Blue Line Consulting

WITH

WATERWAYS CONSULTING

Oyster Creek

Sensitive Site Monitoring Report

prepared for

El Dorado Irrigation District

August 2009

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1.0 INTRODUCTION

Oyster Creek is a small tributary to the Silver Fork American River (Silver Fork), located approximately 20 miles southeast of South Lake Tahoe, California (Figure 1-1). Previous geomorphic investigations conducted during the relicensing of the El Dorado Hydroelectric Project (Project 184) documented instability in the Oyster Creek channel downstream of State Route (SR) 88 (ENTRIX, 2002). A Sensitive Site Investigation/Geomorphology Monitoring Plan (Monitoring Plan) (EID, 2008) was undertaken to determine the causes of instability in Oyster Creek and to identify areas of the creek in need of stabilization. This Monitoring Report presents the results of the Monitoring Plan. This report has been completed in partial fulfillment of requirements set forth in the U.S. Forest Service (USFS) 4(e) Condition No. 37.6 (USFS, 2003), and California State Water Resources Control Board Clean Water Act Section 401 Water Quality Certification Condition No. 13 (SWRCB, 2006) for Project 184.

This report is organized into 6 sections. Section 1 provides information on the project background, objectives and setting. Section 2 presents a description of the study area. Section 3 provides hydrologic and hydraulic analyses. Section 4 presents geomorphic investigations and analyses. Section 5 discusses the causes of instability in the channel and identifies the reaches in need of stabilization. References are provided in Section 6.

1.1 OBJECTIVES

Objectives for the study were established in the Monitoring Plan (EID, 2008) and are as follows:

- Determine the causes of instability in the channel;
- Determine channel reaches in need of restoration/stabilization;
- Determine the sediment transport dynamics and hydraulic forces affecting formation of the present channel and use this information as a basis of design for stabilization measures; and
- Consider and develop mitigation measures to be addressed in Stabilization Plans (prepared separately to address other Project 184 license conditions).

1.2 LOCATION AND SETTING

Oyster Creek originates at Oyster Lake, elevation 7,220 feet, in Amador County. Oyster Lake is fed by subsurface leakage from Silver Lake and by snowmelt. From Oyster Lake the creek flows north for approximately 2,800 feet then crosses under SR 88 through two 36-inch culverts. Downstream of SR 88 Oyster Creek enters El Dorado County, turns toward the west, and flows approximately 4,380 feet to its confluence with the Silver Fork at elevation 7,000 feet. Several unnamed tributaries to Oyster Creek emanate from the west face of Thunder Mountain and join the creek upstream of SR 88 (Figure 1-2). Downstream of SR 88 there is one main active tributary, which is referred to as the North Tributary. Several smaller drainages feed into the creek between SR 88 and the confluence with the Silver Fork.

The Oyster Creek watershed covers approximately 833 acres, or 1.3 square miles (Figure 1-2). The upper portion of the watershed lies within Amador County, and the lower watershed is in El

Dorado County (Figure 1-2). The upper watershed is predominantly steep, volcanic bedrock and talus terrain. The lower watershed is covered with shallow, unconsolidated glacial and alluvial deposits on moderate to gentle slopes and includes the Oyster Creek channel, riparian floodplain, adjacent meadow and uplands. Granitic outcrops are dispersed throughout the lower watershed and the southern portion of the upper watershed.

For the purposes of this document, the "study area" includes the entire Oyster Creek channel from Oyster Lake to the confluence with the Silver Fork. The "project area," as shown in Figure 1-2, includes Oyster Creek and associated riparian and wetland habitats from the SR 88 crossing, downstream to the end of low gradient meadow.

1.3 OWNERSHIP AND LAND USE

The entire Oyster Creek watershed is within the boundaries of the Eldorado National Forest (ENF), which is public land managed by USFS. The District has inholdings that include the Project 184 facilities and some adjacent lands. A significant portion of the project area is private land owned by George Majors (Figure 1-3). This landowner is planning to construct a caretaker's cabin in an upland location adjacent to the northern boundary of the project area (Figure 1-3).

Contemporary land uses in the watershed are predominately recreation, grazing and open space. Recreational improvements in the watershed include the Silver Lake Campground just downstream of Oyster Lake (operated by USFS), the Oyster Creek Picnic Area, and portions of the Silver Lake West Campground (operated by EID). Much of the watershed upstream of SR 88 is part of the ENF Cody Meadow Grazing Allotment (Figure 1-3). The history of grazing in the vicinity of the project area is discussed in a recent grazing management Environmental Assessment prepared by ENF (USFS, 2007) and is summarized in Section 5.1 of this document. Other significant land uses in the study area include a transportation corridor (i.e., SR 88).

2.0 SITE CHARACTERIZATION

The site characterization included field assessments to determine the extent and causes of instability in the channel. Specifically, the field assessments included:

- Topographic survey;
- Reach delineation;
- Habitat descriptions;
- Geomorphic assessments including:
  - bank stability
  - channel geometry
  - bed material composition
  - bedload sampling
- Sub-surface investigation in the vicinity of the bedrock step; and
- Soil sampling and analysis of streambank material.

Field assessments were conducted from August to September 2007, and May to June 2009. The methods and results of the topographic survey, reach delineation and habitat descriptions are provided in this section. The methods and results of the geomorphic assessment, sub-surface investigation and soil analysis are discussed in Section 4, Geomorphology.

2.1 TOPOGRAPHIC SURVEY

HJW Geospatial, Inc. of Oakland, California conducted an aerial topographic survey of the project area. Six ground control points were established, and then aerial imagery was captured on August 3, 2007. A topographic map with 2-foot contours was developed using the ground survey control and ortho-rectified photography. Figure 2-1 shows the results of the aerial topographic survey and a longitudinal profile of the Oyster Creek channel. River stationing (RS) shown along the center line of the main channel is provided to facilitate the communication of information.

2.2 REACH DELINEATION AND DESCRIPTIONS

The initial task of the site characterization was delineating stream reaches. Delineation of stream reaches was based on variability in factors such as geology, channel or valley morphology (e.g., slope or confinement), riparian and/or aquatic habitat. Reaches were delineated beginning at the Oyster Creek-Silver Fork confluence and continued to Oyster Lake. A total of 12 reaches were delineated in the study area (Figure 2-2) and are described as follows.

Reach 1: Oyster Creek-Silver Fork Confluence to Extent of Bedrock Control (850 feet). At the Oyster Creek-Silver Fork confluence, both channels are relatively steep, and controlled by granite bedrock. The confluence itself is occluded by dense vegetation (Photo 1). Above the confluence, the Oyster Creek channel is relatively steep (~4.0 %), with large cobble, boulders and granite outcrops forming the bed. The channel has good connectivity to the floodplain and is only slightly entrenched (Photo 2). Mountain alder (*Alnus incana ssp. tenuifolia*.) forms a dense canopy along the riparian corridor, providing nearly contiguous shading of the stream.

Mixed conifer forest, including lodgepole pine (*Pinus contorta*), red fir (*Abies magnifica*) and Jeffrey pine (*Pinus jeffreyi*) dominate the floodplain overstory. Understory vegetation in the riparian area includes dogwood (*Cornus* sp.), snowberry (*Symphoricarpus* sp.) and ferns (species not identified). Large woody debris (LWD), ranging from 4 to 30 inches in diameter, is abundant in the channel (Photo 3). The LWD appears to be recruited locally, and transport through the reach is limited. At the upstream end of Reach 1 there is an exposed bedrock shelf in the channel (Photo 4). This marks the boundary between Reaches 1 and 2 and is the last point that bedrock is observed in the channel until the major step at the Reach 5/6 boundary.

Reach 2: Aspen Grove (1,055 feet). In Reach 2 the channel gradient decreases (~ 1.8 %) and sinuosity increases. The channel bed is composed of gravel with small cobbles and a few scattered boulders. Riffles and runs are the dominant aquatic habitat features; pool habitat is limited. In the lower portion of Reach 2 alder is dense along the channel banks (Photo 5) and mixed conifer forest dominates the floodplain. In the upper portion of Reach 2 quaking aspen (*Populus tremuloides*) replaces conifers as the dominant species in the tree stratum; aspen and alder are co-dominant along the channel banks (Photo 6). Overall, Reach 2 provides high quality riparian habitat. The creek has good floodplain connectivity and bank stability, shading is provided by native vegetation species, and large woody debris is abundant. The lack of aquatic habitat diversity (i.e., few pools) may limit resting and rearing habitat for fish.

Reach 3: Forest-Meadow Transition (305 feet). Reach 3 is a short transition from the forested floodplain of Reach 2 to the lower portion of the Oyster Creek meadow. Being predominantly gravel/cobble with scattered boulders, stream substrate is similar to Reach 2. This reach has good pool-riffle development and channel-floodplain connectivity. At the upper portion of the reach the left bank remains forested with conifers and quaking aspen, whereas the right bank is meadow with Lemmon's willow (*Salix lemmonii)* growing in the channel and on the meadow surface.

Reach 4: Lower Meadow (865 feet). The channel in Reach 4 is low gradient (0.9%), and deeply incised within the adjacent riparian meadow. The flood-prone channel is moderately sinuous. The streambed material is predominately large gravel and cobble; the banks are composed of fines. Aquatic habitat is primarily riffles and runs. Vegetation in the adjacent meadow is dominated by mesic grasses and forbs interspersed with willows; few wet meadow species (e.g., sedges or rushes) are present. The channel has a narrow inset floodplain dominated by sedges and rushes, providing stability at moderate flows. Near the upstream portion of the reach the banks are forested with lodgepole pine, with alder recruitment occurring; channel geometry remains similar to the downstream portion of the reach.

Reach 5: Middle Meadow (North Tributary to bedrock step, 820 feet). A tributary on the right bank that comes from the north marks the downstream end of Reach 5. This is the largest tributary to Oyster Creek below SR 88. The lower portion of the tributary is incised to the base level of Oyster Creek (Photo 7). Approximately 200 feet upstream of the confluence there is a 4-foot high active headcut in the main tributary channel (Photo 8) and several smaller headcuts migrating from the channel into the meadow. Upstream of the headcut the tributary is at grade with the meadow surface and the channel has the characteristic of a vegetated swale.

Reach 5 is the most deeply incised reach of Oyster Creek (Photo 9). Sinuosity in the flood and bankfull channels is moderate. Riffles and runs are the dominant aquatic habitat, however, there are deep pools in the more sinuous portions of the channel and in locations where woody vegetation induces bed scour. The bed is composed primarily of large gravel; little LWD is present in the channel. Sedges and rushes line the inset floodplain, and alder is common at bankfull stage. Conifers, mostly lodgepole pine, are common along the banks. The upstream end of Reach 5 is marked by an 8-foot bedrock step (Photo 10). A small tributary enters on the left bank just downstream of the bedrock step.

Reach: Upper Meadow (1,330 feet). Reach 6 is highly sinuous, low gradient, and has a well developed inset floodplain. Riffles and runs are the dominant aquatic habitat, with a few large scour pools in the channel. The bed is composed primarily of large gravel and cobble, and appears well armored and vertically stable. No major grade breaks or knickpoints were observed. LWD is present in the upstream portion of the reach and is comprised mostly of large conifers recruited locally through bank failure (Photo 11). Point bars have formed throughout the reach with dense herbaceous (e.g., sedges, rushes) vegetation cover. Woody riparian vegetation species (e.g., alder and willows) are colonizing the point bars along with lodgepole pine. Steep cutbanks have formed opposite the point bars because the channel is incised and flowing through erodible bank material (Photo 12).

Reach 7: Upper Meadow to SR 88 (450 feet). In the upper meadow channel slope increases (2.5 %), sinuosity decreases, and incision is not as severe. Bank height gradually decreases in the upstream direction and floodplain connectivity is reestablished. The bed is composed primarily of cobble and boulders. LWD is abundant throughout the reach. The channel banks are dominated by willow, and aspen/mixed conifer forest occupies the floodplain.

Reach 8: SR 88 to Small Tributary (110 feet). Oyster Creek crosses under SR 88 in two 36-inch corrugated metal pipes (Photo 13). The bed is composed primarily of large cobble and boulders with gravel in the interstices. The channel flows through dense lodgepole pine forest. Some banks are undercut with exposed tree roots. Approximately 100 feet above the crossing a small tributary enters on the right bank, which marks the upstream end of this reach.

Reach 9: Small Tributary to Thunder Mountain Tributary (650 feet). In Reach 9 the channel is relatively steep (3.7%). The bed is composed primarily of large cobble with gravel. Occasional boulders in the banks add variability to the channel planform. There is a considerable amount of downed wood crossing the channel. The channel banks are dominated by herbaceous species and aspen/mixed conifer forest occupies the floodplain. At the upstream end of the Reach 9 the main tributary from Thunder Mountain joins the Oyster Creek channel. Technically the Thunder Mountain tributary could be considered the mainstem of Oyster Creek because the stream length is greater than the length of the branch that emanates from Oyster Lake. However, the Oyster Lake branch has a greater channel width and conveys a larger portion of the stream base flow than the Thunder Mountain tributary.

Reach 10: Thunder Mountain Tributary to Meadow above SR 88 (305 feet). Reach 10 is a short segment of stream with characteristics similar to Reach 9. Vegetation is similar to Reach

9, but aspen trees are not present. At the upstream end of Reach 10 there is a boulder step that transitions to a riparian meadow.

Reach 11: Meadow above SR 88 (680 feet). The riparian meadow above SR 88 has relatively moderate slope and low sinuosity. Riffle-run habitat dominates with a few small step-pools. The banks are well vegetated with sedges and rushes. A few woody plant species are scattered throughout the meadow (Photo 14). The channel has good connectivity to the floodplain and, unlike the meadow downstream of SR 88, there is no evidence of incision or bank erosion. A tributary enters the main channel near the upstream end of the reach. Historically the confluence of this tributary with Oyster Creek was in Reach 4, but this tributary was captured by the formation of the leakage channel (Figure 2-2).

Reach 12: Meadow above SR 88 to Oyster Lake (1,155 feet). Reach 12 has considerable variability. At the downstream end the riparian vegetation is thick, dominated by alder and ferns. There is a tributary at the downstream end of the reach that contributes significant flow to the mainstem. This tributary emanates from several springs likely fed by leakage from Silver Lake. The middle portion of the reach is steeper, with boulders throughout the channel. Oyster Creek flows through Silver Lake campground, just below Oyster Lake (Photo 15). As mentioned in previous documents, Oyster Lake is formed from leakage of Silver Lake. Old tree stumps in the lakebed provide evidence that this area was much drier in recent times.

2.3 HABITAT DESCRIPTION

2.3.1 Aquatic habitat

The aquatic habitat in the study area is discussed in the reach descriptions. In general, the channel is dominated by riffle-run habitat with scattered pools. In steeper portions of the channel there are step-pools, and in the more sinuous sections scour pools have developed. LWD is recruited locally, primarily due to bank failure. Transport of LWD is likely occurring only during large, infrequent flood events.

Fish habitat in Oyster Creek was characterized during the relicensing process. The assessment described shallow, fast runs as the prevailing habitat type, followed by riffles, short pools and cascades. The assessment noted abundant spawning gravel exists throughout the creek (FERC, 2003).

2.3.2 Terrestrial habitat

Vegetation

The study area supports a diverse mosaic of vegetation communities. Reaches 1, 9 and 12 are mixed conifer forest with woody shrubs (e.g., blackberry, snowberry, dogwood species), ferns and herbaceous species in the understory. Alder is a significant component of the riparian shrub stratum. In Reach 2 there is a thriving aspen grove, which is typical of the Quaking aspen/California false hellebore association described by Potter (2005). This plant association typically occurs along the margins of meadows between 6,000 and 8,000 feet in the Sierra Nevada, as along Oyster Creek. Aspen trees are also dispersed throughout Reaches 3, 7 and 9.

In Reaches 4, 5 and 6, vegetation is characteristic of the Lemmon's willow/Sedge association described by Potter (2005). The meadow in Reach 4 is desiccated, as are portions of the meadow adjacent to the stream in Reach 5. The desiccation is a result of channel incision and subsequent decrease in the groundwater elevations and soil saturation. In desiccated portions of the meadow, sedge species have been replaced by willowherb (*Epilobium* sp.) as the dominant vegetation in the herbaceous stratum. Willows are able to persist in the desiccated meadow because their roots can access water at much greater depths than the sedge species.

3.0 HYDROLOGY AND HYDRAULICS

3.1 HYDROLOGY

3.1.1 Background

Surface water hydrology in Oyster Creek is a function of natural hydrologic processes and leakage from Silver Lake. The majority of precipitation falls as snow from November to April and the highest volume of runoff (excluding leakage) is generated by spring snowmelt, typically occurring between April and June. Annual peak discharge on Oyster Creek and elsewhere in the Sierra Nevada is driven by two different processes: 1) Rain-on-snow events that are associated with entrainment of warm, subtropical moisture from the eastern Pacific Ocean and 2) peak snowmelt events. Typically, rain-on-snow events are of a higher magnitude and occur during the winter months, whereas the peak snowmelt-driven events are of a lower magnitude and occur in spring. This hydrologic setting creates a bimodal distribution of flood events i.e., there is a population of floods associated with snowmelt events and a distinct population of floods generated from rain-on-snow events that occur, on average, once every 10 years in the region.

3.1.2 Watersheds

For the purposes of the hydrologic analysis the Oyster Creek watershed was divided into two sub-basins to quantify hydrologic conditions throughout the project area. Sub-basin A (524 acres) includes the entire upper watershed, with the exception of the drainage area that contributes to the North Tributary. Sub-basin B (309 acres) encompasses the area of the upper watershed associated with the North Tributary, and the drainage area below SR 88 (Figure 1-2). The North Tributary, the main drainage feature of Sub-basin B, conflues with Oyster Creek at the Reach 4/5 boundary (Figure 2-2).

3.1.3 Available Data

Hydrologic data relevant to the project site were gathered from the U.S. Geological Survey (USGS), EID, the Project 184 Environmental Impact Statement (FERC, 2003), and the California Data Exchange Center (CDEC). Available data includes Silver Lake stage data, mean daily discharge for Oyster Creek at SR 88 and the outlet of Oyster Lake, and peak flow data from nearby gages with similar drainage area to Oyster Creek.

3.1.4 Analysis

Flood Frequency Analysis

Flood frequency analysis is used to calculate the statistical probability that a flood of a certain magnitude is likely to occur in any given year. It is a useful tool for understand the magnitude and frequency of discharges associated with peak snowmelt or rain-on-snow events, and how those discharges affect channel geometry and bedload transport rates. The best way to evaluate peak flow hydrology using flood frequency analysis is through a long-term record of annual peak flows measured on the stream of interest. Since no long-term peak flood records are available for Oyster Creek, a flood frequency analysis was developed using peak flow data available for nearby gages and was applied to Oyster Creek. This approach is often used at sites where a long-term record of peak flows is unavailable, with the assumption that the gages used and applied to the creek of interest exhibit similar basin characteristics such as geology, precipitation and response times. The gages used to extrapolate flood frequency for Oyster Creek were Silver, Kirkwood, Plum and Picket Pen Creeks. These watersheds are in the project vicinity (Figure 1-1), of similar size to Oyster Creek, and are unrestricted (i.e., there are no dams or impoundments that regulated peak discharges). Table 3-1 provides summary statistics for the stream gages used in the flood frequency analysis.

Table 3-1. Stream gage data used for flood frequency analysis

Stream Gage	Watershed Area (mi^2)	Period of Record used in Analysis
Picket Pen (USGS 11440850)	0.49	1963-1973
Kirkwood Creek (USGS 11437560)	3.62	1963-1974
Plum Creek (USGS 11440500)	7.32	1923-1939
Silver Creek (USGS 11441500)	27.5	1926-2006

Flood frequencies were developed for these gages using USGS PeakFQ software following the Bulletin 17B procedures (USGS, 1982). A cubic foot per second (cfs) per square mile calculation was developed for each of the four watersheds for each return period. An average value for each return period was then used to calculate peak flows for Oyster Creek (Shed A and Shed B) for each return period. Table 3-2 lists the estimated peak flow rates for a 1- to 100-year return period. To validate the results, peak flow values were also calculated using the USGS regional regression equations for the Sierra Nevada (Waananen and Crippen, 1977) for each return period.

Table 3-2. Flood frequency analysis for the Oyster Creek

	Discharge from Flood Frequency Analysis		Estimated Discharge Using Regional Regression Equations	
Return Period (years)	At SR 88 (Sub-basin A)	At D/S end of Project Site (Sub-basins A+B)	At SR 88 (Sub-basin A)	At D/S end of Project Site (Sub-basins A+B)
	(cfs)			
1	6	9	NA	NA
1.5	20	32	NA	NA
2	28	45	22	33
5	58	92	66	97
10	86	137	102	148
25	134	213	171	246
50	180	285	232	333
100	235	373	332	473

The regression equation results are very similar to the flood frequency analysis results for the more frequent events. However, the regression equations tend to predict higher values for the less frequent events. Since the regression equations were developed for the entire Sierra Region and the flood frequency calculations were developed from the gages in the project vicinity, we consider the flood frequency analysis to be a better prediction of peak flows for the project site.

Annual Hydrograph

To understand the contribution of leakage from Silver Lake to the annual hydrograph for Oyster Creek, mean daily flow data from the EID gage at SR 88 (A-24-A) were combined with estimates of leakage from Silver Lake. Mean daily discharge data are available for Oyster Creek at SR 88 for Water Years (WY) 2001 through 2003, with partial data for WY 2004. These data represent the combined discharge of tributaries upstream of SR 88 (Sub-Basin A) plus leakage. Mean daily leakage flows were estimated using mean daily stage data for Silver Lake and the Silver Lake stage-leakage relationship developed during the Project 184 relicensing (Table 3-3).

Table 3-3. Estimated leakage from Silver Lake into Oyster Creek (FERC, 2003)

Silver Lake Stage[1]	Flow at Oyster Creek Gage (at Oyster Lake outlet)		Estimated Total Leakage	
(feet)	(acre-feet/month)	(cfs)	(acre-feet/month)	(cfs)
5	0	0	71	1.2
7	0	0	100	1.7
10	0	0	171	2.9
13	0	0	295	5.0
15	90	1.5	430	7.2
18	280	4.7	652	11.0
20	460	7.7	800	13.4
22.7	800	13.4	1,000	16.8

1. Silver Lake stage is relative to the invert of the discharge pipe; when Silver Lake is at full pond, the water is 22.7 feet above the invert.

An estimate of unimpaired flow for Oyster Creek was developed by subtracting the leakage from the measured mean daily discharge at SR 88. The results are presented in Figure 3-1. For all three years of data, leakage represents a significant portion of total discharge. In addition, leakage from Silver Lake into Oyster Creek has resulted in changes in the annual hydrograph. The magnitude of the peak has increased, and the peak has been pushed from May, which is the historic snowmelt peak, to June, when Silver Lake is at its maximum stage. Table 3-4 provides a summary, by month, of the results.

Table 3-4. Estimated mean daily discharge, by month, in Oyster Creek			
Month	Estimated Leakage Discharge[1]	Discharge @ SR 88[2]	Percent due to leakage[3]
	(cfs)		(%)
Jan	1.7	1.4	~100
Feb	1.8	2.3	78
Mar	2.8	3.1	90
Apr	5.7	5.7	100
May	10.2	12.9	79
Jun	14.9	17.2	87
Jul	14.4	14.4	100
Aug	11.4	11.9	96
Sept	8.2	8.3	99
Oct	3.6	3.6	100
Nov	2.1	1.1	~100
Dec	1.6	0.9	~100

1. Leakage discharge derived from mean daily Silver Lake stage data (1999-2007) using the stage-discharge relationship developed during Project 184 relicensing (FERC, 2003).
2. Discharge at SR 88 based on mean daily records from A-24-A (2000 – 2004); partial data for 2004.
3. Leakage discharge values are estimates based on regression analysis of leakage rates reported in Table 3-3. This accounts discrepancies from discharge measurements at SR 88.

3.2 HYDRAULIC ANALYSIS

3.2.1 Model Set-up

The hydraulic analysis for the project site was performed using HEC-RAS version 4.0 Beta (USACE, 2006). The HEC-RAS model geometry was developed from cross-sectional survey data collected by Swanson Hydrology + Geomorphology (SH+G) in September 2007 and aerial topographic data of the project area developed by HJW GeoSpatial. An existing conditions hydraulic model was developed for Reaches 4 through 7 using 26 cross-sections, spaced at approximately 150-foot increments, with additional sections added near the bedrock step (RS 35+00) and the SR 88 crossing. The model extends approximately from 100 feet upstream and 2,900 feet downstream of SR 88.

The downstream boundary condition was set using the normal depth method. The energy slope was set to 0.009 at the downstream boundary condition. Expansion and contraction coefficients for most cross-sections were set to 0.4 and 0.2 to account for energy losses due to channel sinuosity and varying geometry between cross-sections. The coefficients were increased to 0.5 and 0.3 for the cross-sections immediately upstream and downstream of SR 88. Culvert and road details for the SR 88 crossing were measured in the field by SH+G and were supplemented with topographic data from the aerial survey. Roughness values (Manning’s n) were chosen from field-based observations of the channel and floodplain surfaces. Selections were based on local conditions such as bed substrate, vegetation density, over-bank conditions, and depth under the 100-year flow condition. Roughness values were set at 0.035 for the channel and 0.1 to 0.15 for the channel banks and floodplain containing riparian vegetation (McCuen, 2004).

3.2.2 Flows

Table 3-5 shows the streamflows analyzed with the hydraulic model.

Table 3-5. Flows analyzed with the hydraulic model

Flow Event	At SR 88	D/S of North Tributary
	(cfs)	
Maximum leakage	17	17
[1-yr + mean spring leakage][1,2]	18.5	21.5
2-yr	28	45
[1.5-yr + mean spring leakage]	32.5	44.5
5-yr	58	92
10-yr	86	137
25-yr	134	213
50-yr	180	285
100-yr	235	373

1. Leakage discharge of 12.5 cfs is the mean of the average monthly leakage for May and June, which corresponds to the period of time when peak snowmelt is likely to occur.

2. Flow events shown in brackets were not analyzed because of their similarity to other modeled flows. Discharges for these flow events are included in the table for reference purposes.

3.2.3 Results

Results of the hydraulic analysis are presented graphical and tabular format in Appendix A. Throughout the entire project area all flows are confined within the incised channel; even the modeled water surface elevation (WSE) of the 100-year flood does not reach the meadow surface. The WSE modeled for the 2-year event at SR 88 (i.e., 28 cfs) corresponds well with bankfull flow indicators identified in the field, suggesting the model is a reasonably good predictor of hydraulic conditions for the lower end of flows modeled. Over the entire project area velocities range between approximately 2 and 6 foot per second (fps) for the estimated 2-year event and between about 3 to 10 fps for the 100-year discharge. Predicted shear stress ranges between approximately 0.2 and 2 lb/ft^2 for the 2-year discharge and between about 0.2 and 3.5 lb/ ft^2 for the 100-year event. Maximum shear stress and velocities occur at the bedrock step (Appendix A).

Fischenich (2001) reports permissible velocity and shear stress for sandy loam soils to be 1.75 fps and 0.3 to 0.4 lb/ft^2, respectively. These values are exceeded at most modeled cross-sections during all flow events, suggesting that even low flows can cause erosion of streambanks not protected by vegetation. Permissible velocity and shear stress reported by Fischenich (2001) for various bioengineering treatments, such as brush layering, coir rolls and willow stakes, exceed the hydraulic forces generated in the channel for nearly all flow events. The Oyster Creek Stabilization Plan, which is being completed in fulfillment of separate Project 184 license conditions, will incorporate these types of bioengineering treatments for bank protection.

4.0 GEOMORPHOLOGY

The geomorphic characterization of Oyster Creek involved interpretation of the geologic setting, historical documentation (e.g., maps and aerial photos) and the contemporary channel morphology. These topics are discussed in the following sub-sections.

4.1 GEOLOGIC CONTROLS

4.1.1 Geology

The geologic setting of the Silver Lake region reflects the geologic history of the Sierra Nevada Mountains. Following erosion of the ancestral Sierra Nevada Mountains, the plate boundary between the North America and Pacific plates changed from a subduction zone with compressional force tectonics to the lateral movement of the San Andreas Fault system and extensional tectonics for much of the western United States, including the Basin and Range Province. This change allowed for the uplift of the granitic core of the Sierra Nevada, forming much of the present mountain range. As the late Tertiary period unfolded, continued uplift of the Sierra Crest and formation of the Basin and Range to the east allowed for extensive volcanic activity in the Sierra Nevada. Much of the volcanic deposits are still exposed in the headwaters of the Oyster Creek basin as andesite and dacite flows, breccias, lahars and volcanoclastic flows.

Following the cessation of volcanic activity, the major landform building process consisted of a series of three distinct glacial periods in this region of the Sierra Nevada. The most significant of these are the Tahoe Glacial Period, believed to have peaked 60,000 years before present (ybp), and the smaller, more recent Tioga Stage, which peaked 30,000 ybp. During both of these periods glacial ice, formed along the higher peaks, accumulated in the major river valleys, causing extensive erosion of the volcanic deposits, leaving the batholithic material from the previous era exposed and creating a landscape dotted by lakes, glacial till and, in the lower elevations, moraines. Subsequent erosion of the volcanic terrain in the upper watershed produced Pleistocene and Holocene alluvial basins, such as the meadow downstream of SR 88.

The topography of the meadow surface downstream of SR 88, which mimics the downstream direction of Oyster Creek, suggests that after last peak glacial time (18,000 ybp) the meadow was a lake or *tarn* in the late Pleistocene and early Holocene epochs (10,000+ to 5,000 ybp). The lake subsequently filled with alluvial sediments to create the contemporary meadow surface. After post-glacial period filling, prehistoric Oyster Creek was likely a small alluvial channel confined by dense vegetation and at grade with meadow surface. Tributaries emanating from the northeast traversed the meadow in shallow, vegetated swales, and during flood events flows quickly spread overbank, flooding the meadow. Coarse sediment from the drainages and steep hillslopes above the meadow was delivered through alluvial transport and colluvial debris-flow processes. Coarse material was deposited near the head of the meadow (i.e., the proximal alluvial fan surface), and finer sediments were transported throughout the system. In the contemporary channel bedrock exposures provide localized grade control and influence channel planform.

4.1.2 Soils

Soils in the study area are mapped as Andic Cryumbrepts- Lithic Cryumbrepts Association; Aquepts and Umbrepts, 0 to 15 % slopes; Cryumbrepts Association, 5 to 50 % slopes; Lithic Cryumbrepts, 15 to 75 % slopes; and rock outcrop (NRCS, 2007). All of these soils are inceptisols, with variation occurring predominately due to topography, parent material and moisture regime. Inceptisols are a relatively broad and widespread soil order. In general, inceptisols in the study area are shallow, relatively young soils. Soil development is slowed by low temperatures, erosion and, in some cases, resistant parent material. The dominant soil unit in the project area is the Aquepts and Umbrepts unit. These soils form in alluvium along drainages. Near surface soil textures are silt loam or sandy loam. The soils are classified as "well drained". No erodibility index is provided in the soil survey, but it is evident that the soils along Oyster Creek channel are highly erodible.

Soils Analysis
A composite soil sample was collected from a cut bank in Reach 6 to investigate the properties of the soil that cause it to be prone to erosion. The sample was sent to Wallace Laboratories in El Segundo, California, for analysis. The laboratory analyses included particle size distribution (texture) by hydrometer and standard agricultural suitability. The results of the analyses are included in Appendix B for reference. Soil texture was determined to be sandy loam comprised of 63 % sand, 26.5 % silt and 10.5 % clay. The high sand content in the soil results in poor particle cohesion, causing the soil to be prone to erosion. Other soil parameters were in a normal range, but pH was relatively low (5.38). Low pH in the soil is likely due to leaching of base cations, and/or pyrite or sulfur species in the parent material.

4.2 HISTORICAL DOCUMENTATION

Interpretation of historical documentation is often useful for identifying morphological changes in streams. Historical maps, records and aerial imagery of the study area were analyzed for changes in channel morphology (e.g., planform) that may be indicative of land use impacts and/or natural processes (e.g., floods).

The earliest map obtained that depicts the project area is the 1896 USGS Placerville Folio (Geologic Atlas). The topographic map included in the folio was completed prior to the contemporary Silver Lake dam (1929). Oyster Lake, created from Silver Lake leakage, is noticeably absent from the map (Figure 4-1). In addition, the channel appears to meander along the old SR 88 route, which differs from its current alignment.

As-built plans for SR 88 improvements completed circa 1950 show that the alignment of the channel was modified during construction of the modern roadway (Figure 4-2). Notes on the as-built plans call for "proposed channel change" and "construct inlet ditch" with an excavation volume of 10 cubic yards. It is evident from the as-built plans that the channel was straightened at the crossing. The note "construct inlet ditch" suggests that the culvert invert elevation was set below the existing channel thalweg. Potential implications of this modification and other effect of the SR 88 crossing are discussed in Section 5.

Historical aerial photographs from 1976 to 1996 were obtained from the USFS office in Placerville. These images are provided in Appendix C for reference. The series of historical aerial photos beginning in 1976 do not appear to depict any significant changes in channel morphology or land use.

4.3 GEOMORPHIC ASSESSMENT

The geomorphic assessment of Oyster Creek included multiple investigations aimed at evaluating the stability of the contemporary channel. The assessment included analysis of bank stability, channel geometry, bed grain size distribution, bedload sampling and bed mobility modeling. The methods and results of these assessments are discussed in the following subsections.

4.3.1 Bank Stability

The bank stability evaluation was conducted along the entire length of Oyster Creek (i.e., from the Silver Fork to Oyster lake) using the Bank Erosion Hazard Index (BEHI) approach developed by Rosgen (1996). This method was selected because it was used for a previous assessment on Oyster Creek completed by Bill Lydgate (2002). Repetition of the BEHI method is useful for determining trends in bank stability.

The BEHI method is based on the assumption that the ability of a stream bank to resist erosion is primarily determined by:

- The ratio of streambank height to bankfull stage;
- The ratio of riparian vegetation rooting depth to streambank height;
- The degree of rooting density;
- Streambank angle;
- Bank surface protection afforded by debris, vegetation, or resistant material such as boulders or bedrock; and
- The composition of streambank materials.

These components were evaluated in the field by estimating or measuring reach length, bank height, bankfull depth, bank angle, percent bank face protected (by vegetation), percent root density, rooting depth from top of bank, and bank composition (e.g., particle size). These parameters were measured at one cross-section in each reach that was representative of the stream bank condition and channel geometry over the entire reach.

The bank erosion potential for each stream segment is determined based on the rating system developed by Rosgen (1996). Adjustments are made based on bank material to produce a final rating for each stream segment. The final score is then assigned an erosion potential rating of very low, low, moderate, high, very high or extreme. Results for each survey segment were projected on a GIS layer and are displayed on an aerial photograph (Figure 4-3).

The results presented in Figure 4-3 indicate that bank erodibility/stability varies significantly within the study area. At the downstream end of the project area in Reaches 1 and 2 the BEHI is "low". In these reaches the channel banks are well protected and not at risk of significant erosion. In Reach 3 BEHI increases to "moderate" as a result of channel entrenchment and bank angle. In the lower and middle meadow (Reaches 4 and 5) the BEHI rating is "high" due to channel entrenchment, fine grained bank material and shallow rooting depth. It is our opinion that the BEHI method overestimates the actual erosion potential for these reaches because the rating system evaluates the entire bank profile, whereas only the lower half of the bank is susceptible to erosion due to streamflow (Appendix A, Hydraulic Modeling Results). The lower portions of the banks that are inundated during small to moderate floods are well vegetated with sedges (Photo 9). The middle portions of the bank that have shallow-rooted vegetation may be susceptible to erosion during larger floods, but the overall rating of 'high" may overstate the erosion potential for banks in these reaches.

In Reach 6 the BEHI rating is "moderate" because the banks are more protected by vegetation than in Reaches 4 and 5. However, it is important to note that this rating represents the general condition over the entire reach and that there are discrete areas (i.e., cutbanks on the outer bends of meanders) where erosion potential is extreme (See cutbanks on Figure 4-4). Upstream of the meadow (Reaches 7 through 12) BEHI rating is either "low" or "moderate". No signs of significant recent bank erosion were observed in these reaches.

Lydgate's survey in 2002 rated BEHI as "high" downstream of SR 88 and "very low" upstream of SR 88. These observations are generally consistent with the results of this assessment. It is important to note that the assessment conducted by Lydgate was performed at a coarser spatial scale because that study covered a much larger geographic area (i.e., the entire Project 184 area) than the survey conducted in 2007.

4.3.2 Headcuts

Headcuts are abrupt changes in channel profile that are indicative of potentially unstable geomorphic conditions. Headcuts migrate in the upstream direction until resistant substrate (e.g., bedrock) is encountered or the channel profile achieves equilibrium conditions with respect to slope, sediment size and water discharge. Headcuts in the project area were mapped with a GPS receiver; their locations are shown on Figure 4-4.

The two headcuts in the downstream portion of the project area on the south side of Oyster Creek are associated with an abandoned tributary (Figure 2-2). As mentioned in Section 2, this tributary was captured by the formation of the leakage channel. Headcut HC-1 (Figure 4-4) is formed in an historical alignment of the abandoned tributary and is only a minor feature that does not represent significant geomorphic instability. The headcut that has formed in the main channel of the abandoned tributary (HC-2, Figure 4-4) has migrated to bedrock, which has arrested its upstream movement.

In the main channel of the North Tributary, approximately 200 feet upstream of its confluence with Oyster Creek, there is a 4-foot high active headcut (HC-3, Photo 8); several smaller headcuts are migrating from the North Tributary channel into the meadow (HC-4 and HC-5, Figure 4-4). Upstream of the main headcut, the North Tributary is at grade with the meadow surface and the channel has the characteristics of a vegetated swale. The instability of these headcuts threatens the ecological function of the Oyster Creek meadow and provides a chronic source of fine sediment that may impact downstream aquatic resources. Measures to stabilize the headcuts in the North Tributary will be presented in the Stabilization Plan, which is being completed in fulfillment of separate Project 184 license conditions.

The only headcut identified in the main Oyster Creek channel is the bedrock step at the Reach 5/6 transition. Bedrock at this location provides grade control for upstream reaches of Oyster Creek and is important for long-term channel stability. A reconnaissance-level subsurface investigation was conducted at the bedrock step to examine the extent and elevation of bedrock adjacent to the channel. Bedrock elevations adjacent to the active channel were estimated by measuring depth to bedrock in augured holes and at surface exposures along a cross-section. These data were referenced to topographic data collected at the cross-section (Figure 4-5). Surface bedrock exposures were found on both the left and right banks of the channel at 7 and 13 feet of distance from the thalweg, respectively. Both of these exposures were found to be elevated above the bedrock at the thalweg by approximately 3 feet. These exposures confine the channel to the current alignment, suggesting that flanking and subsequent headcut initiation is unlikely to occur. Because of the importance of this location with respect to long-term channel stability, it should be monitored through repeated cross-section survey as a component of License Condition 37.9, Geomorphology *(Continuing Evaluation of Representative Channel Areas)* (FERC, 2006).

4.3.3 Channel Geometry

Detailed measurements of channel geometry were made in the project area (i.e., Reaches 4 through 7). This included a rod and level survey of 9 cross-sections throughout the project area (Figure 4-6). The cross-sections were referenced to the aerial topographic survey control points to establish a vertical datum. Bankfull stage was estimated at each section. Figures 4-7a through 4-7k show the survey results and representative photographs of each cross-section.

The three channel cross-sections surveyed by Doug Parkinson & Associates (DPA) in 1999 were re-occupied by SH+G to monitor changes in channel geometry. Figures 4-7e through 4-7g show the SH+G survey transposed on the DPA data. At cross-section 5 (Figure 4-7e) there has been some bed scour and approximately 2 to 4 feet of lateral retreat along the left bank, which at this cross-section is nearly vertical and devoid of vegetation. This explains the high rate of lateral erosion. Bed scour in this location is the result of localized pool formation and not indicative of reach-scale degradation, as indicated by repeated cross-section surveys showing no change in bed elevation. At cross-section 6 (Figure 4-7f) the cutbank on river-right has retreated by approximately 2 feet. Cross-section 7 (Figure 4-7g) remained stable. These survey data demonstrate that lateral migration is occurring in Reach 6, and erosion rates are relatively high at cutbanks on the outer bends of meanders. Overall, the streambed elevation has remained stable.

4.3.4 Bed Grain Size Distribution

Bed grain size distribution was quantified by performing pebble counts using the procedure defined by Wolman (1954). Pebble counts were performed at cross-sections 1, 2, 3, 6 and 9 (Figure 4-6). Results of the pebble counts are shown in Figure 4-8 and summarized in Table 4-1.

Table 4-1. Summary of bed grain size distribution at Oyster Creek sampling sites						
Cross-section	**1**	**2**	**3**	**6**	**9**	**Average all sites**
	Grain size (mm)					
D_{16}	17	8	15	16	7	**13**
D_{50}	50	19	35	27	29	**32**
D_{84}	94	31	78	37	50	**58**

Bed grain size distribution is similar among all sampling sites. At the downstream end of the project area (cross-section 1) the bed is composed primarily of small to medium size cobble with some gravel. In the middle and upper sampling sites the bed is composed primarily of medium sized gravels (Photo 16).

4.3.5 Bedload Sampling

Overview

A bedload transport sampling program was undertaken to determine (1) the size and quantity of sediment being transported at a discharge that approximates bankfull stage, and (2) to assess whether the bedload transport rate entering the project area is equal to the rate leaving the project area. Characterizing bed mobility during flows that approximate bankfull stage is useful for evaluating long-term channel stability. Comparison of sediment transport rates at the upstream and downstream extents of the study reach provide an indication of whether equilibrium conditions exist with respect to sediment transport.

Sampling Methods

Bedload sampling was conducted on May 8, June 11 and June 23, 2009. Samples were collected using both USFS bedload traps and a Helley-Smith bedload sampler (Photos 17 and 18). Only the USFS bedload traps were used during the May 8 sampling event. It was evident during the May 8 sampling that a significant portion of the bedload was sand, which is not captured by the USFS bedload traps. Thus, the Helley-Smith bedload sampler, which captures sand and finer material, was employed along with the USFS traps for subsequent sampling events.

The sampling protocol for the USFS bedload traps closely followed procedures defined in *Guidelines for Using Bedload Traps in Coarse-bedded Mountain Streams: Construction, Installation, Operation, and Sample Processing* (Bunte et al., 2007); for the Helley-Smith bedload sampler the protocol followed *Bedload Samplers; Use of Helley-Smith Sampler* (USGS, 1979). Samples were collected at seven locations within the study area, designated Stations A through G (Figure 4-6). Several factors were considered in establishing the sampling station locations, including study objectives, streambed morphology, substrate composition, presence of local sediment sinks or sources, and location within the study area. In general, stations were established at cross-sections that were typical of the overall reach conditions. Samples were collected predominantly in riffle-run habitat, as this is the dominant aquatic habitat in the project area. In most cases the sampling stations were co-located with pebble count sampling sites. Analyses of sample grain size distribution and mass were conducted by Butano Geotechnical Engineers in Watsonville, California. Appendix B provides the complete laboratory results.

Streamflows

Two discharge measurements were taken on May 8; one upstream of the North Tributary at Station E and one just downstream at Station B. The downstream flow measurement was 20 cfs and the upstream was 18 cfs. The contribution of flow from the North Tributary appeared to be in the range of 1-2 cfs (Photos 7 and 8), but fluctuations in mainstem flow between the time of measurements may also account for a portion of the variation. One discharge measurement was taken on June 11 at Station E, as the North Tributary no longer had significant flow. The discharge measurements are shown in relationship to stage data from the EID stream gage located just upstream of the SR 88 crossing (Figure 4-9). Natural runoff was greatest during the May 8 sampling event. Lake stage was 16.8 feet, which corresponds to approximately 9 cfs of leakage flow. The June 11 sampling event corresponded closely with peak discharge measured for 2009. Visual estimates of natural runoff were less on June 11 than that observed on May 8, but lake stage was higher, thus producing greater discharge. During the June 23 sampling event most streamflow was associated with leakage flow.

Results

During the three-day sampling program 17 bedload samples were collected. Bedload sampling results are summarized in Tables 4-2 and 4-3.

Table 4-2. Helley-Smith bedload sampler data

Sample Date ~ Approx. Discharge	**6/11/2009 ~ 26 cfs**		**6/23/2009 ~ 18 cfs**	
Sample Location	**Transport Rate (kg/ft·hr)**	**Description of bedload**	**Transport Rate (kg/ft·hr)**	**Description of bedload**
SITE A	--	--	47	Well graded sand with gravel (0.07 to 5 mm)
SITE B	--	--	5	Well graded sand with gravel (0.07 to 9.5 mm)
SITE C	--	--	72	Well graded sand with gravel (0.07 to 9.5 mm)
SITE D_1	158	Well graded sand with gravel (0.07 to 26 mm)	28	Well graded sand with gravel (0.07 to 9.5 mm)
SITE D_2	--	--	--	--
SITE E	140	Well graded gravel with sand (0.07 to 19 mm)	--	--
SITE F	--	--	40	Well graded sand with gravel (0.07 to 5 mm)
SITE G	150	Well graded gravel with sand (0.07 to 19 mm)	--	--

Table 4-3. USFS bedload trap sample data

Sample Date ~ Approximate Discharge	5/8/2009 ~ 18 cfs		6/11/2009 ~ 26 cfs		6/23/2009 ~ 18 cfs	
Sample Location	**Transport Rate (kg/ft·hr)**	**Description of bedload**	**Transport Rate (kg/ft·hr)**	**Description of bedload**	**Transport Rate (kg/ft·hr)**	**Description of bedload**
SITE A	--	--	--	--	0.01	medium to coarse sand
SITE B	0.25	fine to medium gravel (0.07 to 19 mm)	--	--	--	--
SITE C	--	--	--	--	--	--
SITE D_1	0.02	fine to coarse sand	0.04	well graded sand with gravel	--	--
SITE D_2	0.42	medium to coarse sand and fine gravel (0.07 to 5 mm)	--	--	--	--
SITE E	0.01	fine to coarse sand	0.05	fine sand	--	--
SITE F	--	--	--		0.00	well graded sand with gravel
SITE G	--	--	0.04	fine to coarse sand with several fine gravels	--	--

TABLE 4-3: USFS bedload trap sampling data.

Only the USFS bedload traps were used on the first sampling day (May 8, 2009). Bedload samples were collected at four sampling stations (Figure 4-6, Table 4-3). Transport rates were relatively low at all sampling locations, with only small amounts of coarse sand and gravel captured at each station. The highest transport rate was recorded at the tail of a riffle in a relatively confined section of channel (Site D2, Photo 19). The maximum particle size being mobilized in the stream was similar to the D_{16} size fraction determined from pebble counts (Table 4-1). A small amount of coarser material, close to the median grain size, was mobile during the June 11, 2009 sampling event.

Both the USFS bedload traps and the Helley-Smith sampler were used in June 11 and June 23 sampling events. USFS bedload traps were deployed at two stations that were sampled on May 8 and at two new stations. Bedload transport rates did show a response to the increase in discharge (Tables 4-2 and 4-3). Again, the size of bedload material being mobilized was similar to the D_{16} size fraction determined from pebble counts. Transport rates measured with the Helley-Smith sampler were significantly higher than those measured with the USFS bedload traps. This is because the Helley-Smith sampler captures the sand fraction of the bedload, whereas the USFS bedload traps are designed to pass material finer than coarse sand. Helley-Smith bedload transport rates were similar for all stations sampled within sampling events (Table 4-2).

The June 23 sampling event focused on determining whether bedload transport rates were balanced through the project reach i.e., whether the transport rate is similar at the upstream and downstream extents of the Oyster Creek meadow. The Helley-Smith sampler was the most useful instrument for this evaluation, as the dominant bedload particle size proved to be coarse sand. Bedload samples were collected with the Helley-Smith at the downstream extent of the meadow (Station A), throughout the project reach (Stations B, C and D), and at the upstream end of the meadow (Station F) (Figure 4-6). Transport rates measured at all stations were of similar magnitude (Table 4-2). Transport rates at the upstream and downstream extents of the meadow were remarkably similar, suggesting equilibrium conditions exist at the discharge sampled. Variability in transport rates measured within the project reach can be attributed to numerous factors, including differences in cross-section morphology, slope, flow dynamics and stochasticity. For example, the high transport rate measured at Station C was likely due to local channel slope being slightly greater at this location than at other stations. The transport rate measured at Station B was much lower than other stations with similar morphology. This may have been due to the presence of a scour pool (sediment sink) upstream of the station or the stochastic nature of bedload sampling.

Discussion

USFS bedload traps appeared to provide a more accurate measurement of bed mobility at the given discharges than the Helley-Smith sampler. This is because once the trap is set and the bed has equilibrated, there is minimal disturbance to entrain particles. Gravel in the streambed was at or near the threshold of mobility during all sampling events, so even minor disturbance of the bed, such as touching the Helley-Smith sampler to the bed, had the potential to mobilize sediment that would not have otherwise been entrained. Moreover, sampling duration for the USFS traps was longer than that for the Helley-Smith sampler (per the protocols for the instruments). It is our opinion that the longer duration of sampling provided a more accurate measurement of flow competence (i.e., the maximum particle size mobilized for a given flow) because the bedload was at or near the threshold of entrainment. However, the Helley-Smith sampler clearly provided a better measurement of sediment transport rates at the given discharges because a large fraction of the total bedload transport was sand-sized sediment, which is not captured by the USFS traps.

Overall, the bedload sampling data indicate that (1) flows approximating maximum leakage and bankfull discharges mobilize a small fraction of the bed material in terms of both size and quantity, and (2) that sediment transport rates are balanced through the project reach at flows approximating bankfull discharge. These findings have several implications with respect to channel stability. The fact that only the D_{16} fraction of the bed material is mobile at flows approximating bankfull discharge indicates that the channel has an armored bed layer which is likely to inhibit further degradation. In general, channels where the D_{50} particle size is mobilized at discharges approximating bankfull stage are considered to be in dynamic equilibrium with respect to bedload transport, and are considered “stable”. Whereas, immobility of the D_{50} particle size of the bed at bankfull discharge, as is the case in Oyster Creek, is indicative of aggradation (Johnson et al., 1999; Saldi-Caromile et al., 2004; Parker, 2008). If aggradation is to occur in Oyster Creek it will likely be over long temporal scales in an episodic manner because significant sediment inputs will be associated with large, infrequent flood events. Local bank erosion also provides a source of sediment for channel recovery (e.g., building floodplain), which should be recognized when addressing the project objective of stabilizing streambanks.

Balanced sediment transport measured in the project reach is further indication that the channel is stable at discharges that approximate bankfull flow. Bedload sampling did not detect significant sediment inputs from streambed or bank erosion within the project reach, which indicates that leakage discharge does not currently cause significant bed or bank erosion. No turbidity spikes or large-scale bank failure due to hydraulic erosion were observed. In incised channels bank failures most commonly occur during the recessional period of large flows. This is due to a variety of factors, including differences in pressure between the bank and channel, and loss of bank strength due to reduced cohesion and matric suction (Simon and Darby, 1999). Thus, more significant bank erosion may occur at higher flows.

4.3.6 Bed mobility (modeled)

In addition to the empirical measurements of sediment transport discussed in the previous section, bed mobility was evaluated using the hydraulic model developed for the project area. This analysis is useful for comparison with empirically-derived data and allows for predictions of how the channel may respond to flows greater than those observed during the field measurements.

Bed substrate mobility for a range of discharges was evaluated at the five channel cross-sections that are co-located with the pebble count data. Bed mobility is primarily a function of particle size and boundary shear stress (τ) in the channel. Shear stress in the channel was calculated using the HEC-RAS model. The Shields (1936) equation was used to determine critical shear stress (τ_c) i.e., the force required to mobilize a given particle size. The ratio of boundary shear stress to critical shear stress (τ/τ_c) yields a dimensionless value that can be used to estimate bed mobility (Johnson et al., 1999; Saldi-Caromile et al, 2004; Shields et al., 2008). In general, bed mobility begins when the τ/τ_c ratio exceeds 1; when the ratio exceeds 2 most of the bed is in motion; above 3 the entire bed is mobile (Shields et al., 2008). Bed substrate mobility was estimated using this method for a range of flood events. Additionally, discharges associated with leakage from Silver Lake were evaluated to determine if these flows are capable of mobilizing bed material. Table 4-4 summarizes the results of the bed substrate mobility analysis. The results are presented graphically in Figures 4-9a through 4-9f.

Table 4-4. Streambed Substrate Mobility Matrix.

Flow Event	Flow[1] (cfs)	XS 1			XS 2			XS 3			XS 6			XS 9		
		D_{16}	D_{50}	D_{84}	D_{16}	D_{50}	D_{84}	D_{16}	D_{50}	D_{84}	D_{16}	D_{50}	D_{84}	D_{16}	D_{50}	D_{84}
Max leakage	17	O	X	X	O	O	X	O	X	X	O	X	X	O	X	X
2-yr	28/45	O	X	X	O	O	O	O	X	X	O	O	X	O	X	X
5-yr	58/92	O	O	X	O	O	O	O	X	X	O	O	O	O	X	X
10-yr	86/137	O	O	O	O	O	O	O	X	X	O	O	O	O	O	X
50-yr	180/285	O	O	O	O	O	O	O	O	X	O	O	O	O	O	X
100-yr	235/373	O	O	O	O	O	O	O	O	X	O	O	O	O	O	X

O = Mobile, X = Immobile

1. Flow are partitioned for upstream and downstream of the North Tributary

The modeling results predict that the maximum leakage flow would mobilize the D_{16} fraction of the bed material (Table 4-1, Figure 4-10a), which is consistent with the findings of the field study. The modeling suggests that the D_{50} fraction in cross-section 2 would also be mobile at maximum leakage discharge, which is to be expected because the D_{50} particle size at this cross-section is the lowest of all pebble count locations (Table 4-1). Figure 4-10a shows that the shear stress ratio for the median particle size (D_{50}) is close to 1 for the 2-year event, which approximates the bankfull stage. This suggests the channel is at or near equilibrium conditions from a bed mobility standpoint. The modeling results show the larger fraction of the bed material is mobilized at discharges exceeding a 5 or 10-year flood event (Figures 4-10).

5.0 ANALYSIS OF SITE CONDTIONS

5.1 FACTORS CONTRIBUTING TO HISTORICAL INSTABILITY

Channel instability can largely be attributed to hydro-modification and historical land uses that have modified geomorphic and ecological processes in the Oyster Creek watershed. The factors that led to channel instability are described in the following subsections.

5.1.1 Hydro-modification/Flow Augmentation

The Silver Lake dam was initially constructed in 1876 and then enlarged in 1929. Historically, there may have been natural leakage from Silver Lake into the Oyster Creek basin, and the 1876 dam may have increased leakage, but it was not significant enough to form Oyster Lake, which is noticeably absent from the 1896 topographic map (Figure 4-1). It is reasonable to assume that leakage increased substantially after the dam was enlarged in 1929. It is not known whether the magnitude of the leakage discharge has changed significantly since 1929. As discussed in Section 3, leakage flow is the dominant source of base flow in the channel.

Alluvial channels generally respond to flow augmentation in a predictable manner. Shields et al. (2006) use stream power relationships developed by Lane (1955) to predict channel adjustments in response to increased water discharge:

$$Q_s^0\ Q_w^+ \sim S^-, D_{50}^+, H^+, B^+$$

> where Q_s is sediment discharge, Q_w is water discharge, S is slope, H is water depth and B is channel width. A superscript of + indicates increase, 0 indicates no change, and - indicates decrease.

Essentially, channels that are subject to an increase in water discharge without a corresponding increase in sediment discharge exhibit a decrease in slope and increases in median particle size (D_{50}), flow depth and channel width. While there are no data available for these parameters that document the historical condition of Oyster Creek, channel response can be inferred from observation of the physical setting, including the characteristics of the main tributaries.

It is apparent from field observations that the width and depth of the Oyster Creek channel have increased to accommodate the modified base flow. The median particle size in the channel (D_{50}) is significantly coarser than the substrate observed in tributaries that feed the channel. Adjustments in channel slope are more difficult to infer, but presumably the historical channel was at-grade with the meadow, which has a slope of 2%; the contemporary channel in the meadow has a slope of 1.5 to slightly less than 2%. Minor adjustments in slope for channels that were originally low gradient can be expected.

Not all streams that are subject to artificial increases in discharge would exhibit as marked of a response to flow augmentation as Oyster Creek has. Geologically, the Oyster Creek meadow is particularly prone to instability because it is composed of fine unconsolidated alluvium and lacks widespread grade control. Moreover, land use activities that would compound the effects of the flow augmentation were coincident with the onset of increased discharge. The role of these land use impacts in channel degradation/instability is discussed in the following section.

5.1.2 Historical Grazing Practices

Grazing on lands that are now part of the ENF dates back to the 1850s, when emigrant gold prospectors brought hundreds of thousands of sheep and cattle into the area. Sheep grazing in the project vicinity continued up until the 1940s, and cattle grazing remains a permissible land use practice up to the present day (USFS, 2007). The riparian area upstream of SR 88 is part of the ENF Cody Meadow Grazing Allotment, Silver Lake Unit (Figure 1-3). The meadow downstream of SR 88 is not part of the allotment, but it is reasonable to assume that historic grazing practices in this area were similar to those of the Cody Meadow Allotment. Forest Service documents note that wet and dry meadows around the project area have been historically overgrazed. Records from the 1950s cite a downward trend in range quality, and accounts from the 1960s indicate meadows were still being over utilized. Range conditions in the Silver Lake Unit of the Cody Meadow Allotment were described as "very poor" in 1961, and "poor" in 1963, as a result of heavy sheep grazing and bedding grounds around the meadows (USFS, 2007). The ENF grazing reports from the 1960s note that, "Overuse of the range resulted in severe stream channel, gulley, and sheet erosion problems in meadow areas (USFS, 2007)." Grazing of cattle in the meadow downstream of SR 88 has occurred in recent years, as evidenced by remnants of modern fencing and an account from a local resident (R. Wentzel, pers. comm. 2007). An unpublished USFS site assessment of the Oyster Creek meadow conducted in 1995 notes, "Very heavy grazing in the meadow and in the adjacent forest has heavily impacted both willows and meadow grasses."

The effects of grazing on stream stability in the Sierra Nevada ecosystem have been studied by the USFS (SNEP, 1996) and reviewed by independent scientists (Allen-Diaz et al., 1998). The USFS (1996) concluded that grazing can 1) reduce plant vigor leading to reductions in mass and depth of roots, 2) shift plant community composition and 3) cause streambank trampling. As a result, streambanks may become unstable, and channels with "soft" bottoms can down-cut (SNEP, 1996). The independent science panel (Allen-Diaz et al., 1998) that reviewed the USFS study concluded that, "Stream bank instability results from interacting watershed scale mechanisms occurring through time. These phenomena are almost always linked to several co-occurring natural and man-induced phenomena in the watershed." This synopsis provided by Allen-Diaz et al. (1998) highlights the synergistic effects that land use modifications have on the riparian system.

In the case of Oyster Creek, grazing of the riparian meadow alone may not have caused large-scale channel instability, but the reduction in vegetation cover and root strength associated with grazing likely contributed to channel degradation and bank erosion. Perhaps more importantly, recovery of the Oyster Creek channel from historical incision has been hampered by over-grazing of woody and herbaceous vegetation that provide bank strength and floodplain roughness. Thus, excluding grazing from the Oyster Creek channel and banks will be an important component of channel recovery and the stabilization process.

5.1.3 Effects of SR 88

As mentioned in Section 4.1, the natural hydraulic and sediment transport regime, unimpeded by SR 88 road fill and culverts, favored flooding and deposition of coarse material across the head of the meadow during large flood events. Construction of the modern SR 88 circa 1950 concentrated watershed drainage and altered sediment delivery into the Oyster Creek meadow.

Rather than allowing dispersal of hydraulic force and sediment, the SR 88 fill prism now collects drainage and routes it through two 36-inch culvert crossings underneath the roadway (Photo 13). The concentration of drainage, which historically spread over the entire meadow surface, increased the discharge and hydraulic forces (i.e., velocity, shear stress) within the main channel and tributaries. This increase in hydraulic force was not coupled with an increase in sediment supply; rather the roadway collects and stores alluvial and colluvial sediments, limiting sediment supply to the meadow. These factors are known to induce channel instability, particularly in geologically unstable settings such as the Oyster Creek meadow. Moreover, it appears that the channel was straightened and the culvert invert elevation was set below the existing grade. This would have increased hydraulic force and activated erosion below the protective root zone of the meadow surface, potentially inducing localized channel instability.

In the absence of detailed topographic records of channel geometry it is not feasible to determine precisely how SR 88 improvements relate to the sequence of degradation in the Oyster Creek channel. Given that the leakage flow preceded the changes in the roadway by 20 years it is likely that significant channel adjustments occurred prior to the SR 88 improvements. Nevertheless, the SR 88 roadway has important implications for long-term geomorphic function of Oyster Creek. The crossing has fixed the bed elevation and location of Oyster Creek. Historically, the channel was hydraulically connected to the adjacent meadow and had the ability to migrate laterally along the proximal end of the alluvial fan. Active or passive restoration of these processes is not likely feasible, given the current configuration of the roadway and culverts.

5.2 CONTEMPRORAY CHANNEL MORPHOLOGY

5.2.1 Main Channel

Oyster Creek in the project area has undergone episodes of incision that have formed a channel entrenched within its historical floodplain. It appears that incision in Reaches 4 and 5 occurred well before degradation in Reach 6, as evidenced by the age of trees rooted in the channel banks (Photos 21 and 22) and the angle of the banks. Incision has been arrested at the Reach 6/7 transition by natural grade control provided by cobble, boulders, LWD and dense woody vegetation. While there is no evidence of an active headcut at this location, this area should be monitored (e.g., repeated cross-section survey and longitudinal profile) as a component of License Condition 37.9, Geomorphology *(Continuing Evaluation of Representative Channel Areas)* (FERC, 2006).

The incised reaches of Oyster Creek have developed inset floodplains that have been colonized by woody vegetation such as alder and willow. Mobile bedload in the creek, predominantly sand and pea-sized gravel at flows approximating bankfull, is supplied from tributaries in the upper watershed and bank erosion. While the bed of Oyster Creek has “coarsened” over time, it is not static or “cemented,” thus sediment transport processes which result in the creation and maintenance of morphological and aquatic habitat features (e.g., point-bars, riffles) are still active.

Simon and Hupp (1986) provide a conceptual channel evolution model (CEM) that is useful for interpreting the stages of channel degradation and recovery (Figure 5-1). The entrenched reaches of the mainstem Oyster Creek are largely in Stage 5 of the channel evolution. There is no evidence of degradation, and it is evident that the dominant channel adjustment process is lateral erosion (widening) (Photo 24). Localized areas of deposition in the vicinity of LWD and formation of point-bars suggest that aggradation is occurring. Aggradation of the bed will likely occur over long temporal scales in an episodic manner because significant sediment inputs will be associated with large, infrequent flood events.

Chronic bank erosion in the channel is primarily the result of (1) toe erosion by hydraulic force (i.e., stream flow), and (2) groundwater sapping. Freeze-thaw cycles may also play a role in chronic bank erosion. The dominant process varies throughout the project reach and sometimes changes within small spatial scales on the order of tens of feet. For example, at RS 39+00 the dominant failure mechanism appears to be groundwater sapping (Photo 23), whereas, at RS 38+50 toe scour appears to be the dominant erosion process (Photo 22).

Large-scale bank failures are most likely to occur during the recessional period of large flows when the banks are saturated which results in loss of bank strength due to reduced cohesion and matric suction (Simon and Darby, 1999). Bank erosion will continue until the channel reaches a condition similar to Stage 6 of the CEM (Figure 5-1). In Stage 6 there is enough cross-sectional area to dampen the hydraulic force of large flood events, and bank angles are geotechnically stable. Measures that would accelerate the recovery of the channel will be presented in the Stabilization Plan.

5.2.2 North Tributary

While the mainstem Oyster Creek is in the later stages of recovery from incision, the North Tributary is highly unstable and exhibits characteristics of a Stage 3 channel (Figure 5-1). Instability in the North Tributary is due to the change in base level of the mainstem Oyster Creek. The lower portion of the tributary has incised to the base level of Oyster Creek (Photo 7). Approximately 200 feet upstream of the confluence there is a 4-foot high active headcut in the main tributary channel (Photo 8) and several smaller headcuts migrating from the channel into the meadow. Instability of the North Tributary threatens the ecological function of the Oyster Creek meadow and provides a chronic source of fine sediment that may impact downstream aquatic resources. Measures to stabilize the tributary will be presented in the Stabilization Plan.

5.3 CONCLUSION

This Monitoring Report provides a detailed geomorphic and hydrologic assessment of Oyster Creek. Multiple lines of investigation, including repeated surveys of channel geometry, bedload sampling, bed mobility modeling, and ecological observation, suggest that the channel has adjusted to the hydrology associated with leakage from Silver Lake and is trending toward recovery from historical incision. Though the stream profile is generally stable, streambanks will continue to erode, particularly during large flow events. This is part of the natural recovery process of incised channels. Stabilization measures that would expedite the recovery process and ensure long-term ecological function of the meadow adjacent to the channel will be presented in the Stabilization Plan, which is being completed under separate Project 184 license conditions.

6.0 REFERENCES

Bunte, K., Swingle, K.W., Abt, S.R. 2007. Guidelines for using bedload traps in coarse-bedded mountain streams: Construction, installation, operation, and sample processing. Gen. Tech. Rep. RMRS-GTR-191. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 91 p.

Douglas Parkinson & Associates. 1999. Field classification of selected channel reaches, South Fork American River and Tributaries. Unpublished report prepared for El Dorado Irrigation District.

El Dorado Irrigation District (EID). 2003. El Dorado Relicensing Settlement Agreement. El Dorado Project FERC Project 184.

El Dorado Irrigation District (EID). 2008. Project 184 Geomorphology Monitoring Plan: Sensitive Site Investigation and Mitigation Plan Development. Revised Agency Review Draft. Version 6.0. July 9.

ENTRIX. 2002. EID Project 184 Geomorphic Sites Assessment. December.

Federal Energy Regulatory Commission (FERC). 2003. Final Environmental Impact Statement for Hydropower License, El Dorado Project No. 184-065. July.

Federal Energy Regulatory Commission (FERC). 2006. Order Issuing New License. El Dorado Irrigation District, Project No. 184-065. October.

Fischenich, C. 2001. Stability Thresholds for Stream Restoration Materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29). U.S. Army Engineer Research and Development Center. Vicksburg, MS.

Johnson, P.A., Gleason, G. L., and Hey, R. D. 1999. Rapid assessment of channel stability in vicinity of road crossing. Journal of Hydraulic Engineering 125: 645-650.

Lane, E.W. 1955. The importance of fluvial morphology in hydraulic engineering. Proceedings of the American Society of Civil Engineers 81(745): 1-17.

Lydgate, B. 2002. Geomorphic Rosgen Level 1-3 photographs, survey data, and interpretation. Prepared for El Dorado Irrigation District (via ECORP).

McCuen, R.H. 2004. Hydrologic Analysis and Design (Third Edition), Pearson-Prentice Hall, Upper Saddle River, New Jersey.

Natural Resource Conservation Service (NRCS). 2007. Web Soil Survey. Eldorado National Forest Area, California, Parts of Alpine, Amador, El Dorado, and Placer Counties. Accessed online on August 21, 2007 at: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Parker, G. 2008. Transport of Gravel and Sediment Mixtures. *In:* Garcia, M.H. (Ed.) *Sedimentation Engineering: Processes, Measurements, Modeling, and Practices.* American Society of Civil Engineers (ASCE) Manual and Reports on Engineering Practice No 110.

Potter, D. A. 2005. Riparian plant community classification west slope, central and southern Sierra Nevada, California. R5-TP-022. Vallejo, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture.

Rosgen. 1996. Applied River Morphology. Second Edition. Wildland Hydrology. Pagosa Springs, CO.

Saldi-Caromile, K., K. Bates, P. Skidmore, J. Barenti, D. Pineo. 2004. Technical Appendix: Sediment Transport. *In:* Stream Habitat Restoration Guidelines: Final Draft. Co-published by the Washington Departments of Fish and Wildlife and Ecology and the U.S. Fish and Wildlife Service. Olympia, Washington.

Shields, A. 1936. Application of similarity principles and turbulence research to bed-load movement. Mitteilunger der Preussischen Versuchsanstalt f¨ur Wasserbau und Schiffbau 26: 5–24

Shields, F.D., R.R. Copeland, P.C. Klingeman, M.W. Doyle and A. Simon. 2008. Stream Restoration. *In:* Garcia, M.H. (Ed.) *Sedimentation Engineering: Processes, Measurements, Modeling, and Practices.* American Society of Civil Engineers (ASCE) Manual and Reports on Engineering Practice No 110.

Simon, A., and C. R. Hupp. 1986, Channel evolution in modified Tennessee streams. Proceedings, Fourth Federal Interagency Sedimentation Conference, March, 1986, Las Vegas, Nevada, v. 2, p. 71-82.

Simon, A. and S. Darby. 1999. The Nature and Significance of Incised River Channels. In: Darby, S. and A. Simon (Eds.). *Incised River Channels: Processes, Forms, Engineering, and Management.* John Wiley & Sons.

State Water Resources Control Board of California (SWRCB). 2006. Clean Water Act Section 401Technically-Conditioned Water Quality Certification for Federal Energy Regulatory Commission El Dorado Hydroelectric Project (FERC No. 184).

U.S. Army Corps of Engineers (USACE). 2006. Hydrologic Engineering Center. Computer Program HEC-RAS Version 4.0 Beta. Davis, California.

United States Forest Service (USFS). 1995. No.12 – Oyster Creek. Unpublished site assessment.

United States Forest Service (USFS). 2003. Forest Service Final Terms and Conditions Provided Under 18 CFR 4.34(b)(1) In Connection With the Application for Relicensing of The El Dorado Hydroelectric Project (FERC No. 184). October 31, 2003.

United States Forest Service (USFS). 2007. Preliminary Environmental Assessment for Cody Meadow Sherman Grazing Allotment Management Plans. Eldorado National Forest. R5-MB-000. July.

United States Geological Survey (USGS). 1979. EQUIPMENT & SUPPLIES--Bedload samplers; use of Helley-Smith sampler. Quality of Water Branch Technical Memorandum No. 79.17

United States Geological Survey (USGS). 1982. Interagency Advisory Committee on Water Data. Guidelines for determining flood flow frequency: Bulletin 17B of the Hydrology Subcommittee, Office of Water Data Coordination, U.S. Geological Survey, Reston, VA.

Waananen, A.O. and Crippen, J.R. 1977. Magnitude and Frequency of Floods in California. Water Resources Investigation Report 77-21. U.S. Geological Survey.

Wolman, M.G. 1954. A method of sampling coarse river-bed material: Transactions of the American Geophysical Union, v. 35, p. 951-956.

Personal Communication

Wentzel, Richard. August 9, 2007. Project 184 ERC Member. Personal communication to Kevin Fisher, Swanson Hydrology and Geomorphology.

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OYSTER CREEK

SENSITIVE SITE MONITORING REPORT

FIGURES

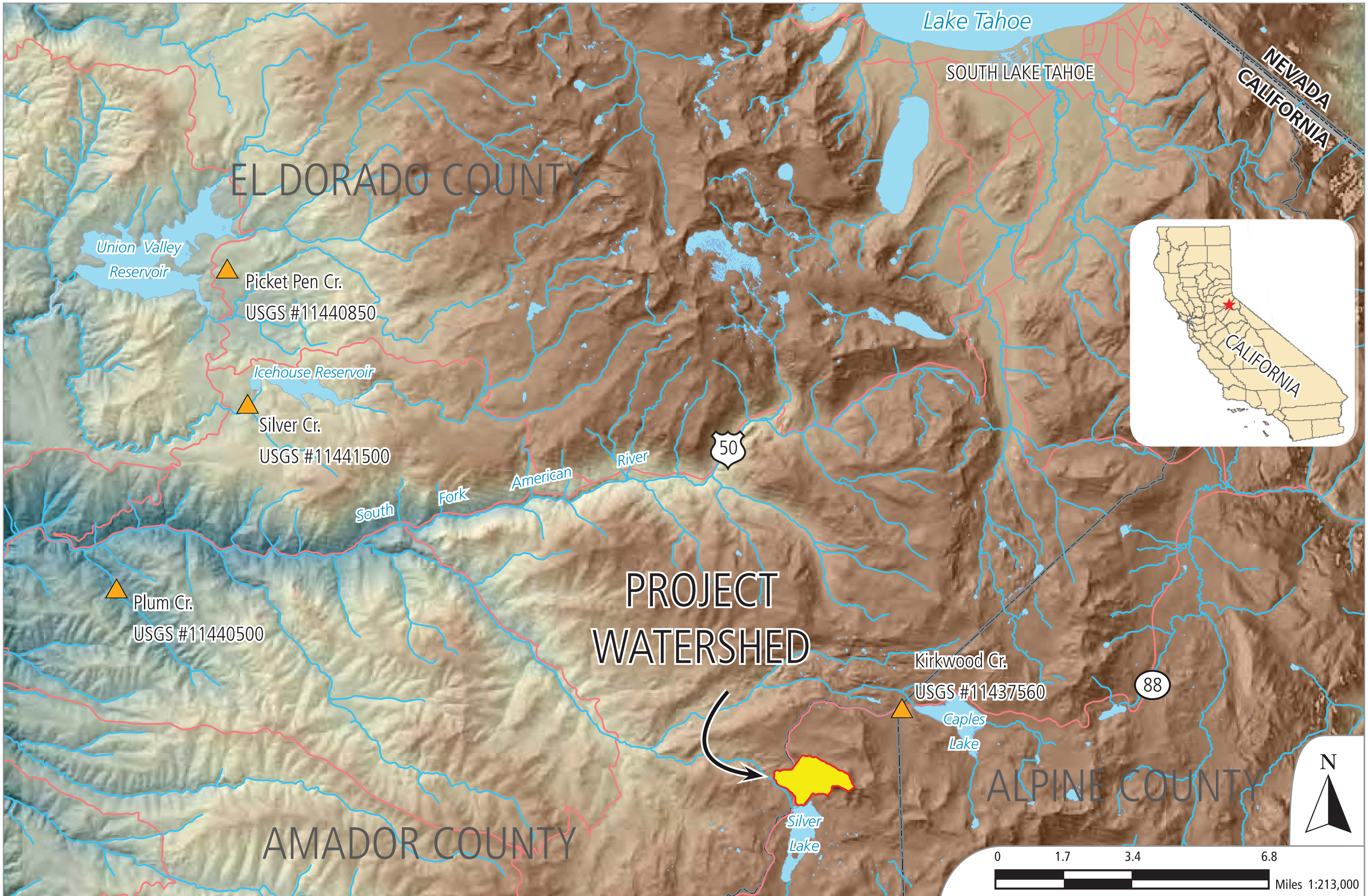

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FIGURE 1-1: Map showing the vicinity of the Oyster Creek watershed and the USGS gage locations used for hydrologic analysis.

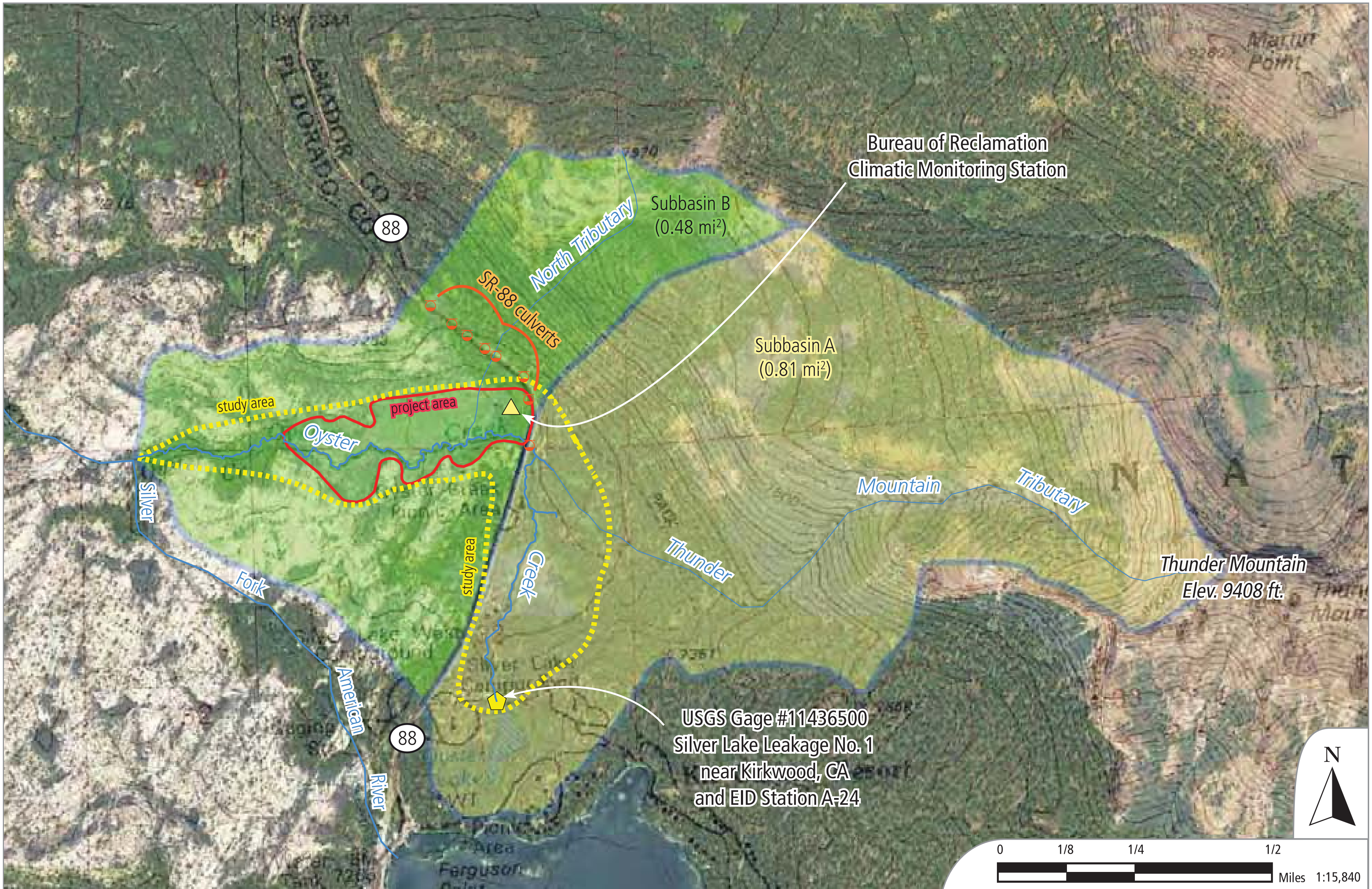

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FIGURE 1-2: Map of the Oyster Creek watershed and hydrologic subbasins. The Oyster Creek "study area" includes the Oyster Creek channel from Oyster Lake to the confluence with the Silver Fork. The "project area" includes Oyster Creek and associated riparian and wetland habitats from the SR 88 crossing downstream to the end of low gradient meadow.

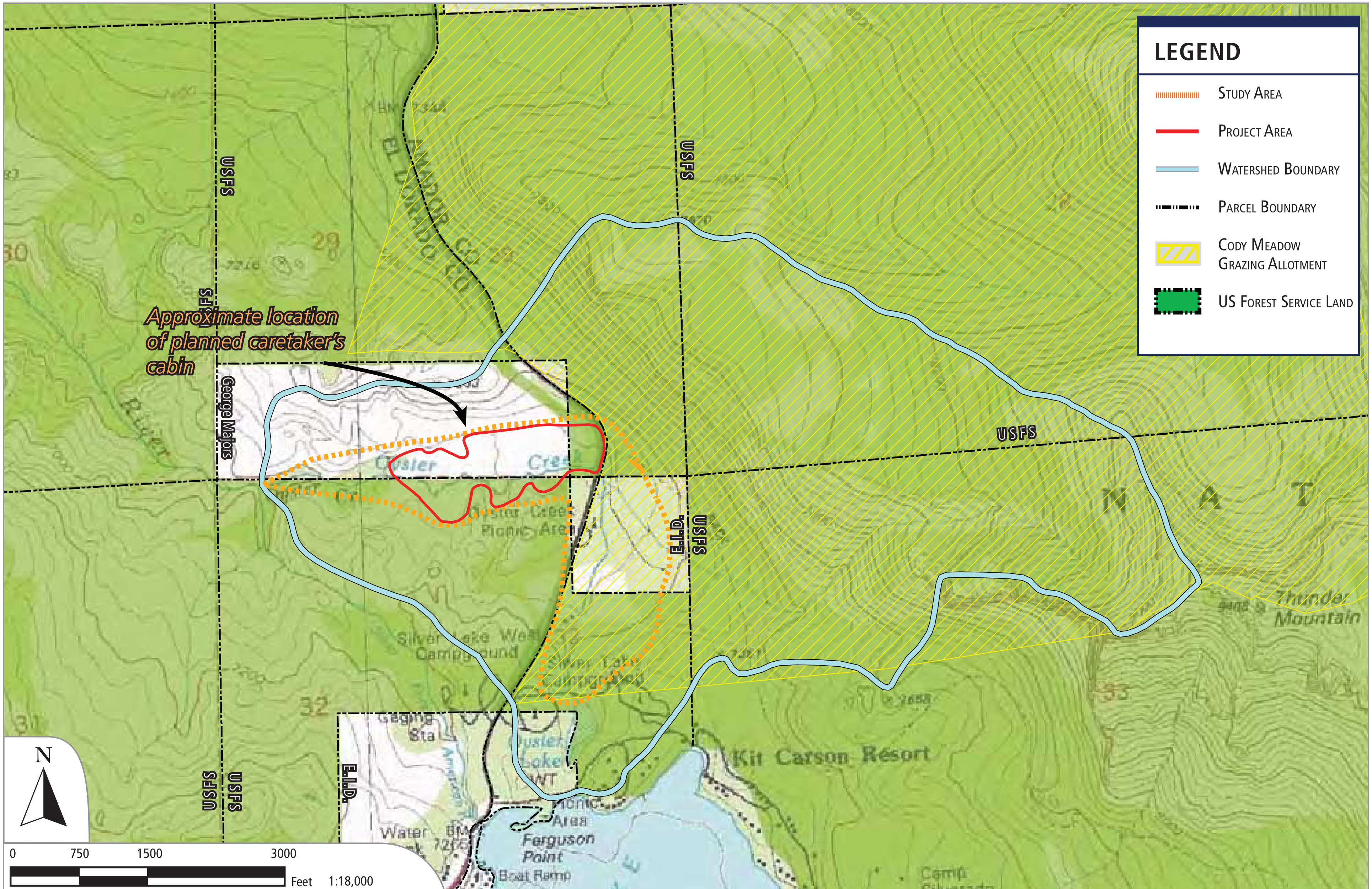

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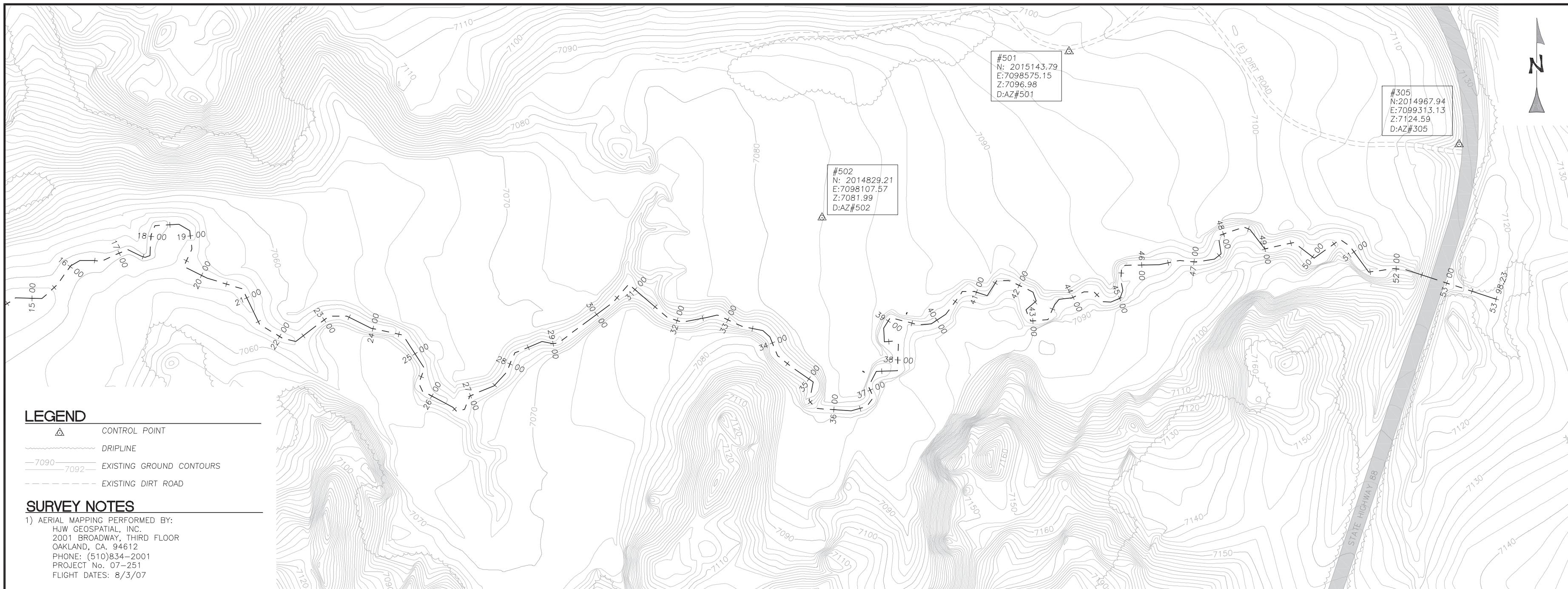
FIGURE 1-3: Land ownership and grazing allotments in the vicinity of the Oyster Creek watershed.



SITE PLAN
SCALE: 1"=100'

LEGEND

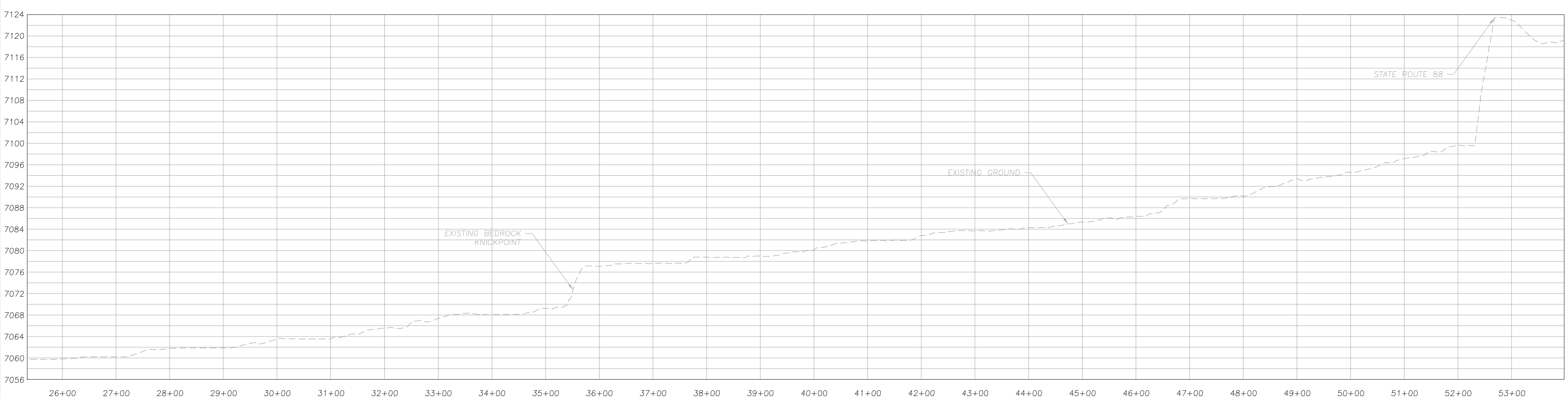
- △ CONTROL POINT
- DRIPLINE
- 7090 / 7092 EXISTING GROUND CONTOURS
- EXISTING DIRT ROAD

SURVEY NOTES

1) AERIAL MAPPING PERFORMED BY:
HJW GEOSPATIAL, INC.
2001 BROADWAY, THIRD FLOOR
OAKLAND, CA. 94612
PHONE: (510)834-2001
PROJECT No. 07-251
FLIGHT DATES: 8/3/07

2) ELEVATION DATUM: NAVD 88

3) BASIS OF BEARINGS: STATE PLANE NAD83, ZONE 2.



PROFILE
SCALE: 1"=100'

WATERWAYS CONSULTING
403B SWIFT ST.
SANTA CRUZ, CA 95060
PH:(831)566-8486//FAX:(888)819-6847
WWW.WATWAYS.COM

DRAFT
NOT FOR CONSTRUCTION

PREPARED AT THE REQUEST OF:
EL DORADO IRRIGATION DISTRICT

SITE TOPOGRAPHY AND PROFILE

OYSTER CREEK STABILIZATION PROJECT

DESIGNED BY: N.A.
DRAWN BY: B.M.S.
CHECKED BY:
DATE: 2-9-08
JOB NO.: 07-597

BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS
0 1"

FIG. 2-1

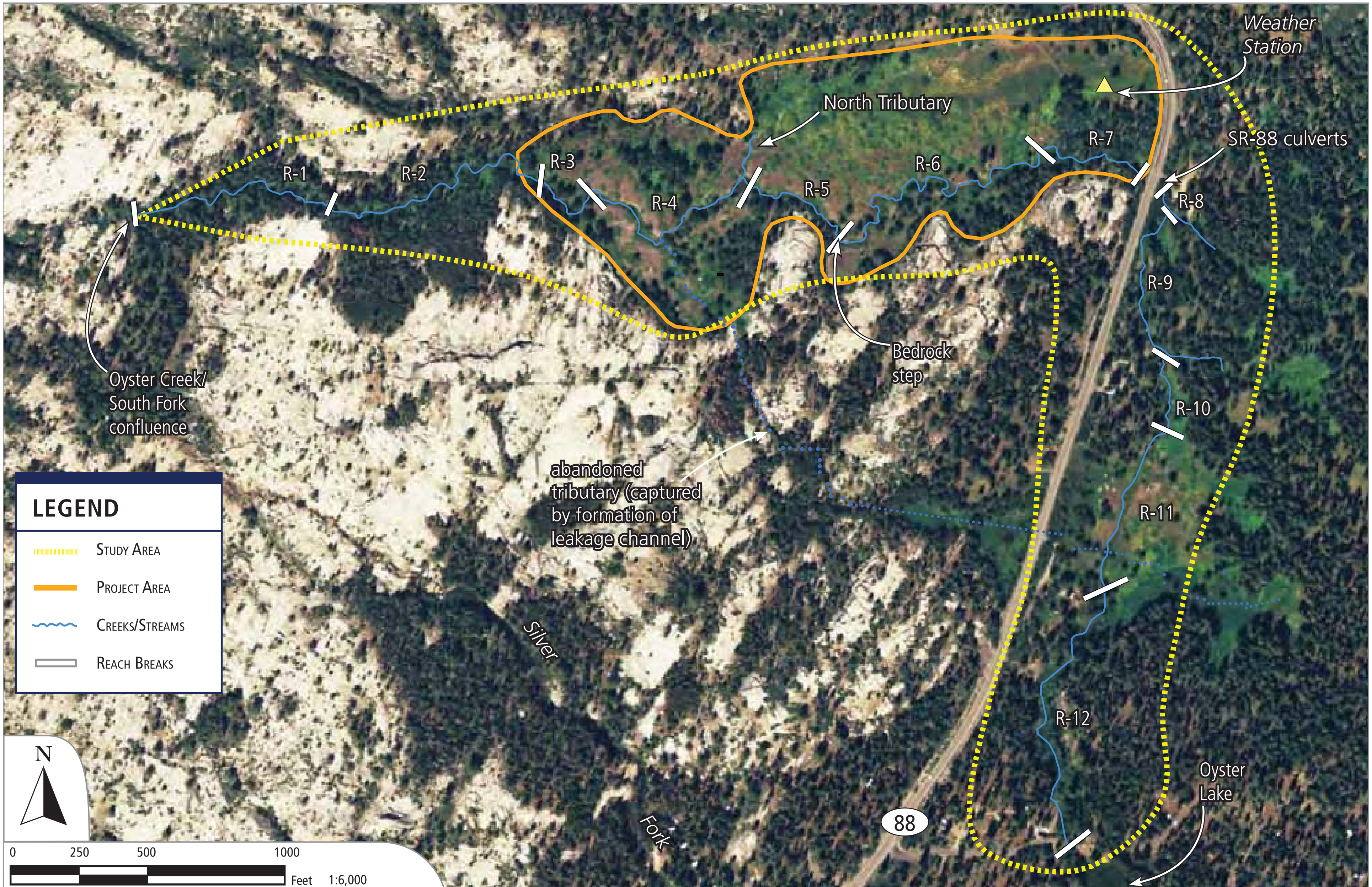


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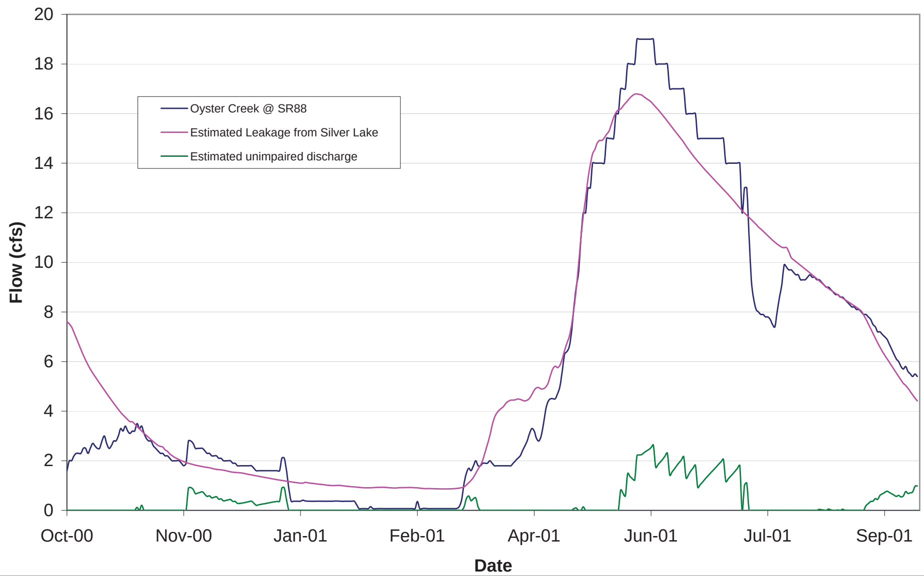
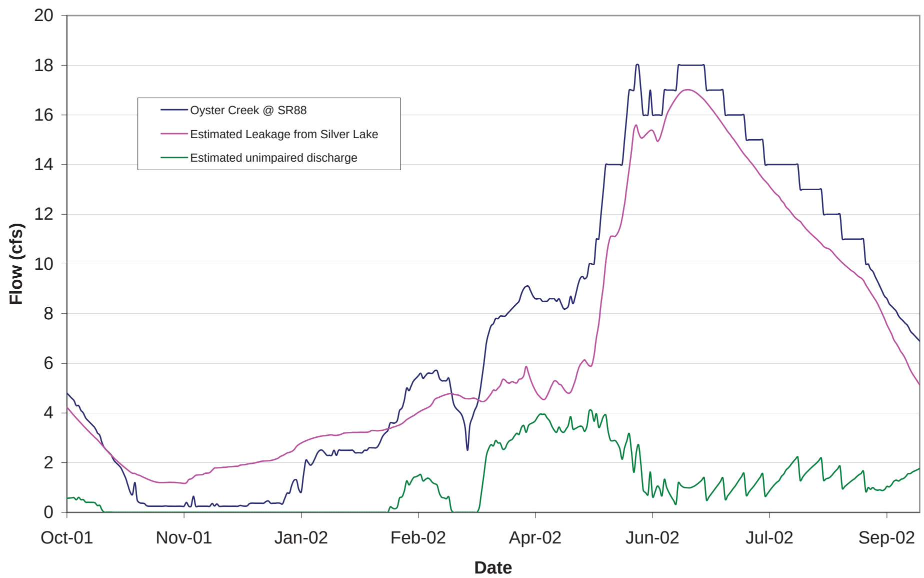
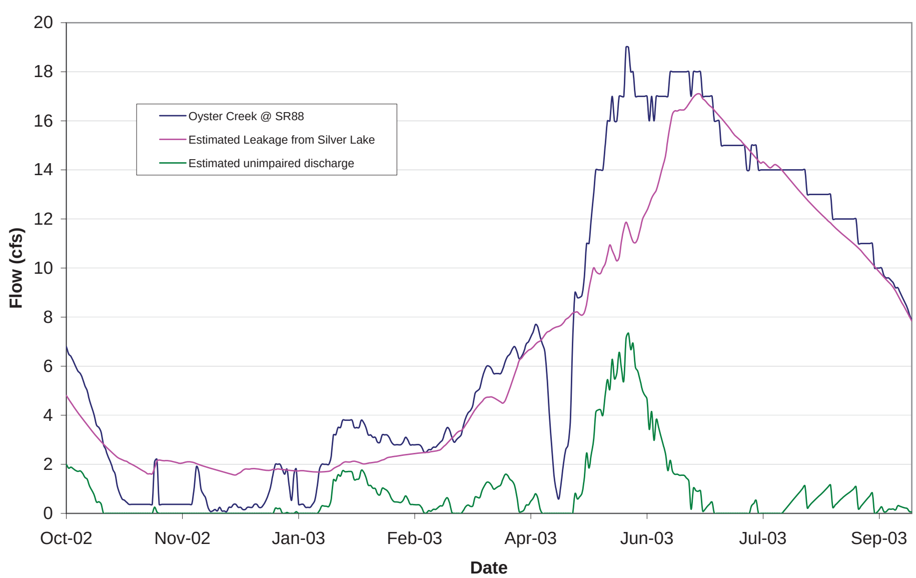
FIGURE 2-2: Map of the study area, project area and geomorphic reach delineations.



WATER YEAR 2001



WATER YEAR 2002



WATER YEAR 2003

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FIGURE 3-1: Oyster Creek annual hydrographs for Water Years 2001-2003 based on estimates of leakage from Silver Lake stage data and EID gaging data (A-24-A). Unimpaired discharge was determined by subtracting estimates of leakage flow from gaging records.

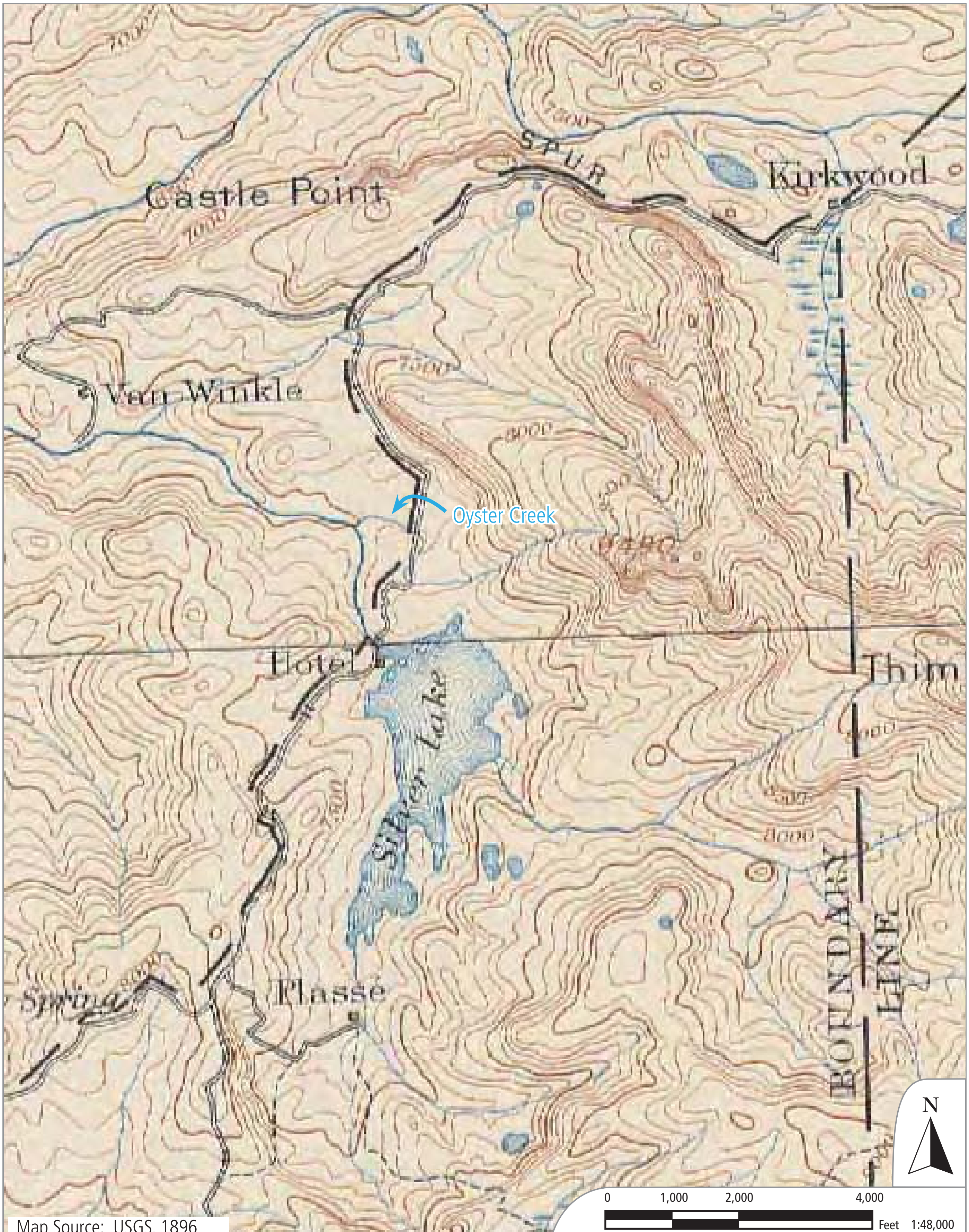

FIGURE 4-1: USGS topographic map from 1896 shows the project area prior to construction of the contemporary Silver Lake dam; note the absence of Oyster Lake.

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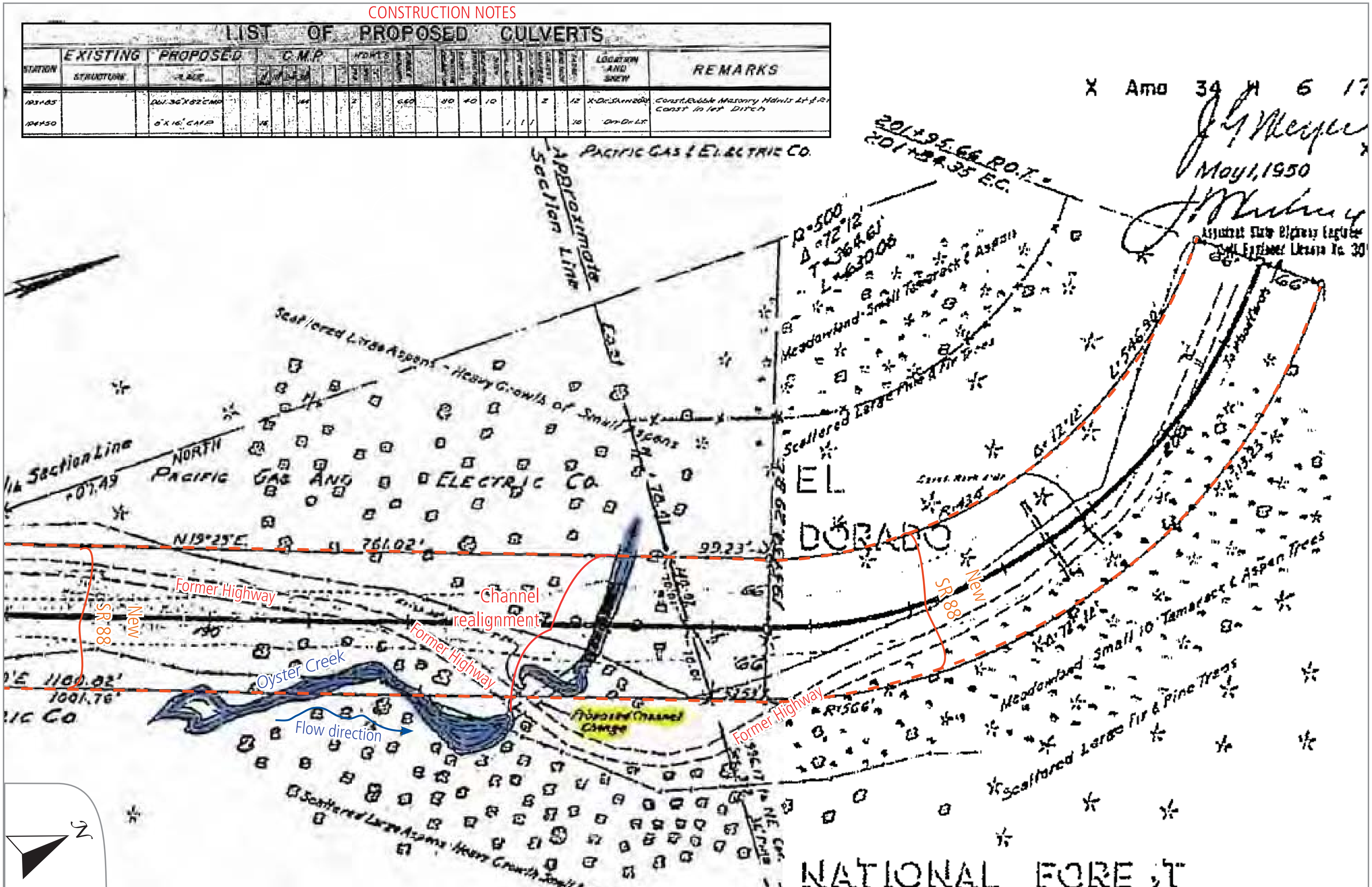
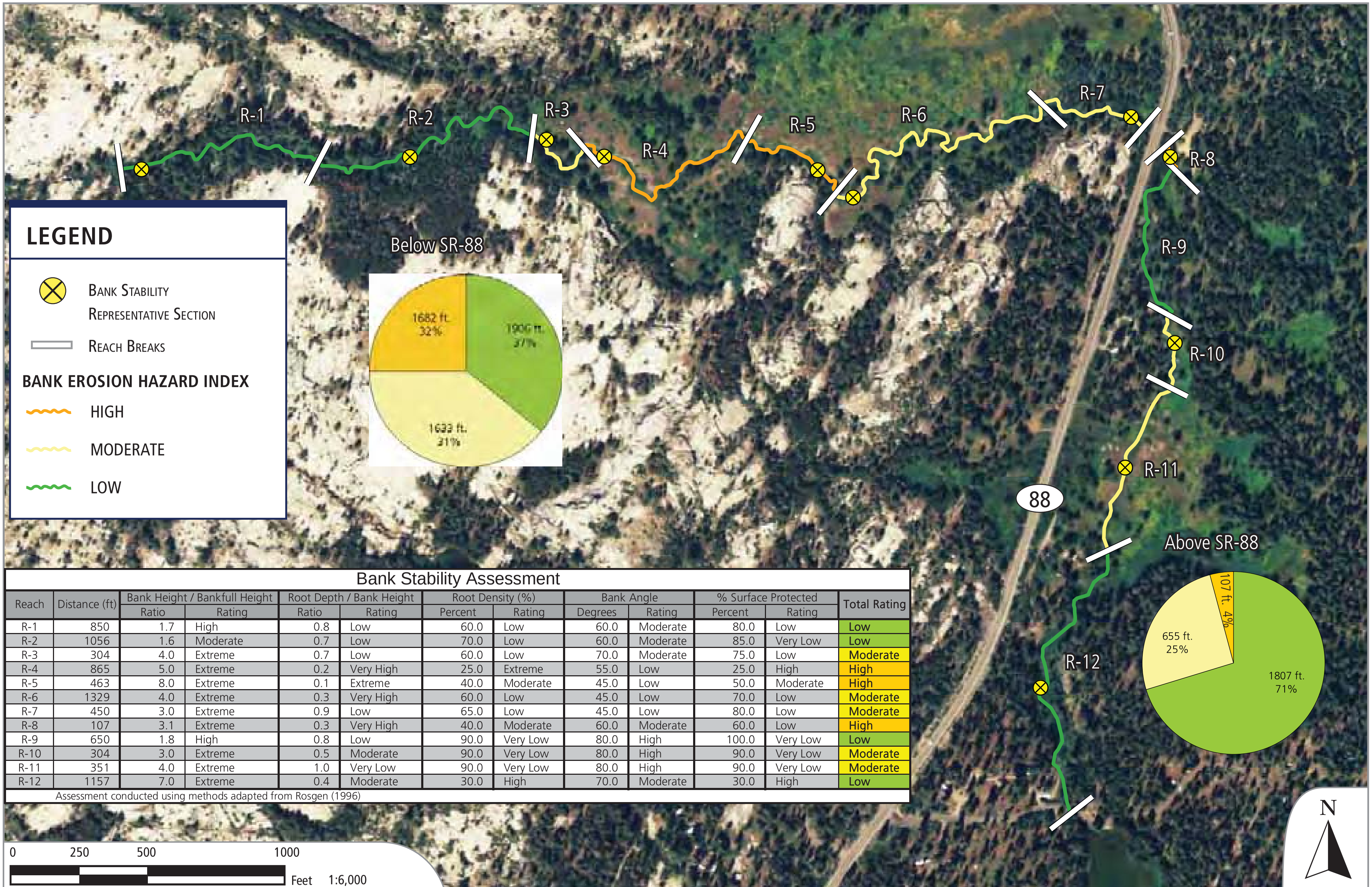


FIGURE 4-2: Caltrans as-built plans from 1950 for SR 88 at Oyster Creek crossing (color added for clarity).



Bank Stability Assessment

Reach	Distance (ft)	Bank Height / Bankfull Height		Root Depth / Bank Height		Root Density (%)		Bank Angle		% Surface Protected		Total Rating
		Ratio	Rating	Ratio	Rating	Percent	Rating	Degrees	Rating	Percent	Rating	
R-1	850	1.7	High	0.8	Low	60.0	Low	60.0	Moderate	80.0	Low	Low
R-2	1056	1.6	Moderate	0.7	Low	70.0	Low	60.0	Moderate	85.0	Very Low	Low
R-3	304	4.0	Extreme	0.7	Low	60.0	Low	70.0	Moderate	75.0	Low	Moderate
R-4	865	5.0	Extreme	0.2	Very High	25.0	Extreme	55.0	Low	25.0	High	High
R-5	463	8.0	Extreme	0.1	Extreme	40.0	Moderate	45.0	Low	50.0	Moderate	High
R-6	1329	4.0	Extreme	0.3	Very High	60.0	Low	45.0	Low	70.0	Low	Moderate
R-7	450	3.0	Extreme	0.9	Low	65.0	Low	45.0	Low	80.0	Low	Moderate
R-8	107	3.1	Extreme	0.3	Very High	40.0	Moderate	60.0	Moderate	60.0	Low	High
R-9	650	1.8	High	0.8	Low	90.0	Very Low	80.0	High	100.0	Very Low	Low
R-10	304	3.0	Extreme	0.5	Moderate	90.0	Very Low	80.0	High	90.0	Very Low	Moderate
R-11	351	4.0	Extreme	1.0	Very Low	90.0	Very Low	80.0	High	90.0	Very Low	Moderate
R-12	1157	7.0	Extreme	0.4	Moderate	30.0	High	70.0	Moderate	30.0	High	Low

Assessment conducted using methods adapted from Rosgen (1996)

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FIGURE 4-3: Bank stability assessment for the study area. Assessment conducted using methods adapted from Rosgen, 1996.

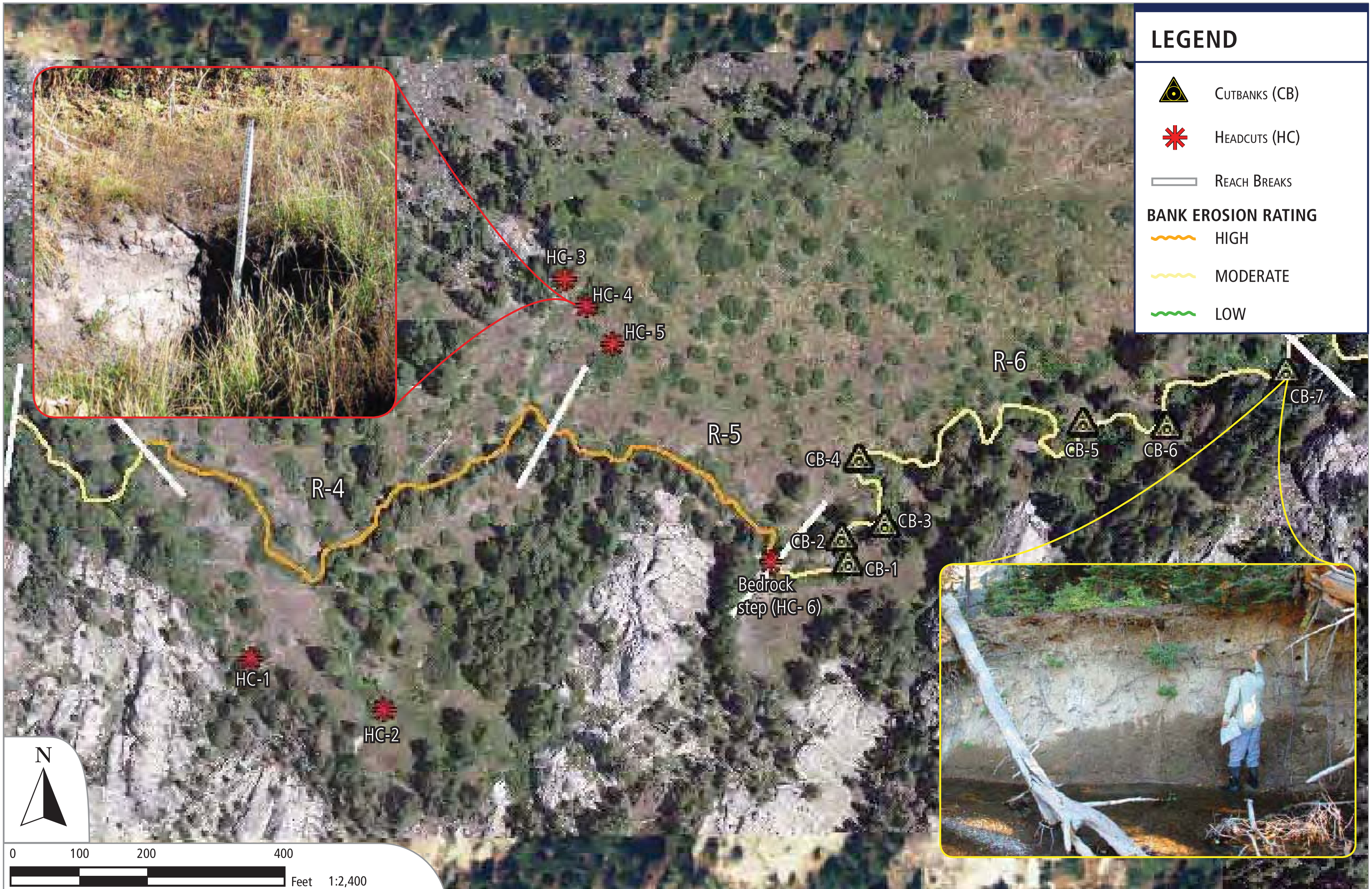

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FIGURE 4-4: Headcuts and cutbanks mapped in the project area.

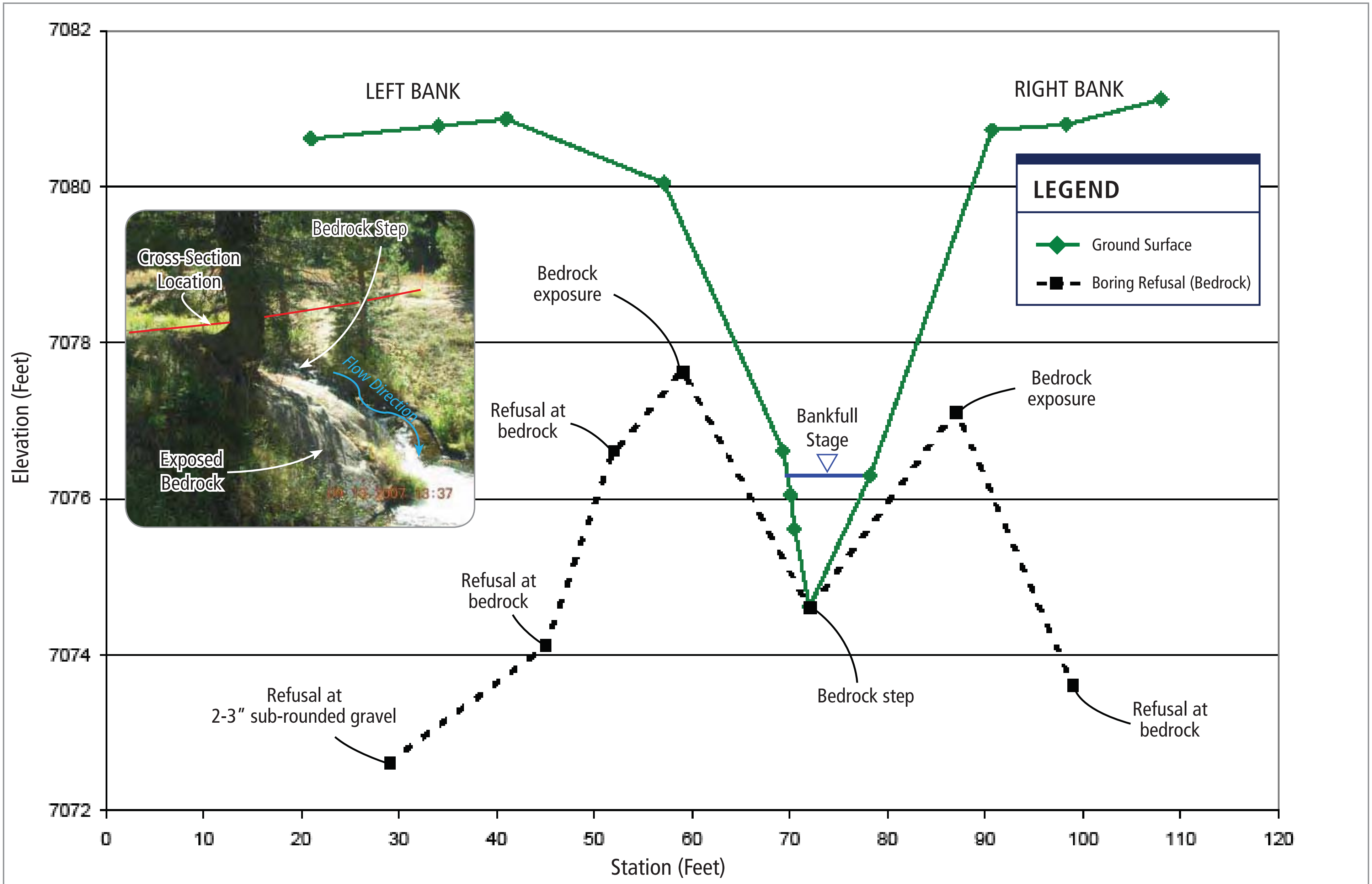

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FIGURE 4-5: Cross-section showing subsurface investigation results at the bedrock step.

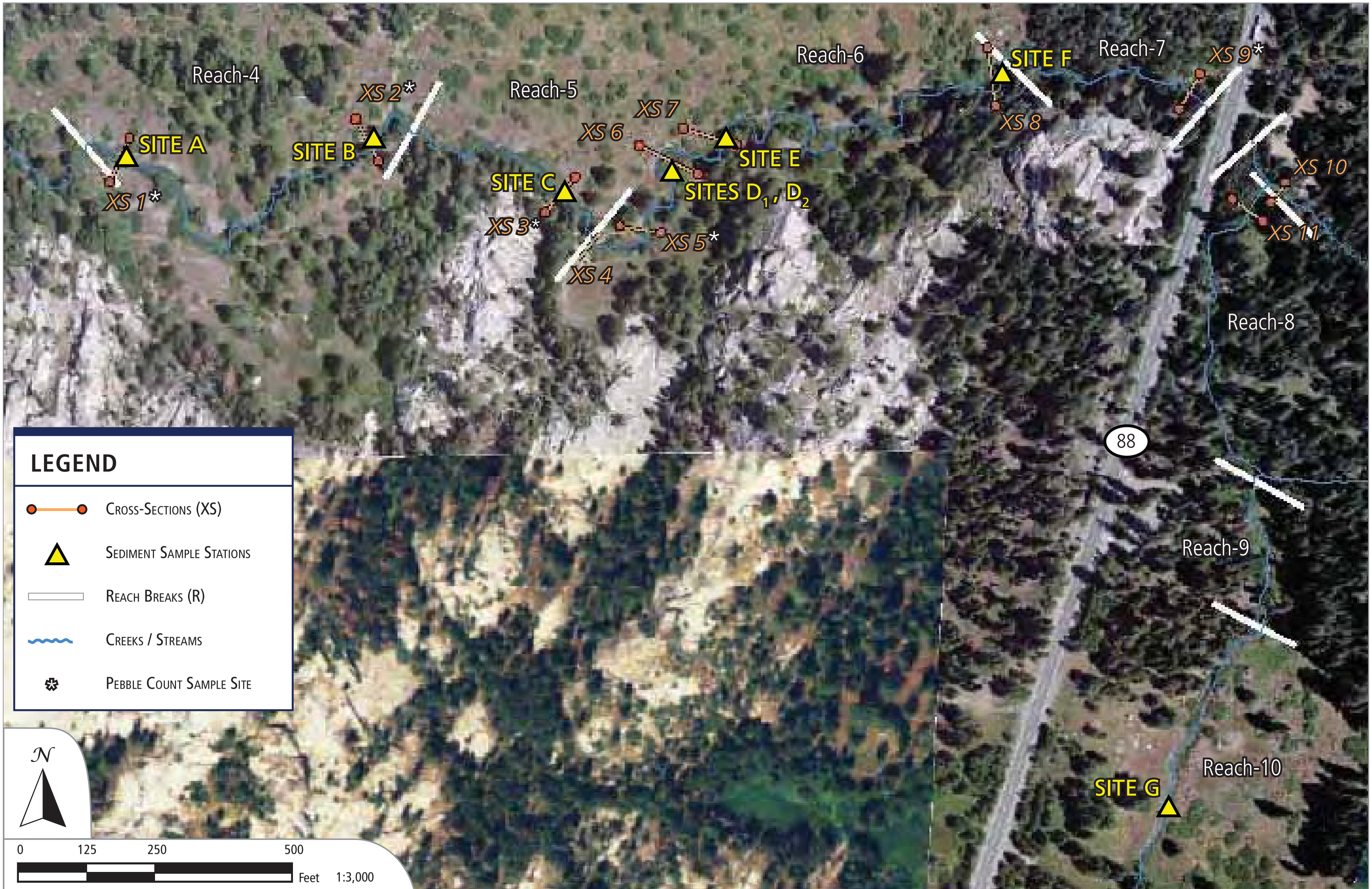

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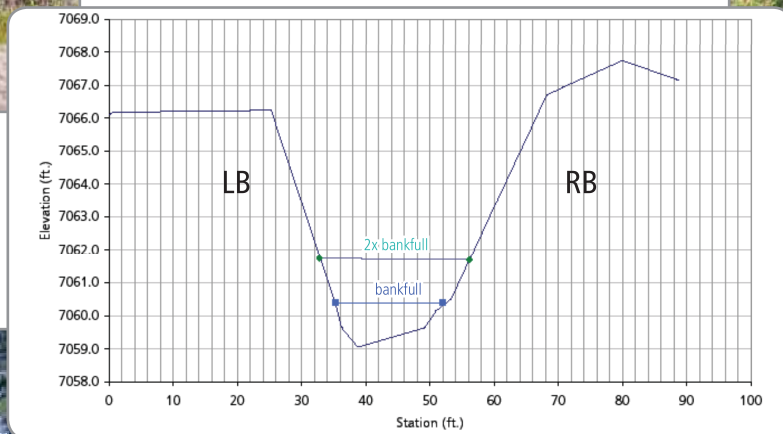
FIGURE 4-6: Cross-section locations and sediment sampling stations.

Cross Section 1

RS 23+50



W_{bkfl} = 16.7 ft.

D_{bkfl} = 1.3 ft.

W/D Ratio = 12.5

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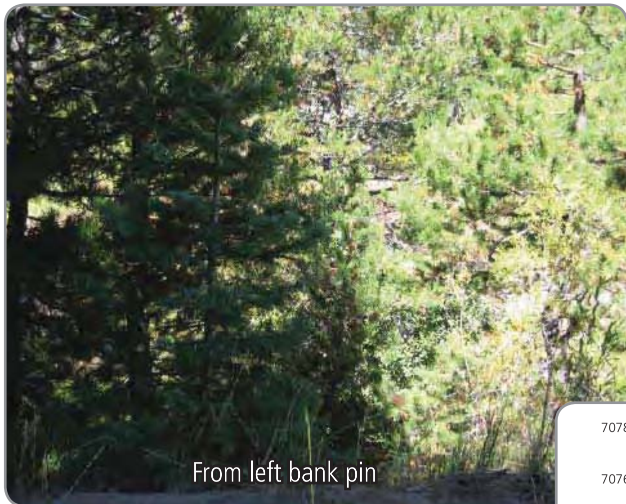
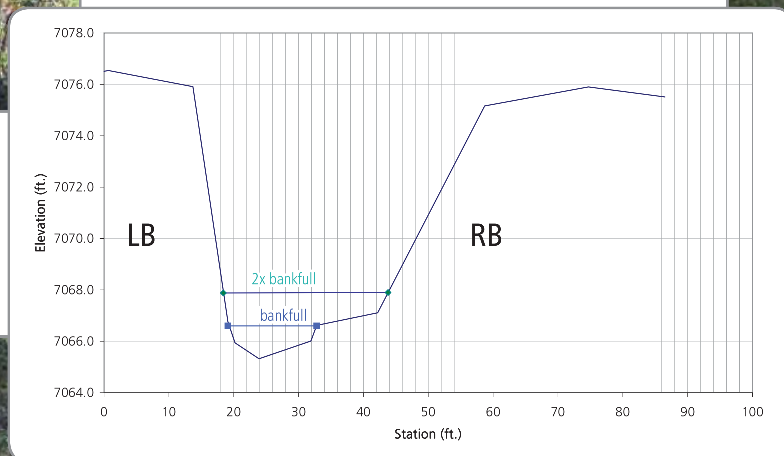
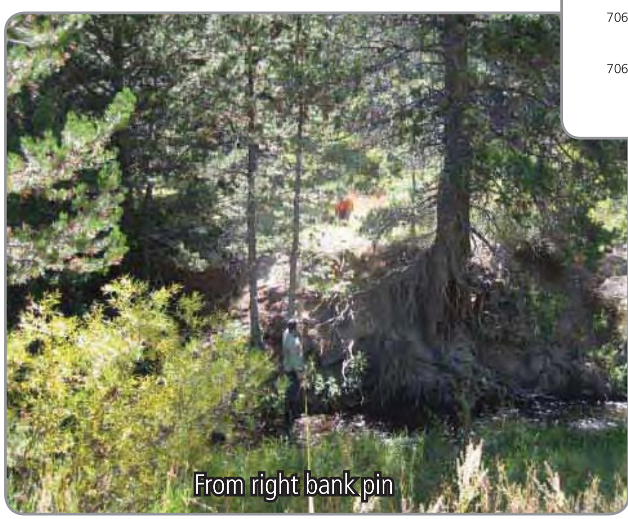
FIGURE 4-7a: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.



Cross Section 2

RS 30+25





W_{bkfl} = 13.7 ft.

D_{bkfl} = 1.3 ft.

W/D Ratio = 10.7

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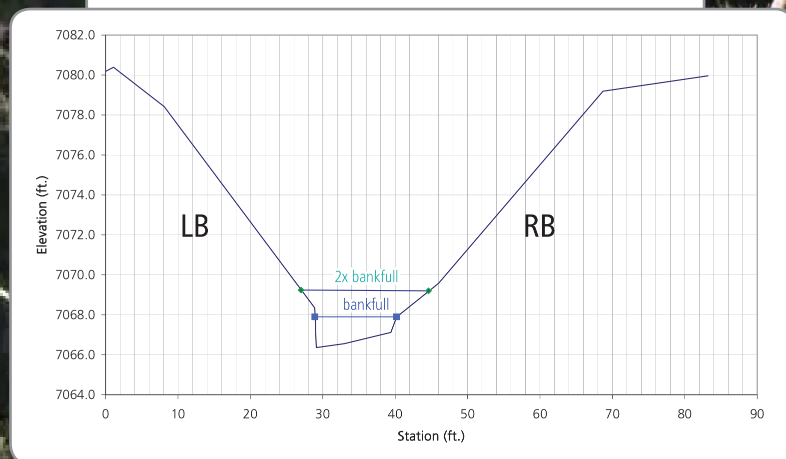
FIGURE 4-7b: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.

Cross Section 3

RS 34+25



W_{bkfl} = 11.3 ft.

D_{bkfl} = 1.3 ft.

W/D Ratio = 8.4

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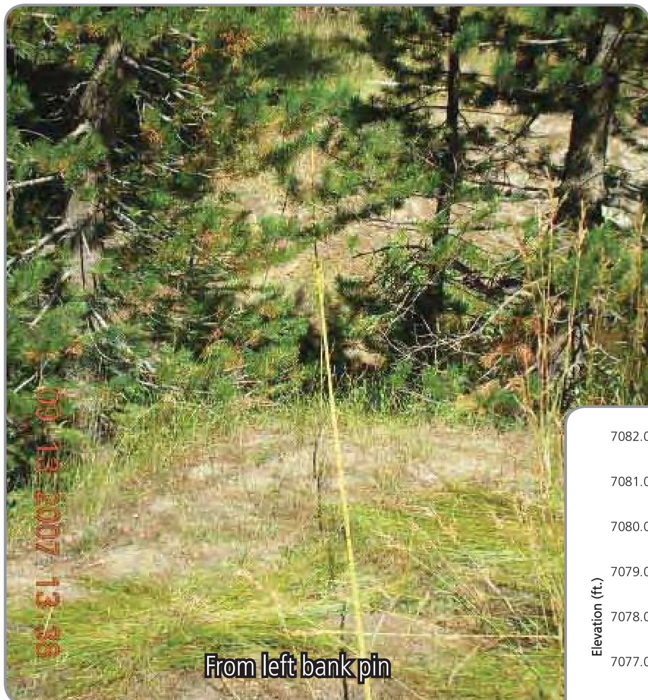
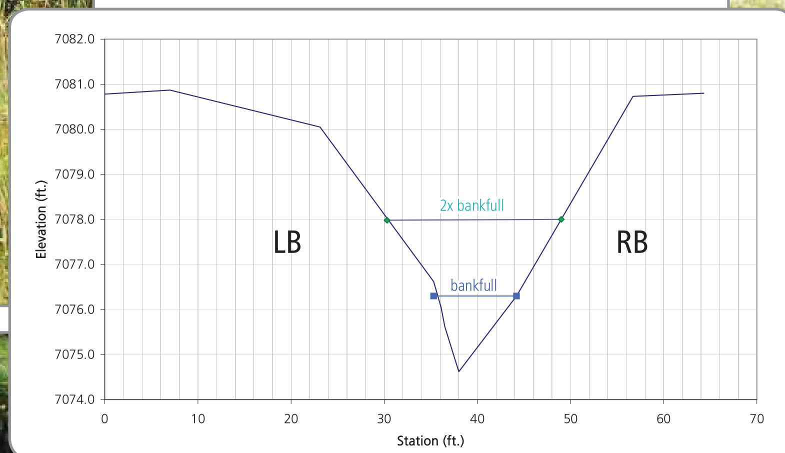
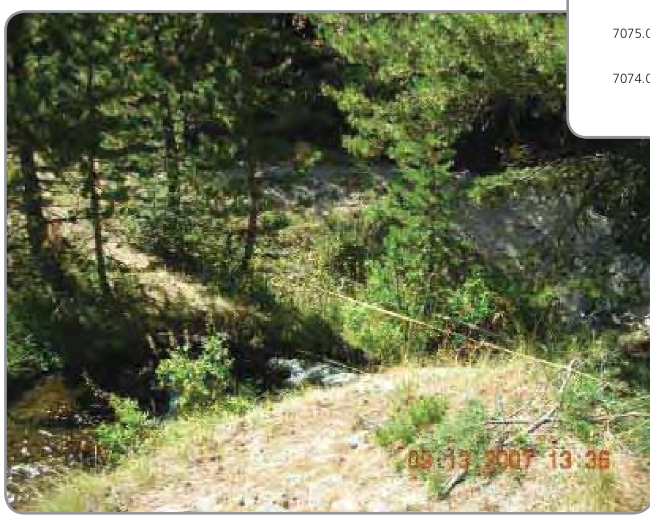
FIGURE 4-7c: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.



Cross Section 4

RS 35+50





W_{bkfl} = 8.9 ft.

D_{bkfl} = 1.7 ft.

W/D Ratio = 5.3

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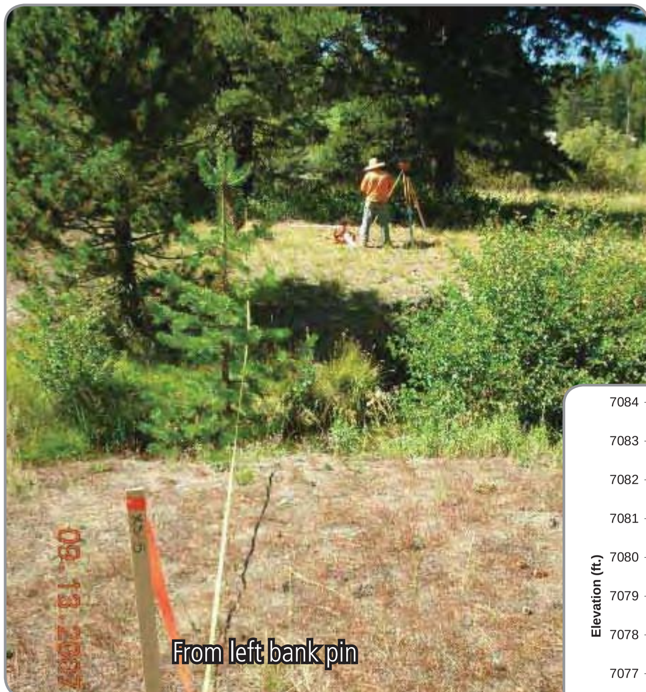
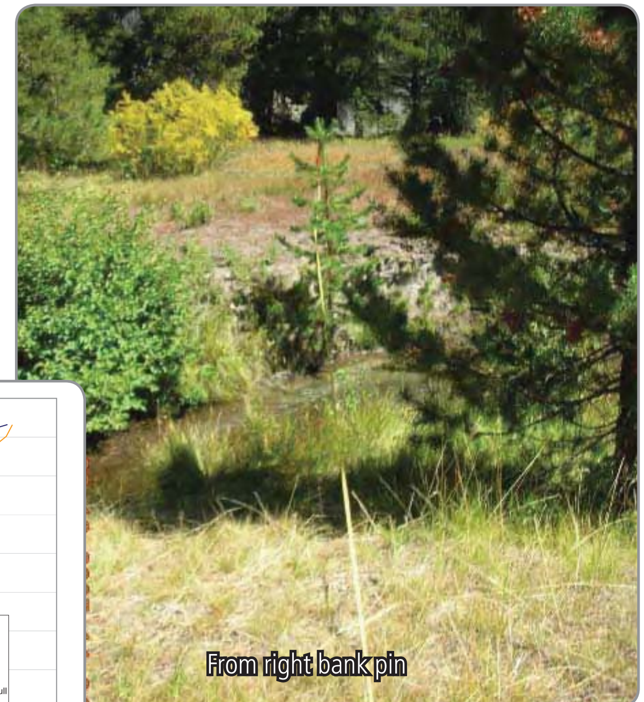
FIGURE 4-7d: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.

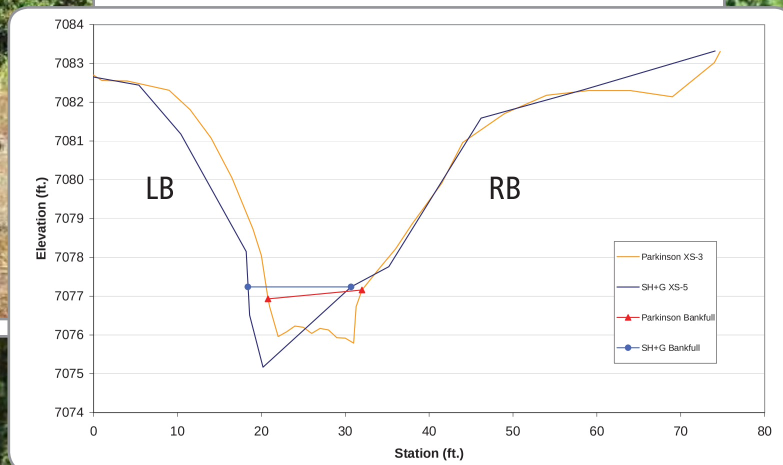


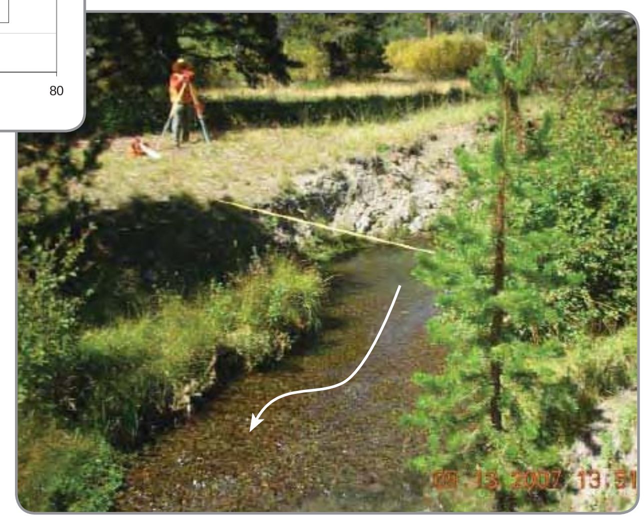


Cross Section 5

(Parkinson XS-1, 1999)

RS 36+75





W_{bkfl} = 12.3 ft.

D_{bkfl} = 2.0 ft.

W/D Ratio = 6.1

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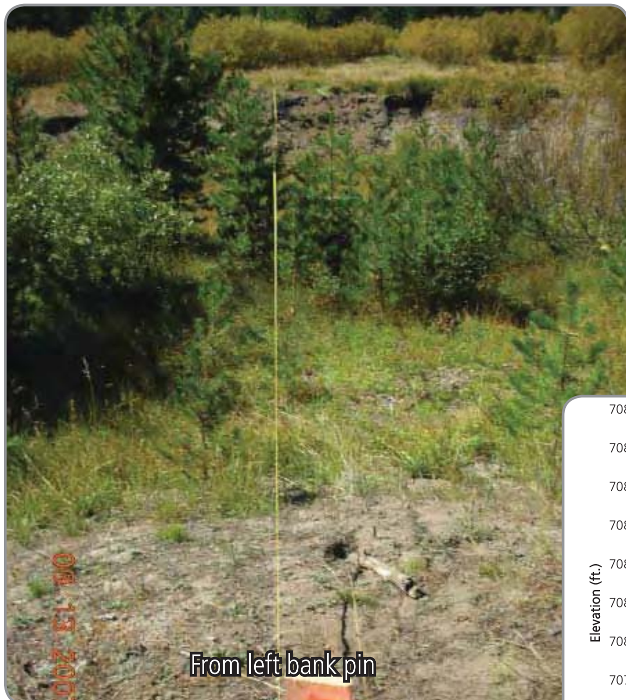
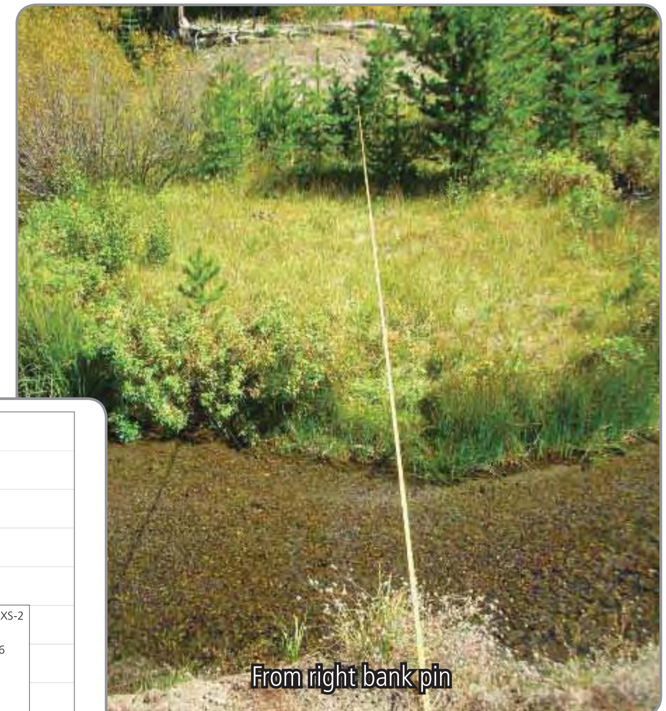
FIGURE 4-7e: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.

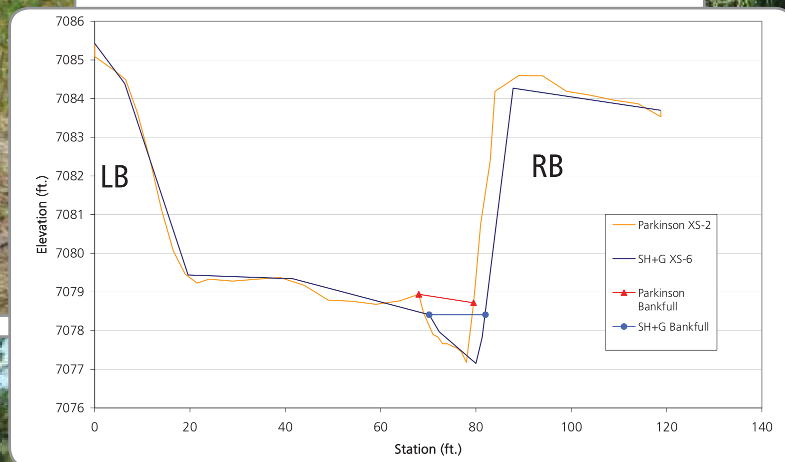


Cross Section 6

(Parkinson XS-2, 1999)

RS 39+00





W_{bkfl} = 11.8 ft.

D_{bkfl} = 1.2 ft.

W/D Ratio = 9.4

FIGURE 4-7f: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.

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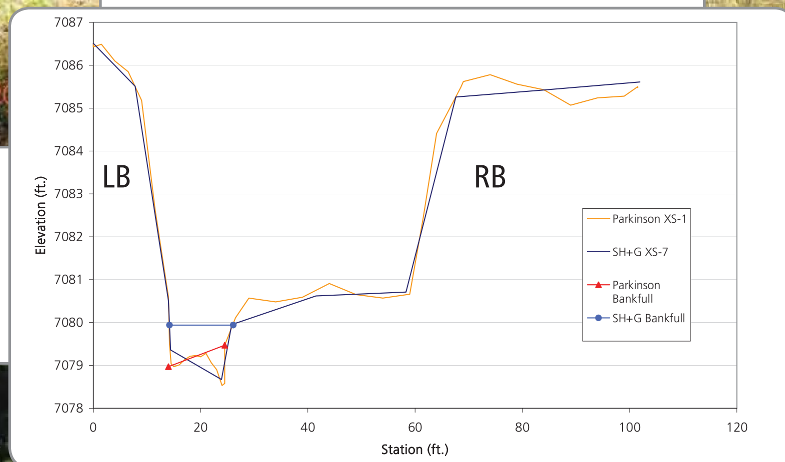
Cross Section 7

(Parkinson XS-1, 1999)

RS 40+50



W_{bkfl} = 11.5 ft.

D_{bkfl} = 1.2 ft.

W/D Ratio = 9.3

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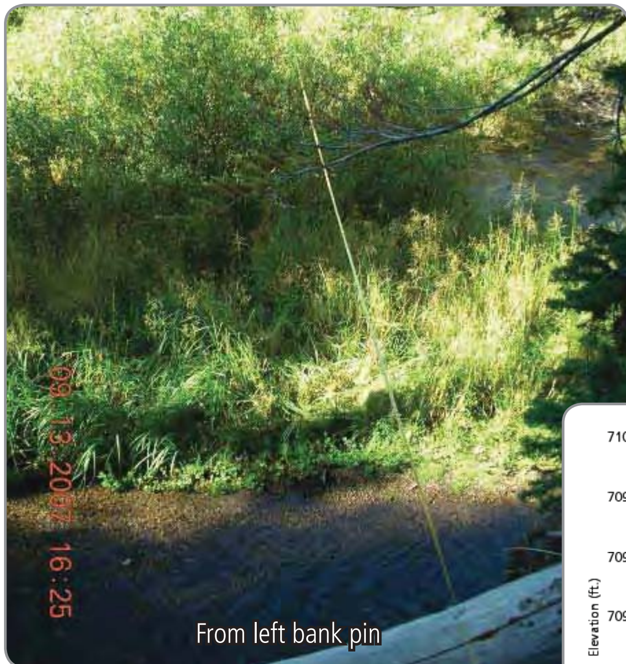
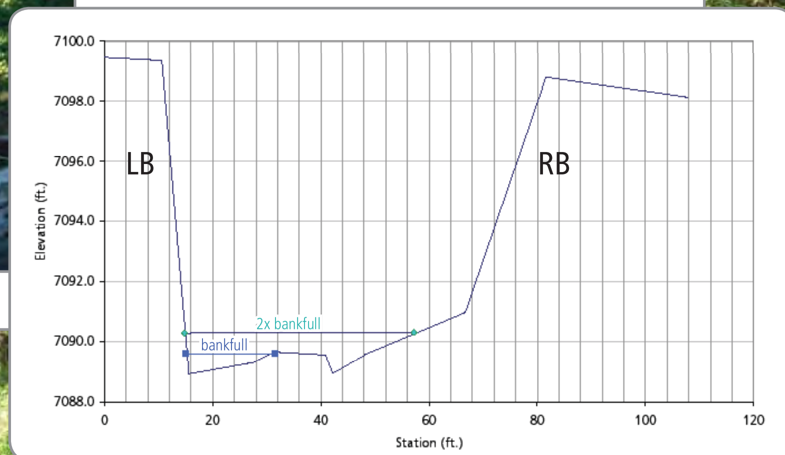
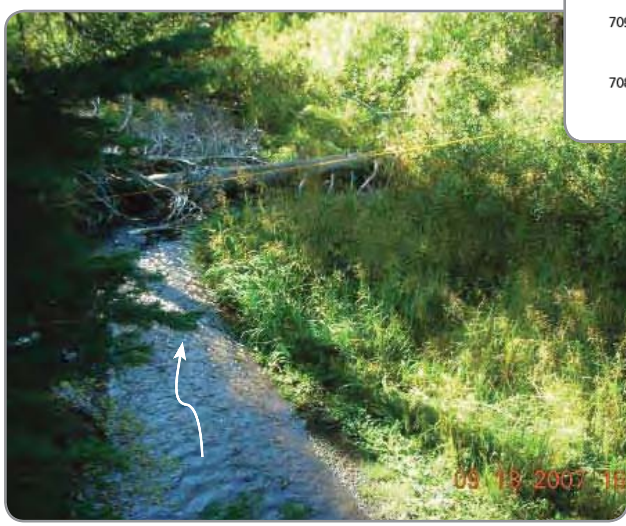
FIGURE 4-7g: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.



Cross Section 8

RS 47+25





W_{bkfl} = 16.4 ft.

D_{bkfl} = 0.7 ft.

W/D Ratio = 24.1

FIGURE 4-7h: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.

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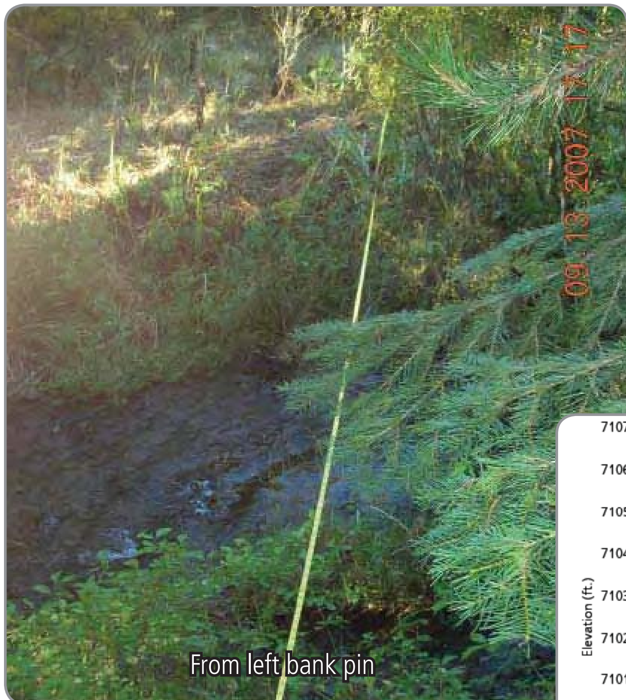
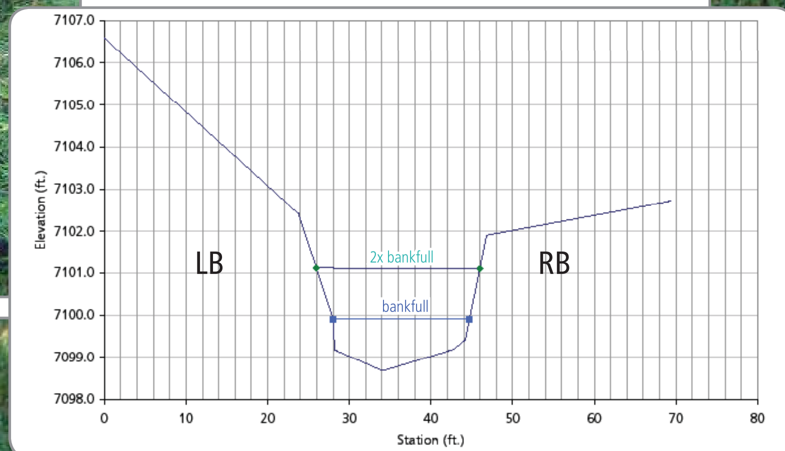


Cross Section 9

RS 52+00



W_{bkfl} = 16.7 ft.

D_{bkfl} = 1.2 ft.

W/D Ratio = 13.7

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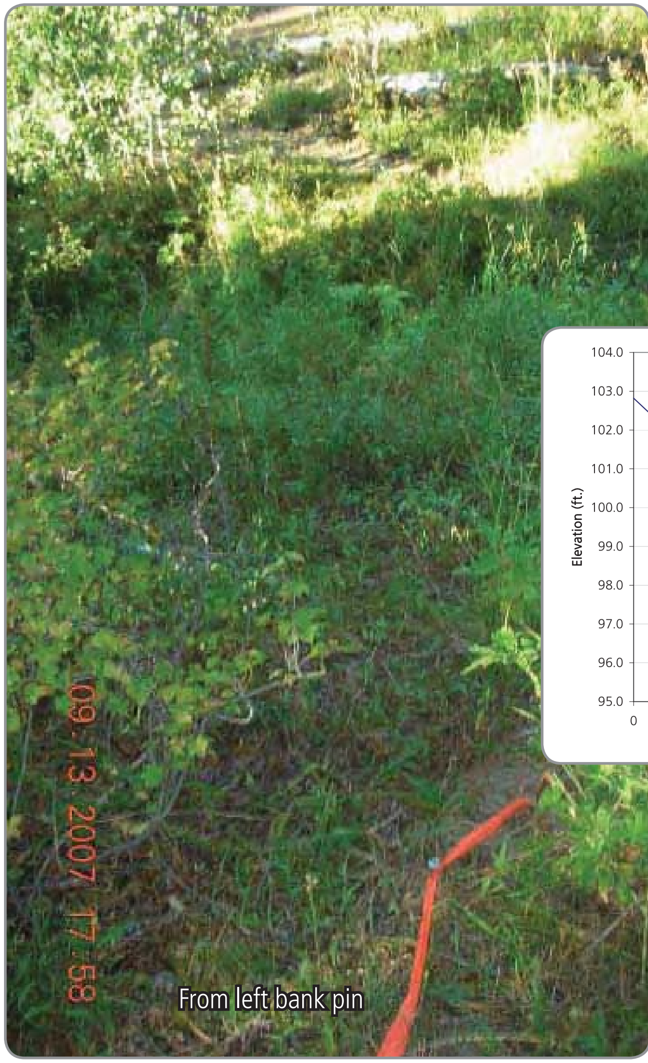
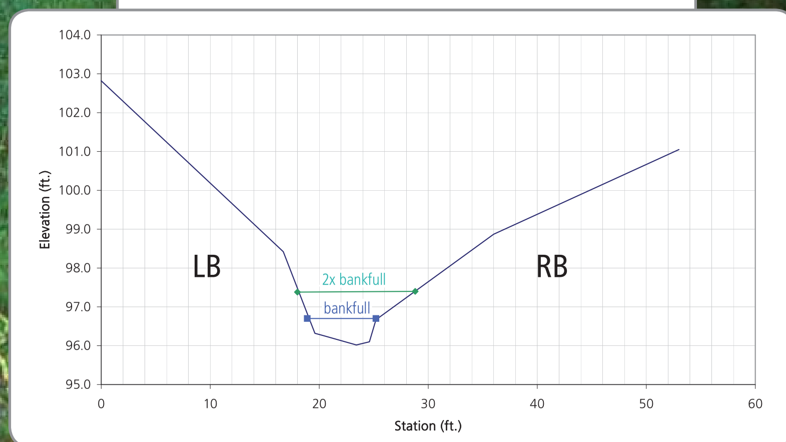
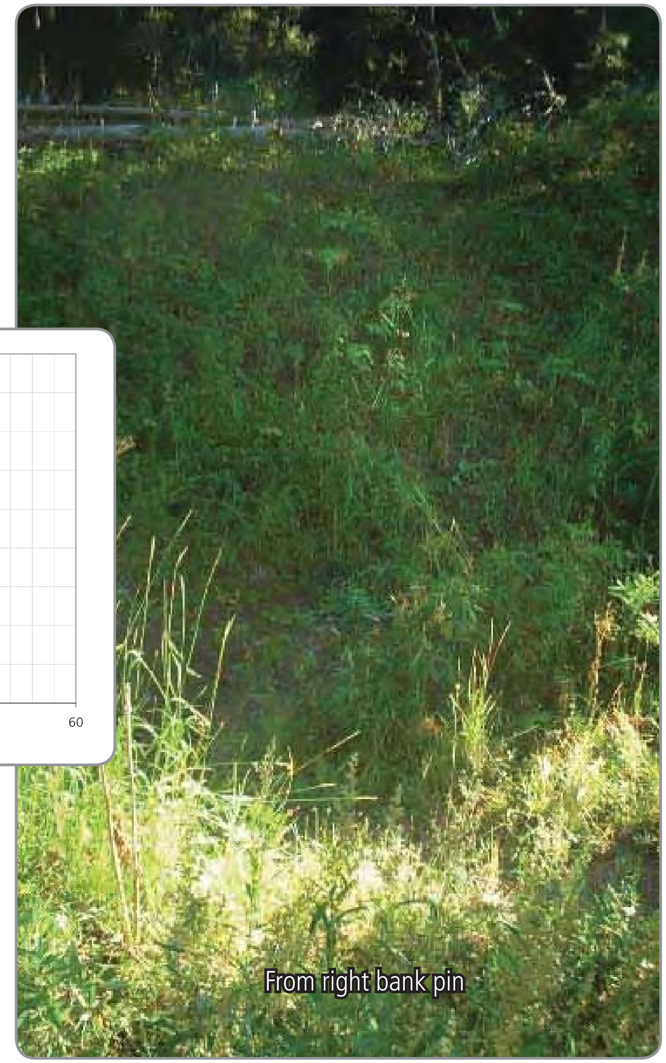
FIGURE 4-7i: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.

Cross Section 10

Thunder Mountain tributary







W_{bkfl} = 6.3 ft.

D_{bkfl} = 0.7 ft.

W/D Ratio = 9.3

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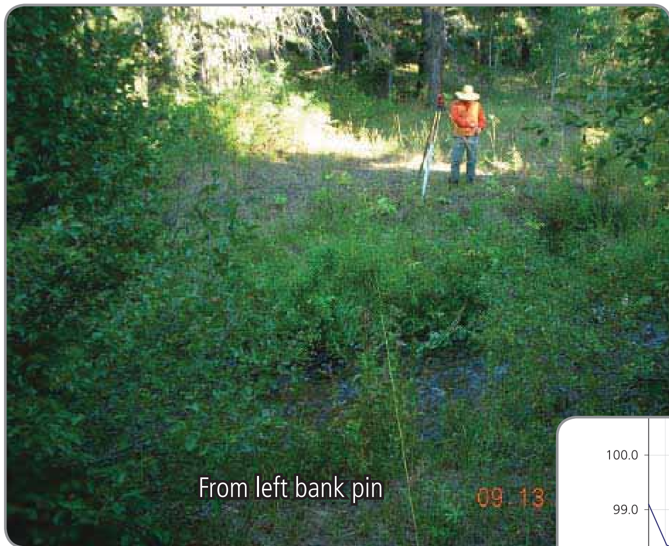
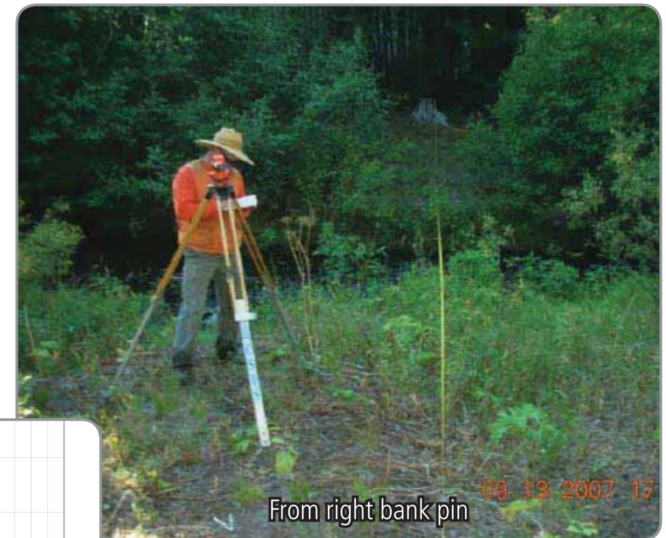
FIGURE 4-7j: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.

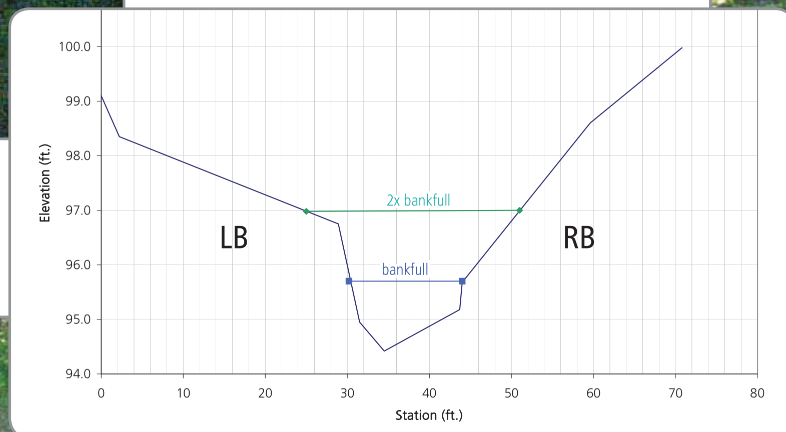


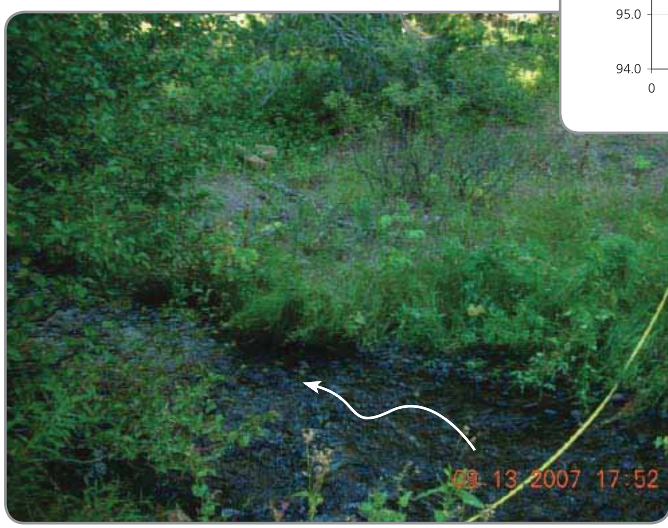
Cross Section 11

Upstream of

Thunder Mountain tributary







W_{bkfl} = 13.8 ft.

D_{bkfl} = 1.3 ft.

W/D Ratio = 10.8

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FIGURE 4-7k: Cross-section survey results. Wbkfl = Bankfull width; Dbkfl = Depth at Bankful; W/D = Width to Depth at bankfull.

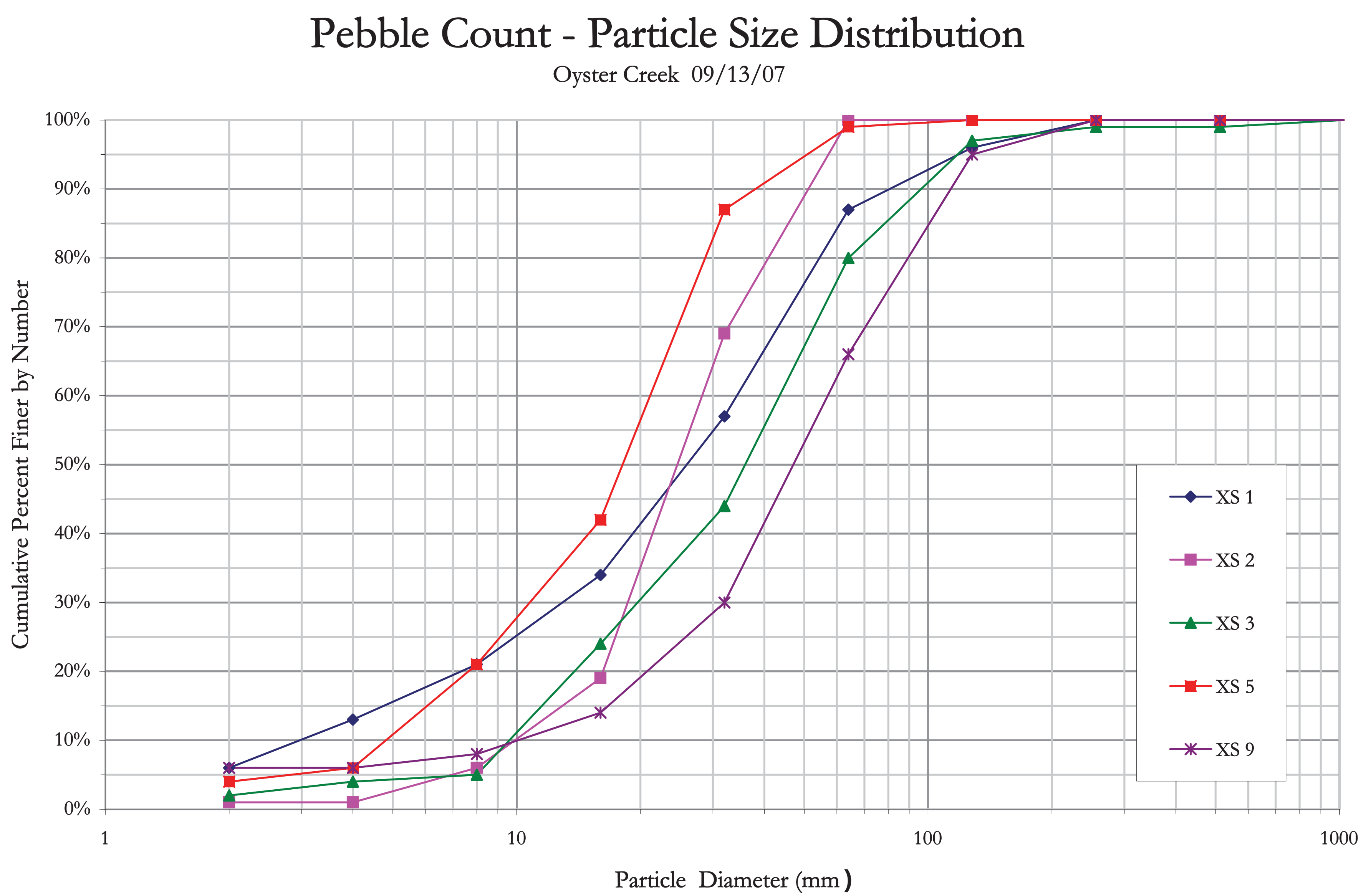

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FIGURE 4-8: Particle size distribution for the 5 pebble count locations.

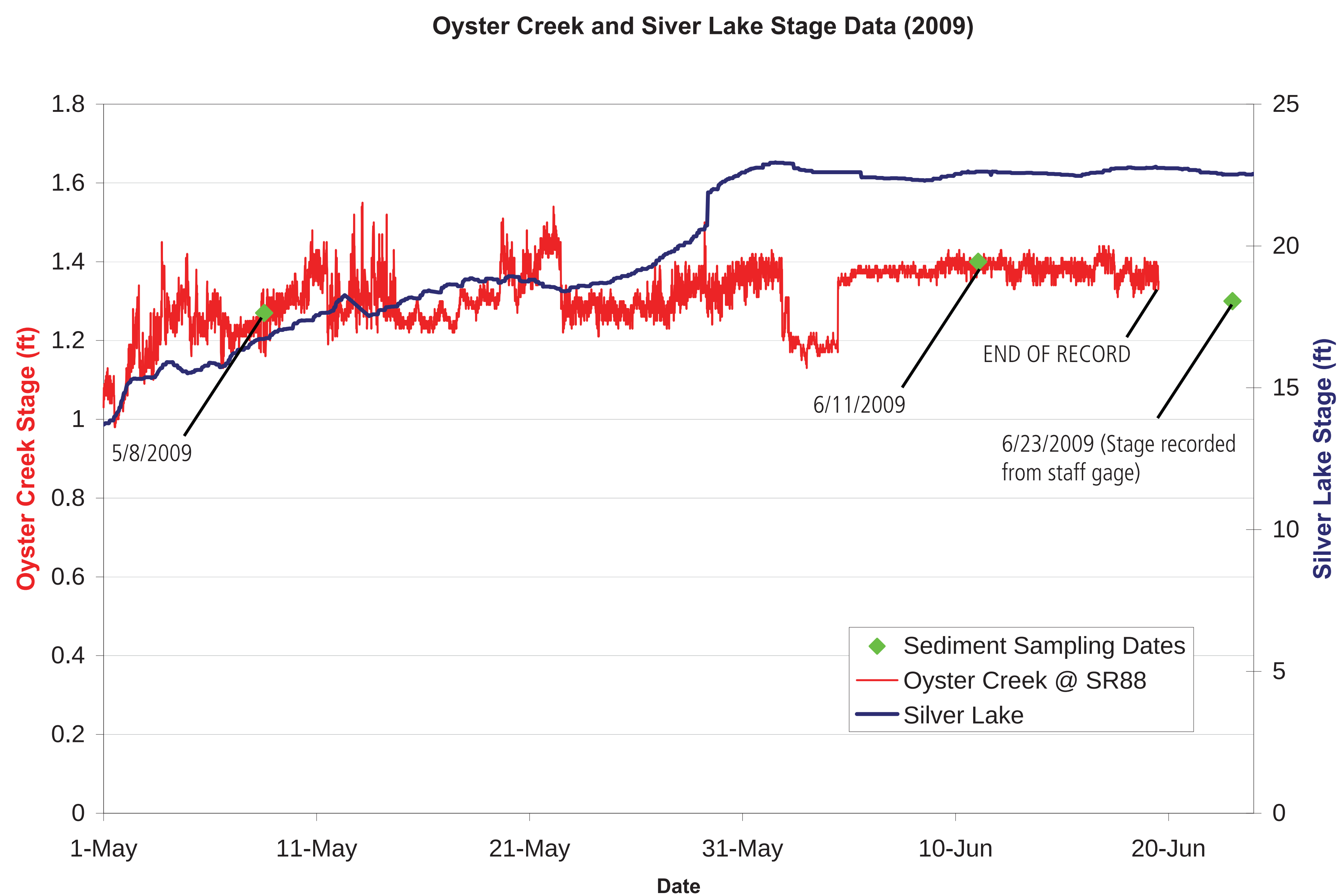

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FIGURE 4-9: Stage data from the Oyster Creek gage at SR 88 plotted with Silver Lake stage data for the 2009 sediment sampling period.

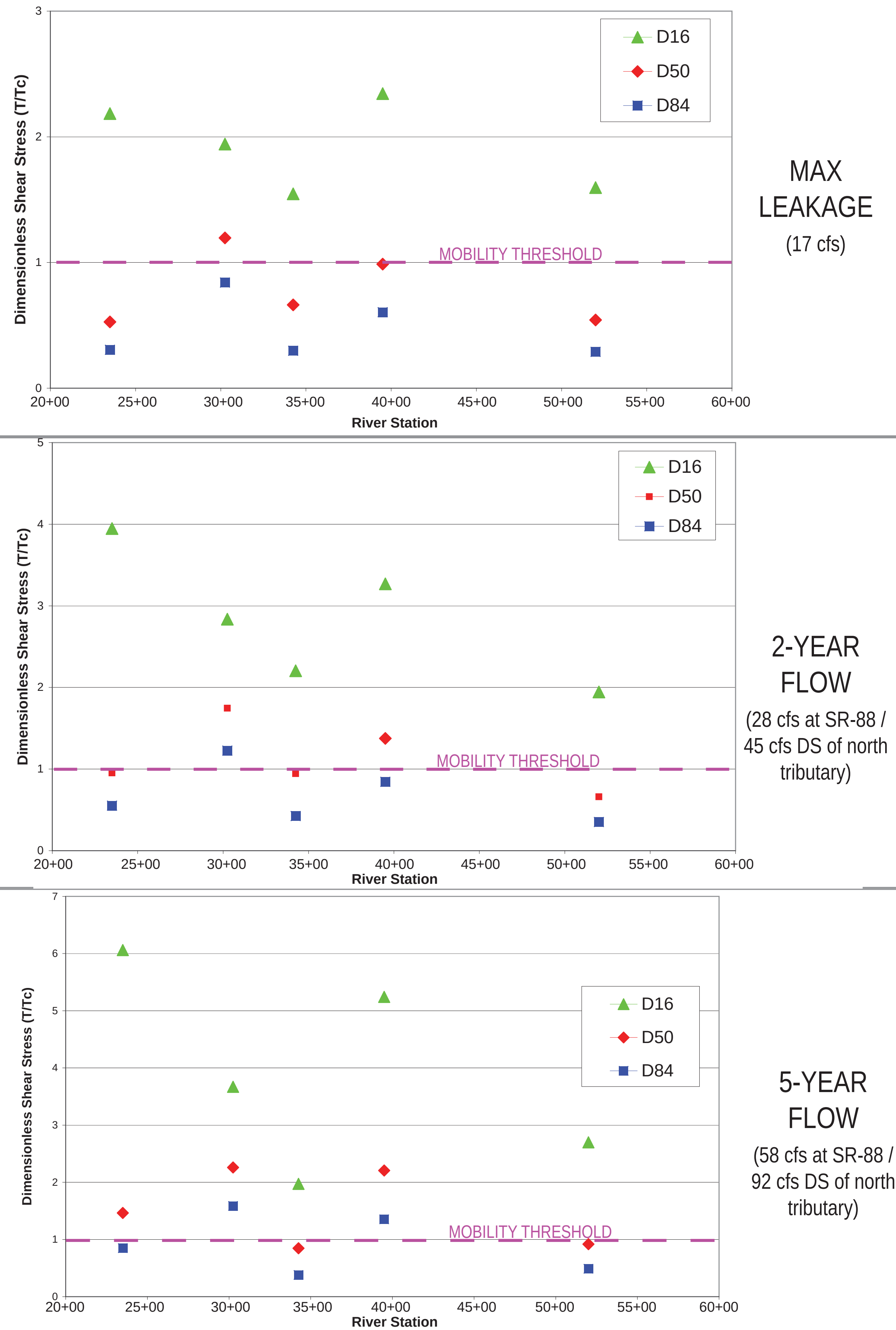

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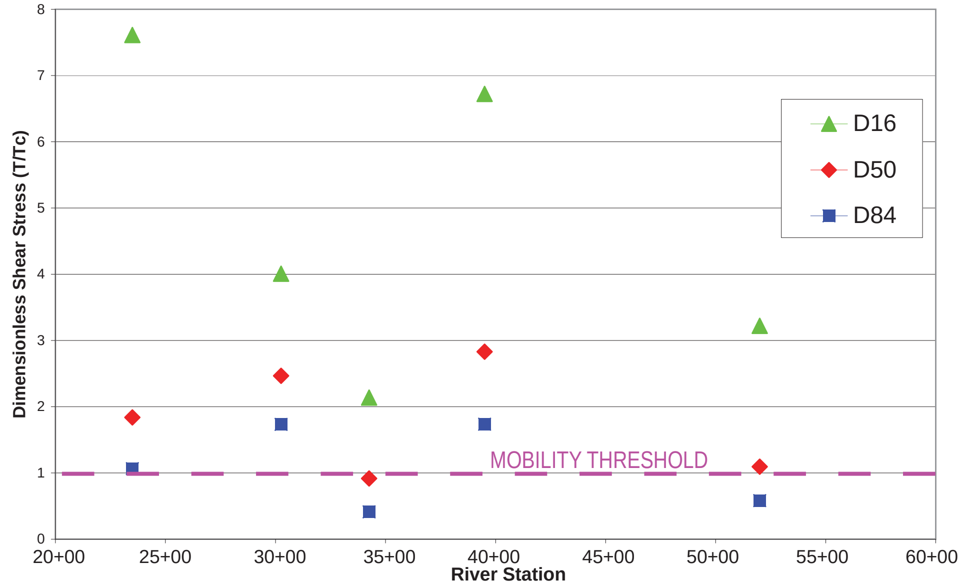
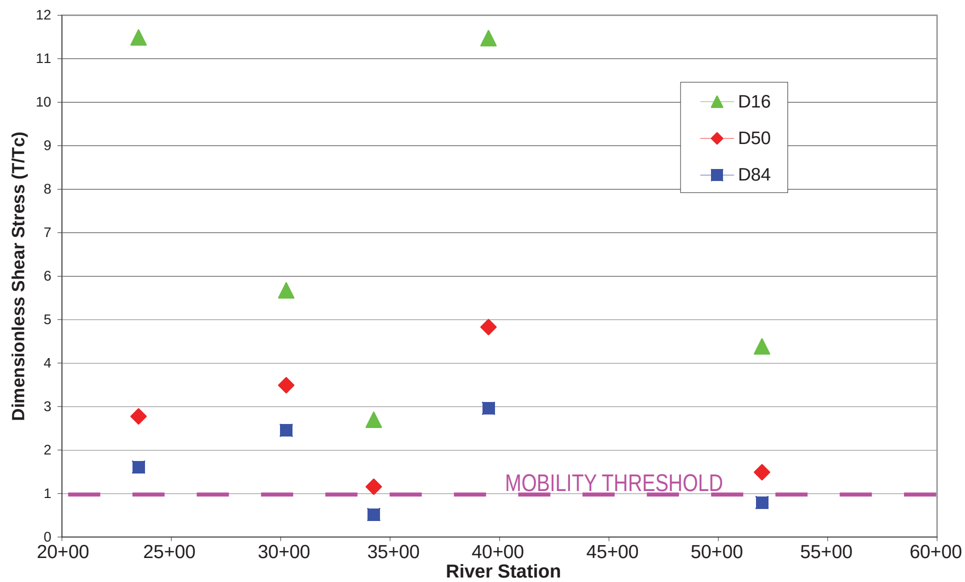
FIGURE 4-10:a Estimated particle mobility based on the ratio of boundary shear stress (τ) to critical sheer stress (τ_c).



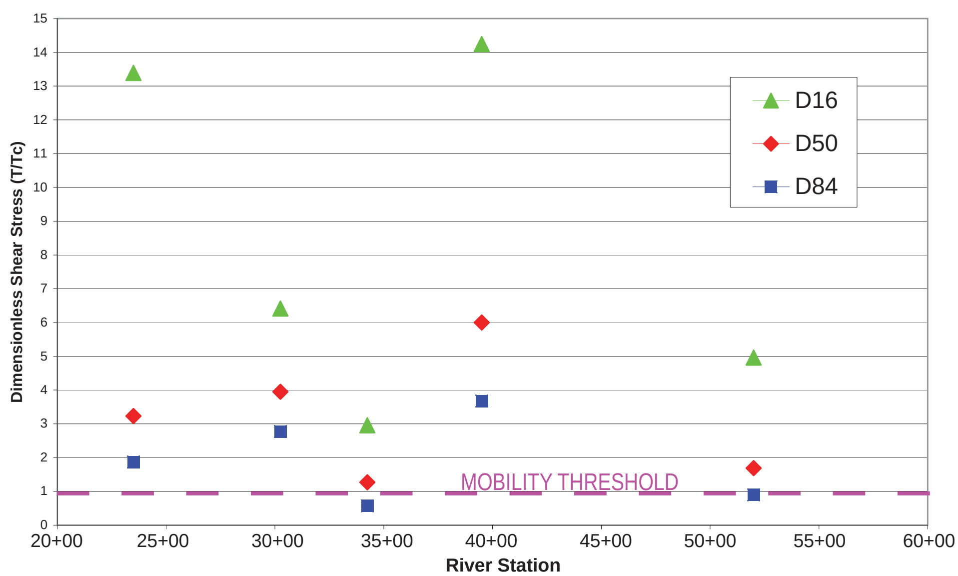
10-YEAR FLOW

(86 cfs at SR-88 / 137 cfs DS of north tributary)



50-YEAR FLOW

(180 cfs at SR-88 / 285 cfs DS of north tributary)



100-YEAR FLOW

(235 cfs at SR-88 / 373 cfs DS of north tributary)

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FIGURE 4-10b: Estimated particle mobility based on the ratio of boundary shear stress (τ) to critical sheer stress (τ_c).

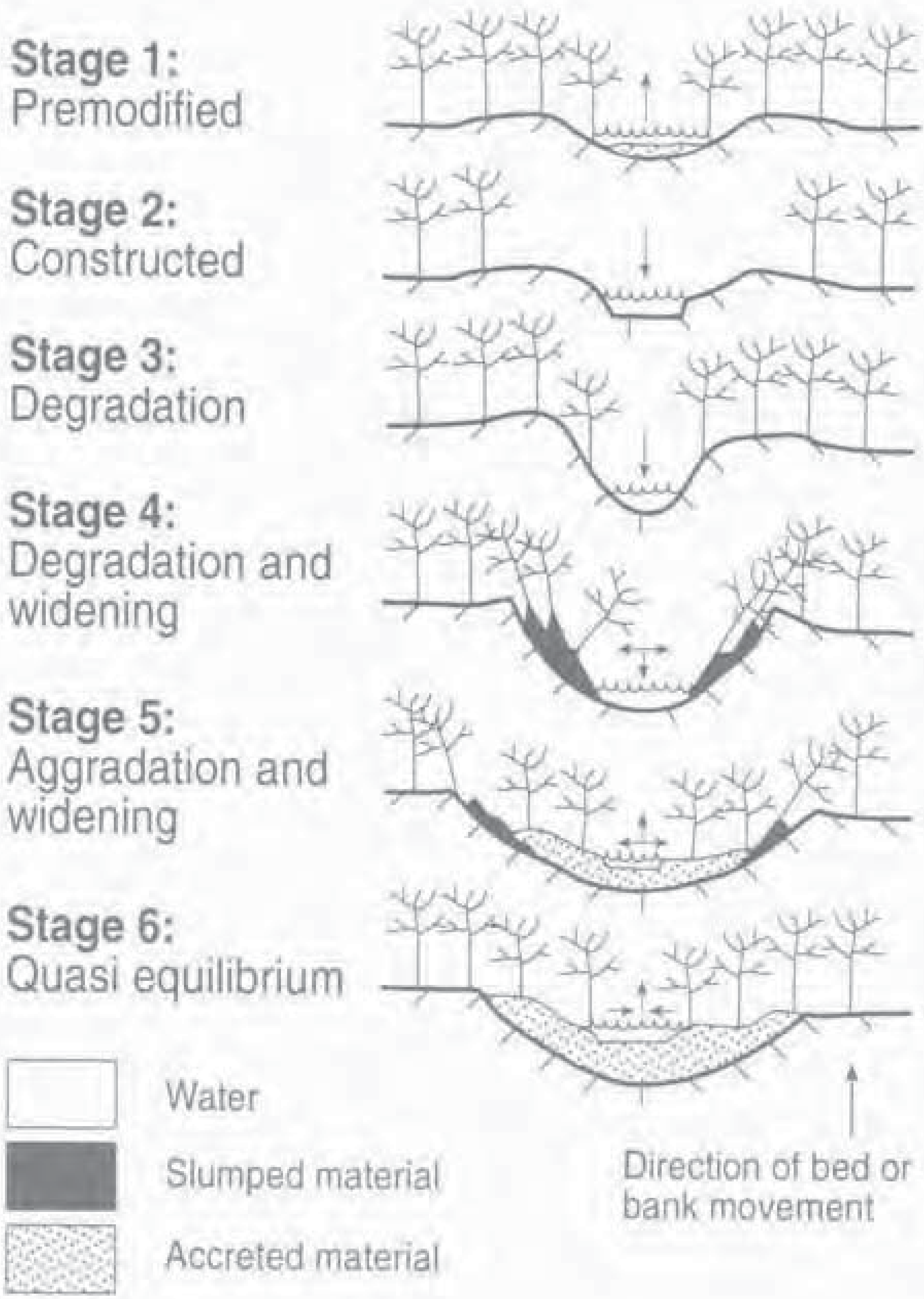

FIGURE 5-1: Channel evolution model (Simon and Hupp, 1986).

Oyster Creek
SENSITIVE SITE MONITORING REPORT

PHOTOGRAPHS

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PHOTOS: (1) Oyster Creek - Silver Fork confluence **(2)** Reach 1 representative section **(3)** Large woody debris in Reach 1 **(4)** Exposed bedrock marking Reach 1/2 boundary.

PHOTOS: (5) Reach 2 representative section **(6)** Aspen and alder are co-dominat on the banks of Reach 2 **(7)** North Tributary, Reach 4/5 boundary **(8)** Active headcut in the North Tributary main channel.


9


10


11


12

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PHOTOS: (9) Typical section in Reach 5 **(10)** Bedrock step marking the Reach 5/6 boundary **(11)** Recruitment of large woody debris in Reach 6 due to local bank erosion **(12)** Steep cutbank opposite point bar in Reach 6.

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PHOTOS: (13) Oyster Creek crosses under SR 88 through two 36-inch corrugated metal pipes **(14)** Riparian meadow upstream of SR 88 **(15)** Oyster Lake **(16)** Example of bed particle size in middle and upper sampling sites (primarily medium sized gravels).

17

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19

20

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PHOTOS: (17) USFS portable bedload traps at Site E **(18)** Helley-Smith sediment sampling at Site D_1 **(19)** Bedload trap at site D_2 **(20)** Examples of sediment samples from both sampling methods.

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PHOTOS: (21) Mature trees rooted near the base level of the channel in Reach 5. **(22)** Trees rooted near the base of the channel in Reach 6 are significantly younger than those in Reach 5. Bank failure at this location (right side of photo) appears to be the result of toe scour. **(23)** Bank failure due to sapping. **(24)** Evidence of lateral migration (widening) in Reach 6.

OYSTER CREEK
SENSITIVE SITE MONITORING REPORT

APPENDIX A

HYDRAULIC MODELING RESULTS

HEC-RAS Plan: [illegible] River: [illegible] Reach: [illegible]

Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	
Downstream Hwy88	5400	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5400	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5400	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	11.62	[illegible]	[illegible]
Downstream Hwy88	5400	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5400	25-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5400	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5400	100-YR	[illegible]	[illegible]	[illegible]	0.02	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5340	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17.77	[illegible]
Downstream Hwy88	5340	2-YR	[illegible]	[illegible]	[illegible]	0.11	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5340	5-YR	[illegible]	[illegible]	[illegible]	0.14	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5340	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5340	25-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5340	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5340	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5300		Culvert						
Downstream Hwy88	5230	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5230	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5230	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5230	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5230	25-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5230	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5230	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5200	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5200	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5200	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5200	10-YR	[illegible]	[illegible]	[illegible]	1.11	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5200	25-YR	[illegible]	[illegible]	[illegible]	1.34	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5200	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5200	100-YR	[illegible]	[illegible]	[illegible]	1.71	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5010	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5010	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5010	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5010	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5010	25-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5010	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	5010	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4900	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4900	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.11
Downstream Hwy88	4900	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4900	10-YR	[illegible]	[illegible]	[illegible]	1.34	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4900	25-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4900	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4900	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4820	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4820	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4820	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	11.74	[illegible]	[illegible]
Downstream Hwy88	4820	10-YR	[illegible]	[illegible]	[illegible]	1.11	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4820	25-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4820	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4820	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4725	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4725	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4725	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4725	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4725	25-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4725	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4725	100-YR	[illegible]	[illegible]	[illegible]	1.34	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4600	Max Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4600	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

HEC-RAS Plan: [illegible] River: [illegible] Reach: Downstream Hwy88 (Continued)

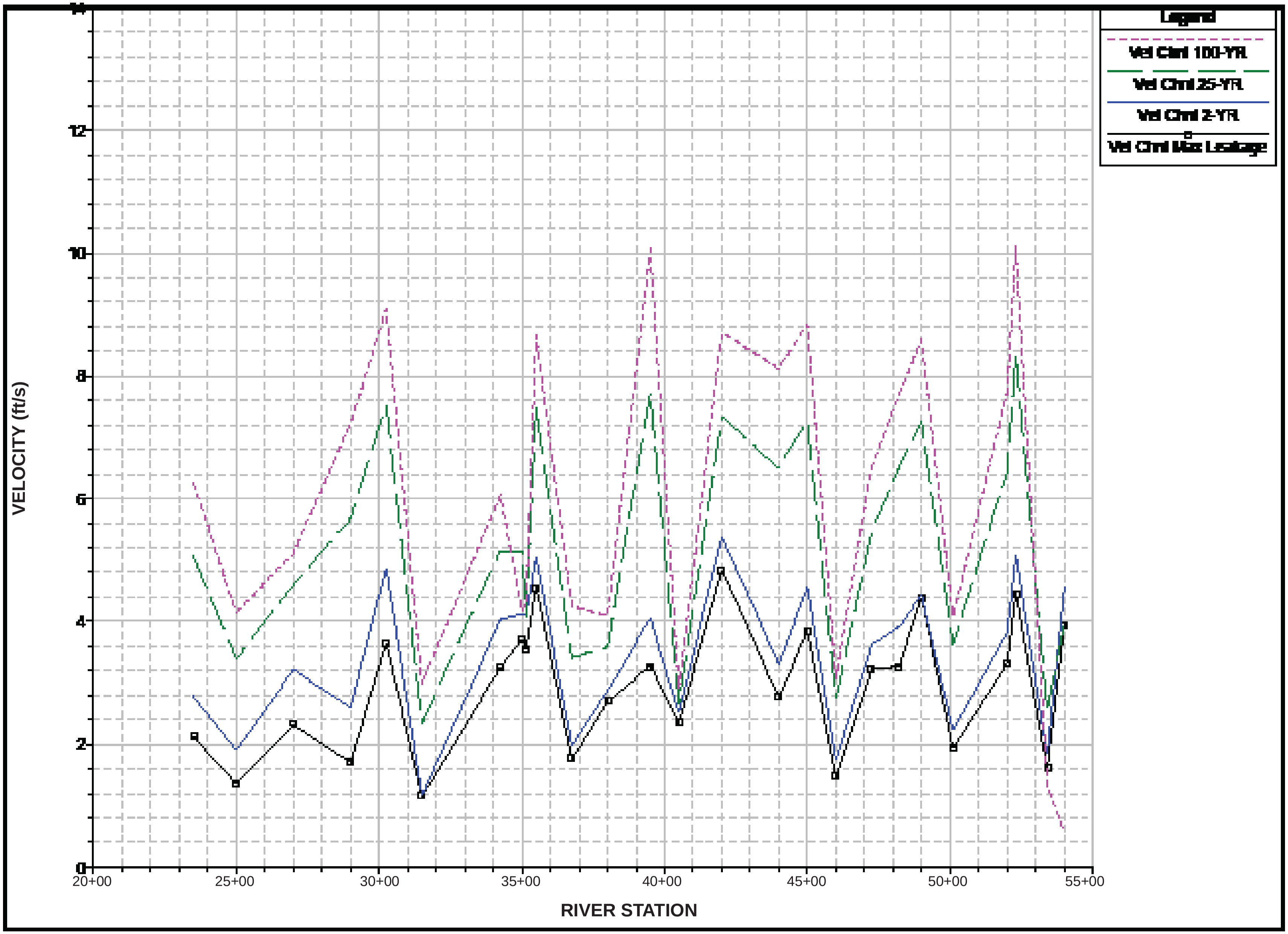
Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	
Downstream Hwy88	4600	5-YR	[illegible]	[illegible]	[illegible]	0.34	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4600	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4600	25-YR	134.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4600	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4600	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4500	Max Leakage	17.40	[illegible]	[illegible]	[illegible]	4.72	[illegible]	[illegible]
Downstream Hwy88	4500	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4500	5-YR	[illegible]	[illegible]	5.51	1.01	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4500	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4500	25-YR	134.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4500	50-YR	[illegible]	[illegible]	[illegible]	1.72	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4500	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4400	Max Leakage	17.40	[illegible]	2.77	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4400	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	10.14	[illegible]	[illegible]
Downstream Hwy88	4400	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4400	10-YR	[illegible]	[illegible]	5.41	[illegible]	[illegible]	[illegible]	0.71
Downstream Hwy88	4400	25-YR	134.40	[illegible]	5.51	1.19	[illegible]	[illegible]	0.77
Downstream Hwy88	4400	50-YR	[illegible]	[illegible]	[illegible]	1.34	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4400	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4200	Max Leakage	17.40	7682.17	[illegible]	[illegible]	[illegible]	[illegible]	1.01
Downstream Hwy88	4200	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.01
Downstream Hwy88	4200	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4200	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4200	25-YR	134.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4200	50-YR	[illegible]	[illegible]	[illegible]	1.77	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4200	100-YR	[illegible]	[illegible]	6.71	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4050	Max Leakage	17.40	[illegible]	[illegible]	[illegible]	7.34	[illegible]	[illegible]
Downstream Hwy88	4050	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4050	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4050	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4050	25-YR	134.40	[illegible]	[illegible]	0.17	[illegible]	[illegible]	0.27
Downstream Hwy88	4050	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	4050	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3950	Max Leakage	17.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3950	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	7.77	[illegible]	[illegible]
Downstream Hwy88	3950	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3950	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3950	25-YR	134.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.77
Downstream Hwy88	3950	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3950	100-YR	[illegible]	[illegible]	[illegible]	2.31	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3800	Max Leakage	17.40	[illegible]	2.71	0.77	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3800	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.17	[illegible]
Downstream Hwy88	3800	5-YR	[illegible]	[illegible]	[illegible]	1.14	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3800	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3800	25-YR	134.40	[illegible]	[illegible]	1.72	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3800	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3800	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3675	Max Leakage	17.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3675	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.11	[illegible]
Downstream Hwy88	3675	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3675	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18.77	[illegible]
Downstream Hwy88	3675	25-YR	134.40	[illegible]	3.41	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3675	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3675	100-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3550	Max Leakage	17.40	[illegible]	[illegible]	[illegible]	3.74	[illegible]	[illegible]
Downstream Hwy88	3550	2-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.01
Downstream Hwy88	3550	5-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.01
Downstream Hwy88	3550	10-YR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3550	25-YR	134.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3550	50-YR	[illegible]	[illegible]	[illegible]	3.34	[illegible]	[illegible]	[illegible]

HEC-RAS Plan: [illegible] River: [illegible] Reach: Downstream Hwy88 (Continued)

Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	
Downstream Hwy88	3550	100-YR	[illegible]	7670.26	5.87	3.64	[illegible]	30.27	[illegible]
Downstream Hwy88	3515	Max Leakage	17.60	[illegible]	[illegible]	1.87	4.70	[illegible]	[illegible]
Downstream Hwy88	3515	2-YR	[illegible]	[illegible]	4.10	2.51	[illegible]	12.30	[illegible]
Downstream Hwy88	3515	5-YR	[illegible]	7669.77	[illegible]	1.37	17.00	[illegible]	[illegible]
Downstream Hwy88	3515	10-YR	[illegible]	[illegible]	[illegible]	1.78	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3515	25-YR	134.60	7670.48	4.00	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3515	50-YR	[illegible]	7670.77	4.33	2.44	43.07	37.27	[illegible]
Downstream Hwy88	3515	100-YR	[illegible]	7671.27	4.30	2.41	55.17	[illegible]	[illegible]
Downstream Hwy88	3500	Max Leakage	17.60	[illegible]	[illegible]	[illegible]	4.00	[illegible]	[illegible]
Downstream Hwy88	3500	2-YR	[illegible]	7668.77	4.12	0.70	[illegible]	11.30	[illegible]
Downstream Hwy88	3500	5-YR	[illegible]	[illegible]	5.00	[illegible]	11.00	14.00	1.02
Downstream Hwy88	3500	10-YR	[illegible]	[illegible]	5.02	1.00	17.12	21.30	[illegible]
Downstream Hwy88	3500	25-YR	134.60	[illegible]	5.14	[illegible]	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3500	50-YR	[illegible]	[illegible]	[illegible]	[illegible]	40.00	[illegible]	[illegible]
Downstream Hwy88	3500	100-YR	[illegible]	[illegible]	4.10	[illegible]	55.74	[illegible]	[illegible]
Downstream Hwy88	3425	Max Leakage	17.60	7667.28	[illegible]	0.47	[illegible]	[illegible]	0.81
Downstream Hwy88	3425	2-YR	[illegible]	7667.38	4.02	0.57	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3425	5-YR	[illegible]	[illegible]	4.81	[illegible]	13.01	11.00	0.07
Downstream Hwy88	3425	10-YR	[illegible]	[illegible]	4.57	[illegible]	19.82	13.47	[illegible]
Downstream Hwy88	3425	25-YR	134.60	[illegible]	5.10	0.74	[illegible]	[illegible]	[illegible]
Downstream Hwy88	3425	50-YR	[illegible]	[illegible]	5.02	[illegible]	37.57	[illegible]	[illegible]
Downstream Hwy88	3425	100-YR	[illegible]	7670.10	5.00	[illegible]	48.82	21.67	[illegible]
Downstream Hwy88	3150	Max Leakage	17.60	[illegible]	1.17	[illegible]	15.04	[illegible]	[illegible]
Downstream Hwy88	3150	2-YR	[illegible]	[illegible]	1.10	0.04	[illegible]	[illegible]	0.10
Downstream Hwy88	3150	5-YR	[illegible]	7667.73	1.02	0.07	40.40	34.00	0.21
Downstream Hwy88	3150	10-YR	[illegible]	[illegible]	[illegible]	0.10	[illegible]	36.70	0.22
Downstream Hwy88	3150	25-YR	134.60	[illegible]	2.30	0.13	70.44	[illegible]	[illegible]
Downstream Hwy88	3150	50-YR	[illegible]	[illegible]	2.57	0.10	80.44	41.00	[illegible]
Downstream Hwy88	3150	100-YR	[illegible]	7669.01	[illegible]	0.10	106.14	44.20	[illegible]
Downstream Hwy88	3025	Max Leakage	17.60	[illegible]	[illegible]	[illegible]	4.00	11.01	1.02
Downstream Hwy88	3025	2-YR	46.60	7666.40	4.00	0.82	9.57	12.00	1.01
Downstream Hwy88	3025	5-YR	82.60	[illegible]	[illegible]	1.10	15.00	16.67	[illegible]
Downstream Hwy88	3025	10-YR	137.60	7667.20	5.51	1.30	24.10	[illegible]	[illegible]
Downstream Hwy88	3025	25-YR	219.60	7667.00	7.02	1.00	30.10	34.00	[illegible]
Downstream Hwy88	3025	50-YR	[illegible]	[illegible]	6.31	1.84	44.57	36.77	[illegible]
Downstream Hwy88	3025	100-YR	379.60	7668.45	[illegible]	2.00	54.70	[illegible]	0.07
Downstream Hwy88	2900	Max Leakage	17.60	7664.38	1.72	0.14	10.14	[illegible]	[illegible]
Downstream Hwy88	2900	2-YR	46.60	[illegible]	2.51	[illegible]	17.00	[illegible]	[illegible]
Downstream Hwy88	2900	5-YR	82.60	[illegible]	3.70	[illegible]	26.07	[illegible]	0.70
Downstream Hwy88	2900	10-YR	137.60	[illegible]	4.50	0.70	[illegible]	[illegible]	0.70
Downstream Hwy88	2900	25-YR	219.60	7665.34	5.00	1.02	40.30	36.10	0.07
Downstream Hwy88	2900	50-YR	[illegible]	[illegible]	5.50	1.00	48.00	[illegible]	[illegible]
Downstream Hwy88	2900	100-YR	379.60	[illegible]	7.02	1.40	[illegible]	[illegible]	[illegible]
Downstream Hwy88	2700	Max Leakage	17.60	7662.41	2.32	[illegible]	7.44	37.00	0.70
Downstream Hwy88	2700	2-YR	46.60	7662.85	3.51	0.44	14.47	38.14	0.70
Downstream Hwy88	2700	5-YR	82.60	[illegible]	3.50	[illegible]	26.02	31.34	0.72
Downstream Hwy88	2700	10-YR	137.60	7663.34	4.10	0.57	36.71	[illegible]	0.07
Downstream Hwy88	2700	25-YR	219.60	[illegible]	4.50	0.61	[illegible]	38.20	[illegible]
Downstream Hwy88	2700	50-YR	[illegible]	7664.38	4.80	0.84	[illegible]	38.77	[illegible]
Downstream Hwy88	2700	100-YR	379.60	7664.78	5.12	[illegible]	87.57	41.07	[illegible]
Downstream Hwy88	2500	Max Leakage	17.60	[illegible]	1.30	0.10	13.30	22.30	0.32
Downstream Hwy88	2500	2-YR	46.60	7661.41	1.02	[illegible]	24.03	[illegible]	0.30
Downstream Hwy88	2500	5-YR	82.60	7661.00	2.51	0.27	30.04	30.01	0.31
Downstream Hwy88	2500	10-YR	137.60	7662.48	2.00	0.40	51.00	30.34	0.30
Downstream Hwy88	2500	25-YR	219.60	[illegible]	3.40	0.57	71.04	[illegible]	0.37
Downstream Hwy88	2500	50-YR	[illegible]	[illegible]	3.77	0.57	[illegible]	38.20	0.37
Downstream Hwy88	2500	100-YR	379.60	7664.00	4.10	0.70	106.40	[illegible]	0.30
Downstream Hwy88	2350	Max Leakage	17.60	[illegible]	2.10	0.31	7.30	14.37	[illegible]
Downstream Hwy88	2350	2-YR	46.60	7660.40	2.70	[illegible]	15.00	16.10	0.40

HEC-RAS Plan: Exist Cond. River: Oyster Creek Reach: Downstream Hwy88 (Continued)

Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	
Downstream Hwy88	2350	5-YR	92.00	[illegible]	3.88	0.88	26.79	30.34	0.82
Downstream Hwy88	2350	10-YR	137.00	7801.43	[illegible]	1.09	30.30	32.01	0.84
Downstream Hwy88	2350	25-YR	213.00	[illegible]	5.07	1.30	44.84	34.34	[illegible]
Downstream Hwy88	2350	50-YR	[illegible]	7802.46	[illegible]	[illegible]	59.77	38.20	[illegible]
Downstream Hwy88	2350	100-YR	273.00	[illegible]	[illegible]	[illegible]	[illegible]	38.21	[illegible]



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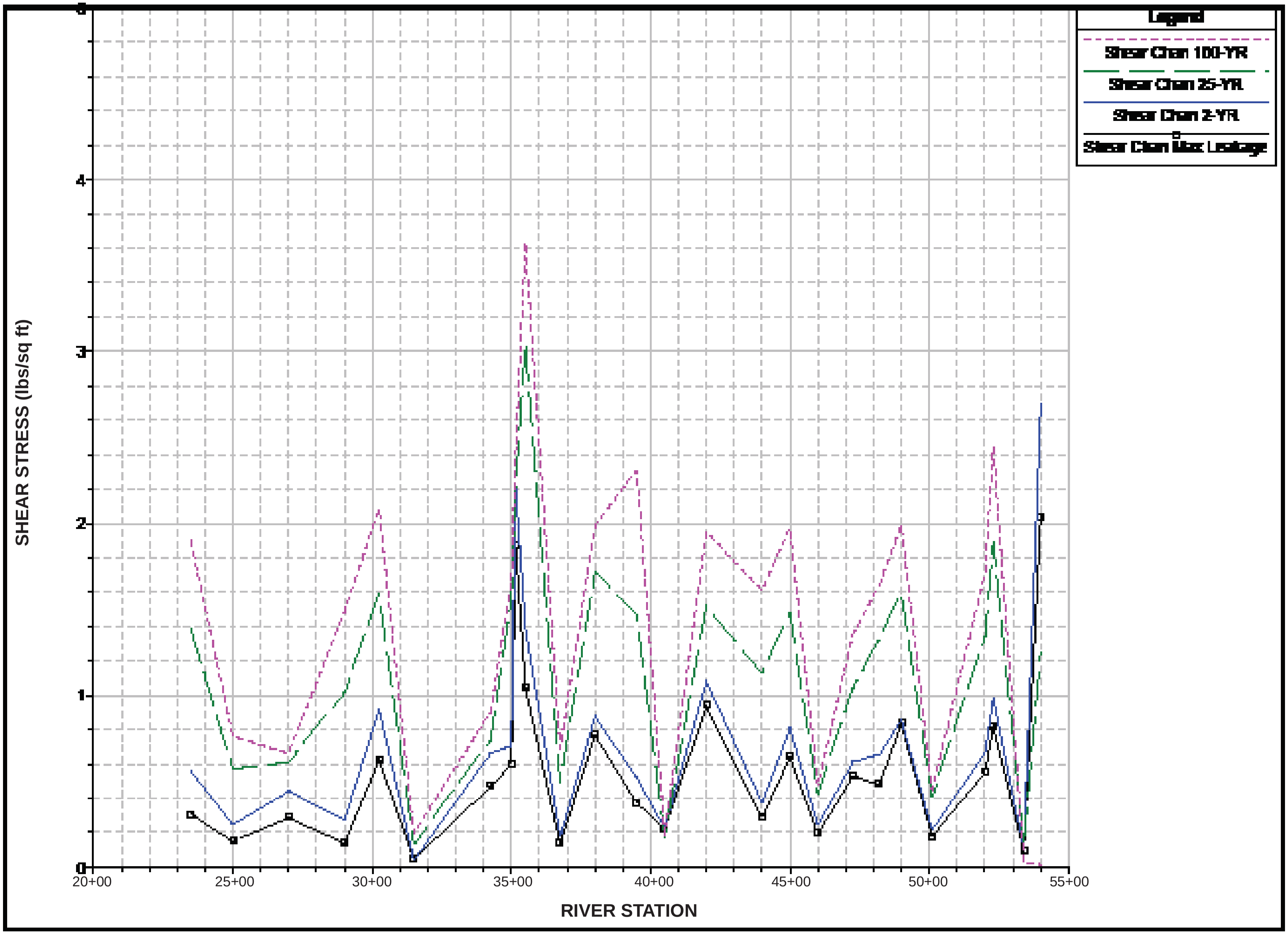
APPENDIX A - HEC-RAS modeling results: Shear stress



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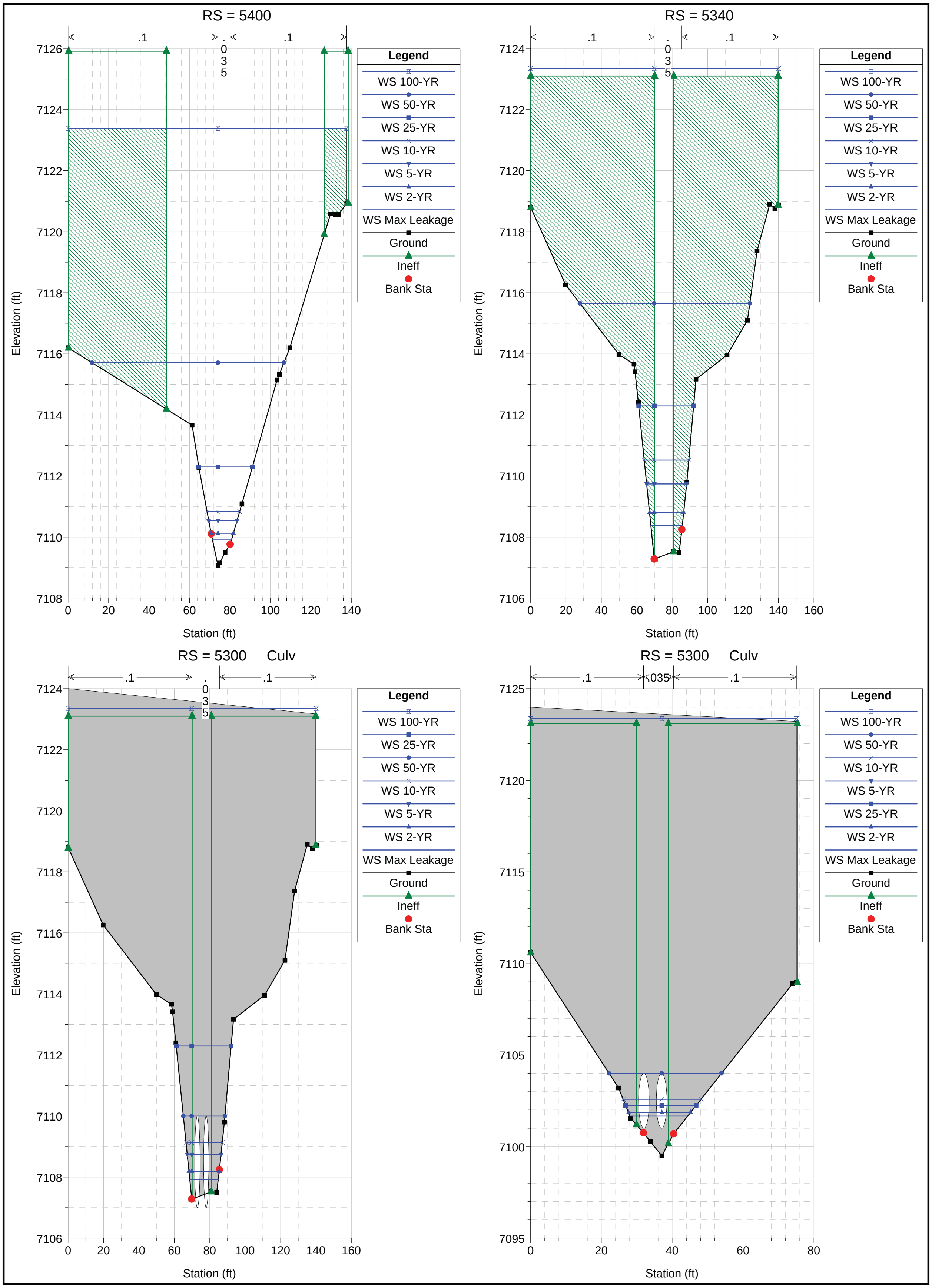
APPENDIX A - HEC-RAS modeling results: Shear stress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WS 10-YR
WS 5-YR
WS 2-YR
WS Max Leakage
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
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.035
.1
Legend
WS 100-YR
WS 50-YR
WS 25-YR
WS 10-YR
WS 5-YR
WS 2-YR
WS Max Leakage
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
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.035
.1
Legend
WS 100-YR
WS 25-YR
WS 50-YR
WS 10-YR
WS 5-YR
WS 2-YR
WS Max Leakage
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
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.035
.1
Legend
WS 100-YR
WS 50-YR
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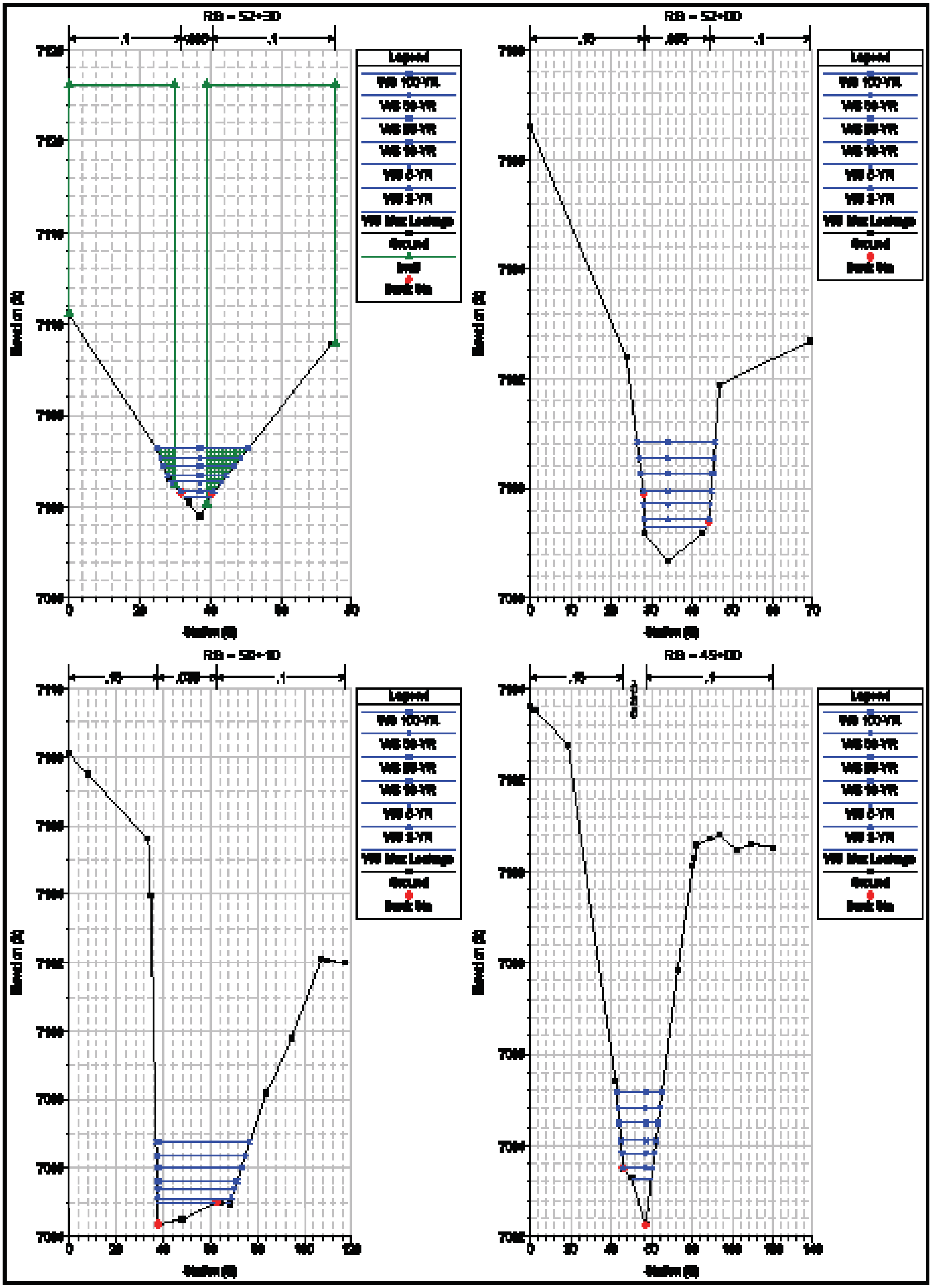
WS Max Leakage
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)



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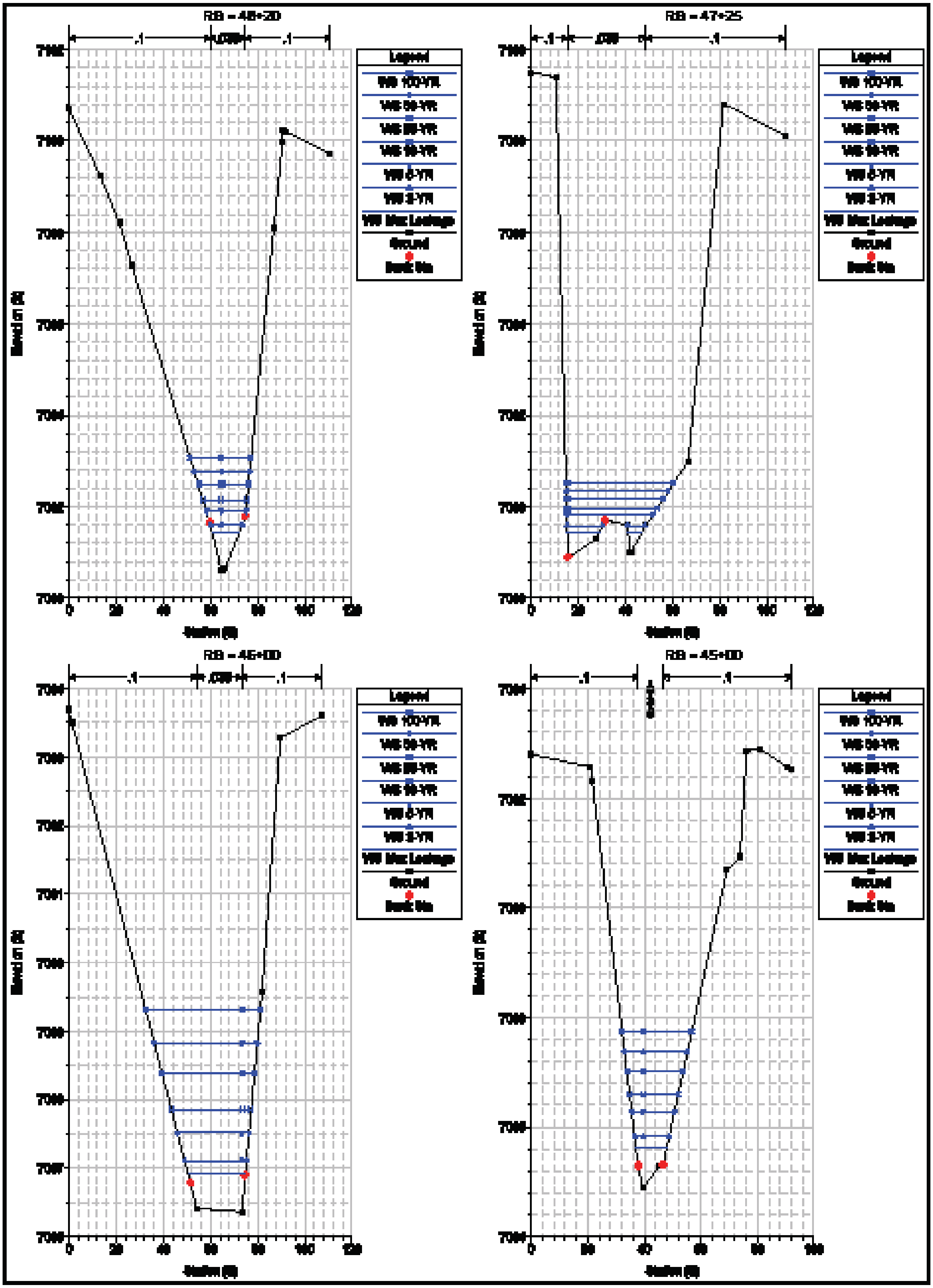
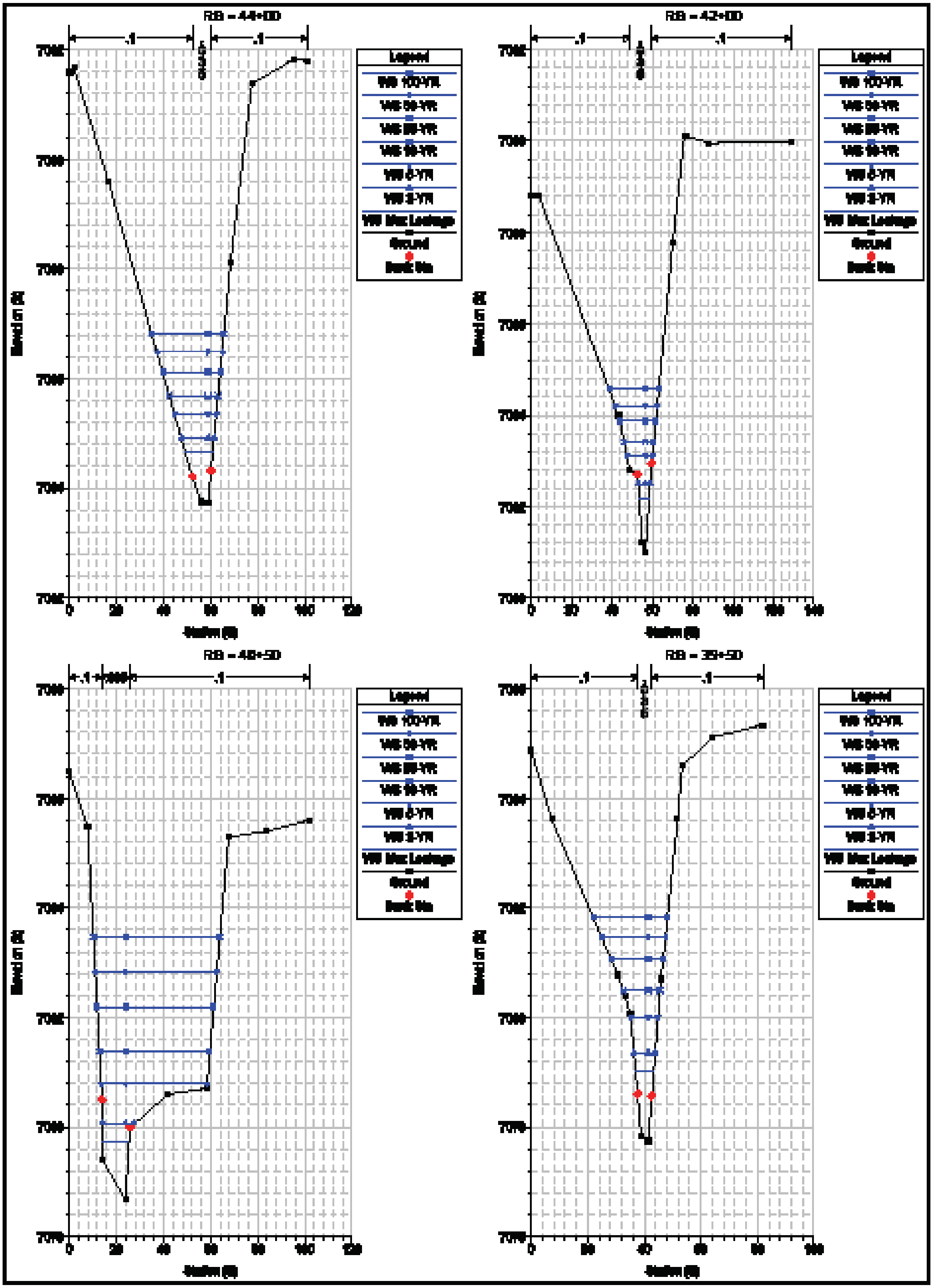
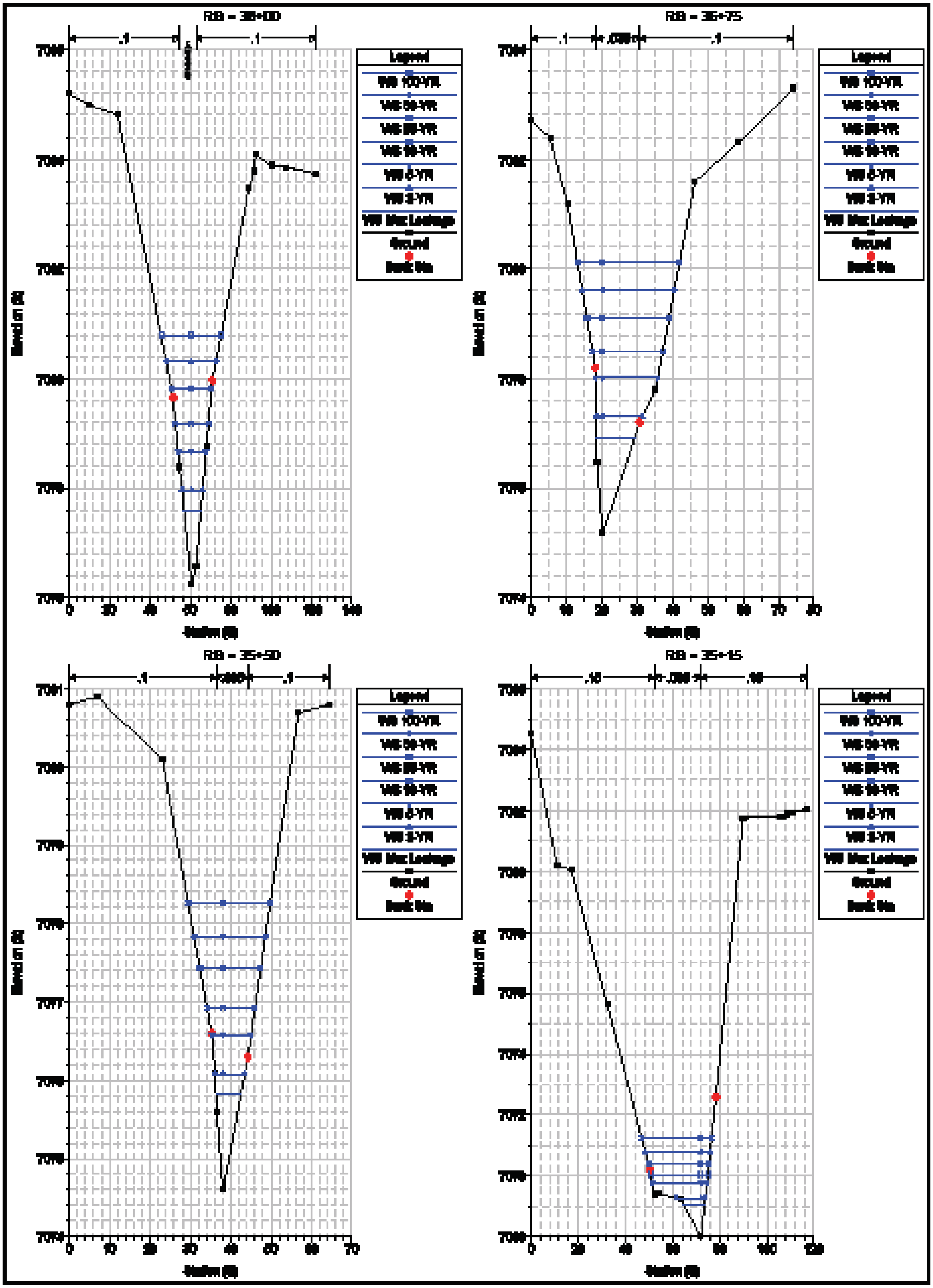
APPENDIX A - HEC-RAS modeling results: Cross-sections





APPENDIX A - HEC-RAS modeling results: Cross-sections



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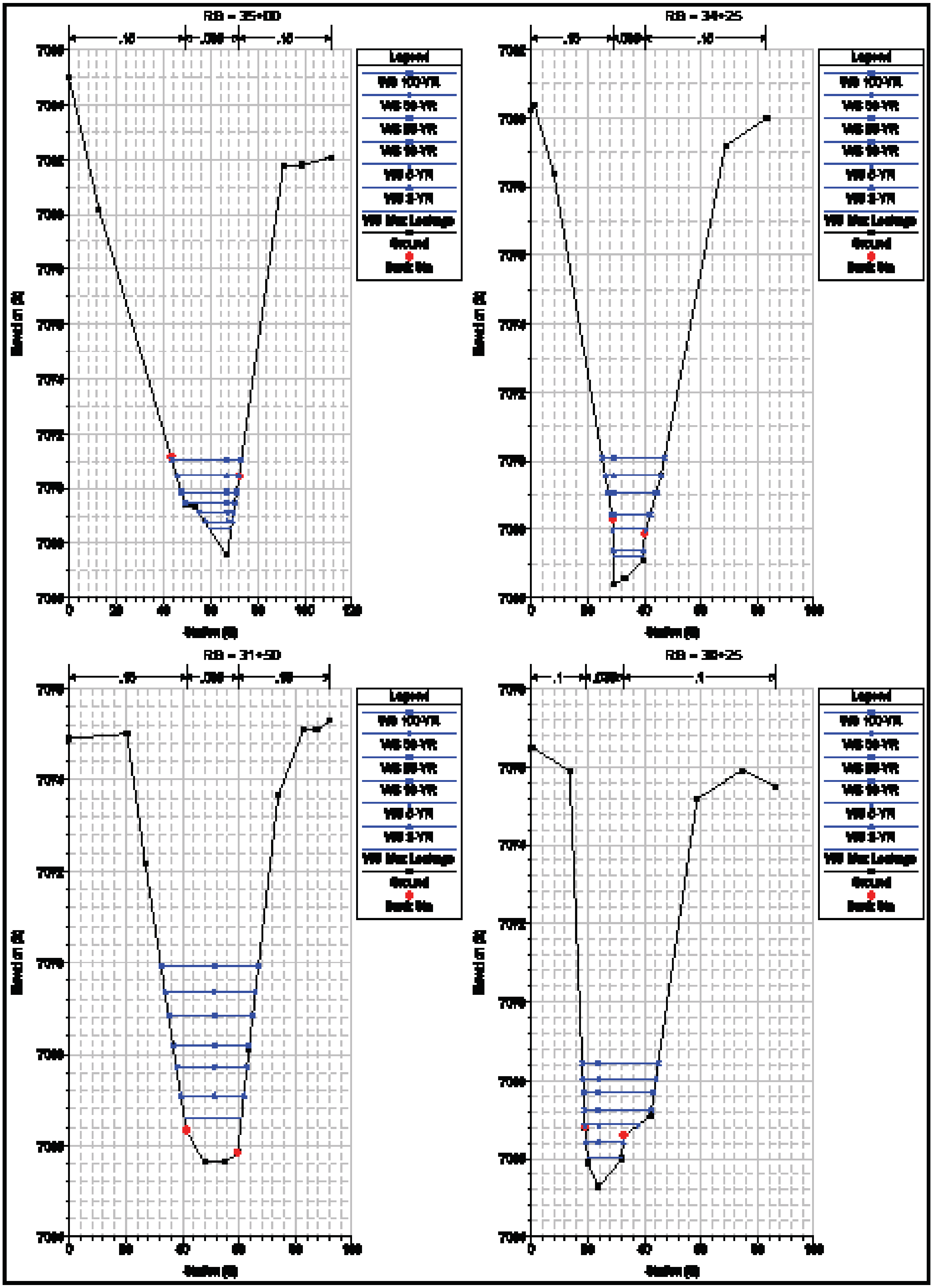
APPENDIX A - HEC-RAS modeling results: Cross-sections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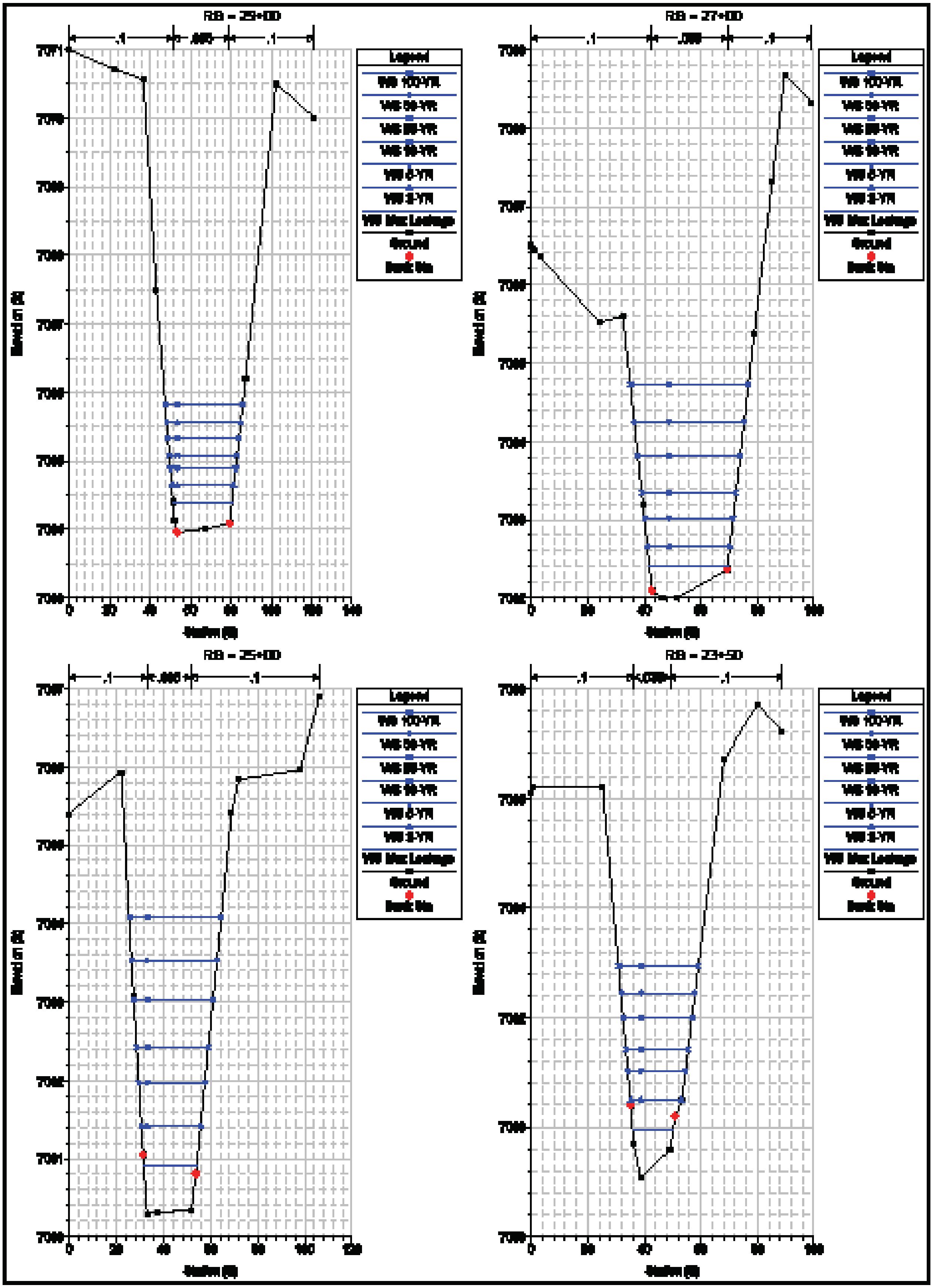
RS = 30+25


RS = 29+00
RS = 27+00
RS = 25+00
RS = 23+50

Oyster Creek
Sensitive Site Monitoring Report

Appendix B

Soil and Bedload Sample Laboratory Results

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FAX: 831-724-1367
WWW.BUTANOGEOTECH.COM

June 3, 2009
Project No. 08-126-SC

SH&G
500 Seabright Avenue
Santa Cruz, California 95062

ATTENTION: Kevin Fischer

SUBJECT: Laboratory Testing Results
Oyster Creek Bedload Sampling (May 8, 2009)

Dear Mr. Fischer:

This letter summarizes the laboratory test results for the referenced samples. Bulk samples were provided by SH&G in gallon plastic bags. The samples consisted mainly of organics.

Sample	Total Wet Mass-with organics (grams)	Total Dry Mass-with organics (grams)	Dry Mass of Soil (grams)	Description
Site #1, Trap #1	59.4	5.5	0	100% organic
Site #1, Trap #2	159.1	28.3	2.2	fine to coarse sand
Site #1, Trap #3	508.8	89.9	1.5	fine sand
Site #2, Trap #1	79.8	15.2	2.8	fine to coarse sand
Site #2, Trap #2	162.8	23.3	0.1	fine sand
Site #2, Trap #3	193.2	22.6	0.3	fine sand

Sample	Total Wet Mass-with organics (grams)	Total Dry Mass-with organics (grams)	Dry Mass of Soil (grams)	Description
Site #2B, Trap #1	287.3	82.3	53.1	medium to coarse sand and fine gravel
Site #3, Trap #1	82.7	28.6	20.5	fine to medium gravel

Gradation analyses were performed on the entire mass of Site #2B, Trap #1 and Site #3, Trap #1. There was not enough mass to run analyses on the other samples.

If you have any questions or if we may be of further assistance please do not hesitate to contact our office.

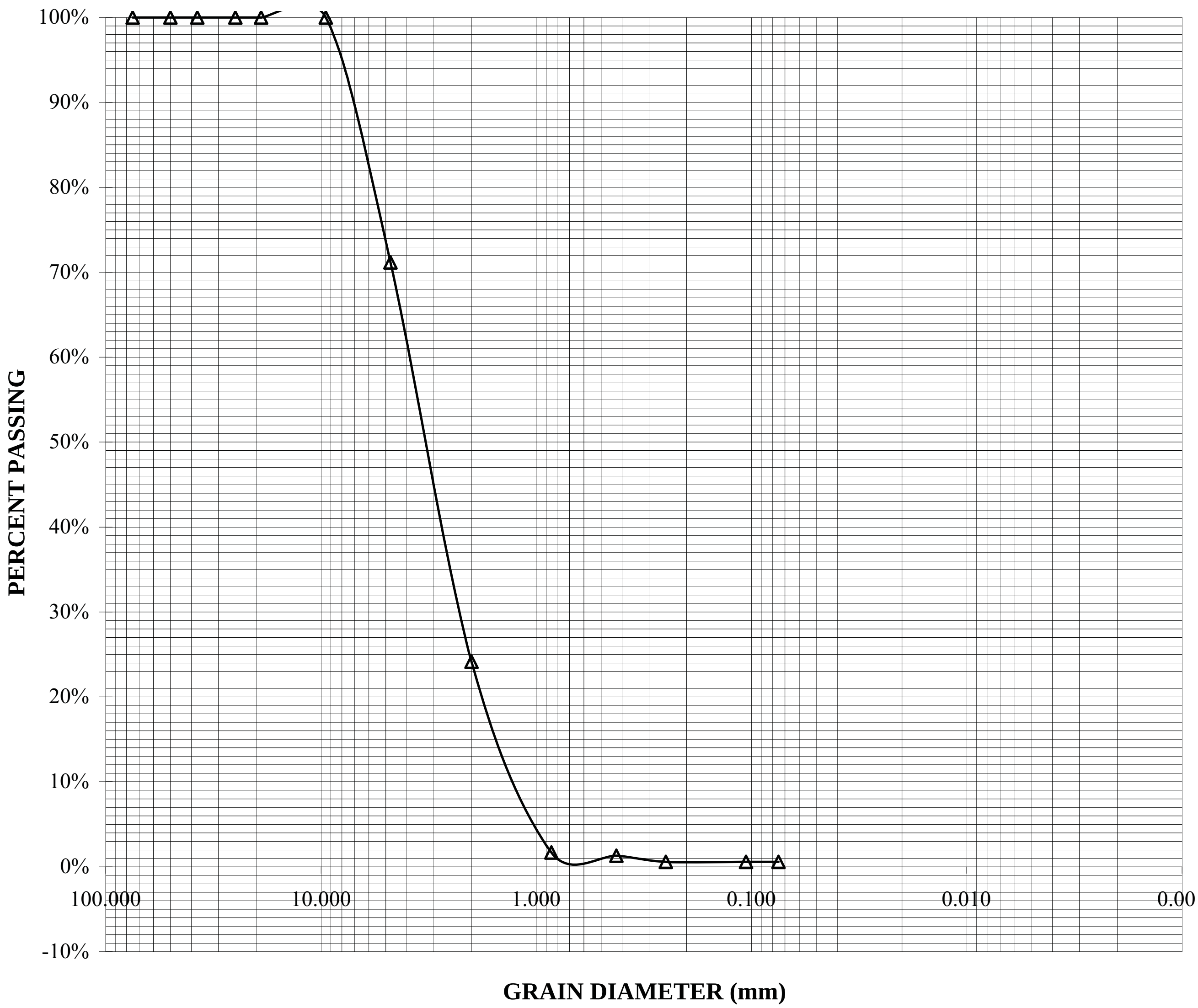
Sincerely,

BUTANO GEOTECHNICAL ENGINEERING, INC.

Greg Bloom
R.C.E. 58819

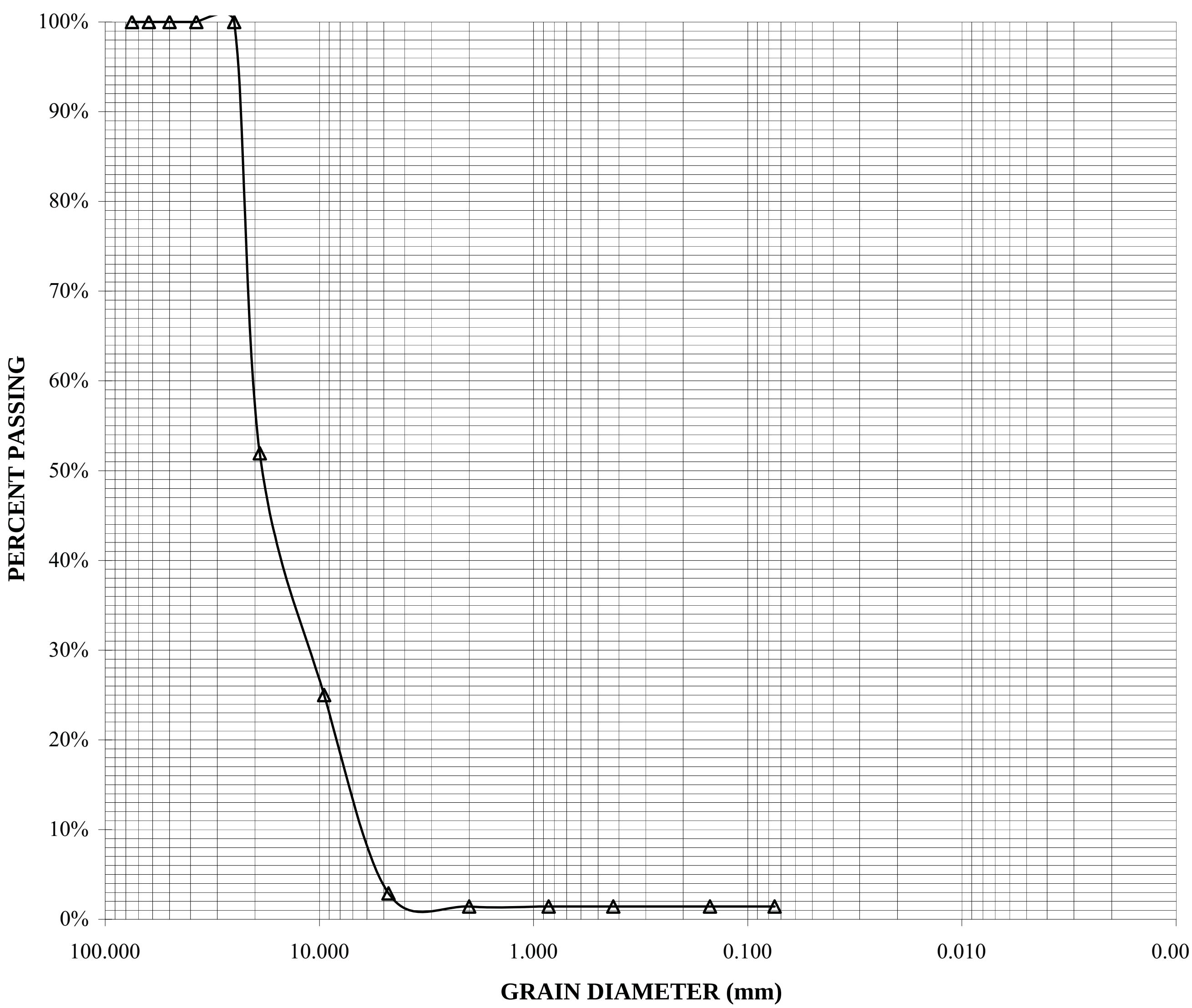
Distribution: 2 to Addressee

BORING:	Site #2B, Trap #1	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL- Sand and Gravel	GP	24.2%	0.6%



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples	C-1

BORING:	Site #3, Trap #1	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL- Gravel	GP	2.9%	1.4%



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples	C-2

BUTANO GEOTECHNICAL ENGINEERING, INC.
231 GREEN VALLEY ROAD, SUITE E, FREEDOM, CALIFORNIA 95019
PHONE: 831-724-2612
FAX: 831-724-1367
WWW.BUTANOGEOTECH.COM

June 17, 2009
Project No. 08-126-SC

SH&G
500 Seabright Avenue
Santa Cruz, California 95062

ATTENTION: Kevin Fisher

SUBJECT: Laboratory Testing Results
Oyster Creek Bedload Sampling - June 11, 2009

Dear Mr. Fischer:

This letter summarizes the laboratory test results for the referenced samples. Bulk samples were provided by SH&G in gallon plastic bags.

Sample	Total Wet Mass-with organics (grams)	Total Dry Mass-with organics (grams)	Dry Mass of Soil (grams)	Description of soil
Site #1, Helly-Smith	519.8	387.8	387.8	Well Graded Gravel with Sand (no organics)
Site #1, Composite	288.6	55.2	0.1	fine sand
Site #2, Helly-Smith	496.3	412.9	410.7	Well Graded Sand with Gravel (minimal organics)
Site #2, Composite	270.1	58.5	8.1	fine to coarse sand with a fine gravel

Site #0, Helly-Smith	153.9	109.1	108.8	well graded gravel with sand (minimal organics)
Site #0, Composite #2	151.8	47.5	11.4	fine to coarse sand with several fine gravels

Gradation Analyses were performed on the entire mass of the Helly-Smith samples from Sites 0, 1, and 2. These samples had no to minimal organics. The composite samples from all 3 sites had significant organic content and not enough soil mass to run a gradation analysis.

If you have any questions or if we may be of further assistance please do not hesitate to contact our office.

Sincerely,

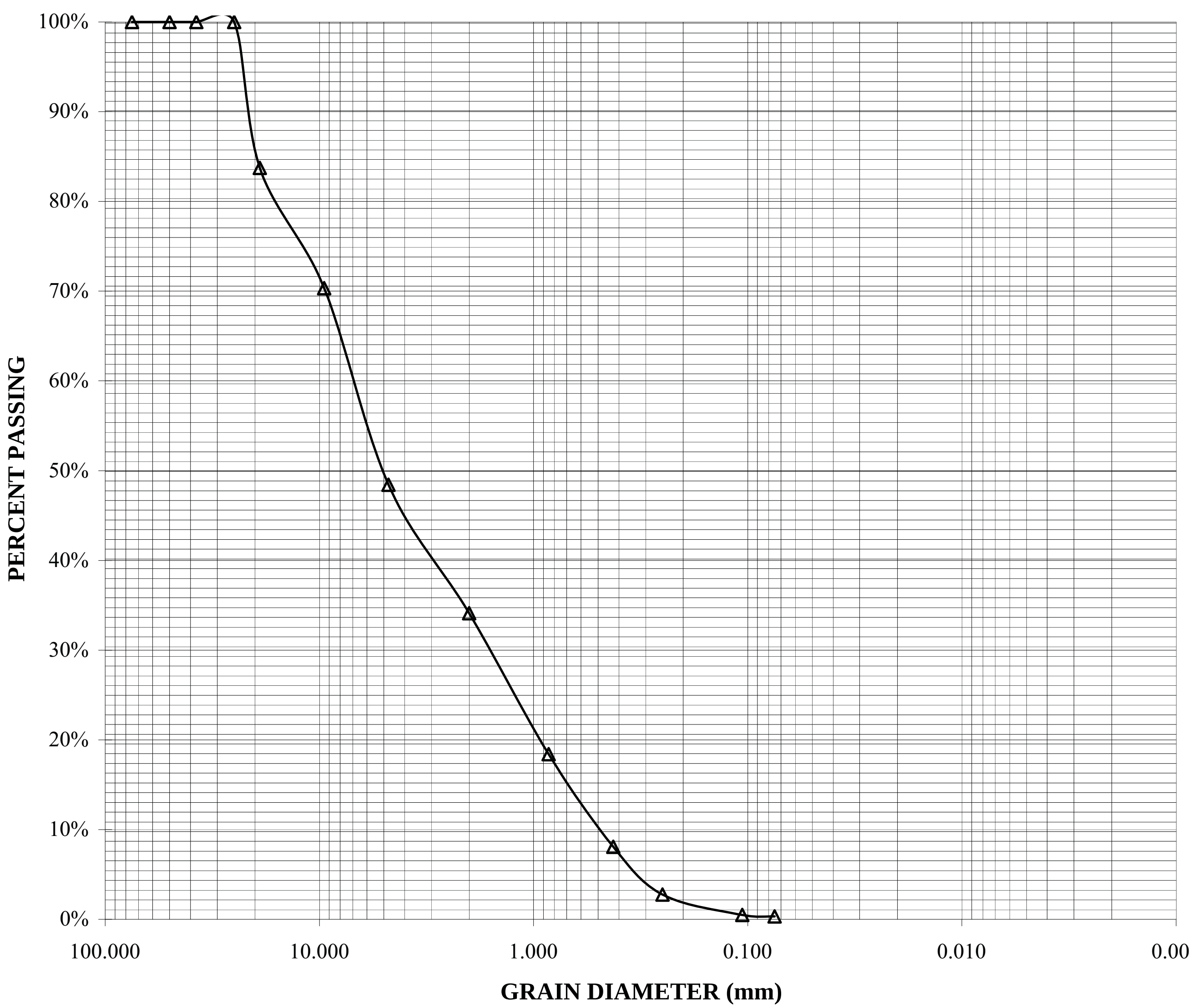
BUTANO GEOTECHNICAL ENGINEERING, INC.

Greg Bloom
R.C.E. 58819

Distribution: (2) Addressee

BORING:	Site 1, Helly-Smith	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL-	GW	34.1%	0.3%

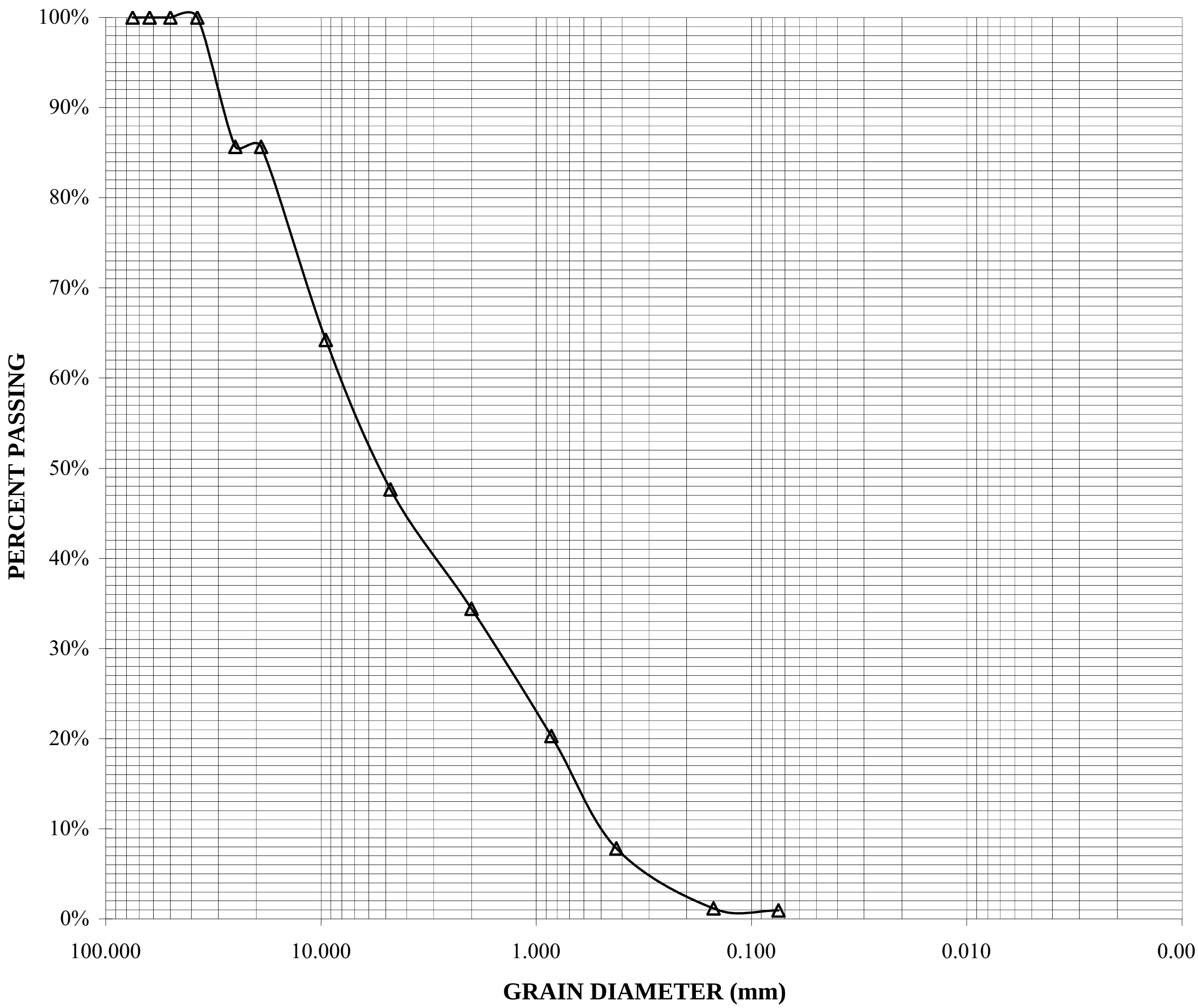
Well Graded Gravel with Sand



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples (June 2009)	C-1

BORING:	Site 2, Helly-Smith	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL-	GW	47.6%	0.9%

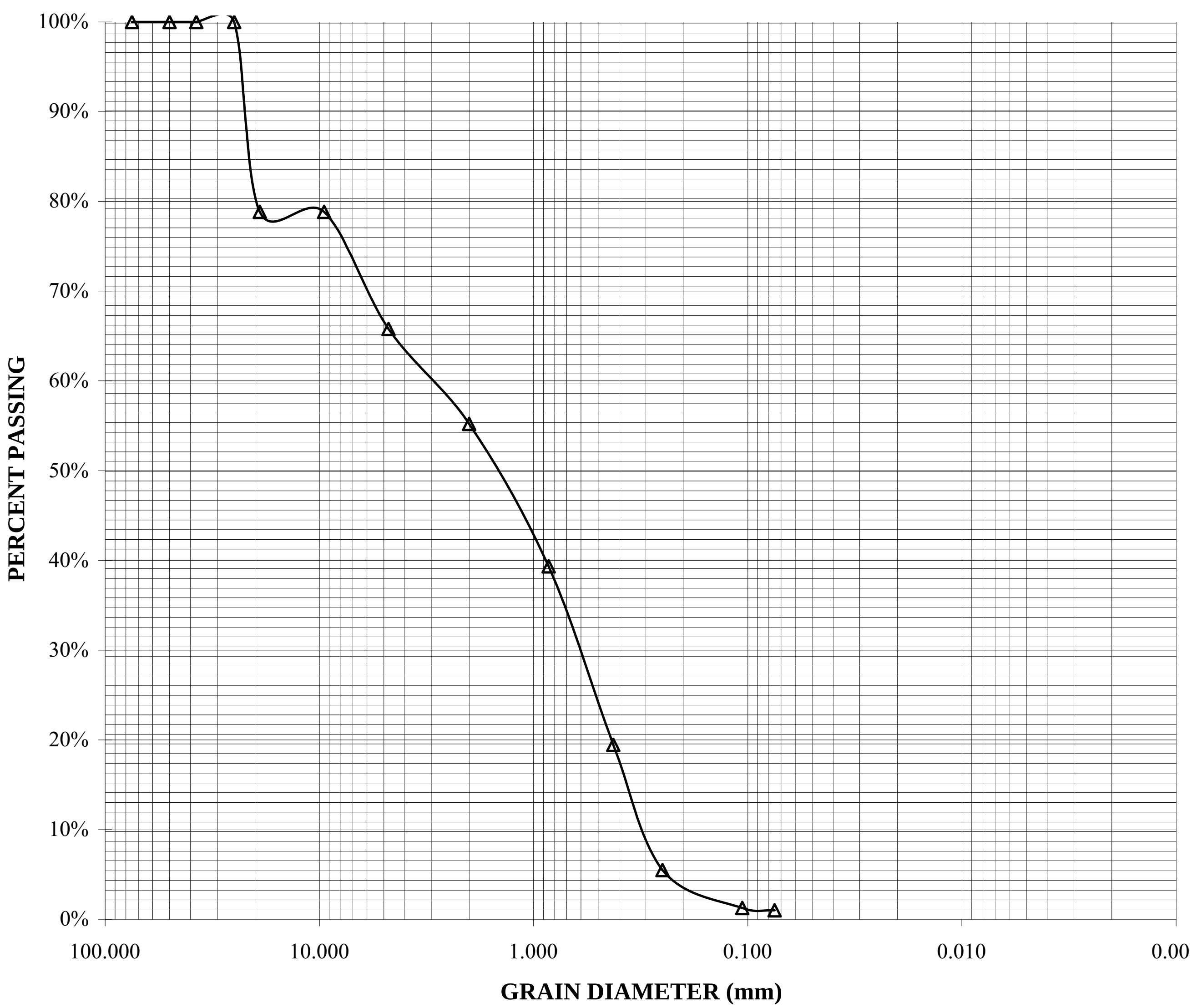
Well Graded Sand with Gravel



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples (June 2009)	C-2

BORING:	Site 0, Helly Smith	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL-	GW	55.2%	1.0%

Well Graded Gravel with Sand



BUTANO GEOTECHNICAL ENGINEERING, INC.	**GRAIN SIZE DISTRIBUTION** Oyster Creek Bedload Samples (June 2009)	FIGURE C-3

BUTANO GEOTECHNICAL ENGINEERING, INC.
231 GREEN VALLEY ROAD, SUITE E, FREEDOM, CALIFORNIA 95019
PHONE: 831-724-2612
FAX: 831-724-1367
WWW.BUTANOGEOTECH.COM

June 29, 2009
Project No. 08-126-SC

SH&G
500 Seabright Avenue
Santa Cruz, California 95062

ATTENTION: Kevin Fisher

SUBJECT: Laboratory Testing Results
Oyster Creek Bedload Sampling - June 23, 2009

Dear Mr. Fischer:

This letter summarizes the laboratory test results for the referenced samples. Bulk samples were provided by SH&G in gallon plastic bags.

Sample	Total Wet Mass-with organics (grams)	Total Dry Mass-with organics (grams)	Dry Mass of Soil (grams)	Description of soil
Site A, Helley-Smith	133.6	114.2	112.3	Well Graded Sand with Gravel (trace organics)
Site A, 3 Trap Composite	292.1	60.5	3.2	Medium to coarse sand (mainly organics)
Site B, Helly-Smith	27.0	16.8	14.4	Well Graded Sand with Gravel (minimal organics)
Site C, Helley-Smith	225.0	200.4	199.5	Well Graded Sand with Gravel (trace organics)

Site D, Helley-Smith	80.4	65.2	64.1	Well Graded Sand with Gravel (trace organics)
Site E, Helley-Smith	126.3	108.1	106.8	Well Graded Sand with Gravel (trace organics)
Site E USFS B-dual trap	127.4	19.2	0.1	Organics with trace amount of fine sand

Gradation Analyses were performed on all of the samples except for Site A 3 trap composite and Site E USFS B-dual trap because of high organic content and minimal amount of soil.

If you have any questions or if we may be of further assistance please do not hesitate to contact our office.

Sincerely,

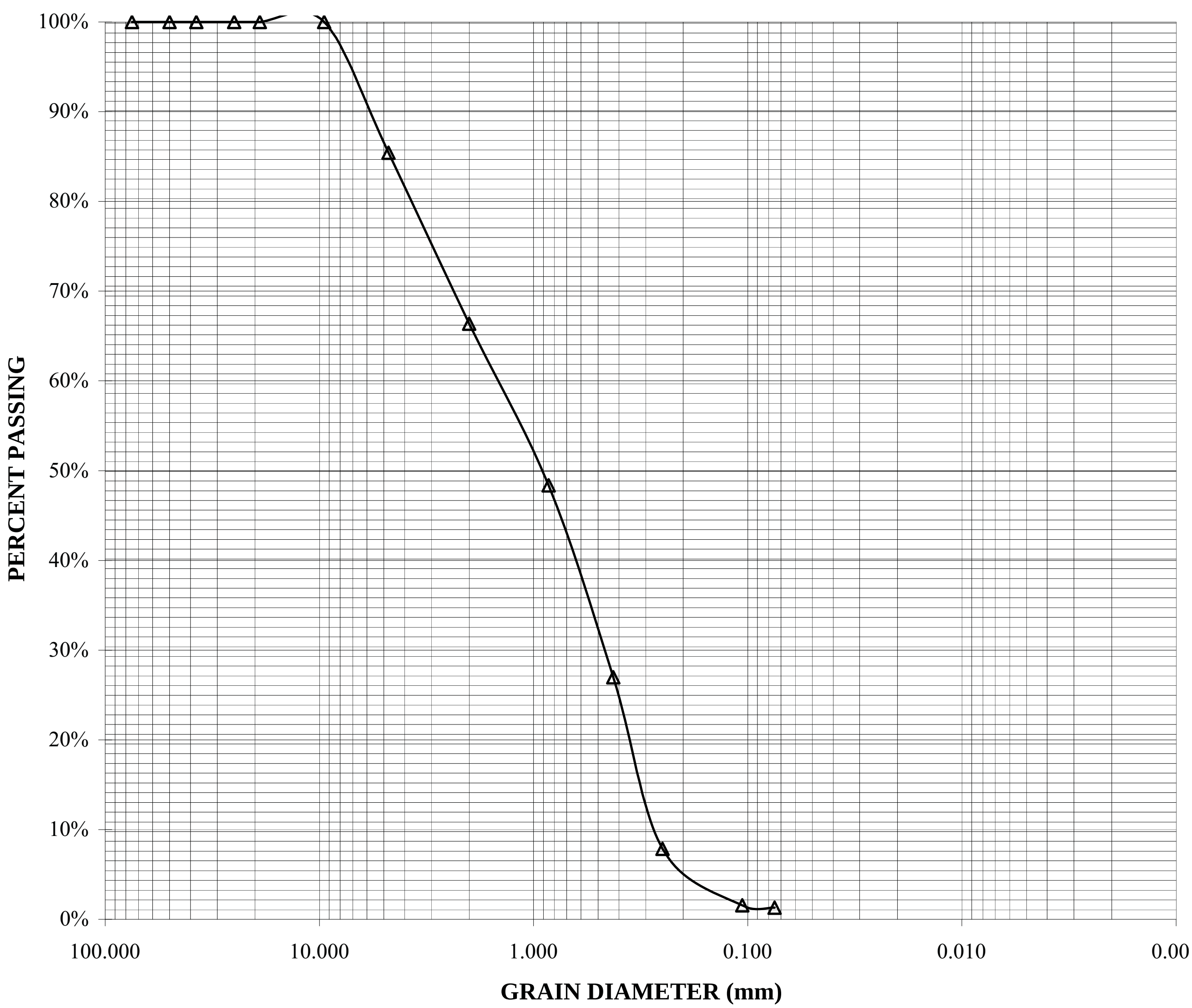
BUTANO GEOTECHNICAL ENGINEERING, INC.

Greg Bloom
R.C.E. 58819

Distribution: (1) Addressee

BORING:	Site A Helley Smith	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL-	SW	66.4%	1.3%

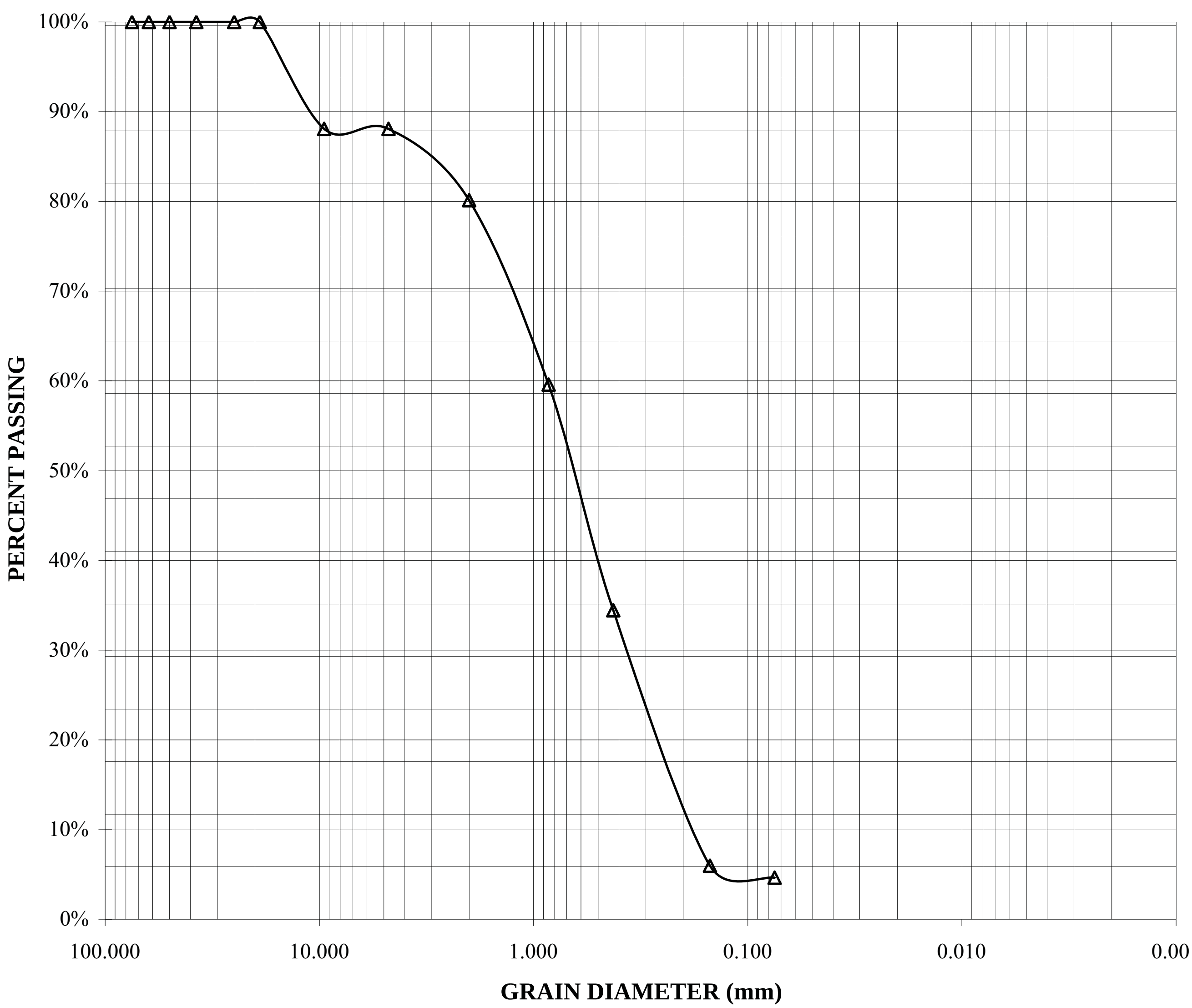
Well Graded Sand with Gravel



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples (June 23rd, 2009)	C-1

BORING:	Site B Helley Smith	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL-	SW	88.1%	4.6%

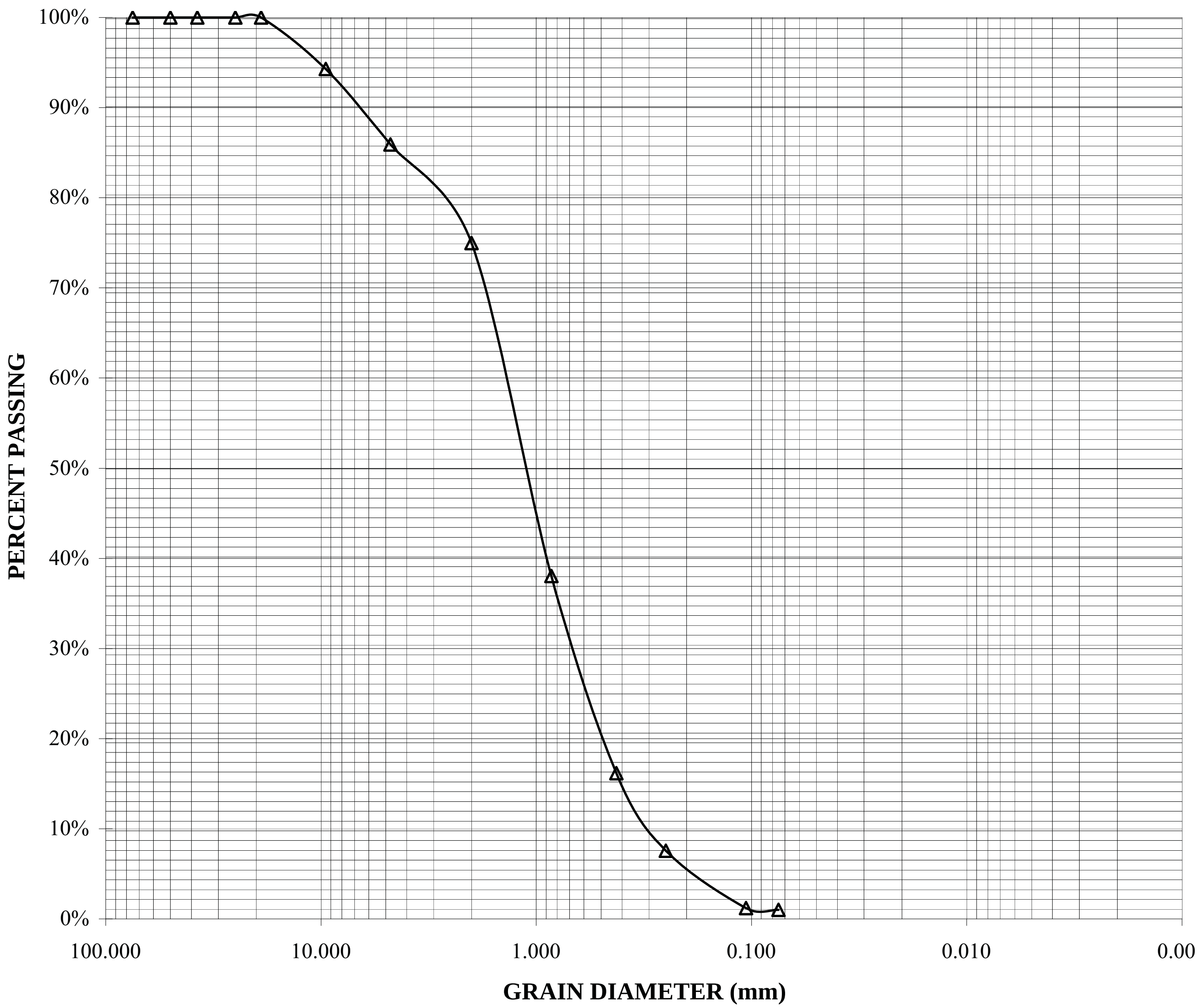
Well Graded Sand with trace Gravel



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples (June 23rd, 2009)	C-2

BORING:	Site C Helley-Smith	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL-	SW	75.0%	1.0%

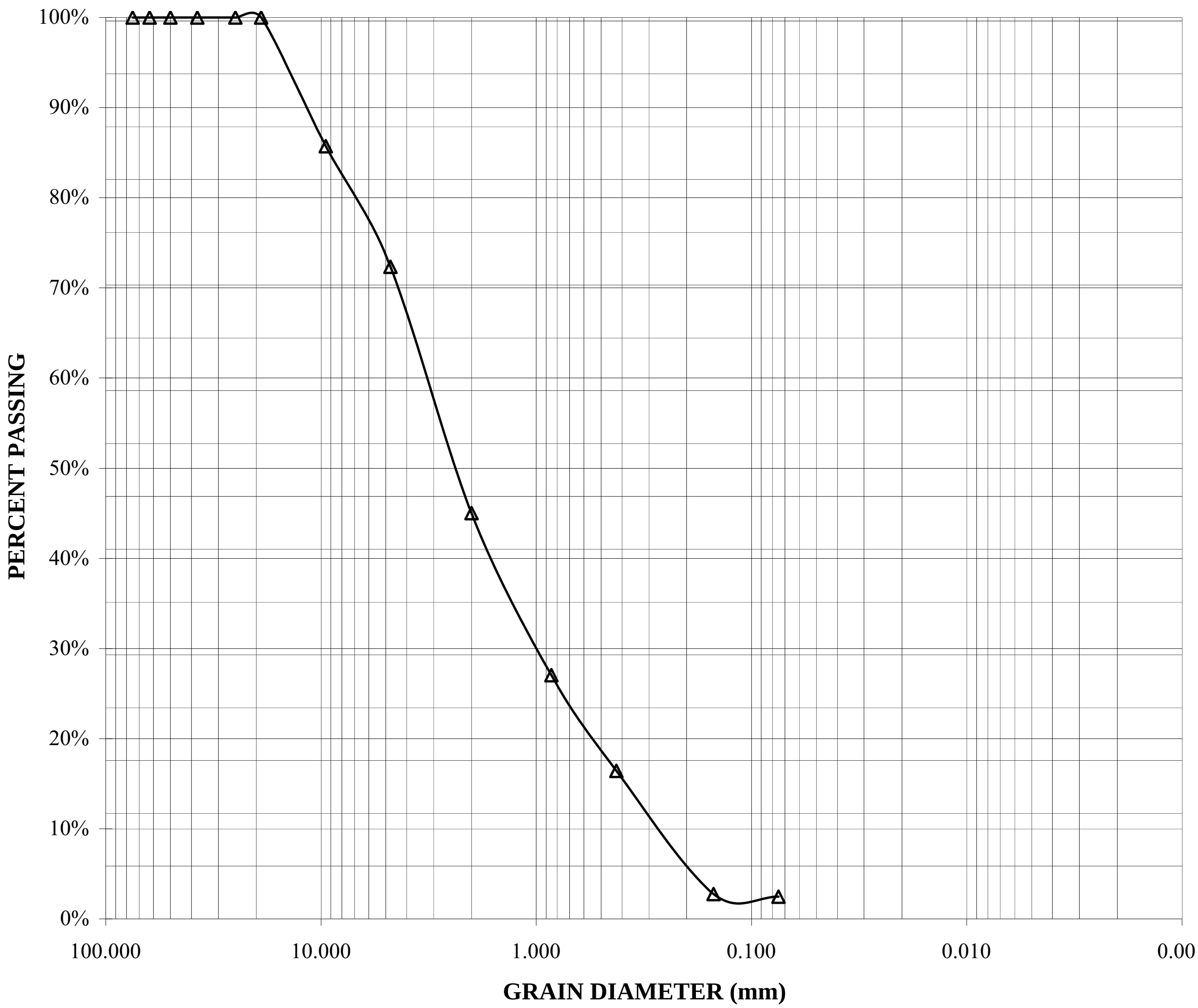
Well Graded Sand with Gravel



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples (June 23rd, 2009)	C-3

BORING:	Site D Helley Smith	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL-	SW	72.4%	2.5%

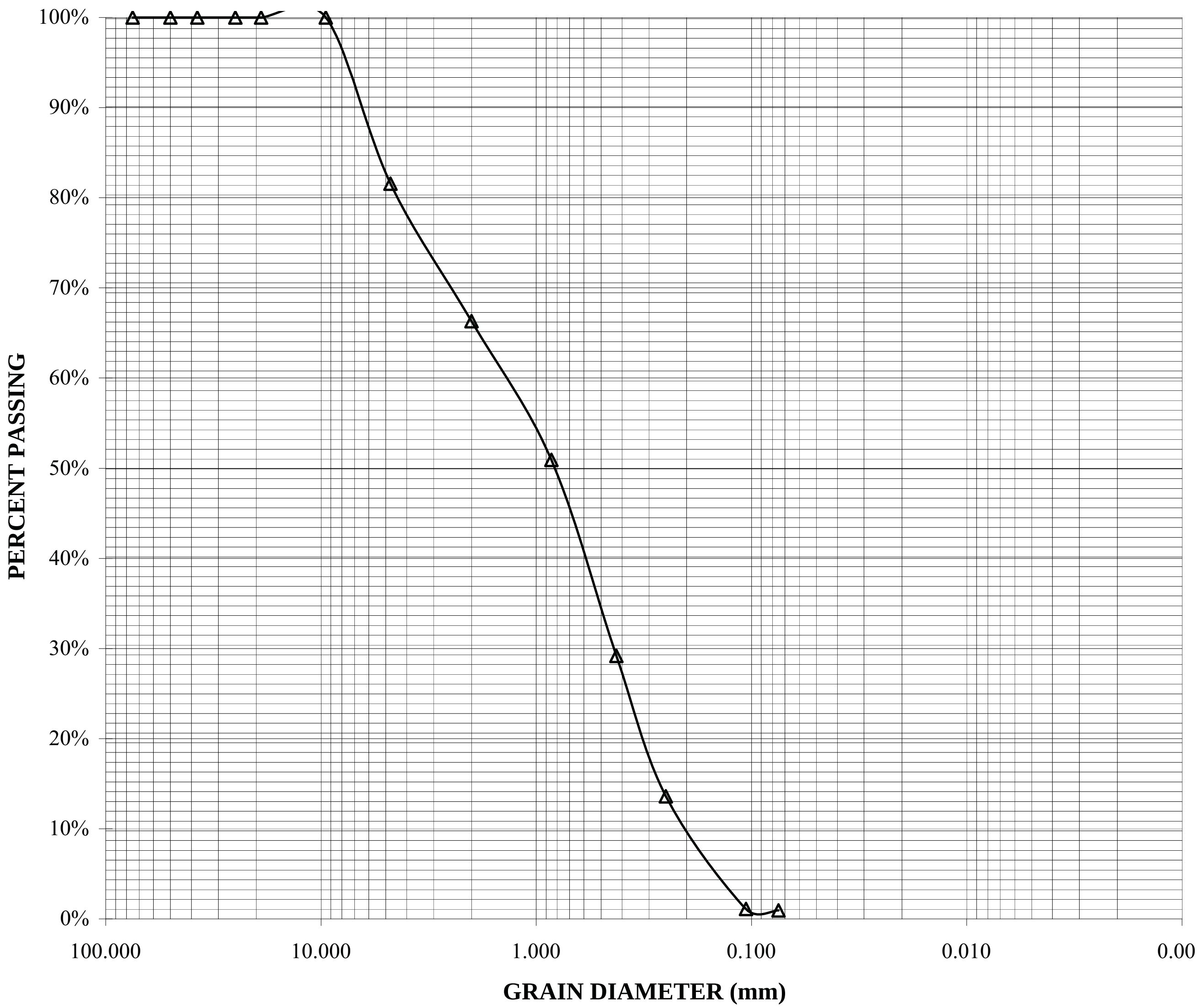
Well Graded Sand with Gravel



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples (June 23rd, 2009)	C-4

BORING:	Site E Helley Smith	PERCENT	PERCENT
DEPTH (ft):	0.0	PASSING No. 4	PASSING No. 200
SOIL-	SW	66.3%	0.9%

Well Graded Sand with Gravel



BUTANO	**GRAIN SIZE DISTRIBUTION**	FIGURE
GEOTECHNICAL ENGINEERING, INC.	Oyster Creek Bedload Samples (June 23rd, 2009)	C-5

OYSTER CREEK

SENSITIVE SITE MONITORING REPORT

APPENDIX C

HISTORICAL AERIAL PHOTOS

Blue Line Consulting
Stream & Wetland Planning ◊ Design ◊ Monitoring

APPENDIX C: 1976 aerial photo of Oyster Creek project area.

Blue Line Consulting
Stream & Wetland Planning ◊ Design ◊ Monitoring

APPENDIX C: 1980 aerial photo of Oyster Creek project area.

Blue Line Consulting
Stream & Wetland Planning ◊ Design ◊ Monitoring

APPENDIX C: 1991 aerial photo of Oyster Creek project area.

APPENDIX C: 1996 aerial photo of Oyster Creek project area.

Blue Line Consulting
Stream & Wetland Planning ◊ Design ◊ Monitoring