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A FEASIBILITY STUDY OF SEDIMENT RETENTION BASINS FOR DEER CREEK, EL GRANADA, CALIFORNIA

Prepared for

San Mateo County Harbor District

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June 30, 1999

PWA Ref. #1285

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1. INTRODUCTION

Deer Creek, also referred to as El Granada Creek, is a small perennial stream located at the Northern end of Half Moon Bay. Fed by a watershed of about 413 acres (0.65 mi^2), the creek flows through the unincorporated community of El Granada, discharging, via an outfall, directly into Pillar Point Harbor near the boat launch ramp (see Figure 1).

Heavy and sustained rainfall associated with the 1997-1998 El Niño winter produced flooding conditions on Deer Creek. During this time blockage of the outfall pipe forced floodwaters and sediment to exit through an emergency overflow box and discharge over the access road to the boat launch ramp. In the process the downstream edge of the road was scoured out and further damage occurred to a bordering pedestrian path and bluff (San Mateo County Harbor District, 1998).

By March of 1998, sediment had accumulated to a depth of nearly 5 feet above the bottom of the boat launch ramp, rendering the facility unusable (Peter Grenell, letter to Ed Wiley, March 2, 1998).
As a result, the San Mateo County Harbor District had to initiate emergency dredging of sand from the harbor. Approximately 5600 yd^3 were removed from Pillar Point Harbor around the docking ramp, outfall culvert, and overflow box during the emergency sediment removal (Peter Grenell, letter to Ed Wiley, March 2, 1998).

This type of sediment deposition is a problem for the harbor since continued closure of part of the launch ramp as well as the access road: 1) reduces full use of the ramp facility, 2) creates traffic congestion on the ramp, 3) reduces San Mateo County Harbor District revenue earned in launching fees, and 4) burdens the harbor with repair costs, and 5) increases the Pillar Point Harbor staff's workload.

This report investigates the feasibility of using a sediment retention basin to help manage and reduce the inflow of sediment from Deer Creek into Pillar Point Harbor. Two locations for a proposed sediment retention basin were investigated, one located on the Stroot Property, upstream of El Granada, and the other within the Caltrans easement along State Route 1. Basic data concerning the hydrology, sediment yield, and sediment sizes transported by Deer Creek were collected and estimated. This information was used to develop preliminary designs for the two candidate basins. In addition, engineer's estimates of construction quantities as well as construction and maintenance costs were completed. The results of this study suggest that it is technically feasible to locate a sediment retention basin along Deer Creek that will aid in reducing the sediment accumulation in Pillar Point Harbor. Permitting issues associated with both basins require further investigation. Other alternatives have been identified but not investigated further in this report even though they may be preferable.

2. DESIGN OBJECTIVES & CONSTRAINTS

The primary design objective is to use a sediment retention basin to trap sediment transported by Deer Creek before it discharges into Pillar Point Harbor. This entails the containment of mainly fine sediments composed primarily of sands and silts, but also including gravels and cobbles to a lesser extent.

For Deer Creek, there are several design constraints associated with implementing a sediment management plan involving sedimentation basins. These primary constraints and concerns include:

1. Nearly the entire corridor of Deer Creek downstream of the Stroot Property is developed to the edge of the creek, save for the Caltrans easement between State Route 1 and Alhambra Avenue. This leaves little room for site selection and layout of sediment retention basins.

2. Occupation of either of the proposed sites is subject to approval by another party. The proposed location within the Stroot Property could be subject to the approval of the current property owner. The proposed location within in the Caltrans easement is subject to their approval.

3. Occupation of either of the proposed sites entails special design considerations related to safety and regulation by another party. The site upstream of the reservoir should not put any further structural burden on the reservoir embankment. For the easement site, ponded floodwater levels within the proposed basin would be above the State Route 1 road bed and therefore might require special design considerations dictated by Caltrans.

4. Environmental review and permitting will likely require substantial effort for both sites. Both sites may include waters of the U.S., requiring U.S. Army Corps of Engineer's review. State review is also expected by the California Department of Fish and Game as well as the Regional Water Quality Control Board. The San Mateo County Resource Conservation District may also desire input.

3. SITE CONDITIONS

The condition of Deer Creek and its watershed were assessed through 1) direct field observations made in a series of field visits, 2) review of materials provided by the San Mateo County Harbor District, 3) review of the County of San Mateo Soil Survey, 4) review of files on the Stroot Property held by the County of San Mateo Resource Conservation District, and 5) review of a historical series of aerial photographs. No detailed reports on Deer Creek, concerning its hydrology, sediment yield, or watershed could be located.

3.1 FIELD OBSERVATIONS

It appears as though the majority of sediment sources for Deer Creek are located largely in the upper portions of the watershed above El Granada. The geomorphic conditions in the uppermost reaches of the watershed within the Stroot Property appear to be dominated by processes related to the introduction of sediment from the valley hillslopes by mass wasting and landsliding. The channel in the upper watershed is deeply incised until it reaches the area around the reservoir. Depths in excess of 30 feet have been noted in the area (Howard Donley Associates, Inc., 1981).

The incision results from the channel cutting into the slide materials after they flow into the valley during episodic events. Several large knickpoints in the creek's profile indicate that Deer Creek is still in the process of downcutting and therefore capable of producing relatively large sediment yields. Eventually the sediment stored behinds these knickpoints will be transported downstream as Deer Creek continues to downcut and adjust its profile.

The channel incision, in addition to debris flows throughout the hillslopes of the watershed, creates a long-term source of sediment for the creek. Additional sediment sources in the upper watershed include the farm plots within the Stroot Property and dirt roads that cross the channel, however, these are felt to be relatively minor contributions.

The sediment generated from the uppermost portions of the drainage network is responsible for siltation of the reservoir since its construction. Details on the history of the reservoir are difficult to find. It was apparently constructed in the early 1900's and its estimated initial capacity was 45.0 ac-ft, however the current capacity is only a minor fraction of that (Howard Donley Associates, Inc., 1981). A review of aerial photographs shows a steady decrease in the planform area of the reservoir. Although some sediment is probably still trapped in the reservoir during large storms, it is likely that the majority of the sediment is now transported through the reservoir outlet spillway. This occurs because the creek no longer enters the reservoir since a small, constructed berm separates the two.

Th embankment of the reservoir appears to be in condition, however, the downstream end of the concrete outlet spillway is currently being undermined by the creek. There is roughly a 5 foot drop from the bottom of the spillway to the creek invert and part of the concrete structure is overhanging.

The mechanisms of sediment production in the uppermost portion of the Deep Creek watershed are what can be anticipated in the site's geomorphic setting, considering the steep hillslopes and underlying geologic materials. Past changes in vegetation through grazing activities undoubtedly changed the hydrologic conditions in the watershed and exacerbated sediment loadings to Deer Creek.

3.2 SOIL SURVEY

The Soil Conservation Service (now the Natural Resource Conservation Service) Soil Survey, as well as its Supplemental, for the County of San Mateo were consulted to qualitatively assess the erodibility of the soils within the Deer Creek watershed. Figure 2 maps the soil series found within the Deer Creek watershed. Table 1 reports gross properties of these soils. Overall the upper watershed is dominated by soils with very high erodibility. This is consistent with field observations of the watershed overall, as well as the condition of the creek channel itself.

3.3 AERIAL PHOTOGRAPHS

The County of San Mateo Resource Conservation District supplied a series of four aerial photographs that covered the Deer Creek watershed from 1943 to 1980. These photographs were used to construct a short history of the watershed as well as to gain insight into the dominant processes that govern the sediment characteristics of the watershed. Figure 3 presents the photographs.

November 11, 1943: The 1943 photograph reveals that Deer Creek flowed through a series of farms throughout the upper canyon as well as on the coastal terrace, enjoying a riparian corridor for much of its length before discharging onto the beach. At this time it appears that the reservoir near the mouth of the upper canyon had retained all or nearly all of its original constructed capacity. A few small scars in the hollows of the upper canyon reveal recent debris flows.

TABLE 1. Characteristics of SCS Soil Types found within the Deer Creek Watershed (Source: USDA SCS, 1961)

Soil Type	Name	Soil Series	Hydrologic Soil Group	Surface Soil Permeability	Subsoil Permeability	Runoff Rate	Erosion Hazard
DeA	Denison coarse sandy loam, nearly level	Denison	C	Moderately rapid	Moderately slow	Very slow	None to slight
DmB	Denison loam, gently sloping	Denison	C	Moderate	Moderately slow to slow	Very slow	Slight
FaB	Farallone loam, gently sloping	Farallone	B	Moderate	Moderately rapid to rapid	Slow	Slight
FcD2	Farallone coarse sandy loam, moderately steep, eroded	Farallone	B	Rapid	Rapid	Slow to medium	Moderate
FyC2	Farallone loamy coarse sand, sloping, eroded	Farallone	B	Very rapid	Very rapid	Slow	Slight
Gu	Gullied land (alluvial soil material)	Gullied Land	C	-	-	-	Very high
MmD2	Miramar coarse sandy loam, moderately steep, eroded	Miramar	C	Rapid	Moderately slow	Medium	Moderate
MmE2	Miramar coarse sandy loam, steep, eroded	Miramar	C	Rapid	Moderately slow	Rapid	High
MmF2	Miramar coarse sandy loam, very steep, eroded	Miramar	C	Rapid	Moderately slow	Very rapid	Very high
MmE3	Miramar coarse sandy loam, steep, severely eroded	Miramar	C	Rapid	Moderately slow	Rapid	High
TeC2	Tierra loam, sloping, eroded	Tierra	D	Moderate	Very slow	Slow	Moderate
TeE2	Tierra loam, steep, eroded	Tierra	D	Moderate to moderately slow	Very slow	Very rapid	Very high

May 27, 1956: This photograph illustrates the episodic nature of sediment yield for the Deer Creek watershed. Scars from recent debris flows are located in nearly every hollow in the upper canyon and throughout the entire region, suggesting that this mode of sediment production is endemic to the region, and is most likely the response to a recent large storm or series of storms. The channel immediately upstream of the reservoir is choked with sediment indicating that it is an area of deposition. Acting as a sediment trap for the system, the reservoir displays a large sand delta covering approximately 1/3 of its surface area. No landscape scarring is seen on the coastal terrace suggesting that the upper canyon is responsible for the majority of sediment production within the catchment.

April 22, 1973: Much of the debris flow scarring in the upper watershed has now healed and covered with vegetation. High sediment loads within the system have occurred since the last photograph as is indicated by the fact that the delta in the reservoir has grown to cover roughly 2/3 of the original surface area.

April 12, 1980: The 1980 photograph shows that the reservoir has filled in a little further and the delta has become vegetated. Between the time of this photograph and the present the reservoir has continued to be filled with sediment and colonized by vegetation, with the current pond area being something like ½ to 1/3 of the 1980 size.

4. HYDROLOGY

A literature search revealed limited hydrologic studies on Deer Creek. As a result, two regional methods involving regression equations were used to estimate the peak discharges on Deer Creek with return periods of 2-, 5-, 10-, 25-, 50-, and 100-years. These peak discharges were estimated at the mouth of Deer Creek, as it discharges into Pillar Point Harbor. Details of these calculations are provided in the following sections.

4.1 PEAK DISCHARGES USING SAN FRANCISCO BAY AREA REGIONAL REGRESSION EQUATIONS

Rantz (1971) developed a set of regional regression equations for the San Francisco Bay Area to estimate peak flood discharges with return periods of 2-, 5-, 10-, 25-, and 50-years. These equations were developed using data from 40 stream flow gaging stations with records ranging from 5 to 87 years, subject to a mean annual precipitation range of 13 to 60 inches, and covering watersheds ranging in area from 0.2 to 196 mi^2. The equations listed in Table 2 were used to estimate the 2-, 5-, 10-, 25-, and 50-year peak discharges on Deer Creek.

A watershed area of 0.65 mi^2 and a mean annual precipitation of 25.5 inches were used.

These equations apply to watersheds with minimum levels of development. In developed watersheds, such as Deer Creek, the estimated discharge is increased based on the percentage of the watershed that is developed and the percentage of the channel that is in culverts or concrete channels. These estimated "urbanizing" coefficients were 1.30, 1.15, 1.15, 1.15, and 1.10 for the 2-, 5-, 10-, 25, and 50-year peak discharges, respectively. These coefficients are multiplied with the original discharge estimates to compute the urbanized peak discharges.

TABLE 2. San Francisco Bay Area Regional Peak Flood Discharge Regression Equations for Various Return Periods (Source: Rantz, 1971)

Return Period (years)	Regression Equation for Peak Discharge*
2	$Q_2 = 0.069A^{0.913}P^{1.965}$
5	$Q_5 = 2.00A^{0.925}P^{1.206}$
10	$Q_{10} = 7.38A^{0.922}P^{0.928}$
25	$Q_{25} = 16.5A^{0.912}P^{0.797}$
50	$Q_{50} = 69.6A^{0.847}P^{0.511}$

* Note: Q = peak discharge (cfs), A = watershed area (mi^2), and P = mean annual precipitation (in.).

4.2 PEAK DISCHARGES USING REGRESSION EQUATIONS FROM THE USGS CENTRAL COAST HYDROLOGIC PROVINCE

Waananen & Crippen (1977) developed a set regional flood frequency regression equations for the entire state of California. By dividing the state into 6 hydrologic provinces they used data from 705 stream flow gaging stations with records ranging from 5 to 87 years and covering watersheds ranging in area from 0.01 to 9020 mi^2. Regression equations were developed for each hydrologic region, providing peak discharge estimates for floods with return periods of 2-, 5-, 10-, 25-, 50-, and 100-years.

Deer Creek is located in the Central Coast Hydrologic Province defined by Waananen & Crippen. Equations for this province, found in Table 3, were used to estimate the 2-, 5-, 10-, 25-, 50-, and 100-year discharges.

A watershed area of 0.65 mi^2, mean annual precipitation of 25.5 inches, and altitude index of 0.495 ft/ft were used.

Again, these equations apply to watersheds with minimum levels of development. These estimated "urbanizing" coefficients were 1.30, 1.15, 1.15, 1.15, 1.10, and 1.10 for the 2-, 5-, 10-, 25, 50-, and 100-year peak discharges, respectively.

TABLE 3. Peak Flood Discharge Regression Equations for Various Return Periods for the Central Coast Hydrologic Province (Source: Waananen & Crippen, 1977)

Return Period (years)	Regression Equation for Peak Discharge*
2	$Q_2 = 0.0061 A^{0.92} P^{2.54} H^{-1.10}$
5	$Q_5 = 0.118 A^{0.91} P^{1.95} H^{-0.79}$
10	$Q_{10} = 0.583 A^{0.90} P^{1.61} H^{-0.64}$
25	$Q_{25} = 2.91 A^{0.89} P^{1.26} H^{-0.50}$
50	$Q_{50} = 8.20 A^{0.89} P^{1.03} H^{-0.41}$
100	$Q_{100} = 19.7 A^{0.88} P^{0.84} H^{-0.33}$

* Note: Q = peak discharge (cfs), A = watershed area (mi^2), P = mean annual precipitation (in), and H = altitude index (1000's of ft), averaging the elevations of the creek at 15% and 85% of the length of the watershed.

4.3 RESULTS

Table 4 reports the peak discharges estimated for Deer Creek. Agreement between the two estimate methods is good, with the USGS Central Coast Hydrologic Province estimates generally being somewhat higher than the San Francisco Bay Area estimates. There is also general agreement with the 100-year design discharge that Caltrans used for the design of the culvert under State Route 1. The estimates exceed those of the SCS for their analysis of a drop inlet structure on the Stroot Property, however, they only considered a watershed of 330 acres draining to the reservoir (USDA SCS, 1985).

For the preliminary design of both sediment retention facilities the adopted design discharge was the 2-year discharge of 43.0 cfs. In addition, the 100-year discharge of 282 cfs was also used to design the overflow weirs for the basins.

TABLE 4. Estimated Peak Discharges at the Mouth of Deer Creek

Return Period (years)	Peak Discharge (cfs)			
	San Francisco Bay Regional Estimate	California Hydrologic Province Estimate	SCS	Caltrans
2	35 (21 to 59)*	43 (15 to 127)*	-	-
5	76 (51 to 114)	88 (36 to 216)	-	-
10	115 (78 to 169)	130 (58 to 292)	68	-
25	168 (112 to 253)	191 (85 to 427)	125	-
50	277 (178 to 430)	229 (96 to 550)	178	-
100	-	282 (110 to 726)	-	296

* Note: Number in parentheses indicate an error band of plus and minus one standard deviation around the reported peak discharge estimate.

5. SEDIMENT YIELD

The sediment yield of a watershed can be defined as the amount of sediment exported by a watershed to a particular point over a specified period of time (Morris & Fan, 1998; ASCE, 1977). The sediment yield can be event specific, such as for a particular storm, or an average, such as an annual average sediment yield.

Several environmental factors directly influence the sediment yield of a watershed, including topography, soils and geology, climate, vegetative cover, land use, as well as sediment transport efficiency factors as watershed size and shape and channel hydraulics (ASCE, 1977). Being dependent upon so many different characteristics of a watershed and particular storm event, accurate estimation of sediment yield is difficult without detailed and lengthy flow and sediment transport data for a particular stream. However, reasonable estimates can be made using a variety of techniques.

Since there are no data available to quantify erosion, sediment transport, and deposition in the Deer Creek watershed, as described below, several techniques were used to estimate the average annual sediment yield.

5.1 REGIONAL WATERSHED CORRELATION

By looking at nearby studied watersheds within the region that exhibit similar hydrologic, geologic, climatic, and vegetative characteristics to the study site, estimates of the sediment yield can be made based on regional trends. To relate the sediment yields of previously studied watersheds to the sediment yield of the study site, the SCS Sediment Yield Transfer Equation can be used:

$$Y = Y_o \left(\frac{A}{A_o} \right)^{0.8}$$

where Y = average annual sediment yield of the watershed under study (tons/year), Y_o = average annual sediment yield of the measured watershed (tons/year), A = area of the watershed under study (mi^2), and A_o = area of the measured watershed (mi^2). This equation is subject to the condition that $0.1 < A/A_o < 10$ (WEST Consultants, Inc., 1993).

Fortunately, several watersheds within the Deer Creek region have been studied in sufficient detail to provide average annual sediment yield estimates. Brief descriptions of each of these sites as well as their average annual sediment yields are provided in Table 5.

In addition to these individual studies on individual creeks, a regional study that provided estimates of sediment yields of creeks in the Santa Cruz region was used. In their sediment budget for the Santa Cruz coastal littoral cell, Best and Griggs (1991) estimated the sediment yields for 13 perennial streams that drain 85% of the land area that contributes sediment to the Santa Cruz littoral cell.

While the coastal watersheds draining the Santa Cruz Mountains are relatively small, they have relatively large sediment yields because of their narrow widths, steep terrain, and deeply incised channels. For these creeks a large portion of sediment produced originates as mass movements (shallow debris flows) and therefore sediment input to stream channels should be very episodic in response to very large storms. Vegetation within the basins consists of redwoods, oak, and madrone on side slopes and in valleys, with chaparral and grasslands on the ridge crests. Overall these watersheds are similar to Deer Creek in terms of their hydrologic, geologic, climatic, land use, and vegetation characteristics (Best & Griggs, 1991)

Using discharge measurements made at 10 streams, and sediment transport measurements at 5 of those streams, the average annual sediment yields of the 13 watersheds were estimated. Overall for the entire study site an annual average sediment yield of 945 tons/mi^2/yr was estimated. Since the study relied on sediment data collected during lower flows and over a relatively short period of time, Best and Griggs felt that the reported annual average sediment yields underestimate long-term conditions, but by no more than 50%. (Best & Griggs, 1991)

Table 6 presents the 7 watersheds from the Best and Griggs study that were used to estimate the annual average sediment yield of Deer Creek.

TABLE 5. Selected Regional Watersheds with Annual Average Sediment Yield Estimates (Various Sources)

Location	Watershed Area (mi^2)	Geology	Elevation Range (feet above MSL)	Annual Precipitation (inches)	Vegetation	Major Land Use Activities Impacting Sediment Yield	Sediment Yield ($tons/mi^2$-year)	Reference
Loch Lomond Reservoir (Newell Creek)	5.1	Sandstone, siltstone, and shale that produce easily erodible materials especially when land disturbance has occurred.	400 to 2300	20 to 60	Redwoods and coastal chaparral	Roads, minor logging, some residential development	1100	Brown (1973)
Lone Tree Creek	0.67	Greywacke, shale, and assorted metamorphic rocks	0 to 1600	34	Grassland (50%), brushland (30%), forest (20%)	None.	611	Lehre (1982)
Colma Creek	10.9	Sandstone, shale, and deposits of firmly cemented sand, silt, and clay.	0 to 1300	?	?	Extensive urbanization, industrial areas, some agriculture, residential and roadway construction.	2940	Knott (1969)

TABLE 6. Santa Cruz Area Creeks with Estimated Annual Average Sediment Yields (Source: Best & Griggs, 1991)

Basin	USGS Discharge Gage?	USGS Sediment Gage?	Watershed Area (mi^2)	Annual Average Sediment Yield (tons/year)
Tunitas Creek	N	N	11.6	1752
Pomponio Creek	N	N	7.2	976
Gazos Creek	N	N	11.5	3486
San Vicente Creek	Y	N	11.2	3664
Laguna Creek	Y	N	8.0	1752
Major Creek	Y	N	4.7	564
Wilder Creek	N	N	5.6	561

5.2 GENERAL REGRESSION

As reported by the Pacific Southwest Inter-Agency Committee (PSIAC, 1974), Flaxman developed a general regression equation useful for estimating the average annual sediment yield of a watershed:

$$\log(Y+100)=524.37231-270.65625\log(X_1+100)+6.41730\log(X_2+100)$$
$$-1.70177\log(X_3+100)+4.03317\log(X_4+100)+0.99248\log(X_5+100)$$

where Y = mean annual sediment yield (tons/mi^2/yr), X_1 = ratio of mean annual precipitation (inches) to mean annual temperature (°F), X_2 = weighted average slope of the watershed (%), X_3 = percent of surface soil particles greater than 1 mm in diameter (%), X_4 = percent of surface soil particles less than 0.002 mm in diameter (%), and X_5 = 2-year peak discharge (cfs/mi^2).

For Deer Creek X_1 was 0.47 (25.5 inches/year of precipitation and annual average temperature of 62 °F), X_2 was estimated to be about 20 %, X_3 was estimated to be about 63 %, X_4 was -3 %, and X_5 was 66.2 (43 cfs 2-year discharge and watershed area of 0.65 mi^2).

5.3 RESERVOIR SURVEY

The aerial photograph series of the Deer Creek watershed clearly show a growing sediment delta located in the upper end of the reservoir in the upper watershed. The 1943, 1956, and 1973 photographs were enlarged and the surface areas of the sediment deposits were planimetered to estimate the surface area of the growing sediment delta.

Specific details on the reservoir were not located. However, the 40 foot earthen embankment at the downstream end of the reservoir was apparently constructed in the early 1900's. It has been estimated that the reservoir had been severely silted in to a depth of about 20 feet. The original storage capacity of the reservoir has been estimated to be approximately 45.0 ac-ft. (Howard Donley Associates, Inc., 1981)

Since details concerning the historic bathymetry of the reservoir could not be found, in order to convert the measured areal growth of the sediment delta into a sediment yield volume, a siltation depth of 20 was used and, to error on the high side, vertical sidewalls of the reservoir and sediment delta were assumed. The SCS Sediment Transfer Equation was then used to scale up the reservoir sedimentation estimates, representative of the sediment yield from the upper 0.51 mi^2 of the watershed, to the entire Deer Creek watershed (0.65 mi^2). The estimated volumes were converted to tons using an average unit weight of 92.5 lbf/ft^3. Table 7 details the results of this investigation.

TABLE 7. Estimated Annual Average Sediment for Deer Creek Based on Estimated Loss of Storage Capacity of the Upstream Reservoir

Time Period	Number of Years	Loss of Pond Area (acres)	Assumed Depth (ft)	Lost Volume (ac-ft)	Lost Weight (tons)	Annual Average Sediment Yield (tons/yr)
November 11, 1943 to May 27, 1956	12.5	-0.95	20	-19	-38,278	3052
November 11, 1943 to March 22, 1973	29.5	-1.59	20	-31.8	-64,066	2176

5.4 RESULTS

Table 8 presents the sediment yield estimates made for the Deer Creek watershed at its outlet into Pillar Point Harbor.

TABLE 8. Estimated Mean Annual Sediment Yields for Deer Creek at its Outlet into Pillar Point Harbor

Method	Basin	Average Annual Sediment Yield for Deer Creek (tons/year)
SCS Sediment Transfer Equation, Studied Watersheds in the Region	Lone Tree Creek	398
	Loch Lomond	1074
	Colma Creek	3340
SCS Sediment Transfer Equation, Santa Cruz Area Creeks*	Tunitas Creek	173
	Pomponio Creek	142
	Gazos Creek	348
	San Vicente Creek	373
	Laguna Creek	233
	Major Creek	116
	Wilder Creek	99
Flaxman Equation		66
Reservoir Sedimentation (1943-1956)		3052
Reservoir Sedimentation (1943-1973)		2176

* Note: These estimates may be doubled since Best and Griggs (1991) felt that their sediment yield estimates might under-represent long-term conditions by 50%.

Overall, the sediment yield estimates generated by comparison with the Santa Cruz area creeks tend to be low. Even after doubling them to account for their underestimation of long-term sediment yield, they still remain low. Similarly, the yield from the Flaxman regression equation is low. The estimates made from the reservoir survey rank as the highest estimates.

An annual average sediment yield of 3100 tons/yr, estimated from the 1943 to 1956 reservoir siltation, was assumed for the design and layout of both candidate sediment retention basins. The emergency removal of sediment from Pillar Point Harbor came to about 5600 yd^3, or 7000 tons. This is slightly more than the adopted yield, but reflects extreme storm conditions associated with the El Niño winter. Still, even though it was the largest estimate, it was felt that 3100 tons/yr was a reasonable estimate of the sediment yield for the Deer Creek watershed. Being the largest, in the absence of further evidence, it also remains the most conservative for design and therefore sizing the proposed basins for this yield would only further help to limit sedimentation within Pillar Point Harbor, both on an annual and storm specific basis.

6. SEDIMENT SIZE ANALYSIS

During the July 21, 1998 site visit 8 sediment samples were collected throughout the Deer Creek watershed and mapped using a hand held Global Positioning System (see Figure 1). Seven of the samples were collected upstream of the reservoir since it is felt that this is the origin of the majority of the catchment's sediment yield. In addition, a sediment sample was collected at the sediment disposal site in Pillar Point Harbor, representing the particle size distribution of sediment that typically reaches the harbor in a storm event.

The Cooper Testing Laboratory was used to conduct sieve and hydrometer analyses on the samples to determine the sediment size distributions. Table 9 classifies each sample and tabulates their composition in terms of percent gravel, sand, and fines (silt and clay). As can be seen from the table, the sediment yield of the Deer Creek watershed is primarily composed of sand and silt with small amounts of gravel and clay. The samples are qualitatively consistent with the sediment composition of the SCS soil series found within the Deer Creek watershed (see Table 10).

TABLE 9. Composition of the Sediment Samples Collected along Deer Creek (Source: The Cooper Testing Laboratory)

Sediment Sample	Material Description	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
1	Dark brown clayey SAND	0.0	0.7	12.2	29.6	29.6	19.0	8.9
2	Black clayey SAND	0.0	2.1	12.8	24.4	33.1	17.3	10.3
3	Dark gray SAND with silt	2.5	19.5	18.5	23.9	27.6	5.9	2.1
4	Brown silty SAND with clay lumps	0.0	0.0	6.9	16.7	52.6	16.1	7.7
5	Dark brown silty SAND	0.0	1.4	11.9	28.2	28.5	20.4	9.6
6	Brown SAND with gravel and silt	1.7	13.9	21.0	26.6	29.4	5.4	2.0
7	Brown silty SAND	0.0	4.6	22.3	31.8	28.8	9.5	3.0
8	Light brown SAND with silt	0.0	1.6	15.4	35.5	36.3	8.0	3.2

TABLE 10. Composition of SCS Soil Series Found in the Deer Creek Watershed (Source: USDA SCS, 1969)

Soil Series	Depth From Soil Surface (in)	Classification	Percent Passing (%)				
			Cobbles > 3 in.	Mid Fine Gravel No. 4	Fine Gravel No. 10	Coarse Sand No. 40	Fine Sand No. 200
Denison	0-45	Clay	100	100	95-100	81-86	60-71
	45-61	Clay Loam or Silty Clay Loam	100	100	95-100	81-86	65-75
Farallone	0-48	Coarse Sandy Loam or Loamy Coarse Sand	100	95-100	90-100	90-100	20-30
Gullied Land	-	-	-	-	-	-	-
Miramar	0-22	Coarse Sandy Loam	100	95-100	90-100	80-90	20-30
	22-37	Coarse Sandy Clay Loam	100	80-85	70-75	60-70	40-50
	>37	Weathered Quartz Diorite	-	-	-	-	-
Tierra	0-12	Loam to Sandy Loam	100	90-100	95-100	60-80	40-60
	21-41	Heavy Clay Loam or Sandy Clay	100	90-100	95-100	75-85	60-70
	41-60	Sandy Clay Loam	100	90-100	95-100	70-80	50-60

Figure 4 presents grain size distribution curves for all 8 samples. Sediment Sample #7 was selected in the preliminary design of the upper retention basin since because of its location it was felt to best represent the particle size distribution of sediment reaching that portion of the watershed. Similarly for the lower candidate retention basin, Sediment Sample #8 was adopted to represent the particle size distribution of sediment transported to the lower reach Deer Creek. It was felt that since this sample was collected at the disposal site of the emergency storm removal, the sample was most indicative of the size distribution in the lower reaches of Deer Creek. Figures 5 and 6 present more detailed plots of the size distributions of Sediment Sample #7 and #8, respectively.

In order to convert between the sediment volume and weight, the unit weight of the two selected samples had to be calculated. This was accomplished using the Lara and Pemberton Equation:

$$W = P_c W_c + P_m W_m + P_s W_s$$

where W = unit weight of sediment (lbf/ft^3), $P_{c,m,s}$ = percentage (%) of the sample that is clay (c), silt (m), and sand (s), and $W_{c,m,s}$ = unit weight coefficients (lbf/ft^3) for clay (c), silt (m), and sand (s). The coefficients reflect not only the difference in deposited density between the different sizes of sediment but also the depositional environment. Based on 1300 sediment samples collected from reservoirs and rivers the coefficients are grouped in terms of how often the sediment is submerged: 1) continuously submerged, 2) moderately submerged, 3) mostly dry, and 4) riverbed sediment (Morris & Fan, 1998). Typically, the more time the sediment is submerged, the lower the density.

For the units weights of the Deer Creek sediment samples, a continuously submerged condition was assumed with the coefficients being 26 lbf/ft^3, 70 lbf/ft^3, and 97 lbf/ft^3, respectively. This is appropriate since it provides an estimate of the sediment volume during and immediately after a storm event, and therefore allows for proper assessment of the sediment storage required for sizing each basin.

A unit weight of 92.3 lbf/ft^3 was computed for Sediment Sample #7 and 92.6 lbf/ft^3 for Sediment Sample #8. An average unit weight of 92.5 lbf/ft^3 was adopted for the design of the retention facilities. Using this value, the design sediment yield becomes 2480 yd^3/year. The density of excavated material will likely be higher since the sediment may be saturated.

7. SEDIMENT RETENTION BASIN DESIGN

As floodwaters enter a sedimentation basin, the flow velocity decreases, allowing sediment, transported both in suspension and along the bed (bedload), to settle by gravity and deposit onto the bed of the basin. The design of a sediment retention facility is an iterative process which attempts to simultaneously meet several constraints that control performance, including:

1. The basin must be long and large enough to temporarily store and detain floodwaters, promote sediment settling, and provide retention storage for the deposited sediment.

2. Inlet and outlet works must minimize turbulence and avoid flow separation to maintain hydraulic efficiency.

3. For the design discharge, flow velocities in the basin must remain below threshold values that inhibit deposition and promote scouring.

4. The outlet facilities must be able to safely pass the extreme design discharge.

The following sections briefly describe the equations and methods used to size and rate the sediment retention basins for Deer Creek.

7.1 SETTLING VELOCITY

The relationship between the settling velocity and sediment diameter is necessary for evaluating the performance of a retention basin in its ability to capture a range of sediment sizes. To estimate the terminal settling velocities of sediment grains, the Rubey Equation was used:

$$V_s = \frac{[1636(\rho_s - \rho)d^3 + 9\mu^2]^{0.5} - 3\mu}{500d}$$

where V_s = terminal fall velocity (m/s), ρ_s = sediment density (kg/m^3), assumed to be 2650 kg/m^3, ρ = water density, assumed to be 1000 kg/m^3, d = sediment diameter (m), and μ = dynamic viscosity of water (N-s/m^2), assumed to be 1.31×10^{-3} N-s/m^2.

7.2 CRITICAL SETTLING VELOCITY

Under theoretical and idealized conditions, the critical settling velocity of a sedimentation basin guarantees that sediment particles with settling velocities of equal or greater value will be trapped with 100% efficiency (Tchobanoglous & Schroeder, 1987). Under real world conditions, this is not the case; however, the critical settling velocity still remains useful as a target for design, indicating the general goal of effectively trapping sediment particles with settling velocities of equal or greater value. The critical settling velocity ($V_{critical}$) is expressed as the design discharge (Q) divided by the planform area of the basin (A):

$$V_{critical} = \frac{Q}{A}$$

This equation is effectively used for design and layout by solving for the planform area, A, which is accomplished by selecting a design discharge, Q, and using the terminal settling velocity of the target grain size as the critical settling velocity.

7.3 BASIN TRAPPING EFFICIENCY

The trapping efficiency of a sediment retention basin is the ratio of the amount of sediment deposited in the basin to the total amount of sediment that has entered the basin. As such, the trapping efficiency is a function of the volumetric capacity of the basin, inflow of sediment, discharge, basin shape, and inlet and outlet works as well as the sediment characteristics (Morris & Wigget, 1972).

Several analytical techniques are available to estimate the trapping efficiency of the basin. For theoretical, ideal conditions, trapping efficiency (E) as a function of sediment diameter is a linear relationship between the settling velocity (V_s) of the sediment particle and the critical settling velocity ($V_{critical}$) derived from the basin layout:

$$E = \frac{V_s}{V_{critical}}$$

However, to attempt to more realistically estimate the trapping efficiencies of the proposed basins for Deer Creek, the above ideal condition was not used. Rather, the trapping efficiency was estimated using a theoretical relationship for turbulent, non-ideal conditions, represented by the following equation:

$$E = 1 - \left[1 + \frac{1}{n}\frac{V_s}{V_{critical}}\right]^{-n}$$

where E = trapping efficiency for a single grain size, V_s = settling velocity of the sediment grain, $V_{critical}$ = critical settling velocity, and n = factor characterizing the hydraulic efficiency of the basin.

To remain conservative in this preliminary layout, the above equation was used with n=1, representing "poor settling characteristics" constituting hindered settling conditions associated with turbulent floodwaters (Morris & Fan, 1998).

7.4 DEPOSITION/SCOURING VELOCITY

Deposition of sediment with a particular size will occur within a sedimentation basin so long as shear stresses (represented by the proxy variable of scouring velocity) that inhibit deposition and promote scouring of that particle size are not exceeded. If this threshold is exceeded, sedimentation may still occur, albeit at a less predictable and much reduced rate. The design scouring velocity used for the sizing of a sediment retention facilities for Deer Creek was adopted from Krone (1962) and is V_{scour} = 0.328 ft/s (~0.1 m/s) for 0.04 mm sediment. This particle size reflects fine silt and sizing at this scale allows the retention basin to effectively capture coarse silt and larger particles.

7.5 OUTFLOW WEIR

The outflow weir regulates floodwaters as they exit the sedimentation basin and re-enter the stream channel. Serving as the only primary outlet for the sedimentation basins for Deer Creek, the outlet weirs were designed to both 1) regulate the 2-year design discharge in order to promote settling and deposition while minimizing scour, and 2) safely pass the 100-year peak discharge. This was accomplished using the standard weir equation:

$$Q = CL\sqrt{2g}H^{\frac{3}{2}}$$

where Q = discharge (cfs), C = weir coefficient, where C is assumed to be 3.09, L = width of the weir (ft), g = gravitational acceleration, assumed to be 32.2 ft/s^2, and H = the height of water above the crest of the weir (ft).

8. RESULTS & DESCRIPTION OF DESIGN LAYOUTS

This section discusses the results of the sediment retention basin design calculations and describes the proposed layouts of the two candidate basins.

8.1 SEDIMENT RETENTION BASIN ON THE STROOT PROPERTY

Figure 7 presents the planform layout of the proposed upper basin located on the Stroot Property, immediately upstream of the reservoir. Figure 8 presents a typical cross-section for the basin.
The basin would be located on the current creek channel where runs adjacent to a flat field, immediately upstream of the existing reservoir on the Stroot Property, beginning at the existing dirt road that crosses the site.

The basin would be excavated into existing grade and would be bordered on the sides by earthen embankments with 1:3 (vertical:horizontal) side slopes. Floodwaters would be conveyed into the basin through a box culvert under the existing road and a rock lined apron would be installed to provide scour protection at the inlet. Similarly, in exiting the basin, floodwaters would pass over an armored rock weir and discharge onto another rock rip-rap scour apron and then discharge into the existing creek.

The total basin depth from the top of the embankments to the base is estimated to be 8.5 feet. This would provide a minimum of 5 feet of sediment storage, 3 feet of storm water detention storage and 0.5 feet of freeboard. The required minimum basin dimensions at the base are roughly 180 feet by 60 feet, with additional areas provided for flow transitions into and out of the basin.

The outflow weir is trapezoidal in shape with a base crest length of 30 feet, a crest width of 10 feet, and side slopes of 1:3. Composed of rock rip-rap, the crest elevation of the weir would be 6 feet above the bed of the basin.

With a full storm water detention volume of 20.4 ac-ft, the weir would pass the design discharge of 43 cfs with only 0.5 feet of head. Two feet of head on the weir will be able to pass more than the 100-year extreme discharge of 282 cfs.

8.1.1 Basin Performance

Figure 9 presents the predicted sediment trapping efficiency of the proposed upper basin. Overall the basin would be quite effective in retaining sands and coarser material. Silts and finer material would not be trapped as efficiently, but space constraints preclude this. Overall it is predicted that the upper basin would trap roughly 90% of the average annual sediment yield.

8.1.2 Benefits

There are a few benefits associated with locating a sediment basin on the Stroot Property:

1. The flat area behind the reservoir is one of the few areas where a basin could be more easily constructed.

2. Even though the basin is located in the upper portion of the Deer Creek watershed, it is felt that it will address the majority of the sediment that is generated within the entire watershed.

8.1.3 Drawbacks

There are several drawbacks associated with locating a sediment basin on the Stroot Property:

1. The basin would be located on private property and construction of the basin would require approval by the current property owner.

2. Located in the upper portion of the watershed, the basin would not address sediment inputs in the lower reaches of Deer Creek through El Granada.

3. Located upstream of the reservoir and embankment, repairs addressing the undermining spillway may be required, which would increase the estimated construction cost.

4. Access to the site for construction and maintenance could be difficult due to the steep and narrow roads that lead to the property.

5. The basin would be located next to a wetland and may impact it, requiring special permitting and/or mitigation measures.

6. Located above a populated area, special design considerations specifically addressing flooding issues and failure or overtopping of the reservoir embankment may be required.

7. Permitting and environment review would be required as the project would eliminate an existing vegetation corridor along the creek.

8.2 SEDIMENT RETENTION BASIN IN THE STATE ROUTE 1 EASEMENT

Figure 10 presents the planform layout of the proposed basin located on the Caltrans State Route 1 easement. Figure 11 presents a typical cross-section for the basin. The basin would be located on the current creek channel in a relatively level field immediately between Alhambra Avenue and State Route 1.

The basin would be excavated into existing grade with vertical sheet pile walls due to the limited space at the proposed site. In addition, since the location is limited in length along the projected centerline of the creek, the basin has to be rotated approximately 90 degrees and split to obtain effective trapping efficiencies.

Floodwaters would enter the basin through an existing box culvert, turn 90 degrees, travel through a straight section, turn 180 degrees in a "U" turn, traverse another straight section and then turn 90 degrees again to exit the basin via an overflow weir that discharges into the inlet of culvert that passes under State Route 1. A concrete weir and an rip-rap apron would be constructed at the terminus of the basin to facilitate sediment trapping and energy dissipation before the water enters the intake which crosses Route 1. The outside walls would be constructed of sheet piles with a concrete cap, as shown on Figure 10. A concrete wall would be constructed down the center of the basin to separate the opposing flow paths of the flood waters. The floor of the basin would be constructed of concrete as well.

Two additional weirs would need to be constructed in the lower detention basin to address flooding in extreme events. The first weir is located in the flow path of the projected center line of the existing creek. This weir would have a crest elevation set higher than the weir at the end of the basin and would convey floodwaters into the State Route 1 culvert intake. The weir would provide a flow path in the event of reduced capacity of the basin or flood events higher than the 100-year flood. A second weir and a emergency overflow basin would be constructed near the terminus of the basin to address the potential blockage or reduced capacity of the State Route 1 culvert.

The total basin depth from the top of the embankments to the base is estimated to be 11 feet. This would provide a minimum of 5.5 feet of sediment storage, 4.5 feet of storm water detention storage and 1 foot of freeboard. Expected basin dimensions at the base are roughly 250 feet long by 50 feet, with additional area provided for the bend between the two arms of the basin. Due to the depth of the basin, a low level outlet such as a sluice gate or multiport pipe might be required for draining of the pond after small storm events.

The outflow weir is trapezoidal in shape with a base crest length of 30 feet and side slopes of 1:2. Composed of concrete, the crest elevation of the weir would be 8 feet above the bed of the basin.
Even with a full storm water detention volume of 20.4 ac-ft, the weir would be able to pass the design discharge of 43 cfs with only 0.5 feet of head. Two feet of head on the weir will be able to pass more than the 100-year extreme discharge of 282 cfs.

Access to the basin could be made via Alhambra Avenue and then down a ramp into the basin. Due to the public location of the basin, chain-link fencing is recommended for the entire perimeter of the site for safety reasons.

8.2.1 Basin Performance

Figure 12 presents the predicted sediment trapping efficiency of the proposed lower basin. Overall the basin would be quite effective in retaining sands and coarser material. Silts and finer material would not be trapped as efficiently because space constraints preclude this. Performance is very similar to that of the upper basin and overall it is predicted that the lower basin would trap roughly 90% of the average annual sediment yield.

8.2.2 Benefits

There are some benefits associated with locating a sediment basin along the Caltrans State Route 1 easement:

1. The downstream location addresses the sediment yield from nearly the entire Deer Creek watershed.

2. Site access for maintenance is available along Alhambra Avenue.

8.2.3 Drawbacks

There are several drawbacks associated with locating a sediment basin along the Caltrans State Route 1 easement:

1. Construction of the basin is dependent upon approval by Caltrans.

2. The basin would be located in a public area and therefore would carry safety and liability issues.

3. The site is limited in size and therefore presents difficult and complex parameters for design, construction, and operation of the basin.

4. The outflow of the basin would pass directly into the culvert system under State Route 1, presenting a difficult hydraulic design in further efforts.

5. Ponding water above the road bed elevation of State Route 1 would pose possible safety and permitting issues. The basin should be designed to include emergency overflow into the adjacent property to avoid flooding on State Route 1 during an extreme event.

6. The integrity of the existing dam and spillway at the upstream reservoir is not addressed.

7. Permitting and environment review would be required since the project would eliminate existing vegetation and large trees in the corridor along the creek.

9. ESTIMATED PROJECT CONSTRUCTION COSTS

This section presents the preliminary engineer's estimated construction costs for the two candidate sediment basins. Rough dimensions were used to estimate design parameters of the basins and initial construction quantities. Unit costs were estimated based on cost estimation guides and discussions with local contractors. Additional unit costs were extracted from the standard cost manual RS Means Building Construction Cost Data 1999. Total cost was compiled by multiplying the estimated quantities by representative unit costs, adding in items necessary for construction, and adding in contingencies. Tables 11 and 12 detail the estimated construction cost for the proposed upper and lower sediment retention basins, respectively.

TABLE 11. Engineer's Estimate of Construction Cost for the Upper Basin

Description	Units	Units Cost (1999 U.S. $)	Quantity	Total Cost (1999 U.S. $)
Excavation	CY	5	5900	$29,500
Embankment Fill	CY	5	3500	$17,500
Clearing and Grubbing	acres	6,000	0.46	$2,800
Inlet structure				
Excavation	CY	5	300	$1,500
Rip-rap, including hauling & instal.	CY	40	280	$11,100
Outlet Weir (30 feet wide)				
Rip-rap, including hauling & instal.	CY	40	560	$22,200
Hauling and off-site disposal	CY	16	4200	$67,200
Subtotal				**$151,800**
Contingencies	%	25%	-	$38,000
Mobilization & Demobilization	%	8%	-	$12,100
Engineering and Design	%	20%	-	$30,400
TOTAL				**$232,300**

TABLE 12. Engineer's Estimate of Construction Cost for the Lower Basin

Description	Units	Units Cost (1999 U.S. $)	Quantity	Total Cost (1999 U.S. $)
Basin Excavation	CY	5	9300	46,500
Structural Backfill	CY	5	100	500
Clearing and Grubbing	acres	6,000	0.45	2,700
Concrete Slab (8")		3	17,500	52,500
Terminus Weir (30 feet width)				
Excavation	CY	5	0.46	-
Structural Backfill	CY		100	500
Reinforced Concrete	CY	400	37	14,800
Rip-rap	CY	40	278	11,100
In-Line Emergency Weir				
Excavation	CY	5	70	400
Structural Backfill	CY	5	100	500
Reinforced Concrete	CY	450	10	4,500
Rip-rap	CY	40	278	11,100
D/S Side Flow Emergency Weir and Overflow Basin				
Excavation	CY	5	2200	11,000
Structural Backfill	CY	5	100	500
Reinforced Concrete	CY	450	10	4,500
Rip-rap	CY	40	278	11,100
Sheet Pile Walls				
Excavation	CY	5	200	1,000
Structural Backfill	CY	5	200	1,000
Sheet Piles	LF	250	400	100,000
Cap For Sheet Piles	LF	100	400	40,000
Fencing	LF	20	540	10,800
Hauling and off-site disposal	CY	16	11,170	178,700
Subtotal				503,700
Contingencies	%	25%		125,900
Mobilization & Demobilization	%	8%		40,300
Engineering and Design	%	20%		100,700
TOTAL				**$ 949,300**

10. ESTIMATED OPERATIONS, MAINTENANCE AND COSTS

Since both basins are sized for approximately the annual average sediment yield of Deer Creek, it is anticipated that sediment removal operations would be required on an annual basis. Periodic monitoring of the basins should take place, especially during the winter season. Since very large storms can transport many times the average annual sediment yield, sediment removal in the basins may be required after large storm events to maintain capacity of the basin.

Ideally, material dredged from the basins could be disposed of South of Pillar Point Harbor along the eroding beaches of Half Moon Bay. This plan was not fully considered due to concerns expressed by the Marine Sanctuary. It was assumed that materials removed from the basins could be transported 20 miles and for disposal.

It is possible that a local contractor could recover the material use it for local projects, thus providing a discounted cost for removal of sediment from the basins. This would require coordination with the contractor and careful administration of the facility to insure the basins are adequately performing.

Specific elements of annual maintenance costs include sediment removal and storage of the material off-site, phasing the removal of the sediment to maintain trapping capacity in the basin, establishing trucking routes and times to respond to public concerns, and other issues to be determined. Permitting costs and environmental mitigation costs were not assessed.

Tables 13 and 14 summarize the estimated annual operations and maintenance costs for the two candidate facilities.

TABLE 13. Engineer's Estimate of Operation and Maintenance Cost for the Upper Basin

Operation or Item	Quantity	Units	Unit Cost (1999 U.S.$)	Total Cost (1999 U.S. $)
Excavation of Sediment	2500	CY	$5	12,500
Hauling and off-site disposal	2500	CY	$16	40,000
Subtotal				**$ 52,500**
Maintenance	2 %	% of Capital Cost	-	4,600
Mobilization & Demobilization	8 %	%	-	4,200
Contingencies	25 %	%	-	13,100
Total				**$ 74,400**

TABLE 14. Engineer's Estimate of Operation and Maintenance Cost for the Lower Basin

Operation or Item	Quantity	Units	Unit Cost (1999 U.S.$)	Total Cost (1999 U.S. $)
Excavation of Sediment	2500	CY	5	12,500
Hauling and off-site disposal	2500	CY	16	40,000
Subtotal				**$ 52,500**
Maintenance	1 %	% of Capital Cost	-	9,500
Mobilization & Demobilization	8 %	%	-	4,200
Contingencies	25 %	%	-	13,100
Total				**$ 79,300**

11. ALTERNATIVES

Three additional alternatives are proposed for consideration. At this stage these alternatives are only conceptual and do not have proposed designs and engineer's estimates of construction and operations and maintenance costs.

11.1 CULVERT REPLACEMENT & HARBOR DREDGING

This alternative would involve upgrading the existing conveyance infrastructure through El Granada at each existing creek crossing to convey water and sediment during all flows up to the 100-year event. This would entail the replacement of culverts and removal of any flow obstructions along the entire length of the Deer Creek, beginning below the reservoir. Improvement of these facilities will increase the sediment transport capability of the creek and sediment would still be discharged into the harbor. Provided that the outlet into the harbor is resized for the 100-year event, the conveyance of floodwaters and sediment should not damage the harbor's infrastructure as it did during the 1997-1998 El Niño winter. In conjunction with this plan regular dredging of the deposited sediment in the harbor would be required.

11.1.1 Benefits

1. Does not require manipulation of the stream channel, except in the locations of the existing crossings.
2. Does not interrupt natural sediment flux and changes in the Deer Creek channel network.
3. Does not require additional maintenance other than dredging.

11.1.2 Drawbacks

1. Sedimentation in the harbor would continue at existing or increased rates.

2. May not adequately address sedimentation problems in the reach of channel through the community, if they exist.

3. The integrity of the existing dam is not addressed.

4. The project would require extensive road work and therefore could have high construction costs.

11.2 EROSION CONTROL

This alternative would involve erosion control structures and rehabilitations along the entire length of Deer Creek and within upper watershed to help to reduce the sediment yield. These could include localized bank protection and grade control structures.

11.2.1 Benefits

1. Sediment sources in the existing channels, including bank erosion and vertical incision, can be controlled by the placement of grade control devices and rock bank protection.

2. Little or no maintenance is required after the structures are placed in the channel.

3. Structures can be placed to minimize impacts to aquatic habitat

11.2.2 Drawbacks

1. Sediment sources associated with mass wasting and landsliding from the hillslope areas are not addressed.

2.

3. Riparian vegetation may be removed during construction in some areas and therefore present difficulties in permitting.

3. The integrity of the existing dam structure is not addressed.

4. Equipment access may be difficult in some areas.

5. Channel grading may be required in some areas.

11.3 STREAM RELOCATION

An examination of tideland surveys in 1883, 1914 and 1946 indicate steady progressive erosion of beaches in Half Moon Bay. It appears that cliff and beach erosion within the present Pillar Point Harbor was the source of most of the sand for downcast beaches. The local creeks that discharge into the harbor also used to supply sediment. However, harbor breakwaters have curtailed that erosion and contained the sediment discharged from the creeks, thereby curtailing sand nourishment to the downcast beaches. This lack of the nourishment causes loss of beaches in the downcast area. (SMCHD, 1972)

Consequently, relocation of the stream channel along the median strip between Alhambra Avenue and State Route 1 presents itself as an alternative that would eliminate the harbor sedimentation problem, associated with Deer Creek, as well as help to restore the replenishment of sand to the eroding beaches to the South of the harbor.

11.3.1 Benefits

1. Removes the discharge of sediment from Deer Creek to the marina.

2. Does not interrupt natural sediment flux and changes in the Deer Creek channel network.

3. Does not require significant maintenance if designed to convey sediment through the roadway median.

4. Provides a regular sediment source to the beaches South of harbor.

5. Provides an opportunity for a creek parkway along the median strip.

11.3.2 Drawbacks

1. An extended length of armored channel would need to be created to divert the sediment along the median strip.

2. The integrity of the existing dam and spillway is not addressed by this alternative.

3. Permitting could be very difficult to obtain especially with the Marine Sanctuary.
6. Acquisition of property may be required.

The permitting issues associated with this alternative have already been explored to some extent. Conceptual development of this alternative would allow a more complete evaluation. Letters addressing some of the permitting issues can be found in the Appendix.

12. CONCLUSIONS & RECOMMENDATIONS

1. Both candidate basins have been investigated and both appear to be technically feasible. However, the upper basin located on the Stroot Property is considered preferable due to lower cost and risk. The lower basin site next to State Route 1 is very constrained and the site geometry is not conducive to the location of an adequate basin.

2. If one of the investigated candidate basins is selected for construction, prior to development of full construction documents the following is required: 1) detailed elevation survey of the site, 2) jurisdictional delineation of the site, 3) environmental review and permitting, 4) further engineering leading to detailed design, and 5) flow routing hydraulic analysis to ensure the design will operate under a variety of rainfall events.

3. Environmental review and permitting will likely involve multiple agencies and require time and potentially design refinement.

4. Other alternatives exist and can be evaluated.

5. The spillway adjacent to the reservoir embankment is currently being undermined by flows from Deer Creek. Without repair, flooding and sediment hazards downstream in El Granada could result.

6. Modifications to the reservoir, including the breaching of the concrete outlet works and the construction of a berm along the creek have resulted in sediment bypassing the reservoir and increased sediment yield to the lower watershed of Deer Creek. In combination with the incised condition of the creek, the erosive soils, and the presence of knickpoints along the creek, continued sediment problems in Pillar Point Harbor will likely continue if they are not addressed.

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FIGURES

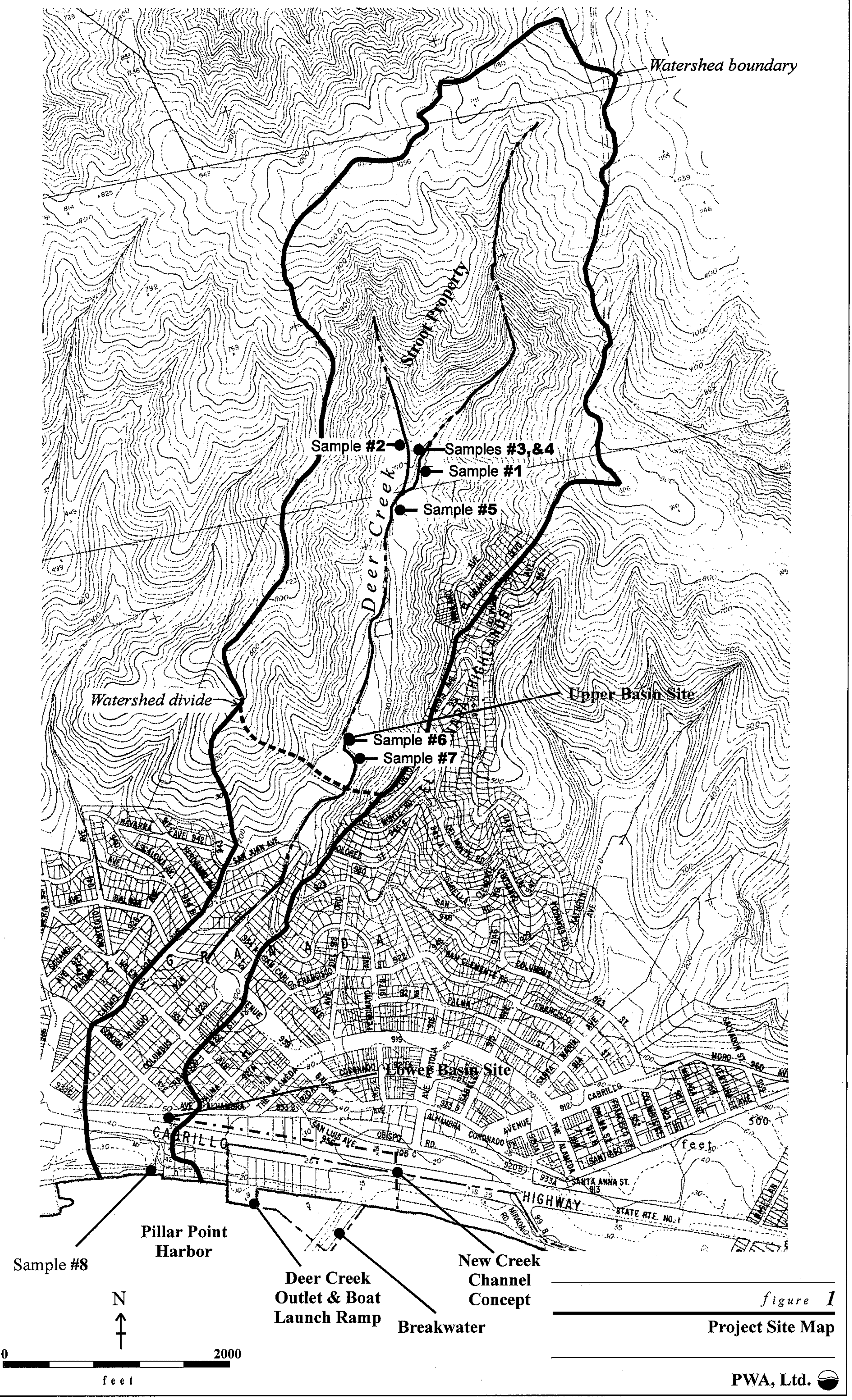


figure **1**

Project Site Map

PWA, Ltd.

N

0 1

mile

figure **2**

SCS Soil Series

PWA

1943 | 1956 | 1973 | 1980

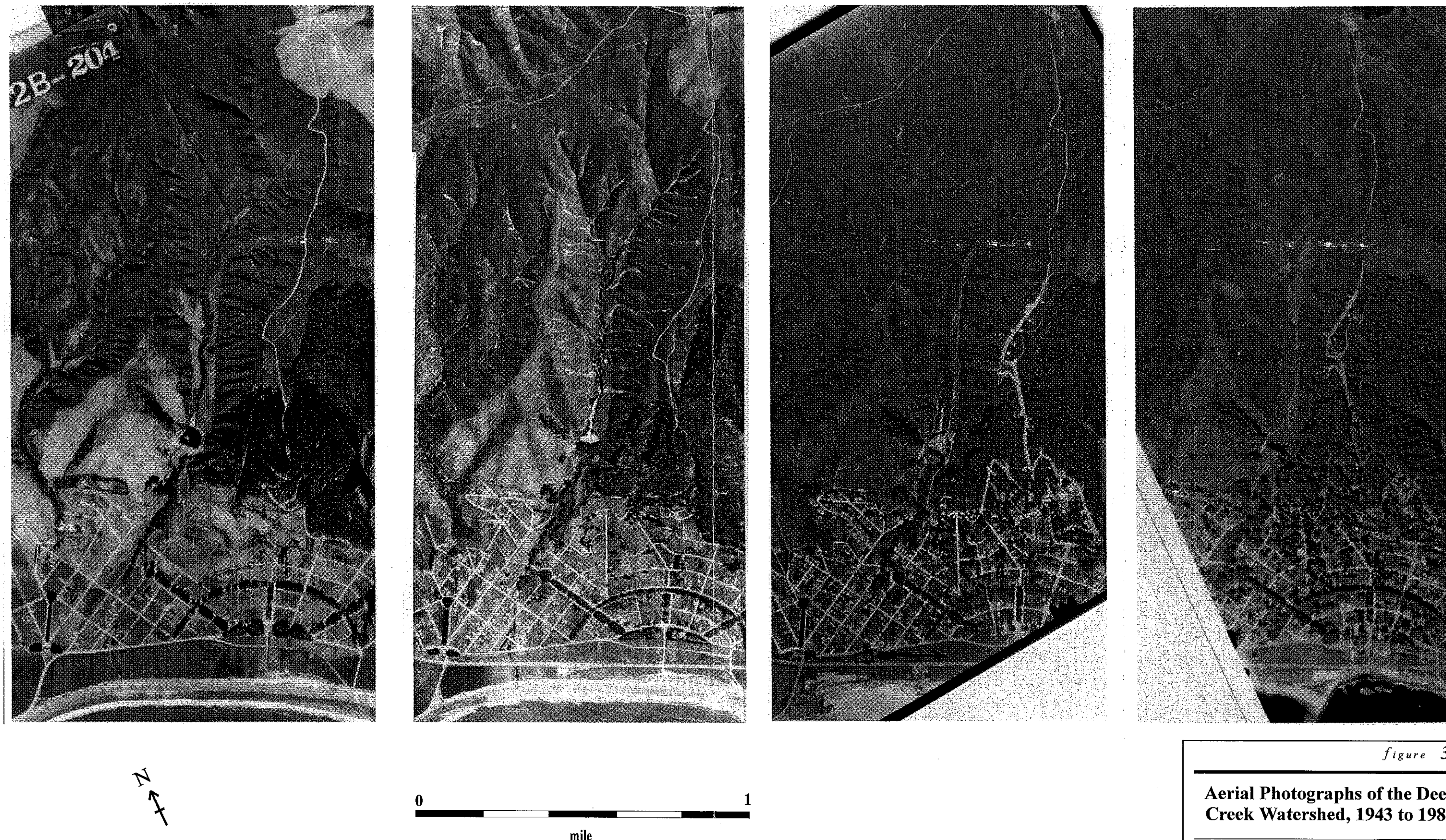
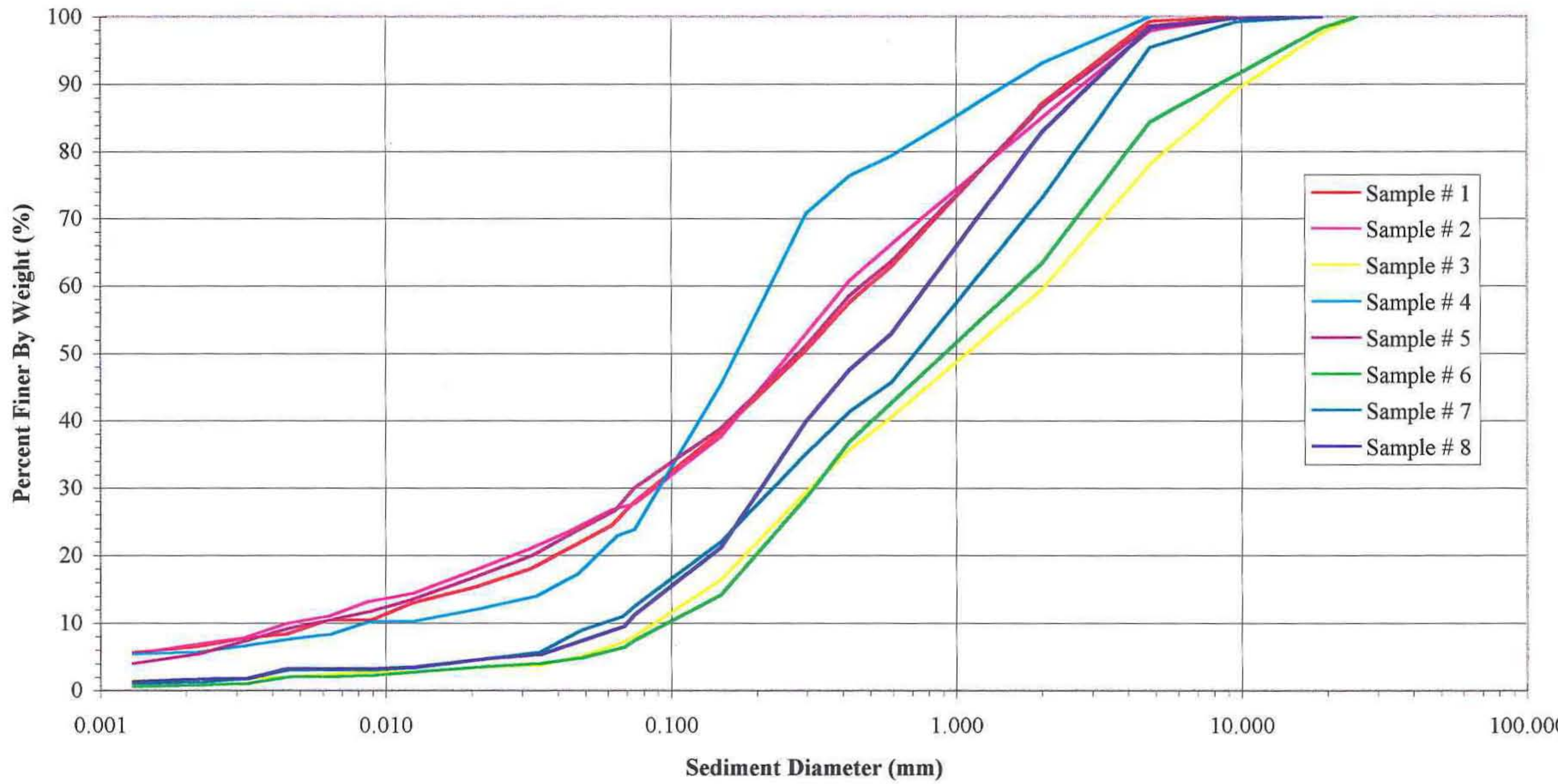


figure 3

Aerial Photographs of the Deer Creek Watershed, 1943 to 1980

PWA, Ltd.

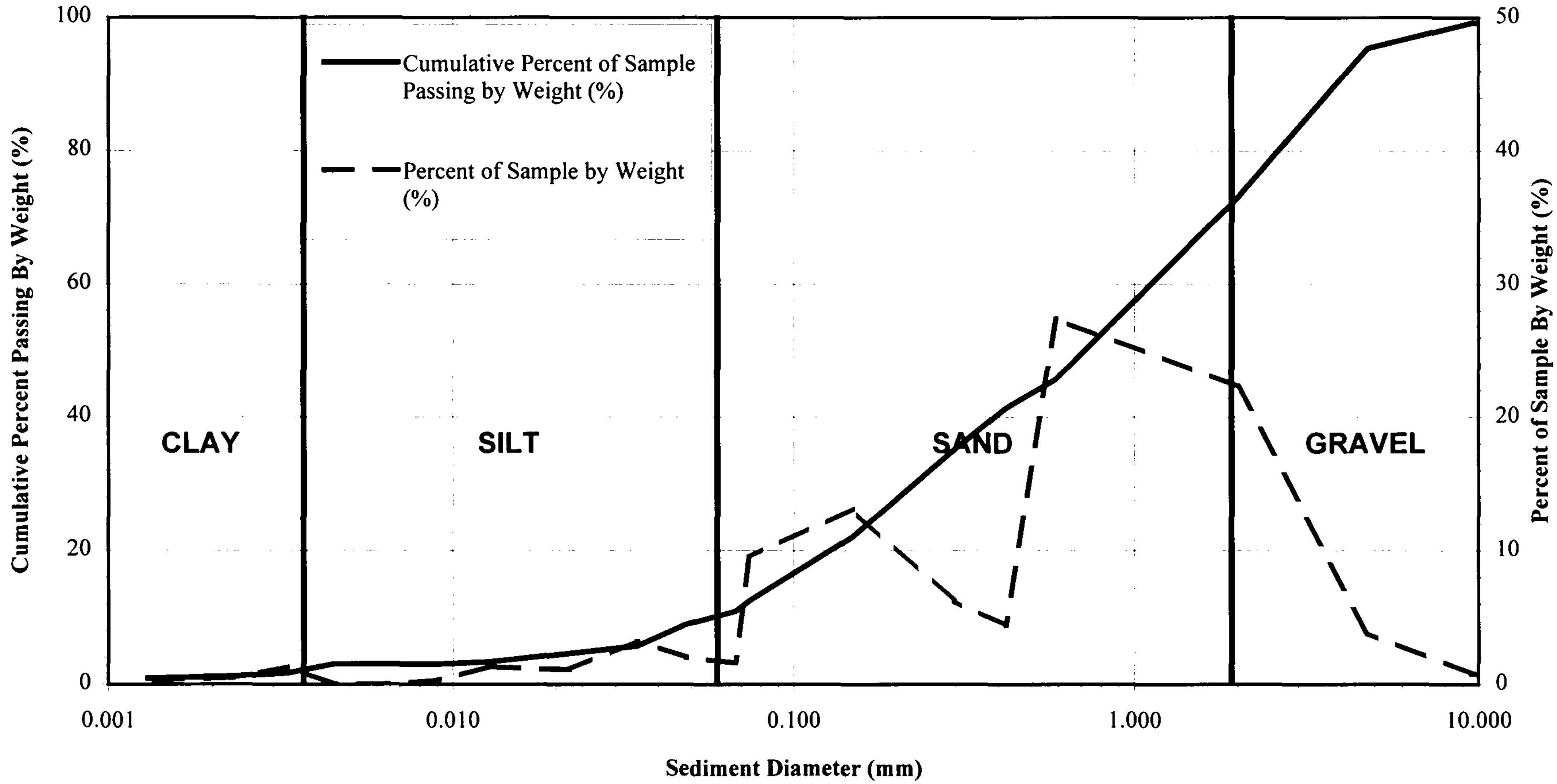


Source:
Notes: "Grab Bag" sediment samples were collected on July 12, 1998. Cooper Testing Laboratory performed seive analysis and hydrometer tests to generate the particle distribution curves.

figure 4

Particle Size Distribution Curves for the 8 Sediment Samples Collected in the Deer Creek Watershed

PWA | PWA #: 1285

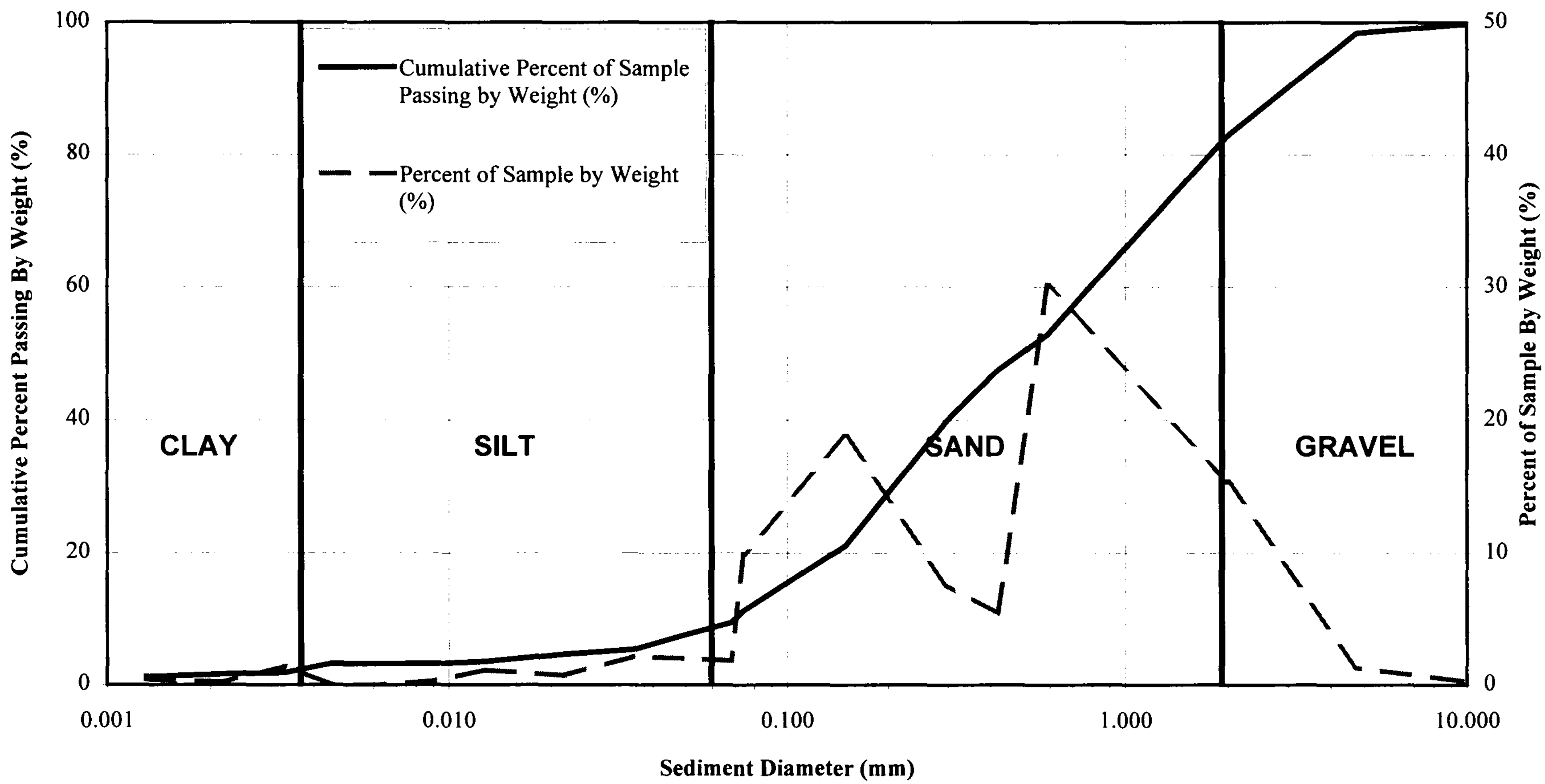


Note: Estimated Dry Unit Weight of 92.3 lbf/ft^3

figure 5

Sediment Sample #7 Used for the Sediment Basin Near the Reservoir

PWA | PWA #: 1285 Deer Creek



Note: Estimated Dry Unit Weight of 92.6 lbf/ft^3

figure 6

Sediment Sample #8 Used for the Sediment Basin in the Caltrans Easement

PWA	PWA #: 1285 Deer Creek

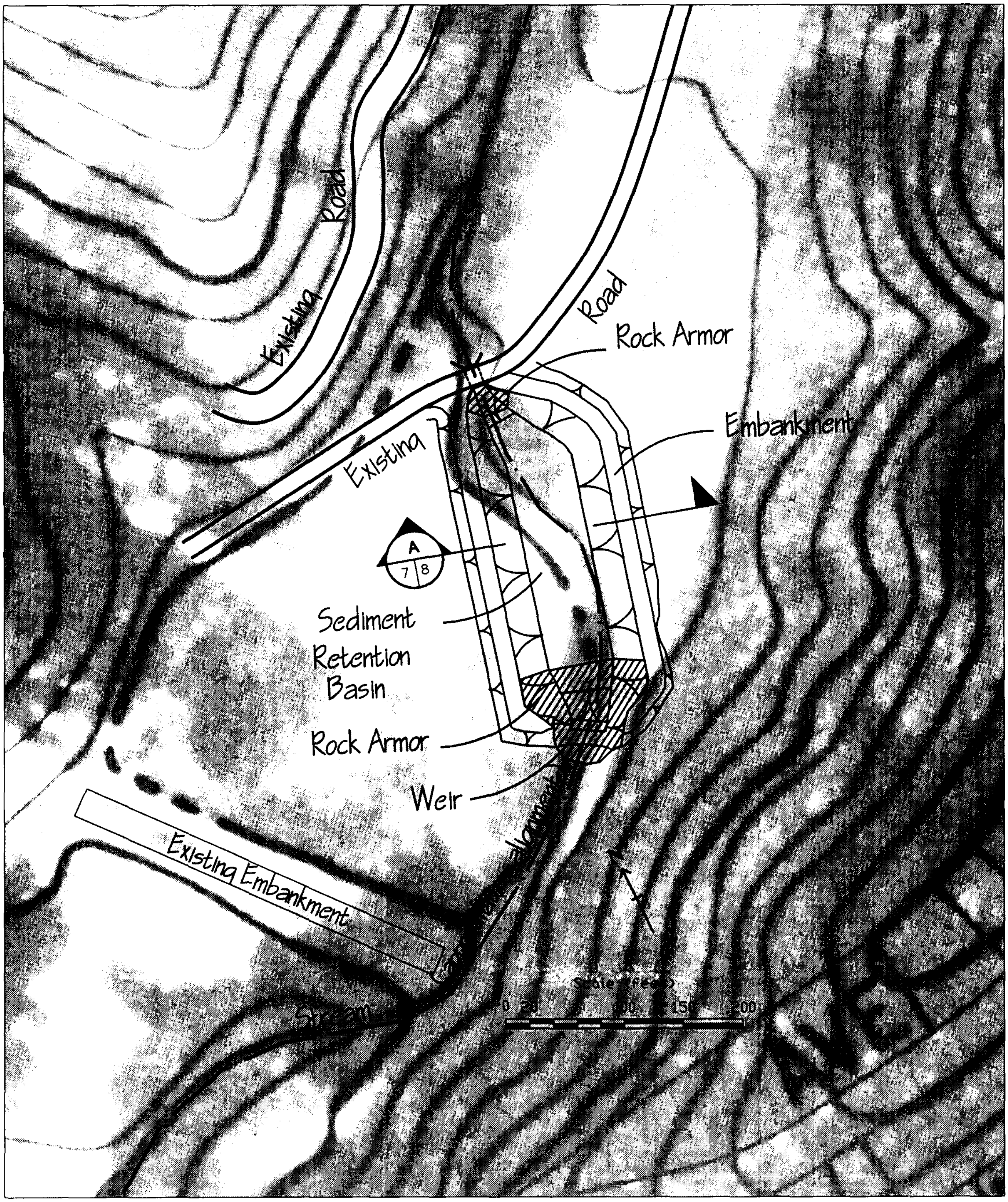
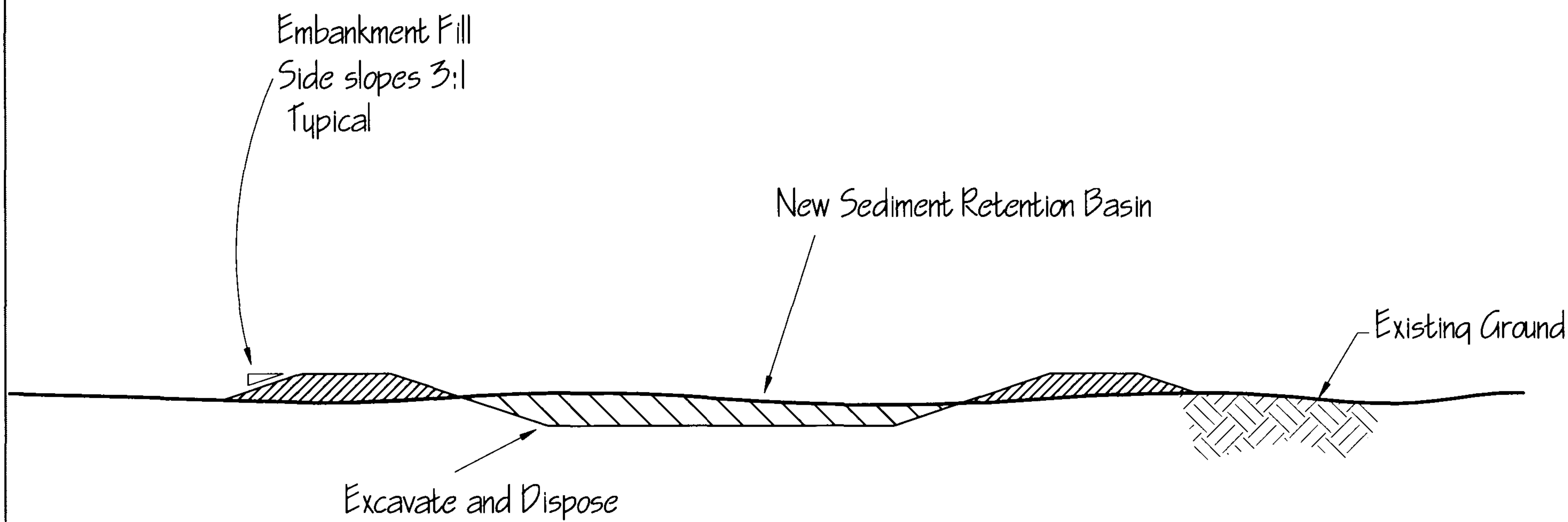


figure 7

Upper Sediment Retention Basin Site and Layout

CAD\1285\SECTPREL.DWG 6/29/99 DR



CROSS SECTION — A (7 | 8)

Not to Scale

figure **8**

Typical Cross Section for Upper Sediment Retention Basin

PWA

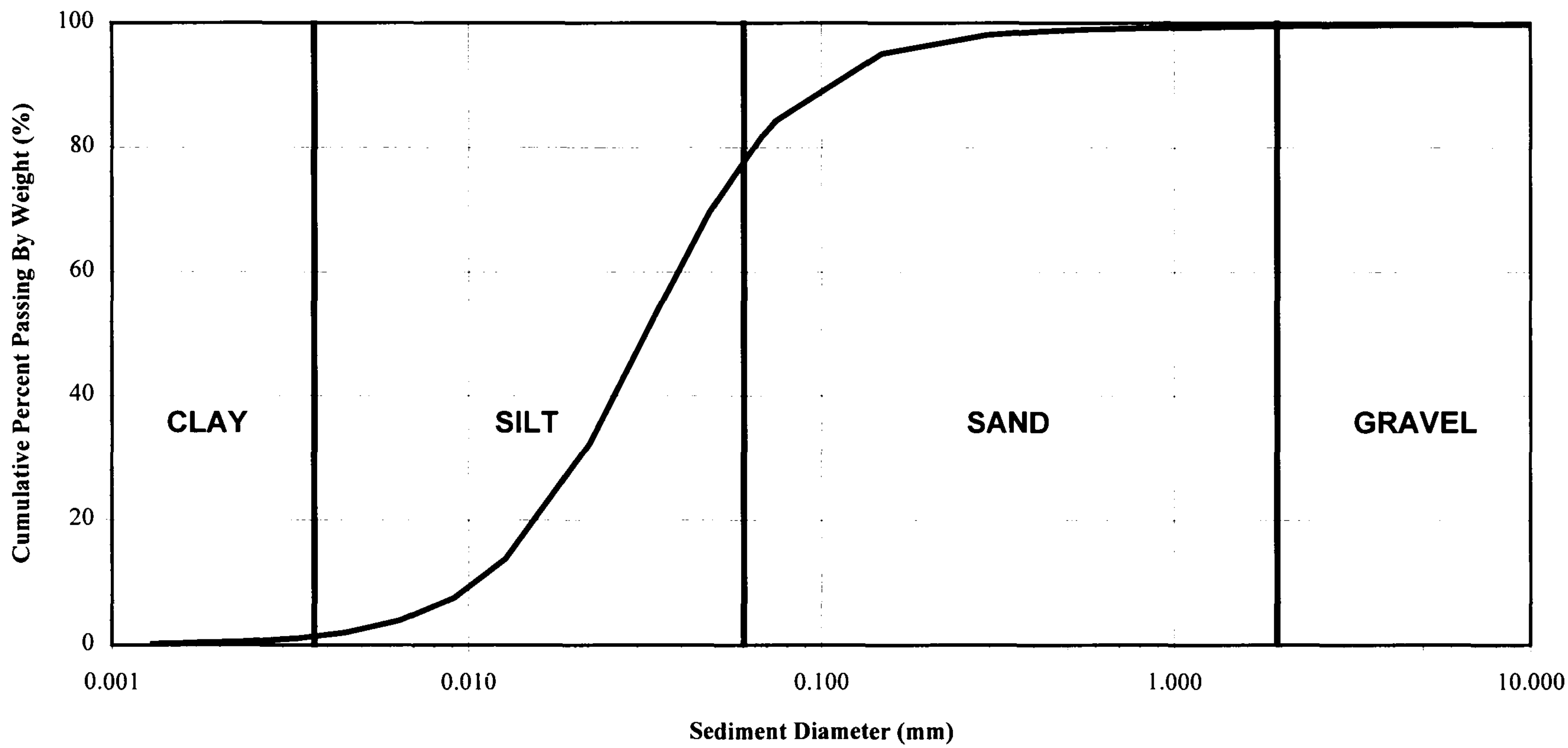


figure 9

Predicted Trapping Efficiency as a Function of Sediment Diameter for the Upper Basin

PWA	PWA #: 1285 Deer Creek

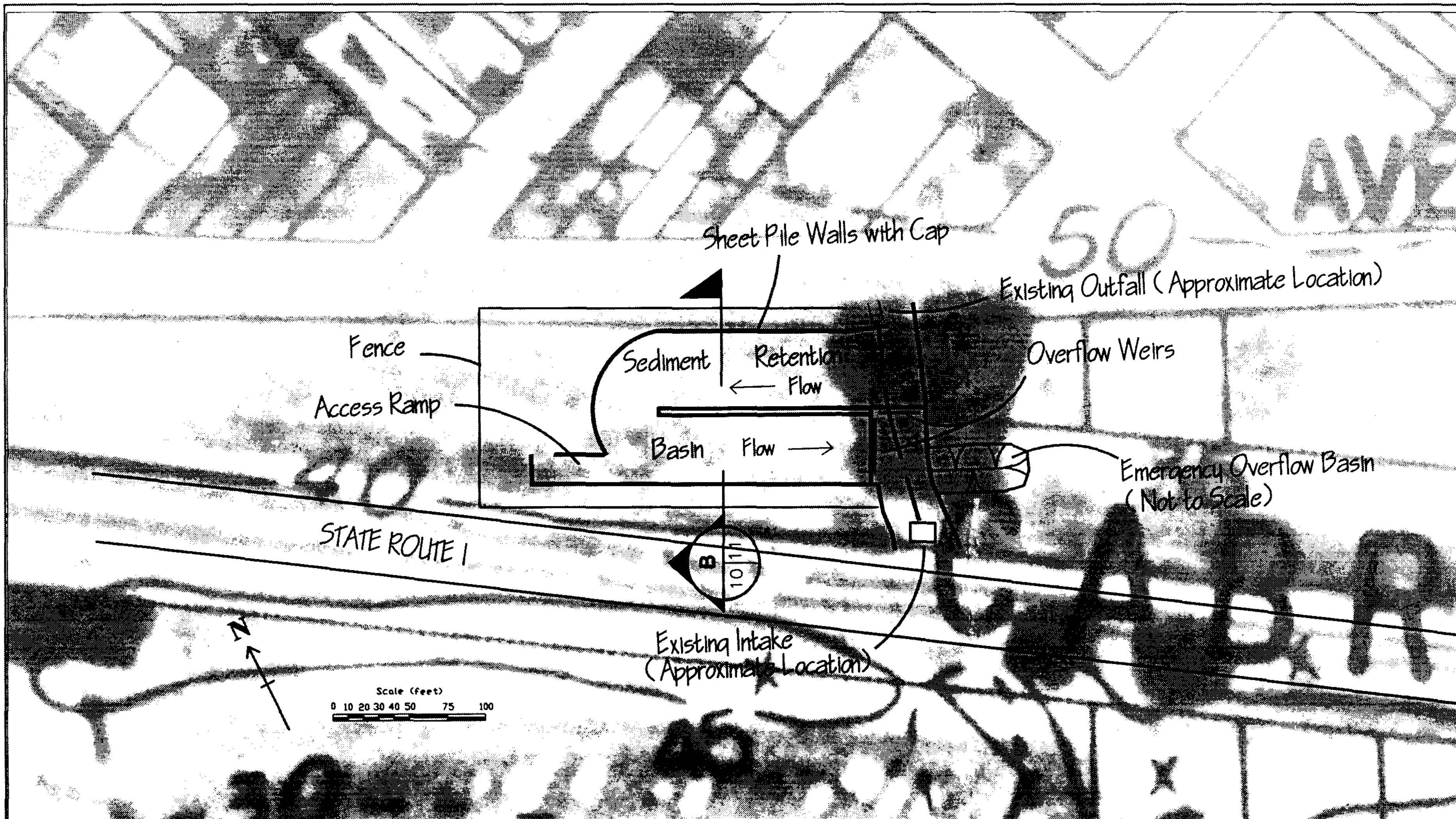
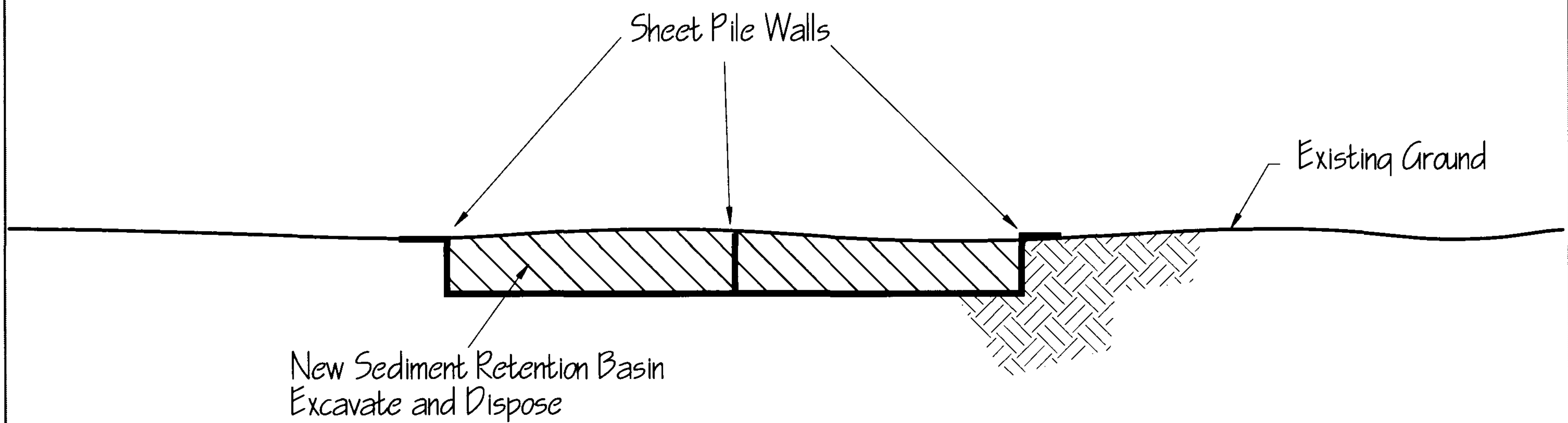


figure 10

Lower Sediment Retention Site and Layout

CAD\1285\SECTPREL.DWG 6/29/99 DR



CROSS SECTION B

Not to Scale

B
10 | 11

figure 11

Typical Cross Section for Lower Sediment Retention Basin

PWA

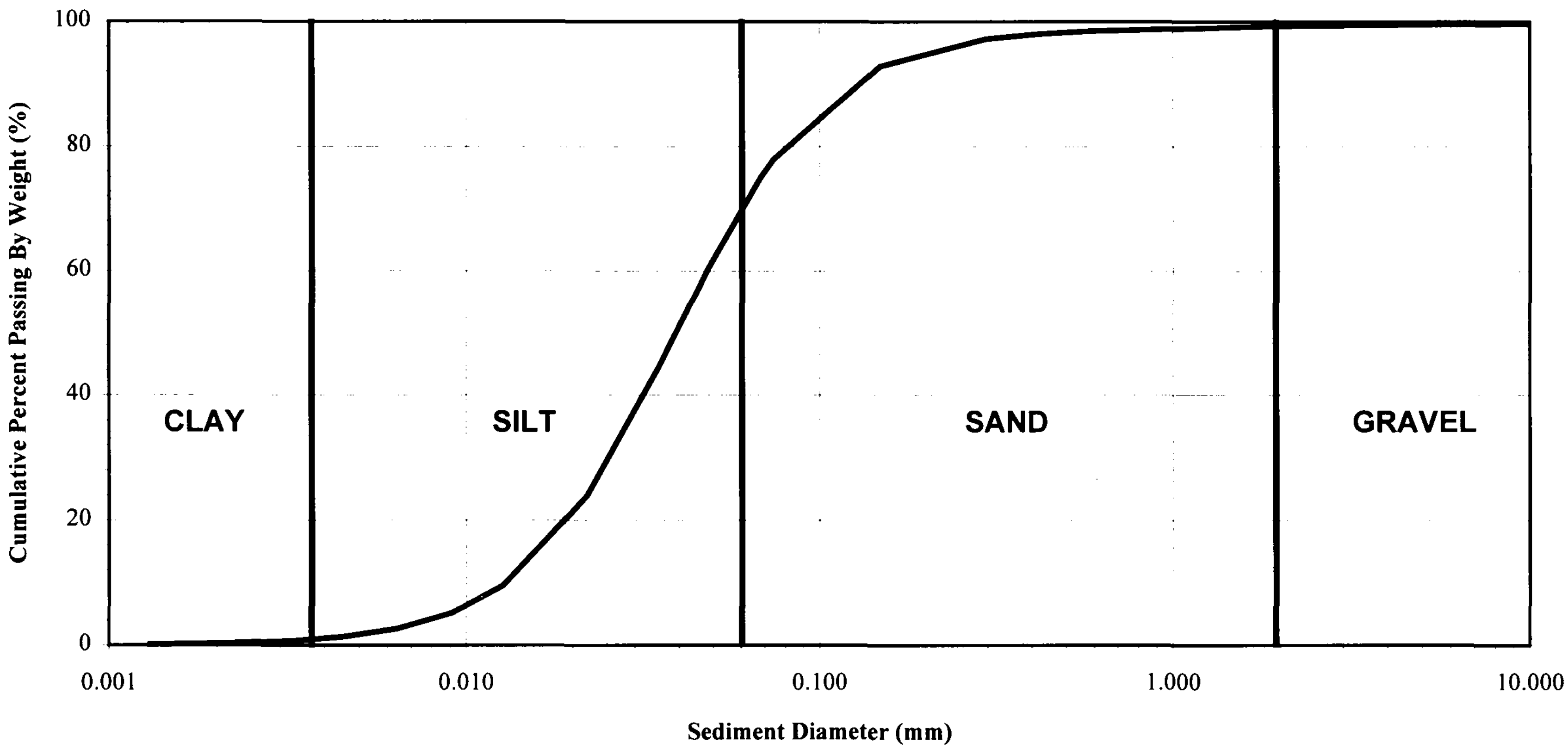


figure 12

Predicted Trapping Efficiency as a Function of Sediment Diameter for the Lower Basin

PWA	PWA #: 1285 Deer Creek

APPENDIX
Deer Creek Correspondence

FAXED DEC 11 1998

PWA
PHILIP WILLIAMS & ASSOCIATES
CONSULTANTS IN HYDROLOGY

770 Tamalpais Drive, Suite 401
Corte Madera, CA 94925
Phone 415.945.0600
Fax 415.945.0606
e-mail sfo@pwa-ltd.com

MEMORANDUM

VIA FAX; 2 Pages .
FAX NO.: 650-726-7740

DATE: December 11, 1998

TO: Peter Grenell , SMCHD

FROM: Bob Battalio

RE: **Deer Creek Re-Routing**
PWA Ref. # 1285

I have briefly reviewed the re-routing concept internally with other PWA staff, and with staff from Caltrans and the Regional Water Quality Control Board (RWQCB), and provide this report of my findings. I understand that you intend to contact other agencies.

Permits or similar, will likely be required from Caltrans, the RWQCB, the US Army Corps of Engineers, California Department of Fish & Game, San Mateo County and / or the California Coastal Commission, and possibly the Marine Sanctuary. Environmental review under CEQA. will also be required, but the level of effort is not known to me at this time.

Caltrans will require an encroachment permit for any work within their Highway One right-of-way. Flood / erosion control for the highway and maintenance responsibility are key issues. The permit will also be required for the sediment basin, if the SMCHD elects to proceed with that alternative.

The RWQCB will review the project through the required certification (or waiver or similar) of the Army Corps permit. This will include a review of any impacts to riparian vegetation or wetlands areas, and review of engineering, geomorphic, and biological analysis required for the appropriate design of a new creek channel. A NPDES permit focused on erosion control during implementation is also expected to be required. These permits will likely be required for the sediment basin alternatives as well.

It is difficult for agencies to be specific without reviewing a description of the project that addresses the scope of the construction and technical feasibility.

Multi-objective, natural system enhancement projects such as this are challenging, but the type of project the regulatory and environmental community will support if they believe it is technically feasible. Land use and ownership issues are also key to the project feasibility. Our proposed approach to develop a conceptual project description and commensurate evaluation of technical feasibility is the appropriate first step if you wish to proceed.

San Mateo County Harbor District

April 23, 1999

Bob Battalio
Philip Williams & Associates
770 Tamalpais Drive
Corte Madera, CA 94925

Dear Bob,

As you can see from the enclosed letter, our biologist has concluded that there is little opportunity for a fish-related enhancement resulting from a relocated Deer Creek. Ed Ueber of the Farallones Sanctuary has reiterated that relocation of the creek would be considered to be an artificial action and hence the creek's effluent, however clean and beneficial for beach replenishment, would be considered an unacceptable deposition into Monterey Bay National Marine Sanctuary waters in the absence of an consequent biological enhancement. Consequently, we must reluctantly conclude that further investigation of relocating Deer Creek is not productive for us.

Thus, I now request that you complete your report on Deer Creek Sedimentation as soon as possible, focusing on the sediment catchment basin analysis you have already carried out. Please call me if you have questions.

Sincerely,

SAN MATEO COUNTY HARBOR DISTRICT

Peter Grenell
General Manager

PG/waf

Enclosure: Letter from Jerry J. Smith

cc: Dan Temko, Harbor Master, Pillar Point

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04/21/99 5 01
FORM - SMCHD102 (3/98)

One Johnson Pier, P.O. Box 39, El Granada, CA 94018 - 0039
Telephone (650) 726-4723 - Facsimile (650) 726-7740

Jerry J. Smith P.D.
Fisheries Ecologist

Department of Biological Sciences
San Jose State University
San Jose, CA 95192

Ofc (408) 924-4855
Home(408) 923-3656

3047 Baronscourt Way
San Jose , CA 95132
19 April 1999

Mr. Peter Grenell
General Manager,
San Mateo County Harbor District
P.O. Box 39
El Granada, CA 94018

RECEIVED

APR 21 1999

GENERAL MANAGER
S.M.C.H.D.

Dear Mr. Grenell:

On April 15th I did a reconnaissance-level survey of Deer Creek through the town of El Granada. The stream is quite small, with about 2 foot average wetted width, and with much of the channel through town underground in 3 foot diameter culverts. The stream has a gradient of more than 2 percent and has a sandy stream bed and banks. Steelhead spawning habitat is absent, and because of the steepness and sandy bedload there are no developed pools as potential steelhead rearing habitat. Although the pond and the upper portion of the stream (on private property) were not checked, the very steep gradient (>5%) and sandy soils in the upper watershed should also result in lack of pools and spawning habitat. Despite the culverts and several steeper sections, steelhead could potentially migrate upstream through the channel within town during winter flow conditions.

Although the stream is well-shaded and apparently has cool, perennial flows, the stream presently could not support steelhead and has no realistic potential for supporting steelhead even with attempts to modify the habitat conditions. Relocating the culvert through Highway 1 would not improve access to an otherwise suitable stream for steelhead. Neither would lower channel relocation adversely impact access to a presently usable steelhead stream. The stream is also generally unsuitable for California redlegged frogs, although it is possible they could use the pond in the upper watershed.

Sincerely,

Jerry J. Smith