Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938

May 30, 2006

SENT VIA EMAIL

Sandra Guldman
Friends of Corte Madera
Creek Watershed
Box 415
Larkspur, CA 94977

Subject: Preliminary fish ladder concept design for Corte Madera Creek flood control channel, for transition between units three and four.

Dear Sandra,

The following describes in detail the concept fish ladder design we have developed for the transition between Units 3 and 4 in the Corte Madera Creek flood control channel. This concept design is intended to be associated with the fish ladder component of Alternative I (No-Action Alternative), which is part of the Alternative Analysis developed by the ACOE in conjunction with the Marin County Water Conservation and Flood Control District. If Alternative I is selected, this fish ladder would replace the existing, failed wooden Denil fish ladder located at the upstream end of Unit 3.

This is a preliminary concept design, subject to some change following our June 6th meeting with staff from the County, ACOE, and Federal and State resource agencies. Although the current concept drawings place the fish ladder within the upstream end of the Unit 3 concrete channel, the developed design can be transposed to an upstream location, if deemed more suitable.

Please contact us if you have any questions or comments.

Michael Love
Project Hydrologist
mlove@h2odesigns.com

Antonio Llanos, P.E.
Project Engineer
llanos@h2odesigns.com

CC: Matt Smeltzer, Joe DeMaggio, James Reilly

Enclosed: Concept Design Report and Fish Ladder Drawings
Location of sewer lines in plan and profile

1.0 BACKGROUND

The Corte Madera Creek watershed continues to support populations of steelhead trout (*Oncorhynchus mykiss*), which are listed as threatened under the Federal Endangered Species Act. The creek also historically supported runs of coho salmon, which were observed in the watershed until the early 1980s. However, they have been extirpated from the watershed, likely in part due to the construction of the flood control channel in lower Corte Madera Creek in the late 1960s and early 1970s. This project is specifically focused on providing suitable passage conditions within the Corte Madera Creek flood control channel for adult anadromous steelhead as they attempt to swim from the ocean to upstream freshwater spawning habitat. Passage of coho salmon was also part of the design considerations, in the event that they return to the system.

Steelhead have been observed on numerous occasions successfully swimming through Units 1, 2, 3, and 4 to reach spawning areas in the upper watershed. Units 1 and 2 and the lower 1,500 feet of Unit 3 are tidally influenced and are believed to provide unimpeded passage for adult steelhead. The upper 2,000 feet of Unit 3 is suspected of providing only partial passage, depending on flow conditions. As a separate component of this project, adult steelhead passage conditions within Unit 3 are being assessed and alternatives are being evaluated for improving passage using video observation and two-dimensional hydraulic modeling.

Figure 1 – Existing Denil fish ladder and bypass weirs at the upstream end of Unit 3 (a) during low-flow in June 2005 and (b) in January 2006, following the New Years flood.

At the transition from Unit 3 (flood control channel) to Unit 4 (natural channel) there exists a wooden Denil fish ladder that is intended to provide passage over a grade control structure (Figure 1). Steelhead have often observed attempting to pass through the existing wooden Denil fish ladder, but frequently failing. Although it has functioned relatively well at low flows, generally steelhead migrate during high winter flows. At higher flows when steelhead are observed at the site, the ladder has failed to provide suitable passage conditions due to the ladder's inadequate hydraulic capacity combined with adverse hydraulic conditions at the ladder entrance.

During the January 1st 2006 flood event the ladder was severely damaged, leaving the left sidewall partially collapsed. Minor repairs were made following the flood, and at least one steelhead was able to successfully make it upstream of the damaged ladder. However, in its current state it will likely continue to block the majority of fish attempting to swim upstream, and appears susceptible to complete failure during future high flow events.

2.0 DEVELOPMENT OF CONCEPT DESIGN

The target species for design of the fish passage structure at the transition between Units 3 and 4 is an adult steelhead trout. Although coho salmon are extirpated from the watershed, considerations for passage of coho salmon were included in the design. Upstream passage of juvenile salmonids was considered unnecessary since there is little to no rearing habitat within the flood control channel and, if washed into the concrete channel, juveniles would not be able to swim back upstream to the fish ladder due to the high water velocities.

2.1 Fish Passage Flows

Designing a fish ladder for the Corte Madera Creek Unit 3 transition required estimating the range of streamflows that adult steelhead attempt to migrate. This range of flows will define the desired operational flow range for the fish passage structure.

In northern and central California steelhead typically migrate from the ocean into coastal freshwater streams and rivers for spawning during high flow events occurring from December through March (Lang et al., 2004; Love, 2006). The steelhead observations in Corte Madera Creek from fall of 2004 through winter of 2006 show them attempting to pass through the existing Denil ladder from early December through March. As part of this project, eight years of recorded observations of steelhead attempting to pass over a barrier in lower Alameda Creek, a tributary to southern San Francisco Bay, were examined. The observations indicate that the majority of steelhead within the San Francisco Bay region migrate between early January and mid-March. Therefore, a migration period from December 1st through March 31st was deemed appropriate for developing fish passage design flows.

The standard method of identifying the appropriate range of fish passage flows for a structure is to develop a flow duration curve for the site. In larger drainages, such as Corte Madera Creek (drainage area of at end of Unit 3 of 18.1 mi^2), a common upper fish passage flow for salmon and steelhead is the 10% exceedance flow during the period of migration. The 10% exceedance flow is the discharge that is equaled or exceeded in the stream an average of 10% of the days for the indicated period; December through March in this case. From observations made in Northwest California, most salmon and steelhead appear to stop migrating at flows below the 50% (median) exceedance flow during the period of migration (Lang et al., 2004). However, a lower fish passage design flow is likely not needed for this project since fish ladder designs considered for this site are not limited by low-flows.

The Corte Madera Creek at Ross stream gage, operated by the USGS from 1951 to 1993 (43 years of record), is located near the Lagunitas Road bridge, less than 800 feet upstream of the existing fish ladder. The historic daily average streamflow data from this gaging station was used to construct two flow duration curves for the project site; one representing year-round flow (annual) and the other representing flow conditions during the period of assumed adult steelhead migration (December through March) (Figure 2).

The 50% exceedance flow and 10% exceedance flow for the migration period is 14 cfs and 177 cfs, respectively. Based on the 10% exceedance flow, we defined the high fish passage design flow for the fish ladder to be 177 cfs.

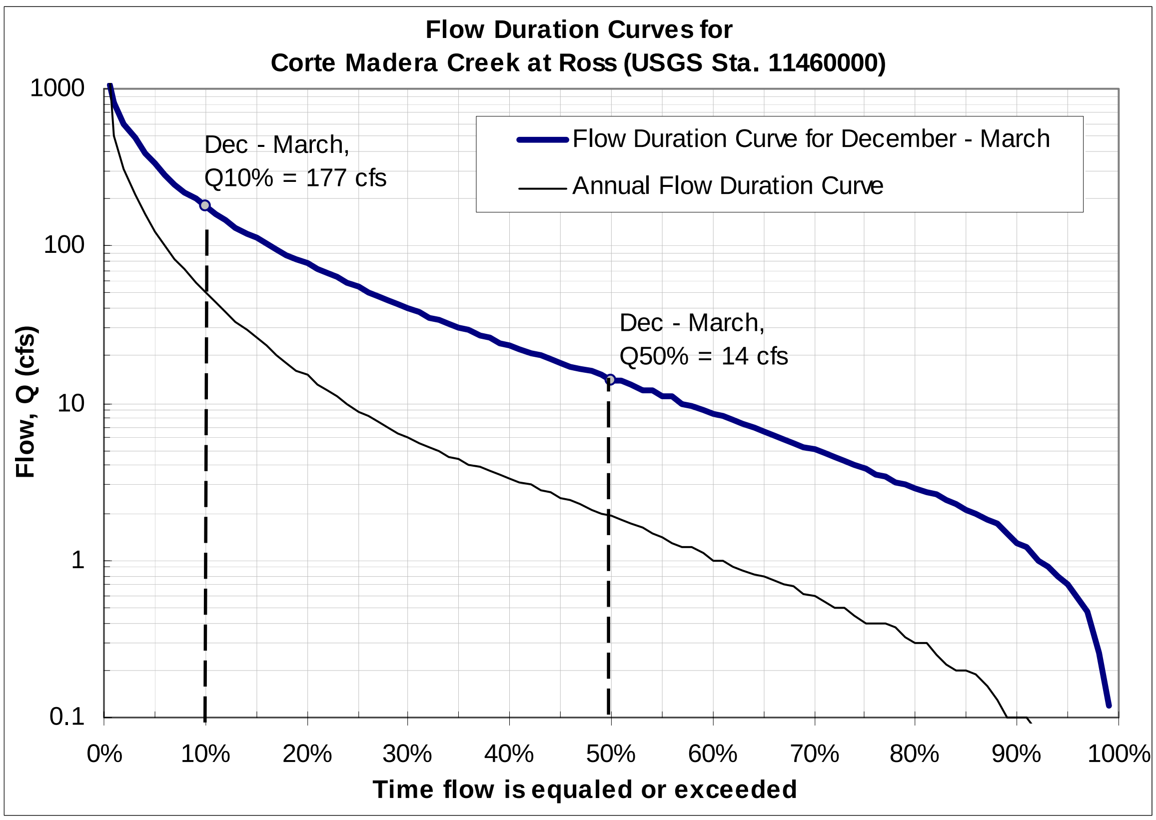


Figure 2 – Annual and steelhead migration period (November through March) flow duration curves for Corte Madera Creek, constructed using daily average flows recorded from 1951 to 1993 at the USGS gage at Ross.

2.2 Selection of Preferred Fish Passage Structure Type

Various types of fish passage structures were considered before selecting a preferred structure type for the site. Since this concept design is associated with Alternative I (No-Action), the ladder should have a minimal foot print and not affect existing water levels both upstream and downstream of the structure during high flow events. Additional considerations were (1) the ability to operate efficiently over a wide range of migration flows, (2) to provide adequate attraction flows at the entrance to the structure, and (3) to minimize susceptibility to debris or sediment loading. The following sections briefly describe the various fish passage structures considered.

2.2.1 Roughened Rock Channels

A roughened channel or "nature-like" fishway is an oversteepened channel designed to allow for passage of fish and other aquatic organisms in addition to accommodating peak flows and associated debris and sediment. The primary hydraulic function of a roughened channel is to create conditions suitable for fish passage while dissipating energy through an oversteepened section of channel. Hydraulic criteria for fish passage in a roughened channel includes maximum water velocities, minimum water depths, and maximum turbulence.

The steep sections of a roughened channel contain rock cascades, which increase the channel's overall roughness and dissipate energy. These cascades form complex flow patterns with large variations in water velocities, providing migrating fish numerous pathways to choose from as they swim upstream. To maintain stability, the maximum recommended slopes for roughened channels range between 4 and 5%. Avoiding excessive turbulence or the need for extremely large rock to maintain stability may require a more gentle slope.

The roughened channel alternative was considered not suitable for a No-Action Alternative due to the potentially large footprint. Constructing a roughened channel at the transition between Units 3 and 4 would likely involve extensive work within the channel and stream banks in the reach between the concrete channel and the Lagunitas Bridge. Due to the high flows associated with both fish passage and flooding, the slope of the roughened channel would likely need to be substantially less than 4%.

Although not considered suitable for Alternative I, a roughened rock channel may be a preferable design option for some of the other flood control alternatives being considered.

2.2.2 Roughened Chutes (Denil and Alaskan Steeppass Ladders)

Roughened chutes are steel, or wooden, ramps placed at slopes up to 20%. Fitted with tightly spaced baffles, they use turbulence to slow water and create depth. The most common types are Denil and Alaskan Steeppass chutes (CDFG, 1998). The existing fish passage structure at the end of Unit 3 consists of a Denil style chute. Roughened chutes are usually used in combination with a bypass weir, which allows a portion of the streamflow to go around the ladder.

Alaskan Steeppass and Denil structures have various characteristics not appropriate for the site, including (1) highly susceptible to plugging by small and large debris and (2) very limited hydraulic capacity, leading to (3) insufficient attraction flow at higher migration flows.

2.2.3 Pool and Weir Fish Ladders

Pool and weir fish ladders provide suitable passage conditions for salmon and steelhead by taking advantage of their leaping abilities. This type of fish passage structure consists of a series of pools formed by weirs placed across the channel. The weirs form a series of drops that fish leap or swim over, while the pools dissipate energy of the plunging water and provide needed resting areas for the fish.

In general, pool and weir fish ladders function efficiently over a limited range of flows. The operational efficiency of a pool and weir fish ladder is determined by the pool volume and water level downstream of each weir. They are designed to provide fish passage by maintaining *plunging flow* hydraulics throughout the fish passage design flow range (Figure 3). As flow increases, the pool can become too turbulent for fish passage. As the weirs become partially submerged (backwatered) by the downstream water level the hydraulic regime will transition from plunging flow to streaming flow. A pool and weir fish ladder can become a barrier to fish once streaming flow begins due to excessive velocities.

Given their limited operational flow range, many pool and weir fish ladders contain a bypass weir to allow a portion of the streamflow to go around the ladder. To ensure the fish are able to easily find the entrance of the ladder, a sufficient proportion of the total flow must be maintained in the ladder (attraction flow). A common criteria for minimum allowable attraction flow is maintaining at least 25% of the total flow within the ladder.

Preliminary analysis indicates that this criteria could not be satisfied given the geometry of the project site and the magnitude of the high fish passage design flow.

2.2.4 Hybrid Pool and Chute Fish Ladder – Preferred Design

Pool and chute fish ladders are a hybrid of the roughened chute and pool and weir fish ladders. At moderate to high fish passage flows the weirs are shaped to allow streaming flow down the center portion of the ladder and plunging flow along the sides of the ladder. This allows the fish to migrate upstream along the margins of the ladder where quiet, less turbulent water is found, while a large proportion of the flow streams down the center portion of the ladder. By accommodating streaming flow, these types of ladders can operate over a wider range of flows. They are often designed to completely span the channel, eliminating the need for a bypass weir and concerns about attraction flow.

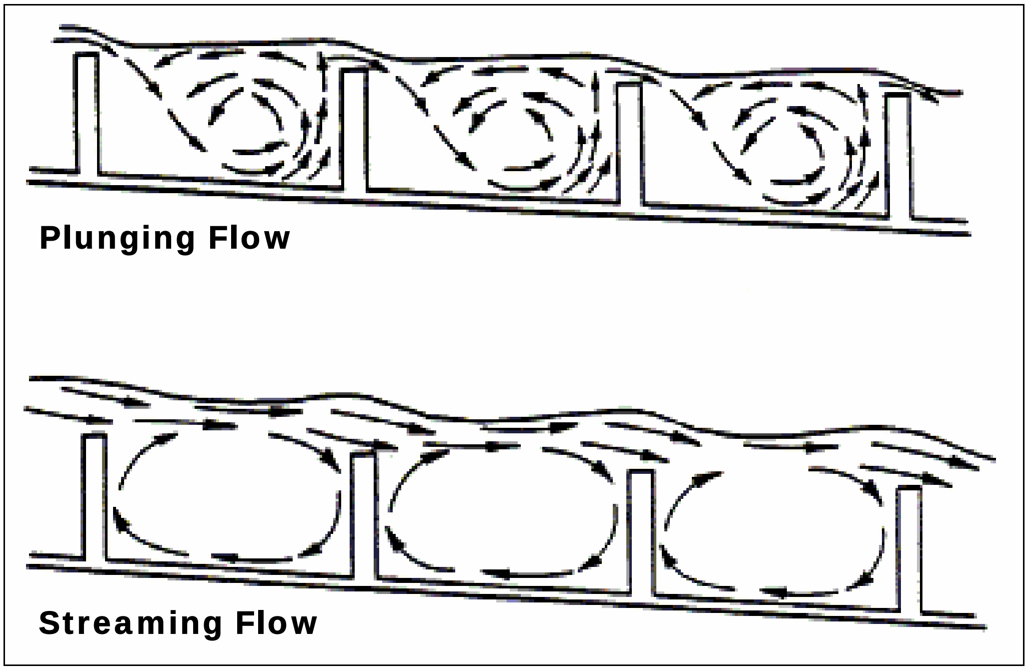


Figure 3 – Plunging and streaming flow in a fish ladder (longitudinal view).

Typically constructed of concrete or sheet pile, pool and chute fish ladders are able to accommodate fish passage over a wider range of flows than the other two fish ladder types. They are constructed at relatively steep slopes, often ranging between 10% and 16%. However, experimentation and monitoring of pool and chute fish ladders has shown that they may produce undesirable hydraulic conditions when used at sites with drops greater than 6 feet (Bates, 2001). The existing wooden structure currently maintains 5 feet of drop. Since these structures typically span the entire channel, they are less susceptible to problems with debris than other ladder types.

Of the four alternatives examined, the pool and chute fish passage structure best satisfies the design objectives associated with fish passage and the No-Action Alternative, and was selected as the preferred fish ladder type for the concept design.

2.3 Pool and Chute Fish Ladder Concept

The design of pool and chute fish ladders is described in detail by Bates (2001). They consist of a tapered weir crest preferable for salmonid passage. The lateral slope of the weir crest often ranges between 5H:1V and 6:H:1V. This lateral slope produces a thin sheet of plunging flow along the edges of the wetted weir crest, which is easier for fish to leap over and minimizes turbulence along the pool margins. The area along the edge of the pool that is free from plunging water is referred to as the *fish passage corridor* (Figure 4). As flow increases, the wetted weir width increases and streaming flow begins to form down the center of the weir. Although velocities within the streaming flow may be too fast for fish to swim against, plunging flow and a quiet-water passage corridor are maintained along the edges of the weir. Bates (2001) recommends a minimum passage corridor of 2 feet at the high fish passage design flow.

The portion of the flow that is streaming tends to build up velocity as it travels over each weir, while the plunging flow portion dissipates its energy into the receiving pool. Therefore, only the plunging flow portion of the total flow creates turbulence in the pools. Because of the high velocities associated with the streaming flow, its important to provide a large enough pool at the bottom of the ladder to accommodate the velocity expansion associated with the streaming flow jet. Otherwise the expansion can create excessive turbulence, which can hinder fish passage.

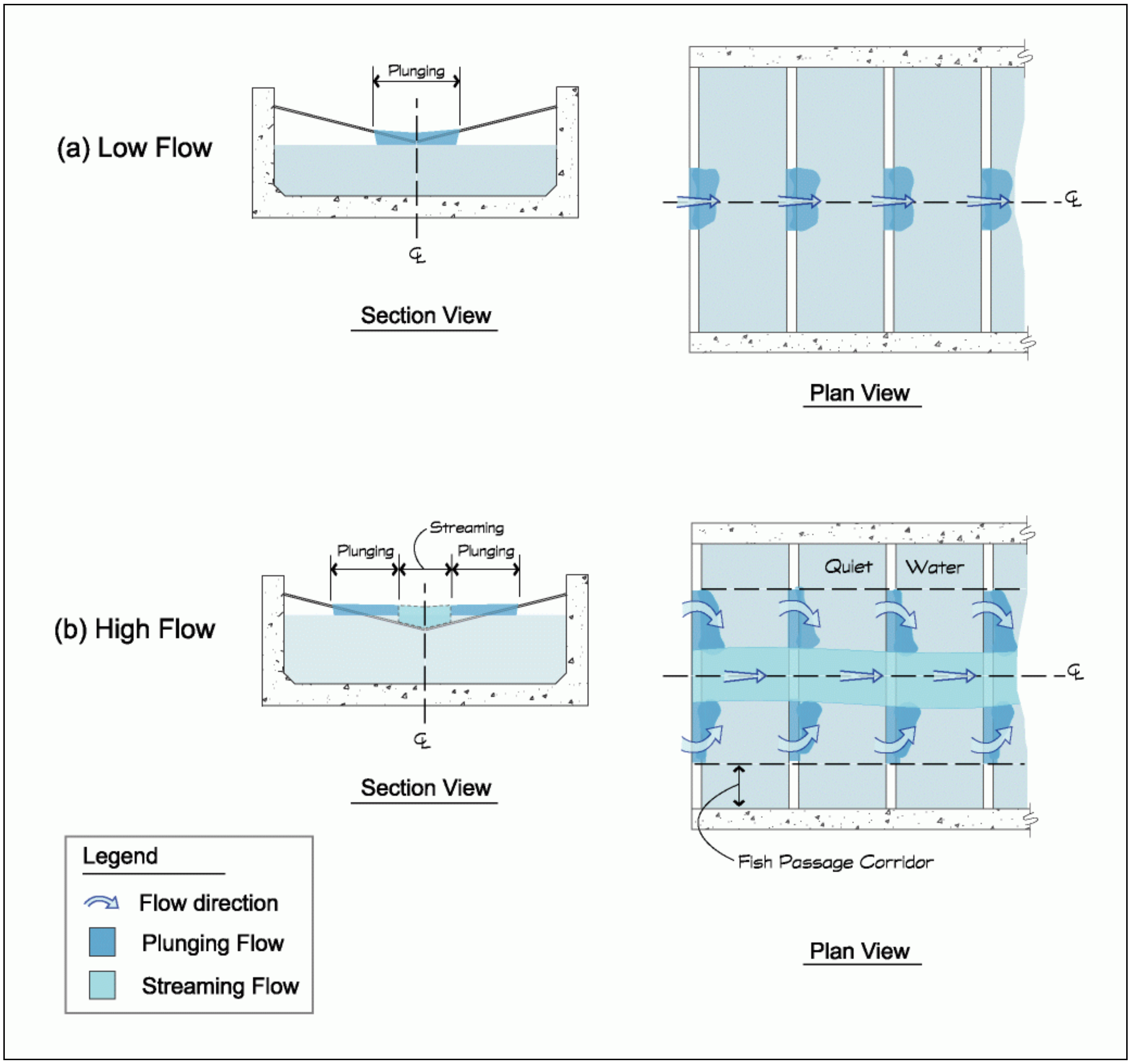


Figure 4 – Illustration of flow conditions within a pool and chute fish ladder. At lower flows (a) water plunges over the wetted portion of the weir. At higher flows (b) the weirs become partially submerged, producing streaming flow down the center and plunging flow along the edges. A tapered weir shape creates an area of quiet-water along the margins of the fish ladder, referred to as the fish passage corridor.

2.4 Site Constraints and Preferred Location

There are several site constraints that will affect the location and placement of the fish ladder. The primary constraints considered in developing the concept fish ladder are the existing upstream channel conditions, buried sewer lines under the channel and existing fish ladder, and a storm drain which discharges into the concrete channel approximately 11 feet downstream of the existing fish ladder.

2.4.1 Upstream Channel

The channel upstream of the fish ladder is naturalized. One of the design constraints included maintaining existing channel bed and water surface elevations upstream of the fish ladder. Channel and water surface elevations upstream of Unit 3 are controlled by the existing fish ladder and wood wall, which acts as a grade control structure. This structure is about 5 feet in height and has the same overall cross sectional shape as the channel. The proposed fish ladder is designed to match the elevation and shape of the existing structure as best as possible to maintain existing upstream hydraulic conditions.

2.4.2 Sewer Lines

Currently there are 2-24 inch sewer pipes encased in concrete that run diagonally under the channel immediately upstream of the concrete channel. Based on plan and profile drawings of the sewer line provided by the County and dated March 1973, the top of the concrete encasements at the deepest point is approximately at elevation 4.5 feet, and gains elevation as they approach either bank. Based on the pool depths required for a fish ladder it is infeasible to place most of the fish ladder over the buried pipes. However, it may be possible to place the upper most weirs and pool over the sewer line.

2.4.3 Storm Drain

A 48 inch storm drain discharges into the flood control channel from right bank approximately 11 feet downstream of the existing fish ladder. The invert of the storm drain is flush with the toe of the floodway wall. If a fish ladder is placed in front of the storm drain or downstream, it may have the potential to backwater the outlet at high flows affecting the capacity of the storm drain. A more detailed analysis of the storm drain would be warranted to better define this constraint. The relocation of the storm drain outlet further downstream could also be considered.

2.4.4 Preferred Location

Based on the site constraints, design parameters of the pool and chute ladder, and the desire to minimize the project footprint, the preferred location for the proposed ladder was identified as within the existing concrete flood control channel. The top of the fish ladder would be located at the upstream edge of the existing concrete channel.

2.6 Hydraulic Modeling of Pool and Chute Fish Ladder

With V-shaped weirs, flow can exist in both the plunging and streaming state simultaneously (Figure 3). For instance at flows with submergence the lowest portion of the weirs near the center can be in streaming mode while the upper edges of the weir will be plunging. To account for this, hydraulics within the fish ladder were modeled using a combination of:

1. A set of empirical equations for predicting the transition between plunging and stream regimes,

2. Standard V-shaped weir flow equations with partial submergence for plunging flow, and

3. Uniform flow equation using Chezy coefficient for streaming (chute) flow.

2.6.1 Identifying Transition from Plunging to Streaming Flow

Equations for predicting the flow at which the plugging regime transitions to the streaming regime were developed empirically from flume studies of rectangular weirs (Rajartanam, 1988; Ead 2004). To apply these equations to a V-shaped weir, the weir was divided into 6 inch increments. Each increment was assumed to have a horizontal weir crest. The transition equations were then applied to each segment to determine whether it was in the plunging or streaming regime. From this, the location and width of the streaming flow could be identified for each weir within the ladder.

2.6.2 Plunging Flow Calculations

For portions of the weir that contained plunging flow, the hydraulics were calculated using standard equations for V-shaped weirs (King, 1939). For portions of the weir that were partially submerged and still sustained plunging flow, the flow was adjusted using a submergence ratio (Villemonte, 1947).

2.6.3 Streaming (Chute) Flow Calculations

For the section of the weirs with streaming flow, the weirs are submerged and act as large scale roughness elements. Flow for this condition can be predicted with the Chezy equation, which assumes uniform flow. As variables in the Chezy equation, the cross

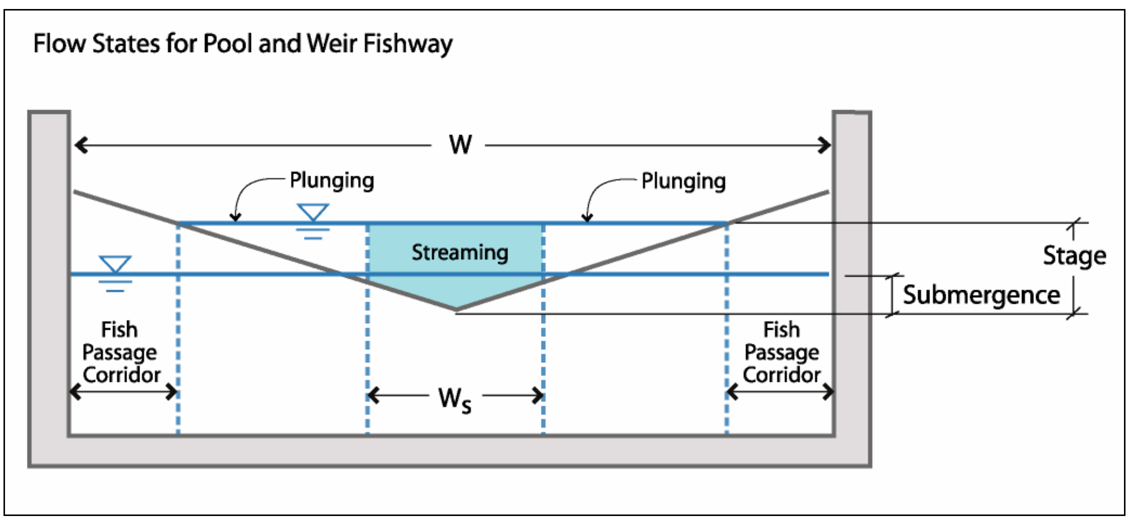


Figure 3 – Flow states and definitions for a pool and chute fish ladder.

sectional area and wetted perimeter were calculated from the streaming flow width and weir shape. The slope used in the Chezy equation was the overall slope of the fish ladder. Bates (2001) provides a range of Chezy roughness coefficients (C) for pool and chute fish ladders empirically derived from scale model tests. Based on the slope of the proposed fish ladder, we used a Chezy coefficient of 22 ft/s^2 in the analysis.

2.6.4 Entrance Conditions

The entrance of the fishway is the most downstream end of the structure and requires an additional hydraulic analysis. Having appropriate entrance conditions is critical to maintaining proper fish passage performance. The water level at entrance of the fish ladder is controlled by the downstream channel shape and slope. Since the water depths over the weirs increase more rapidly than the depth in the downstream channel, this has the potential to create an excessive drop over the lowest weir.

To analyze this transition and determine the drop over the lowest weir at the design flows, a stage-discharge rating curve was developed to predict water level in the floodway at the fish ladder entrance. Uniform flow conditions were assumed and a Manning's roughness coefficient of 0.015 and slope of 0.00368 ft/ft were used.

2.7 Pool Volume and Turbulence

Pools below each weir dissipate energy associated with plunging flow. Energy dissipation occurs through turbulence. A measure of turbulence typically used in design of pool and weir and pool and chute fish ladders is the Energy Dissipation Factor (EDF), which is the rate of energy dissipated per volume of water. The EDF is a measure of turbulence and resulting bubble formation. For pool and weir and pool and chute fish ladders, EDF values greater than 4 ft-lb/s/ft^3 indicates turbulence within a pool is sufficient to disorient and fatigue adult salmon and steelhead (Bates 2001). At flows up to the high fish passage flow EDF was calculated for plunging flow using the pool volume outside of the region of streaming flow (W_S).

2.8 Fish Passage Corridor

The fish passage corridor is defined by the width of weir that is dry. The pool below the dry weir does not directly experience any plunging or streaming flow, and thus provides the best upstream passage conditions. It is measured as the horizontal distance from the inside wall to the edge of the wetted weir. A passage corridor of at least two feet on each side is recommended (Bates, 2001).

2.9 Fish Passage Design Criteria

Hydraulic design of a pool and chute fish ladder for Corte Madera Creek was based on the following design parameters:

Maximum water surface drop over weirs………………….	1.0 ft
Minimum pool depth between weirs…………………….	2.0 ft
Minimum width for fish passage corridor (per side)………	2.0 ft
Maximum energy dissipation factor in each pool (EDF) …	4.0 ft-lb/s/ft^3

3.0 PREFERRED DESIGN

3.1 Weir Geometry and Dimensions

The proposed geometry for the Corte Madera fish ladder is a series of tapered (lateral sloping) weirs with the crests aligned along the center of the concrete channel (see attached conceptual drawings). Using the procedures and design parameters previously discussed, a variety of different pool and chute configurations were analyzed. The preferred fish ladder geometry is provided in the concept drawings, and has the following characteristics:

Fish ladder width	30-ft
Number of Weirs	5
Weir side slope	5:1 (H:V)
Spacing between weirs	9-ft
Total length of structure	64-ft
Fish ladder slope	0.10 ft/ft

A fish ladder width of 30 feet was selected since it fits both the concrete channel width and the natural channel width in Unit 4 and provides sufficient weir length to meet design criteria at the high fish passage design flow. The weir side slopes of 5:1 are preferred for fish passage. Coincidentally, they also match (1) the slope of the floor in the existing concrete channel and (2) the slope of the wooden bypass weirs on the existing fish passage-grade control structure.

In pool and chute ladders the streaming flow typically accelerates over the first two weirs, causing the velocity head to increase while the hydraulic head decreases. To address these hydraulic conditions and avoid creating water surface drops greater than one foot, the first and second weirs are lowered by 0.2 feet and 0.1 feet, respectively.

3.2 Summary of Hydraulic Conditions for Fish Passage

The fishway was modeled as described above to evaluate hydraulic conditions for low and high fish passage design flows and to identify the upper end of operational flows. Results are summarized in Table 1

3.2.1 Passage Conditions for Adult Salmon and Steelhead

Adult upstream migrating steelhead would have little difficulty ascending the proposed pool and chute fish ladder. The ladder provides desired passage conditions for adult salmon and steelhead up to 198 cfs, which is slightly higher than the upper fish passage design flow of 177 cfs. Above 198 cfs the fish passage corridor is less than 2 feet wide but turbulence remains below the EDF threshold of 4.0 ft-lb/s/ft^3. It is likely that most adult steelhead would continue to be able to ascend the ladder at flows above 198 cfs.

Table 1 - Predicted hydraulic conditions for 30-ft wide pool and chute fish ladder with V-shaped weirs at 5:1 (H:V) side slopes, and 1-ft drop between weir crests.

Weir Parameter	Fish Passage Design Flows: Low	Fish Passage Design Flows: High	Minimum Fish Passage Corridor[1]	Maximum Turbulence[2]
Flow	16 cfs	177 cfs	198 cfs	470 cfs
Depth over weir[3]	1.2 ft	2.5 ft	2.6 ft	3.4 ft
Energy dissipation factor (EDF)	1.2 ft-lb/s/ft^3	2.9 ft-lb/s/ft^3	3.0 ft-lb/s/ft^3	4.0 ft-lb/s/ft^3
Wetted weir width	12.0 ft	25.0 ft	26.0 ft	30 ft
Streaming flow width	0	7.0 ft	8.0 ft	16 ft
Streaming flow velocity	0	8.4 ft/s	8.7 ft/s	10.3 ft/s
Water surface drop over lowest weir[4]	0.98 ft	0.93 ft	0.91 ft	0.80 ft

[1] Recommended minimum fish passage corridor width is 2 feet, which occurs when the wetted width is 26 feet.
[2] Maximum turbulence is when EDF reaches 4.0 ft-lb/s/ft^3.
[3] Submergence at higher flows limit the effective pool depth to a maximum of 3.0 ft.
[4] Difference in water surface upstream and downstream of the entrance weir.

3.2.2 Effect on Hydraulic Capacity of Flood Control Channel

Modeling the effect of the proposed fish ladder on hydraulic capacity of the flood control channel was beyond the scope of this project. However, it was considered in development of the conceptual design. Based on the HEC-RAS model of the existing channel provided by the County of Marin, the upper 800 feet of the Unit 3 flood control channel appears to have adequate capacity for flows in excess of 8,100 cfs, which is above the original project design flow of 7,800 cfs. Under existing conditions flows overtop and exit the channel in the vicinity of Lagunitas Bridge above 3,300 cfs due to inadequate channel capacity. As a result, Unit 3 only receives a fraction of the total flow during events above 3,300 cfs. The proposed fish ladder for the No-Action Alternative is expected to only raise water levels slightly within the upper 60 feet of the Unit 3 concrete channel. To determine if this raised water level is significant, additional hydraulic modeling of the channel with the proposed fish ladder should be preformed if this alternative is selected.

The proposed placement of the weirs in the fish ladder was selected to minimize backwater effects on the existing 48-inch storm drain that discharges along the right bank. If the No-Action Alternative is selected, further hydraulic analysis should be conducted to determine the effect of the proposed ladder on storm drain capacity. The ladder could likely be moved an additional 10 feet upstream and still avoid interfering with the existing sewer lines. This would further decrease the backwater effect on the storm drain.

3.3 Transferability of Concept Design

The hydraulics and geometry of the concept fish ladder is not specific to the proposed location. If deemed more desirable, the concept fish ladder could be transferred to the naturalized channel between Unit 3 and Lagunitas Bridge.

Placing the fishway upstream of the sewer lines would require extending the concrete floodway further upstream to protect the sewer pipes from scour. Additionally, erosion protection, such as rock or concrete, would need to be placed along the bed and banks of the channel within the fish ladder since it would not be confined by the concrete floodway

4.0 CONCLUSION

The proposed concept design for a fish passage structure associated with the Corte Madera Creek Flood Control Channel Alternative I (No-Action) is a concrete pool and chute fish ladder that meets the physical site constraints and CDFG and NOAA fisheries design criteria for passage of adult salmon and steelhead. The proposed design meets the project criteria while minimizing the footprint of the structure, resulting in a cost-effective design alternative.

Additionally, the proposed concrete pool and chute fish ladder provides grade control at the upstream end, addressing concerns about upstream headcutting. Concrete is a common and familiar construction material, and the V-shaped weir is a simple design to form and build. If Alternative I is selected as the preferred alternative, additional hydraulic analysis and structural design will be required to develop a final design for the fish passage structure.

5.0 REFERENCES

Bates, K. 2001. *Fishway Design Guidelines for Pacific Salmon*. Working paper 1.6 9/2001 Washington Department of Fish and Wildlife.

California Dept. of Fish and Game (CDFG). 1998. *California Salmonid Stream Habitat Restoration Manual*.

California Dept. of Fish and Game (CDFG). 2002. *Culvert criteria for fish passage*...

Ead, S.A., et. al. 2004. *Flow regimes and structure in pool and weir fishways*. Journal of Environmental Science 3:379-390

King, H.W. 1939. *Handbook of Hydraulics*, Third Edition, McGraw Hill Book Company

Lang, M., Love, M., and Trush, W., 2004. "Improving Stream Crossings for Fish Passage." *Rep. No. 50ABNF800082*, National Marine Fisheries Service.

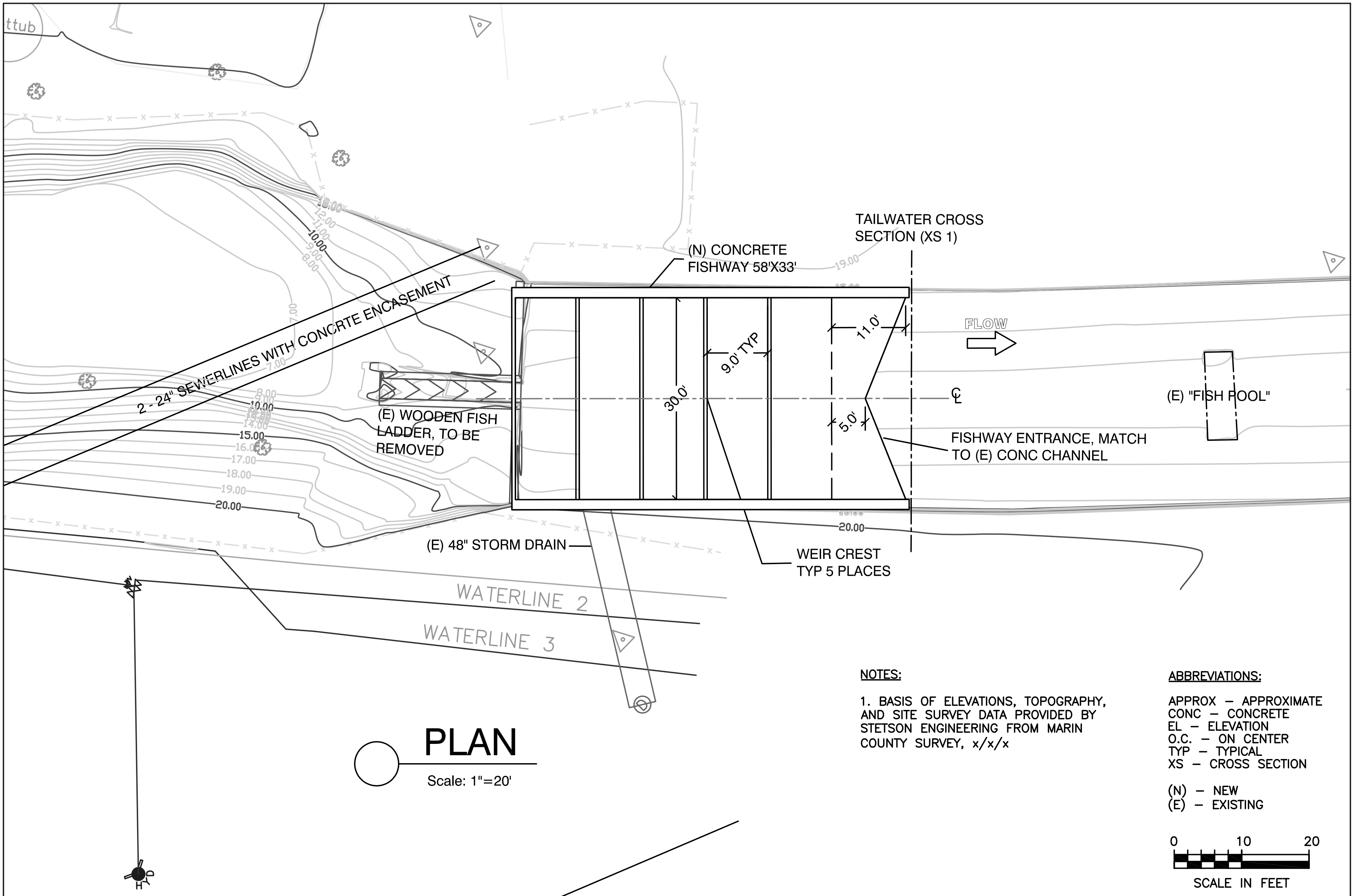
Love, M. 2006. Letter Report: Assessment of Fish Passage Conditions at the Niles Canyon Flow Measurement Weir on Alameda Creek, California. Prepared for the Federation of Fly Fishers, April 20 2006, 14 pages.

National Marine Fisheries Service (NMFS). 2001. *Guidelines for salmonid passage at stream crossings*. NMFS SW Region. 14 pages.

Rajaratnam, N. 1988. *Plunging and Streaming Flows in Pool and Weir Fishways.* Journal of Hydraulic Engineering ASCE. Vol. 114 No.8 Paper No. 22697-2

Villemonte, J.R., 1947. Submerged weir discharge studies. *Engineering News Record, 866*, Dec.

Washington Department of Fish and Wildlife (WDFW). 2003. *Design of Road Culverts for Fish Passage*. (http://wdfw.wa.gov/hab/engineer/habeng.htm#upstrm).



NOTES:

1. BASIS OF ELEVATIONS, TOPOGRAPHY, AND SITE SURVEY DATA PROVIDED BY STETSON ENGINEERING FROM MARIN COUNTY SURVEY, x/x/x

ABBREVIATIONS:

APPROX – APPROXIMATE
CONC – CONCRETE
EL – ELEVATION
O.C. – ON CENTER
TYP – TYPICAL
XS – CROSS SECTION

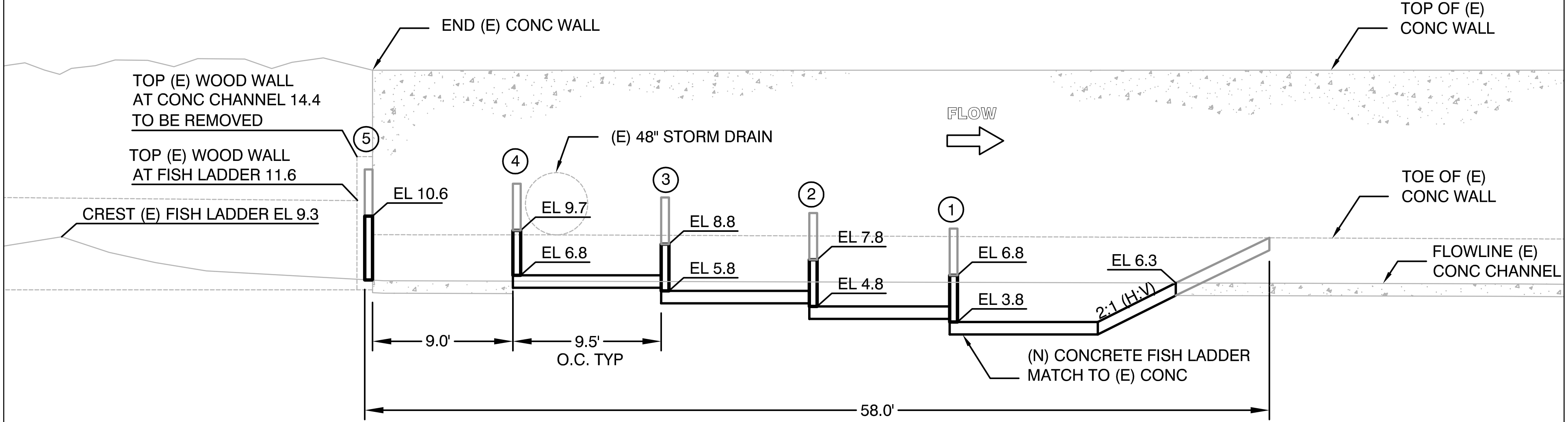
(N) – NEW
(E) – EXISTING

Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938

ALTERNATIVE I (No-Action)
Conceptual Design, Fish Passage
Structure for Transition Between Units 3 & 4

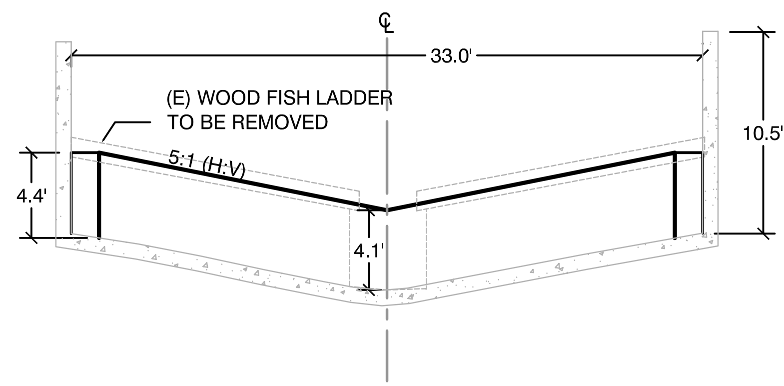
Corte Madera Creek Flood Control Channel
Friends of Corte Madera Creek Watershed

Date: 5/31/06 | Design: ML/AL | Sheet: 1 of 4



ELEVATION

Scale: 1"=10'



SECTION 5

Scale: 1"=10'

NOTES:

1. BASIS OF ELEVATIONS, SITE SURVEY DATA PROVIDED BY STETSON ENGINEERING FROM MARIN COUNTY SURVEY, x/x/x

2. THICKNESS OF CONCRETE WALL AND FLOOR OF FISH LADDER, UNKOWN. ASSUMED TO BE 0.8–FT.

ABBREVIATIONS:

APPROX – APPROXIMATE
CONC – CONCRETE
EL – ELEVATION
O.C. – ON CENTER
TYP – TYPICAL
XS – CROSS SECTION

(N) – NEW
(E) – EXISTING

1 WEIR NUMBER

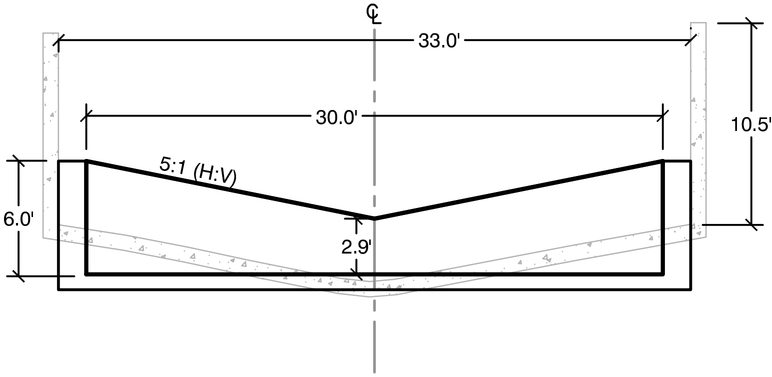
0 5 10
SCALE IN FEET

Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938

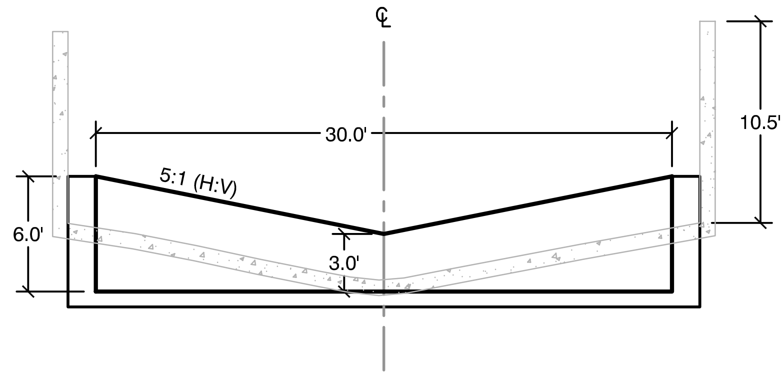
ALTERNATIVE I (No-Action)
Conceptual Design, Fish Passage
Structure for Transition Between Units 3 & 4

Corte Madera Creek Flood Control Channel
Friends of Corte Madera Creek Watershed

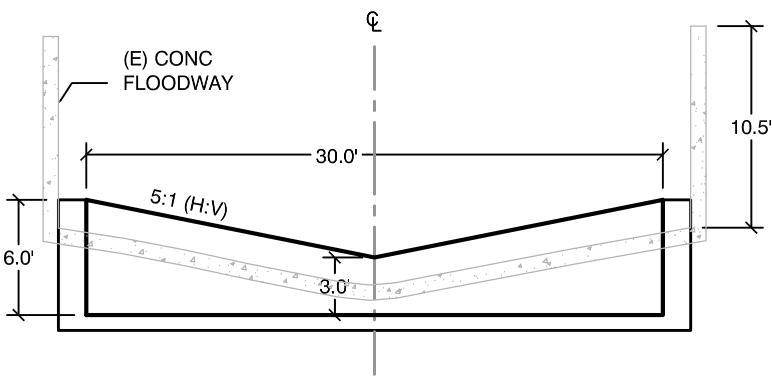
Date: 5/31/06 | Design: ML/AL | Sheet: 2 of 4



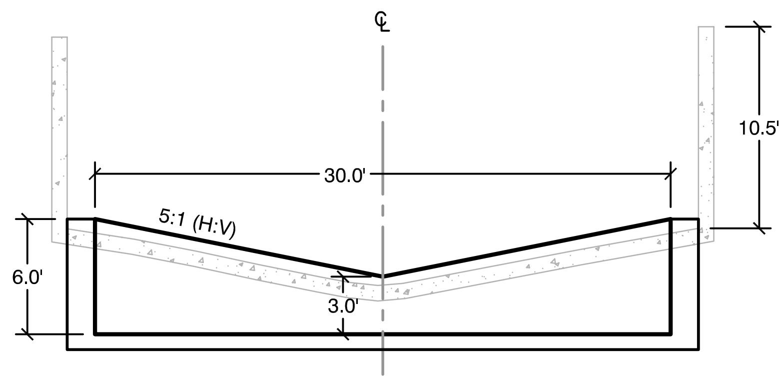
SECTION 4
Scale: 1"=10'



SECTION 3
Scale: 1"=10'



SECTION 2
Scale: 1"=10'



SECTION 1
Scale: 1"=10'

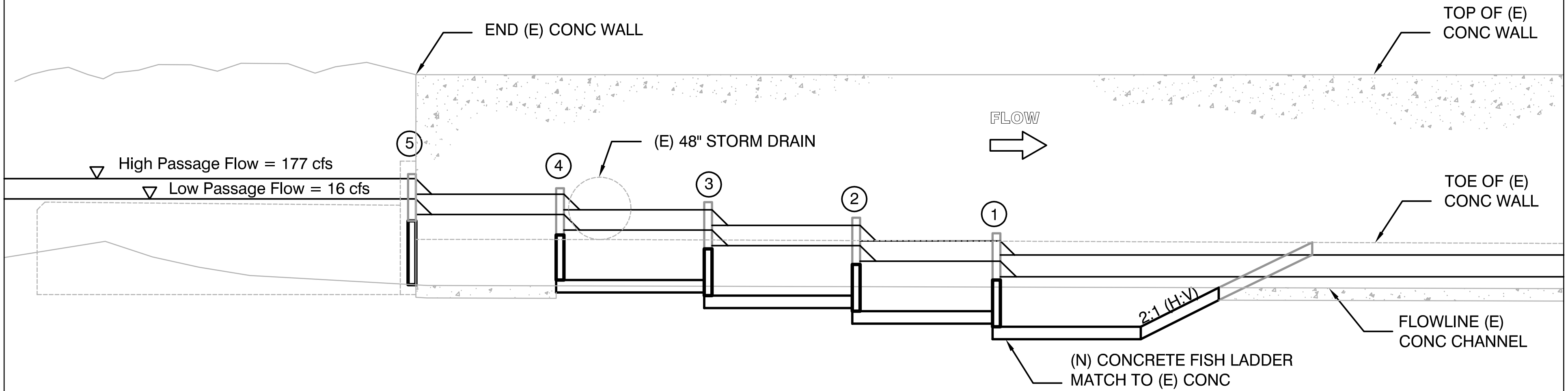
Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938

ALTERNATIVE I (No-Action)
Conceptual Design, Fish Passage
Structure for Transition Between Units 3 & 4

Corte Madera Creek Flood Control Channel

Friends of Corte Madera Creek Watershed

Date: 5/31/06	Design: ML/AL	Sheet: 3 of 4



WATER SURFACE PROFILE

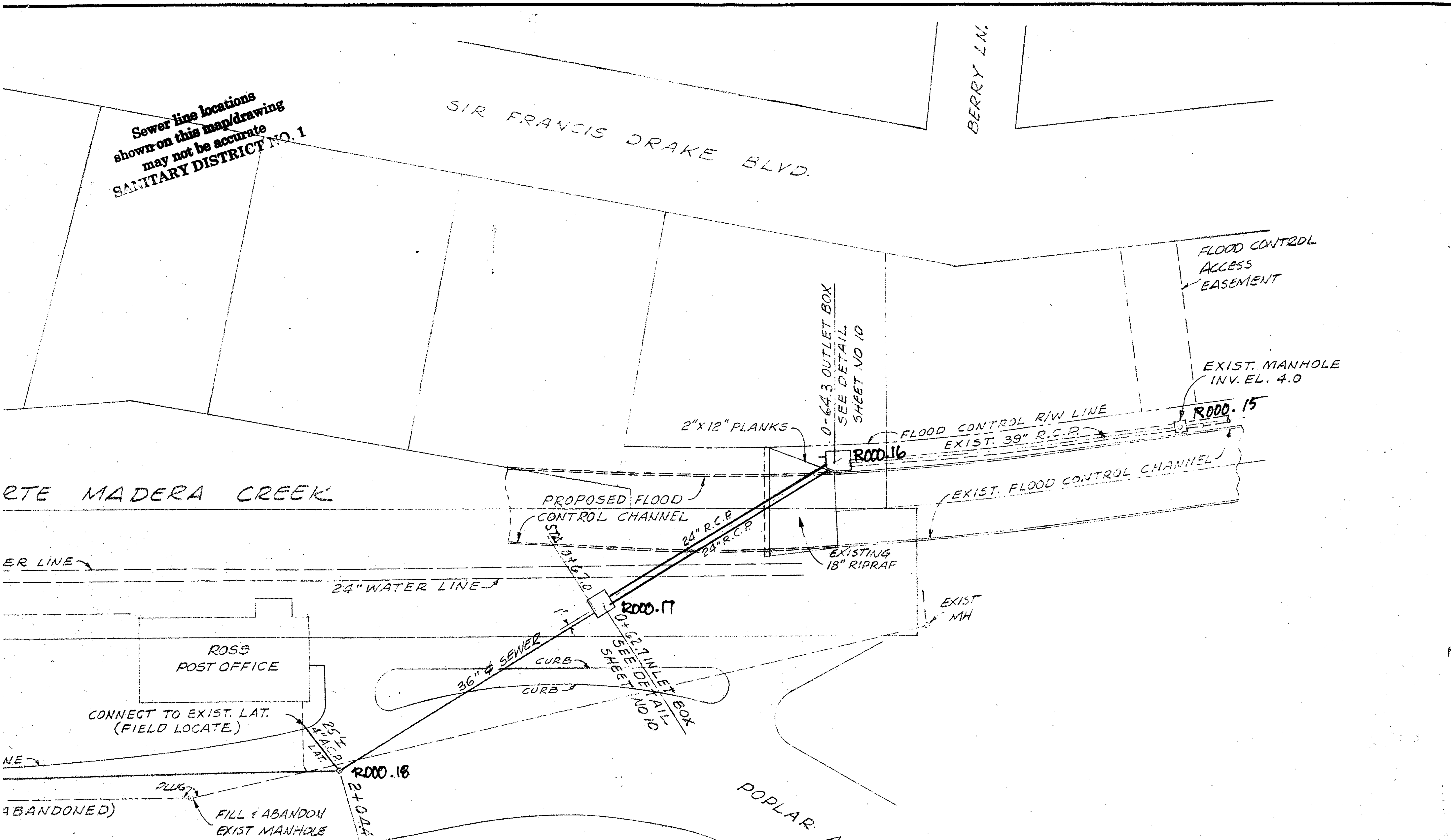
Scale: 1"=10'

Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938

ALTERNATIVE I (No-Action)
Conceptual Design, Fish Passage
Structure for Transition Between Units 3 & 4

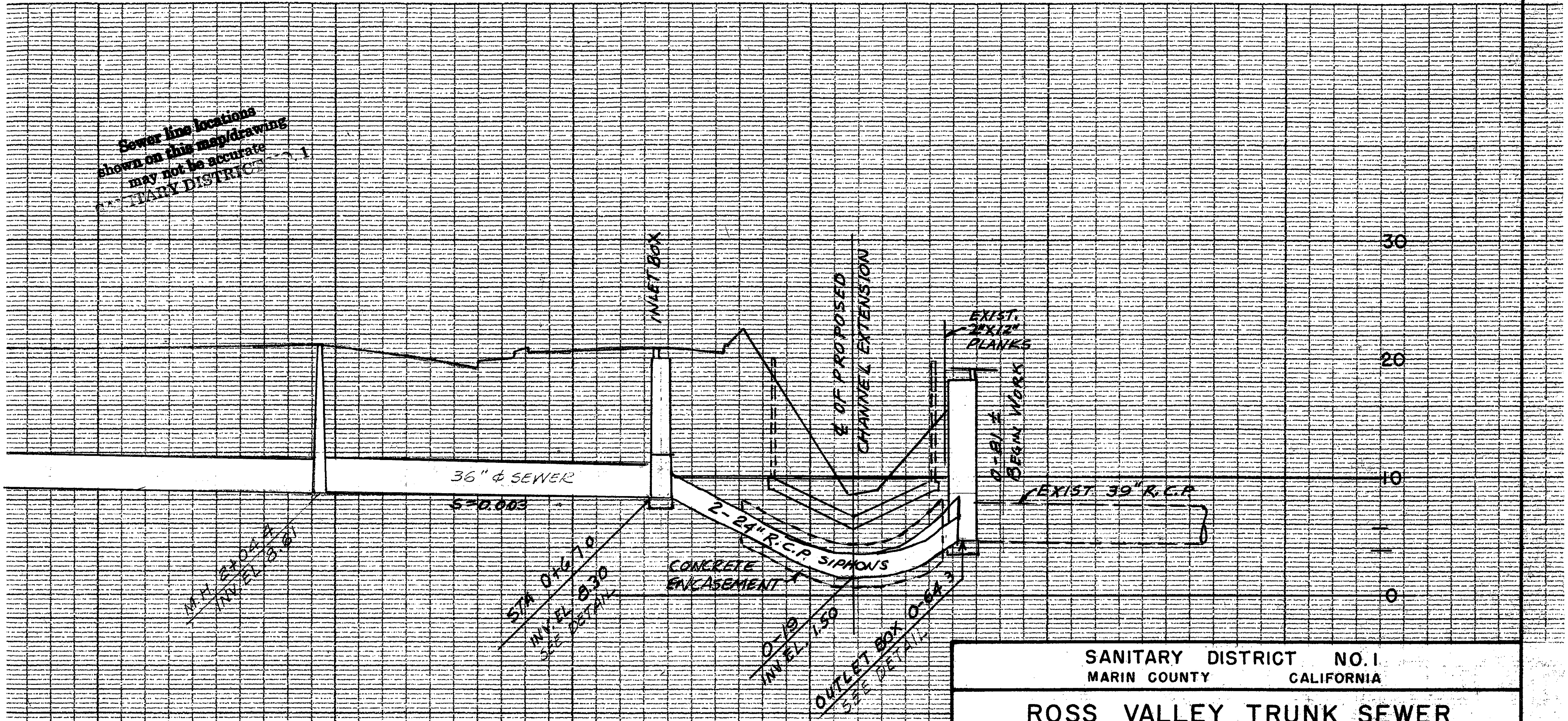
Corte Madera Creek Flood Control Channel
Friends of Corte Madera Creek Watershed

Date: 5/31/06 | Design: ML/AL | Sheet: 4 of 4



PLAN

SCALE: 1"=40'



SANITARY DISTRICT NO. 1
MARIN COUNTY CALIFORNIA

ROSS VALLEY TRUNK SEWER

PLAN AND PROFILE
STA. 0+00 TO STA. 10+00

J. WARREN NUTE, INC. - CIVIL & SANITARY ENGINEERS
SAN RAFAEL CALIFORNIA

DRAWN BY: H.I.T.	SCALE: HORIZ. 1"=40' VERT. 1"=8'	SHEET 3
CHECKED BY: JWN	DATE: MARCH 1973	OF 12 SHEETS