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FarWest
RESTORATION
ENGINEERING

Tech Memo

To: Mill Valley StreamKeepers

From: Roger Leventhal, P.E., FarWest Restoration Engineering

Date: December 13, 2004

Re: Preliminary Fish Barrier Culvert Modifications and Flood Assessment, Arroyo Corte Madera del Presidio and its tributary, Old Mill Creek, Mill Valley, Marin County, California

1.0 Introduction

1.1 OVERVIEW

Previous studies (Ross Taylor 2003) of culverts in Marin County identified two culverts along Arroyo Corte Madera Del Presidio ("Arroyo Corte Madera") and three culverts along Old Mill Creek as barriers to fish passage within Mill Valley, California. This memo evaluates preliminary barrier modifications to these culverts along with the associated impacts to flood conveyance within the culverts.

The habitat in the upper watersheds for both mainstem Arroyo Corte Madera and Old Mill Creeks is excellent for salmonids and represents an excellent opportunity to improve fish passage and utilization within the watershed if these barriers can be successfully reduced.

1.2 SCOPE OF WORK

FarWest Restoration Engineering (FRE) work was retained by the non-profit Mill Valley StreamKeepers (MVSK) to develop preliminary sketches of barrier design modifications of five culvert identified by Ross Taylor for the County of Marin. These and other potential barriers were noted in the following season (Spring 2003) during a salmonid habitat assessment conducted for MVSK by the non-profit Institute for Fisheries Research.

Specifically, FRE performed the following work under this project:

- Inspected the barrier sites and reviewed existing fish passage results at the following culverts identified by Ross Taylor to represent barriers to fish migration (site numbers from Taylor 2003):
  - MR-068 – Arroyo Corte Madera at Locust Avenue
  - MR-069 – Arroyo Corte Madera under building (at confluence of Arroyo Corte Madera Mill Creeks)
  - MR-075 – Old Mill Creek at Miller Avenue

- MR-076 – Old Mill Creek under Post Office
- MR-077 – Old Mill Creek at Cascade Drive

- Prepared preliminary and conceptual design sketches for the retrofitting of the culverts to allow for fish passage.
- Perform a preliminary assessment of the flooding impacts from proposed culvert modifications to provide a recommendation for moving forward into final analysis and design.
- Prepared a preliminary design report and recommendations for next steps.

Analysis of the proposed culvert modifications for fish passage benefits will be performed under the next phase of work. This phase performed here included a preliminary evaluation of the flooding impacts of proposed barrier modifications to gain the qualified support of the City of Mill Valley for implementation of the next stream restoration steps.

All fish passage designs should be reviewed by NOAA Fisheries and DFG engineers prior to implementation.

1.3 ASSUMPTIONS AND LIMITATIONS

This report provides only a preliminary assessment and designs for fish passage enhancement through existing culverts to enable applications for implementation grant funding. Due to budget and schedule constraints the analysis was necessarily in its scope. We provide recommendations here for additional work during subsequent project phases to provide additional analysis for some of these culverts and to further refine design and cost estimates for going forward with those in which the City will collaborate. The designs and costs described within are subject to change following additional analysis. Analysis was based upon surveying and hydrology data provided by others. Independent checking of this information was not part of this project.

In particular, the flood flow evaluations are preliminary and are intended to provide a basis for evaluation of impacts due to barrier modifications. They are not a determination of absolute water levels under flood conditions. This analysis is for assisting MWSK and the City of Mill Valley with the basis for moving forward into final hydraulic analysis and design for barrier modifications. In addition, the evaluation of water levels under flood conditions does not account for the presence of debris or sediment build-up within the channel.

1.4 OVERVIEW OF FISH BARRIERS

The typical fish passage barriers created by culverts include the following:

- Elevated flow velocities in the culvert
- Flow depth is too shallow in the culvert for fish passage
- Too great a distance between the downstream pool and the culvert outlet to allow for fish to leap
- Excessive debris accumulation
- Excessive turbulence and velocities at the culvert inlet due to constriction of flows.

Definitions of barrier types and potential impacts.

Barrier Category	Definition	Potential Impacts
Temporal	Impassable to all fish some of the time	Delay in movement beyond the barrier for some period of time
Partial	Impassable to some fish at all times	Exclusion of certain species and life stages from portions of a watershed
Total	Impassable to all fish at all times	Exclusion of all species from portions of a watershed

Culverts that form even partial barriers may cause problems because even if culverts are eventually negotiated, excess energy expended by fish may result in their death prior to spawning or reductions in viability of eggs and offspring. Migrating fish concentrated in pools and stream reaches below road crossings are also more vulnerable to predation by a variety of avian and mammalian species, as well as poaching by humans. Culverts which impede adult passage limit the distribution of spawning, often resulting in under seeded headwaters and superimposition of redds in lower stream reaches.

The goal of the analysis is to recommend modifications to existing culverts identified as fish barriers by previous consultants.

1.5 FISH PASSAGE REQUIREMENTS

There are specific velocity and depth requirements for the successful passage of adult and juvenile salmonids in culverts. The table below summarizes the depth and velocity requirements for Steelhead (O. *mykiss)* used for this project. In reality, . . . ?

Table 1

Salmonid/Lifestage	Maximum Prolonged Velocity (ft/sec)	Maximum Burst Velocity (ft/sec)	Depth (ft)
Juvenile >6 inches	4	5	0.5
Juvenile <6 inches	1.5	5	0.5
Adult Anadromous			
-Culvert length<60 feet	6	10	0.8 (1)
-60-100 feet	5	10	0.8
-100-200 feet	4	10	0.8
-200-300 feet	3	10	0.8
->300 feet	2	10	0.8

Note (1) Adjusted downward from DFG requirement of 1.0 feet.

However for culvert retrofits on round culverts at slopes less than 3 to 3.5 percent, corner baffles represent one of the only options to raise water levels and reduce velocities to provide fish passage. The increased value for Manning's n for culvert baffles is difficult to estimate. Based upon our review of existing literature, we have used what we consider to be a conservative value of Manning's n under flood flows of 0.06.

Culvert Weirs. Culvert weirs are solid or v-notched structures that cross the entire culvert bottom and are intended to provide for a pool-weir fishway within the culvert. This type of design is subject to the design limitation for a pool-weir fishway design including the requirements to have sufficient pool depth and volume to keep turbulence factors at a limit of 4 lb/ft2-s.

Back Flooding Weirs. This approach involves installing rock or log weirs across the channel downstream of the culvert outlet to raise tailwater elevations and provide additional backwater to facilitate fish passage.

Step-Pool Construction. For conditions where there is a perched culvert and greater than three feet of grade change is required, a step-pool channel morphology can be constructed in a series of rock steps alternating with pool to reduce the required leaping distance and elevation change.

Concrete or Gabion Sills. A more engineered approach is to install a concrete or gabion sill in the channel with a low flow notch down the center of the channel to raise grades and tailwater elevations. This approach may be more permanent than solutions involving rock and logs but it is not as natural and will likely be more difficult to permit.

For each of these approaches, the hydraulic capacity of the culvert to convey flood flows will have been reduced. During final design, the impacts on flood control of installing any structures to aid fish passage will need to be evaluated.

For this project, we have selected different restoration approaches on a preliminary basis and applied them to those culverts indicating fish passage issues. The approaches are preliminary and are intended to allow for project evaluation. Detailed designs and cost estimates should be performed during the next phase of the project.

4.0 Culvert Modifications and Analysis

4.1 MR-068 – ARROYO CORTE CREEK AT LOCUST AVENUE

The Arroyo Corte culvert at Locust Avenue is a 6.4 foot high by 22.2 foot wide arch culvert with a concrete bottom that runs under Locust Avenue and also under an apartment building. At the inlet to the culvert, there is also a 125 foot long concrete apron that was included in the fish passage evaluations.

R. Taylor noted the following barriers to fish passage:

Juvenile Steelhead: Fails to meet passage criteria

Adult Steelhead: Meets criteria for 23% of range of estimated migration flows; fails to meet depth criteria only for flows below 61 cfs (adult flow range is 3 to 78.4 cfs).

In addition, R. Taylor evaluated that the culvert was capable of passing the 250 year flow without overtopping, therefore, flooding was not indicated to be a problem with this culvert.

4.1.1 Preliminary Culvert Retrofit/Restoration Options

Approaches to raising flow depths within the culvert for fish passage include cutting a low flow channel through the channel bottom, installation of baffles, or raising tailwater depths by installing outlet weirs or modifying downstream flow conditions. For this culvert, since there is a wide concrete bottom (approx 22 feet wide) and the outlet jump is only about one foot, we believe that cutting a low flow channel approximately 4 to 10 feet wide is the best way to provide fish passage over a wider range of flows with the proper depth. This low flow channel will be filled with gravel and rock to provide a natural bottom passageway through the culvert. Figure 1 shows the profile of the existing culvert and the proposed modifications to the culvert to achieve fish passage. However, the impacts on adjacent buildings and the cost for structural improvements have not been performed for this report. If notching of a low flow channel is not possible or cost-prohibitive, then baffles and raising of the downstream tail water elevation will be evaluated for their effectiveness to improve the barrier passage characteristics and impacts to flood control. .

On advantage of cutting a low flow into the culvert bottom is that the flooding flow conveyance of the culvert will not be reduced and would likely be increased. However, a limitation during final design is to make sure that construction of the low flow passage channel doesn't impact the structural integrity of the existing culvert. In our experience, it is unlikely that the bridge support footings extend to the middle of the channel and it would therefore may be possible to cut a low flow channel and then reinforce the culvert footings as shown in Figure 2. The structural design will be developed during final design activities.

Summary of Proposed Barrier Modifications (assuming cutting of low flow channel is possible)

- The proposed barrier modification will consist of cutting of the following:
- Demolition and removal of concrete and asphalt to a depth of approximately 18 to 24 inches from a 4 to 10 feet wide channel along the bottom of the structure
- Reinforcement of the channel side slopes with a concrete reinforcement to an assumed depth of three feet (to be confirmed during final design)
- Placement of rock and gravel to provide a natural bottom passageway within the culvert.
- Installation of three log weir at the tailwater section to raise tailwater elevation
- Removal of portions of the upstream asphalt entranceway.

4.1.2 Hydraulic Evaluations

4.1.2.1 Fish Passage

Analysis of the proposed modifications for fish passage will be conducted under the next phase of work activities. We anticipate that some kind of baffles within the fishway will be required to provide resting areas for fish passage.

4.1.2.2 Preliminary Assessment of Flooding Impacts

As indicated above, previous studies have indicated that the hydraulic capacity of the existing culvert is more then adequate to convey the 100-year flood flows and the proposed modifications should maintain or possibly increase that capacity. Since we do not believe that the proposed approach will

not decrease the hydraulic capacity of the proposed culvert no additional flood modeling was developed.

4.2 MR-069 – ARROYO CORTE CREEK UNDER BUILDING (AT CONFLUENCE OF ARROYO CORTE AND MILL CREEKS)

This culvert was mapped as a 7 foot diameter 111 foot long concrete culvert at a slope of approximately 2.93 percent. The outlet pool of the culvert is the confluence of Arroyo Corte and Old Mill Creeks.

R. Taylor calculated the following barriers to fish passage:

Juvenile Steelhead: Fails to meet passage criteria for velocity.

Adult Steelhead: Fails to meet criteria for velocity for flows from 7 cfs to 33.6 cfs (passage flow range of flows is 3 to 33.6 cfs)

In addition, R. Taylor evaluated that the culvert was undersized with an approximate storm capacity of only the 25 year flow event.

4.2.1 Preliminary Restoration Alternatives

This steep slope (approximately 3 percent) and length (111 feet) of this culvert represents a difficult design issue for fish passage. It is very unlikely that corner baffles will produce low enough velocities to meet the requirements of Table 1 above. A quick culvert analysis using 33.6 cfs (the one percent upper passage flow) indicates that the velocity through the culvert will be approximately 12.3 ft/sec, well above the design guidelines of 4 ft/sec described above for adult salmonids in a culvert over 100 feet.

Therefore, construction of a pool-weir fishway within the culvert may be required to achieve passage goals. In addition, tailwater elevations will be raised by construction of a series of downstream log sills to raise the tailwater condition. Given that passage of juvenile salmonids is required, the step height of the proposed pool-weir fishway will be limited to 0.5 feet. The step culvert section helps achieve pool volumes to dampen turbulence but these design elements will have to be evaluated during the subsequent design phase of the project. Figure 3 shows the existing culvert and proposed modifications.

For analysis purposes, it was assumed that a pool weir fishway will be constructed in the culvert with step 18 inches high at spacing of approximately 8 feet for a total number of steps of approximately fourteen. This baffle weir will provide a pool depth of approximately one foot or twice the 0.5 foot step height.

This barrier is further complicated since it shares the downstream tailwater pool with MR-075 Old Mill Creek at Miller Avenue described below.

Summary of Proposed Barrier Modifications

The proposed barrier modification will consist of cutting of the following:

- Construction of a downstream tailwater pool steps to raise elevations 1-2 feet.

- Install a series of weirs and pool cross-baffles to reduce velocities and increase depths to meet guidelines; or make recommendations for barrier replacement. Figure 7 shows a typical baffle expansion ring taken form the State of Washington Department of Fish and Wildlife manual.
- Install upstream berms or flood proofing to contain channel breakout flows.

4.2.2 Hydraulic Evaluations

4.2.2.1 Fish Passage

Hydraulic evaluation of the proposed pool-weir fishway to meet fish passage goals will be developed under the next phase of the project work.

4.2.2.2 Preliminary Assessment of Flooding Impacts

FRE performed a preliminary assessment of the potential impacts on flood control from the proposed passageway. For this analysis, we set-up a HEC-RAS model run using upstream and downstream cross-sections to approximate the upstream and downstream conditions from the culvert. To account for the proposed pool-weir, we used two methods, 1) we assumed that the culvert was embedded 18 inches and this reduced the hydraulic capacity of the culvert by this depth and 2) we used a much higher Manning's n value of 0.07 to account for the increased roughness of the culvert due to the baffles system.

For this analysis, we ran the calculations under the 100-year flow estimates using both the Log-Pearson estimate of 693 cfs and the Wannanen estimate of 536 cfs. Table 2 contains the results of this evaluation.

The results indicate overtopping of the culvert for both 100-year flow conditions. The increase in water level due to the baffles/pool weir system is approximately 1 to 2 feet. Note that communications with City of Mill Valley staff indicate that upstream culverts at Throckmorton and Sunnyside may have more significant existing flooding impacts, thereby reducing the flood flows to MR-069.

4.3 CULVERT MR-075 – OLD MILL CREEK #1 AT MILLER AVENUE

The MR-075 culvert is located along Old Mill Creek under Miller Avenue right through downtown Mill Valley. The culvert is 218.5 feet long at a diameter of 7 feet and is laid at an overall slope of 1.72 percent (Figure 4). There is a break in slope halfway through the culvert. The outlet pool of the culvert is the confluence of Arroyo Corte #2 (MR-069).

Previous studies (R. Taylor 2003) determined the following barriers to fish passage for this culvert:

Juvenile Steelhead: Fails to meet passage criteria for velocity and depth.

Adult Steelhead: Fails to meet criteria for velocity for flows from 5.5 cfs to 20 cfs (passage range of flows is 3 to 40.3 cfs)

In addition, R. Taylor evaluated that the culvert was undersized with an approximate storm capacity (HW/D=1) of only the 14 year flow event. Taylor estimated that Miller Avenue is overtopped on a 92-year storm event.

4.3.1 Preliminary Restoration Alternatives

A first-cut culvert analysis using HY-8 shows that at a flow of 40.3 cfs (the one percent upper passage flow) the velocity through the culvert is approximately 11 ft/sec, well above the design guidelines of 3-4 ft/sec described above for adult salmonids in a culvert over 200 feet.

However, when the Manning's n value is raised to 0.06 a value consistent with draft results from the State of Washington studies of corner baffle hydraulics, the velocity is reduced to a value of approximately 6 ft/sec, much closer to the guideline goals. Therefore, construction of corner baffles may be enough to meet the velocity and depth requirements for the project. If further analysis indicates that baffles do not achieve design goals, then installation of a pool-weir fishway within the culvert may be required. In addition, tailwater elevations will be raised by construction of a series of downstream log sills to raise the tailwater condition. Given that passage of juvenile salmonids is required, the step height of the proposed corner baffles will be limited to 0.5 feet.

For analysis purposes, it was assumed that baffles will be constructed in the culvert with step 12 inches high at a spacing of approximately 1.2 times the culvert diameter (DFG guidance criteria) for a total number of steps of approximately 30.

This barrier is further complicated since it shares the downstream tailwater pool with MR-069 Arroyo Corte #2 described above.

Summary of Proposed Barrier Modifications

- The proposed barrier modification will consist of cutting of the following:
- Construction of a downstream tailwater pool steps to raise elevations one to two feet.
- Evaluate the effectiveness of installing corner baffles or if required a series of step-pool weirs to reduce velocities to meet guidelines.
- Install berms or floodwalls along those areas of the creek identified during final hydraulic analysis as showing overbank flooding.

4.3.2 Hydraulic Evaluations

4.3.2.1 Fish Passage

Hydraulic evaluation of the proposed baffles and tailwater control system will be developed under the next phase of the project work. Preliminary culvert analysis indicates that baffles may be able to reduce velocities under the one percent passage flow condition to acceptable results. Surveys indicate a two foot jump in elevation in the middle of this culvert. It is likely that at least one cross-weir will be required during final design activities to address fish passage issues with this elevation change.

4.3.2.2 Preliminary Assessment of Flooding Impacts

To assess the potential impacts on flood control from the proposed baffle system, we set-up a HEC-RAS model run using four cross-sections to approximate the upstream and downstream conditions from the culvert. To account for the loss of hydraulic conveyance using the corner baffles, we assumed that the culvert was embedded one foot and reduced the hydraulic capacity of the culvert by this amount. We also analyzed water levels under flood flow conditions by using a Manning's n of 0.06 to account for baffle roughness.

For this analysis, we ran the calculations under the 100-year flow estimates using both the Log-Pearson estimate of 830 cfs and the Wannanen estimate of 642 cfs. The results indicate a potential increase in water levels from 0.6 to 3 feet from barrier modification implementation depending on the assumption method. Table 3 shows the results of the water level rise under flood conditions.

The results indicate overtopping of the culvert for both 100-year flow conditions.

4.4 MR-076 – OLD MILL CREEK #2 UNDER POST OFFICE

The Old Mill Creek #2 culvert is a 95.5 foot long culvert at a slope of approximately 0.74% . The culvert is a 7 foot diameter circular culvert at the inlet and a 7 foot by 10 foot box culvert at the outlet. The culvert condition was mapped as fair to poor with exposed rebar at the invert. Figure 5 shows the culvert and proposed modifications.

Previous studies (R. Taylor 2003) determined the following barriers to fish passage for this culvert:

Juvenile Steelhead: Fails to meet passage criteria for velocity and depth.

Adult Steelhead: Fails to meet passage criteria for velocity and depth.

In addition, R. Taylor evaluated that the culvert was undersized with an approximate storm capacity (HW/D=1) of only the 14 year flow event. Taylor estimated that Miller Avenue is overtopped on a 74-year storm event.

4.4.1 Preliminary Restoration Alternatives

A preliminary culvert analysis using HY-8 at a upper one percent passage flow of 40.3 cfs indicates that the velocity through the culvert is approximately 8 ft/sec, above the design guidelines of 5 ft/sec described above for adult salmonids in a culvert under 100 feet.

However, when the Manning's n value is raised to 0.06 a value consistent with draft results from the State of Washington studies of corner baffle hydraulics, the velocity is reduced to a value of approximately 6 ft/sec, much closer to the guideline goals. Therefore, construction of corner baffles may be enough to meet the velocity and depth requirements for the project to allow for sufficient fish passage under a wider percent of passage flow conditions. If further analysis indicates that baffles do not achieve design goals, then installation of a pool-weir fishway within the culvert may be required. In addition, tailwater elevations will be raised by construction of a series of downstream log sills to raise the tailwater condition. Given that passage of juvenile salmonids is required, the step height of the proposed corner baffles will be limited to 0.5 feet.

For flooding analysis purposes, it was assumed that baffles will be constructed in the culvert with step 12 inches high at a spacing of approximately 8 feet for a total number of steps of approximately 13 steps.

4.4.2 Hydraulic Evaluations

4.4.2.1 Fish Passage

Preliminary culvert assessments indicate that corner baffles may be able to reduce velocities to or close to design requirements. Additional analysis of culvert flows will be performed in the subsequent design phase.

4.4.2.2 Preliminary Assessment of Flooding Impacts

We set-up a HEC-RAS model run using four cross-sections to approximate the upstream and downstream conditions from the culvert in order to assess the potential impacts on flood control from the proposed baffle system. To account for the corner baffle system, we assumed that the culvert was embedded 12 inches and reduced the hydraulic capacity of the culvert by this amount. We also peformed a hydraulic evaluation assuming the baffles increased the hydraulic roughness to a value of 0.06.

For this analysis, we ran the calculations under the 100-year flow estimates using both the Log-Pearson estimate of 830 cfs and the Wannanen estimate of 642 cfs. Table 3 shows the results of the flooding analysis for both flow rates.

The results indicate overtopping of the culvert for both 100-year flow conditions. The anticipated rise in water level was calculated to be approximately 0.6 to 3 feet from existing water levels under flood conditions.

4.5 MR-077 – OLD MILL CREEK #3 (CASCADE CREEK) AT CASCADE DRIVE

Old Mill Creek #3 is a 8 foot high by 10 foot wide arch culvert 6 ft by 5 ft arch culvert approximately 18 feet in length at a slope of approximately 2.4%. The overall condition is fair to poor with cracking of the culvert floor. The primary barrier for fish passage is a series of steep steps cut into the upstream asphalt apron that is essentially impassible for fish. Figure 6 shows the existing culvert and proposed replacement bridge.

Previous studies (R. Taylor 2003) determined the following barriers to fish passage for this culvert:

Juvenile Steelhead: Fails to meet passage criteria for velocity and depth.

Adult Steelhead: Fails to meet passage criteria for velocity and depth.

In addition, R. Taylor evaluated that the culvert was sized correctly to handle the 100-year storm (in fact, Taylor indicated this culvert could handle the 250-year flow event).

4.5.1 Preliminary Restoration Alternatives

Given the short length of the culvert, we propose to replace the culvert with an arch bridge with a natural bottom. The width of the bridge would be designed to meet DFG and NOAA Fisheries guidelines to be approximately 25 percent larger then the active channel width of 18 feet, therefore, the bridge width would be approximately 22 feet at an estimated width of 14 feet (single traffic lane). The series of upstream step would be regraded into a series of steps approximately 0.5 feet in height graded back into the park at a slope of approximately 5 percent.

Summary of Proposed Barrier Modifications

The proposed barrier modification will consist of cutting of the following:

- Remove the existing culvert and upstream asphalt.
- Regrading of channel bottom to remove asphalt and establish a five percent channel slope along the creek bottom into the park.
- Install a new arch bridge with a natural bottom at a width of approximately 22 feet.

4.5.2 Hydraulic Evaluations

4.5.2.1 Fish Passage

Further fish passage should not be required assuming that a properly sized arch bridge with a natural bottom and grading of steps is accomplished. If additional analysis is required, this work would be accomplished during the next phase of design work.

4.5.2.2 Preliminary Assessment of Flooding Impacts

Sine the proposed bridge will have an increased hydraulic capacity over the current culvert (which is already properly sized), no additional flood modeling was conducted.

5.0 Preliminary Cost Estimates

Preparation of cost estimates will be performed during the next phase of design activities.

6.0 Recommended Next Steps

We recommend that the following steps be implemented for this project:

- Conduct additional field surveys to better to perform final hydraulic analysis.
- Conduct additional fish passage modeling where indicated to design the corner baffle or weir-pool hydraulics and indicate if fish passage can be achieved.
- Perform a final flood modeling evaluation for each culvert for passage of flood flows and determine whether the recommended restoration alternatives may impact flood protection.
- Develop final designs and cost estimates for restoration/retrofit alternatives.
- Develop final plans and specifications for construction.

7.0 References/Bibliography

Documents used during preparation of this plan include the following:

- California Department of Fish and Game (CDFG), Culvert Criteria for Fish Passage, May 2002. Log - Pearson?
- Ross Taylor and Associates, 2003, Marin County Stream Crossing Inventory and Fish Passage Evaluation. Prepared for Marin Department of Public Works.
- Lang et. al, Improving Stream Crossings for Fish Passage, Final Report, Undated.

Waananen (1997) [p.4]
Log-Pearson

Tables:

Table 1: Culvert Characteristics
Table 2: Summary of Water Surface Level Analysis for MR-069
Table 3: Summary of Water Surface Level Analysis for MR-075 and MR-076

Figures:

Figure 1: Profile Section of MR-068
Figure 2: Cross-Section of MR-068 Showing Proposed Barrier Modification
Figure 3: Profile of MR-069
Figure 4: Profile of MR-075
Figure 5: Profile of MR-076
Figure 6: Profile of MR-077

Table 1
Summary of Mill Valley Culvert Characteristics
December 9, 2004

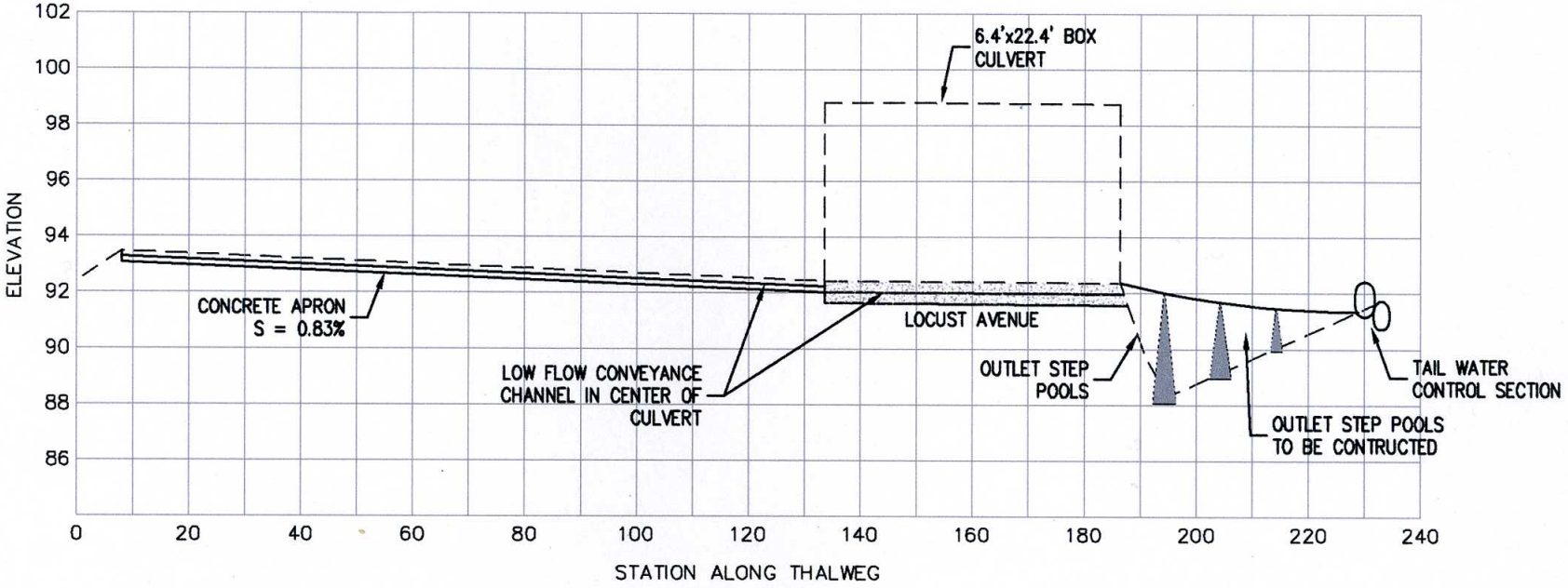
	MARIN COUNTY STREAM CROSSING LOCATIONS AND CHARACTERISTICS								
ID #	Stream Name	Type of Culvert	Construction Material	Corrugation Dimensions	Culvert Length (ft)	Culvert Dimensions: Diameter, height/width, or rise/span (ft)	% Slope thru Culvert	Culvert Condition	Average Active Channel Width (ft)
MR-068	Arroyo Corte Madera del Presidio #1	Box	Concrete	Smooth	52.8	6.4 X 22.4	0.13	Good	12.2
MR-069	Arroyo Corte Madera del Presidio #2	Circular	Concrete	Smooth	111.7	7	2.93	Good	9.2
MR-075	Old Mill Creek #1	Circular(at inlet) with many varied sections	Concrete	Smooth	218.5	7	1.72	Fair- big cracks and gaps in floor	8.3
MR-076	Old Mill Creek #2	Circular - then Box	Concrete	Smooth	95.5	7	0.74	Poor- worn, rebar showing.	8.3
MR-077	Old Mill Creek #3	Arch with concrete floor	Concrete	Smooth	17.7	8 X 10	2.37	Fair- concrete floor is cracked.	18.0

Table 2
Summary of Water Surface Elevation Results from HEC-RAS Study
MR-069 Arroyo #2 Under Building
Mill Valley Culvert Barrier Assessment
December 9, 2004

		Waananen Regression Equation 100-yr Flow = 536 cfs						*Log Pearson Distribution 100-yr Flow = 693 cfs*					
section # upstream to downstream	*assumed top of bank elevation*	water surface elevation under existing conditions	*depth of existing flooding (ft)*	water surface elevation assuming pipe embedded 18 inches	**change in wse (ft)**	water surface elevation assuming increased mannings n value	**change in wse (ft)**	water surface elevation under existing conditions	*depth of existing flooding (ft)*	water surface elevation assuming pipe embedded	**change in wse (ft)**	water surface elevation assuming increased mannings n value	**change in wse (ft)**
182	110	113.38	3.38	114.3	**0.92**	114.96	**1.58**	114.69	4.69	115.51	**0.82**	116.24	**1.55**
172	110	113.39	3.39	114.3	**0.91**	114.96	**1.57**	114.7	4.7	115.52	**0.82**	116.25	**1.55**
Culvert MR-069		Inlet controlled culvert											
49	107	103.18	-3.82	103.18	**0.00**	103.18	**0.00**	103.91	-3.09	103.91	**0.00**	103.91	**0.00**
44	107	103.4	-3.6	103.4	**0.00**	103.4	**0.00**	104.15	-2.85	104.15	**0.00**	104.15	**0.00**
31	107	103.46	-3.54	103.46	**0.00**	103.46	**0.00**	104.22	-2.78	104.22	**0.00**	104.22	**0.00**
10	107	102.16	-4.84	102.16	**0.00**	102.16	**0.00**	102.7	-4.3	102.71	**0.01**	102.71	**0.01**
0	107	101.9	-5.1	101.9	**0.00**	101.9	**0.00**	102.45	-4.55	102.45	**0.00**	102.45	**0.00**

Table 3
Summary of Water Surface Elevation Results from HEC-RAS Study
MR-075 and MR-076
Old Mill Creek #1 and 2
Mill Valley Culvert Barrier Assessment
December 9, 2004

		Waananen Regression Equation 100-yr Flow = 642 cfs						*Log Pearson Distribution 100-yr Flow = 830 cfs*					
cross-section # upstream to downstream	*assumed top of bank elevation*	*water surface elevation under existing conditions*	*assumed depth of existing flooding (ft)*	*water surface elevation assuming pipe embedded 12 inches*	***change in wse (ft)***	*water surface elevation assuming increased mannings n value*	***change in wse (ft)***	*water surface elevation under existing conditions*	*assumed depth of existing flooding (ft)*	*water surface elevation assuming pipe embedded 12 inches*	***change in wse (ft)***	*water surface elevation assuming increased mannings n value*	***change in wse (ft)***
408	109.5	117.63	8.13	118.25	**0.62**	120.44	**2.81**	119.57	10.07	120.13	**0.56**	122.23	**2.66**
395	110.5	117.24	6.74	117.91	**0.67**	120.2	**2.96**	119.07	8.57	119.68	**0.61**	121.9	**2.83**
culvert MR-076			0						0				
297	113.93	114.69	0.76	115.32	**0.63**	117.66	**2.97**	116.29	2.36	116.91	**0.62**	119.27	**2.98**
283	112.5	114.79	2.29	115.41	**0.62**	117.71	**2.92**	116.41	3.91	117.01	**0.6**	119.33	**2.92**
culvert MR-075			0						0				
49	107	103.68	-3.32	103.68	**0**	103.68	**0**	104.49	-2.51	104.49	**0**	104.49	**0**
44	107	103.91	-3.09	103.91	**0**	103.91	**0**	104.75	-2.25	104.75	**0**	104.75	**0**
31	107	103.98	-3.02	103.98	**0**	103.98	**0**	104.83	-2.17	104.83	**0**	104.83	**0**
10	107	102.53	-4.47	102.53	**0**	102.53	**0**	103.17	-3.83	103.17	**0**	103.17	**0**
0	107	102.27	-4.73	102.27	**0**	102.27	**0**	102.92	-4.08	102.92	**0**	102.92	**0**
Notes:													
All elevations are assumed based upon surveys by R. Taylor 2003.													



CULVERT PROFILE

SCALE: 1"=30'(H), 1"=6'(V)

NOTE: IF CONSTRUCTION OF LOW FLOW CHANNEL IS INFEASABLE THEN BAFFLES WILL BE EVALUATED.

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FIGURE 1
MILL VALLEY FISH BARRIER CULVERT MODIFICATIONS
ARROYO CORTE MADERA DEL PRESIDIO #1
LOCUST AVENUE (MR-068)

DATE: 12/09/2004

SCALE: 1"=30'(H)
1"=6'(V)

SHEET: 1 OF 6

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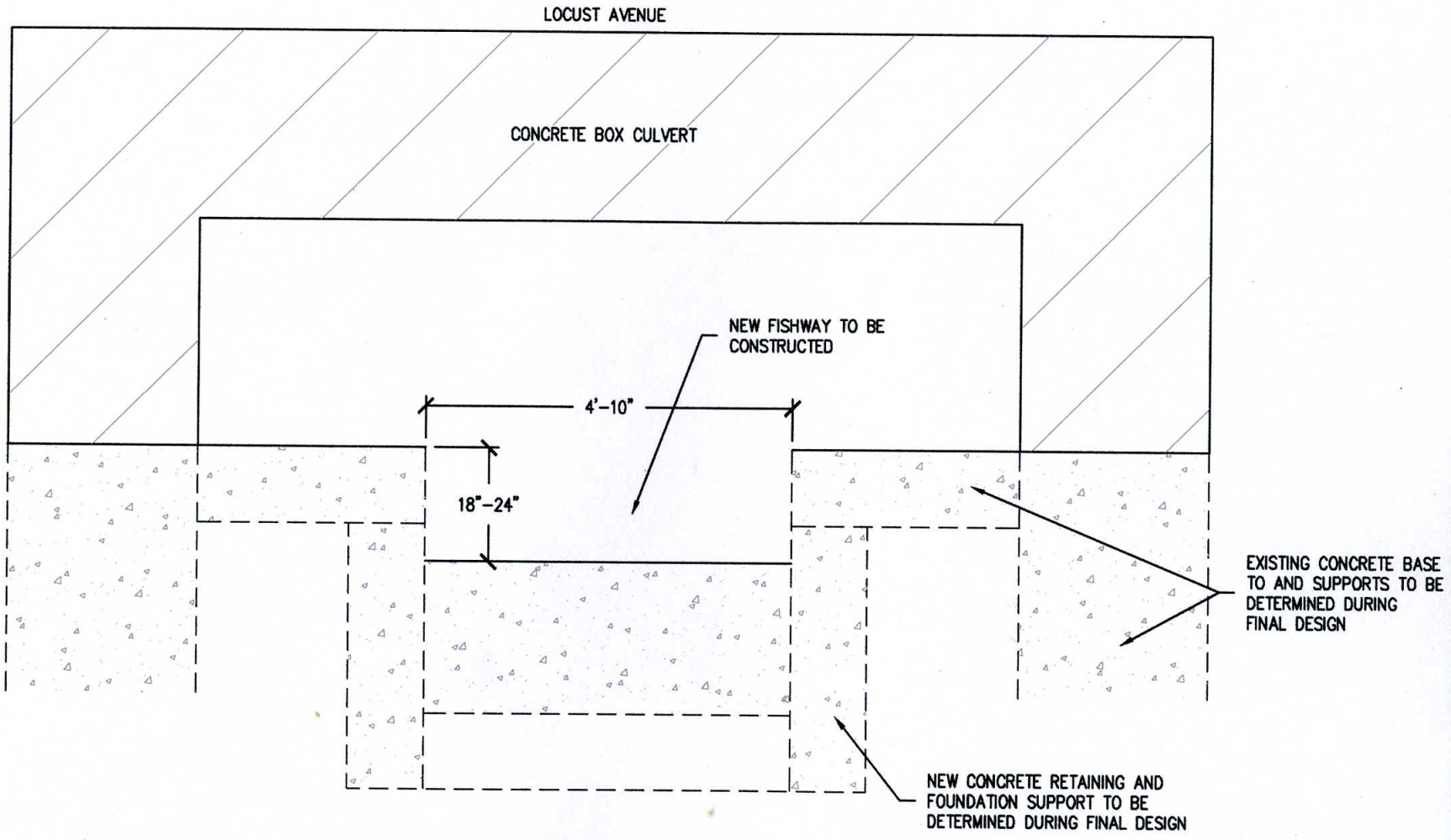

CULVERT SECTION

SCALE: 1"=2'

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FIGURE 2
MILL VALLEY FISH BARRIER CULVERT MODIFICATIONS
SECTION THROUGH CULVERT MR-068
LOW FLOW FISH CHANNEL ALTERNATIVE

DATE:	12/09/2004
SCALE:	1"=2'
SHEET:	2 OF 6

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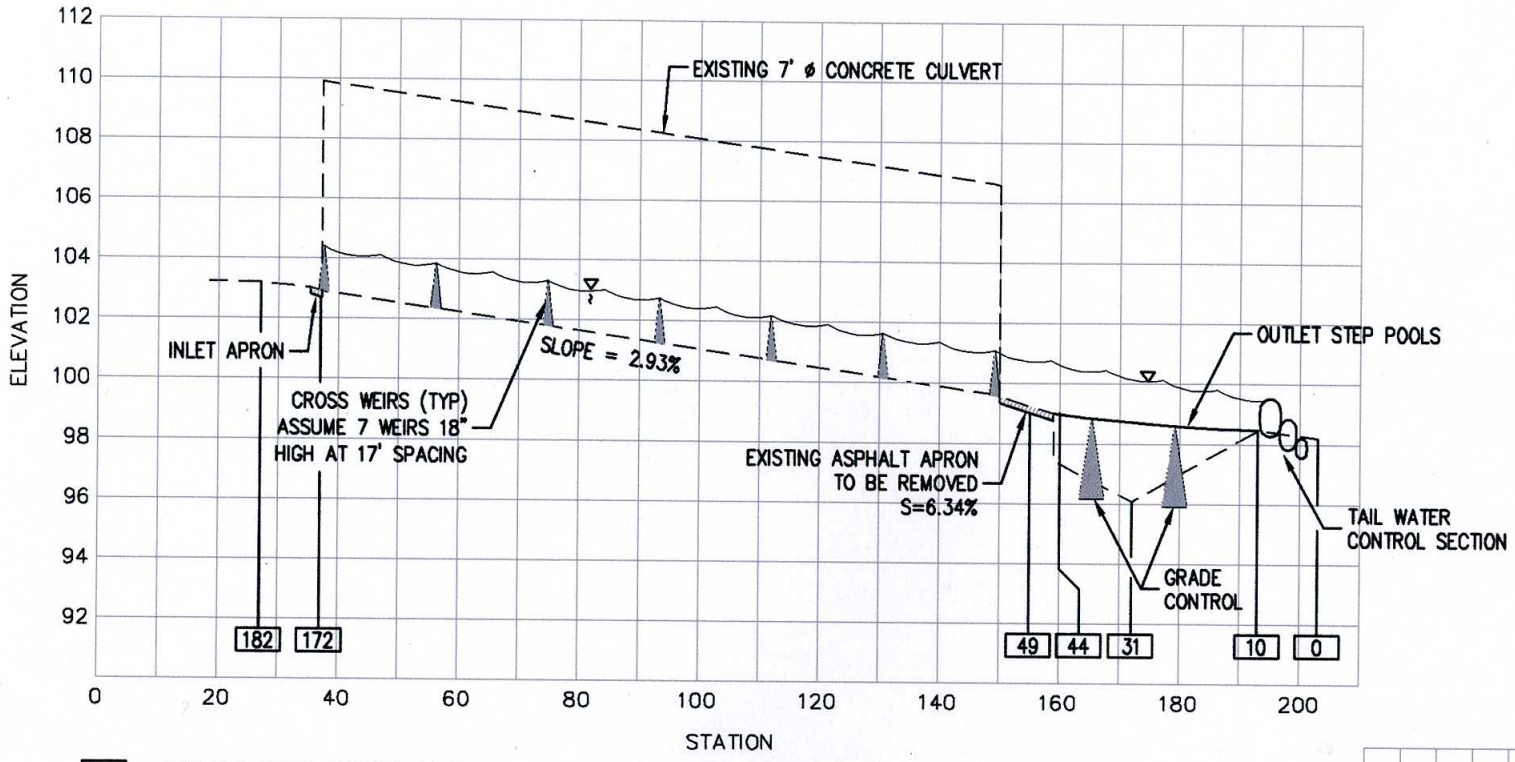
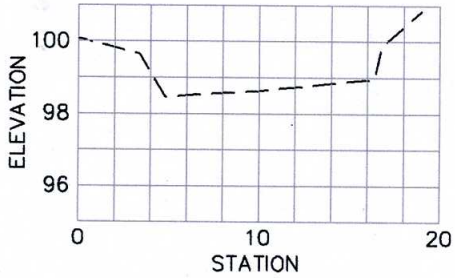


10 = HEC-RAS CROSS SECTION LOCATION

CULVERT PROFILE

SCALE: 1"=30'(H), 1"=6'(V)



CULVERT CROSS SECTION @ STA 193

SCALE: 1"=10'(H), 1"=5'(V)

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FIGURE 3
MILL VALLEY FISH BARRIER CULVERT MODIFICATIONS
ARROYO CORTE MADERA DEL PRESIDIO #2
UNDER BUILDING (MR-069)

DATE: 12/09/2004
SCALE: AS NOTED
SHEET: 3 OF 6

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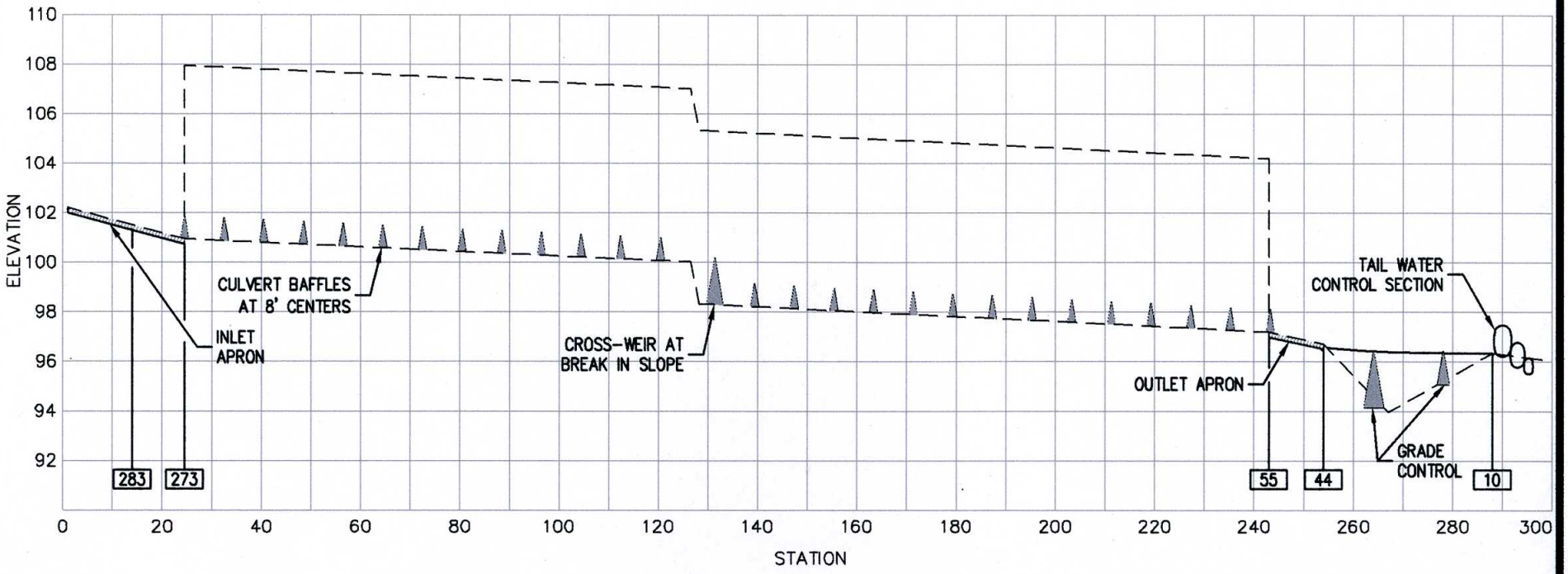
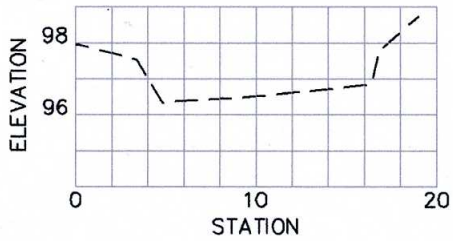


CULVERT PROFILE

SCALE: 1"=30'(H), 1"=6'(V)

10 = HEC-RAS CROSS SECTION LOCATION



CULVERT CROSS SECTION @ STA 288

SCALE: 1"=10'(H), 1"=5'(V)

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FIGURE 4
MILL VALLEY FISH BARRIER CULVERT MODIFICATIONS
OLD MILL CREEK #1
MILLER AVENUE (MR-075)

DATE: 12/09/2004

SCALE: AS NOTED

SHEET: 4 OF 6

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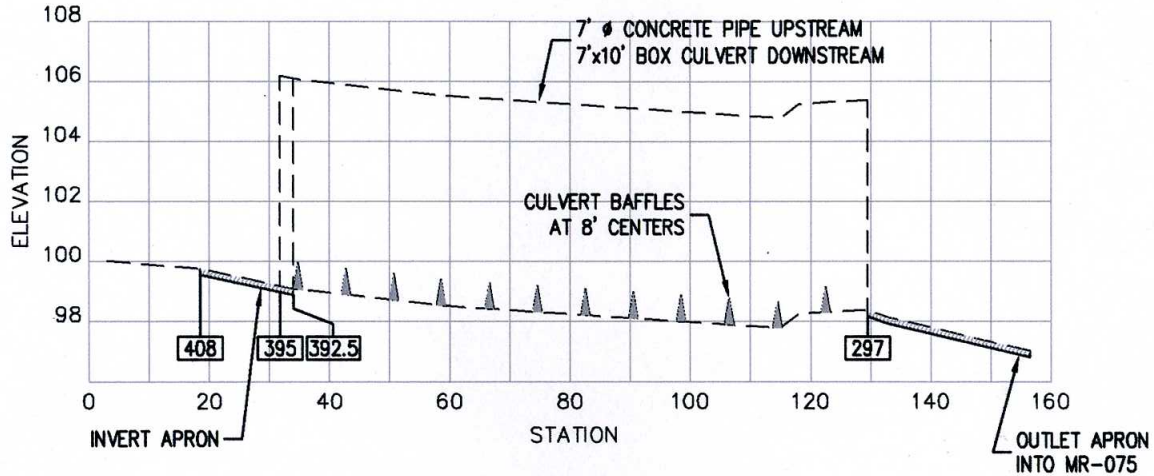

CULVERT PROFILE

SCALE: 1"=30'(H), 1"=6'(V)

297 = HEC-RAS CROSS SECTION LOCATION

FarWest RESTORATION ENGINEERING	FIGURE 5 MILL VALLEY FISH BARRIER CULVERT MODIFICATIONS OLD MILL CREEK #2 UNDER POST OFFICE (MR-076)	DATE: 12/09/2004 SCALE: 1"=30'(H) 1"=6'(V) SHEET: 5 OF 6

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