoon 11/0.5 8/0.5 9/0.5	17
30		30.5-34.0' cuttings suggest more coarse-fine sand, less gravel, more fines		RD	Drilled down w/ tricone bit add 1 sk bentonite to flush cuttings; water loss not significant (have used total of ~5 sks. bentonite in hole to here)	
32						
34	GC (GP)	34.2-34.6 distinctive gray-brown clayey sandy gravel	J-4 J-5	PB 1.6/2.5	Cored w/ Pitcher barrel assembly. samples appear relatively undisturbed after extrusion	
36				RD	Drilled down w/ tricone bit	
	GP?	37.0-39.0' cuttings suggest relatively little clay binder				
38						
	GC (GP)			DR 0.0/1.5	Drove standard split spoon 11/0.5 11/0.5 11/0.5	2
40				RD	Drilled down w/ tricone bit	
		Bedrock				
42		43.5-44.0 METAGRAYWACKE: cuttings suggest dk. to gray grn meta-graywacke sandstone; little clayey binder in cuttings; hard drilling			mod. chatter, rig shows at 43.5'	
44	rock				SHEET 2 OF 2	

original embankment

B.H. - 44.0'

terminate hole at 44.0

Important Information About Your

Geotechnical Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

The following information is provided to help you manage your risks.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared *solely* for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. *Do not rely on a geotechnical engineering report* whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. *Always* contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are *Not* Final

Do not overrely on the construction recommendations included in your report. *Those recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual

subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.*

A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure contractors have sufficient time* to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a *geoenvironmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, a number of mold prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; ***none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.***

Rely, on Your ASFE-Member Geotechncial Engineer for Additional Assistance

Membership in ASFE/The Best People on Earth exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you ASFE-member geotechnical engineer for more information.

ASFE
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Appendix 5 to Attachment 3

Long-Term Hydrologic Analysis of Re-operating Phoenix Lake for Flood Detention and Water Supply

Prepared for
Marin County Flood Control and Water Conservation District, Flood Zone 9

Prepared by
Stetson Engineers Inc.
January 20, 2011

INTRODUCTION

Phoenix Lake is located on Ross Creek, a major tributary of Corte Madera Creek. The lake is owned, operated, and maintained by MMWD primarily for the purpose of water supply in the dry season, but also for wildlife habitat and public recreation and enjoyment. The watershed above Phoenix Lake encompasses about 1,400 acres. When filled to the spillway crest (elevation 174 ft), the lake covers 17 acres and holds approximately 300 acre-ft of water based on the 2009 bathymetric survey (Figure 1).

The lake dam is penetrated by a gated, 30-inch diameter, low-level outlet pipe that has an intake invert elevation at 130 ft (NGVD29[1]) and a discharge capacity of approximately 115 cfs when the lake is full[2]. This low-level outlet is normally kept closed and has been used infrequently since it was built. The spillway is situated on the right side of the dam (looking upstream). In 1985 the spillway was modified by lowering the crest by six feet, from elevation 180 ft down to elevation 174 ft. This modification effectively lowered the normal lake water level and reduced the lake storage capacity by about 120 acre-ft, from 420 acre-ft to its present day capacity of 300 acre-ft.

Phoenix Lake currently functions as a de facto detention basin. During heavy storms, the lake water level rises above the spillway crest. The resulting "surcharge" storage attenuates stormflow and reduces the peak flow in the creek downstream. In theory, the attenuation effect could be enhanced through changes in lake operations. Modifications to the intake of low-level outlet pipe would be needed to facilitate changed operations. Preliminary analysis by Stetson indicates that drawing the lake level down ahead of a forecasted storm to el.140 ft, in concert with installing a 6-foot high inflatable/deflatable rubber dam across the spillway, would provide sufficient storage space in the lake to detain floodwaters and effectively reduce 100-year peak flows along Ross Creek and Corte Madera Creek, including key breakout points in Ross.

Further study of the compatibility of operating Phoenix Lake for both flood detention and water supply is needed in light of the lake's role in providing water supply during the dry

[1] All elevations used herein are referenced to the NGVD29 datum.
[2] Based on a head vs. discharge curve for the pipe developed by Stetson Engineers using HEC-HMS.

season, as well as wildlife functions and recreational opportunities to the community. Manipulation of lake levels for flood detention would be limited to the wet season, which should allow enough time for the lake to refill by late spring. The purpose of this hydrologic study was to analyze and verify whether natural inflows to the lake during the spring refilling period are indeed sufficient to refill the lake (to the pre-1985 lake water level of 180 ft raised by the 6-ft high inflatable dam) for a given starting date for refilling (e.g., March 15th or April 1st). This study considered the likelihood that regulatory agencies would require instream flow releases during the spring refilling period to maintain instream flow conditions necessary to sustain/enhance downstream aquatic habitat, which otherwise would have occurred as spillway overflow under historical lake operations.

ANALYSIS

The following steps were taken to conduct the hydrologic study:

1) Select representative hydrologic period of analysis
2) Analyze historical daily spillway overflows during spring to determine the anticipated required instream flow releases
3) Analyze historical daily inflows to Phoenix Lake during spring
4) Conduct reservoir re-operations analysis for spring using new operating rules

1) Select Representative Hydrologic Period of Analysis

The representative hydrologic period of analysis was selected after analyzing the historical flow records in spring at the Ross streamflow gage. USGS has monthly flow records at the Ross gage available from 1953 to 1993 (41 years). Figure 2a shows the average flow for each year for the period from March 1 to May 31 and Figure 2b shows the average flow from April 1 to May 31. Both graphs show that the period of 1984 to 1993 was dry in spring. The spring of 1988 was the second driest over the 41 year period[3]. To be conservative, the period from 1984 to 2010 was initially selected for the hydrologic study. This period includes the dry springs of 1984 to 1993 and records for latest years.

After reviewing the historical daily water level records of Phoenix Lake provided by MMWD for the initially selected period, seven years (1984, 1985, 1989, 1990, 1991, 1992, and 1996) were found to have incomplete data and, therefore, were removed from the selected period of analysis. The final selected period of analysis was from 1986 to 2010, excluding 1989-1992 and 1996. This final selected analysis period (20 years) still includes dry springs of 1987, 1988, and 1993 (shown in Figures 2a and 2b) and other dry springs post-1993.

[3] The spring of 1977 was the driest and the spring of 1988 was the second driest over the 41 year period. The average daily flows at Ross gage during the period of March 1 to May 31 in 1977 and 1988 were 2.22 cfs and 2.43 cfs, respectively (Figure 2a). The average daily flows at Ross gage during the period of April 1 to May 31 in 1977 and 1988 were 1.22 cfs and 2.52 cfs, respectively (Figure 2b).

2) Analyze Historical Daily Spillway Overflows during Spring to Determine the Anticipated Required Instream Flow Releases

The historical daily spillway overflows were estimated using the recorded daily water level records of Phoenix Lake and the spillway head vs. discharge curve provided by MMWD (refer to Figure 3 for the spillway head vs. discharge curve). The estimated historical daily spillway overflows during spring of all years are shown in Figure 4a and detailed in Figures 4b to 4e. The spikes shown in Figures 4b to 4e represent spillway overflows caused by storms. When there were no storms, spillway overflows were generally less than 3 cfs, and there were a lot of times during spring that there were no spillway overflows.

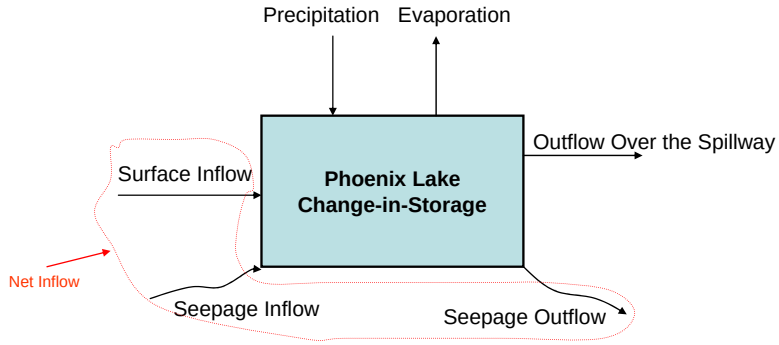
3) Analyze Historical Daily Inflows to Phoenix Lake during Spring

The study requires accurate estimates of historical daily inflows to the lake during spring. There are two basic methods available:

- Method 1: Use the recorded flows at Ross streamflow gage to prorate to Phoenix Lake by applying the drainage area ratio.
- Method 2: Use a water budget analysis approach of Phoenix Lake to back-calculate historical daily inflows.

Theoretically, if historical recorded lake levels are available and the spillway rating curve is reasonably accurate at low flows, Method 2 should be more accurate than Method 1. This is because flow during the spring in the Ross Valley is mostly base flow and prorating base flow from Ross gage to Phoenix Lake by applying the drainage area ratio may not be accurate.

Since recorded historical daily lake levels at Phoenix Lake are available, Method 2 was used to estimate the historical daily inflows to the lake in spring. The water budget components (see the chart below) include surface inflows to the lake, precipitation, evaporation, outflows over the spillway, seepage inflows and seepage outflows, and the resulting change-in-storage estimated from the recorded lake levels. The term "net inflow" in the chart below represents the sum of surface inflow and seepages.



Water Budget under "As-Operated" Conditions

The water budget analysis was conducted on a daily basis. Daily precipitation at Phoenix Lake was provided by MMWD. Daily outflow over the spillway was estimated using the recorded lake levels and the spillway rating curve. Daily evaporation was first estimated using the averaged long-term average monthly pan evaporation at San Francisco Airport and Oakland Airport converted to lake evaporation by multiplying a pan-to-lake evaporation coefficient of 0.75 (see Table 1), and then uniformly distributed to each day. The long-term average monthly evaporation data at San Francisco Airport and Oakland Airport were obtained from the California Climate Data Archive. The data show that long-term average monthly evaporation at San Francisco Airport is close to that at Oakland Airport, suggesting that long-term average monthly evaporation in Marin County would be similar too. It is worth noting that evaporation is a very minor component in the water budget analysis and would have negligible effect on the daily inflow estimates.

Table 1 Long-Term Monthly Pan Evaporation at San Francisco and Oakland Airports and Estimated Lake Evaporation

Month	Long-Term Monthly Pan Evaporation at San Francisco Airport (inch)	Long-Term Monthly Pan Evaporation at Oakland Airport (inch)	Averaged Monthly Pan Evaporation for the Two Stations (inch)	Averaged Monthly Lake Evaporation (inch)
Jan	1.7	1.8	1.8	1.3
Feb	2.4	2.3	2.4	1.8
Mar	3.8	3.8	3.8	2.9
Apr	5.3	4.8	5.1	3.8
May	6.4	5.7	6.1	4.5
Jun	7.1	6.4	6.8	5.1
Jul	6.7	6.4	6.6	4.9
Aug	6.6	6.0	6.3	4.7
Sep	5.9	5.4	5.7	4.2
Oct	4.4	4.0	4.2	3.2
Nov	2.4	2.4	2.4	1.8
Dec	1.7	1.8	1.8	1.3
Annual	54.5	50.7	52.6	39.5

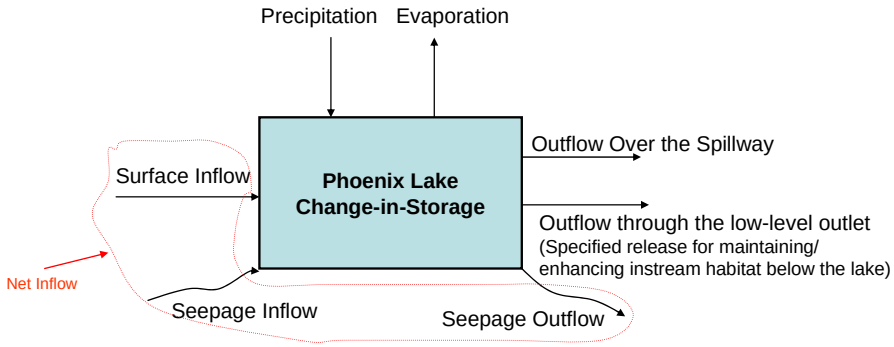
Note: Lake Evaporation = Pan Evaporation × 0.75.

Once the daily change-in-storage, precipitation, evaporation, and outflow over the spillway are estimated, the net inflow to Phoenix Lake can be back-calculated using a water budget analysis approach. The back-calculated net inflows to Phoenix Lake are shown in Figure 5a and detailed in Figures 5b to 5e. The net inflows are the sum of surface inflows, seepage inflows, and seepage outflows. Figures 5a to 5e show that there were days that the net inflows were negative, indicating seepage outflows were higher than inflows in those days.

4) Conduct Reservoir Re-Operations Analysis for Spring Using New Operating Rules

A reservoir operations analysis was conducted to re-operate the reservoir for spring using new operating rules (e.g., fall and winter drawdown for flood control, minimum instream flow releases). The purpose of the analysis was to evaluate refilling of the lake during the spring after Step 1 drawdown for wet season flood detention according to the "rule curve" (see Figure 6) which was developed to meet the needs of both flood detention in the wet season and water supply in the dry season. Operating according to the rule curve would draw down the lake far enough (to elevation 160 ft; Step 1 drawdown) to enable complete drawdown to the final target level, elevation 140 feet, within 24-hours of a forecasted large storm event[4]. The existing 30-inch low-level outlet has sufficient capacity to enable drawdown even during times when heavy base inflows can precede impending storms (see Figure 9).

Compared to the water budget method described in Step 3, the reservoir operations analysis included an additional outflow component; that is, instream flow release through the low-level outlet for maintaining/enhancing instream habitat below the lake (see the chart below). The amount of instream flow release through the low-level outlet in spring under re-operated conditions was assumed to be similar, on average, to the historical spillway overflows, which were analyzed in Step 2 [5].



[4] The "rule curve" (see Figure 6) does not set a defined time for the initial drawdown to el. 160 ft. Drawdown of Phoenix Lake will follow a two-step procedure. The first step is initial drawdown of the lake and the second step is final drawdown of the lake and opening of the low-level outlet. The first step can occur at any time during the rainy season. Watershed moisture conditions will be continually monitored by tracking soil moisture content, groundwater levels, discharges from seeps and springs, and base flows in creeks. When this monitoring indicates watershed moisture approaching saturation, then the lake will be gradually drawn down to elevation 160 ft, 14 ft below the spillway crest, and maintained at that level. (It is possible that the initial drawdown will not happen during very dry years when the water supply of Phoenix Lake is needed most). The second step will be triggered by a forecast of potential flooding issued by the National Weather Service, in which case the low level outlet will be opened and the lake will be further drawn down 20 ft, to elevation 140 ft, and maintained at that level. The low-level outlet will remain open thereafter, continuing on its own to pass inflows into the lake. The lake will fill during the storm as inflow into the lake exceeds outflow through the low-level outlet.

[5] An instream flow release requirement may be imposed by regulatory agencies, but the amount of the release can not be determined at this time. Agencies would likely base their requirement on consultation with Flood Zone 9 and MMWD and on an instream flow study performed by a fishery scientist and hydrologist. For purposes of this analysis, instream releases of 1 to 2 cfs, or inflow, whichever is less, were used.

Water Budget under Re-Operated Conditions

Given the available net inflows estimated in Step 3, the outcome of whether the lake can be refilled by late spring depends on (1) the starting date for refilling, (2) the initial lake level at the starting date for refilling, and (3) the instream flow release through the low-level outlet. Table 2 is a summary of the selected simulated scenarios. The simulation results of lake levels for the starting date of April 1st are shown in Figures 7a to 7d. Results for the starting date of March 15th are shown in Figures 8a to 8d. In the analysis, when the lake level first reaches the spillway crest (i.e., 174 ft), no further instream flow release through the low-level outlet was made because the spillway overflows, thereafter, would maintain instream habitat below the lake.

Table 2 Summary of Simulated Scenarios

Scenario	Initial Lake Level (ft in NGVD29)	Starting Date for Refilling	Instream Flow Release Through the Low-Level Outlet (cfs)
1	160 ft	April 1st	2 cfs
2	160 ft	April 1st	1 cfs
3	160 ft	April 1st	2 cfs or inflow, whichever is less
4	160 ft	April 1st	1 cfs or inflow, whichever is less
5	160 ft	March 15th	2 cfs
6	160 ft	March 15th	1 cfs
7	160 ft	March 15th	2 cfs or inflow, whichever is less
8	160 ft	March 15th	1 cfs or inflow, whichever is less

Assuming Scenario 8 is the preferred scenario, the simulation results shown in Figure 8d indicate that there will be four water years (1988, 2004, 2007, and 2009) that could not refill the lake by late spring if the initial lake level on March 15th is at elevation 160 ft. Examination of recorded flows at the Ross streamflow gage in the wet season of these years shows that there could be no need to draw down the lake to elevation 160 ft in 1988 and 2007 because these two years were not wet enough to saturate the watershed in the wet season (see Figures 9 and 11). There is a need to draw down the lake to elevation 160 ft in 2004 (see Figure 10). No flow graph was prepared for 2009 since the flow records are judged not reliable.

Table 3 is a summary of increased yield of water for the analysis years by raising the spillway crest from the current elevation 174 ft to the pre-1985 elevation 180 ft. The average increased annual yield over the 20-year analysis period is estimated to be about 107 acre-ft and the increased annual yield in the shortage year 1988 is estimated to be

about 50 acre-ft. (Refer to Figure 12 for historical rainfall at Lake Lagunitas that was used to classify water year type).

Table 3 Estimated Additional Annual Yield of Water By Raising the Spillway Crest from Current Elevation to Pre-1985 Elevation 180 ft

Year	Year Type	Additional Yield (acre-ft)	Note
1986	Wet	120	
1987	Dry	120	
1988	**Dry**	**50**	Estimated without first-step drawdown
1993	Normal	120	
1994	Dry	120	
1995	Wet	120	
1997	Normal	120	
1998	Wet	120	
1999	Normal	120	
2000	Normal	120	
2001	Dry	120	
2002	Normal	120	
2003	Normal	120	
2004	Normal	-60	
2005	Wet	120	
2006	Wet	120	
2007	Dry	120	Estimated without first-step drawdown
2008	Normal	120	
2009	Normal	100	
2010	Normal	120	
Long-Term Average Yield		**107**	
Yield in Shortage Year 1988		**50**	

FINDINGS

1) Operating Phoenix Lake at a lower level during the winter would add reliability to the flood control function of the lake. But operating at a lower level is not essential if (a) watershed saturation is continually and closely monitored and (b) large storms are reliably forecasted sufficiently in advance to enable drawdown of the lake before the storms begin.

2) Operating Phoenix Lake full during the winter, at el. 174 ft, would still enable complete drawdown to the final target level for winter flood operations, elevation 140 ft, within 48-hours of a forecasted large storm event (see Figure 13).

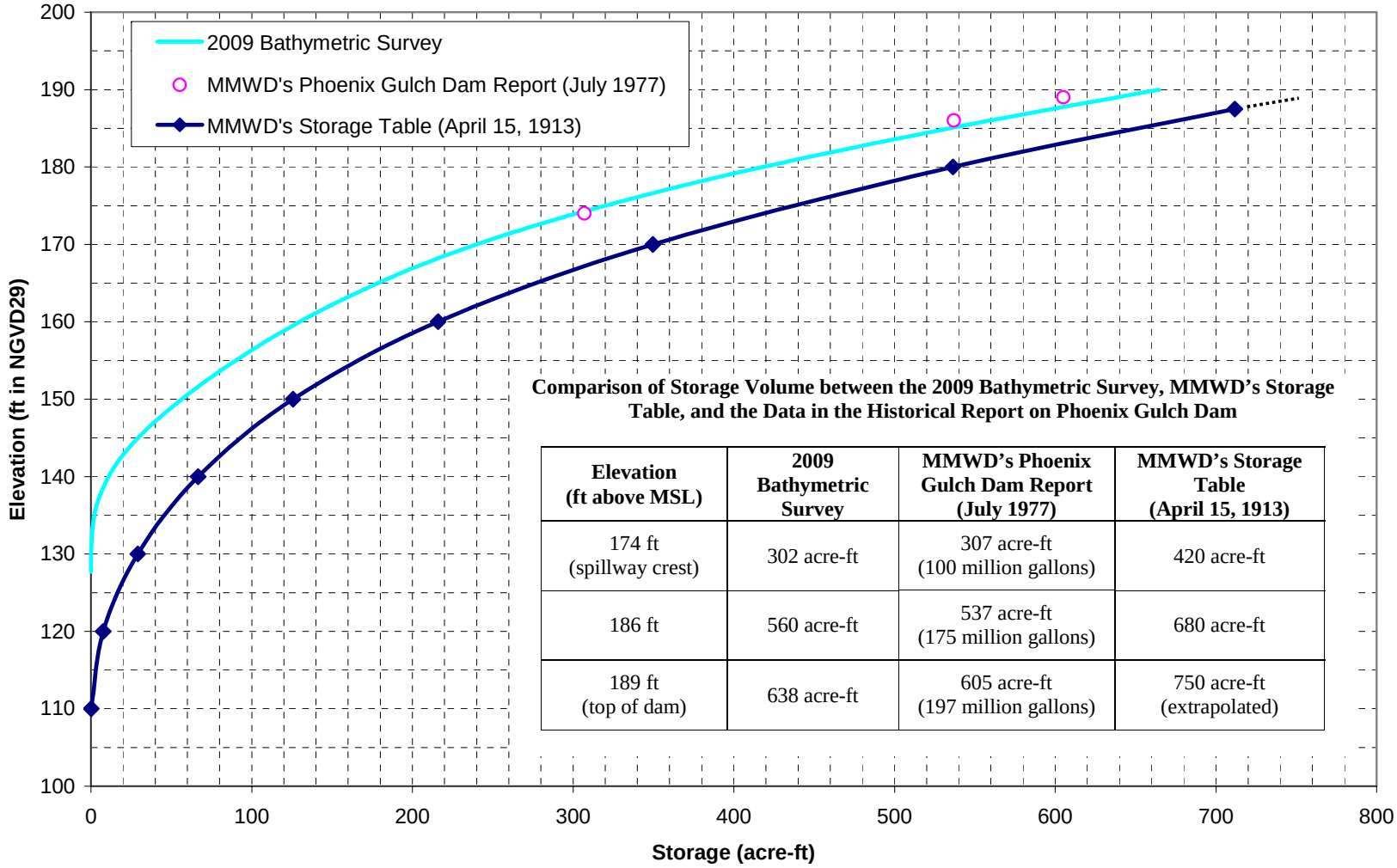
3) Operating Phoenix Lake partially drawn down during the winter, at el. 160 ft, would enable complete drawdown to the final target level for winter flood operations, elevation 140 ft, within 24-hours of a forecasted large storm event (see Figure 9).

4) In most years, inflow into Phoenix Lake during the spring would be sufficient to refill the lake from the winter flood operations drawdown level, el. 160 ft, to the raised spillway crest, el. 180 ft. In very dry years, complete refill may not occur. However, it is possible that the first-step drawdown to elevation 160 ft may not happen during these very dry years.

5) The starting date of refill (e.g., March 15th or April 1st), and the amount of the required instream flow release (e.g., 1 cfs, 2 cfs, or inflow) significantly affects refilling of the lake.

6) Raising the spillway crest from the current elevation 174 ft to the pre-1985 elevation 180 ft could increase the long-term average annual yield by about 107 acre-ft and an annual yield in a shortage year (e.g., 1988) by about 50 acre-ft.

Figure 1 Phoenix Lake Elevation - Storage Curve



Comparison of Storage Volume between the 2009 Bathymetric Survey, MMWD's Storage Table, and the Data in the Historical Report on Phoenix Gulch Dam

Elevation (ft above MSL)	2009 Bathymetric Survey	MMWD's Phoenix Gulch Dam Report (July 1977)	MMWD's Storage Table (April 15, 1913)
174 ft (spillway crest)	302 acre-ft	307 acre-ft (100 million gallons)	420 acre-ft
186 ft	560 acre-ft	537 acre-ft (175 million gallons)	680 acre-ft
189 ft (top of dam)	638 acre-ft	605 acre-ft (197 million gallons)	750 acre-ft (extrapolated)

Figure 2a Average Daily Flow at Ross Gage from March 1 to May 31

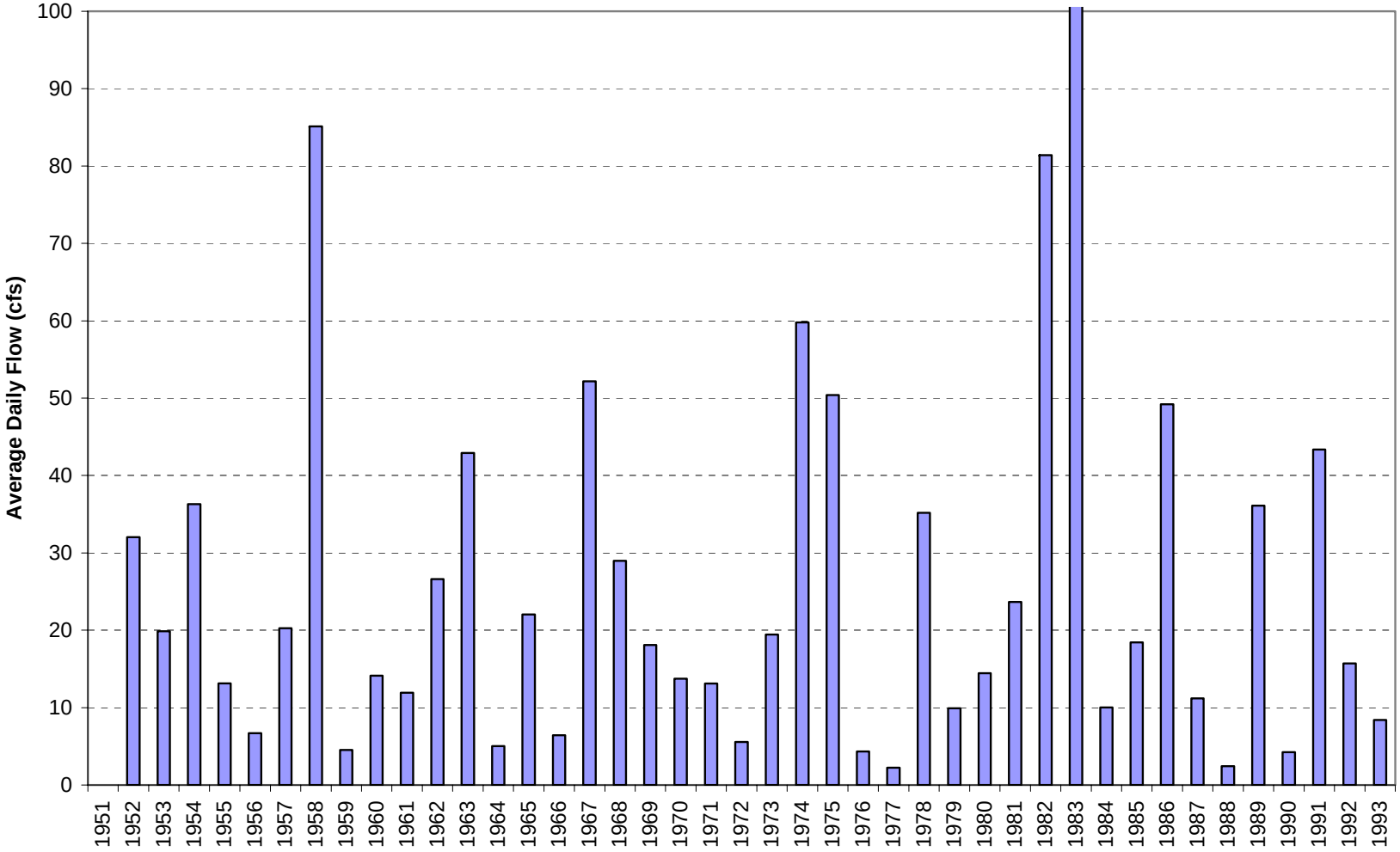


Figure 2b Average Daily Flow at Ross Gage from April 1 to May 31

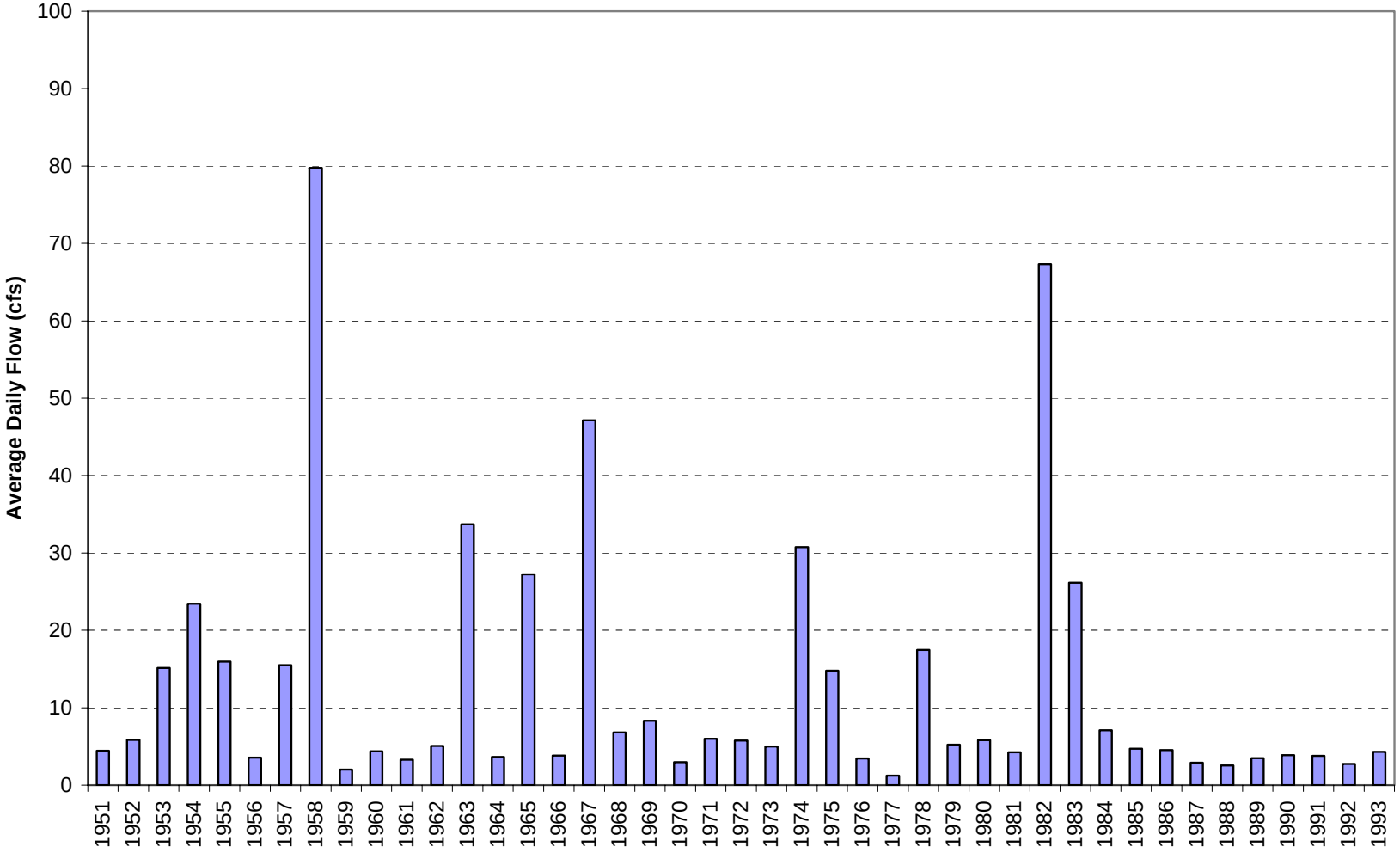
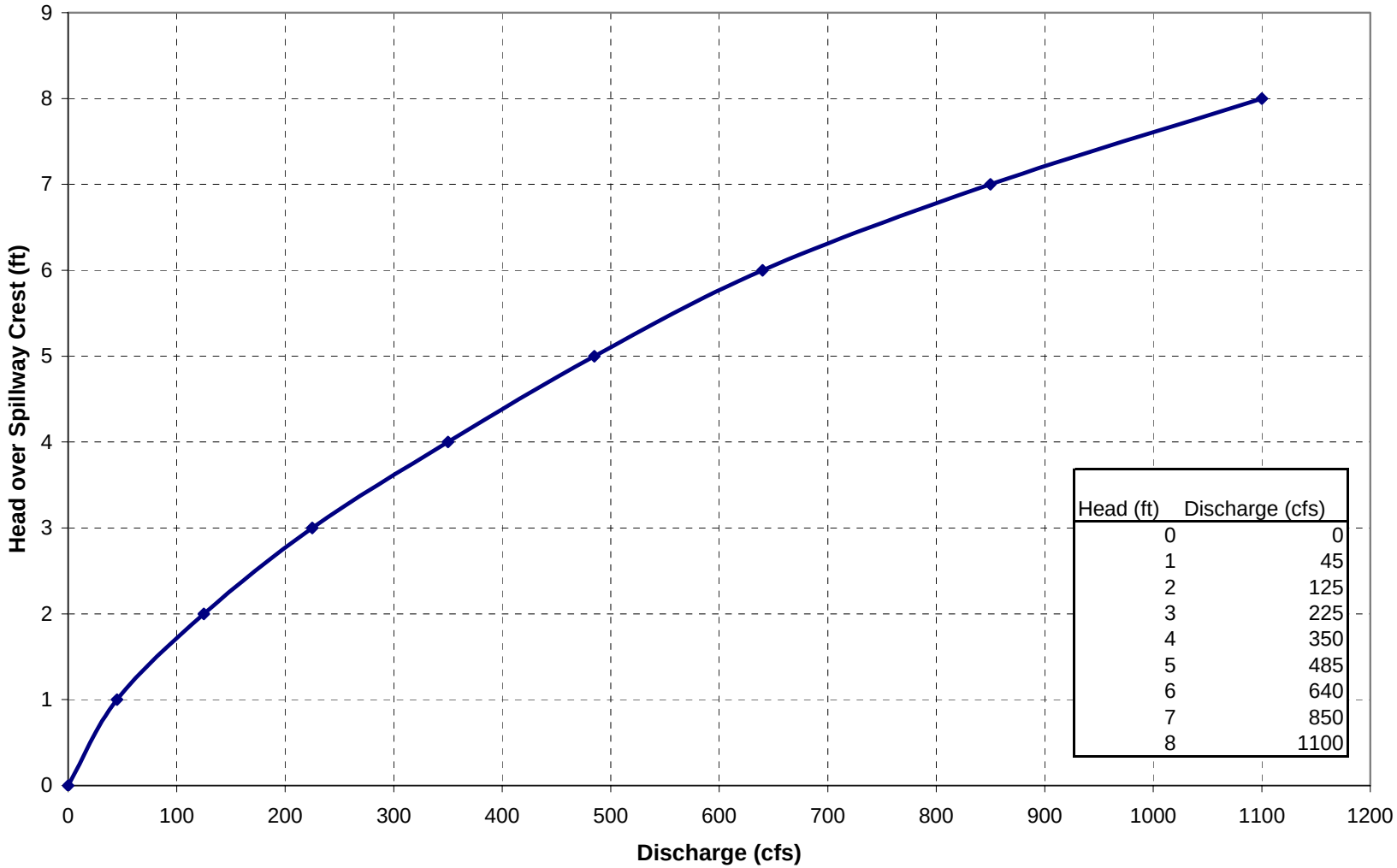


Figure 3 Phoenix Lake Spillway Discharge Rating Curve



Head (ft)	Discharge (cfs)
0	0
1	45
2	125
3	225
4	350
5	485
6	640
7	850
8	1100

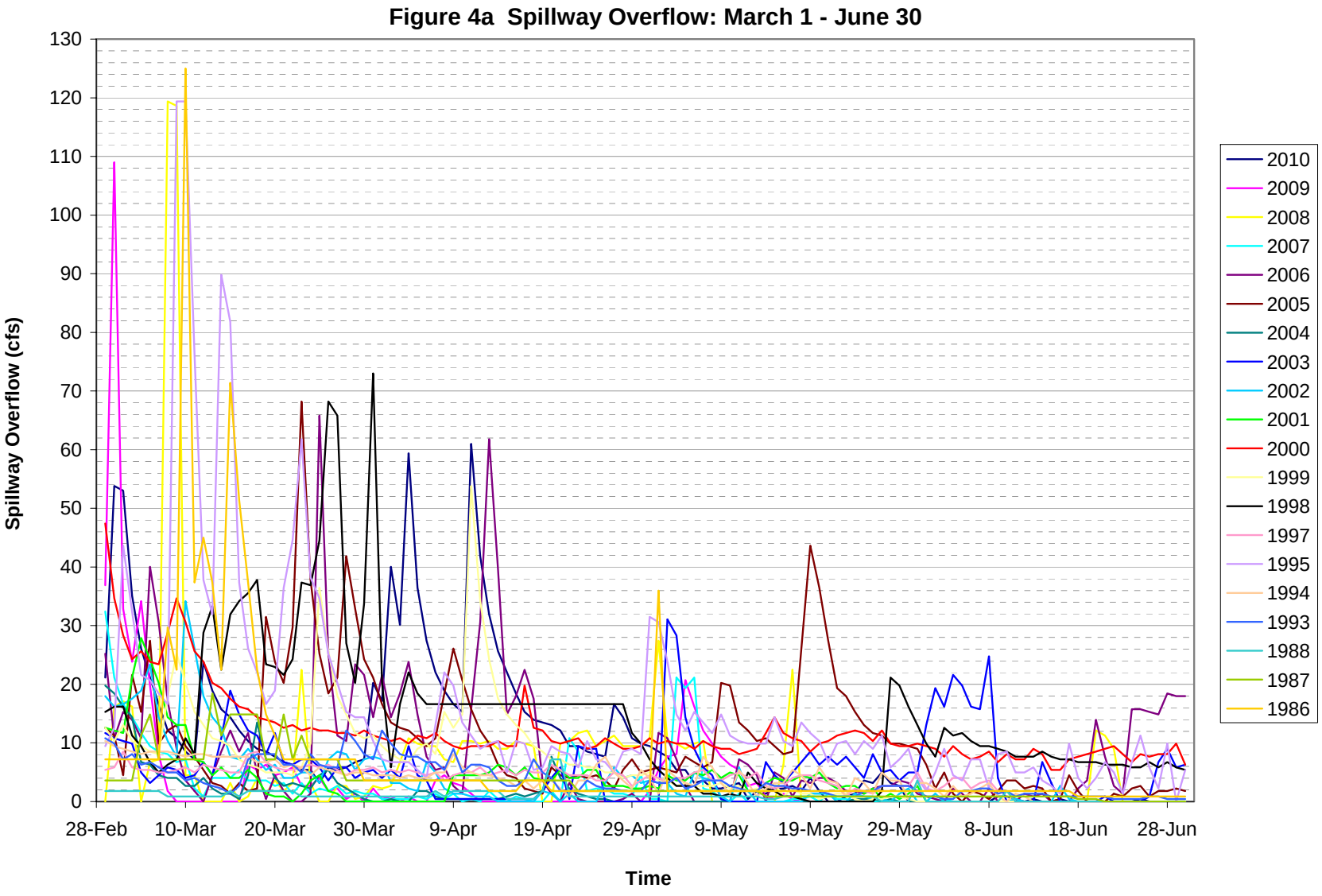


Figure 4a Spillway Overflow: March 1 - June 30
Spillway Overflow (cfs)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
28-Feb
10-Mar
20-Mar
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
8-Jun
18-Jun
28-Jun
Time
2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
1995
1994
1993
1988
1987
1986

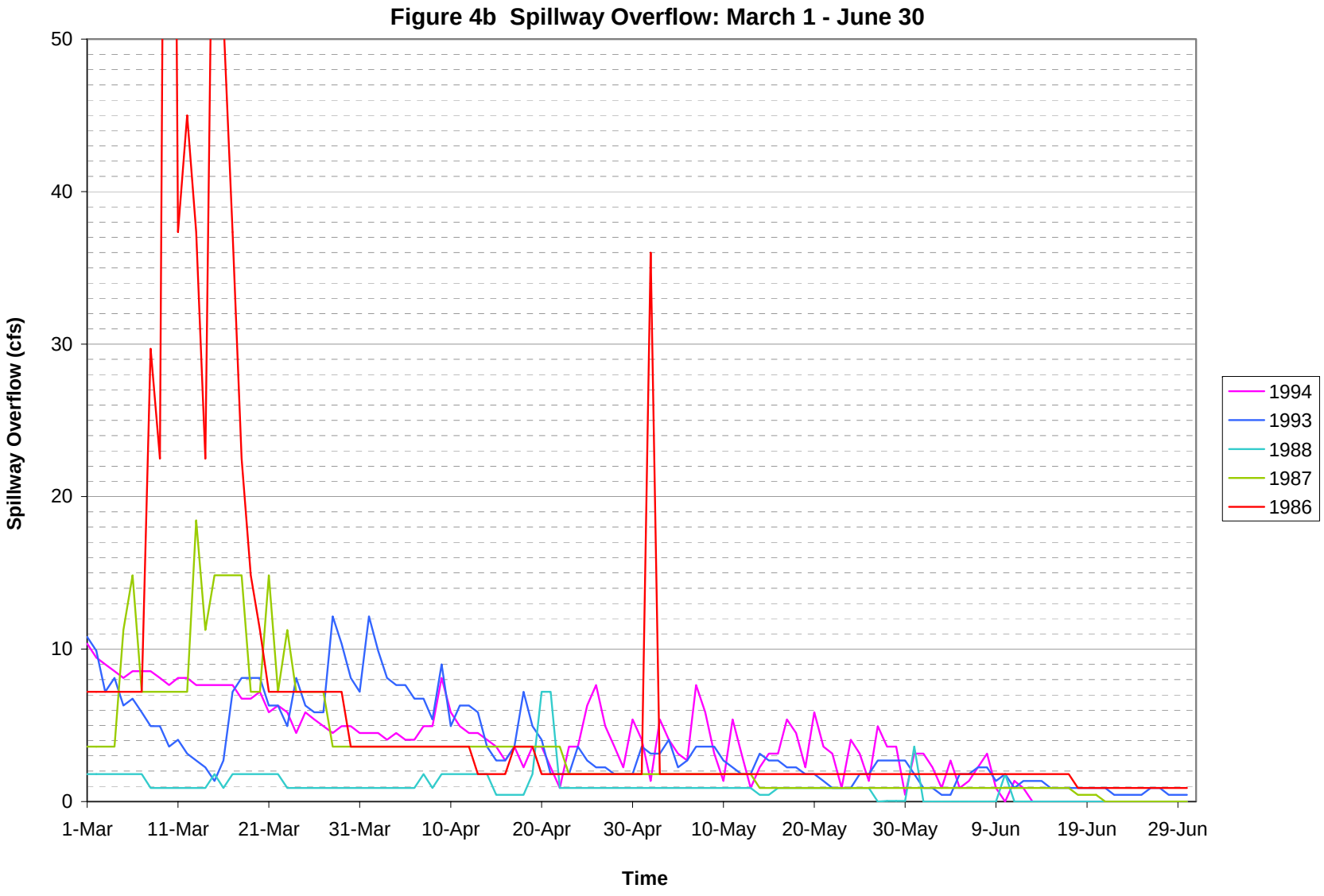


Figure 4b Spillway Overflow: March 1 - June 30
Spillway Overflow (cfs)
50
40
30
20
10
0
1-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr
10-May
20-May
30-May
9-Jun
19-Jun
29-Jun
Time
1994
1993
1988
1987
1986

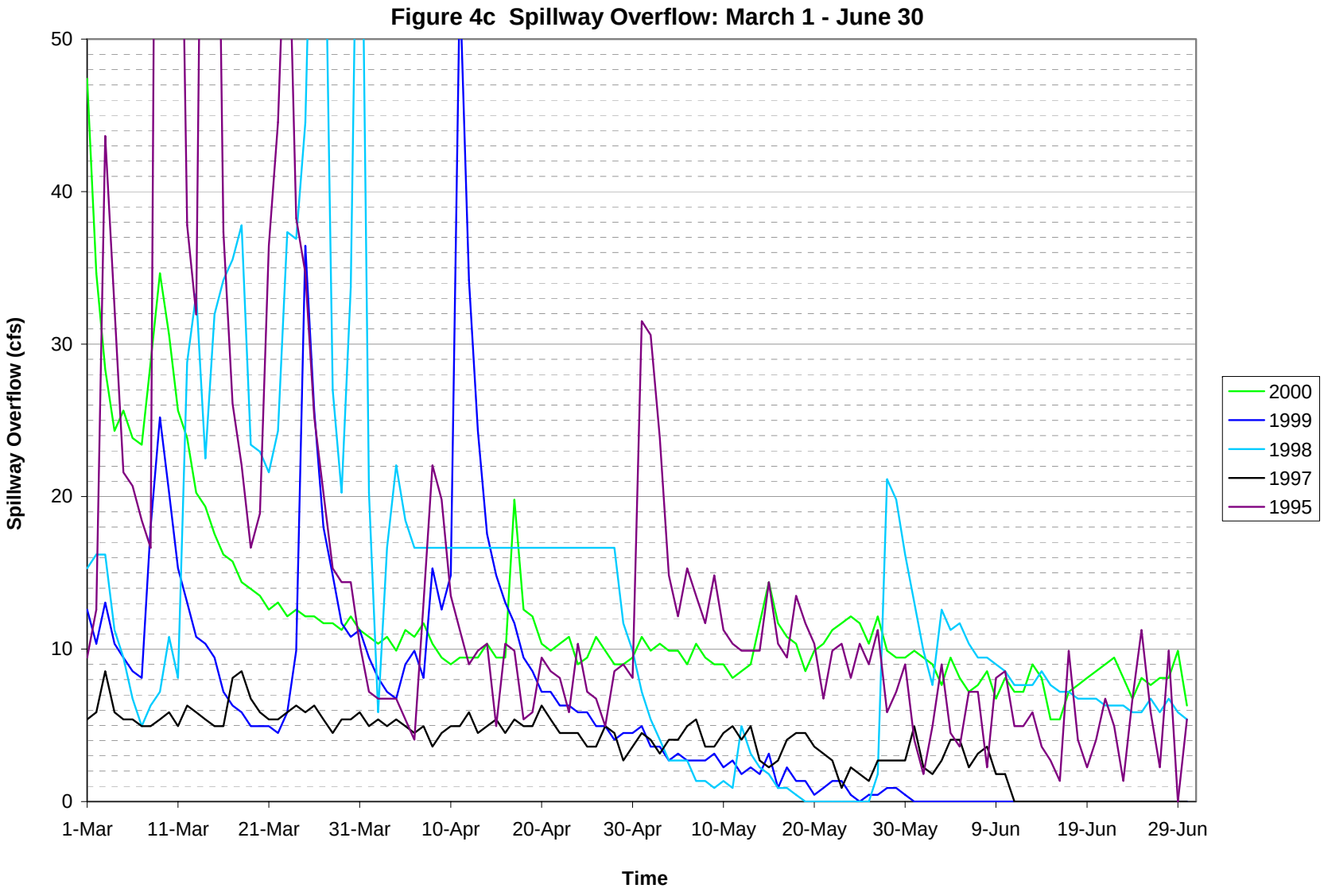


Figure 4c Spillway Overflow: March 1 - June 30
Spillway Overflow (cfs)
50
40
30
20
10
0
1-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr
10-May
20-May
30-May
9-Jun
19-Jun
29-Jun
Time
2000
1999
1998
1997
1995

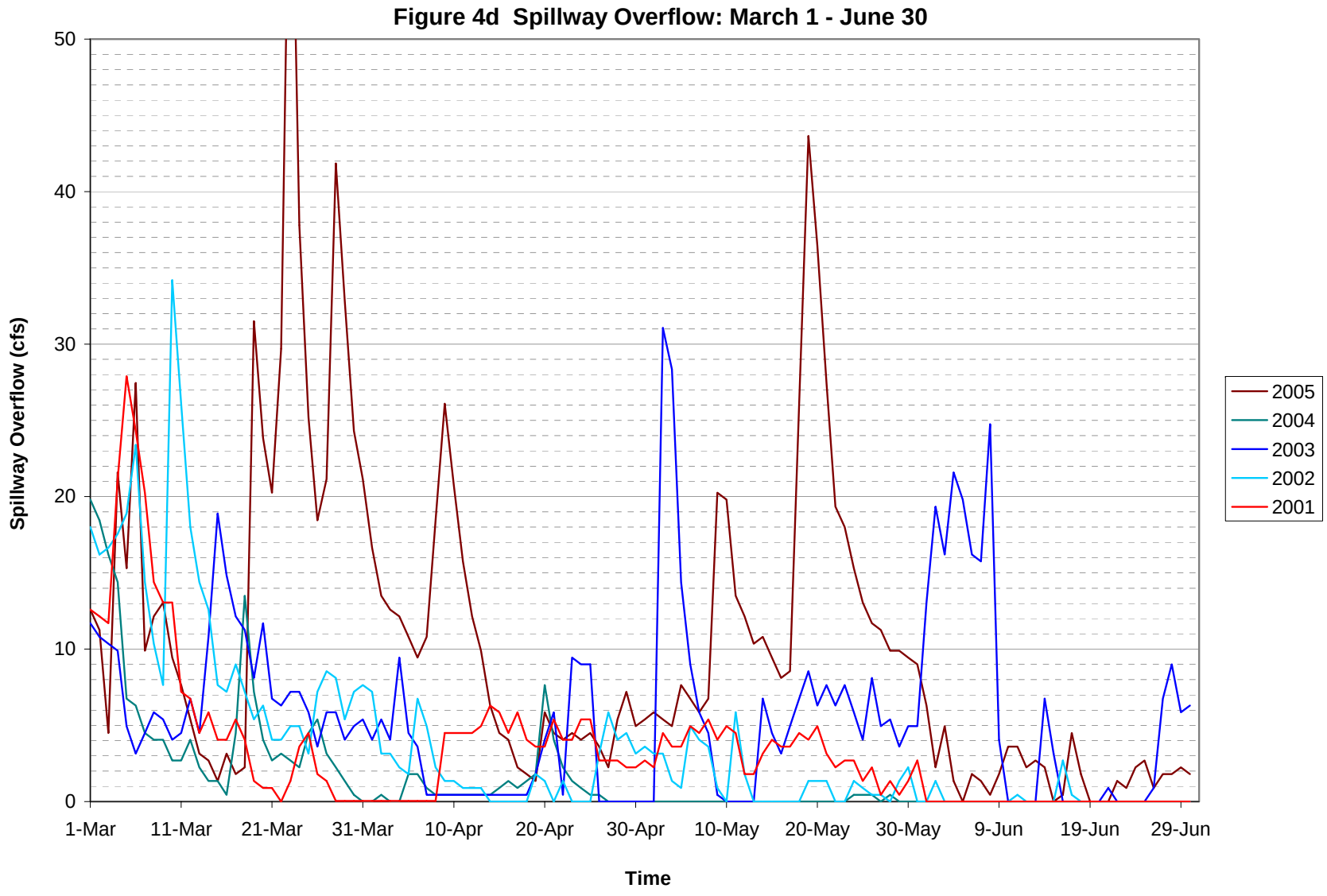


Figure 4d Spillway Overflow: March 1 - June 30
Spillway Overflow (cfs)
50
40
30
20
10
0
1-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr
10-May
20-May
30-May
9-Jun
19-Jun
29-Jun
Time
2005
2004
2003
2002
2001

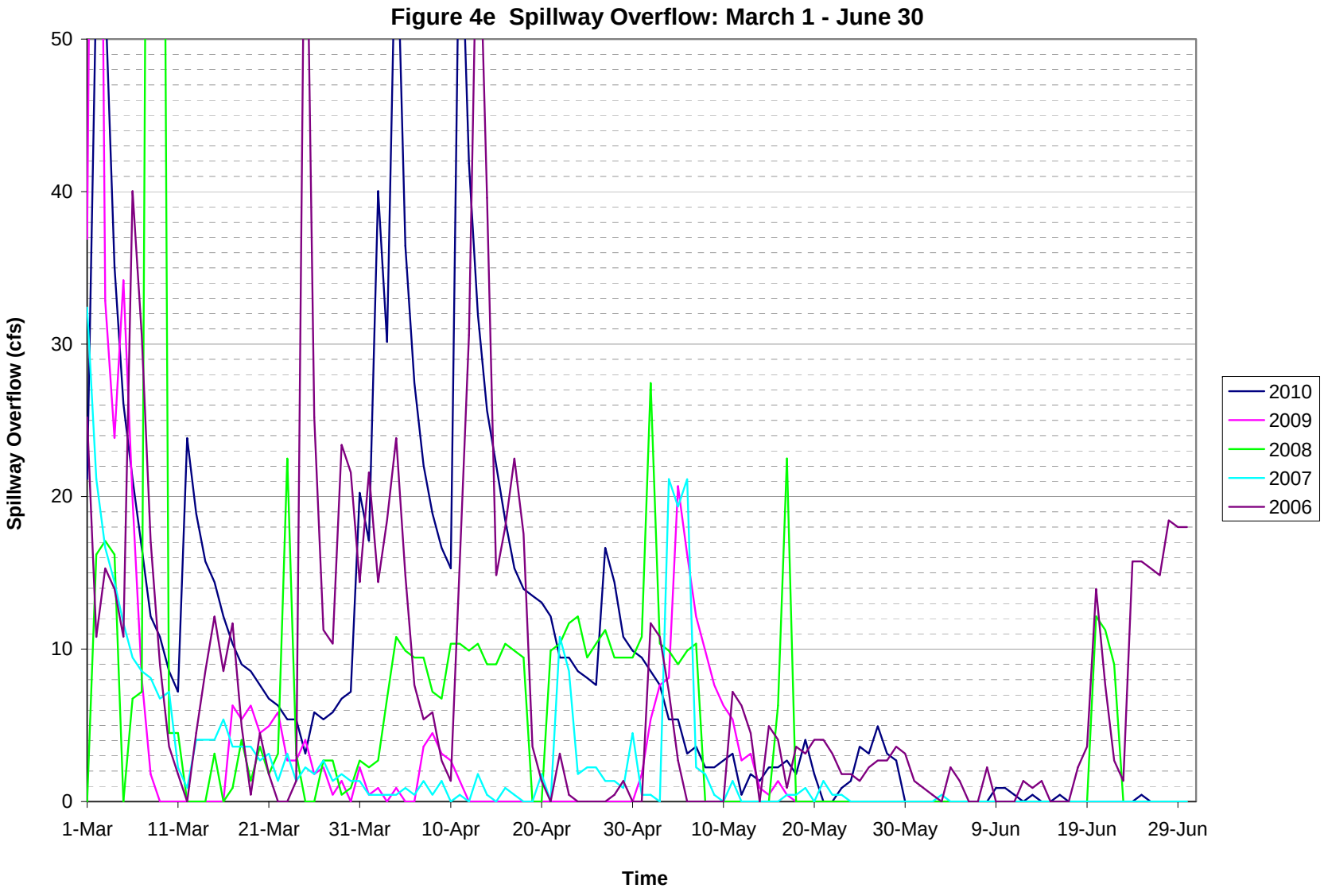
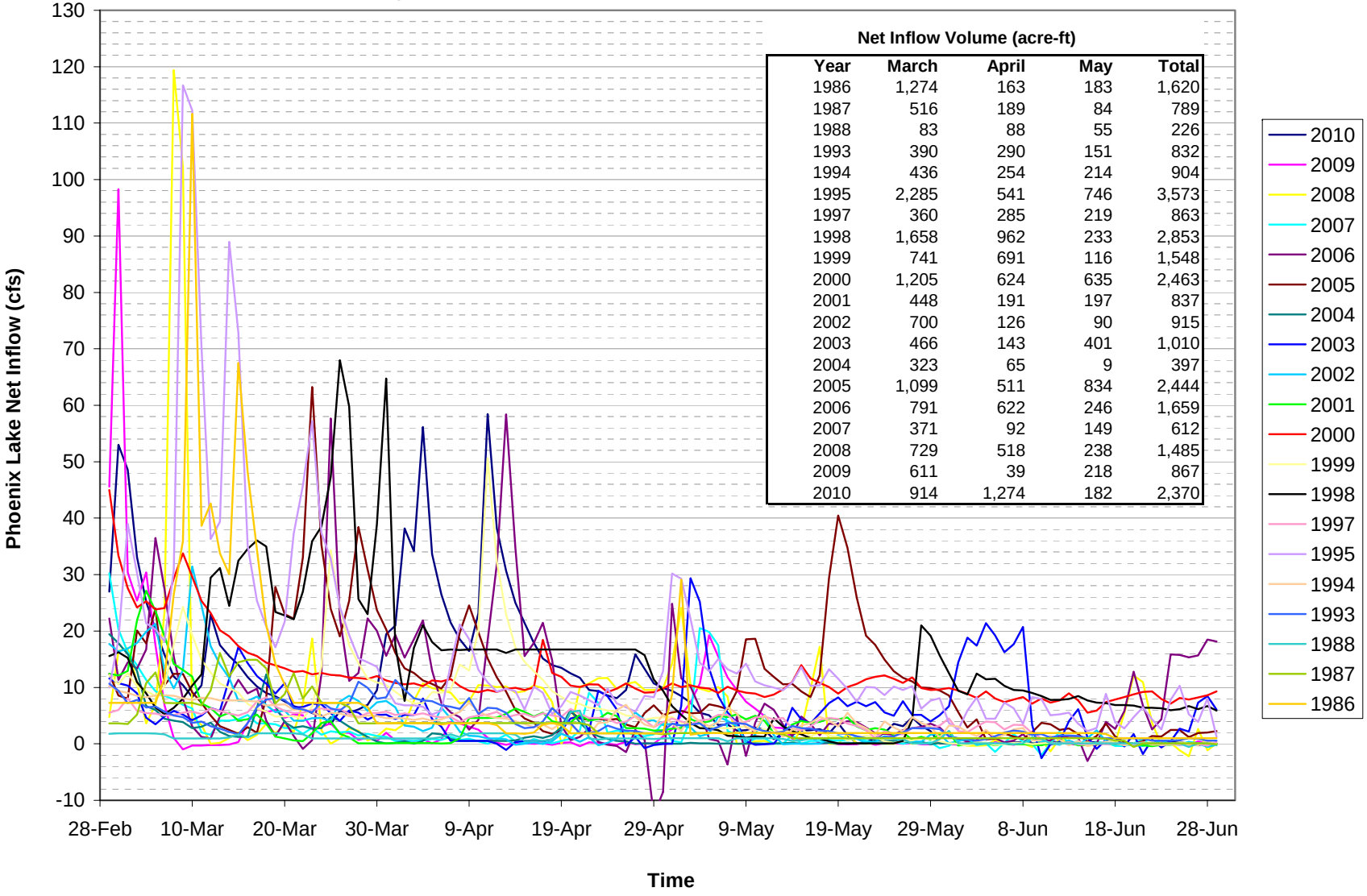


Figure 4e Spillway Overflow: March 1 - June 30
Spillway Overflow (cfs)
50
40
30
20
10
0
1-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr
10-May
20-May
30-May
9-Jun
19-Jun
29-Jun
Time
2010
2009
2008
2007
2006

Figure 5a Phoenix Lake Net Infow: March 1 - June 30



Net Inflow Volume (acre-ft)

Year	March	April	May	Total
1986	1,274	163	183	1,620
1987	516	189	84	789
1988	83	88	55	226
1993	390	290	151	832
1994	436	254	214	904
1995	2,285	541	746	3,573
1997	360	285	219	863
1998	1,658	962	233	2,853
1999	741	691	116	1,548
2000	1,205	624	635	2,463
2001	448	191	197	837
2002	700	126	90	915
2003	466	143	401	1,010
2004	323	65	9	397
2005	1,099	511	834	2,444
2006	791	622	246	1,659
2007	371	92	149	612
2008	729	518	238	1,485
2009	611	39	218	867
2010	914	1,274	182	2,370

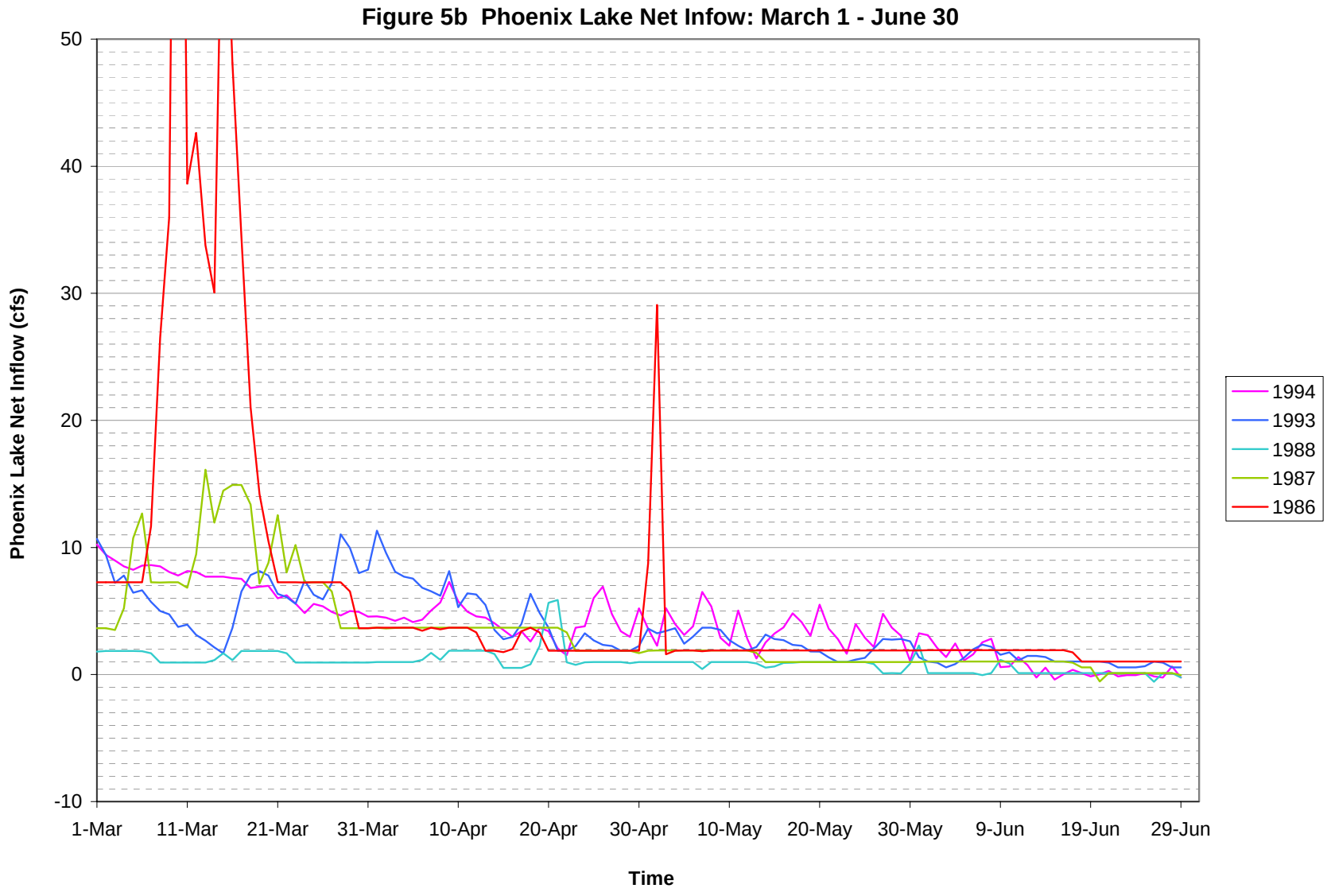


Figure 5b Phoenix Lake Net Infow: March 1 - June 30
Phoenix Lake Net Inflow (cfs)
50
40
30
20
10
0
-10
1-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr
10-May
20-May
30-May
9-Jun
19-Jun
29-Jun
Time
1994
1993
1988
1987
1986

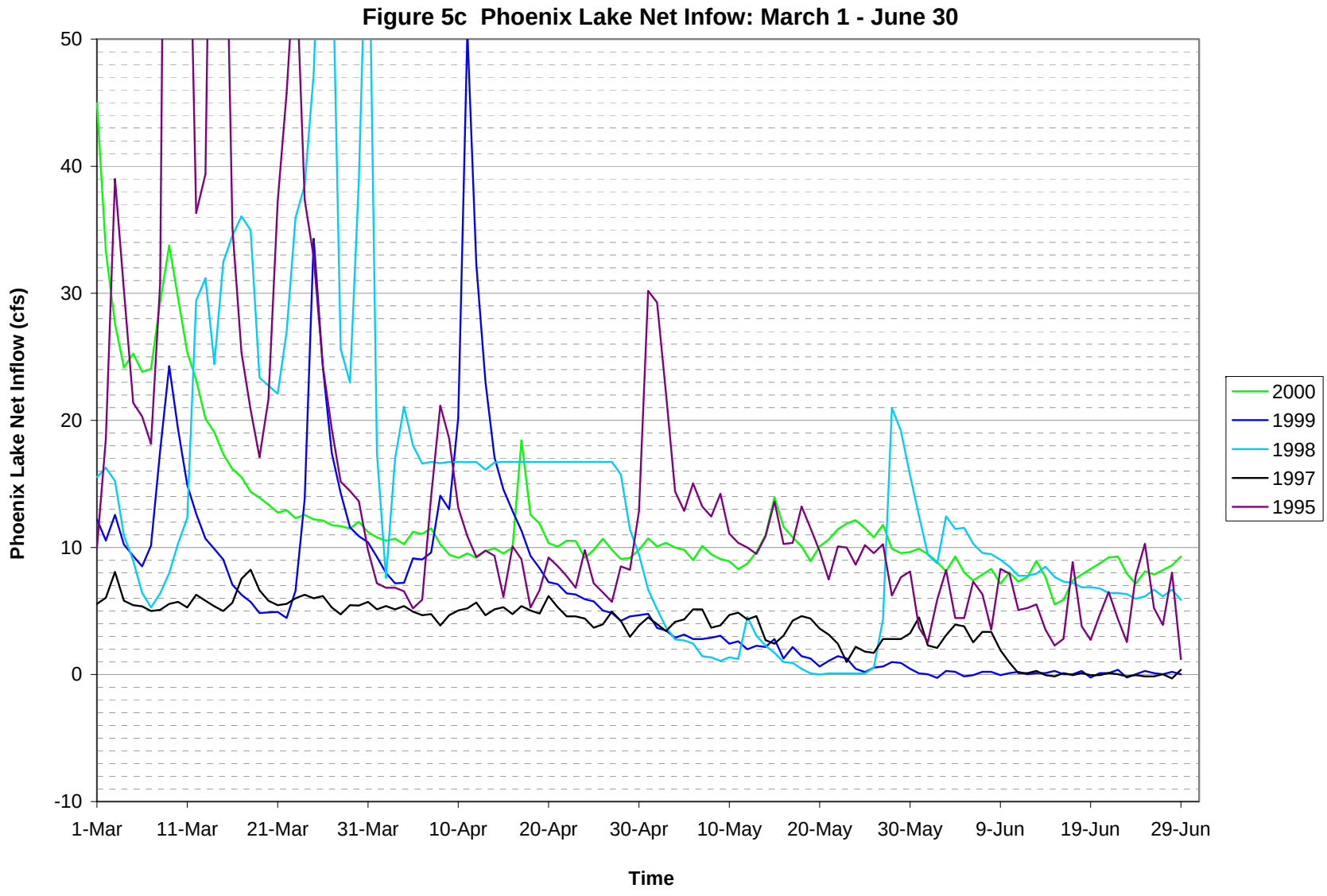


Figure 5c Phoenix Lake Net Infow: March 1 - June 30
Phoenix Lake Net Inflow (cfs)
50
40
30
20
10
0
-10
1-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr
10-May
20-May
30-May
9-Jun
19-Jun
29-Jun
Time
2000
1999
1998
1997
1995

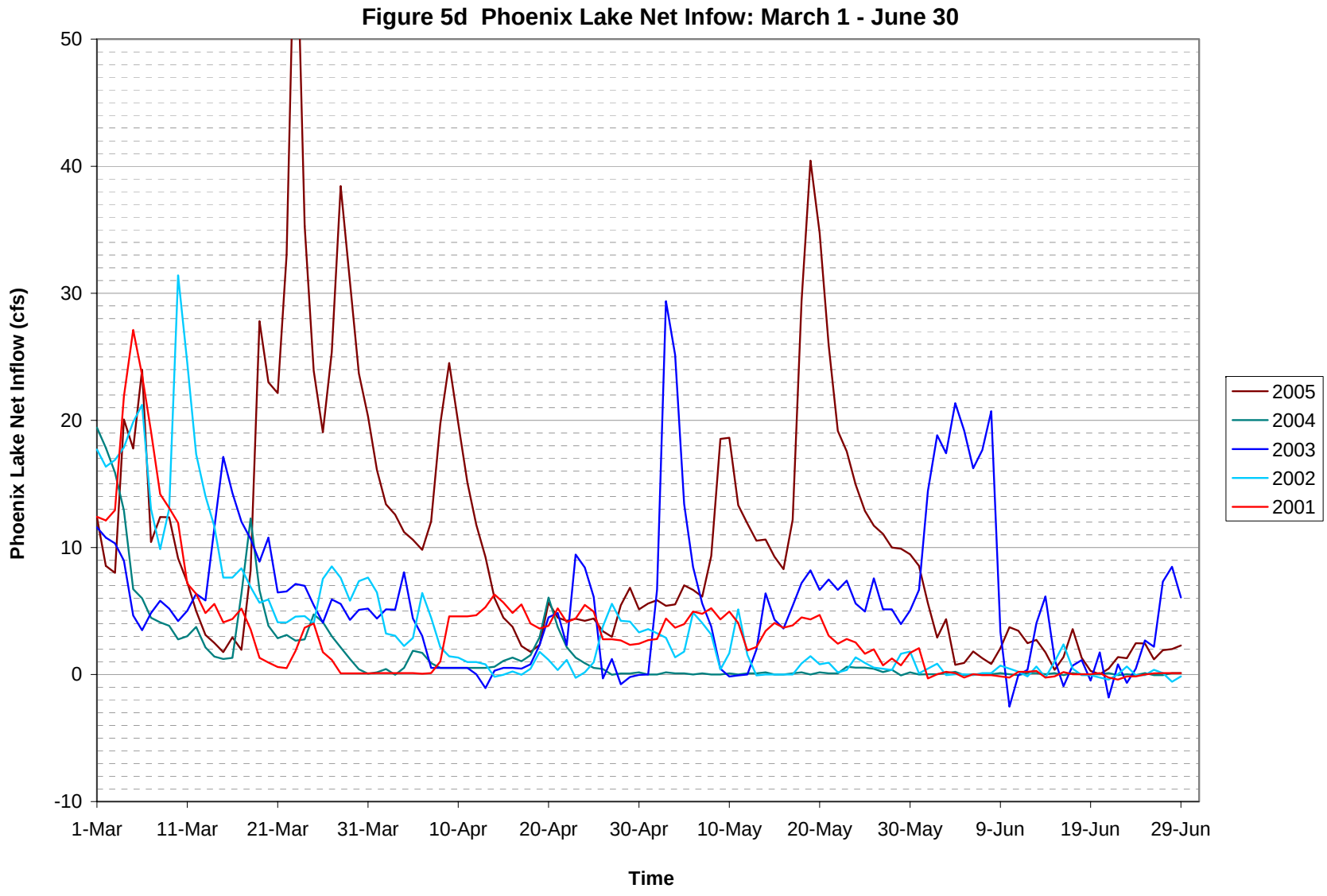


Figure 5d Phoenix Lake Net Infow: March 1 - June 30
Phoenix Lake Net Inflow (cfs)
50
40
30
20
10
0
-10
1-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr
10-May
20-May
30-May
9-Jun
19-Jun
29-Jun
Time
2005
2004
2003
2002
2001

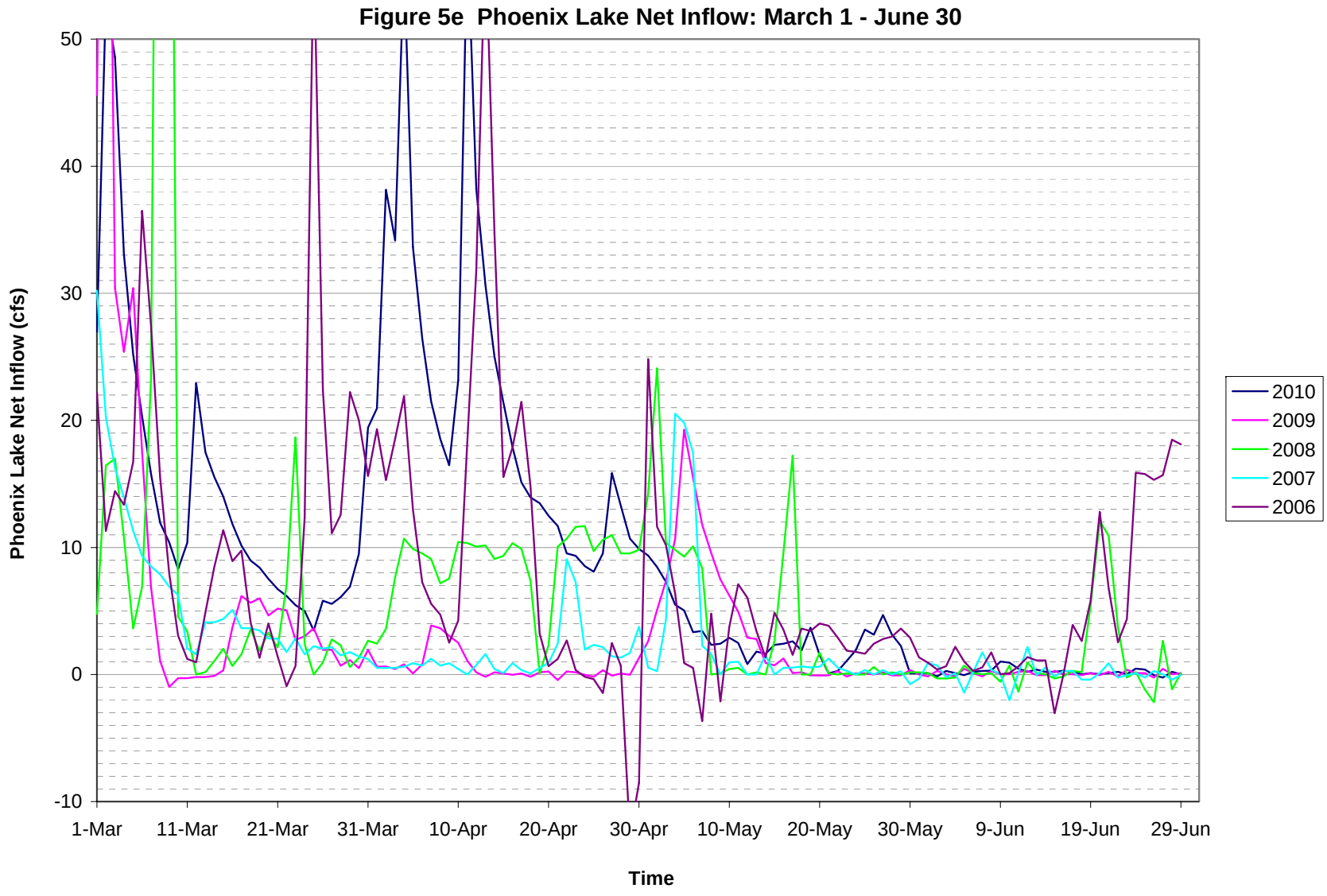
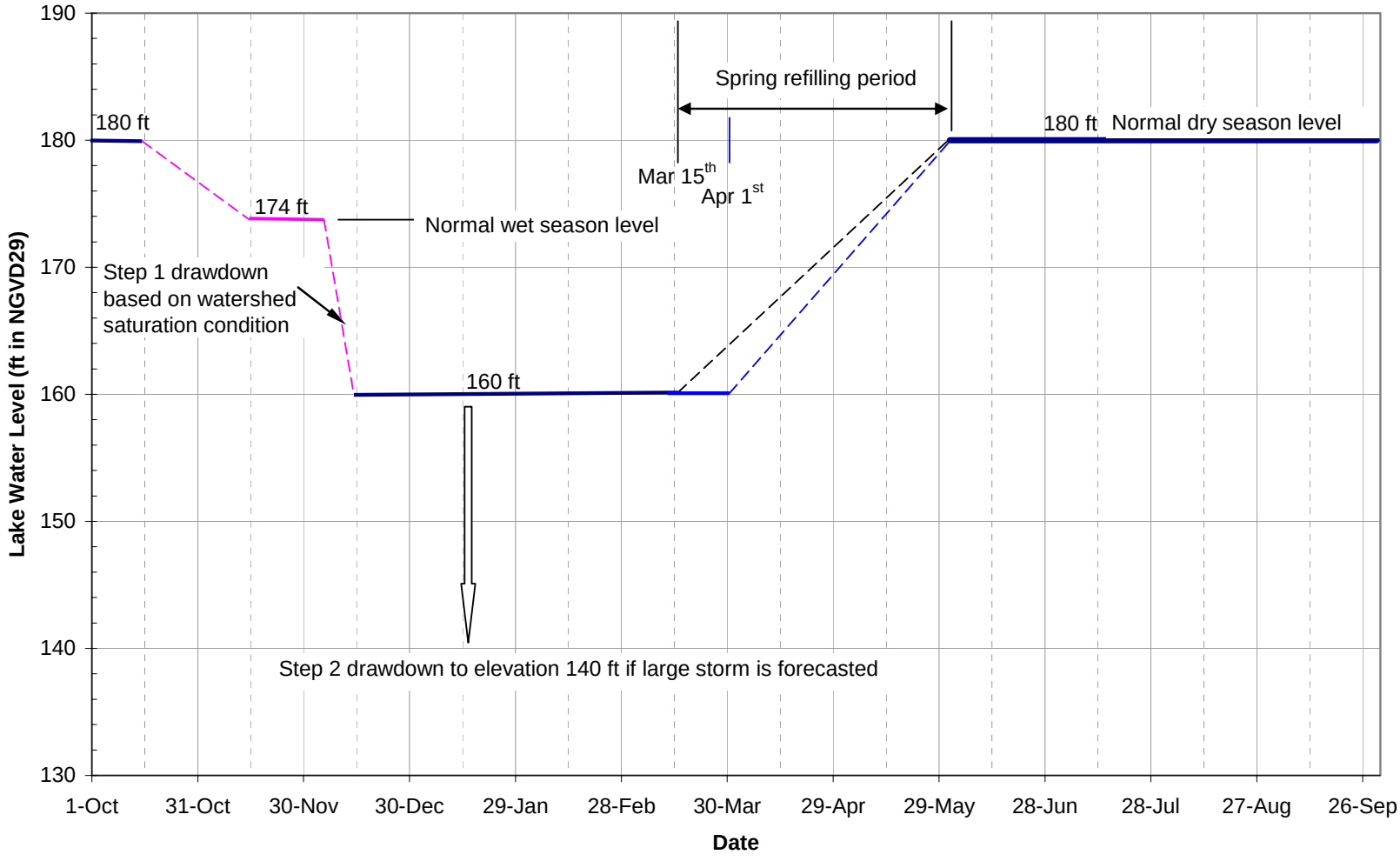


Figure 5e Phoenix Lake Net Inflow: March 1 - June 30
Phoenix Lake Net Inflow (cfs)
50
40
30
20
10
0
-10
1-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr
10-May
20-May
30-May
9-Jun
19-Jun
29-Jun
Time
2010
2009
2008
2007
2006

Figure 6 Rule Curve Used in Reservoir Re-Operations Analysis



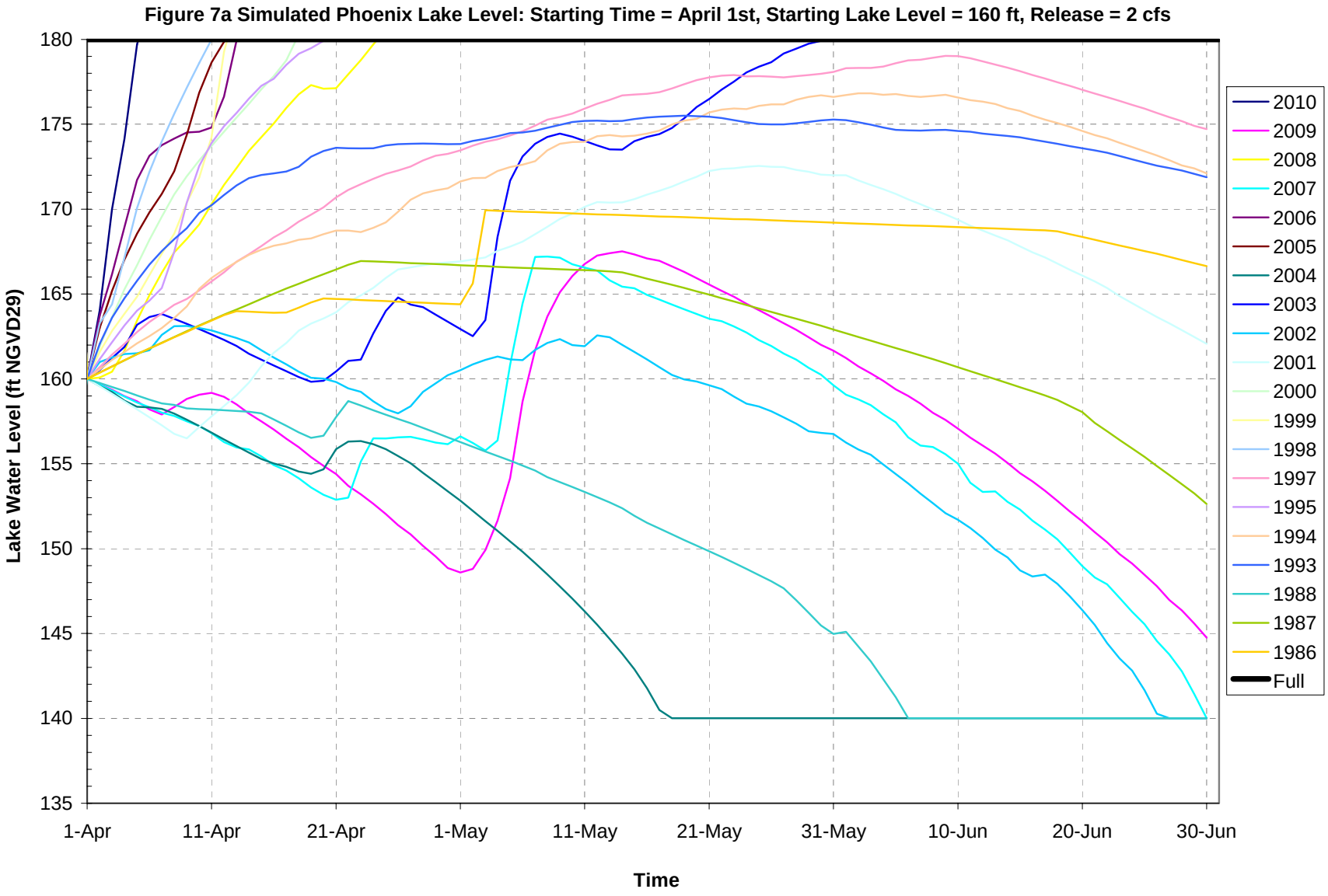


Figure 7a Simulated Phoenix Lake Level: Starting Time = April 1st, Starting Lake Level = 160 ft, Release = 2 cfs
Lake Water Level (ft NGVD29)
180
175
170
165
160
155
150
145
140
135
1-Apr
11-Apr
21-Apr
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
Time
2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
1995
1994
1993
1988
1987
1986
Full

Figure 7b Simulated Phoenix Lake Level: Starting Time = April 1st, Starting Lake Level = 160 ft, Release = 1 cfs

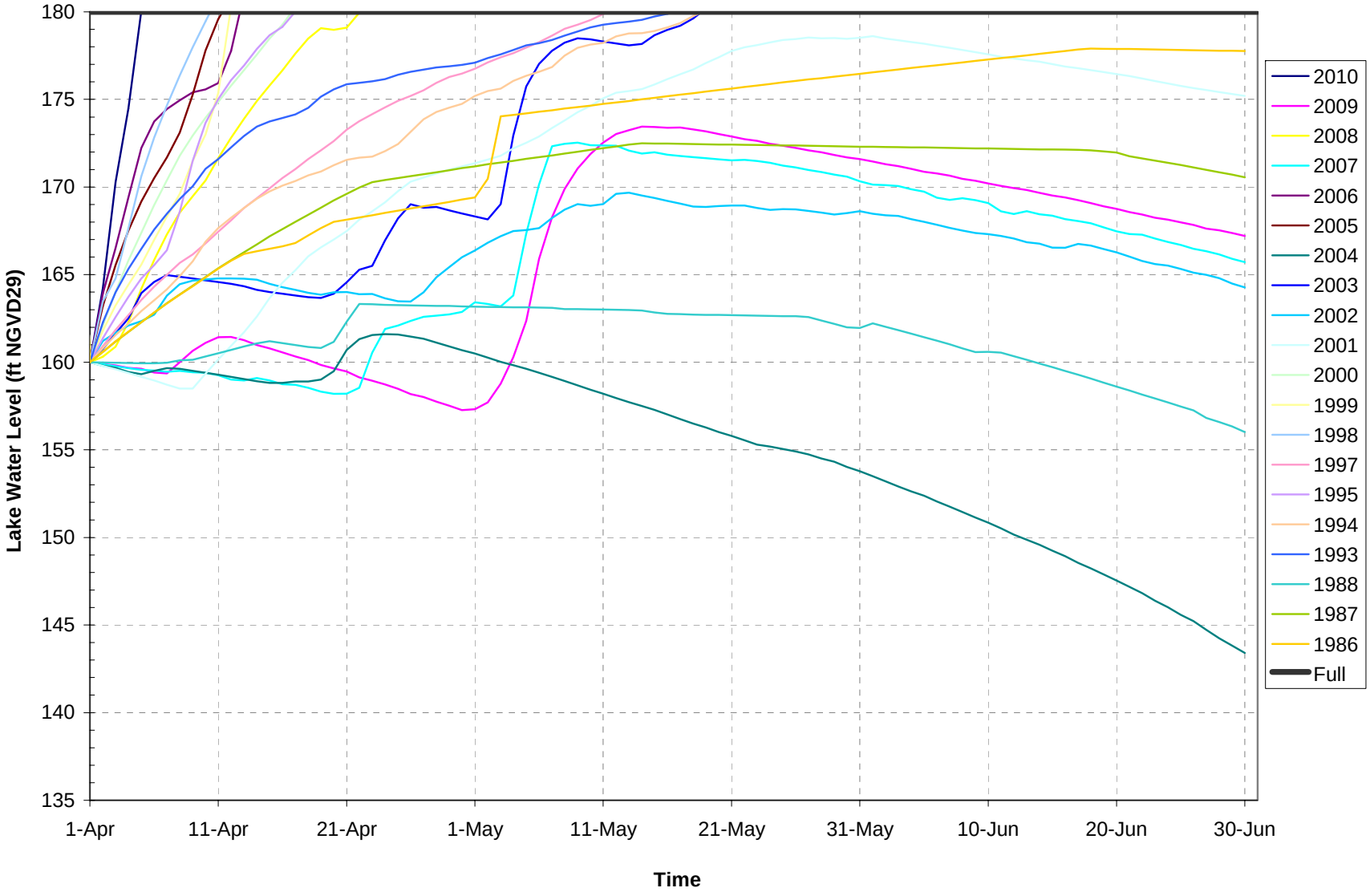


Figure 7c Simulated Phoenix Lake Level: Starting Time = Apr 1st, Starting Lake Level = 160 ft, Release = 2 cfs or Inflow

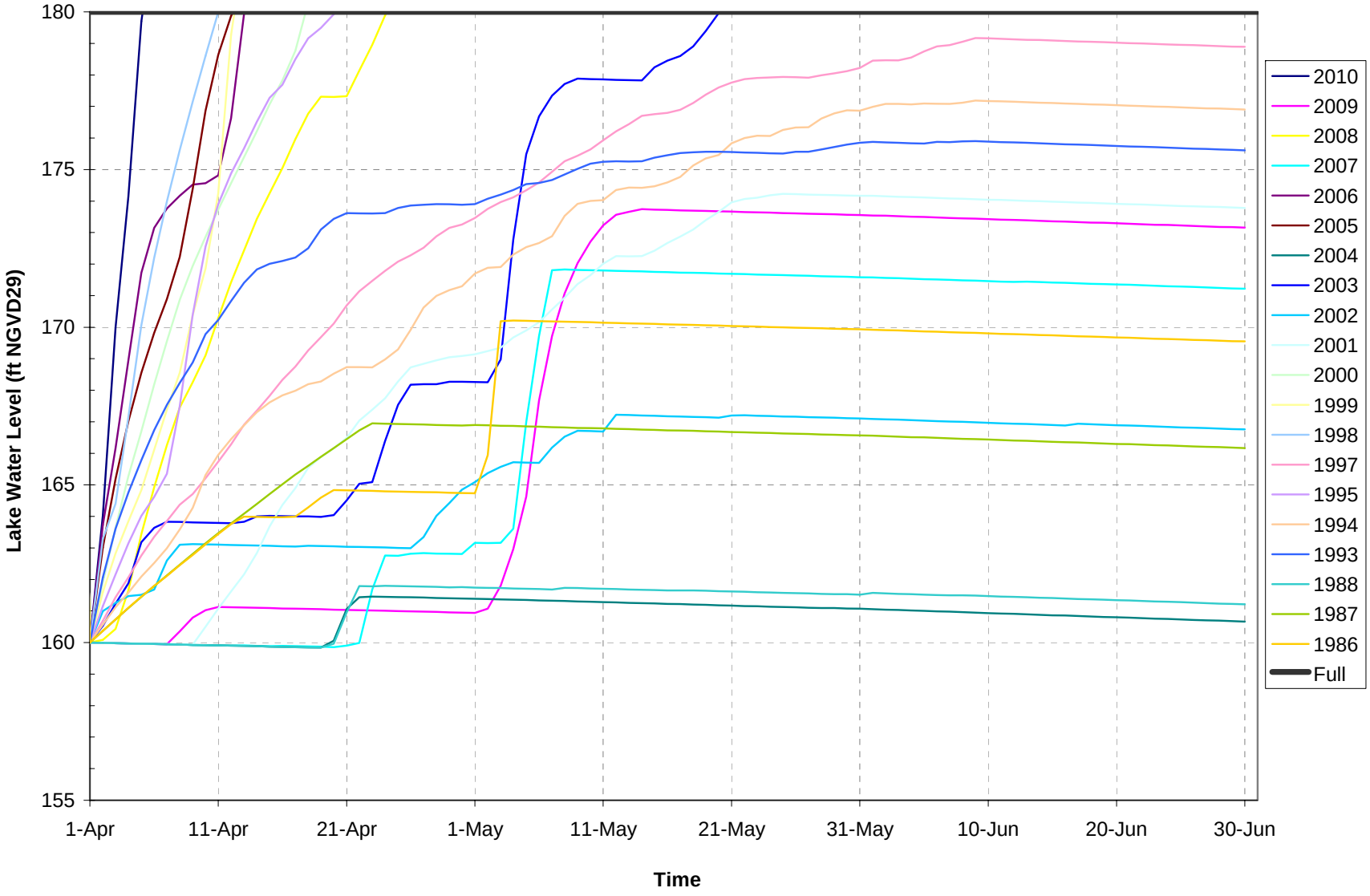


Figure 7d Simulated Phoenix Lake Level: Starting Time = Apr 1st, Starting Lake Level = 160 ft, Release = 1 cfs or Inflow

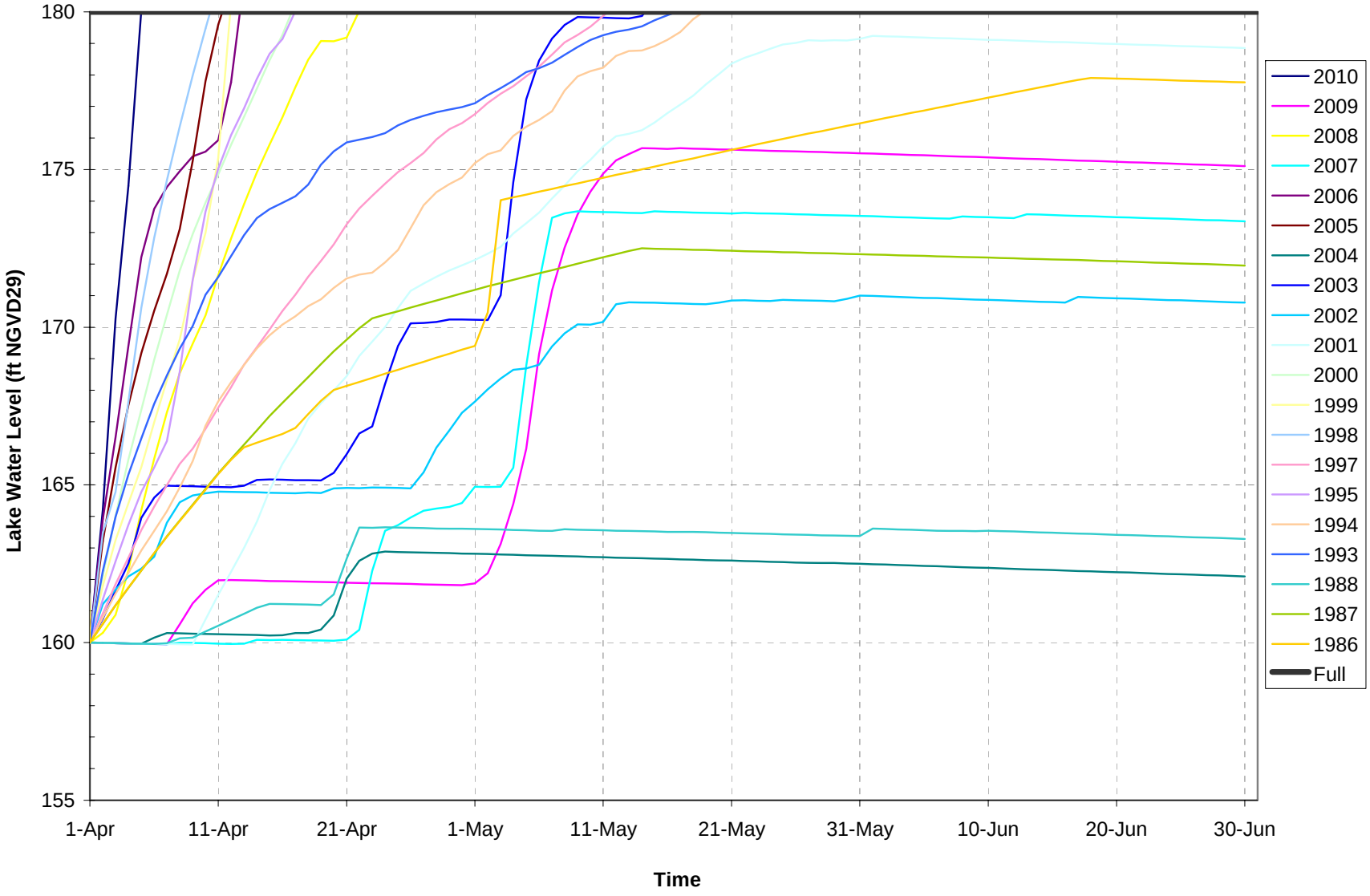


Figure 8a Simulated Phoenix Lake Level: Starting Time = Mar 15th, Starting Lake Level = 160 ft, Release = 2 cfs

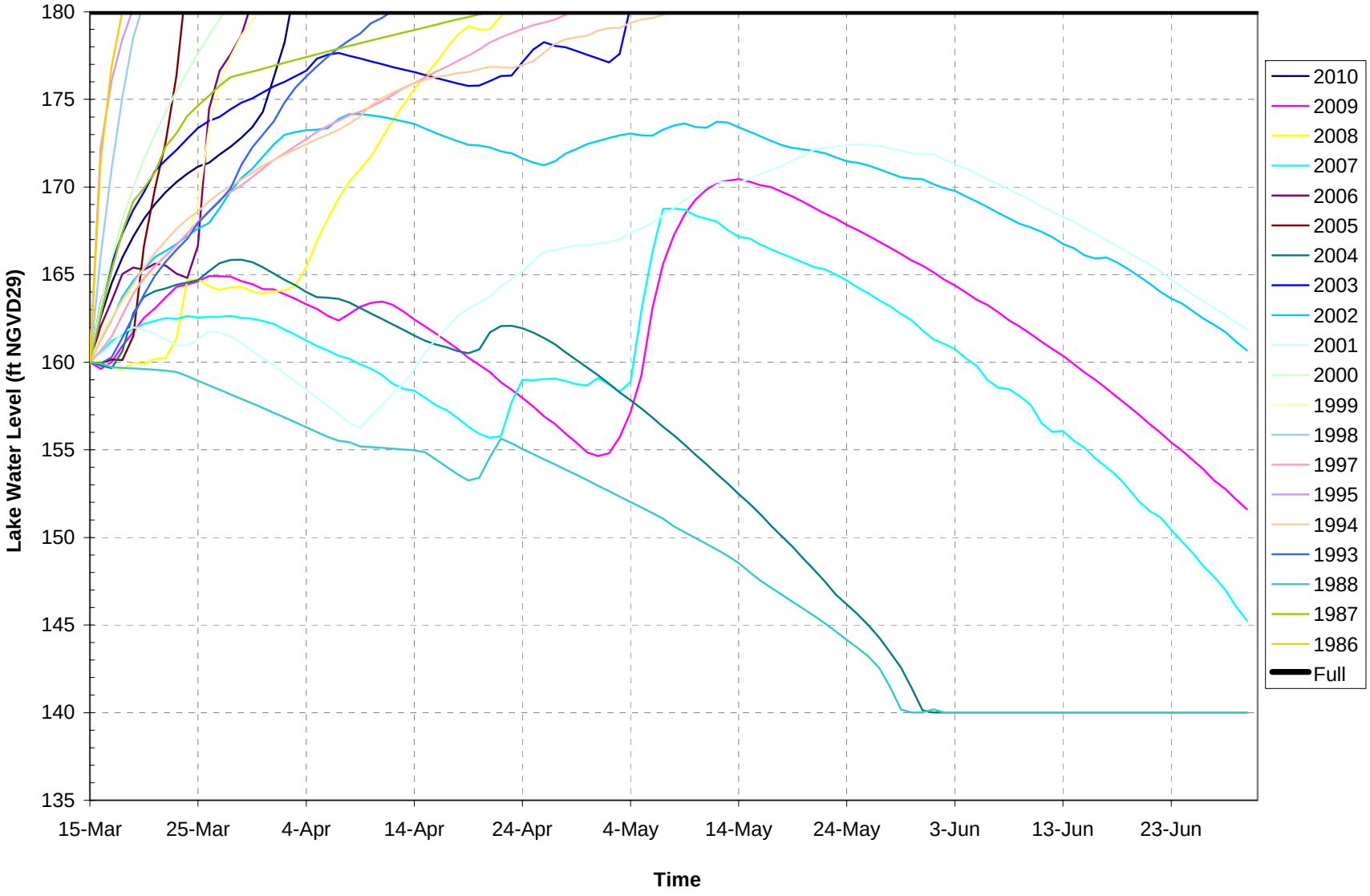


Figure 8b Simulated Phoenix Lake Level: Starting Time = Mar 15th, Starting Lake Level = 160 ft, Release = 1 cfs

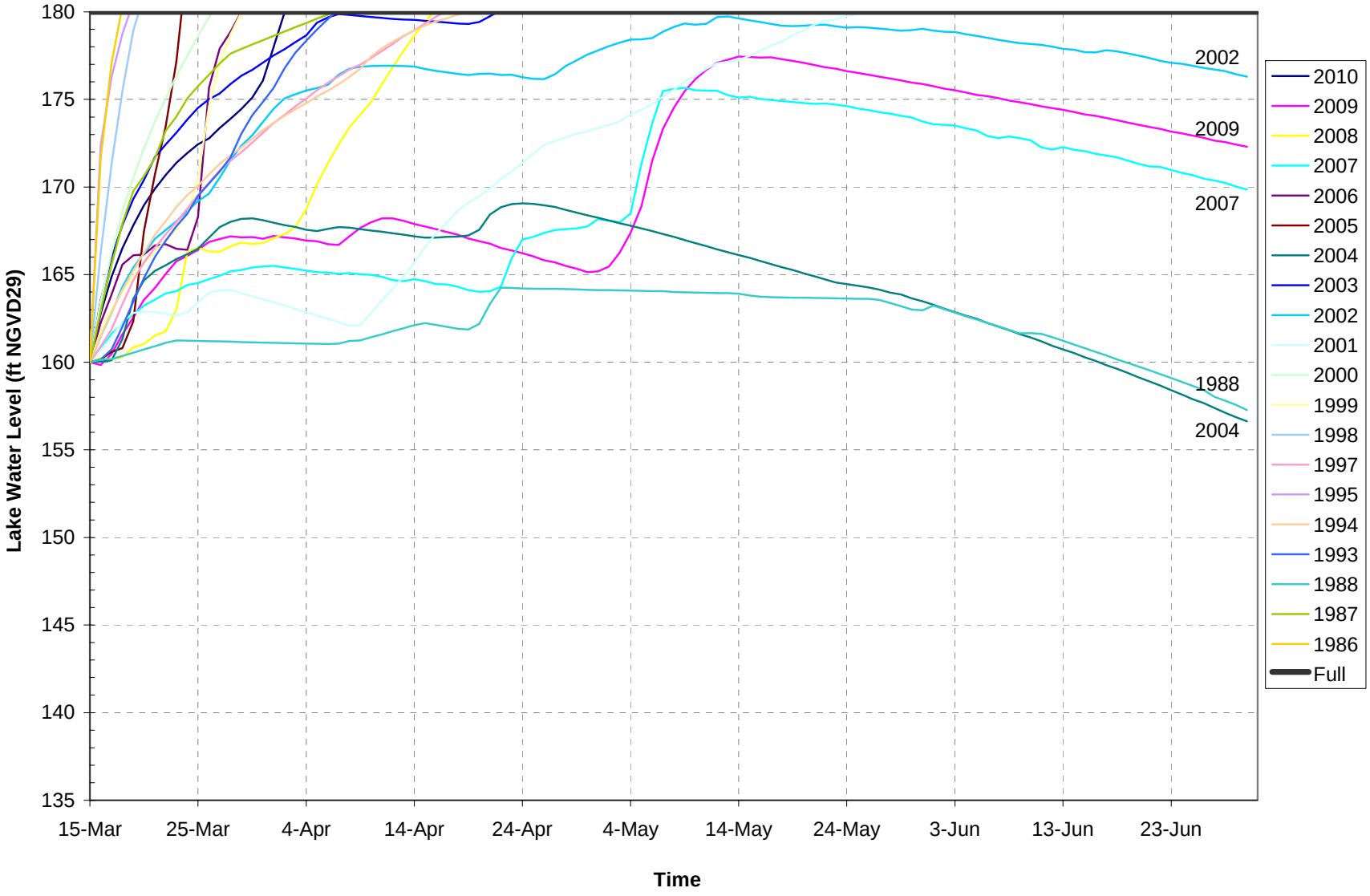


Figure 8c Simulated Phoenix Lake Level: Starting Time = Mar 15th, Starting Lake Level = 160 ft, Release = 2 cfs or Inflow

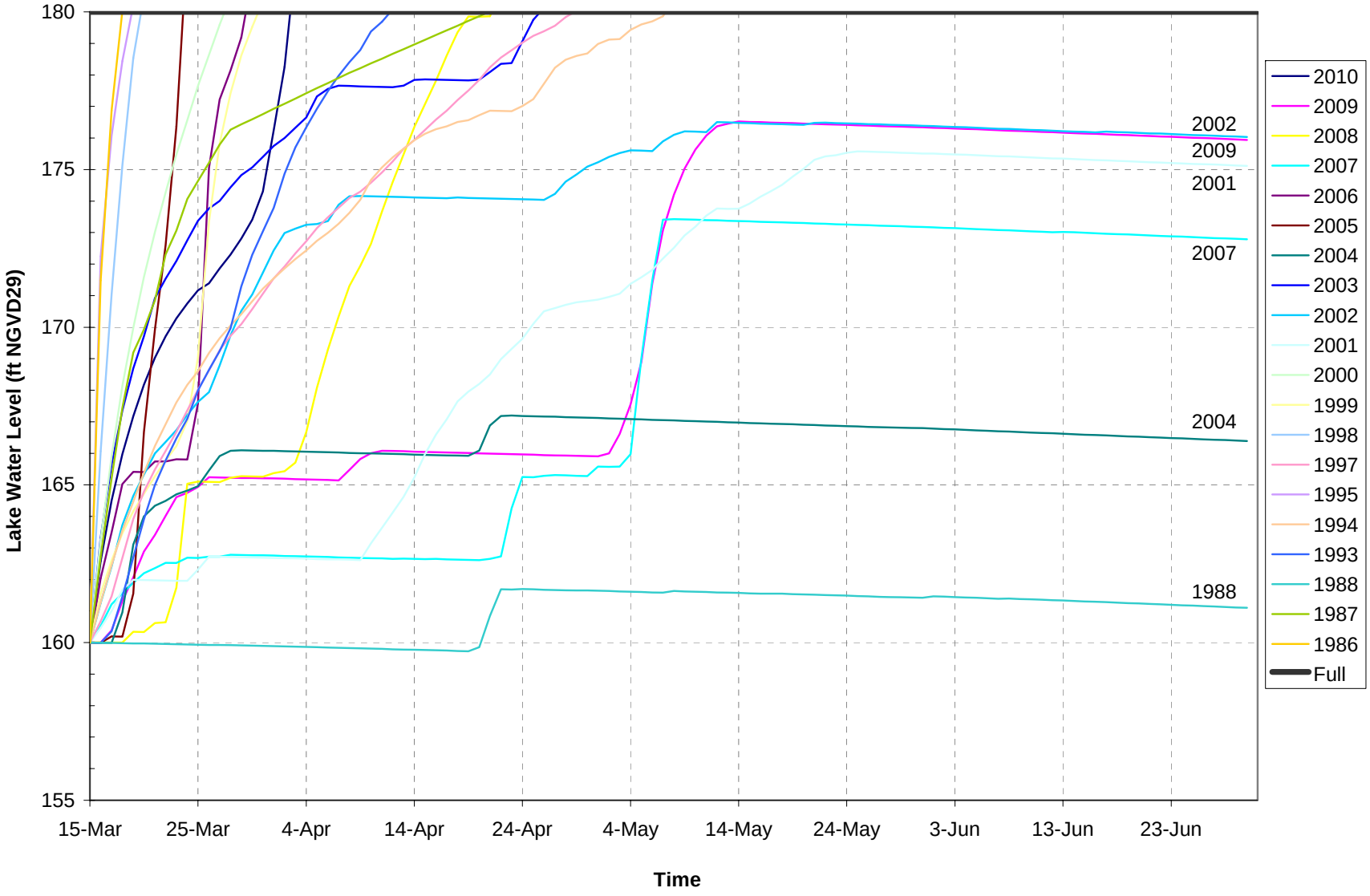


Figure 8d Simulated Phoenix Lake Level: Starting Time = Mar 15th, Starting Lake Level = 160 ft, Release = 1 cfs or Inflow

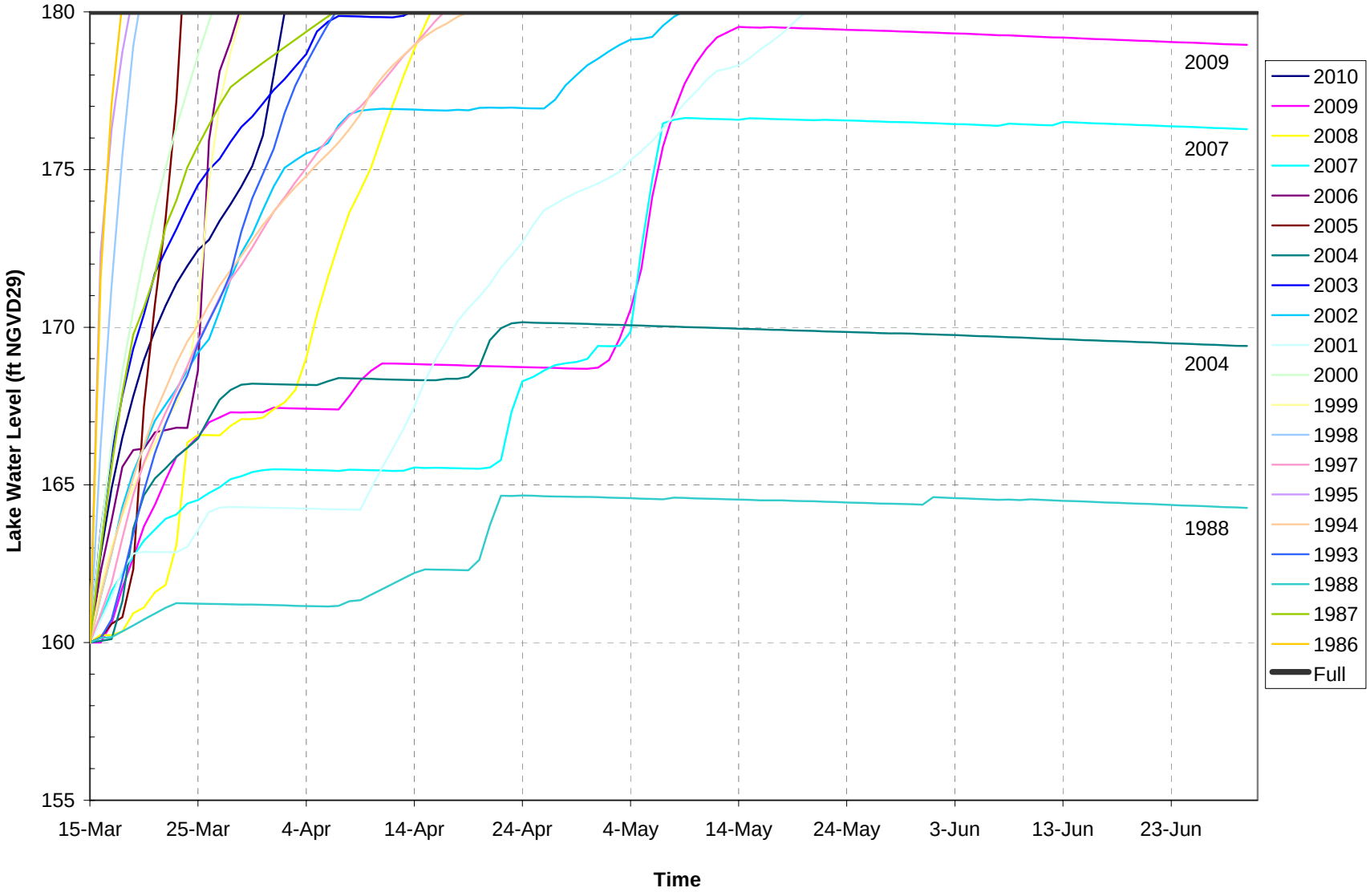


Figure 9 Mean Daily Flows at Ross Gage, 1988

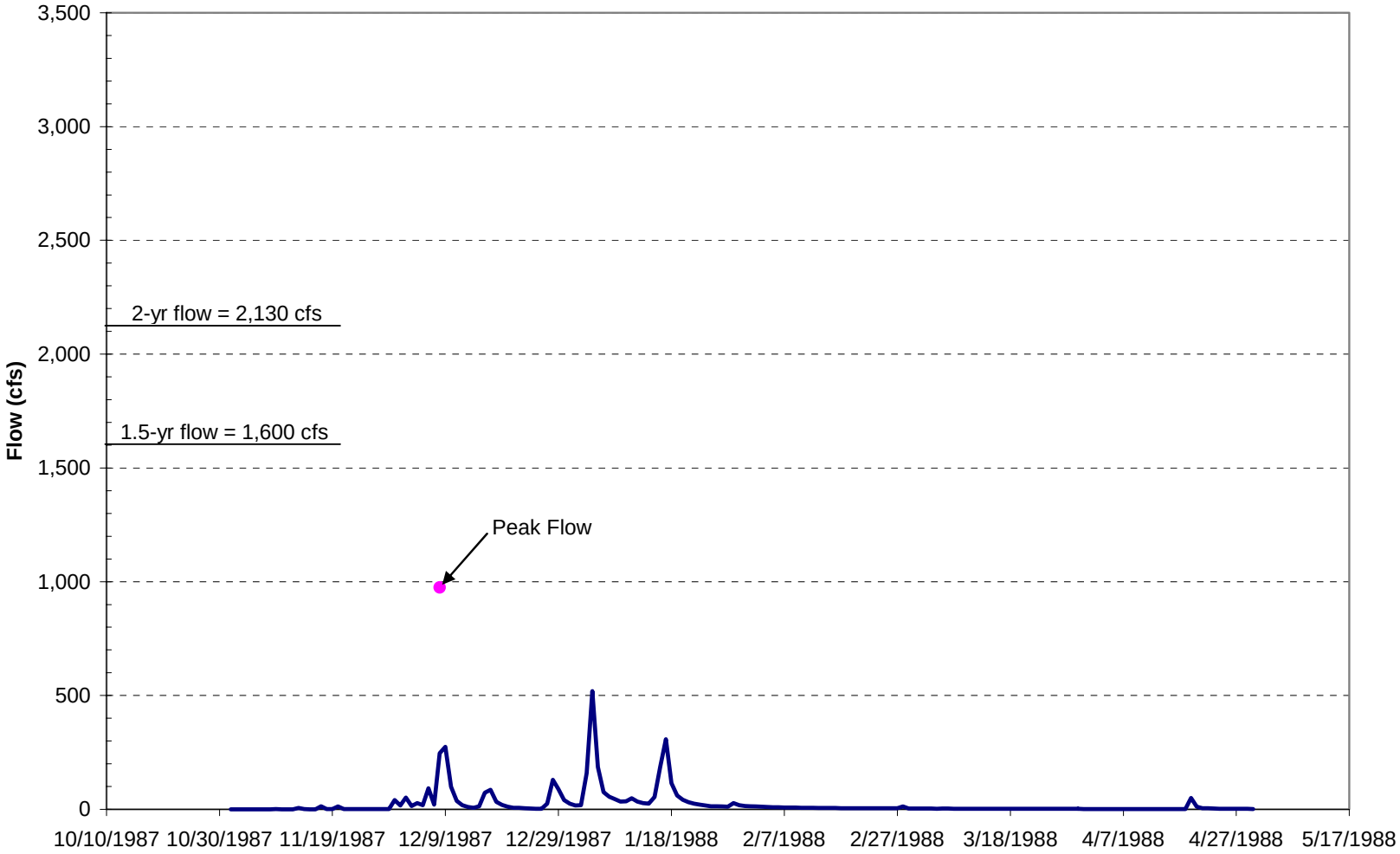


Figure 10 Real-Time Flows at Ross Gage, 2004

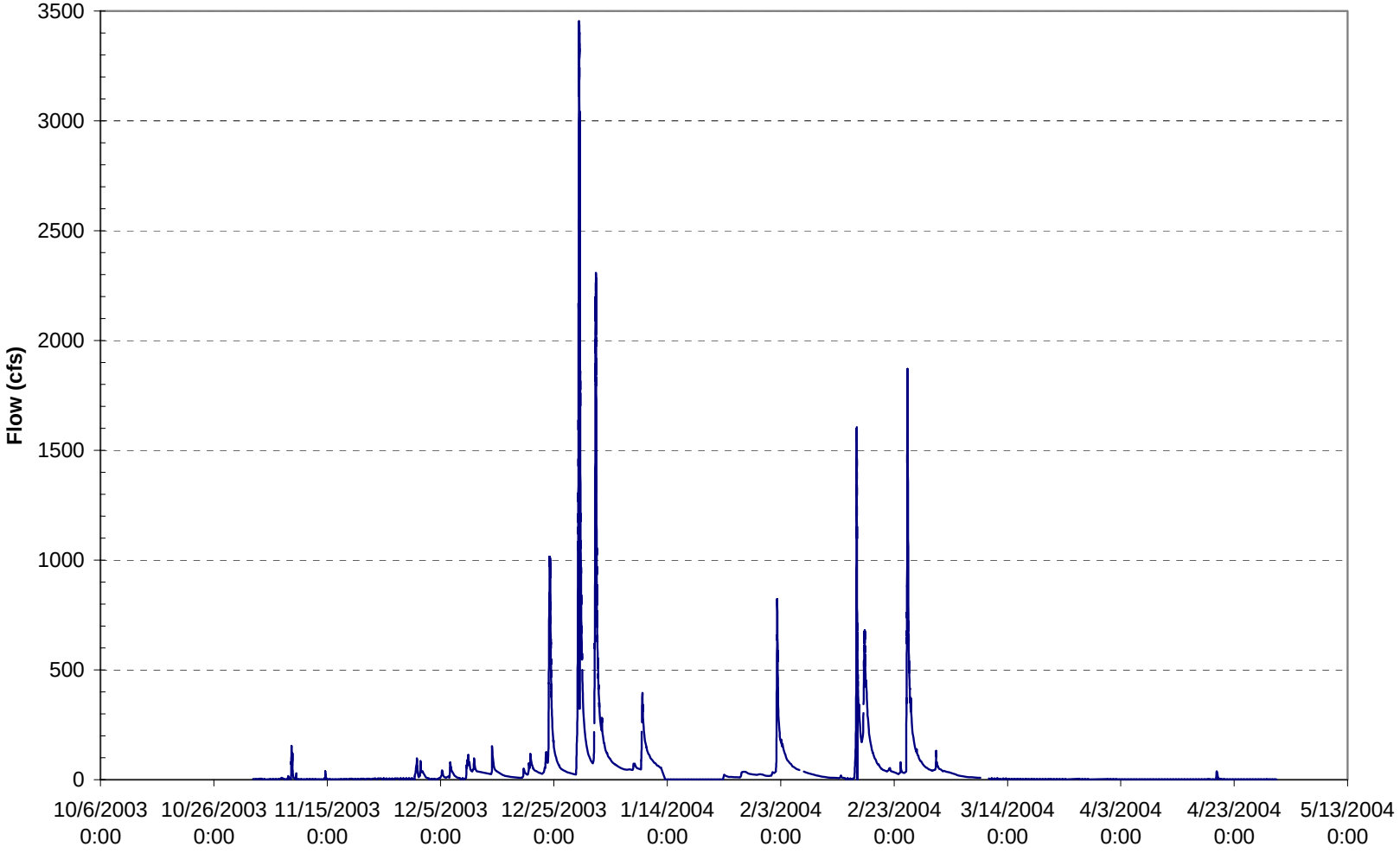


Figure 11 Real-Time Flows at Ross Gage, 2007

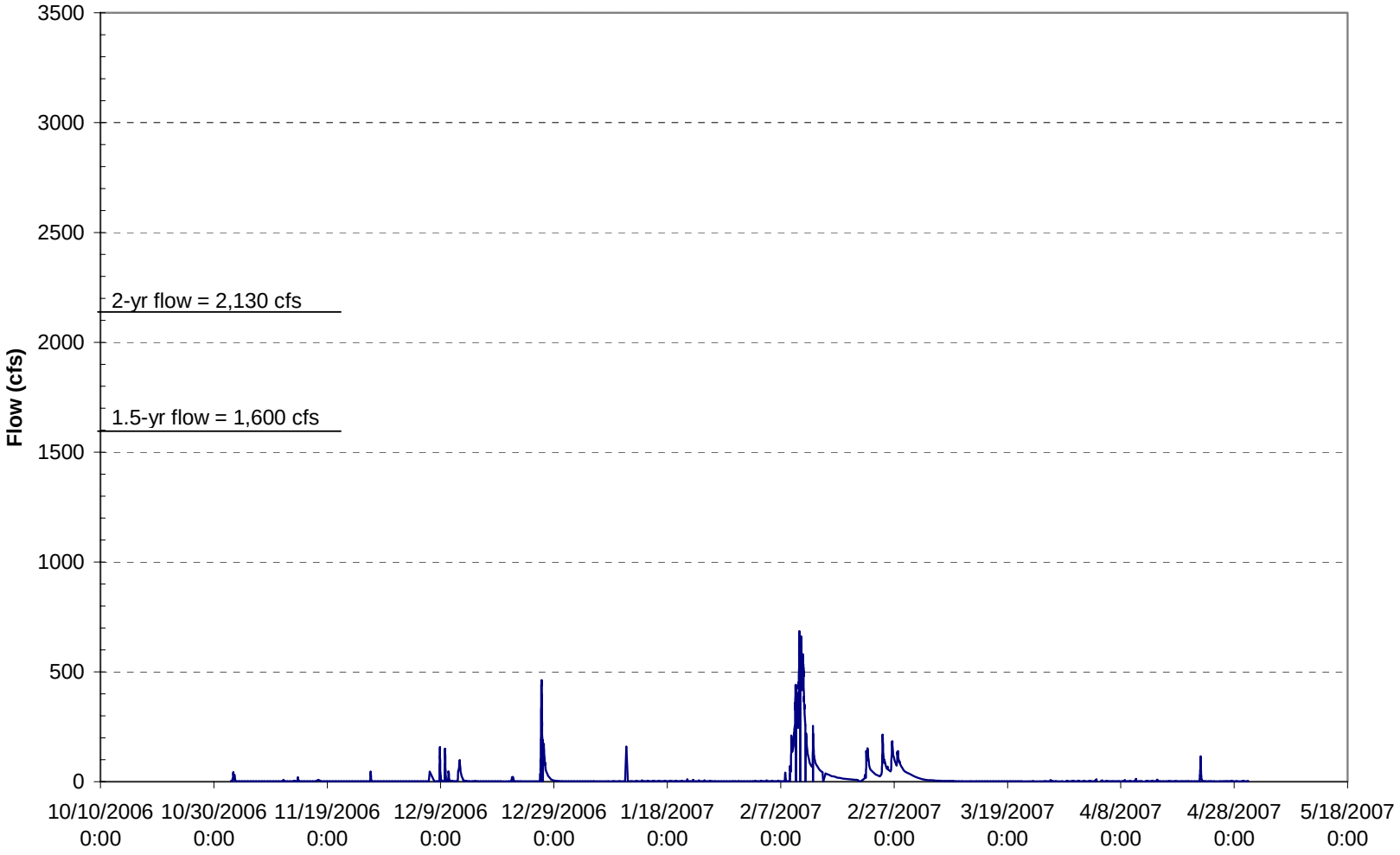


Figure 12 Historical Annual Rainfall at Lake Lagunitas

Rainfall at Lake Lagunitas is unpredictable, with annual figures ranging from 18-112 inches. The rainfall year runs from July 1 to June 30. MMWD customers have endured 3 droughts this century: 1929-34, 1976-77, 1987-92.

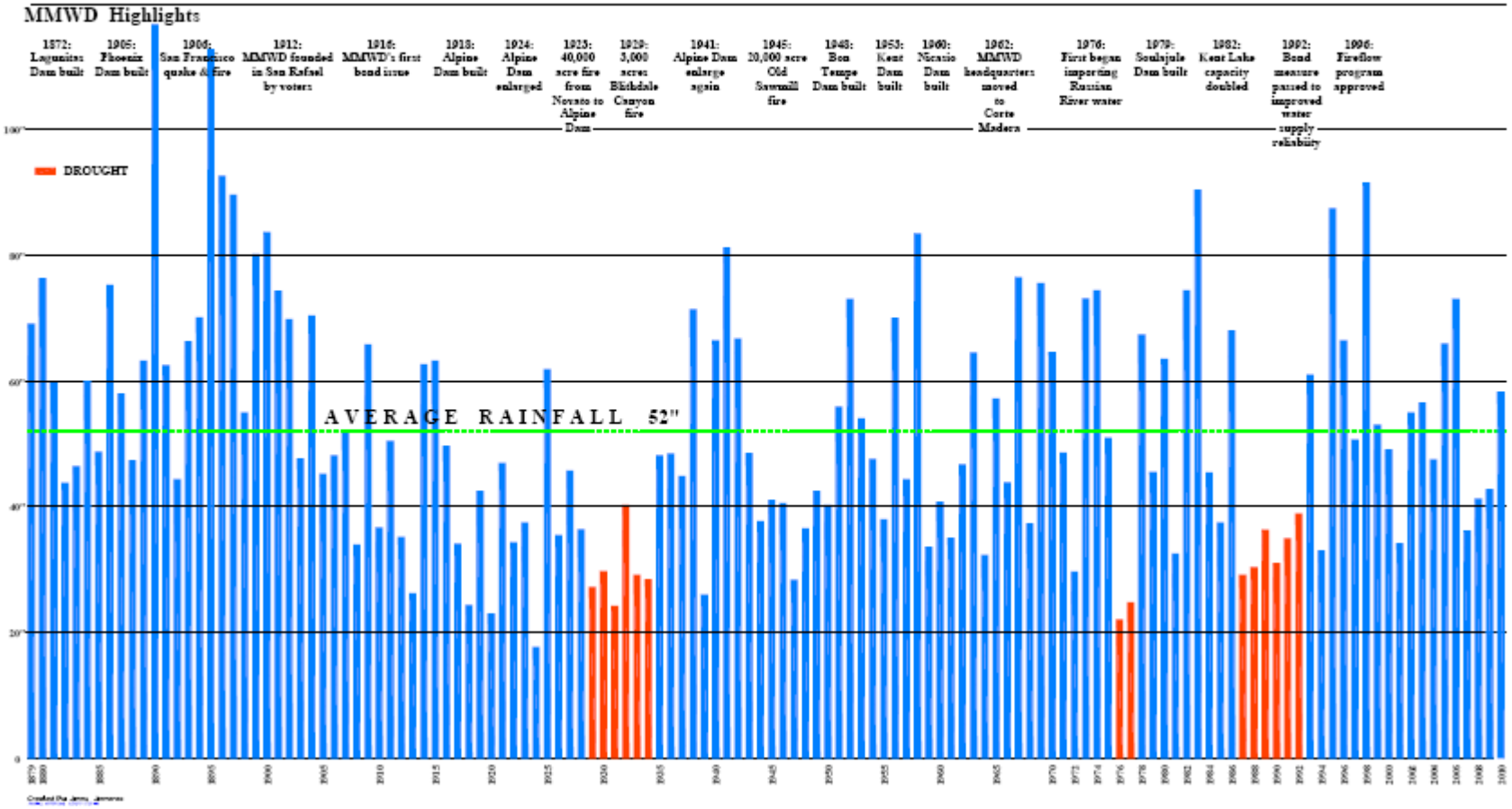
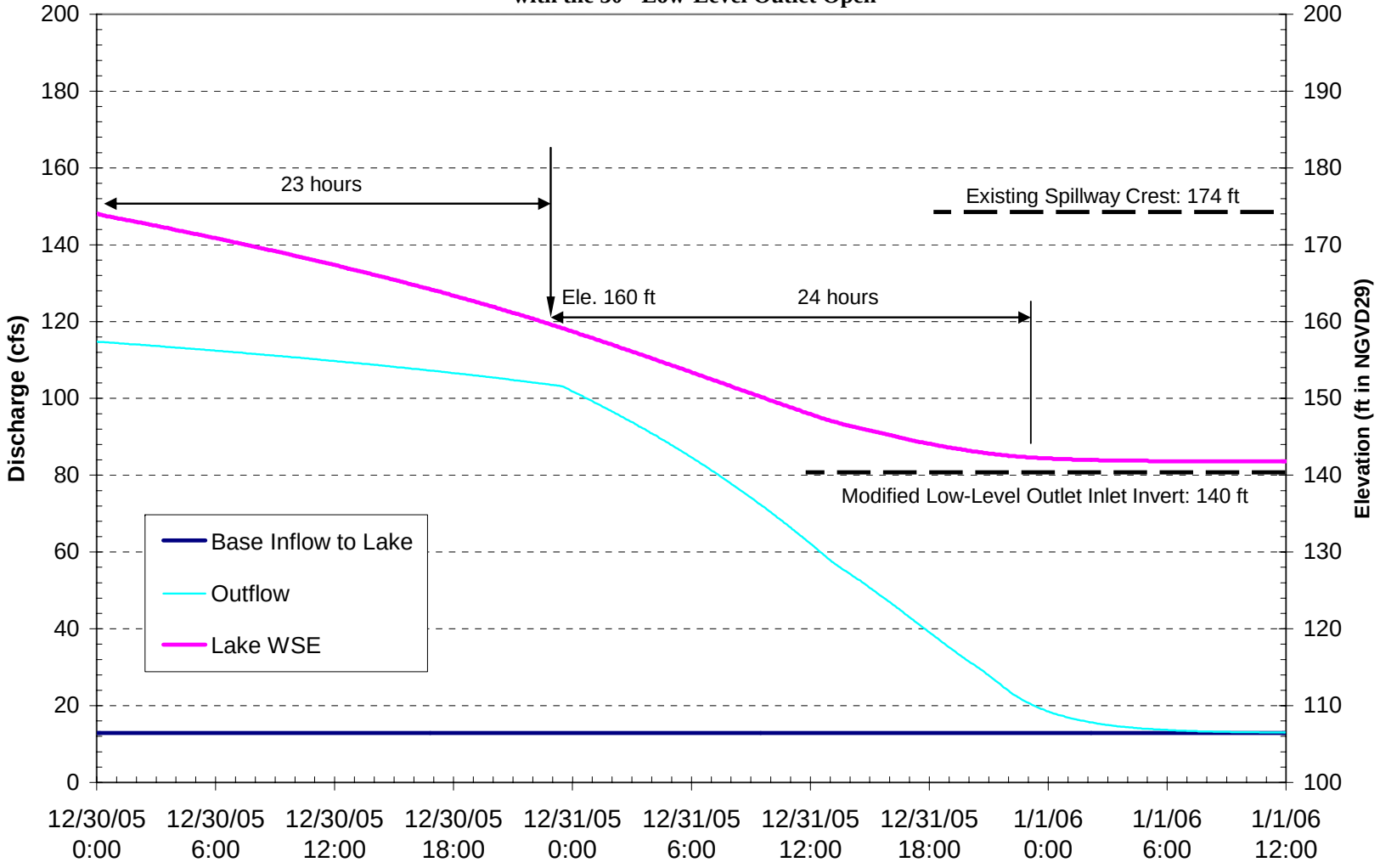


Figure 13 Analysis Results of Routing Baseflows That Occurred on December 31, 2005 through the Dam with the 30" Low-Level Outlet Open



Appendix 6 to Attachment 3

Water Temperature/Water Quality Issues in Phoenix Lake and Ross Creek Below the Dam and Recommended Solutions for Improving Water Quality and Cold Freshwater Habitat

Stetson Engineers Inc.
February 24, 2011

INTRODUCTION

Phoenix Lake is located on Ross Creek, a major tributary of Corte Madera Creek. The lake is owned, operated, and maintained by Marin Municipal Water District (MMWD) primarily for the purpose of drinking water supply for use during shortages, but also for wildlife habitat and public recreation and enjoyment. The lake is formed by an earthen embankment dam across Ross Creek that was built in 1906, enlarged in 1909, and strengthened in 1969. The watershed above Phoenix Lake encompasses about 1,400 acres. When full (i.e., elevation 174 ft NGVD29), the lake covers about 17 acres and holds approximately 300 acre-feet of water based on the 2009 bathymetric survey.

The dam is penetrated by a gated, 30-inch diameter, low-level, outlet pipe that has an intake invert elevation at 130 ft and a discharge capacity of 115 cubic feet per second (51,600 gallons per minute) when the lake is full. This low-level outlet is normally kept closed and has been used infrequently since it was built. The spillway is situated on the right side of the dam (looking upstream). In 1985 the spillway was modified by lowering the crest by six feet, from elevation 180 feet down to elevation 174 feet.

Under current operations, since the low-level outlet is normally kept closed, overflows above the spillway crest will be the primary outflows from the lake to downstream (and these outflows are from the warm top layer of the lake). If the lake water level is below the spillway crest, the small leakages through the dam (which are from the cold bottom layer of the lake) will be the only outflows that keep the downstream wet.

In order to assess the influence of Phoenix Lake on cold freshwater habitat and water temperatures in Ross Creek below the dam (which generally need summertime water temperature in the range of 12°C to 17°C to support steelhead rearing habitat), the Friends of Corte Madera Creek Watershed, in cooperation with the Marin Municipal Water District and four local property owners, conducted a monitoring program at Phoenix Lake and Ross Creek in 2008 and 2009. Water temperatures in Ross Creek were monitored at four different locations with continuously recording temperature loggers. Dissolved oxygen (DO) concentrations were monitored once a month using Hydrolab in the lake near the intake at different depths and at two locations of Ross Creek below the dam. The monitoring locations are shown in Figure 1.

OBSERVED DATA

1) Observed Water Temperature and DO Profiles in Phoenix Lake near the Intake

The observed water temperature and DO profiles in Phoenix Lake in 2008 are shown in Figure 2, and in 2009 the observed results are shown in Figures 3. There was strong thermal stratification in Phoenix Lake. The epilimnion extended about 15 to 20 ft in depth with water temperature at 20°C – 25°C. The hypolimnetic water temperature was measured at 10-12°C.

The DO profiles in Phoenix Lake show very low dissolved oxygen concentration in the hypolimnion, even in April (Figure 3). This low DO in the lake hypolimnion would not support cold freshwater habitat. Low DO also has a negative effect on other water quality parameters. The anaerobic chemicals (i.e., hydrogen sulfide, iron, manganese, and others) could release from the bottom of the lake.

2) Observed Water Temperature and DO in Ross Creek below the Dam

Figure 4 shows the observed water temperature and DO just below the dam. It also shows the measured lake water levels. As shown in Figure 4, the temperature abruptly decreased from about 20°C to less than 15°C in early May. After this time, the lake water level was generally below the spillway crest, the majority of the flow was the dam leakage (which is cold), not from the spillway overflow (which is warm). This suggests that releasing water using the low-level outlet, instead of the spillway, would maintain the released water cold enough to support steelhead rearing habitat (which generally need summertime water temperature in the range of 12°C to 17°C).

Figure 4 also shows that when the majority of the flow was from the dam leakage, the DO concentration just below the dam was also relatively low (below 5 mg/L, the required DO level for cold freshwater habitat). However, the relatively low DO will be quickly increased by re-aeration within a short distance. This phenomenon is shown in Figure 5.

3) Algae Blooms in the Epilimnion of Phoenix Lake

Although no monitoring data are available about algae blooms and dominant species, MMWD reported algae blooms in the lake and their impacts on the surface water treatment plant and drinking water quality. Visual observations during the monitoring program conducted by the Friends of Corte Madera Creek Watershed also indicated algae blooms in the lake.

Algae blooms reduce water clarity and the overall aesthetic appeal of the lake to fishermen and other recreationalists who visit the lake. Algae also affect the filtration process and increase MMWD's treatment costs at its Bon Tempe Treatment Plant. Algae, particularly blue-green algae, can create taste and odor problems in the treated drinking water.

WATER TEMPERATURE/WATER QUALITY ISSUES AND RECOMMENDED SOLUTIONS

Issue #1: Algae Blooms in the Epilimnion of Phoenix Lake

Recommended solution: Install a SolarBee device with the intake set at 5 ft for epilimnetic circulation without disrupting the stratification. This approach helps prevent blue-green algae (cyanobacteria) blooms and the associated toxins. Treating the epilimnion will also be effective in improving the hypolimnion as well, because inhibiting blooms through epilimnetic circulation results in less organic decomposition of dead and dying algae that have settled to the reservoir floor. This reduction in organic decomposition reduces oxygen demand and increases DO levels throughout the water column.

Issue #2: Low DO in the Hypolimnion of Phoenix Lake That Does Not Support Cold Freshwater Habitat

Recommended solution: Install another SolarBee device for hypolimnetic circulation and aeration without disrupting the stratification. This solution is designed to increase the DO concentration in the lake hypolimnion to above 5.0 mg/L, the required level for cold freshwater habitat. This solution can also help inhibit releases of the anaerobic chemicals from the bottom of the lake.

Issue #3: High Water Temperature Overflow Over the Spillway Does Not Support Steelhead Rearing Habitat in the Ross Creek below Phoenix Lake Dam

Recommended solution: Modify the low-level outlet and release cold water through the low-level outlet. Note that the recommended solution for Issue #2 is designed to increase the DO concentration in the lake hypolimnion to above 5.0 mg/L. Increasing the DO concentration in the lake hypolimnion would, of course, increase DO in the released water from the low-level outlet, which is from the lake hypolimnion.

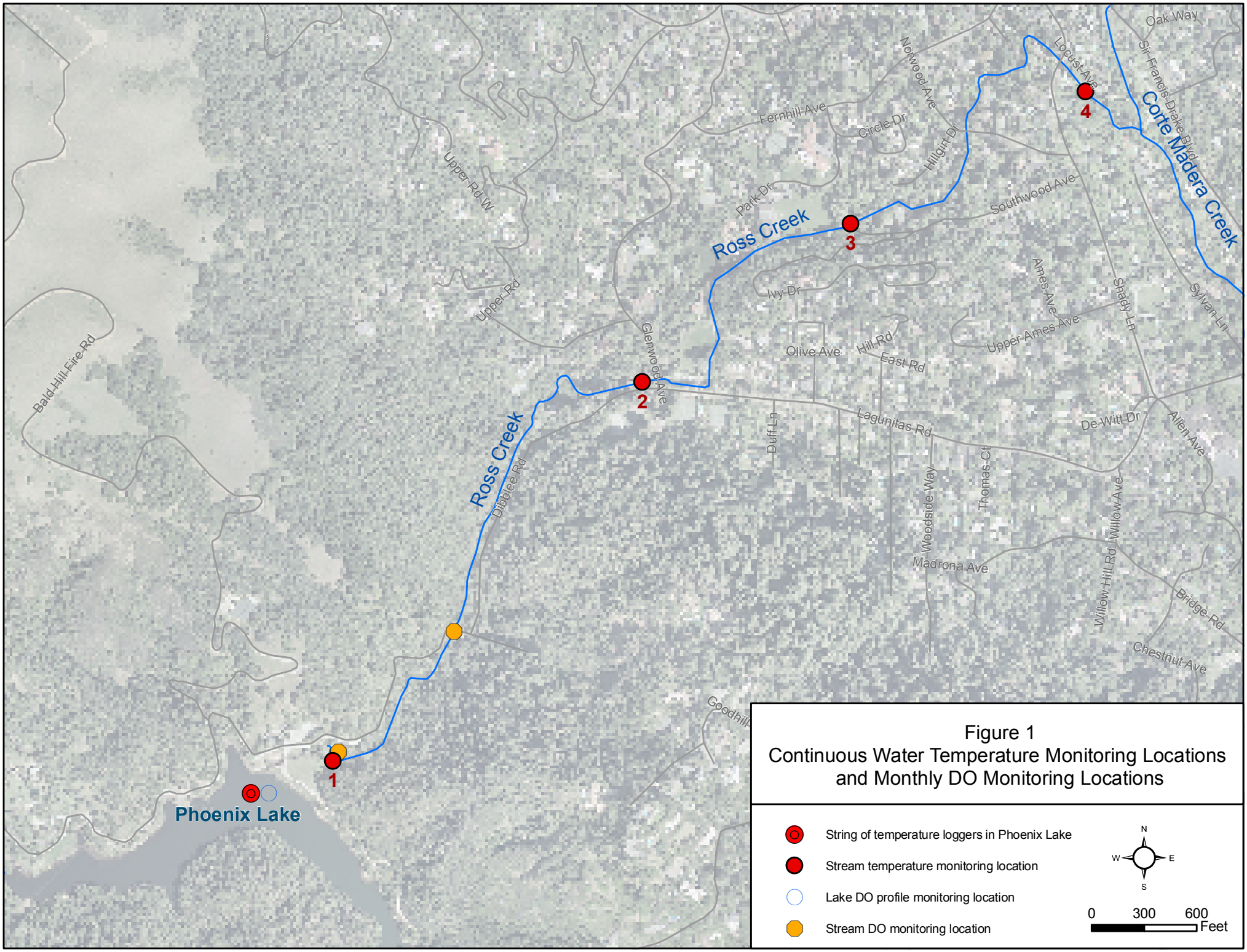
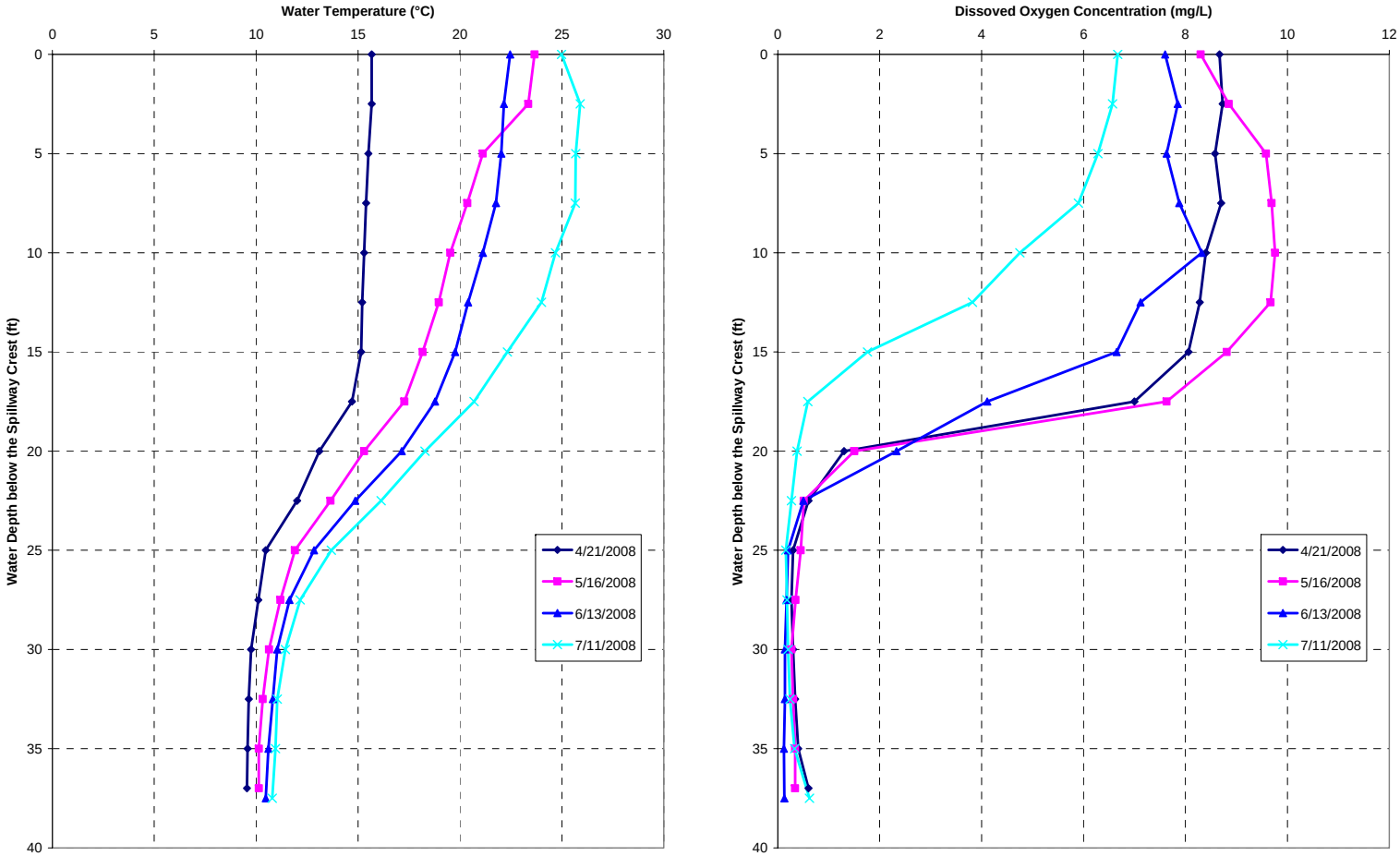


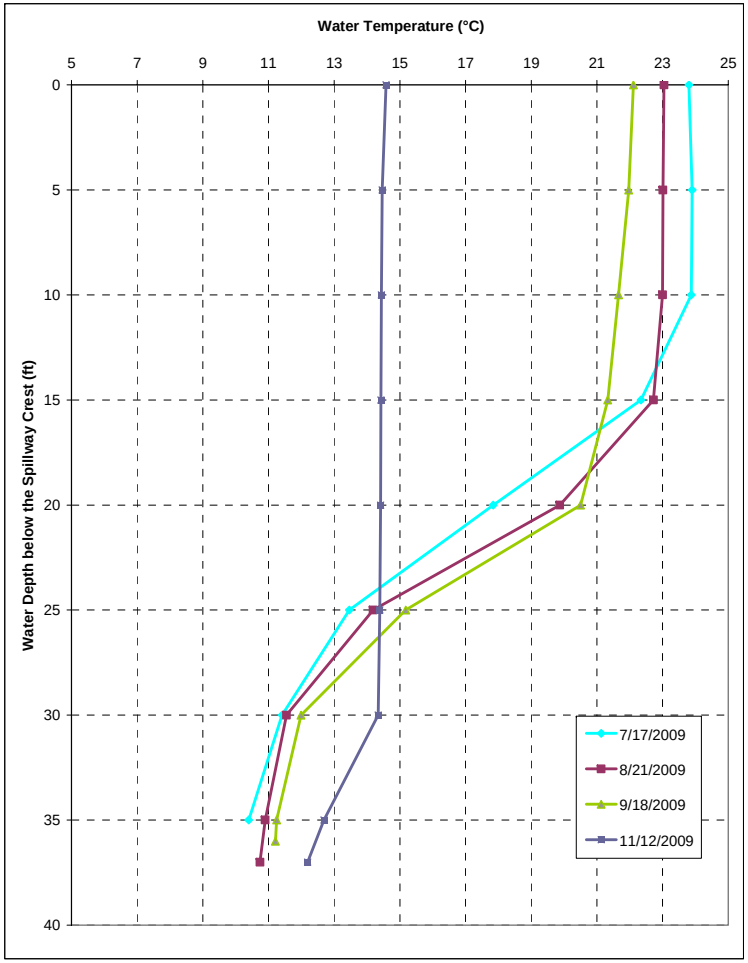
Figure 1
Continuous Water Temperature Monitoring Locations and Monthly DO Monitoring Locations



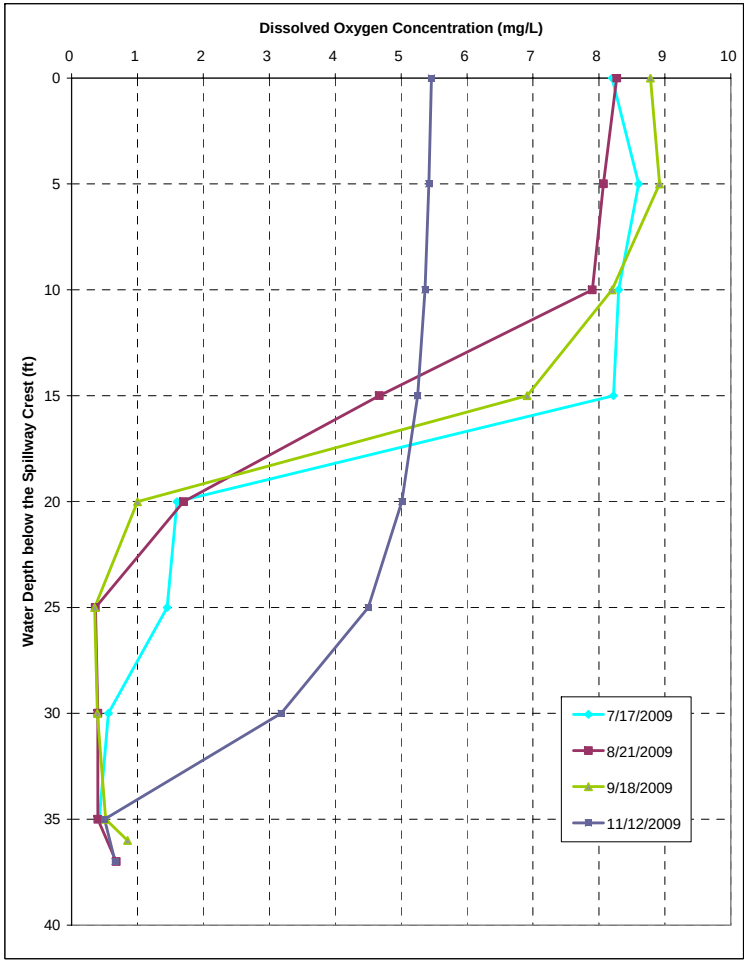
a) Water Temperature Profile

b) DO Profile

Figure 2 Observed Water Temperature and DO Profiles in Phoenix Lake, 2008



a) Water Temperature Profile



a) DO Profile

Figure 3 Observed Water Temperature and DO Profiles in Phoenix Lake, 2009

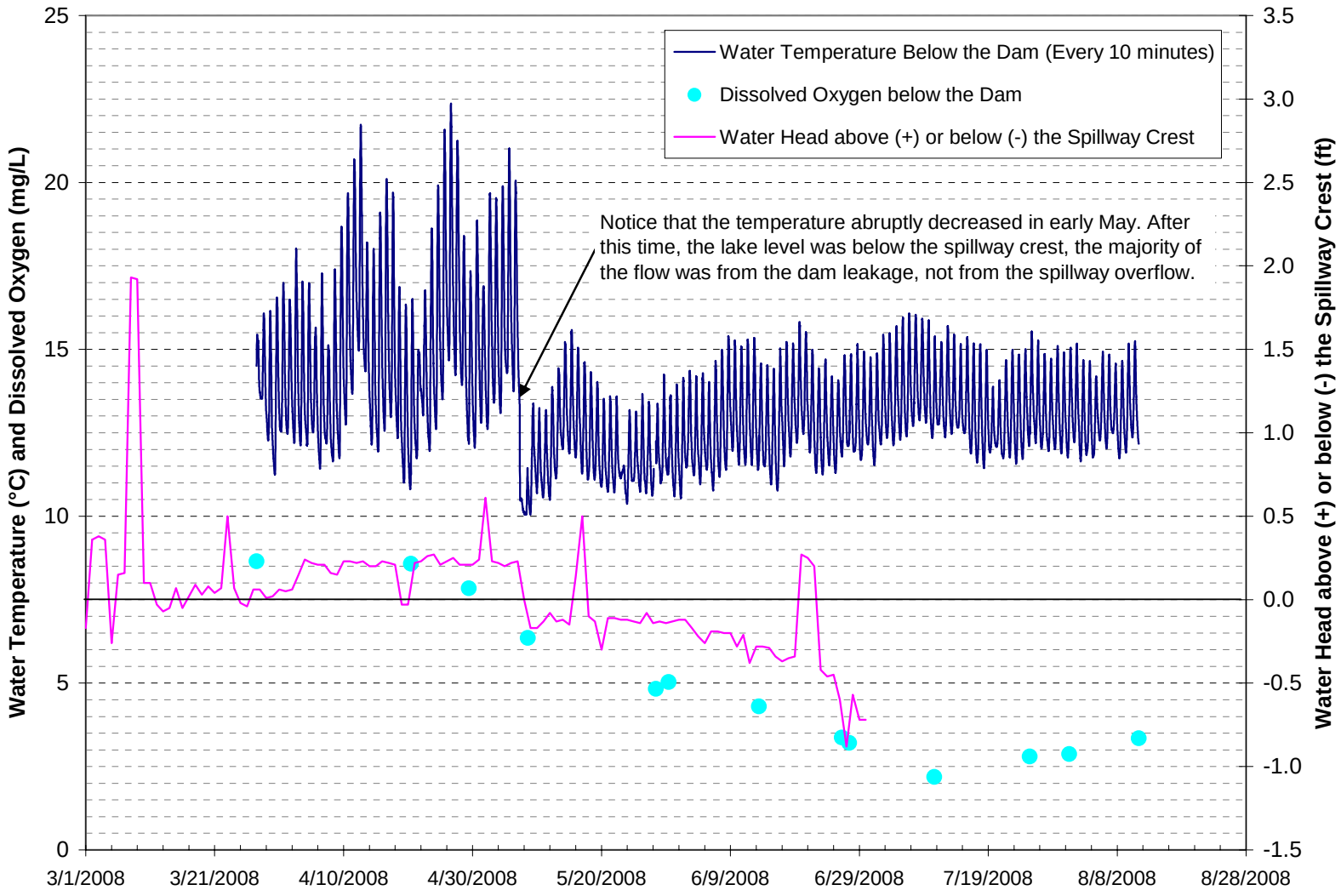


Figure 4 Observed Water Temperature and DO in Ross Creek below Phoenix Lake Dam, 2008

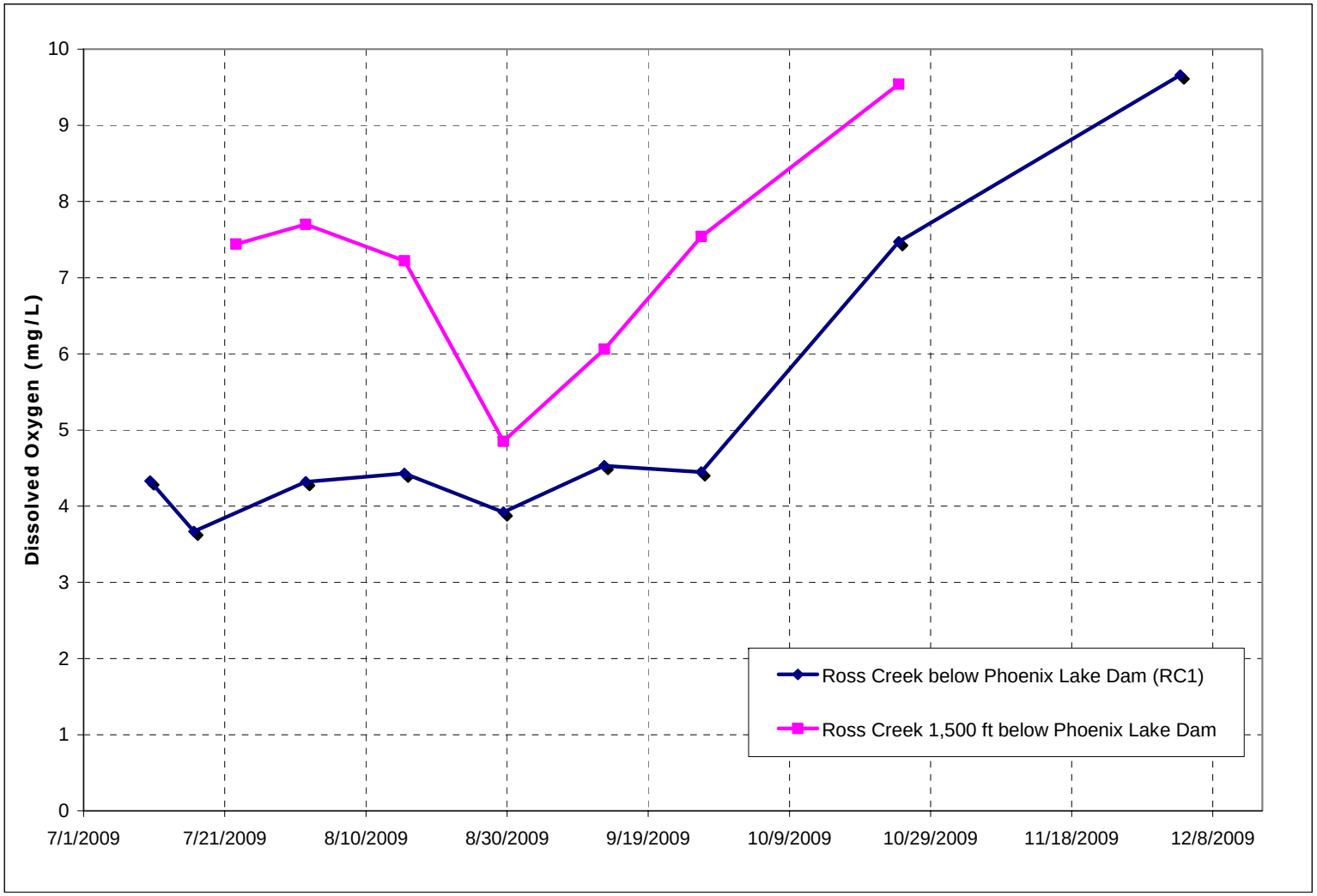


Figure 5 Observed DO in Ross Creek below Phoenix Lake Dam and 1,500 ft below the Dam, 2009

Appendix 7 to Attachment 3

SolarBee Proposal for Phoenix Lake

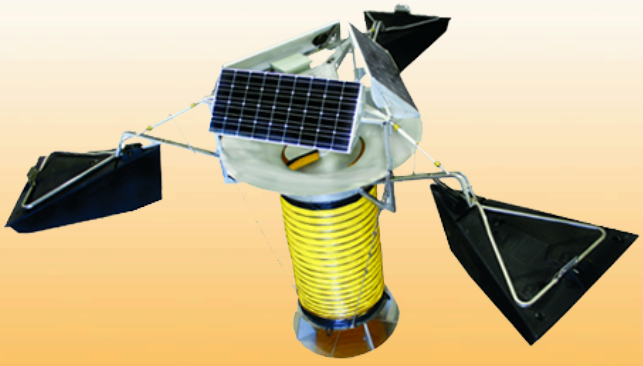
Dave Summerfield - Regional Manager
951-693-4896 • Dsummerfield@SolarBee.com

Shanna Shervheim - Inside Sales
866-437-8076 • Shanna@SolarBee.com

Proposal for:

San Rafael, California Raw Water Reservoir

c/o Xiaoqing Zeng
Stetson Engineers, Inc.



February 23, 2011

Photo of San Rafael Raw Water Reservoir provided by Google Earth

3225 Highway 22 • Dickinson, ND 58601
Tel: (701) 225-4495 • Toll Free: (866) 437-8076 • Fax: (701) 225-0002
www.SolarBee.com

1.0 PROJECT DESCRIPTION

1.1 Name and Location of the Reservoir:

San Rafael Raw Water Reservoir, three miles west/southwest of San Rafael, California
(GPS: lon 37.955075°, lon -122.576692°)

1.2 Description of the Reservoir:

San Rafael Raw Water Reservoir is a 17.5 acre lake with a capacity of approximately 300 acre-feet, a maximum depth of 44 feet and an average depth of about 20 feet when full. The surface elevation of the full lake is 174 feet. It is currently used primarily as a drinking water supply reserve for use during shortages, usually in the dry summer season and in drought years. This is a manmade lake and has a dam on the north side. At the deepest point in the reservoir adjacent to the dam, there is a 30" outlet pipe which is normally closed and has been used only infrequently since the dam was built. There is no boat traffic on the lake, but fishing from shore is

Under new operations, the lake will be used for both floodwater detention and drinking water reserve. During the rainy season, from December to March, the lake will be operated at a surface elevation of 160 feet (maximum depth of 30 feet), but will be drained to 140 feet when a storm event is anticipated. This will bring the maximum depth to approximately 10 feet and, given the bathymetry of the lake, leave the east and west ends dry until runoff from the watershed refills the lake.

From April to November, the lake will be operated full at a surface elevation of 174 feet. If dry conditions cause a drinking water shortage, water will be drawn from the lake and diverted to a nearby reservoir and then to treatment.

1.3 SolarBee Objectives, the Problems to Solve:

Epilimnetic and Hypolimnetic Deployment - Primary Objectives: To provide long-distance circulation in order to control harmful blue-green algae blooms in the epilimnion, increase dissolved oxygen levels in the hypolimnion, improve fish habitats, and improve overall water quality.

1.4 SolarBee's Recommendation:

To meet the above objectives, we recommend the installation of one (1) SB10000 v18 machine with the intake set for epilimnetic circulation and one (1) SB7500 v18 machine with the intake set near the reservoir floor for hypolimnetic circulation. This approach should provide sufficient hypolimnetic oxygenation to improve fish habitats while preventing any potential blue-green algae issues, even with the transport of nutrient-rich hypolimnetic water to the surface. Utilizing both epilimnetic and hypolimnetic applications should provide consistently good quality water throughout the water column year-round, regardless of fluctuations in water levels. While we believe that treating the epilimnion would be effective in improving the hypolimnion as well, the extremely low dissolved oxygen levels in the hypolimnion warrant the deployment of an additional machine set for hypolimnetic circulation.

1.5 Proposed Layout:

The SB10000 v18 and SB7500 v18 machines are not drawn to scale, and final placement will be determined prior to delivery and installation.

Photo Source: Google Earth

2.0 INVESTMENT OPTIONS

2.1 Budget Estimate for the Recommended Machines:

Equipment Purchase (See Appendix A for details)

Quantity	Description	Purchase Cost Each	Purchase Cost Total
1	SB10000 v18 with 10 feet of hose:	$45,100.00	$45,100.00
1	SB7500 v18 with 50 feet of hose:	$47,000.00	$47,000.00
		Total Equipment Cost:	$92,100.00
		Applicable Taxes:	to be determined
2	Factory Delivery, Installation and Startup:	$8,010.00	$16,020.00
		Multiple Unit Delivery Discount: 10%	($1,602.00)
		Total Delivery, Installation, and Startup Cost:	$14,418.00
		Total Investment (excluding taxes):	$106,518.00

Beekeeper cost of	$2,663	per year for years 1 & 2	(see Appendix C):	- Optional -
Beekeeper cost of	$6,391	per year for years 3, 4 & 5	(see Appendix C):	- Optional -

5-Year Lease Purchase (See Appendix E for details)

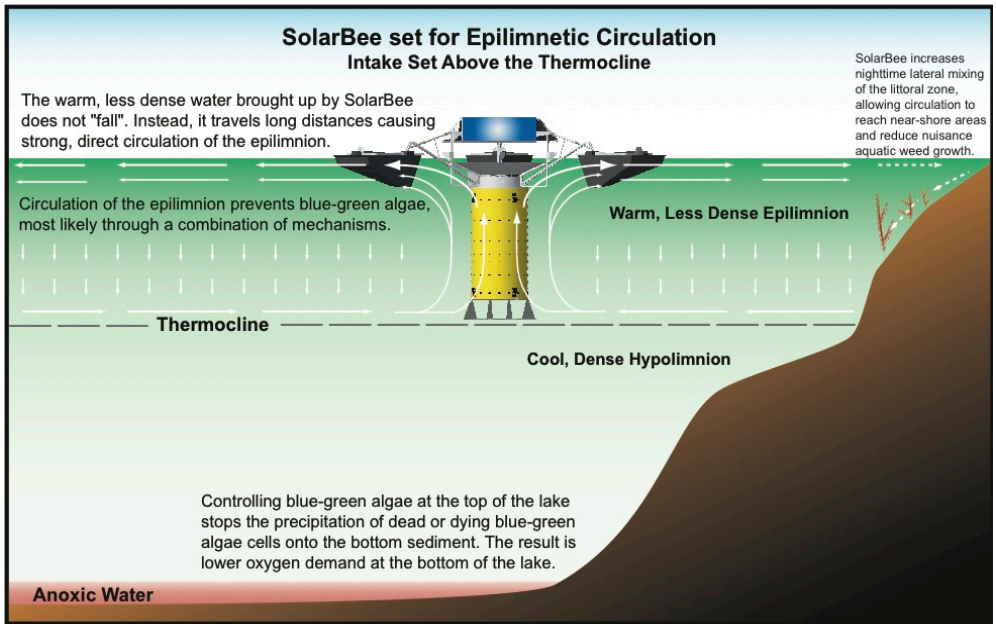
Cost for recommended machines per above:	- Included -
Factory Delivery, Installation and Startup:	- Included -
Beekeeper cost for years 1 & 2 (see Appendix C):	- Included -
Beekeeper cost for years 3, 4 & 5 (see Appendix C):	- Included -
Total Monthly Lease Purchase Cost (excluding taxes):	$2,466.00

Rental (See Appendix F for details)

Monthly rental cost for recommended machines per above:	$2,397.00
Monthly Beekeeper cost during the term of the rental:	- Included -
Factory Delivery, Installation and Startup:	$14,418.00

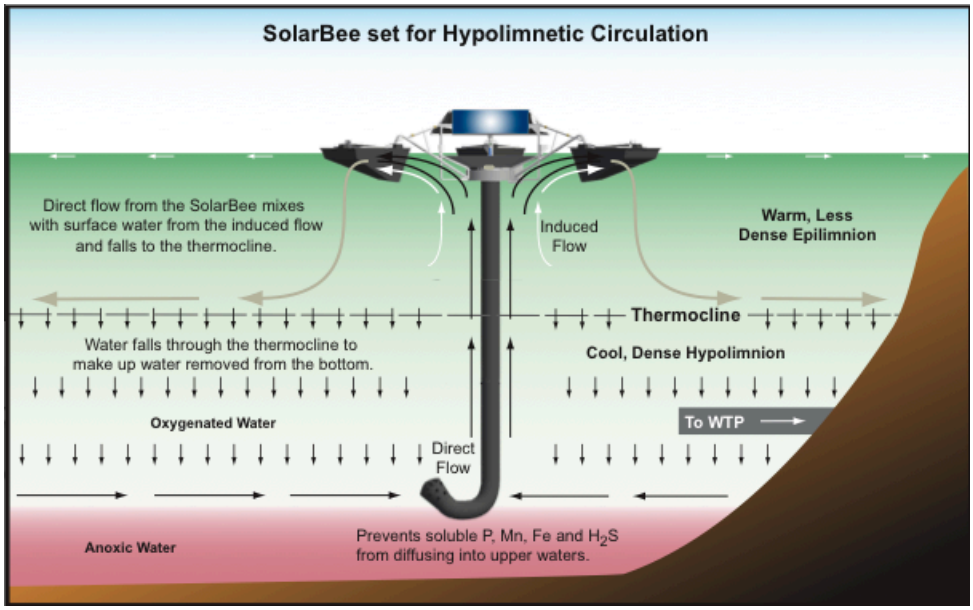
SB10000 v18 (Epilimnetic Circulation):

The SB10000 v18 features a 10,000 gpm (14.4 MGD) total flow leaving the machine, near laminar flow output for long distance circulation, 316 stainless steel and non-corrosion polymer construction, 25-year life high efficiency brushless electric motor design that provides day and night operation with a solar-charged battery power system, digital control system for intelligent power management with factory programmed reverse functions and anti-jam routines specific to this application, SCADA outputs, three (3) 80-watt solar panels, 36" diameter intake hose, anchoring system, and bird deterrent. See Appendix D - SolarBee Limited Replacement Warranty for information on the most extensive warranty in the industry.



SB7500 v18 (Hypolimnetic Circulation):

The SB7500 v18 set for hypolimnetic circulation features a 1,500 gpm (2.16 MGD) total flow leaving the machine, near-laminar flow output for long-distance circulation, 316-stainless steel and non-corrosion polymer construction, 25-year life high-efficiency brushless electric motor designed to provide day and night operation with a solar-charged battery power system, digital control system for intelligent power management with factory programmed reverse functions and anti-jam routines specific to this application, SCADA outputs, three (3) 80-watt solar panels, 24" diameter intake hose, anchoring system, and bird deterrent. See Appendix D - SolarBee Limited Replacement Warranty for information on the most extensive warranty in the industry.



Appendix B: Factory Delivery and Field Services

SolarBee, Inc. sends a factory trained Delivery & Field Services Team with specialized equipment to deliver, assemble, place, and start up your SolarBee machines. A training session on operation and maintenance is also provided for your personnel. Each Team member undergoes training such as Fall Protection, Confined Space Entry, Working Over Water, and Water Quality Testing.

As part of our standard operating procedures, the factory trained Delivery & Field Services Team will conduct vertical profiles with a YSI multi-parameter submersible probe, and at each test point measure dissolved oxygen, pH, temperature and specific conductance at every foot from the surface down to a depth of 25 feet, and at 5-foot intervals thereafter. A Secchi depth measurement will also be made at each test location. GPS coordinates are recorded for each machine and test point location.

Your water quality is our highest priority. Our commitment continues long after the Delivery & Field Services Team leaves your location and we strive to maintain contact with all our customers. Our Customer Service, Application Engineering, and Science Departments are available for any questions regarding machine operation and water quality.

Appendix C: Beekeeper Service Program

The Beekeeper is a program that utilizes Factory Crews to service and maintain proprietary designed equipment. The Beekeeper provides for more than just maintenance and service:

- It extends the warranty during the term of the Beekeeper
- It covers damage from Acts of God and vandalism
- It provides for power system upgrades and updates
- It provides hardware, firmware, and software for computer upgrades
- It provides scientific and technical support
- It provides for scheduled and unscheduled field service calls
- and much more, please request the Beekeeper brochure for more details

Appendix D: General Provisions

This is a Budget Estimate, please call for a firm Quotation:

This budget estimate replaces all prior budget estimates for this project. It is valid until replaced by a subsequent budget estimate, or for 60 days, whichever occurs first.

Purchase of the SolarBee circulation equipment in this quotation is an "Equipment Purchase," not a "Construction Project":

SolarBee circulation equipment is portable, and can be easily relocated or removed entirely from the premises at any time. It does become an integral part of any building or other structure, and never becomes part of "real estate". Therefore, to purchase SolarBee circulation equipment, the city or other organization purchasing SolarBees should use the same procedure as for purchasing other portable equipment, such as a forklift, a drill press, or an office desk. SolarBee reserves the right not to accept an order if the purchase is incorrectly characterized as a "construction" project. SolarBee, Inc. has not found any state or other jurisdiction where construction or contractor statutes apply to portable equipment that is sold by a factory, with on-site final assembly and startup performed by factory personnel.

Assumptions:

This quotation may be based on worksheets and calculations that have been provided to the customer, either previously or else attached to this quotation. The customer should bring to our attention any discrepancies in data used for these calculations.

SolarBee Limited Replacement Warranty:

All new and factory-refurbished SolarBee equipment is warranted to be free of defective parts, materials, and workmanship for a period of 2 years from the date of installation. In addition, the SolarBee brushless motor is warranted for a period of 10 years from the date of installation. Photovoltaic modules (solar panels) carry manufacturer warranties, some ranging up to 25 years (see manufacturers' warranty for details). This warranty is valid only for SolarBee equipment used in accordance with the owner's manual, and consistent with any initial and ongoing factory recommendations. This warranty is limited to the repair or replacement of defective components, at SolarBee's discretion. During the first 2 years, the warranty also includes both parts and labor. In lieu of sending a factory service crew to the site for minor repairs, SolarBee, Inc. may choose to send the replacement parts to the owner postage-paid and, in some cases, may pay the owner a reasonable labor allowance to install the parts.

Except as stated above, SolarBee and its affiliates expressly disclaim any and all express or implied conditions, representations and warranties on products furnished hereunder, including without limitation all implied warranties of merchantability or fitness for a particular purpose.

Please consult your state law regarding this warranty as certain states may have legal provisions affecting the scope of this warranty.

Appendix E: Lease Provisions

Standard Agreement:

Pricing in the above quotation is based on 5 years, 60 monthly payments, and a $0 down payment. For a quotation based on other terms, please call SolarBee, Inc., at 1-866-437-8076.

Non-Appropriation Provision:

Lessee's (borrower's) payment obligation will terminate if the lessee fails to appropriate in future budgets the funds needed to make the lease payments. Because of this non-appropriation provision, neither the lease nor the lease payments are considered debt, and payments can be made from the savings in your operating budget.

Maintenance of the Equipment:

Lessee is to provide minor routine care and maintenance of the Equipment as described in the owners manual. The Beekeeper Service Program is required, and is included in the cost shown above for the term of the lease. See above Appendix C for description of the Beekeeper program.

Additional Lease Provisions:

If the lease option is selected, a master equipment lease/purchase agreement will be sent to lessee, that shall cover all terms and conditions of the lease.

Appendix F: Rental Provisions

Rental Payment Terms:

The installation day of the month is the anniversary day for determining when a new rental month begins. There are no partial months; if the equipment is in place on the first day of the rental month, a whole month of rental is due. Rental invoices will be provided each month and payment is due 30 days from the invoice date. The installation charge mentioned above will be added to the first month's rental invoice.

Rental Period, Month-to-Month:

The rental period shall be for one month, beginning on the installation date, and shall continue automatically, for one month at a time beginning on each monthly anniversary of the installation date, until the longer of (a) 12 months, or (b) 90 days after written notice is received by SolarBee, Inc. from the renter to terminate the rental. Furthermore, SolarBee, Inc. has the right to terminate the rental agreement and re-possess the equipment at any time, without notice to the renter, if the renter becomes delinquent in rent payments.

Periodic Rental Cost Adjustment:

The rental cost may be adjusted periodically by SolarBee, Inc. upon 90 day written advance notice to the renter, after the minimum rental period mentioned above. SolarBee, Inc. expects, but does not promise, to make such adjustments only once per year on the annual anniversary of the installation, and expects that adjustments will be limited to reflect (a) a general inflationary adjustment equal to the Consumer Price Index, and (b) any additional costs by the factory associated with keeping the rental equipment functioning properly and meeting the renter's goals for the project. The renter, at its option as mentioned above, may cancel the rental agreement with 90 day notice if the proposed new rental costs are ever not acceptable.

Rental Conversion to Purchase:

The renter may convert this rental to a purchase, at the price shown in the Equipment Purchase section above. To convert this rental to a purchase, the renter should request SolarBee Inc, at least 60 days before the desired purchase date, to supply a firm quotation to convert the rental to a purchase. When conversion to a purchase is made, 50% of prior rents paid will be applied to the purchase price, up to a maximum of 50% of the equipment purchase price. Title to the rental equipment does not pass to the renter unless and until payment of all outstanding rental invoices, and the conversion purchase price for the equipment, is received by the SolarBee, Inc.

Rental Equipment Availability:

SolarBee, Inc. has a limited supply of rental machines available; either new or slightly used or "demonstrator" equipment may be installed at the factory's option. If the equipment installed for a rental is slightly used, then the factory warrants that: (1) the equipment is clean, current, and in like-new condition with a full new-equipment warranty, and (2) the equipment is equivalent to new equipment with the very latest technology and improvements. Also note that SCADA or other remote monitoring options may have been included in the purchase cost in Section 2 above, but these components are not included with rental equipment. If a rental is desired, the SCADA remote monitoring equipment would be installed only after the equipment had been converted to a purchase, unless other provisions have been made.

Maintenance of the Equipment:

Renter is to provide minor routine care and maintenance of the Equipment as described in the owners manual. The Beekeeper Service Program is required and is included in the cost shown above for the term of the rental. See above Appendix C for description of the Beekeeper.

Appendix 8 to Attachment 3

Water Temperature/Water Quality Issues in Phoenix Lake and Ross Creek Below the Dam and Recommended Solutions for Improving Water Quality and Cold Freshwater Habitat

Stetson Engineers Inc.
February 24, 2011

INTRODUCTION

Phoenix Lake is located on Ross Creek, a major tributary of Corte Madera Creek. The lake is owned, operated, and maintained by Marin Municipal Water District (MMWD) primarily for the purpose of drinking water supply for use during shortages, but also for wildlife habitat and public recreation and enjoyment. The lake is formed by an earthen embankment dam across Ross Creek that was built in 1906, enlarged in 1909, and strengthened in 1969. The watershed above Phoenix Lake encompasses about 1,400 acres. When full (i.e., elevation 174 ft NGVD29), the lake covers about 17 acres and holds approximately 300 acre-feet of water based on the 2009 bathymetric survey.

The dam is penetrated by a gated, 30-inch diameter, low-level, outlet pipe that has an intake invert elevation at 130 ft and a discharge capacity of 115 cubic feet per second (51,600 gallons per minute) when the lake is full. This low-level outlet is normally kept closed and has been used infrequently since it was built. The spillway is situated on the right side of the dam (looking upstream). In 1985 the spillway was modified by lowering the crest by six feet, from elevation 180 feet down to elevation 174 feet.

Under current operations, since the low-level outlet is normally kept closed, overflows above the spillway crest will be the primary outflows from the lake to downstream (and these outflows are from the warm top layer of the lake). If the lake water level is below the spillway crest, the small leakages through the dam (which are from the cold bottom layer of the lake) will be the only outflows that keep the downstream wet.

In order to assess the influence of Phoenix Lake on cold freshwater habitat and water temperatures in Ross Creek below the dam (which generally need summertime water temperature in the range of 12°C to 17°C to support steelhead rearing habitat), the Friends of Corte Madera Creek Watershed, in cooperation with the Marin Municipal Water District and four local property owners, conducted a monitoring program at Phoenix Lake and Ross Creek in 2008 and 2009. Water temperatures in Ross Creek were monitored at four different locations with continuously recording temperature loggers. Dissolved oxygen (DO) concentrations were monitored once a month using Hydrolab in the lake near the intake at different depths and at two locations of Ross Creek below the dam. The monitoring locations are shown in Figure 1.

OBSERVED DATA

1) Observed Water Temperature and DO Profiles in Phoenix Lake near the Intake

The observed water temperature and DO profiles in Phoenix Lake in 2008 are shown in Figure 2, and in 2009 the observed results are shown in Figures 3. There was strong thermal stratification in Phoenix Lake. The epilimnion extended about 15 to 20 ft in depth with water temperature at 20°C – 25°C. The hypolimnetic water temperature was measured at 10-12°C.

The DO profiles in Phoenix Lake show very low dissolved oxygen concentration in the hypolimnion, even in April (Figure 3). This low DO in the lake hypolimnion would not support cold freshwater habitat. Low DO also has a negative effect on other water quality parameters. The anaerobic chemicals (i.e., hydrogen sulfide, iron, manganese, and others) could release from the bottom of the lake.

2) Observed Water Temperature and DO in Ross Creek below the Dam

Figure 4 shows the observed water temperature and DO just below the dam. It also shows the measured lake water levels. As shown in Figure 4, the temperature abruptly decreased from about 20°C to less than 15°C in early May. After this time, the lake water level was generally below the spillway crest, the majority of the flow was the dam leakage (which is cold), not from the spillway overflow (which is warm). This suggests that releasing water using the low-level outlet, instead of the spillway, would maintain the released water cold enough to support steelhead rearing habitat (which generally need summertime water temperature in the range of 12°C to 17°C).

Figure 4 also shows that when the majority of the flow was from the dam leakage, the DO concentration just below the dam was also relatively low (below 5 mg/L, the required DO level for cold freshwater habitat). However, the relatively low DO will be quickly increased by re-aeration within a short distance. This phenomenon is shown in Figure 5.

3) Algae Blooms in the Epilimnion of Phoenix Lake

Although no monitoring data are available about algae blooms and dominant species, MMWD reported algae blooms in the lake and their impacts on the surface water treatment plant and drinking water quality. Visual observations during the monitoring program conducted by the Friends of Corte Madera Creek Watershed also indicated algae blooms in the lake.

Algae blooms reduce water clarity and the overall aesthetic appeal of the lake to fishermen and other recreationalists who visit the lake. Algae also affect the filtration process and increase MMWD's treatment costs at its Bon Tempe Treatment Plant. Algae, particularly blue-green algae, can create taste and odor problems in the treated drinking water.

WATER TEMPERATURE/WATER QUALITY ISSUES AND RECOMMENDED SOLUTIONS

Issue #1: Algae Blooms in the Epilimnion of Phoenix Lake

Recommended solution: Install a SolarBee device with the intake set at 5 ft for epilimnetic circulation without disrupting the stratification. This approach helps prevent blue-green algae (cyanobacteria) blooms and the associated toxins. Treating the epilimnion will also be effective in improving the hypolimnion as well, because inhibiting blooms through epilimnetic circulation results in less organic decomposition of dead and dying algae that have settled to the reservoir floor. This reduction in organic decomposition reduces oxygen demand and increases DO levels throughout the water column.

Issue #2: Low DO in the Hypolimnion of Phoenix Lake That Does Not Support Cold Freshwater Habitat

Recommended solution: Install another SolarBee device for hypolimnetic circulation and aeration without disrupting the stratification. This solution is designed to increase the DO concentration in the lake hypolimnion to above 5.0 mg/L, the required level for cold freshwater habitat. This solution can also help inhibit releases of the anaerobic chemicals from the bottom of the lake.

Issue #3: High Water Temperature Overflow Over the Spillway Does Not Support Steelhead Rearing Habitat in the Ross Creek below Phoenix Lake Dam

Recommended solution: Modify the low-level outlet and release cold water through the low-level outlet. Note that the recommended solution for Issue #2 is designed to increase the DO concentration in the lake hypolimnion to above 5.0 mg/L. Increasing the DO concentration in the lake hypolimnion would, of course, increase DO in the released water from the low-level outlet, which is from the lake hypolimnion.

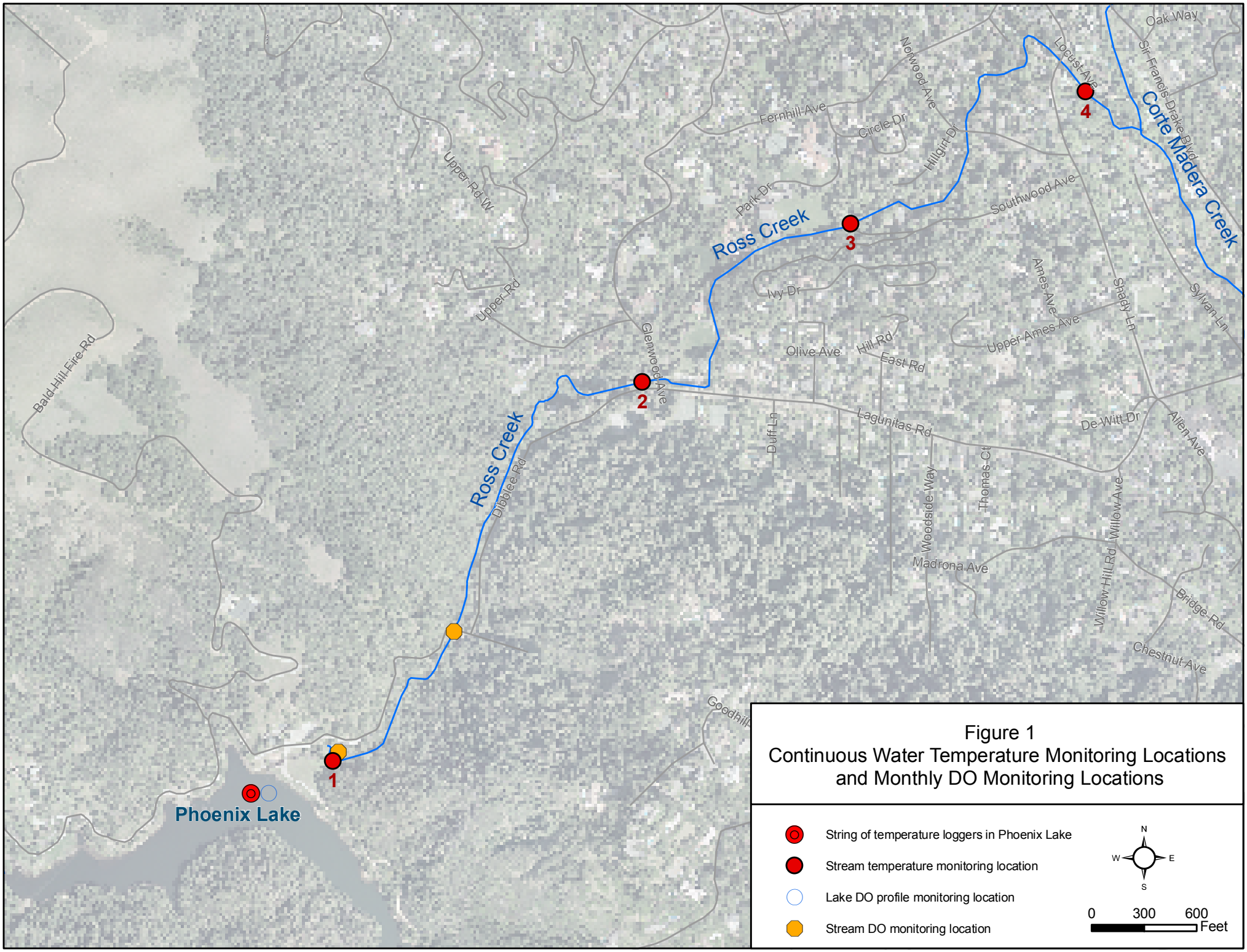
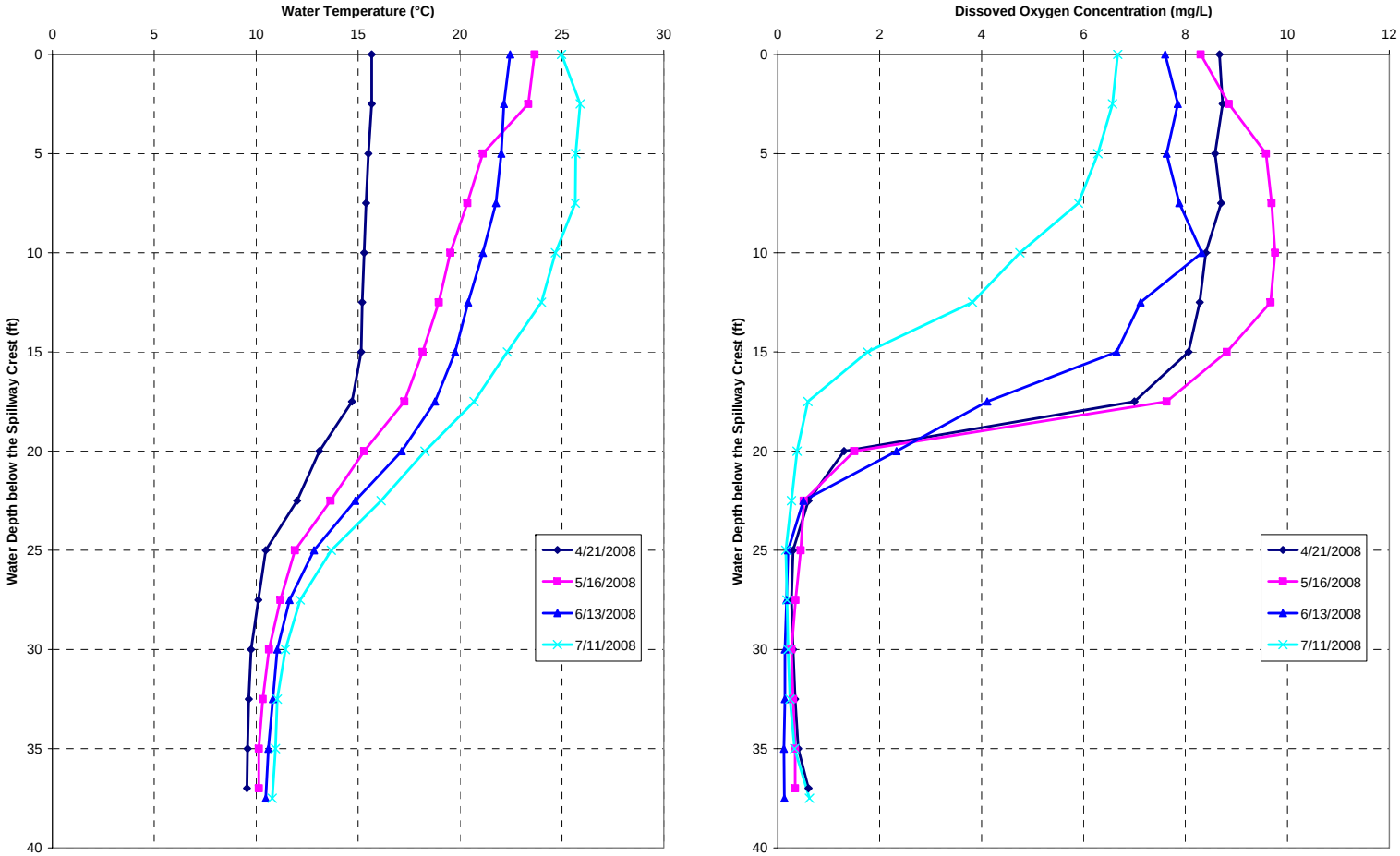


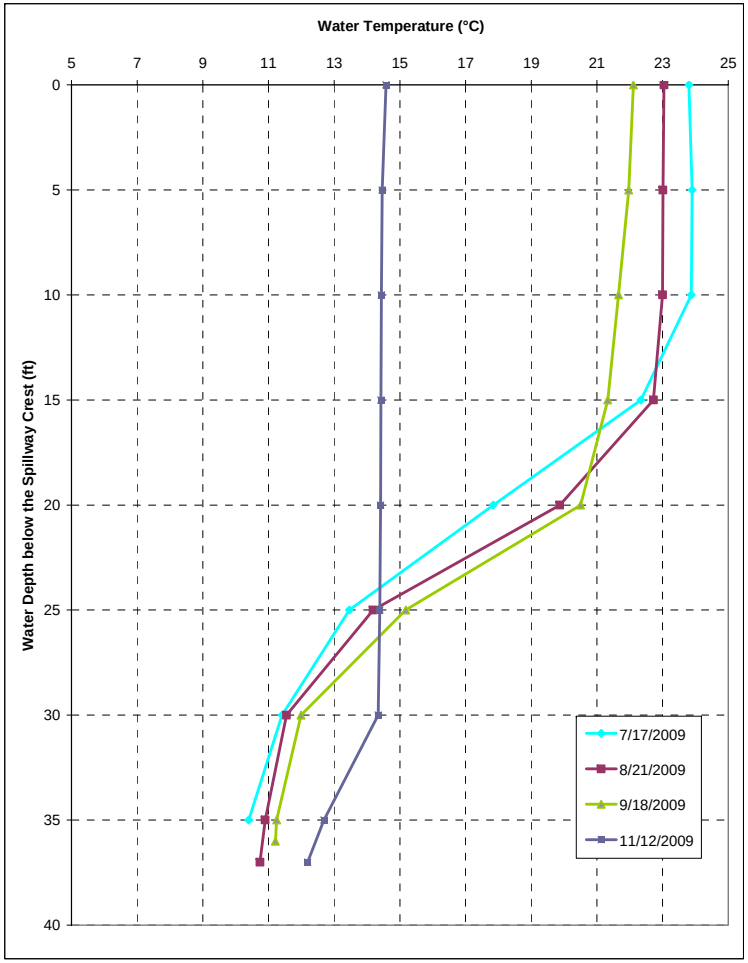
Figure 1
Continuous Water Temperature Monitoring Locations and Monthly DO Monitoring Locations



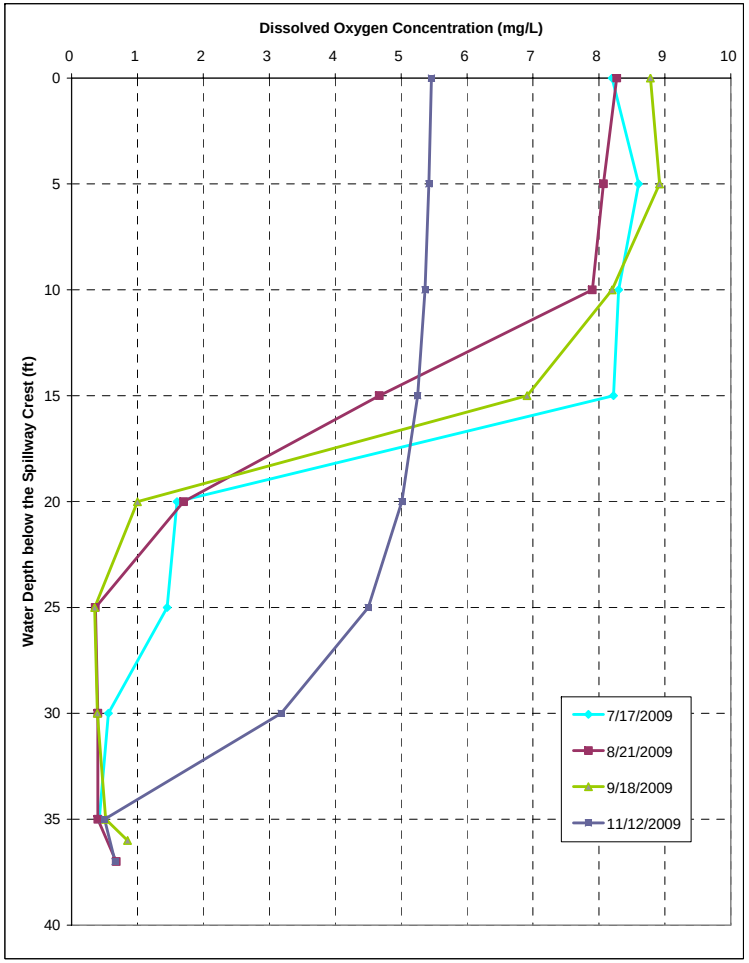
a) Water Temperature Profile

b) DO Profile

Figure 2 Observed Water Temperature and DO Profiles in Phoenix Lake, 2008



a) Water Temperature Profile



a) DO Profile

Figure 3 Observed Water Temperature and DO Profiles in Phoenix Lake, 2009

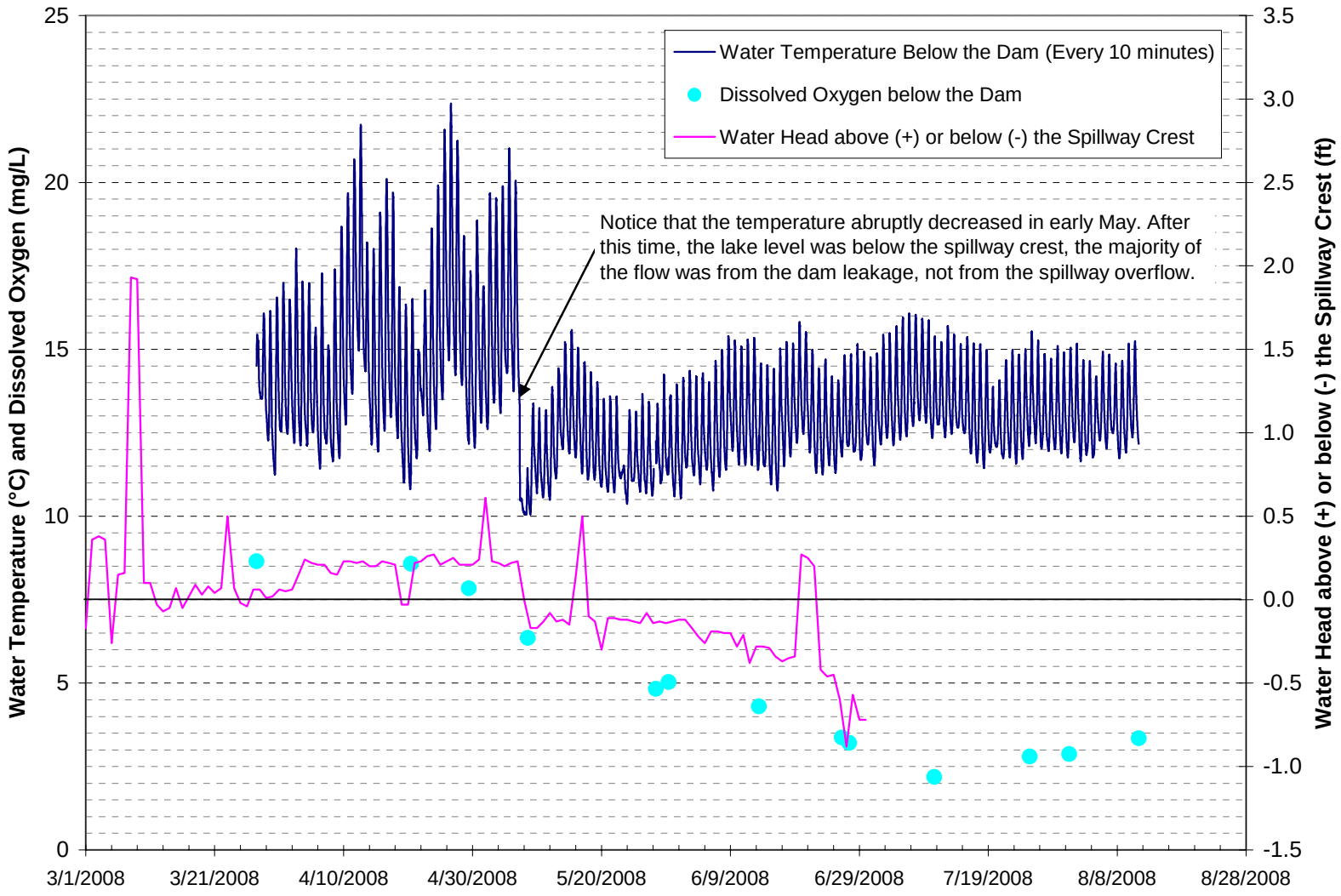


Figure 4 Observed Water Temperature and DO in Ross Creek below Phoenix Lake Dam, 2008

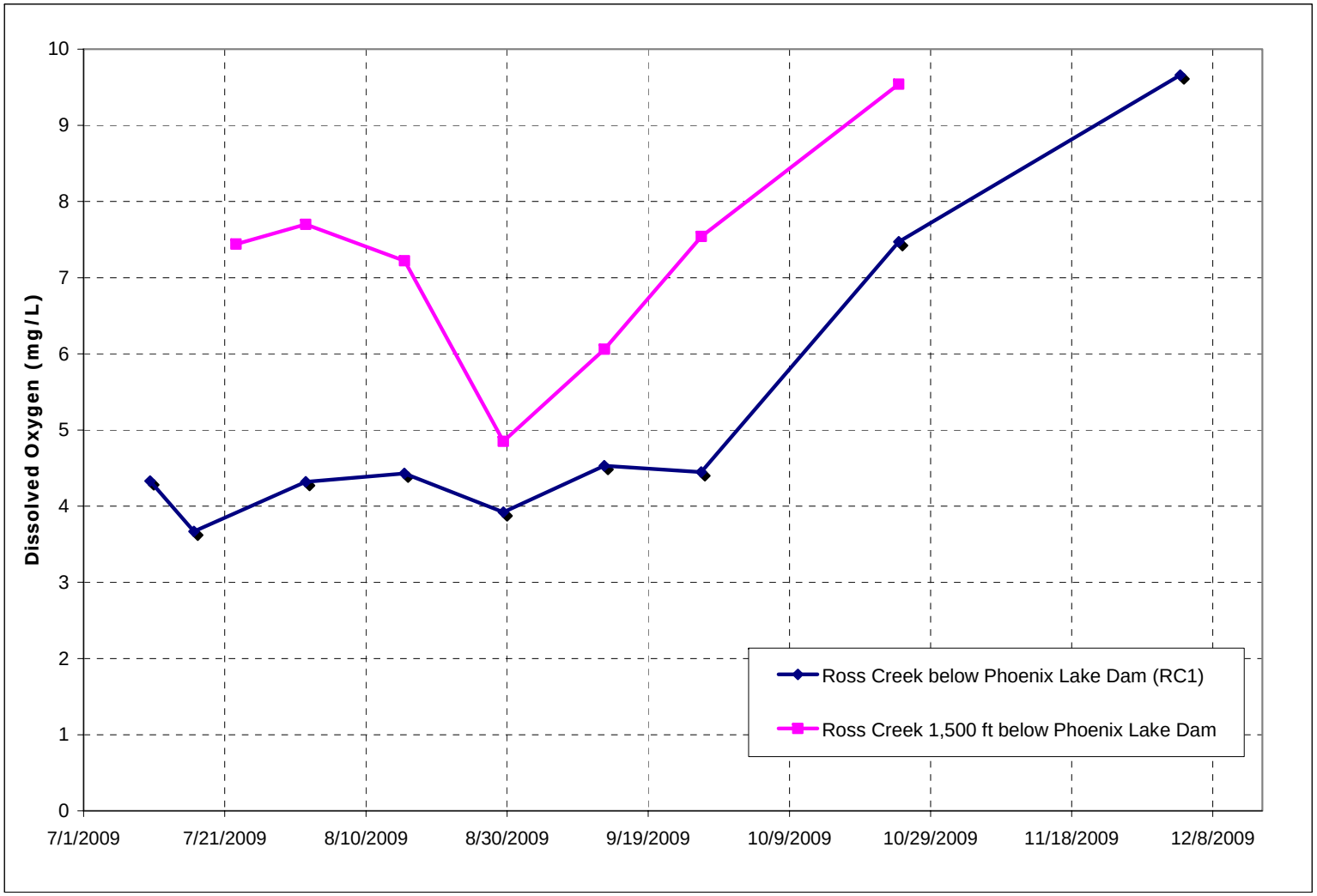


Figure 5 Observed DO in Ross Creek below Phoenix Lake Dam and 1,500 ft below the Dam, 2009

Appendix 9 to Attachment 3

Ross Creek Water Temperature Monitoring Report by Friends of Corte Madera Creek Watershed

Friends of Corte Madera Creek Watershed
P.O. Box 415 · Larkspur · California 94977
info@friendsofcortemaderacreek.org (415) 456-5052 www.friendsofcortemaderacreek.org

September 27, 2008

Ed Schulze, Chair
Wildlife & Fisheries Advisory Committee
Cooperative Extension
1682 Novato Boulevard, Suite 150B
Novato CA 94947

Cc: Mike Swezy

RE: Final Report for Grant FY 2007-2008

Dear Ed,

Friends of Corte Madera Creek Watershed, in cooperation with Marin Municipal Water District and four local property owners, has completed the first year of monitoring at Phoenix Lake and Ross Creek. Temperatures were monitored with continuously recording temperature loggers manufactured by Onset Corporation (model HOBO U22 Water Temp Pro loggers v2). We have spent $2,313.99 for the permit from MMWD, equipment, and the repair and calibration of the Hydrolab. Approximately 200 volunteer-hours have been spent installing and maintaining equipment, downloading loggers, using the Hydrolab to gather additional data and to calibrate the loggers, and analyzing data. A table of expenditures is attached.

Ross Creek
MMWD gave permission to deploy loggers in the upstream potions of the creek and three private property owners allow us to access the creek below Glenwood Avenue. The loggers were placed at five locations along Ross Creek, also shown on Figure 1. The most upstream location is just below Phoenix Dam (RC1); the next downstream station is near the bridge at Glenwood Ave. (RC2); the next downstream is located at the end of Southwood Avenue, adjacent to the Branson School Campus (RC3); the most downstream station is located near Shady Lane, just upstream of the confluence with Corte Madera Creek (RC4).

Logger Installation and Data Gathering: The temperature loggers were designed for long term deployment. Although the loggers are relatively robust, each was enclosed in a section of pipe which was then cabled to a root, rock, or tree. A photograph of one deployment, the logger at station RC4, is shown in Figure 2.

All loggers were set to record data points at ten-minute intervals. The accuracy of the device is 0.2˚C over the range of 0˚C to 50˚C. In order to ensure that all loggers were operating correctly, a calibration measurement was taken using the Hydrolab on each service occasion.

Once deployed in the pipe, the loggers are inconspicuous and no one appears to have tampered with any of them. We attempted to locate sites with relatively deep, moving water; the deepest pools were not selected, because we wanted to measure the temperature of water moving in the creek. Stagnant pools out of the current were avoided due to concern that they could possibly be stratified. The Ross Creek loggers were installed on March 28, in the four locations shown on Figure 1. A fifth logger was placed in a pool downstream of the low-release outlet on April 30.

Loggers were downloaded at approximately 2-week intervals. The three downstream loggers were removed in mid-May when the creek dried, but the upper two, on MMWD land upstream of Natalie Coffin Green Park remain in place.

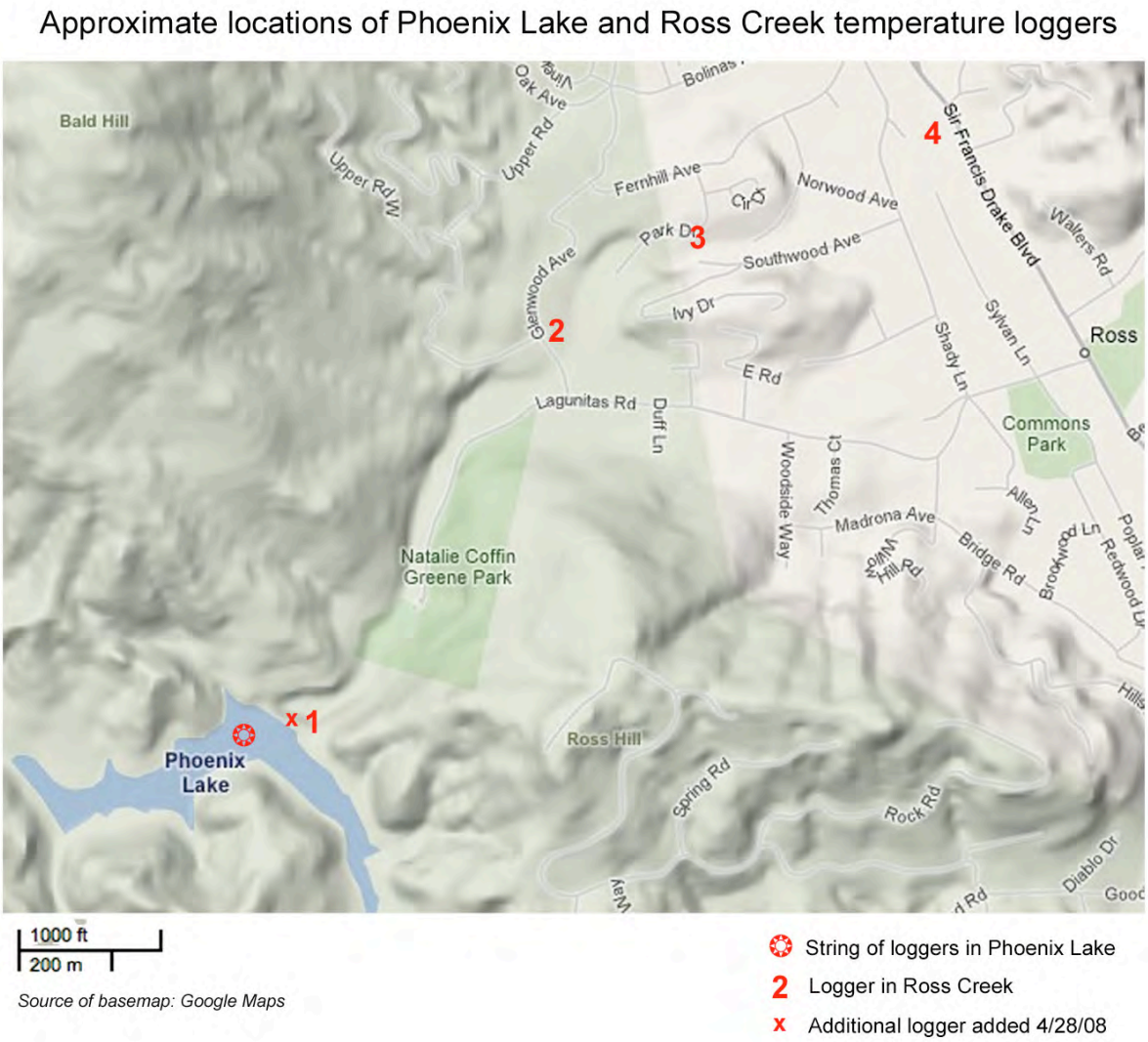


Figure 1. Deployment locations of continuously recording temperature loggers in Ross Creek, Summer 2008 field season.

Figure 2. Continuously recording temperature logger deployed at Ross Creek near Shady Lane (RC4). The site is just upstream of the confluence with Corte Madera Creek. Logger is indicated by the red circle.

Water Temperatures in Ross Creek

One objective of this monitoring project was to determine if temperatures in Ross Creek could support steelhead. Steelhead generally need summer rearing habitat in the range of 12˚C to 17˚C.

Graphs of temperature time series for loggers deployed in Ross Creek are included as Figures 3 through 6. Each graph is a record of water temperature at a particular location. Figure 3 includes measurements beginning in March and concluding in September, 2008. Figures 4 through 6 also begin in March, 2008 but conclude in May, 2008 when the creek dried and loggers were de-watered.

Graph 3 is a record of temperatures just below the dam. Notice that the temperature abruptly decreases in early May. Flow no longer passed over the spillway after early May. After this time, temperatures at the location at Natalie Coffin Greene (RC1) decreased because the majority of the flow was from the reservoirs lower level outlets.

Graph 4 is a record of temperatures at the next downstream location, at the Glenwood Ave Bridge (RC2). The stream dried by early May; however, during the time that flow was maintained, temperatures were appropriate for salmonids.

Graph 5 is a record of temperatures at the next downstream location, at Southwood Avenue (RC3). In this location, the stream dried later, in mid-May. Additional flow may be attributed to groundwater inflow between the two sites. Temperature of groundwater would be cooler than stream temperatures during early spring and summer. During the time that flow was maintained, temperatures were appropriate for salmonids.

Graph 6 is a record of temperatures at the most downstream location, at Shady Lane (RC4). In this location, the stream dried in early May. Up until late March, temperatures were appropriate for salmonids.

Temperatures in the three downstream locations (RC 2, RC3, and R4) were consistently within the appropriate range for steelhead, but the stream dried by mid-May. This is early for young salmonids. If Phoenix Lake could be operated to ensure that Ross Creek had flow into June, it may be possible to improve conditions for young salmonids.

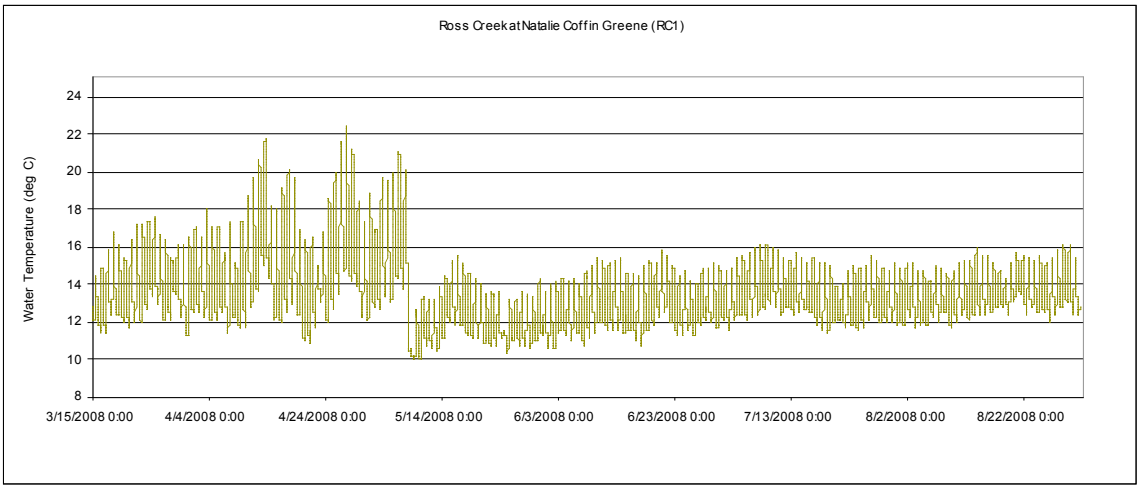


Figure 3. Temperatures recorded in Ross Creek at station RC1 (below Phoenix Dam).

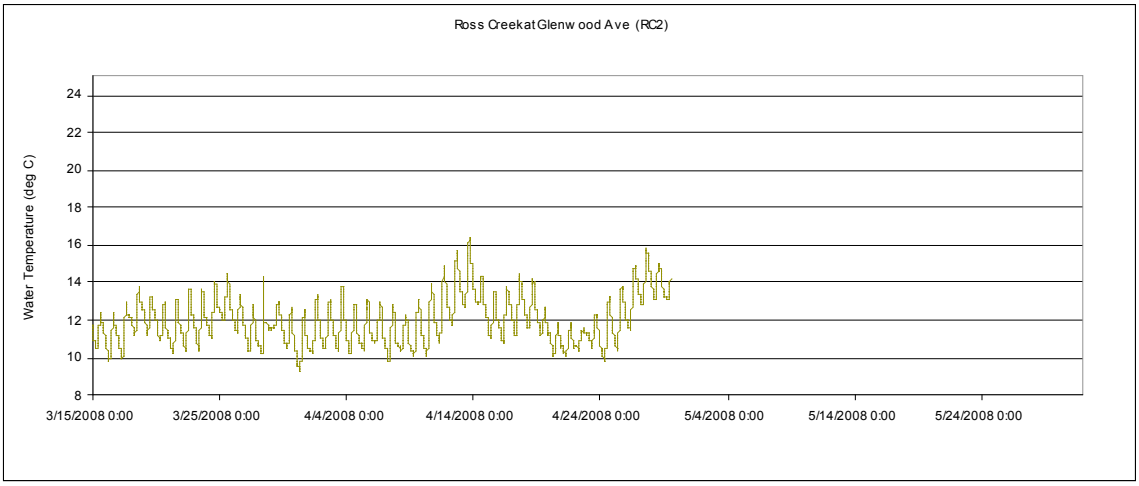


Figure 4. Temperatures recorded in Ross Creek at station RC2 (near the bridge at Glenwood Ave).

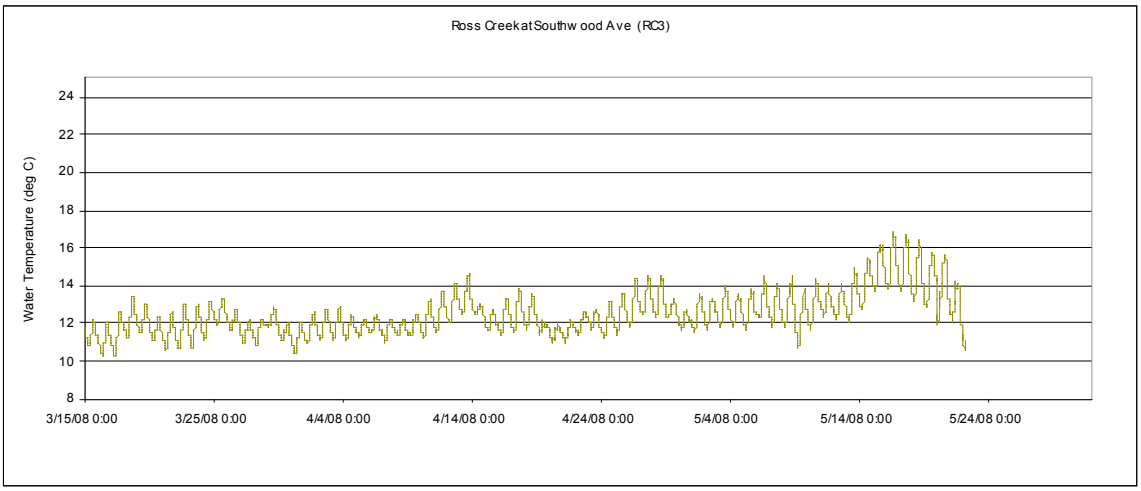


Figure 5. Temperatures recorded in Ross Creek at station RC3 (end of Southwood Ave).

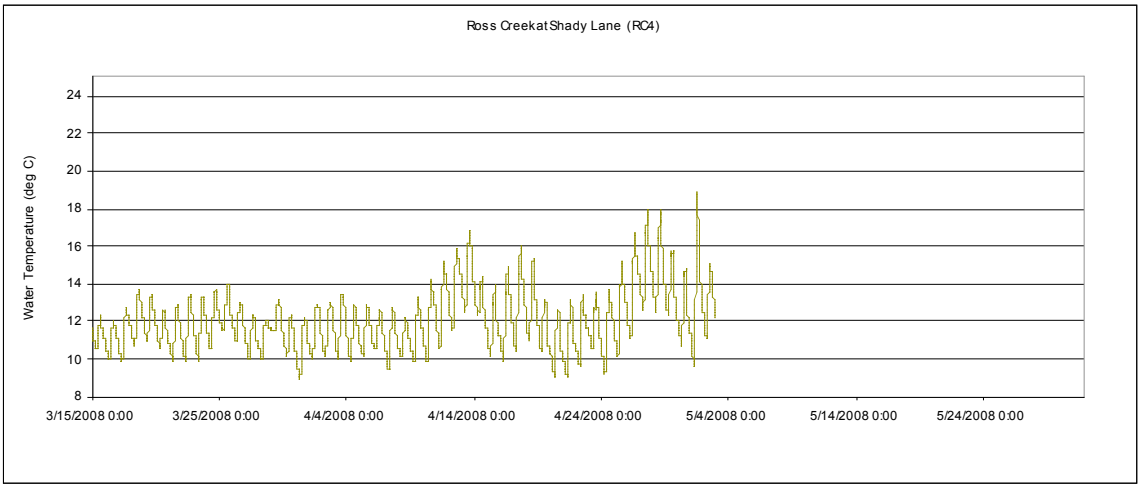


Figure 6. Temperatures recorded in Ross Creek at station RC4 (near Shady Lane).

Phoenix Lake

In order to better understand the temperature dynamics of Phoenix Lake, loggers were deployed in Phoenix Lake. Figure 1 shows the approximate location of the string of loggers. MMWD provided essential logistical support in both the deployment and ongoing maintenance of our equipment. Eric Ettlinger drives us to the lake from Sky Oaks Ranger Station, and assists us in reaching our deployment in a MMWD boat. He has helped us install the loggers, and download them. This project would not be possible without his help and the support of the resources staff, particularly Mike Swezy.

Logger Installation and Data Gathering: A string of six loggers was installed in Phoenix Lake on March 21, 2008. The loggers are attached to a rope with an 8-lb anchor at the bottom and three floats on the top. Loggers are attached at 2 ft, 8 ft, 14 ft, 20 ft, 26 ft, 30 ft, and 36 ft elevation measured from the bottom of the lake. To download the loggers, the rope is lifted from the lake into the boat, each logger is connected to the data shuttle, which reads and then empties the logger memory. After all six loggers are downloaded, the string is replaced at approximately the same

location. The loggers have been downloaded six times, on April 21, May 16, June 14, July 11, August 8, and September 4, 2008. Because MMWD staff is fully committed to conducting salmonid surveys in Lagunitas Creek until mid-October, we plan to do the next download in late October.

Results: Figure 7 is a graph of seven temperature profiles derived from logger data. Each profile is a snapshot in time of temperatures at six depths. The reservoir was weakly stratified at the beginning of our field season, and becomes more strongly stratified as time continues into the summer months.

We are interested in temperatures suitable for steelhead, which generally need summer rearing habitat with water in the range of 12° C to 17°C. From our field observations in Ross Creek, we now understand that when water is present in Ross Creek, temperatures are generally within this suitability range. However, during times when the flow in Ross Creek is not suitable for steelhead, it would need to be augmented by releases from Phoenix Lake. In order to sustain suitable habitat, these additional releases would have to come from lower lake elevations.

Returning once again to Figure 7, profiles indicate that surface temperatures are between 12˚C and 17˚C until early May when surface layers begin to warm significantly. During the critical months of May and June, water would have to be released from the lower levels of Phoenix Lake if suitable habitat were to be maintained in Ross Creek.

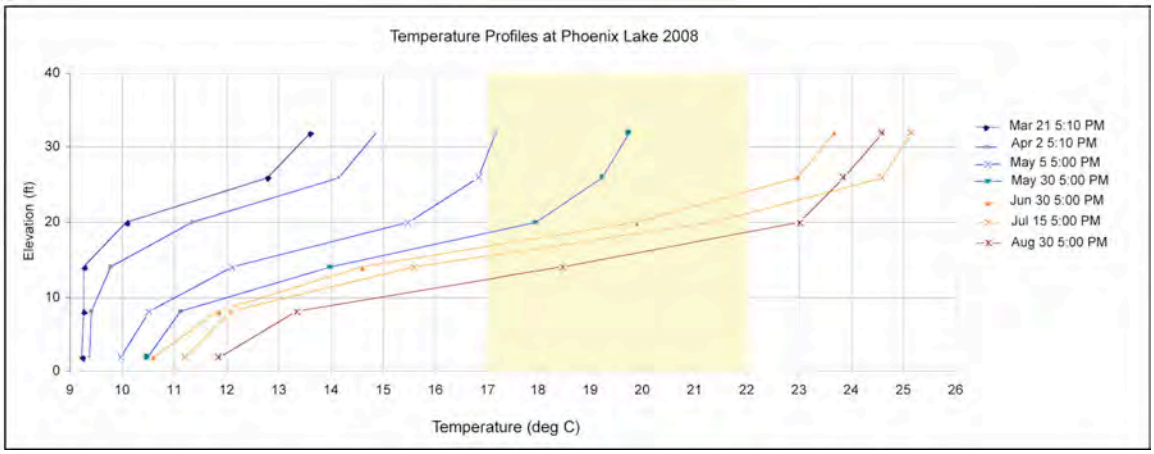


Figure 7. Temperature profiles in Phoenix Lake at seven times during the 2008 deployment period. The yellow highlight indicates the general range of temperature suitable for summer rearing habitat.

Figure 8 is another way of looking at this lake data. Time series plot of temperatures at all six elevations are shown. The figure suggests that if water were released from the dam at an elevation of 14 feet or lower, it is possible that cold temperatures could be maintained in Ross Creek.

In order to determine if such an approach is feasible it will be necessary to first determine the volume of water contained in the reservoir at these (lower) elevations. Current bathymetry was not available during our field season.

Additional analysis is also required to determine if releasing water from lower elevations will affect reservoir stratification. Releasing water from lower level outlets will reduce the volume of the cool water pool and may reduce the ability for the lake to remain stratified through the critical late spring and summer months.

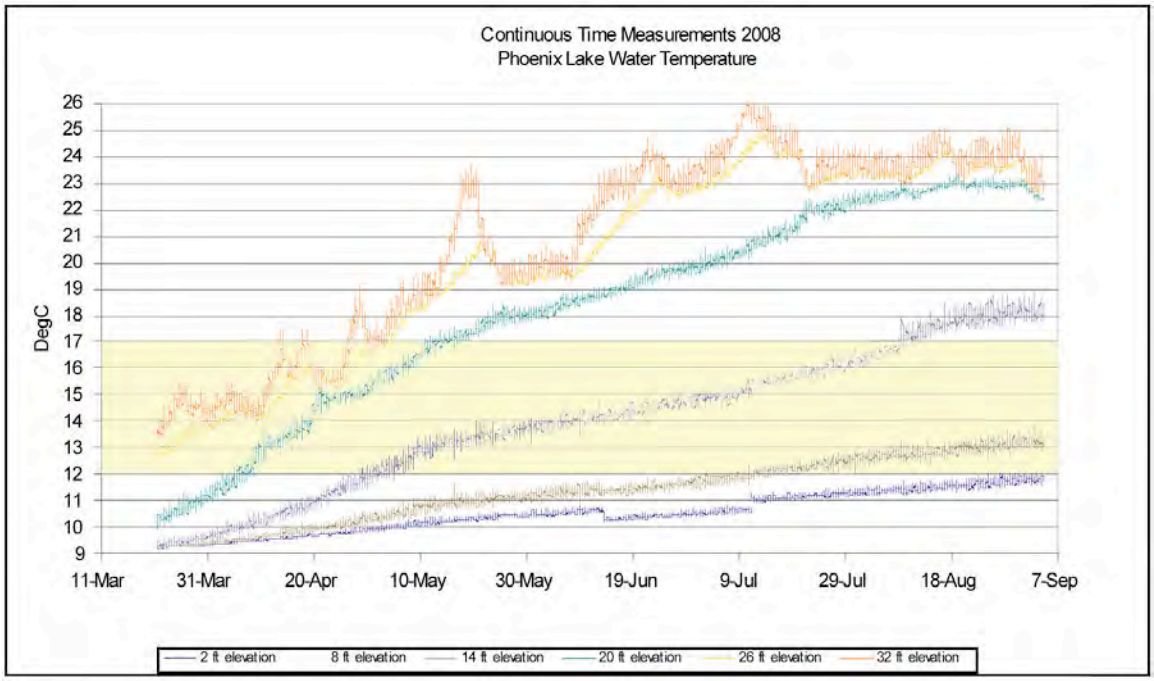


Figure 8. Temperature measurements in Phoenix Lake recorded at six depths during 2008. The yellow highlight indicates the general range of temperature suitable for summer rearing habitat.

We look forward to continuing this project with the equipment we bought with the W&F contribution.

Sincerely,

Cindy Lowney
Project Manager, Friends of Corte Madera Creek Watershed

Expense Report and Accounting

Wildlife and Fisheries Grant FY 2007-2008
Phoenix Lake/Ross Creek Temperature

Name of Organization: Friends of Corte Madera Creek Watershed

Address: P.O. Box 415, Larkspur CA 94977

Program Director: Cindy Lowney

Telephone Number:

Total Grant Award: $1,500

Period Ending: September 2008

Itemized List of Expenses	
	Cost
Permit (MMWD)	100.00
Hardware (anchors, rope, shackles, fasteners)	294.15
Onset: HOBO Water Temp Pro v2 Loggers (10)	1,020.00
Onset: HOBO Waterproof Shuttle	219.00
Onset: Software (HOBOware Pro	99.00
Onset: Shipping and Handling	27.00
Hydrolab Calibration and Repair	554.84
	$ 2,313.99

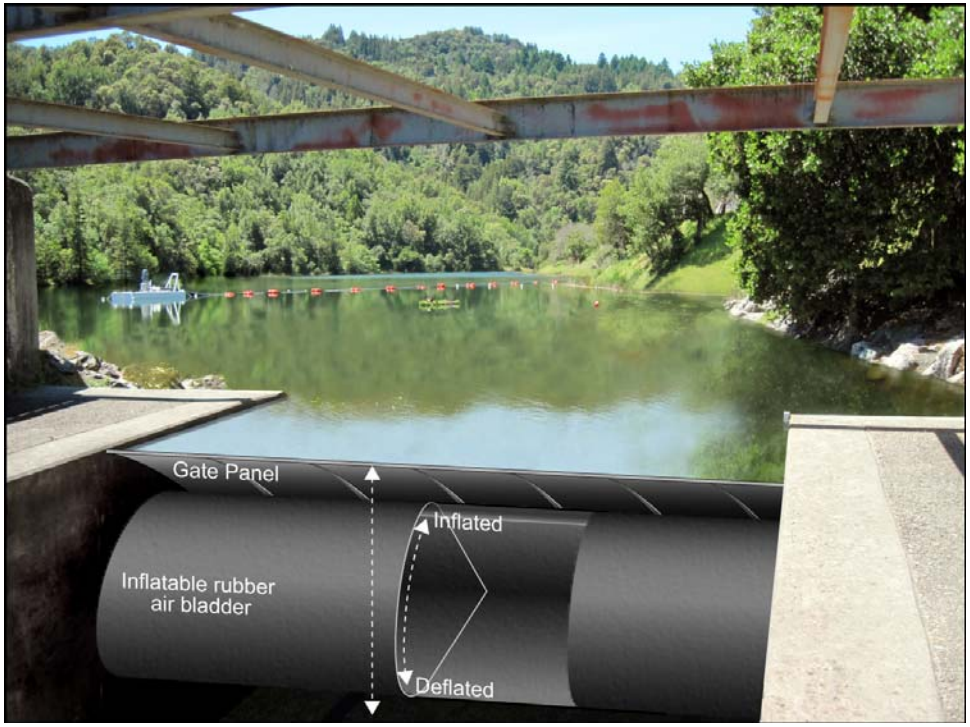
Total Paid by W&F	$1,500.00
Total Paid by Friends	813.99
Total Amount of Reimbursement Requested	0
Funds Remaining in Grant	0

Certification: I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and obligations are for the purposes set forth in the services agreement.

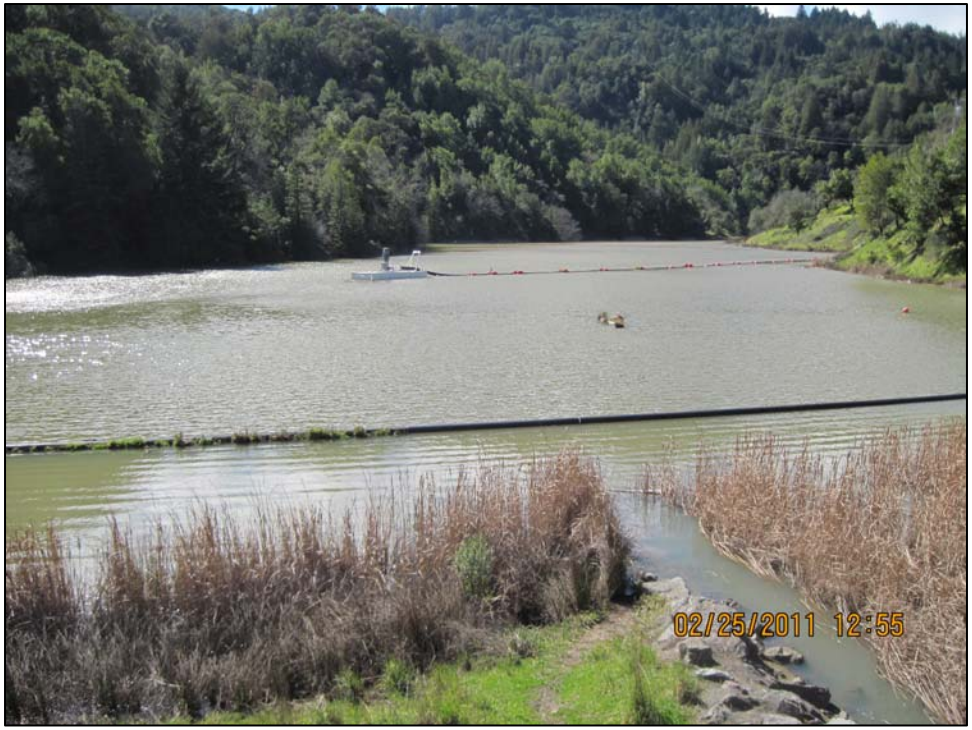
Signature of Finance Officer

Date

Phoenix Lake Photos



Phoenix Lake provides a variety of recreational opportunities for visitors from throughout the Bay Area. Photo shot from the dam crest showing the floating barge water supply pump station.

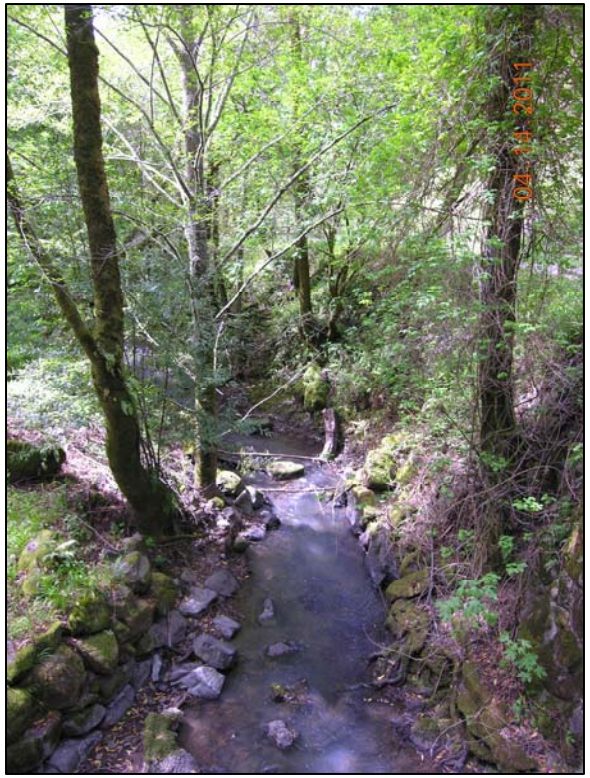


Grant proposal includes a 6-foot high pneumatic spillway gate that would increase lake storage capacity by 120 acre-feet providing both flood detention and water supply benefits.

Grant proposal includes seismic retrofit of the dam consisting of a compacted earthen buttress and drainage blanket on the downstream face and rows of auger cast displacement piles along the upstream face and dam crest. Photo shot looking north along the dam crest.

Grant proposal includes erosion protection on the upstream face to prevent sloughing during rapid drawdown for flood detention and raising of the dam crest by two feet to provide added freeboard. Photo shot looking south along the dam crest.

The existing 30-inch low-level drain pipe discharges to Ross Creek from its outlet vault situated at the downstream base of the earthen embankment dam. Grant proposal includes a new intake at el. 140 ft and a low-flow gate for precise control of cool water withdrawn from the lake hypolimnion.



Ross Creek below Phoenix Lake provides critical habitat for steelhead and other coldwater aquatic wildlife. Photo shot from Natalie Coffin Greene Park located below Phoenix Lake in Ross.