Prepared for:
East Kaua'i Soil and Water Conservation District
Kaua'i, HI

Prepared by:
AECOM
Honolulu, HI
60185286
February 2011

Hanalei Valley Irrigation Intake Protection/Streambank Stabilization Preliminary Investigation

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EXECUTIVE SUMMARY

The intent of the Hanalei Valley Irrigation Intake Protection/Streambank Stabilization Preliminary Investigation project was to build on previous assessments and alternative development efforts to develop and evaluate two alternatives that will provide for reliable, long-term solutions to supply irrigation water from the Hanalei River to the Hanalei National Wildlife Refuge (NWR).

Through the initial assessment of alternatives, it was determined that providing a complete blockage of the current breach channel entrance may result in channel breaching events occurring either upstream or downstream of the existing site. It was determined that the best approach would be to develop a structure capable of withstanding the stream energy associated with high flows and that would control the amount of water exiting from the main Hanalei River and entering the breach channel.

The project efforts also investigated the use of rock vanes or stream barbs to redirect the erosive velocities of the river away from the bank and into the center of the river. The vanes could also be used to develop desirable flow conditions downstream of the breach that would improve sediment transport through the reach.

Two alternatives were developed and are presented in this report. Both alternatives provide for maintaining flows in the main channel of the Hanalei River and supplying the NWR diversion structure with adequate flows.

Alternative No. 1 is designed to restore the historic river bank. The restoration effort would tie into existing stream bank elevation upstream and downstream of the current breach location with a weir constructed at the current breach location. The weir would have a 4-foot (ft) diameter Corrugated Metal Pipe (CMP) through it to provide low flows into the breach channel. Rock vanes would also be used in the project-river reach to protect the streambank immediately upstream of the breach and improve sediment transport capabilities downstream of the breach.

Alternative No. 2 also incorporates the construction of a weir at the breach location. The crest elevation of the weir would be set to restrict high flows from entering the breach channel up to approximately the “bank full” condition. As with the first alternative, a 4-ft diameter CMP would be used to allow for low flows to enter the breach channel and rock vanes would be used to protect against stream bank erosion and improve sediment transport capacity through the project reach.

The estimated construction costs associated with each alternative are similar in magnitude, with Alternative No. 1 expected to cost $1.1 million and Alternative No. 2 expected at $1.0 million. The construction materials generally consist of large precast concrete blocks and cement grouted rock. The reduced cost for Alternative No. 2 reflects the lower volume of imported rock and concrete due to the lower weir crest elevation.

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ACRONYMS AND ABBREVIATIONS

%	percent
AHR	American Heritage River
ARMD	Agricultural Resources Management Division
BMP	Best Management Practice
CDUA	Conservation District Use Application
CDUP	Conservation District Use Permit
cfs	cubic feet per second
CMP	Corrugated Metal Pipe
CWA	Clean Water Act
CWB	Clean Water Branch
CWRM	Commission on Water Resource Management, DLNR, State of Hawaii
cy	cubic yard
CY	calendar year
CZM	Coastal Zone Management
DA	Department of the Army
DBEDT	Department of Business, Economic Development and Tourism , State of Hawaii
DLNR	Department of Land and Natural Resources, State of Hawaii
DOA	Department of Agriculture, State of Hawaii
DOH	Department of Health, State of Hawaii
EA	Environmental Assessment
EIS	Environmental Impact Statement
EKSWCD	East Kauaʻi Soil and Water Conservation District
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act
ft	foot/feet
ft^2	square feet
FONSI	Finding of No Significant Impact
GIRC&D	Garden Island Resource Conservation and Development
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HWH	Hanalei Watershed Hui
JD	Jurisdictional Determination
LiDAR	Light Detection and Ranging
M&N	Moffat and Nichol
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
NWR	National Wildlife Refuge
O&M	Operation and Maintenance
OCCL	Office of Conservation and Coastal Lands, DLNR, State of Hawaii
OP	Office of Planning, DBEDT, State of Hawaii
SCAP	Stream Channel Alteration Permit
SHPD	State Historic Preservation Division
SMA	Special Management Area
SMAP	Special Management Area Permit
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

WHIP	Wildlife Habitat Incentives Program
WO	Watershed Operations
WQC	Water Quality Certification
WSE	water surface elevation
WSP	Watershed Surveys and Planning
WY	water year
XS	cross section

1.0 INTRODUCTION

The Hanalei National Wildlife Refuge (NWR), located in the Hanalei Valley on the north shore of the Island of Kauaʻi (Figure 1-1), was established in 1972 to provide a habitat for endangered Hawaiian waterfowl, including aeʻo (Hawaiian stilt), ʻalae ʻula (Hawaiian moorhen); ʻalae keʻokeʻo (Hawaiian coot); koloa maoli (Hawaiian duck); and nēnē (Hawaiian goose). Within the NWR are commercial taro farms that produce more than 1/3 of all taro used to manufacture poi in the State of Hawaii. Taro is grown in inundated ponds, known as loʻi, which require a constant flow of irrigation water. The operation of taro fields within the refuge provides open water habitat for the waterfowl within the refuge while also providing for cultivation of the culturally significant crop.

The Hanalei River is the source of the irrigation water required to keep the ponds inundated, making the area good for both taro cultivation and as a bird habitat. Water is withdrawn from the river near the upstream boundary of the NWR and conveyed to the taro and wildlife ponds through a diversion structure, associated ditches, and pipelines. Beginning in 1995, high flow events in the Hanalei River have led to repeated channel avulsion events that have adversely impacted the supply of water at the diversion structure. Currently a portion of the Hanalei River flow bypasses the diversion structure through a permanently-flowing breach new channel. This new river course has reduced the available flow at the diversion, resulting in adverse impacts to the diversion's ability to supply water to the NWR.

Local concern regarding a reliable water source for the taro fields and also concern for the general health of the river itself, has caused local stakeholders to request assistance from the National Resources Conservation Service (NRCS) to develop possible solutions. The East Kauaʻi Soil and Water Conservation District (EKSWCD), along with the NRCS, initiated the project to address these concerns.

The goals of the preliminary investigation are to identify, develop, and assess measures to protect the water supply for the NWR. To accomplish these goals, AECOM completed the following:

- Analyzed the existing condition related to high flow events in the project reach.
- Developed an understanding of the geomorphic processes within the river reach, including the sediment transport.
- Evaluated design parameters related to flow depth and velocity for proposed alternatives.
- Recommended specific solutions for stabilizing the stream reach.
- Provided cost estimates for the proposed alternatives.
- Evaluated and itemized permitting requirements.
- Researched potential funding sources.

The development of the alternatives required taking into account the needs and goals of multiple stakeholders, and attempted to work with the natural tendency of the Hanalei River to migrate across the river valley. Alternative selection criteria were developed, providing a quantitative method for comparing the two alternatives. The criteria included:

- Maintain Flow for NWR Diversion
- Risk of Future Breach
- Construction Cost
- Working with Nature

Approaches to the alternative development were built from previous investigative efforts of the Hanalei River and the issues associated with the relationship between the breach channel and water supply.

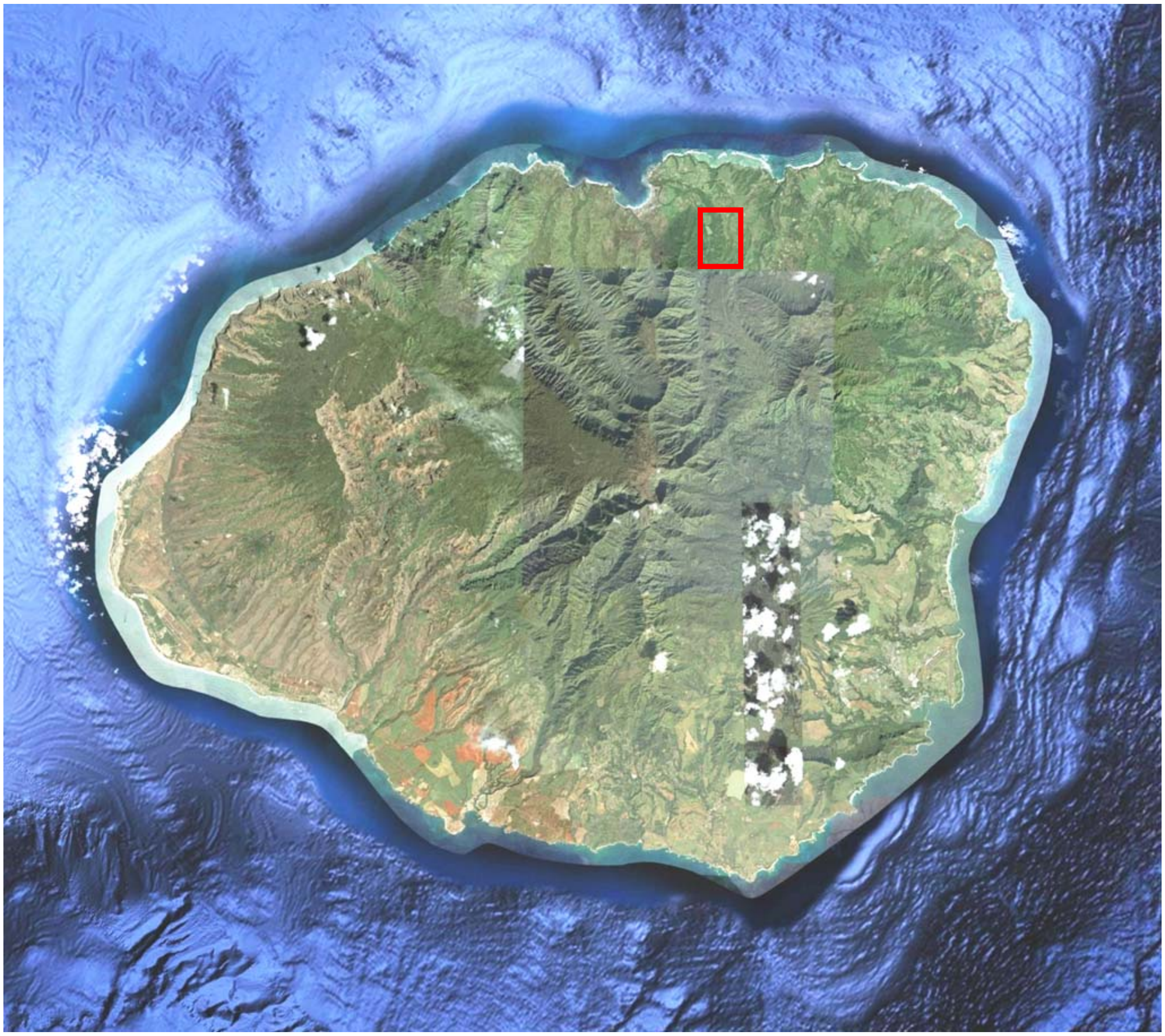

Figure 1-1: Vicinity Map for the Hanalei Valley Irrigation Intake Protection/Streambank Stabilization Preliminary Investigation

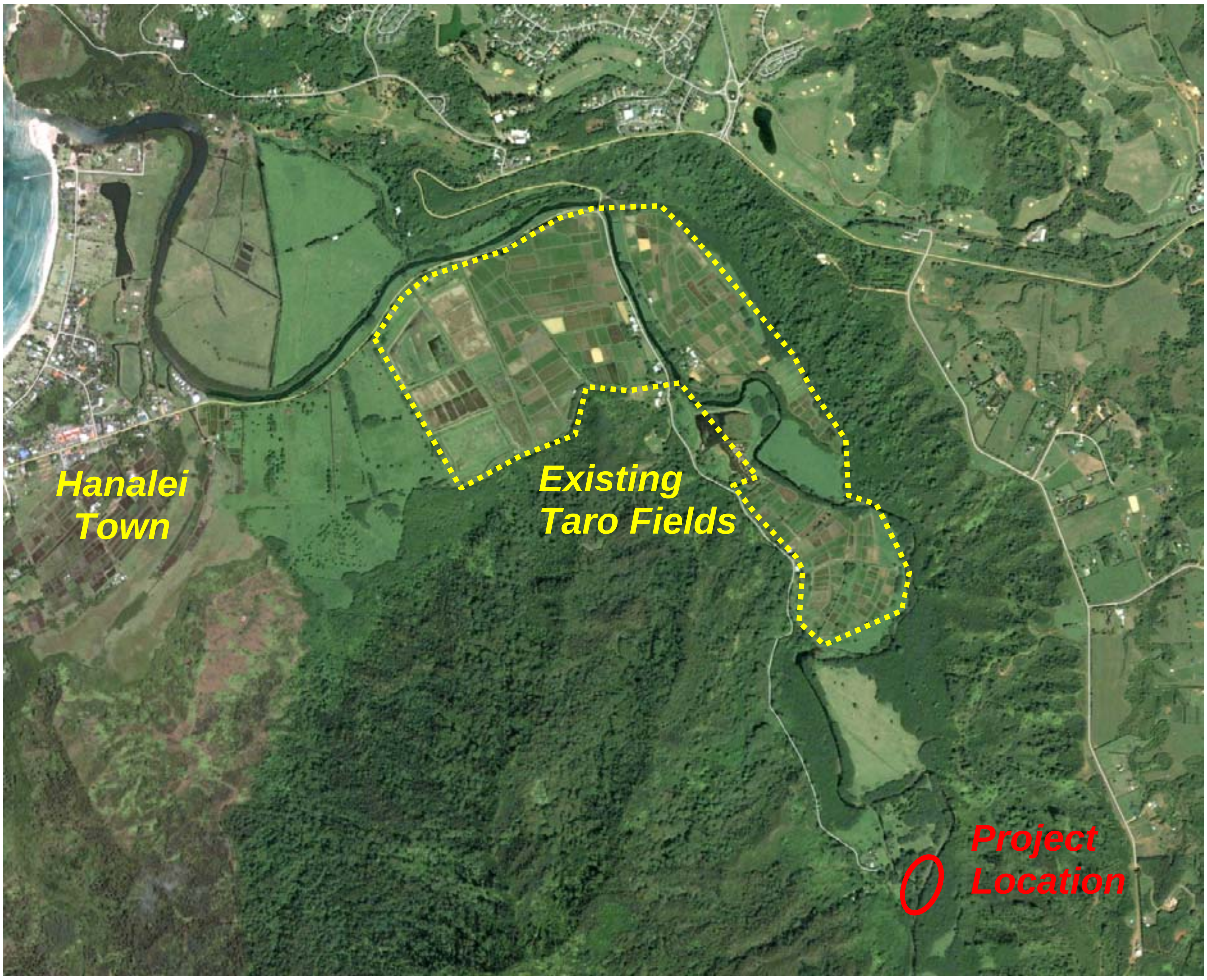

Figure 1-2: Project Location Relative to Taro Fields

2.0 BACKGROUND

The supply of water to the Hanalei NWR is controlled by a diversion structure along the Hanalei River. The concrete structure contains an adjustable sluice gate that, based on the stage in the river, controls the volume of the flow conveyed from the river to the taro ponds in the NWR.

The current diversion system was constructed near river mile 4.5 in the 1980's to replace an aging open ditch system. High maintenance costs and the fact that much of the open ditch alignment was inside the NWR boundaries made development of the new system desirable. The existing diversion system, completely located within the NWR boundary, has a flow capacity of 50 cubic ft per second (cfs). Once water is diverted from the Hanalei River at the concrete intake structure (Figure 2-1), it enters a larger diameter pipeline consisting of mostly 48-inch pipe. The pipeline runs in a northerly direction toward the NWR's taro fields, the pipeline crosses the Hanalei River using an inverted siphon. The flow then enters into a pipe manifold, delivering flow to a series of irrigation distribution laterals before finally reaching the taro patches.

Figure 2-1: The Hanalei River Diversion Structure

2.1 BREACH CHANNEL DEVELOPMENT

The first known breaching event on the Hanalei River associated with the project area resulted from the November 1995 flood event. This event corresponds with the largest recorded peak flow on the Hanalei River: 44,600 cfs. The elevated river stage associated with the flood event resulted in river flow overtopping the left bank (looking downstream) and carving out a side channel (Figure 2-2). According to United States (U.S.) Geological Survey (USGS) estimates, following the initial breach the bypass channel captured approximately half of the flow in the river (USGS 1999) during subsequent high flow events. During low flow conditions, the split flow between the main stem Hanalei River and the breach channel limits the amount of flow delivered to the NWR diversion structure.

Figure 2-2: Hanalei River Breach Channel Location

In response to the adverse impact to their water supply, the U.S. Fish and Wildlife Service (USFWS) used heavy machinery to pile rock material at the upstream end of the breach, plugging the bypass channel and returning all flows back to the Hanalei River.

Since the initial 1995 breach and repair, subsequent high flow events have reactivated the breach channel. After a high flow event reopened the breach channel in September 1996, the USFWS under pressure from local residents did not repair the breach opening. In early 1999, another high flow event caused the breach channel to capture more of the Hanalei River flow to where almost all flow entered the breach channel. The USFWS used heavy equipment to dredge the main channel so that adequate river flow was returned to the diversion structure. This continued practice has sustained the flow in the main stem of the Hanalei River while allowing water to still flow through the breach channel.

2.2 PREVIOUS STUDIES

One of the goals of this project is to build off previous efforts related to the Hanalei River breach channel and flow diversion for the Hanalei NWR. A recent effort titled Preliminary Feasibility Assessment – Hanalei River Diversion (Moffat and Nichol 2007) investigated whether the diversion structure could be moved to a location where the breach channel would have reduced or negated impacts. The report assessed four alternatives, and included a feasibility-level comparison of probably construction costs, Operation and Maintenance (O&M) costs, environmental impacts, and sensitivity to channel avulsion (Table 2-1). The least-cost alternative was determined to be Alternative No. 2: Weir at the Breach to Maintain Main Channel Flow. As such the current study has been developed to further develop the design concepts, potential impacts, and construction requirements for a breach channel weir.

Table 2-1: Alternative Advantages and Disadvantages (Source Moffat & Nichol, 2007)

Alternative	Probable Construction Cost	Probably Annual O&M Cost	Environmental Impacts	Construction Outside NWR?	Sensitivity to Channel Avulsion
1: Diversion Structure Upstream of Breach	$1,300,000 [a]	Small [a]	Low	Yes	Low
2: Weir at the Breach to Maintain main Channel Flow	$400,000 [b]	Variab [b]	Low	Yes	High
3: Diversion Structure and Pump Near Inverted Siphon	$980,000	$84,000 – $111,000	Low	No	Low
4: Diversion Structure and Weir Near the Confluence	$1,400,000	Small	High	No	Medium

Notes:

[a] Construction cost and maintenance cost assume a pipeline from the new diversion structure to the existing diversion structure. Costs should be quite different if the approach were to repair the old China Ditch irrigation System.

[b] Construction cost assumes a rock weir, which has the lowest construction costs but will likely require significant ongoing maintenance after flood event. Alternative include sheet pile or concrete weirs.

3.0 STAKEHOLDER INPUT

A successful project requires recognizing and attempting to address the concern of all stakeholders to the extent possible. Due to the cultural, economic and environmental importance of the Hanalei River, many groups are included as stakeholders for this project. These groups include federal, state, and local agencies, local farmers and landowners, and concerned groups and citizens.

There were two stakeholders meetings held prior to the beginning of major efforts associated with the Hanalei River project. The first meeting was held July 1, 2010 at the Laney/Morita residence near the project site. The AECOM project team, NRCS and EKSWCD personnel, representatives of the taro growers and community associations, and the project site leaseholders attended the meeting. The purpose of the initial meeting was to obtain input from the people who may be directly impacted by the project and to discuss any project concerns.

The outcome of the July 1, 2010 meeting was a list of concerns that would need to be addressed in the development and assessment of the project alternatives. The major project issues are listed below:

- Project outcome needs to be able to withstand site conditions so that future emergency actions are not required.
- Provide safe habitat and passage for native o’opu.
- Address mosquito issues associated with standing water.
- Discourage use and promulgation of invasive species.
- Provide alternatives appropriate for the natural environment.

The second stakeholders meeting was held on July 2, 2010 at the Waiʻoli Huiʻia Church in Hanalei town. The intent of this meeting was to provide concerned people with details of the project issues, goals, and approaches for the project. This meeting was attended by the AECOM team, NRCS and EKSWCD personnel, local taro farmers, and a group of local youth volunteers. The meeting was more general with most attendees just wanting to hear the background information and how the project would move forward.

The meeting minutes and attendees list for each of the meetings are located in Appendix A

4.0 EXISTING CONDITIONS INVENTORY AND ANALYSIS

Before the development of alternatives designed to meet the project goal of providing a reliable flow to the Hanalei NWR diversion structure can be complete, it is necessary to develop an understanding of the natural and man-made environments of the project site. This section of the report details the existing conditions that will guide the development of alternatives. Included are assessments of: Site Condition, Hydrology, River Hydraulics, and Geomorphology. Through the assessment of the existing conditions a more complete vision of why the breach has occurred, how best to take advantage of site conditions, and how to stay clear of constraints.

4.1 SITE CONDITIONS AND TOPOGRAPHY

The existing Hanalei River breach channel is located along the left bank of the river approximately 1,600 ft upstream of the NWR diversion structure. Figure 4-1 is a photograph of the upstream end of the breach taken in July 2010. The breach was initiated during a high flow event where floodwaters overtopped the left bank and cut a side channel through a historic wetland. The breach location (Figure 2-2), has developed an approximately 1,300-ft long channel with a top of bank widths of approximately 40-ft. The breach channel conveys a portion of the flow in the Hanalei River bypassing roughly 2,500 ft of the river.

Figure 4-1: The Entrance of the Hanalei Breach Channel

The reach of the Hanalei River near the breach is a well defined channel with vegetated banks. Figure 4-2 illustrates the Hanalei River cross section immediately downstream of the where the breach channel is located. The cross section is oriented looking downstream. The cross section data is a combination of surveyed data within the channel to top of bank and also sampling of the Light

Detection and Ranging (LiDAR) data for the floodplain and overbank area. The channel slope for the project of the Hanalei River is approximately 0.7 percent (%).

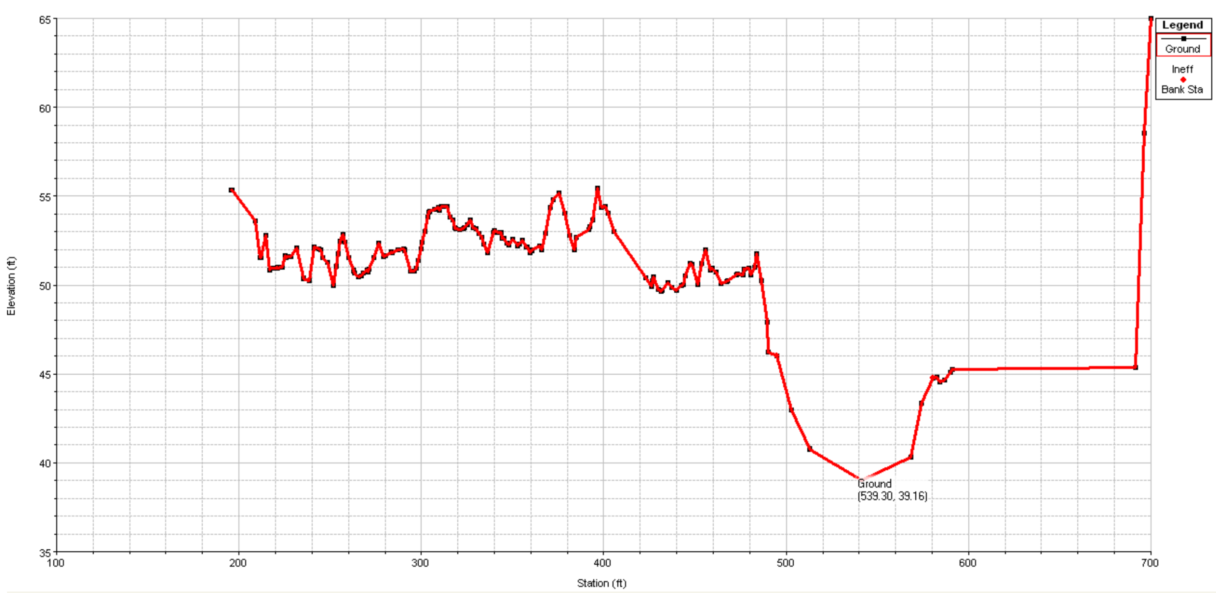

Figure 4-2: Hanalei River Cross Section Downstream of Breach

Figure 4-3 is a cross section of the breach channel near the midpoint of the channel. The sloping left bank represent the grassy expanse associate with the Morita residence. Because the breach channel is approximately 1,200 ft shorter than the Hanalei River, the channel is steeper, 1.6%. The steeper slope associated with the breach channel encourages flow in the river to find the shortest, steepest flow path, resulting river flow being attracted to the breach channel. The right extent of the cross section has been modified for Hydrologic Engineering Centers River Analysis System (HEC-RAS) modeling purpose by creating a near vertical slope.

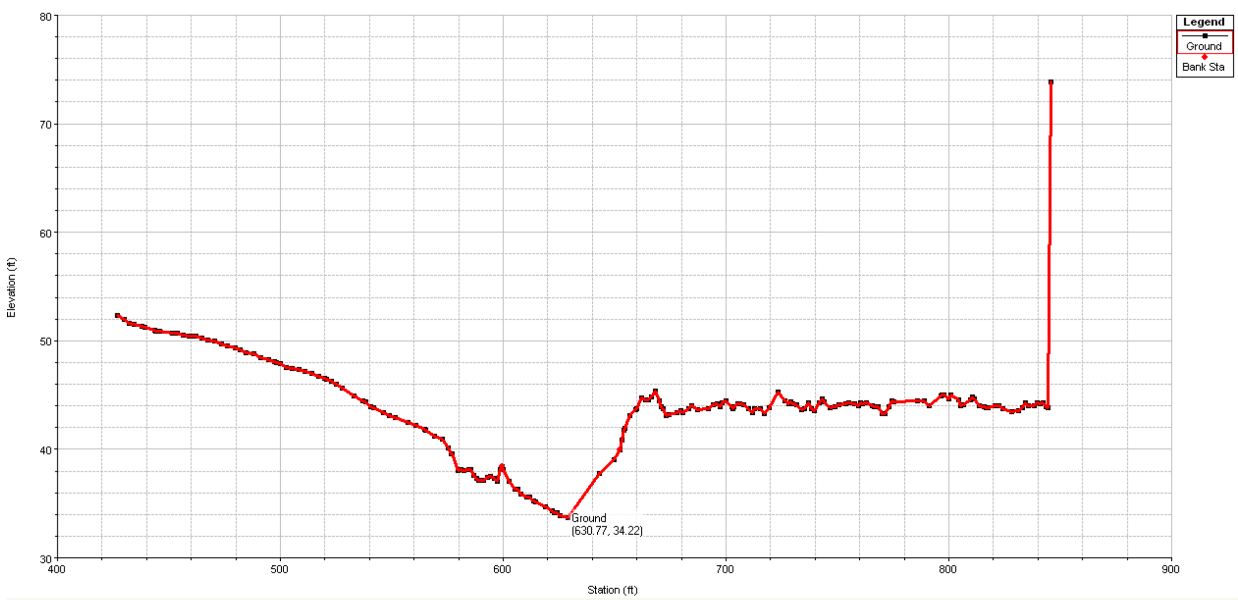

Figure 4-3: Cross Section of Breach Channel

4.2 HYDROLOGY

A hydrologic analysis of the historic Hanalei River flows was conducted to develop an understanding of the design flow rates to be incorporated in the development and assessment of the project alternatives. The USGS has operated a continuous recording stream gage on the river since 1962. The original location of the gage was approximately 500 ft upstream of the intake structure. In the year 2000, following the repeated breach channel incidents, the gage was relocated about 2,000 ft upstream of the channel breach. Figure 4-4 shows the two locations of the gage along the Hanalei River. Table 4-1 provides a data summary for the gage.

Figure 4-4: The Hanalei River USGS Stream Gage Locations

Table 4-1: USGS Hanalei River Flow Gage Summary

Gage ID	Gage Name	Drainage Area	Average Daily Flow for WY 2009	Maximum Recorded Flow	Minimum Average Daily Flow
16103000	Hanalei River nr Hanalei, Kaua'i, HI	18.7	206	44,600 cfs (November 3, 1995)	31 Multiple occurrences Fall 1975

WY water year

4.2.1 Flood Frequency Analysis

The USGS Hanalei River gage has historically recorded stream flows at hourly and 30-minute intervals. Along with the time interval records, the gage also records peak flows based on recorded peak stage elevations in the river channel at the gage. Using the annual peak flow rates, a flood-frequency analysis was used to estimate the magnitude and frequency of flood discharges based on recorded historic flows. Frequency commonly is expressed in terms of exceedance probability (a dimensionless number ranging from 0 to 1.0) or as a recurrence interval (the reciprocal of exceedance probability) in years, such as the 100-year flood event. The recorded annual peak flows for the Hanalei River gage are plotted in Figure 4-5.

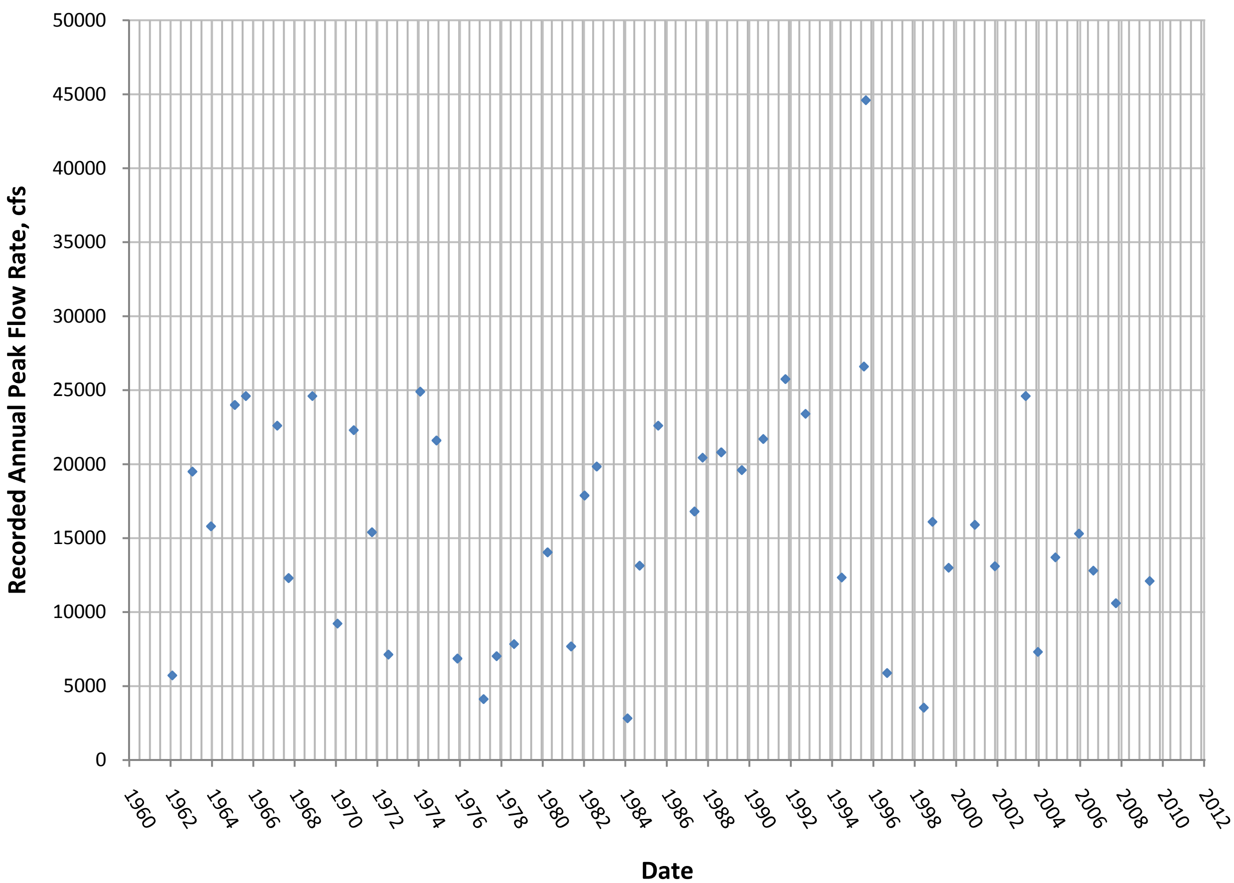

Figure 4-5: Recorded Annual Peak Flow at the Hanalei River USGS Gage 16103000 (WY 1960 – 2009)

For the period of record of Water Year (WY) 1962-2009 shown in Figure 5-3, peak flows generally ranged between 5,000 and 26,000 cfs. The November 1995 (WY 1996) peak flow of 44,600 cfs stands out as considerably higher than any previous recorded peak. Because the November 1995 flow is so distinct, it is worth considering whether factors other than rainfall could have affected the event.

One condition that could result in an unusually high peak flow would be a debris burst, where a landslide temporarily blocks the river channel creating a storage area upstream of the blockage. When the volume of trapped water overtops the debris dam there is a rapid release of the stored water creating a floodwave that travels downstream.

Another possible cause could be an unusually high sediment load being conveyed through the system. For heavy sediment loads (mudflows), the volume of sediment can be near 30% of the total volume. This results in “debris bulking”, where typical volumes of water appear larger because the water is mixed with a heavy load of rocks and sediment. Recording flow gages do measure flow, they record the stage (water surface) of the river and then estimate flow based on the rating curve for the gage site. For example, a debris flow of 34,000 cfs may result in a recorded river stage that corresponds to a flow of 44,600 cfs due to the 30 % mixture of water and debris.

A third possible condition that could lead to the high flow rate would be a high volume of precipitation. A review of the rainfall measured in the area in relation to the peak flow was conducted for the Hanalei River recorded peaks. Table 4-2 lists the annual peak flows for Water Years 1993–2009 recorded at the USGS gage, along with corresponding 24-hour recorded rainfall totals at a location on Mt. Waiʻaleʻale in the Hanalei River headwaters for the day of the peak flow event, as well as the day prior to the peak flow. The recorded data indicates the rainfall associated with the November 1995 is not particularly large when compared to other recorded storm events. The recorded rainfall total for the November 1995 event is very similar to the rainfall total associated with the February 2001 peak flow of 15,900 cfs. Of course, the daily total rainfall data that is provided does not provide a direct indicator of the peak rainfall intensity typically expressed in inches per hour. If the recorded daily total of November 1995 included a period of very high intensity, then perhaps the resulting peak flow in excess of 44,000 cfs is reasonable.

Table 4-2: Annual Peak Flows and Associated Precipitation Data for the Hanalei River, WY1993-2009

			Mt. Waiʻaleʻale Precipitation (in)		
Water Year [a]	**Date**	**Recorded Peak Flow (cfs)**	**2-Day Total**	**Previous Day**	**Day of Peak**
1993	12/3/1992	23,400	13.27	1.43	11.84
1994	9/2/1994	12,340	9.10	7.88	1.22
1995	9/30/1995	26,600	16.4	1.71	14.69
1996	11/3/1995	**44,600**	**14.06**	**3.13**	**10.93**
1997	11/12/1996	5,880 [b]	16.48	0.44	16.04
1998	8/23/1998	3,540 [b]	8.80	5.14	3.66
1999	1/22/1999	16,100	9.79	1.60	8.19
2000	11/4/1999	13,000	7.89	0.18	7.71
2001	2/9/2001	15,900	14.61	3.92	10.69
2003	7/26/2003	24,600	10.64	6.04	4.60
2004	2/27/2004	7,310	10.99	4.62	6.37
2005	1/1/2005	13,700	10.10	3.08	7.02
2006	2/21/2006	15,300	19.54	7.74	11.80
2007	11/1/2006	12,800	10.01	1.18	8.83
2008	12/5/2007	10,600	5.04	4.67	0.37
2008	7/23/2009	12,100	6.39	0.92	5.47

[a] Water Year 2002 did not have corresponding rainfall so it is not shown.
[b] Breach channel was open with a majority of flow bypassing the USGS Gage.

In developing the design flows for the Hanalei Project, it was decided to conduct the flood frequency analysis with and without the November 1995 event. This approach will provide a better understanding of how a single significant flood event may impact the statistical approach used in the flood frequency analysis. The USGS program PKFQWin was used to estimate the peak flow rates associated with various flood return intervals using the Bulletin 17B approach (Flynn et al. 2006).

Figure 4-6 graphs the results of the flood frequency analysis along with the annual recorded peak flows. As the graph illustrates, the November 1995 flood event has a significant impact on the analysis results. Including the November 1995 event skews the lower 95% Confidence Limit so that the recorded flows fall below the limit. The numeric results presented in Table 4-2 indicate the inclusion of the November 1995 data point increases the estimated peak flow for the 10-year by 7.5%, from 26,250 cfs to 28,230 cfs. Estimated peak flow for the 25-year storm differs by 9.9%, increasing from 31,430 cfs to 34,540 cfs.

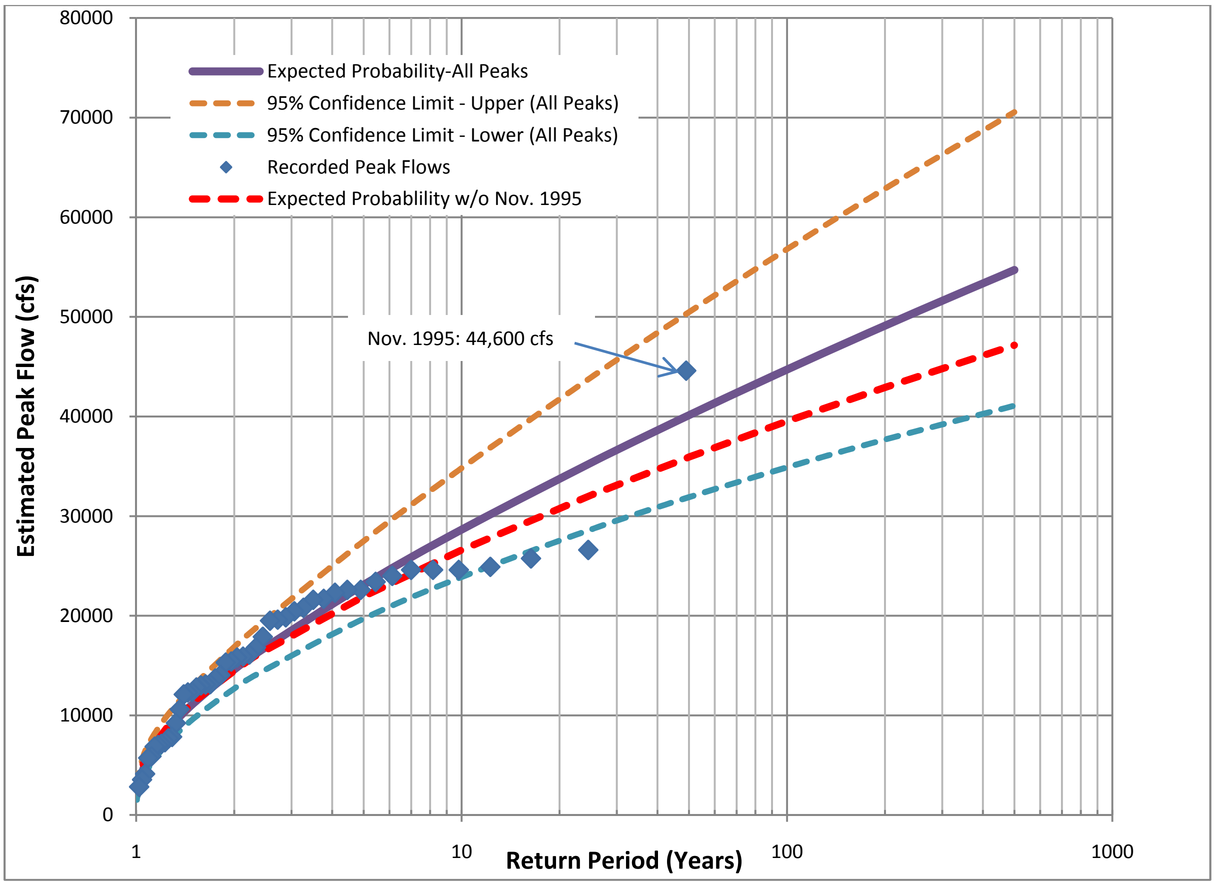

Figure 4-6: Flood Frequency Analysis for the Hanalei River

Table 4-3: Hanalei River Flood Frequency Analysis

Annual Exceedance Probability	Recurrence Interval	Bulletin 17B Peak Flow Rates (cfs)	
		w/o Nov 1995	With Nov 1995
0.95	1.05	5,274	4,867
0.9	1.11	6,758	6,366
0.8	1.25	8,949	8,639
0.6667	1.5	11,420	11,270
0.5	2	14,470	14,610

Annual Exceedance Probability	Recurrence Interval	Bulletin 17B Peak Flow Rates (cfs)	
		w/o Nov 1995	With Nov 1995
0.4292	2.3	15,870	16,170
0.2	5	21,780	22,930
0.1	10	26,250	28,230
0.04	25	31,430	34,540
0.02	50	34,950	38,930
0.01	100	38,190	43,050
0.005	200	41,210	46,940
0.002	500	44,900	51,780

4.2.2 Flow Duration Curve

The flow duration curve is a plot of recorded flows that illustrates the percentage of time that a flow in a stream or river is likely to be equaled or exceeded. The shape of the curve in the high-flow region indicates the type of flood regime the basin is likely to have, whereas, the shape of the low-flow region characterizes the ability of the basin to sustain low flows during dry seasons. A steep curve for high flows typically indicates rain-caused floods on small watersheds. In the low flow end of the curve, a flat curve indicates that moderate flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity, which sustains the base flow to the stream.

For developing in-stream hydraulic structures, a flow duration curve characterizes the relative amount of time that flows past a site are likely to equal or exceed a specified value of interest. With an understanding of the characteristics for the expected duration of flow, the proposed structures can be designed to withstand the forces of the flow over a period of time. In the case of the Hanalei River, an important aspect to the development of the alternatives will be to estimate if and for what duration the breach channel will be active during high flow events.

The Hanalei River flow duration curve shown in Figure 4-7 was developed using the USGS flow records with a 30-minute interval for the period of October 1, 1990 through September 30, 2008. As expected for a small watershed with large rainfall events and steep valley slopes, the high flow end of the curve is very steep, dropping from roughly 24,000 cfs to 1,000 cfs within the initial 4 percent of the duration curve. The flattened shape of the curve within the lower flows is indicative of a stream with a consistent groundwater contribution to baseflow.

4.2.3 Development of the Unit Storm Hydrograph

There are two important aspects related to flood events: the peak flow and the volume of the flow. The peak is important because it is related to the point when a high flow event provides the maximum energy and typically the maximum depth. The volume of flow is related to the shape or area under the curve of the flow hydrograph, which is a plot of the flow rate over time for a runoff event.

As the flows in the Hanalei River start to increase in response to a rainfall event, the energy of the flow also increases. The energy of the stream is the driving force for transporting sediment and bed material. To better understand the duration and shape of the hydrograph related to the flooding event on the Hanalei River, the recorded flows for the annual peak events were assessed. The hydrograph of each of the flood events were overlaid so that the peaks all occurred at the same time. Figure 4-8 shows how the flow hydrographs for each of the annual peak flows compare.

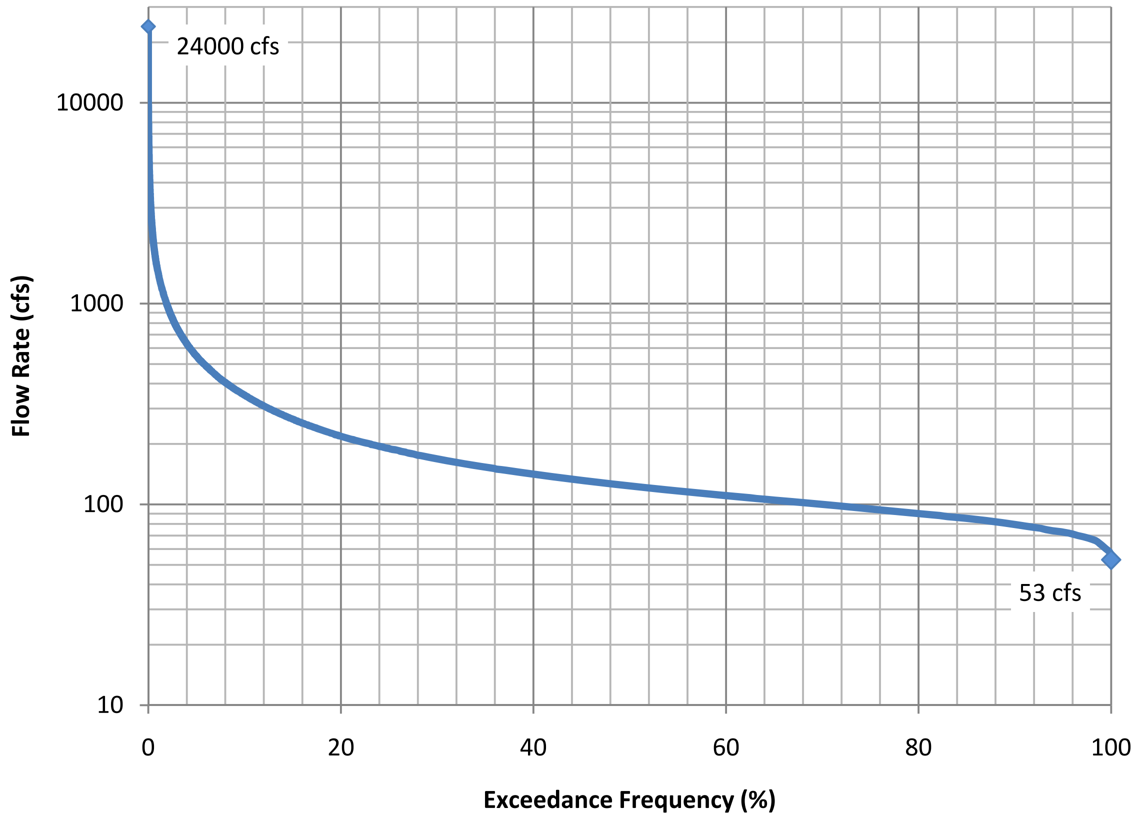

Figure 4-7: Flow Duration Curve for the Hanalei River, WY 1990-2008

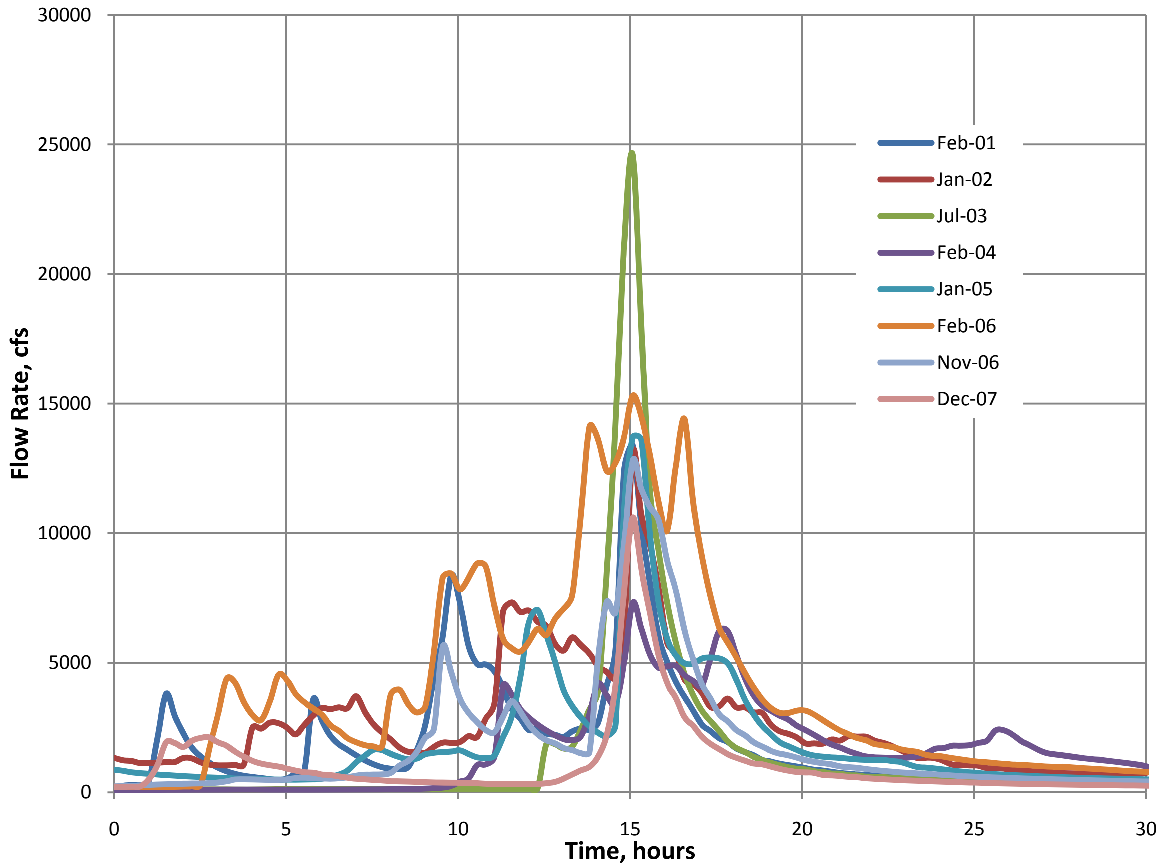

Figure 4-8: Peak Flow Hydrographs for the Hanalei River, WY 2001-2008

As Figure 4-8 illustrates, the typical flood event on the Hanalei River involves at least two peaks with the smaller peak coming before the larger peak. Rarely are there peaks following the largest peak. The duration of the hydrograph is generally 30 hours. Using the hydrographs shown in Figure 4-8, each one was unitized over the 30-hour time frame. The unit hydrographs for each of the annual peaks are shown in Figure 4-9. Along with the unitized hydrographs from the actual storm events, an average unit hydrograph was developed for use as the design unit storm hydrograph for the Hanalei River, for WY 2001-2008.

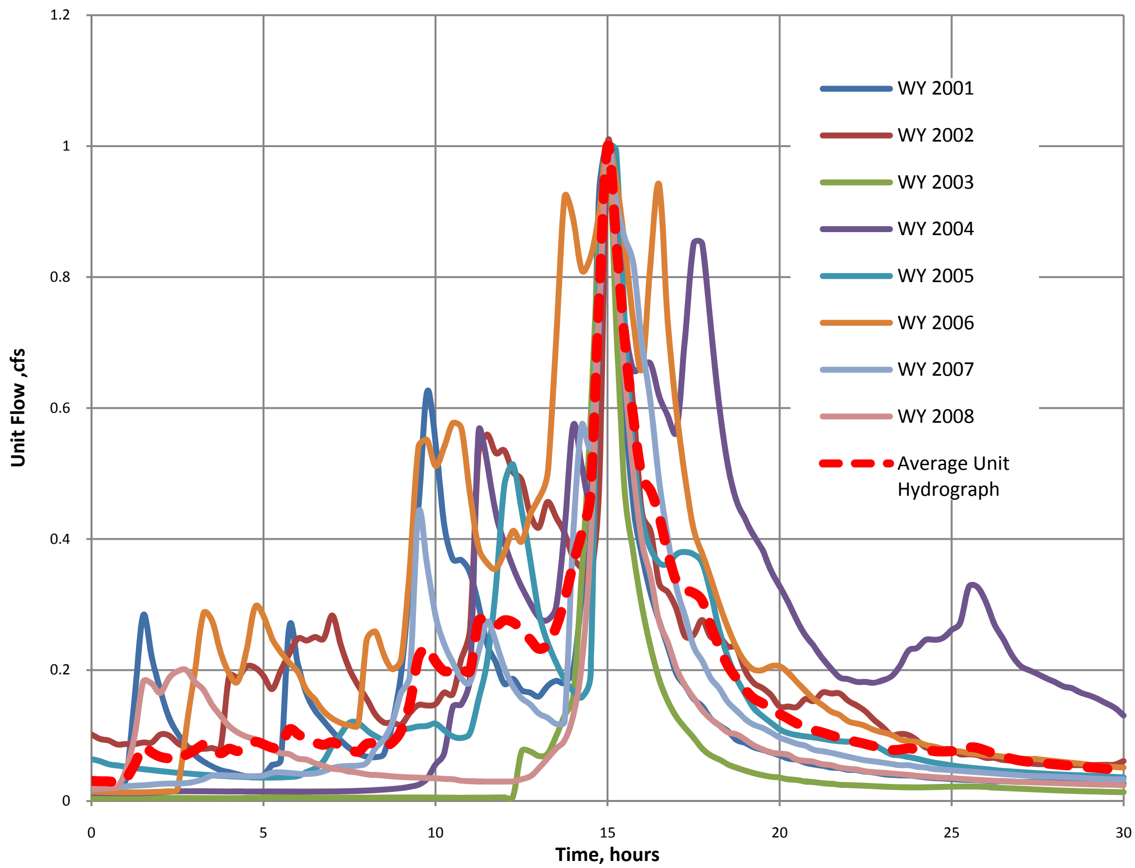

Figure 4-9: Unit Storm Flow Hydrograph for the Hanalei River

The unit hydrograph will allow for the scaling of any peak flow to create a complete storm hydrograph. For example, if the design peak flow is 20,000 cfs, the unit hydrograph can be scaled to produce a flood flow representative of the Hanalei River with a peak flow resulting with 20,000 cfs. Along with the flow duration curve, the unit hydrograph provides a tool for developing and assessing alternatives for the Hanalei River project site.

4.3 HYDRAULIC MODELING

The project reach of the Hanalei River is very high energy. During flood flows, the stream conveys large flows at high velocities having the capacity to transport large quantities of sediment and bed material. To develop a better understanding of the energy associated with the river as well as floodwater elevations, a hydraulic model of the project reach was created using the HEC-RAS modeling program developed by the U.S. Army Corps of Engineers (USACE). HEC-RAS is a one-dimensional hydraulic model used to estimate flow depths, velocity and other parameters in a riverine environment.

The USACE developed a geographic information system interface for the HEC-RAS program, HEC-GeoRAS, to create the channel geometry input files as well as map the model results. For the Hanalei River project, LiDAR topographic data was interfaced with the HEC-GeoRAS program. Figure 4-10 shows the HEC-RAS plan view of the project area. The orange lines represent the cross section locations and extent while the blue lines are the stream center lines.

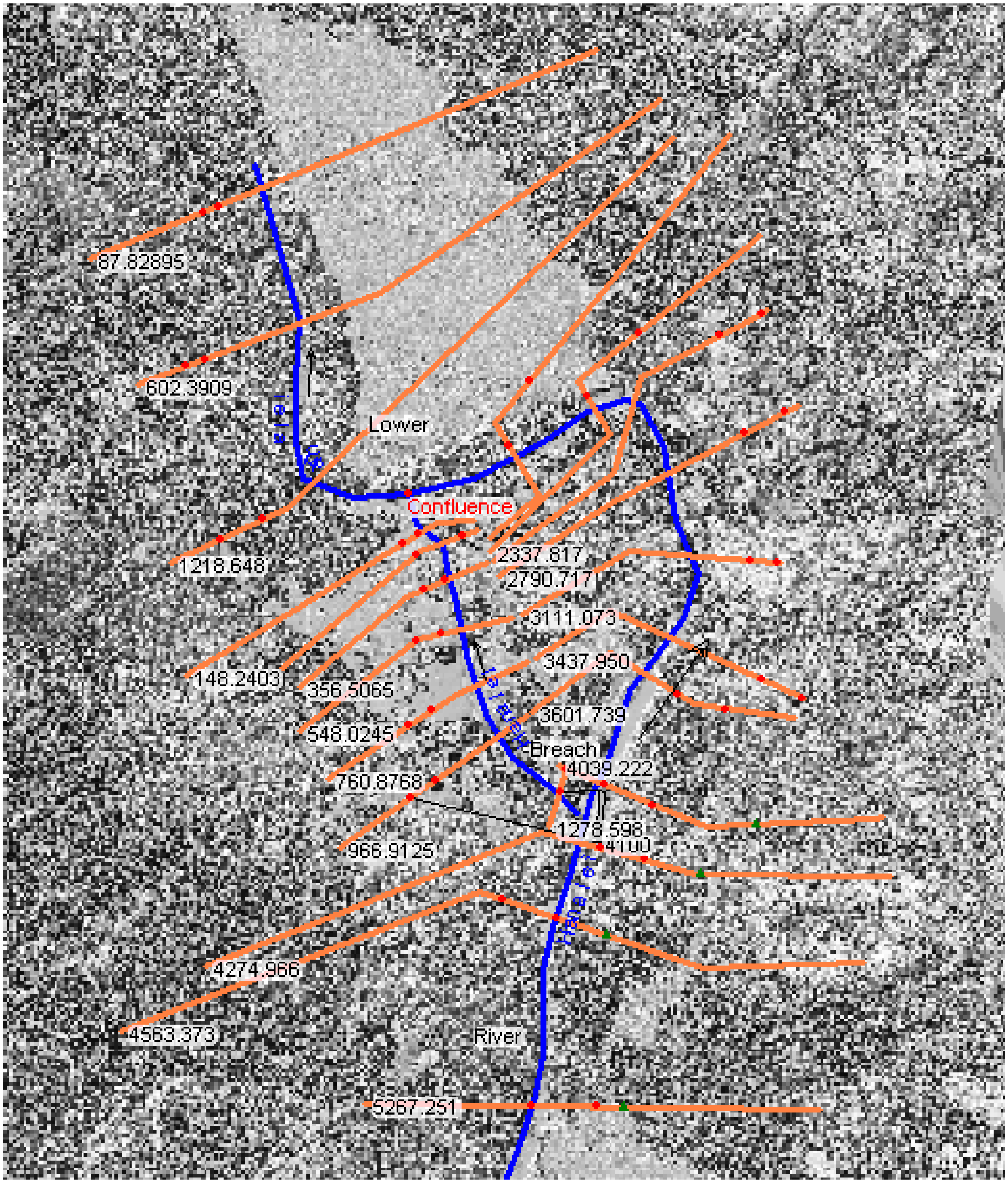

Figure 4-10: Hanalei River HEC-RAS Schematic

The background illustration is "hillshade" representation of the LiDAR data for the area. Due to the thick tree canopy in the area, the LiDAR data required heavy editing in order to provide a good modeling surface. Using HEC-GeoRAS, cross sections were derived from the LiDAR. Figure 4-11 shows the results of the initial HEC-GeoRAS cross section (gray line) and the final edited cross section (red line).

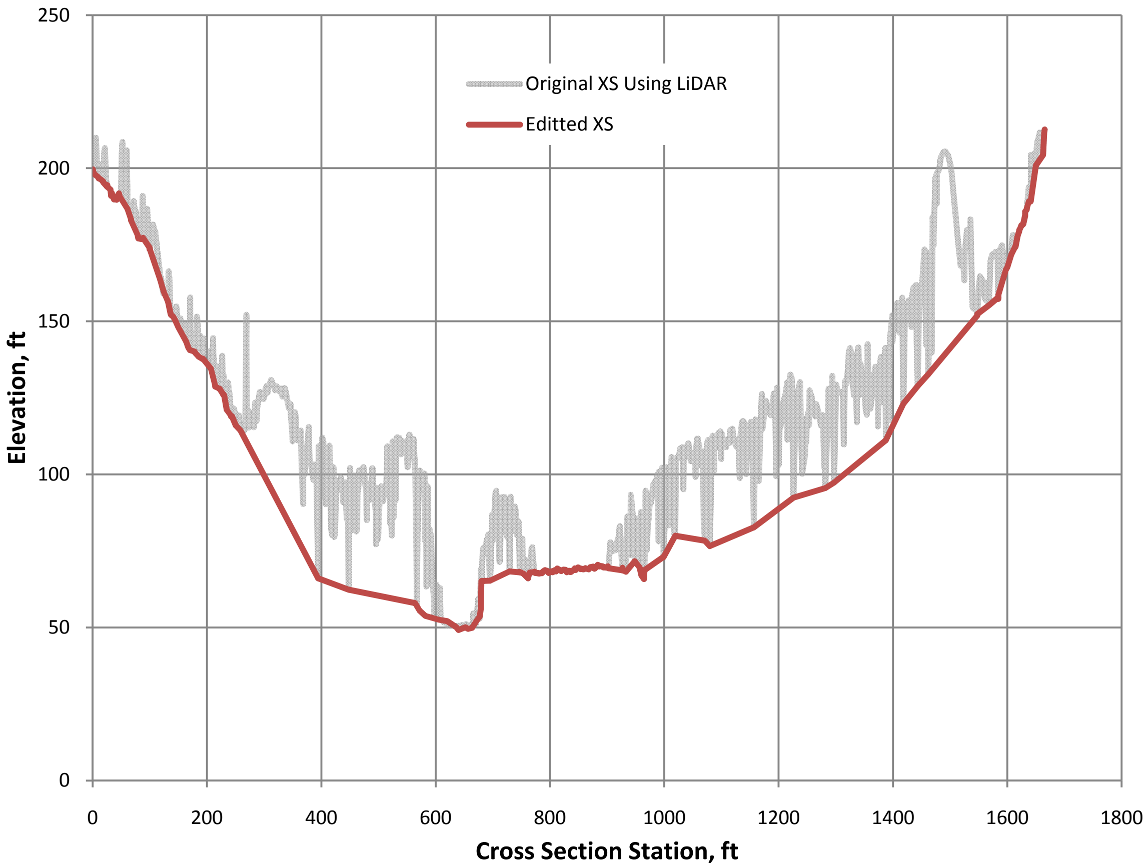

Figure 4-11: Typical Cross Section Edits for the Hanalei River

As the figure shows, the majority of the LiDAR data points were associated with tree and vegetation canopy but there are numerous locations where the LiDAR penetrated the vegetation to the ground. Once edited, the AECOM river channel survey data was incorporated into the cross sections.

The HEC-RAS model included both the main channel of the Hanalei River and the breach channel. The actual breach location along the north bank of the river was incorporated into the hydraulic model as a lateral weir structure. The breach channel opening dimensions and elevations in the model are based on AECOM survey points. The surveyed data represents current site conditions. During high flow conditions, the energy in the stream transports and deposits material throughout the project reach, changing the interaction between the river and breach channel.

4.3.1 Model Calibration and Validation

The calibration and validation of the Hanalei River HEC-RAS model was based on peak flow stage elevation recorded by the USGS flow gage when it was located near the intake structure. The USGS gage datum was not tied to the same datum as the AECOM survey data so a conversion was developed. The datum relationship at the USGS gage was based on the information in the Preliminary Feasibility Assessment Hanalei River Diversion (Moffat and Nichol 2007). In the report, a surveyed cross section roughly in the same location as AECOM cross section (XS) 2790 was assumed to have the same thalweg elevation. The Moffat and Nichol (M&N) report tied the cross section thalweg to the datum of the old USGS gage. The relationship from the river thalweg to the USGS datum was estimated at 1.2 feet. Based on the AECOM surveyed thalweg elevation of 31.9 ft near the same location as the M&N report, the USGS gage datum was estimated to be 33.1 ft.

Three storm peak flows were selected for calibrating the Hanalei River HEC-RAS model, with flows ranging from 12,340 cfs to 21,700 cfs. The three flow events were from a period prior to the channel breaches so it can be assumed the recorded flow at the gage represents the entire flow. Using the recorded flows, the Manning's "n" value was manipulated until the estimated HEC-RAS water surface elevation (WSE) at XS 2790 was similar. The calibration results are shown in Table 4-4,

Table 4-4: Hanalei River High Flow Calibration

Date	Flow Peak (cfs)	USGS WSE (ft)	HEC-RAS WSE (ft)
July 23, 1987	16,800	45.55	46.15
November 18, 1990	21,700	46.74	46.92
September 2, 1994	12,340	44.31	43.37

With only the one calibration location, modifications to the Manning's "n" values were kept constant through the model for both the channel and overbank areas. The calibrated Manning's "n" value for the channel was determined to be 0.05, while the floodplain/over bank area was set to 0.08. Both of these values fall within the range for streams and floodplains similar to the Hanalei River project reach (Chow, 1959).

Using the calibrated HEC-RAS, the Hanalei River hydraulic model was validated to WSE elevations surveyed by AECOM as part of the project. The AECOM survey team was in the field from July 5–7, 2010. During this time period the recorded daily flow in the Hanalei River was approximately 150 cfs. Using this flow, the model was run to verify that the calibrated Manning's "n" values were appropriate. Table 4-5 compares the estimated HEC-RAS WSE with the elevations surveyed by AECOM.

Table 4-5: Hanalei River Low Flow Calibration

Cross Section	Survey WSE (ft)	HEC-RAS WSE (ft)	Elevation Difference (ft)
1996.837	28.2	27.81	-0.39
2337.817	32.4	31.64	-0.76
2486.057	32.5	31.78	-0.72
2790.717	36.4	33.78	-2.62
3111.073	38.0	37.19	-0.81
3437.950	39.6	39.52	-0.08
3601.739	40.4	40.76	+0.76
4039.222	44.7	44.19	-0.51
4274.966	45.1	44.5	-0.60
4563.373	45.0	44.57	-0.43
5267.251	52.1	50.59	-1.51
148.2404 (Breach)	25.8	24.75	-1.05
1278.598 (Breach)	43.8	42.34	-1.46

The difference between the surveyed WSE and the HEC-RAS estimated WSE is generally within the expected range. It is important to remember that when modeling low flow events through river sections with cobbles and boulders, the bed material has a larger impact on the channel roughness than during larger flows, as the low flow conditions require the flow to go around the larger rocks, thus reducing the available flow area. As the flow area gets larger, resulting from higher flows, the impacts to the flow area are reduced.

Assuming the HEC-RAS is providing a reasonable representation of the flow conditions within the project reach of the Hanalei River, the model estimated the flow split to be 98 cfs remaining in the main stem of the Hanalei River with 52 cfs flowing through the breach channel. Field measurements of actual flows were not conducted to verify this result, but a visual estimation of the flow split during the field reconnaissance suggested a similar ratio of flows. Figure 4-12 illustrates the estimated HEC-RAS water surface profile for a flow rate of 150 cfs. The breach channel is graphically depicted as a lateral weir in the figure.

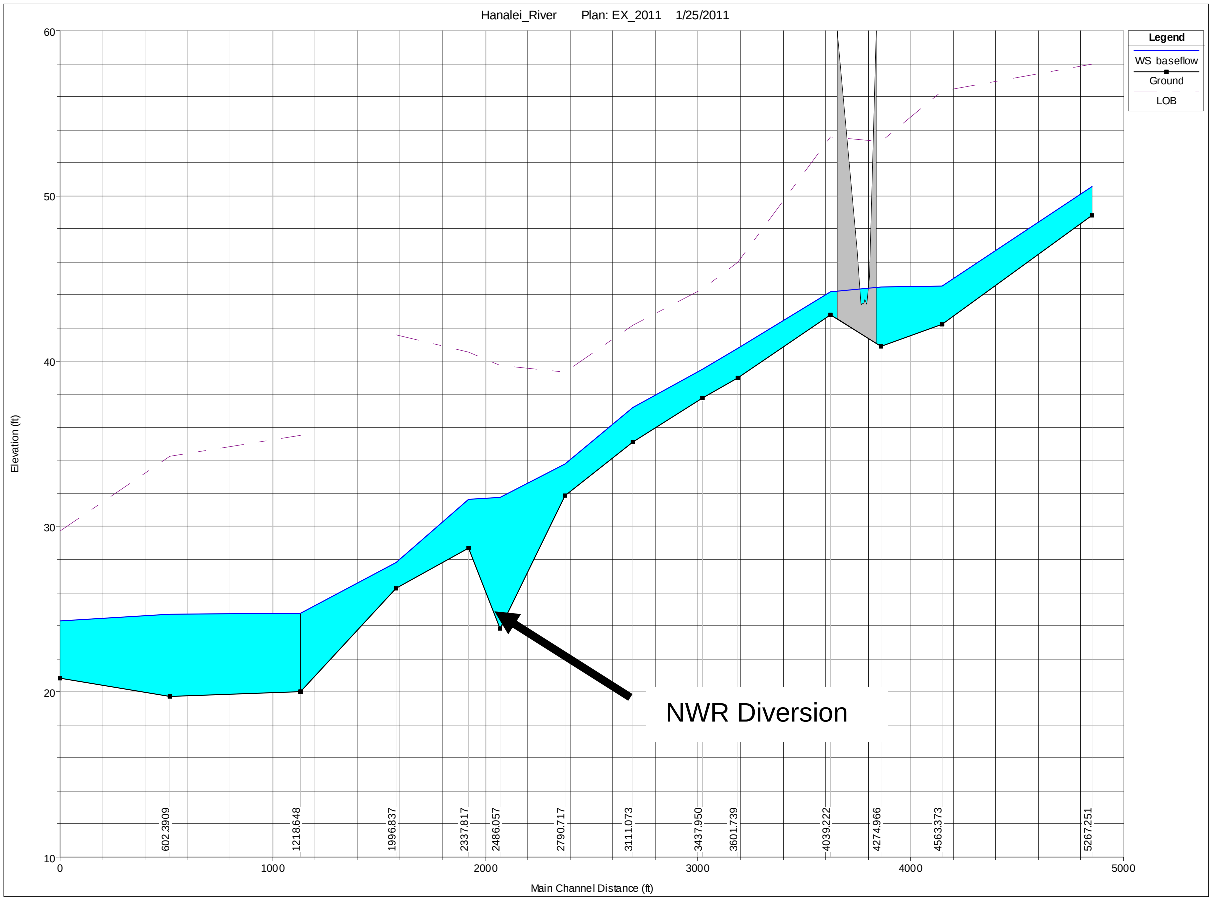

Figure 4-12: Hanalei River 150 cfs Water Surface Profile

4.3.2 Bank Full Channel Capacity

Prior to developing alternatives for the protection against flow entering the breach channel, it is important to estimate the current channel flow capacity at the "bank full" or the effective dominant discharge. For alluvial streams, bank full discharge can be defined as the maximum discharge that the channel can convey prior to flow expanding onto the floodplain. However, for incised river systems that have abandoned their floodplain, the full channel flow would not be equal to the "bank full discharge". The use of the term gets confusing and has prompted many geologist to use the term effective discharge. The actual physical parameter that defines the "bank full" or effective discharge event is the peak of shear within a channel and thus its peak sediment transport capacity. Much research has been conducted on the topic and it is well established that even in an incised system (where the channel has down-cut and abandoned the flood plain), the location of debris/root and vegetation interaction at the original bank full discharge will still result in the peak sediment capacity. Thus, bank full represents the channel discharge that most efficiently moves sediment.

Although the Hanalei River is partially incised, bank full (effective discharge) indicators, although intermittent, are present, particularly along the right bank (left and right bank are referenced while facing downstream) and were identified to exist at approximately four feet above the water surface at base flow level. Based on the unpublished rating curve for the USGS gauging station, the prominent, right bank, bank full floodplain correlates to approximately 4000 cfs. This wide depositional bench is at the same nominal elevation above the water surface as several other prominent features that were observed between the gauging station and the breach.

It should be noted that M&N report (2007) indicated 15,000 cfs as “bank full”, based on the flow that filled the channel. The channel location resulting in the 15,000 cfs was at the historic USGS gage location. It is unclear of what indicators were used by M&N for this estimate, but AECOM was not able to verify that estimate. It is possible that M&N reported the true channel full event and not the “bank full” or effective discharge as observed by AECOM in 2010, based on established floodplain features at the current gage site.

To estimate bank full flows for the project reach, the HEC-RAS model was used. Of particular concern is the estimated bank full flows immediately downstream of the breach. This is the area where sediment deposition occurs during high flow events, and as part of the project it is important to create flow conditions that will transport material through the reach instead of depositing it. Using an iterative process at XS 3601.739, the model results shown in Figure 4-13 indicate bank full flow can be expected to be between 2,000 and 3,000 cfs for existing conditions. XS 3601.739 is located approximately 400 ft downstream of the breach opening. The bank full flow estimated using HEC-RAS indicate the stream reach downstream of the breach location is under capacity, resulting in channel aggradation.

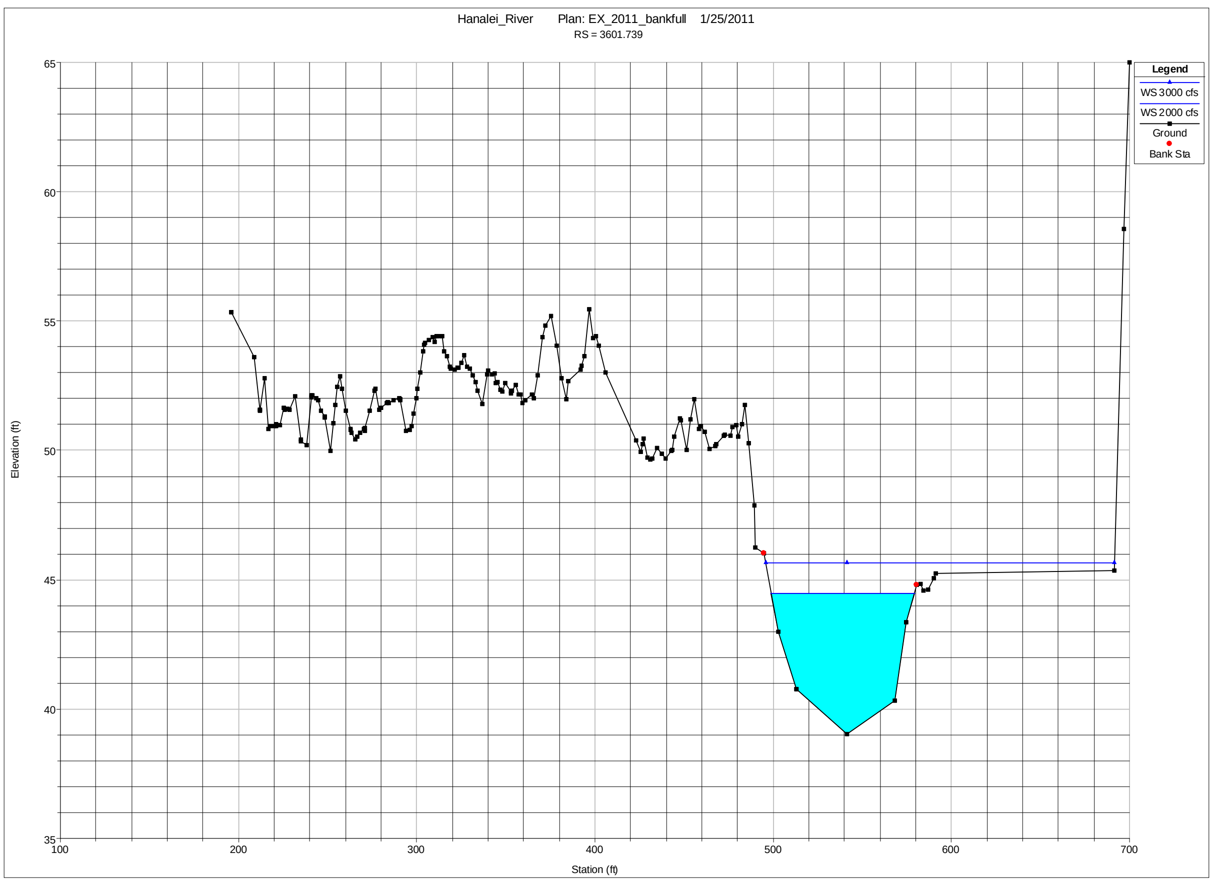

Figure 4-13: Bank Full Flow Rate Assessment at XS 3601.739 (looking downstream)

4.4 GEOMORPHIC ANALYSIS

The following analysis is based on site observations, review of cross-sectional data, and other topographic data. The site was visited on September 14 and 15, 2010. Areas evaluated include the breach, the bypass channel, confluence of bypass channel and river, and the upstream gauging station.

4.4.1 Observations

Immediately upstream of the breach, a large pool is present in the main channel. Two separate glides have formed on the downstream end of the pool, one for the main channel and one for the bypass channel. Each glide then leads into a separate riffle. The channel upstream of the breach appears stable with no significant indicators of instability (such as mid-channel bars, eroding banks, or excessive sediment deposits), with the exception of the left bank at the gage location. The erosive left bank at the gage site is likely due to the clearing of deep rooted vegetation, which is assumed to have taken place during gage construction.

Figure 4-14: Existing Pool Upstream of Breach (looking upstream)

The river upstream and downstream of the breach is moderately incised with a natural levee on the left bank that creates a laterally confined channel until the high flows overtop the levee. The right bank consists of a floodplain situated at a lower elevation than the left bank. Evidence of overbank flooding was present at all locations where the observer was able to leave the channel and access the floodplain behind the natural levy. The riffle upstream of the breach has an approximate slope of 1% (0.01 ft/ft). A surveyed cross-section upstream of the breach indicates that the bank full cross-sectional area is about 667 square feet (ft^2) and has a width/depth ratio of 14.5.

Figure 4-15: Existing Glide Leading into Breach Channel

The riffle on the main channel downstream of the glide has a slope of about 1% (1.35 ft of drop over 130 ft). It is long and straight relative to the rest of the river's planform, running approximately 650 ft without a meander or pool. Measurements of bedload material in the mainstem riffle downstream of the breach indicated that the D100 (the 100th percentile diameter of the bedload particles) is a medium boulder with an intermediate axis of 600 to 900 millimeters (2.1 to 2.9 ft).

Immediately downstream of the breach, the cross-sectional area of the main channel is approximately 671 ft^2, while the breach channel entrance has a cross-sectional area of approximately 509 sq ft. Based on our understanding of past events, an emergency repair action occurred in November 2009, in which the mainstem channel downstream of the breach was excavated to restore the flow capacity of the main channel. The excavated material was disposed of by placing a 100 ft long, 15 ft wide berm across the breach opening. Excess material was used to fill a large scour pool that had developed in the breach channel behind the original bank. The repairs downstream of the channel have a resulting cross sectional area of 435 ft^2 and a width/depth ratio of 19. During high flow events, this remaining, natural constriction of the main channel may be diverting more water to the bypass channel possibly leading to additional down cutting and erosion in the bypass channel. Additionally, the reduced cross-sectional area is causing a reduction in sediment transport capacity.

To further validate the observed conditions at the area downstream of the breach, a sediment transport analysis was undertaken using the POWERSED model, as described in the EPA WARSSS methodology (Rosgen 2006). POWERSED uses data of channel geometry and slope, flow data from a gage site, and suspended sediment and bedload transport data to estimate the relative sediment transport capacity of a channel. Key to the model is the ability to compare an upstream, reference cross-section with a downstream “unstable” cross-section. The reference cross-section must be a section which is considered relatively stable in that it is moving the sediment load being produced by the watershed without aggrading or degrading. The model evaluates the relationship between unit stream power and sediment transport at the reference section, then uses this relationship with the calculated unit stream power of the altered section to evaluate whether the altered section has the capacity to move the sediment load being produced by the watershed. A channel which lacks the capacity to move the sediment load is expected to aggrade, while one with too much capacity is expected to degrade.

To conduct the POWERSED analysis, cross-section data for the areas upstream and downstream of the breach was input into the software program RiverMorph, and bank full elevation and area were estimated assuming that bank full is approximately 4,000 cfs (see Section 4.3). Average water surface slope was approximated from survey data collected along the river, and was estimated at 0.0068 ft/ft (0.7%). Due to time and budget constraints, actual data of suspended sediment and bedload were not collected; however, since the goal of the sediment transport study was a relative comparison of two sections rather than absolute estimates of sediment load, assumed values based on site conditions were used for sediment and bedload material size. A cross-section taken approximately 400 ft upstream of the breach was assumed to be a stable cross-section, with the ability to transport sediment without aggrading or degrading. The downstream section for comparison was a section where the cross-sectional area is reduced, and is approximately 400 ft downstream of the breach. For the purposes of the model, the downstream area was assumed to have the same discharge as the upstream section.

The POWERSED results show a reduction in transport capacity at the area downstream of the breach of approximately 63%. The cause of this drastic reduction is clear when examining plots of discharge vs. unit stream power for both sections (Figure 4-16). The downstream channel has a cross sectional area of approximately 452 ft^2, compared with the area upstream of the breach of approximately 667 ft^2. Thus, when the bank full event flows through the mainstem section downstream of the breach, it flows onto the floodplain well before the upstream section resulting in a significant reduction in velocity and stream power, with a resulting reduction in sediment transport capacity. The channel downstream of the breach can therefore be expected to aggrade until a stable channel form is reached. As shown in Figure 4-16, the altered channel (downstream of the breach), experiences a large drop of Stream Power when channel flows reach approximately 2,000 cfs.

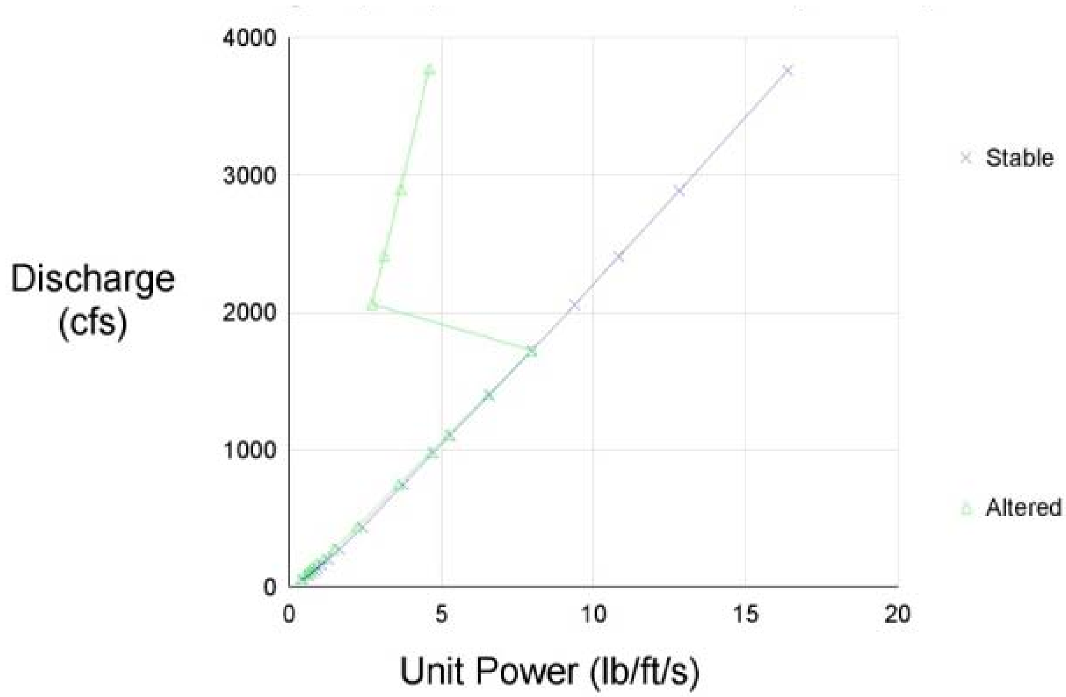

Figure 4-16: Discharge v Unit Stream Power for Hanalei River

In addition to the reduction in stream power due to the smaller cross-sectional area in the downstream channel, a second factor to take into account is that, due to the breach, flow from the main channel is now divided between two channels. Upstream of the breach the river is able to adequately transport its bedload (sediment) without any indications of aggradation. When the flow is split, shear stress and stream power are reduced and the channel is no longer able to transport the larger bedload particles. The most likely outcome of this diversion of river flow is that the small boulders and large cobble that are transported during high flow events upstream of the breach are now being deposited in the glide of the main channel, causing the channel to aggrade and diverting more flow into the bypass channel.

Evidence of channel incision was also noted on the mainstem reach well downstream of the breach and just upstream of the confluence of the breach/cutoff channel and the main channel. Figure 4-17 shows the sorted and washed alluvial deposits in the breach channel, and is the same condition seen in immediate upstream and downstream of the breach channel. The deposits are evidence of a channel bed elevation of approximately 3-4 ft above the current bed elevation.

In order to ensure that the proposed solution for the breach will be a sustainable repair, AECOM believes that understanding the possible causes of the breach is essential. One likely scenario is that the breach is a result of a headcut that started in the natural low point or valley in the floodplain to the left bank side of the breach, just upstream from Taro Patch Hale. Multiple lines of evidence, including drainage ditches that flow to the breach channel, the location of the “China Ditch” (an abandoned and historic ‘auwai), and the old culvert at the confluence of the two channels, all demonstrate that there has been a drainage system in the location of the current breach channel for a long time, at least up to the location of Taro Patch Hale. The breach channel leaves the main channel with an abrupt fall well over a 2% slope in the first few hundred feet till it reaches the yard area of Taro Patch Hale, where a valley has definitively formed on both the left and right bank sides of the breach channel. Immediately upstream of the breach, the main valley wall on the North (left bank) turns away from the Hanalei River providing a floodplain. Two apparent swales in the floodplain and the abandoned China ditch, as well as overbank flooding from the main channel, may converge overbank flood flows at the location of the shallow valley depression near Taro Patch Hale, and where the lateral confinement of steep valley walls has ended.

Figure 4-17: Soil Stratification at Breach

Regardless of the exact cause of the breach, the reduction in stream power by a divergence of flow into the breach channel and reduction in cross-sectional area downstream will cause deposition of bedload immediately downstream of the location of the breach. Bedload deposits will continue to build, directing more flow into the breach channel. If the flows were evenly distributed between both channels, the breach channel will continue to move bedload more efficiently due to its steeper slope while the main channel will continue to aggrade due to the loss of stream power. However, this is merely a conceptual model of the possible cause of the breach based on a reconnaissance level assessment of the site and observations of the combinations of topography that may have concentrated the extreme flood flows in a location that was situated to allow the carving and creation of a new channel. There are many other possible causes for the breach. The important feature of this conceptual model is the convergence of overbank flows in the breach channel. After completion of any proposed repairs to the breach, flows from major flood events will still converge in the location of the breach channel and must be accounted for in the proposed solution.

5.0 ALTERNATIVES ANALYSIS

As defined, the goal of this preliminary investigation is to identify, develop and assess measures to protect the water supply for the NWR. Based on analysis of existing conditions regarding the watershed hydrology, the river hydraulics and the geomorphology of the project reach, the AECOM team developed and assessed two alternatives that meet the project goals, both located at the breach site.

The developed alternatives address transport of sediment and bedload through the main channel and downstream of the proposed breach repair. Because some flow may be diverted from the main channel, the river is losing some stream power and the ability to transport bedload. The final development of alternatives will provide for improved sediment transport through the project reach while also establishing a control structure at the breach location to control the amount of flow into the existing breach channel.

The tow proposed alternatives at the breach location consider three elements: a weir structure, low flow capacity, and improved sediment transport. The only element required to meet the primary goal of project would be the weir structure; the other two elements are intended to meet additional project goals (stakeholder concerns) and improve the natural function of the Hanalei River.

5.1 DESIGN FLOW LEVEL OF PROTECTION

The initial project goals suggested by the NRCS were to provide for the restriction of flow into the breach channel for flows equal to the 10-year and the 25-year flood event. Any flows higher than the design flows would result in overtopping the streambank protection designed to protect the breach location, allowing flows to be conveyed through the current breach channel. The design flow level of protection is not to convey the usual sense of protecting downstream structures from flooding, but rather to establish reasonable targets for the breach channel weir/berm height. An initial investigation was conducted using the HEC-RAS model of the project reach of the Hanalei River to determine the required height of a structure designed to restrict flow into the breach channel.

Using the calibrated HEC-RAS model of the project reach of the Hanalei River, the model was run with the 10- and 25-year design flows shown in Table 4-2. The analysis included the resulting peak flows estimated with and without the 44,600 cfs peak flow event from November 1995. The resulting water surface profiles are shown in Figure 5-1. The results shown in the figure also include the water surface profile for a base flow of 150 cfs. As expected, each of the modeled flows result in some flow being diverted into the breach channel. This is evidenced by the estimated water surface being above the weir invert representing the breach channel opening. The gray area depicted in Figure 5-1 represents the surveyed breach opening geometry.

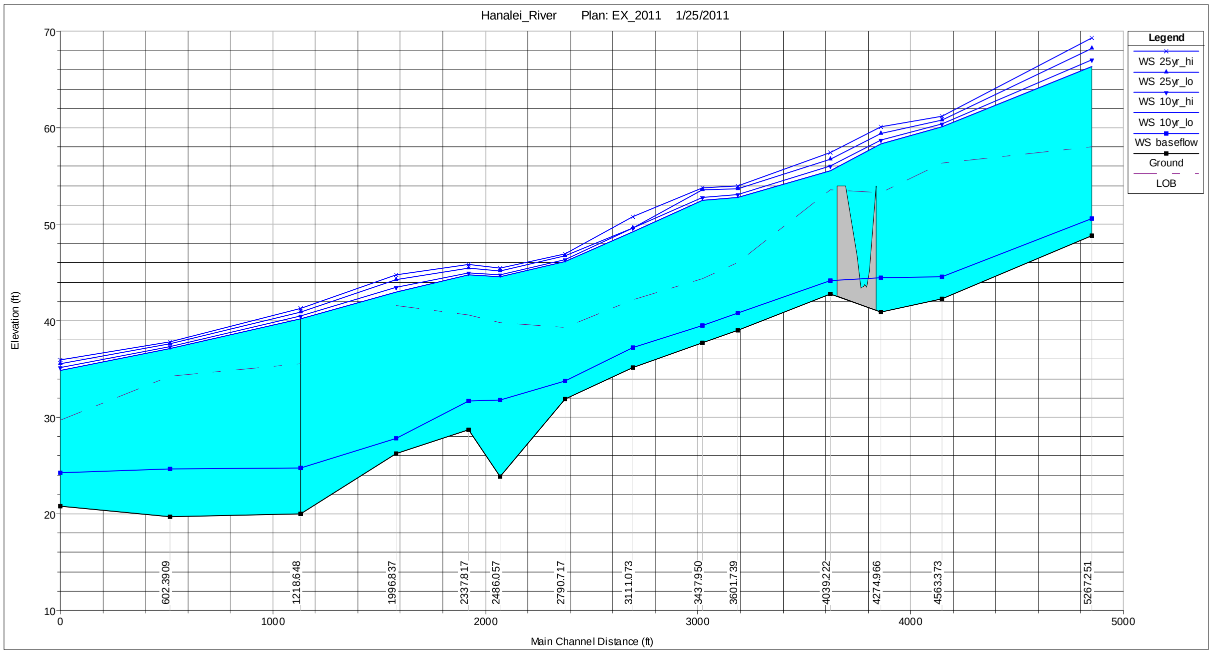

Figure 5-1: Existing Conditions Water Surface Profiles

Table 5-1 lists the estimated WSE associated with each of the modeled flow events as well as the estimated flow in both the mainstem Hanalei and the breach channel. It should be noted that the flow distribution-split presented in the table is based on the AECOM surveyed cross sections (July 2010). The river channel and breach opening cross-sectional areas have likely changed to some degree since the survey date. It is anticipated that the during a high flow event, the actual geometry of the project area may very due to bed material deposition and geomorphic changes. This may result in slightly different flow profiles that shown in Figure 5-1.

Table 5-1: Existing Condition Flow Profiles

	Flow Condition			
Location Water Surface Elevation (ft)	**10 Yr low Q=26,250 cfs**	**10 Yr high Q=28,230 cfs**	**25-Yr low Q=31,430 cfs**	**25 Yr high Q=34,540 cfs**
Upstream of Breach (HEC-RAS XS 4274.966)	58.28	58.73	59.44	60.09
Downstream of Breach (HEC-RAS XS 4039.222)	55.56	56.05	56.76	57.39
Discharge Mainstem Hanalei (cfs)	16,820	18,123	20,223	22,245
Discharge Breach Channel (cfs)	9,430	10,107	11,207	12,295

In order to estimate the conditions needed to prevent any flow from entering the breach channel, the lateral structure dimensions used to define the geometry of the breach location were edited so the top elevation is above the maximum WSE of the resulting design flows. The results of the modeling simulating a completely blocked breach channel is shown in Figure 5-2.

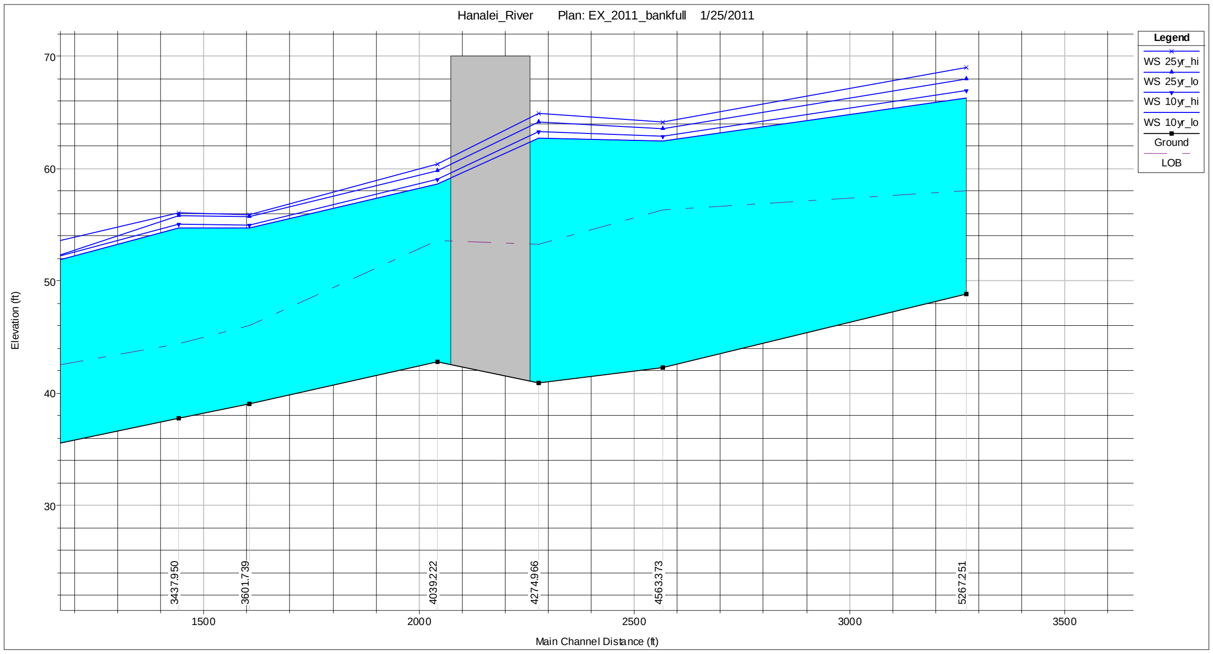

Figure 5-2: Estimated WSE with All Flow Constrained to the Hanalei River Main Channel

The WSE at the downstream end of the modeled breach blockage ranges from 59.2 to 60.9 ft for the 10-year low flow to 25-year high flow flood event respectively. The upstream WSE ranges from 62.4 to 64.6 ft respectively. Based on these initial modeling results, the top of any structures designed to prevent flow in the breach channel at the design flows would range from an estimated 60 to 65 ft. The modeling result assumes flow can only enter the breach channel through the current location.

A review of the topographic data from both the AECOM survey and the NRCS LiDAR reveals the river banks adjacent to the breach channel are less than 60 ft in elevation. The highest elevations found near the breach are approximately 52 ft along the downstream bank and 56 ft upstream of the breach. So even if a structure with the required elevations was constructed at the breach opening, flood flows would likely find a new flow path from the Hanalei River into the breach channel. If this were to occur, it is likely the erosive energy of the flows would create a new breach channel opening, thus effectively negating any benefits created by the structure blocking the current breach location.

5.2 BREACH CHANNEL FLOW DIVERSION

The current breach channel configuration causes flows to split from the main channel at all times. During low flow conditions of 150 cfs, the model validation results as shown in Section 4.3 indicate a flow split of approximately 100 cfs in the Hanalei River and 50 cfs in the breach channel. Current residents of the land occupied by the breach channel find that during low flows, the breach channel provides aesthetic benefits. There is also concern that if some continuous flow is not provided to the breach channel, issues related to mosquito propagation and fish passage (‘o‘opu) may develop. As such, one of the design goals of the project is to develop an alternative that would provide flow into the breach channel during low flows at a rate similar to existing conditions while limiting high flows into the channel. These high flows are a potential safety issue to the residents and flood flows in the breach channel are very erosive.

Providing low flows to the breach channel while also providing some level of high flow protection will require that the proposed alternative include a flow conveyance structure such as a culvert or gate within the flow-retarding berm. To simplify operation, a non-gated culvert was selected as the preferred conveyance structure. A 4-ft diameter CMP with its invert set at the elevation of the existing breach entrance thalweg was selected as the initial culvert recommendation and was subsequently incorporated into the HEC-RAS. Other culvert dimensions and materials may also provide for an adequate breach channel flow diversion, this assessment provided a relative size of culvert that may be incorporated into the developed alternatives.

Figure 5-3 illustrates the water surface profile for a low flow condition based on 150 cfs in the Hanalei River. The resulting flow split leaves 110 cfs in the main river with 40 cfs flowing through the culvert and into the breach channel. The resulting modeled flow split was intended to match the estimated low flow split currently occurring at the breach channel.

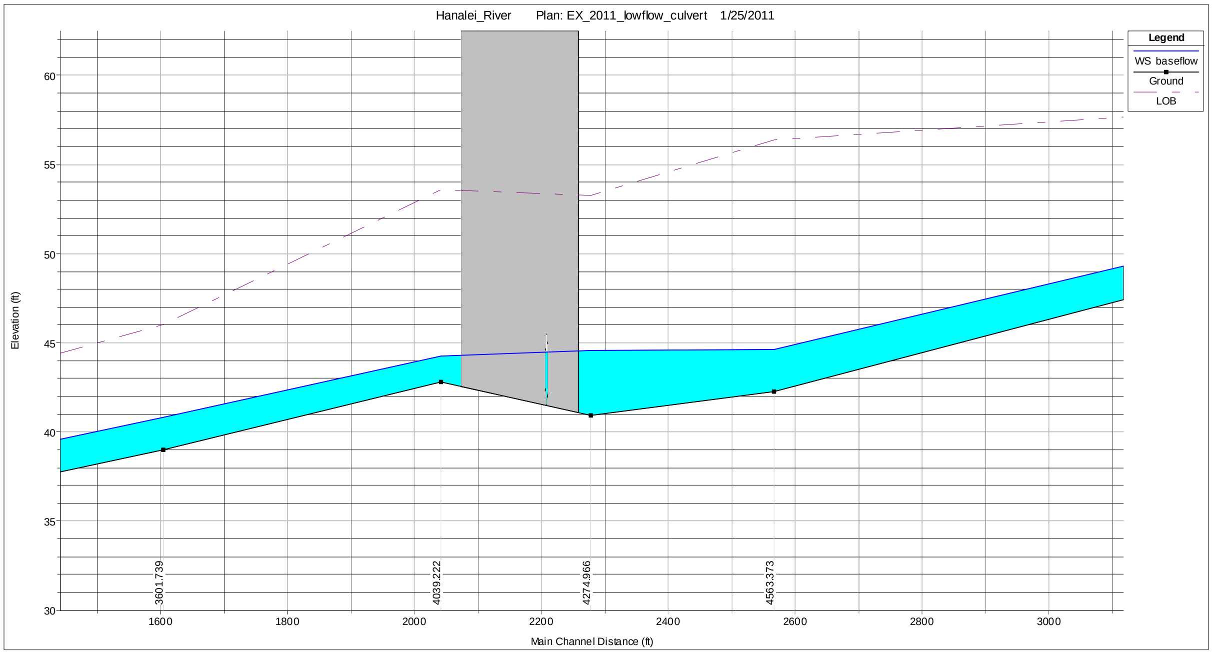

Figure 5-3: Low Flow Water Surface Profile with 4-ft Diameter Culvert

5.3 BREACH CHANNEL FLOW RESTRICTION

Based on the initial assessment of the eliminating flows from entering the breach channel for high flows related to the 10-year through 25-year event findings presented in Section 5.1, a new alternative development approach was developed. The new approach was based on providing the greatest level of protection to the breach channel while limiting the possibility a new breach channel to form.

Assuming the low flow diversion alternative that incorporates the culvert will be part of the final protection of the breach location, a maximum level of protection alternative was developed based on the maximum available ground elevations at the breach site. The HEC-RAS model was used to estimate what would be the flow rate associated with the maximum possible protection level at the breach location. This is defined as placing a structure that would tie into the existing grade at the breach locations effectively estimating the original left bank topography prior to the occurrence of any breach event. The HEC-RAS modeling effort shown in Figure 5-4 indicates that flows up to approximately 5,000 cfs would not overtop the replaced left bank. The results of this modeling exercise indicate approximately 175 cfs would be conveyed through the culvert and into the breach channel. The other 4,825 cfs would remain in the main stem. Flows above 5,000 cfs would be split with the majority of the flows remaining in the main stem.

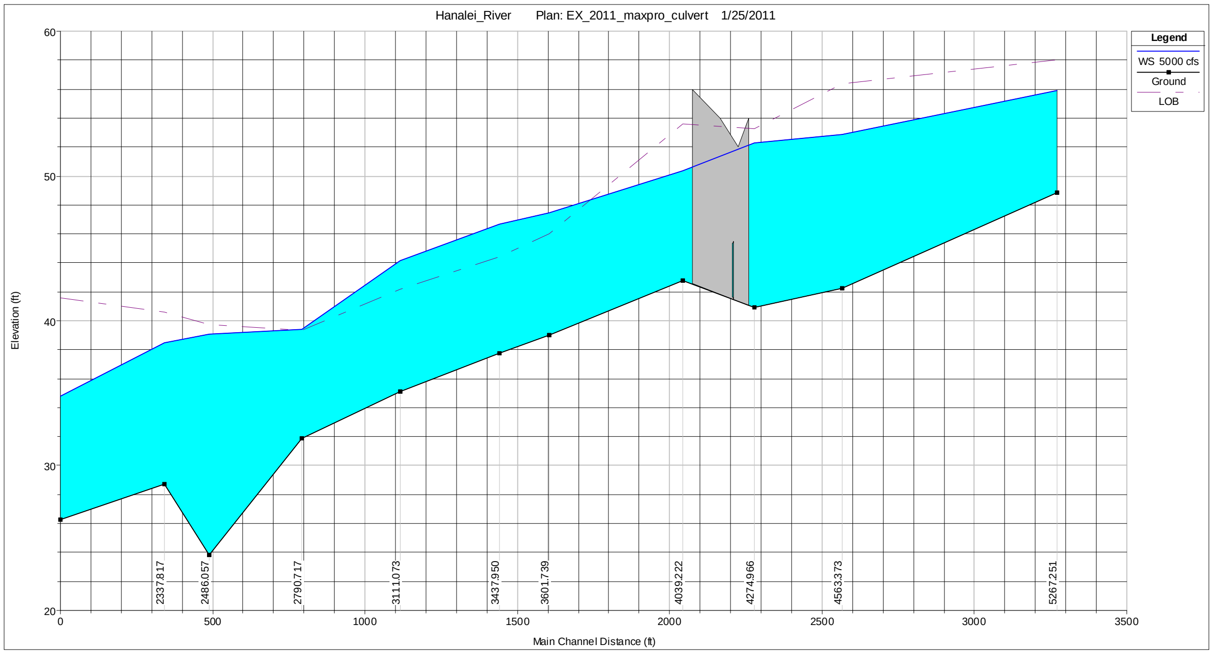

Figure 5-4: Estimated WSE with All Flow Remaining In the Hanalei River, Except for the 4' Culvert Diversion

The maximum level of protection provided by effectively rebuilding the historic streambank at the breach location would force the WSE associated with high flows to be at or above the ground elevation near the existing breach site. The topography of the river reach upstream and downstream of the current breach location indicates that flooding events may locate an alternative flow path from the river to the breach channel if the current location is restricted. If this were to occur, the breach may develop with a new entrance location, channeling flow into the existing flow path and resulting in the same consequences of substantial loss of flow in the main channel.

An alternative to completely blocking the existing breach location and possibly causing the breach to move elsewhere within the river reach is to account for the flow split during high flow events. This approach would provide for a control structure at the breach location that would accommodate overtopping while returning the natural sediment transport function to the project reach.

5.4 SEDIMENT TRANSPORT AND STREAMBANK STABILIZATION

A consequence of the stream breach is the loss of stream energy and thus the ability of the river to transport bedload through the main stem of the Hanalei River. When the high flows are split at the breach location, the stream energy is also split causing bed load to be deposited in the river channel. This has resulted in the channel invert of the main stem of the Hanalei River to be elevated through aggradation of material. As shown in Figure 5-7, the channel bed elevation increases immediately downstream of the breach location. It is believed the momentum of the bed material being transported during high flows carries the material past the breach entrance, but because of the flow split, the amount of energy in the main stem is significantly reduced causing the material to be deposited. Future bed material sampling efforts may be required to verify that the rock material in the channel downstream of the breach channel accumulated bed load material and not just armored bedrock.

Although the modeling results shown in Figure 5-4 provide for the flow in the Hanalei River mainstem to be above 4,000 cfs (bank full), prior to overtopping the bank and flowing into the breach channel, the channel capacity downstream of the breach is still between 2,000 – 3,000 cfs. This means the channel is likely to continue to aggradate even with the bank returned to pre-breach conditions.

To provide greater sediment transport capacity through the Hanalei River main stem, it is important to have a channel geometry that accommodates bank full flows and the resulting ability to transport bed material. To accomplish this, the flow capacity of the river needs to be the estimated bank full flow of 4,000 cfs. The base flow water surface profile shown in Figure 5-5 illustrates the invert of the Hanalei River mainstem near the breach channel. As the figure shows, downstream of the breach channel, there is an approximately 3 ft increase in the channel invert. The rapid increase in the bed elevation corresponds to where the stream energy would decrease due to the flow split.

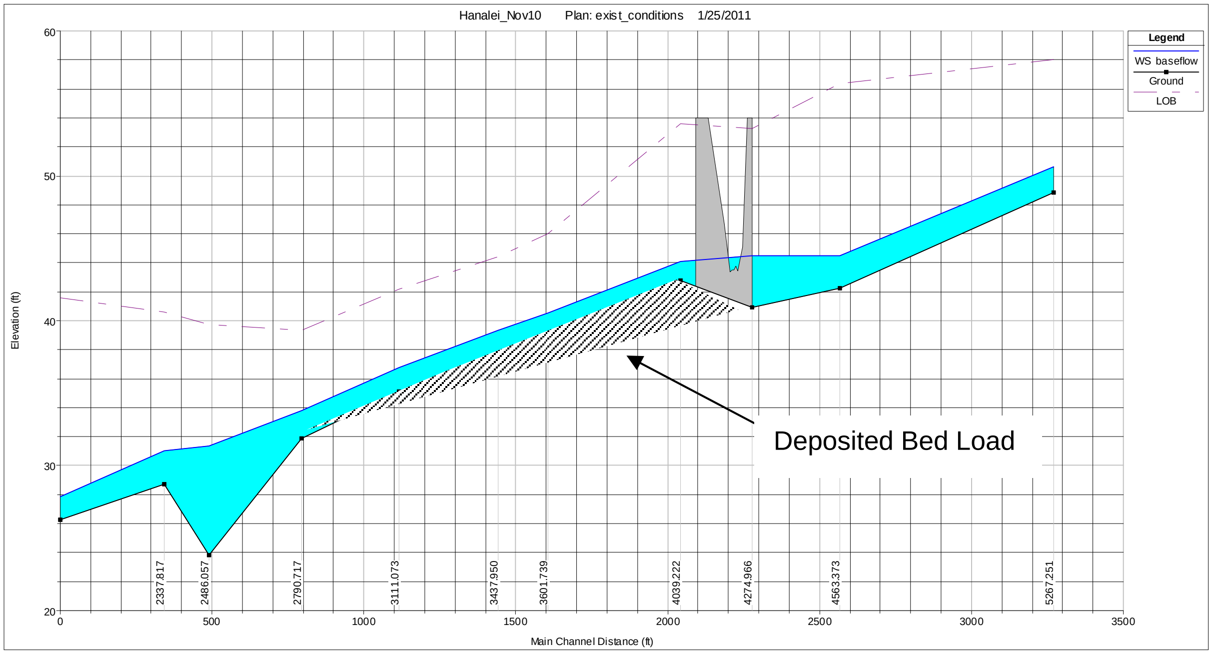

Figure 5-5: Location of Aggradated Bed Load

To increase the flow capacity of the Hanalei River downstream of the breach, the invert of the channel was lowered in the HEC-RAS model to provide for a continuous slope through the modeled reach. By removing the deposited material, the channel capacity downstream of the breach channel is increased from 2,000 to 3,000 cfs up to more than 4,000 cfs. By providing the channel capacity for bank full conditions, the stream should be able to transport more material.

Figure 5-6 shows the water surface profiles for flows ranging from base flow up to 8,000 cfs. For a proposed weir designed to restore the stream bank to pre-breach conditions, the removal of the aggradated bed load increased the level of protection of the weir from 5,000 cfs to over 8,000 cfs before overtopping occurs. Based on this analysis, a lower weir set to an elevation of approximately 49 feet would result in the bank full flow of 4,000 cfs remaining in the main stem prior to overtopping.

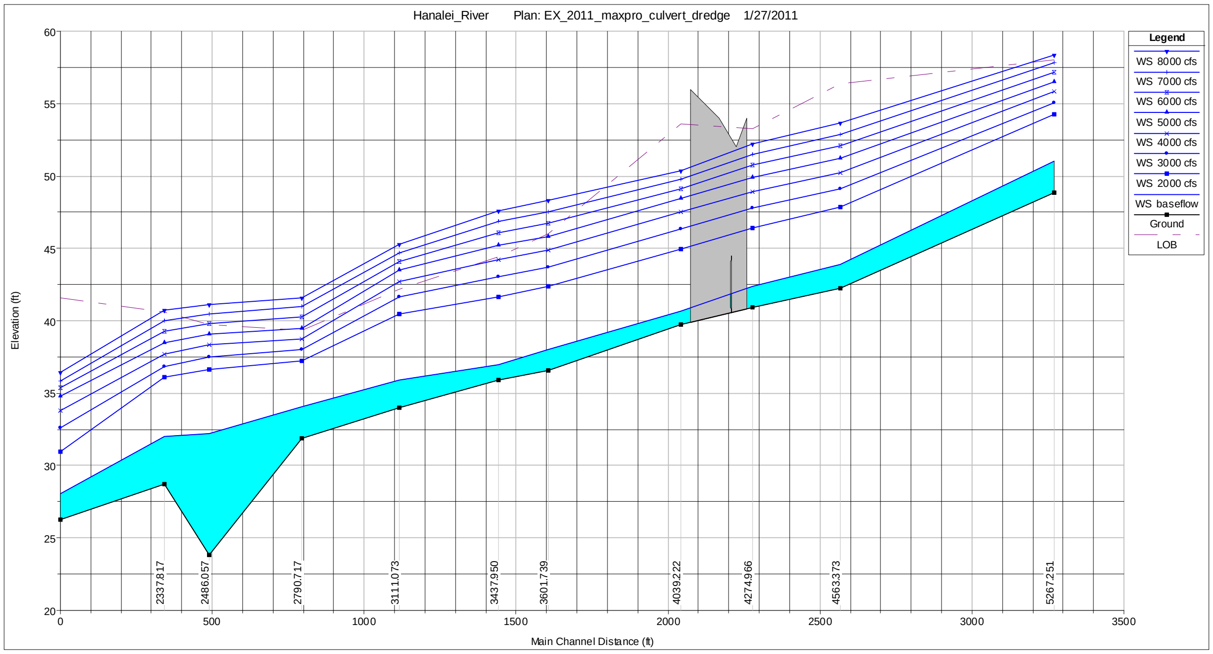

Figure 5-6: Estimated WSEs for 4,000 cfs With and Without Aggradated Material Removed

The removal of the aggradated material impacts the water surface elevations at the breach location, this change also impacts the hydraulics of the culvert designed to convey flows into the breach channel. When the material is removed the invert of the culvert will also be lowered to match the invert of the channel. During subsequent design efforts, the size (and shape) of the culvert may be re-engineered to provide an agreed upon flow split into the breach channel that meets the needs of the stakeholders.

5.4.1 Streambank Erosion Protection

The existing breach channel is located along the outside bank of a mild meander in the river alignment. Immediately upstream of the breach location, the stream bank is experiencing erosion resulting in near vertical banks and a deep thalweg along the toe of the bank. Both of these features are typical of the development of river meander, where stream energy is being focused on the outside bend of the river. If left unaddressed, the continued erosion of the stream bank may adversely impact the breach channel protection. As part of the Hanalei River alternative development, it is proposed to use stream vanes to provide erosion protection and increase the stream energy through the project reach.

Vanes correctly placed within an alluvial river system are used to transfer energy away from stress points in the stream and rivers toward the center of the channel. The redirecting of stream energy (erosive velocities) away the banks, moves the thalweg and the associated high shear stress to a less risky location, the center of the channel. One of the benefits of the using vanes, is the relocated stream energy stays within the local area and does not get transferred upstream or downstream.

Vanes are also effective for addressing stream reaches experiencing channel aggradation as is the Hanalei River downstream of the current breach channel. The placement of vanes or even short vanes that may be termed “barbs” reduces the width to depth ratio, increasing sediment transport. By installing rock vanes along the project reach of the Hanalei River and creating enough energy downstream of the breach, the bed material that has been accumulated since the breach developed will be transported downstream.

5.5 ALTERNATIVES DETERMINATION AND DESCRIPTION

Based on the alternatives analysis presented in Section 6, the two alternatives developed for the Hanalei Valley Irrigation Intake Protection/Streambank Stabilization Preliminary Investigation are presented below. Conceptual drawings for each of the alternatives are provided in Appendix B. Each of the alternatives incorporate similar design elements, with the level of protection against flows breaching at the current location being the major difference. Table 5-3 contains the HEC-RAS results for each of the alternatives, illustrating the dynamics of the anticipated flow splits.

5.5.1 Alternative No. 1: Maximum Weir Elevation

Alternative No. 1 involves constructing a weir at the breach location that approximates the original left bank condition, tying into the existing land surface elevations both upstream and downstream of the breach channel. The weir will be constructed to withstand the forces associated with overtopping of flows into the breach channel with a crest ranging in elevation from roughly 52 to 56 ft. The weir have a semi-impervious core of concrete or sheet pile and large angular rock stacked on both the upstream and downstream face. The top width of the structure is set at 12 ft, in order to provide vehicular access across the weir. Concrete will be used on the downstream face of the weir to protect against the erosive forces associated with overtopping during high flows. The concrete will incorporate native rock material to provide a more natural appearance and provide additional roughness (energy dissipation).

This alternative includes a culvert to provide flows to the breach channel. During low flow periods, the culvert will provide adequate flows for fish passage. A continuous flow source in the breach channel is also required to limit conditions that lead to stagnant water leading to increased mosquito activity. During periods of high flows, the culvert will limit flows entering the breach channel to flows that are not erosive.

In order to reduce bank erosion and improve the project reaches sediment transport capabilities through the project reach near the current breach location, rock vanes are to be used. On the Hanalei River upstream of the breach channel, a series of rock vanes are to be constructed on the left bank of the river. They rock vanes will extent into the river channel about 1/3 of the total river width. The vanes will be composed of rock larger than the current D100. If large rock is not available, steel piling or concrete blocks in conjunction with natural rock will be used. Downstream of the breach channel, a series of rock vanes are to be constructed. The purpose of these rock vanes is to improve the hydraulics of the reach and provide for a more sediment transport through the reach.

Alternative No. 2: Minimum Weir Elevation

Alternative No. 2 is similar to Alternative No. 1 with a weir constructed at the breach location. The weir will be designed and constructed to withstand anticipated overtopping flows higher that 4,000 cfs. The elevation of the weir crest will be set at 48.50 feet. The weir will have a semi-impervious core of sheet pile or concrete blocks. Large, loose, angular rock will be stacked around the cores on both the upstream and downstream faces to provide additional protection and stability to the weir. The crest of the weir will be made of concrete to provide a smooth flow path from the river to the breach channel. Additional large and concrete will be required to provide for erosion protection immediately downstream of the weir. Concrete surfaces will incorporate native rock material to provide a more natural appearance.

This alternative also includes a culvert to provide continuous flows to the breach channel. During low flow periods, the culvert will provide flows for to allow for fish passage upstream through the breach channel. A continuous flow source in the breach channel is also desirable to limit conditions that lead to stagnant water leading to increased mosquito activity. During high flows events up to bank full flow, the culvert will limit flows entering the breach channel to flows that are not erosive. For flows higher that 4,000 cfs, the breach channel will receive a portion of the flow from the mainstem Hanalei River

In order to reduce bank erosion and improve the project reaches sediment transport capabilities through the project reach near the current breach location, rock vanes are to be used. On the Hanalei River upstream of the breach channel, a series of rock vanes are to be constructed on the left bank of the river. They rock vanes will extent into the river channel about 1/3 of the total river width. The vanes will be composed of rock larger than the current D100. If large rock is not available, steel piling or concrete blocks in conjunction with natural rock will be used. Downstream of the breach channel, a series of rock vanes are to be constructed. The purpose of these rock vanes is to improve the hydraulics of the reach and provide for a more sediment transport through the reach.

5.6 COMPARISON OF FLOW DISTRIBUTIONS

The HEC-RAS model was used to estimate the impacts on the flow split of the two alternatives. Table 6-2 contains the resulting division of flows. The modeling was conducted with and without the impacts of removing the aggradated material downstream of the breach.

Table 5-2: Flow Distributions for Proposed Alternatives

	Flow Rate, cfs						
	Base Flow	**2,000**	**Bank full**	**6,000**	**8,000**	**10-Yr Low**	**25-Yr Low**
Total Flow	**150**	**2,000**	**4,000**	**6,000**	**8,000**	**26,250**	**31,430**
Alternative No. 1- Maximum Weir w/o Dredging							
Flow in Hanalei River	111	1,864	3,835	5,807	7,644	21,501	25,176
Flow Split to Breach Channel	39	136	165	193	356	4,749	6,254
Alternative No. 1- Maximum Weir with Dredging							
Flow in Hanalei River	140	1,897	3,859	5,835	7,820	22,959	26,677
Flow Split to Breach Channel	10	103	141	165	180	3,291	4,753
Alternative No. 2- Minimum Weir w/o Dredging							
Flow in Hanalei River	110	1,864	3,554	5,058	6,546	18,946	22,441
Flow Split to Breach Channel	40	136	446	942	1,454	7,304	8,989
Alternative No. 2- Minimum Weir with Dredging							
Flow in Hanalei River	140	1,897	3,859	5,692	7,342	20,712	24,252
Flow Split to Breach Channel	10	103	141	308	658	5,538	7,178

When the flows splits shown in Table 5-3 are compared to the existing condition flow splits shown in Table 5-1, there is an approximate reduction of flow going in the breach of 20–36%, depending on the alternative. The Table 5-2 results with dredging, utilize the original 4 ft diameter culvert with only the inlet invert elevation adjusted to account for the material removal. Additional modeling efforts can be conducted to design culvert for the dredging model runs so that flows through the culvert under both conditions are similar.

It is also important to remember, not only is flow reduced into the channel, but since the weir structure is designed to be permanent, the duration of high flows into the breach channel will be greatly reduced. Figure 5-7 illustrates the flood hydrograph associated with the 10-Year Low flood of 26,250 cfs. Also shown on the hydrograph is the flow rate at which the Alternative No. 2, including channel dredging, would overtop the weir and allow increased flows into the breach channel. Based on the figure, the increased flows would occur for approximately 9 hours. Under existing conditions, the increased flow would occur for the entire storm duration of 30-hours

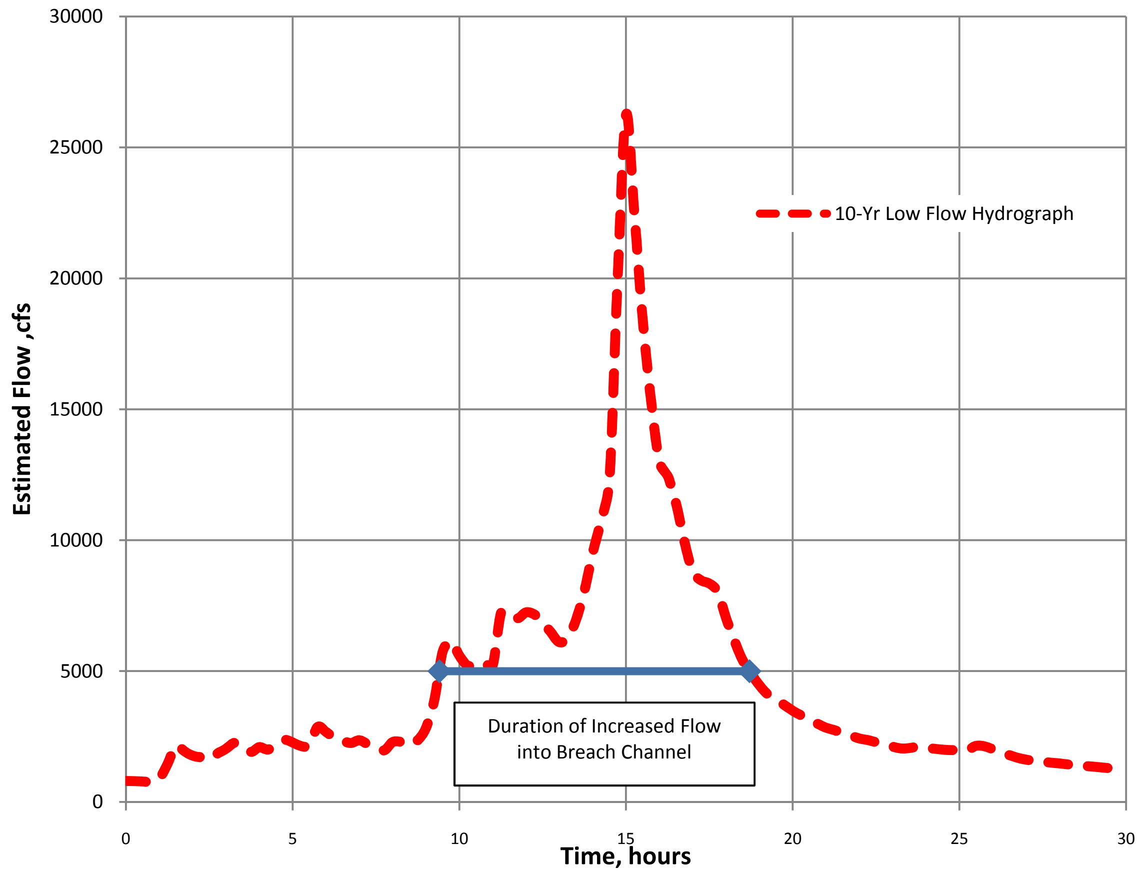

Figure 5-7: Estimated Duration of Flow Split for 10-Yr Flood Event

5.7 Comparison of Alternatives

The primary goal of the Hanalei River project is to protect the supply of river water to the NWR diversion structure. The key to meeting this goal is to select an approach that anticipates the river's energy and is designed to withstand the forces of the Hanalei River during high flows. Also needed, is providing the ability to maintain the stream channel geometry that transports sediment through the system instead of being deposited in the river reach downstream of the current breach channel.

In making the final recommendation for which of the alternatives presented in this report to select, criteria was developed to provide a method for evaluation. The developed alternatives present in Section 5.0 are all feasible as far as constructability, but they do differ in the other aspects. Following are the criteria developed for evaluation and selection.

Maintain Flow to NWR Diversion. The NWR diversion is designed to convey 50 cfs. To maintain the ability of the diversion structure to supply water to the NWR, flow in the Hanalei River must be maintained, particularly during low flow period. Under current conditions, the amount of flow remaining in the Hanalei River can drop to very low levels as the majority of flow is captured by the breach channel. For the assessment of alternatives associated with this project, maintaining flows in the main stem Hanalei River requires a permanent structure at the current breach channel that will required limited maintenance.

Alternative No. 1.	With proper construction, the proposed weir structure is intended to provide for continuous flow in within the main stem. The structure may be overtopped, allowing flow to enter the current breach channel, but as flows recede, the structure is intended to provide for flows to return to the main river channel	Rating 3
Alternative No. 2.	The alternative is designed to be overtopped at lower flow rates while still providing for the return of the flows to the main stem of the Hanalei River. During large storm flows more water will enter the current breach channel than Alternative No. 1, but during low flow periods, the two alternatives should function similarly.	Rating 3

Risk of Future Breach. The existing breach channel resulted from high flows in the Hanalei River overtopping the left bank causing erosion and creating a new side channel. This alternative comparison criteria is dependent on whether the proposed structure will cause a new breach to develop either upstream or downstream or the existing channel. During extreme high flow events the left bank of the Hanalei River is overtopped in multiple locations resulting in inundation of the land between the breach channel and river. This allows for flood flows to find alternatives paths to the breach channel.

Alternative No. 1.	This alternative attempts to reconstruct the historic stream bank at the current breach site based on ground elevations near the breach. As flood flows rise and overtop the banks, the flows will flow toward the current breach looking for the path of least resistance. Since the structure is design to withstand overtopping, a new breach channel may develop elsewhere.	Rating 1
Alternative No. 2.	This alternative provides for a controlled release of flow into the current breach channel. By providing a flow path, it is the goal of this alternative to not create a situation where flow from the Hanalei River finds another path to the current breach channel. With this alternative, the highest flow energy will be focused at the structure.	Rating 3

Working with Nature. In 1998 the Hanalei River was designated an American Heritage River (AHR). The AHR program has three objectives: protect the natural and environmental resources of the river, provide for economic revitalization of the river community, and preserve the historic and culture of the river and watershed. As such, it is important for the alternatives be compared based on the how well they preserve of restore the natural function of the river. Currently the historic river channel is not maintaining its past ability to convey flow and transport sediment. Both alternatives are intended to restore the historic natural function of the river while allowing for some natural evolution of the channel (e.g. meandering).

Alternative No. 1.	By maintaining the Hanalei River's bank full capacity through the project reach and using rock vanes, the alternative will use natural materials to provide the ability of the river to transport the incoming bed load through the reach.	Rating 3
Alternative No. 2.	As with Alternative No. 1, this alternative is designed to return the river reaches sediment transport capacity. The lower weir elevation associated with this alternative, allows the river to maintain a high flow bypass channel (the current breach channel) to relieve stresses from the main stem of the river	Rating 3

Construction Cost. The similarity between the two alternatives results in cost estimates that are different only because the volume of material to be used. The higher weir elevation associated with Alternative No. 1 mean more fill material is required to complete the structure. With both alternatives, the removal of the aggradated material downstream of the breach channel is optional. It is recommended because it does restore the channel to bank full capacity. Section 6.0 details the considerations used to develop the cost estimate also provides the estimated cost to construct each alternative.

Alternative No. 1.	This alternative requires 876 cubic yards of material to construct the structure required to block the existing breach channel.	Rating 2
Alternative No. 2.	This alternative requires 712 cubic yards of material to construct the structure required to block the existing breach channel. Because the crest of the structure is lower than Alternative No. 1, the volume of material is less. The lower crest elevation also translate to less material for the core of the structure.	Rating 3

Table 5-3 lists the criteria and attempts to apply a relative value ranging from 1-3, with 3 being the greatest advantage. The alternative with the highest summation of values provides the greatest benefit for achieving the project intent

Table 5-3: Alternative Selection Evaluation

Criteria	Alternative No. 1	Alternative No. 2
Maintain Flow to NWR Diversion	3	3
Risk of Future Breach	1	3
Working with Nature	3	3
Construction Cost	2	3

Based on the results in Table 5-3, Alternative No. 2 best meets the goals for the Hanalei Valley Irrigation Intake Protection/Streambank Stabilization Preliminary Investigation. Both alternatives meet the basic needs of the project by providing river flow to the NWR diversion, but Alternative No. 2, adds additional benefit with regards to construction cost and maintaining/controlling flows in both the river and breach channel.

6.0 CONSTRUCTION CONSIDERATIONS

The Hanalei Valley is very isolated with limited access to the site for both equipment and materials. The following sections discuss factors that will impact the cost of constructing to proposed alternatives. The final subsection provides a conceptual level construction cost estimate for each alternative.

6.1 SITE ACCESS AND EQUIPMENT MOBILIZATION

- The proposed project site is located off Ohiki Rd. To access the site, the contractor will be required to construct a temporary access route to the construction area. The access road would be approximately 4,600 ft long (see Appendix B, Sheet 2).
- Large equipment exceeding the 15 ton load limit of the Hanalei Bridge will have to access the project site from Kapaʻka Street east of the bridge. An existing dirt road descends steeply into the valley (Appendix B,, Sheet 2), requiring equipment to be walked down the road. The road can only be used for mobilization with special permission from State of Hawaii Department of Land and Natural Resources.
- Lighter equipment can be transported over the Hanalei Bridge (e.g. PC120 Excavator, WA320 Wheel Loader, and D41-E Dozer).
- Materials will have to be transported over the Hanalei Bridge using lighter trucks and smaller loads.

6.2 MATERIAL AVAILABILITY

Material availability in Hanalei Valley is grossly limited, mainly due to the 15 ton weight limit of the Hanalei Bridge. Materials need to be shuttled over the bridge in small loads, or supplied from stockpiles within the Valley. It should be expected that construction materials will be at premium costs, and onsite materials should be used whenever possible.

6.2.1 Ready-Mix Concrete

The two main suppliers of ready-mix concrete are Glover Honsador and Thronas O Inc. Neither supplier has the ability to transport ready-mix concrete across the Hanalei Bridge. The 15 ton weight limit cannot accommodate the gross weight of an empty concrete truck. Concrete must be batched in Hanalei.

There are two ready-mix concrete companies that can supply Hanalei:

1. Kobayashi Trucking & Equipment is based in Hanalei. They have a concrete batch plant located in Hanalei and can deliver ready-mixed concrete to the jobsite. The cost for 3,000 psi pump mix is $295 per cubic yard volume delivered to the proposed project site.
2. KCS, Inc. provides mobile concrete batch trailers at 4 cubic yard (cy) capacity. The trailer can be hauled over the bridge to the project site. KCS can also set up a mobile batch plant capable of producing 15 cy/hr.

6.2.2 Large Rock Rip-Rap

- Rip-rap can be obtained from local rock quarry, Kauai Aggregates located in ʻEleʻele, Kauaʻi.
- The rock must be hauled in special trucks called rock haulers. The rock haulers cannot cross the bridge. The loads would need to be transferred to smaller trucks and shuttled across the bridge to the construction site.
- Unit cost for rock rip-rap is $70 per cy, not including installation. Earthworks Pacific, a local contractor estimates the installed price to be about $500 to $600 per cy for 2 ft. diameter rip-rap at the Hanalei project site.

6.3 ESTIMATED CONSTRUCTION COSTS

Conceptual level construction cost estimates for Alternatives 1 and 2 are presented in Table 6-1 and Table 6-2, respectively. Material quantities have been estimated from dimensions as shown in the conceptual plans (Appendix B). Material unit costs were based on cost data obtained from multiple sources, including material suppliers, local quarries, local contractor's, recent construction bids for the Hanalei vicinity, and cost data reference manuals. The following sources contributed to the preliminary cost estimates:

- Earthworks Pacific, Inc. (Contractor, Kaua'i)
- Kaikor Construction (Contractor, O'ahu)
- Kobayashi Trucking & Equipment (Trucking, Ready-Mix Concrete, Aggregates, Hanalei Kaua'i)
- Ka'iwa Construction (Contractor, Pre-cast Concrete, Kaua'i)
- GPRM Prestress (Pre-cast Concrete, O'ahu)
- Healy Tibbets (Contractor, Sheet pile, O'ahu)
- Past Project Bid Results – Kaumualii Highway Emergency Slope Stabilization, Hawaii Department of Transportation, 2007
- Past Project Bid Results – Kilauea Stream Debris and Sediment Removal, Department of Land and Natural Resources, 2009
- Naval Facilities Engineering Command Cost Data Book, 2002

6.3.1 Potential Cost Impacts

Additional factors that have been considered in the cost estimate in the following:

- Material shortages (e.g., rock rip-rap)
- Limited heavy material loads and construction equipment over the Hanalei Bridge
- Time and cost to mobilize heavy equipment using the dirt road
- Cost to develop and maintain access routes for use during construction, and cost for post construction restoration of these areas
- Potential need for biological and/or archeological monitoring services during construction
- Disposal of bed material removed from the main stem Hanalei River within the breach channel
- The contractor would be required to utilize Best Management Practices (BMPs) during construction to prevent any environmental pollution in and around Hanalei River. These temporary measures could consist of silt fences, turbity curtains, sand bags, and sedimentation ponds

6.3.2 Estimated Construction Costs

Conceptual level cost estimates are presented below for each engineering design alternative. The costs of the final remedial designs may vary from the conceptual level estimates based on other factors including land acquisitions, community needs, environmental issues, aesthetics, and local politics.

6.3.2.1 ALTERNATIVE NO. 1 – MAXIMUM WEIR

Conceptual level costs are estimated to be in the range of $1.1 million to construct Alternative No. 1 – Maximum Weir using Option A, precast concrete block core, or $1.3 million for Option B, steel sheet pile core. The higher cost for Option B is attributable primarily to the additional complexity of installing the steel sheet piles on site. See Table 6-1 and Table 6-2 below for details.

6.3.2.2 ALTERNATIVE NO. 2 – MINIMUM WEIR

For Alternative No. 2, the construction costs are estimated to be in the range of $1.0 million to construct Option A, precast concrete block core, or $1.3 million for Option B, steel sheet pile core. Again, the higher cost for Option B is attributable primarily to the additional complexity of installing the steel sheet piles on site. Furthermore, Alternative No. 2, Option A is estimated to be less costly than Alternative No. 1, Option A. This is attributed to reduced imported rock and concrete volume in the notched spillway. Further details and cost itemization are provided in Table 6-3 and Table 6-4 below.

Table 6-1: Estimated Construction Cost for Alternative No. 1, Option A

Item No.	Item	Approximate Quantity	Unit	Unit Price	Amount
1.0	Mobilization/ De-mobilization (15% of all items)	1	LS	$126,000	$126,000
2.0	Installation, Maintenance, Monitoring, and Removal of BMPs	1	LS	$125,000	$125,000
3.0	Clearing and Grubbing	10,000	SF	$3	$30,000
4.0	Temporary Coffer Dam	1	LS	$40,000	$40,000
5.0	Excavation	262	CY	$50	$13,100
6.0	Precast Concrete Segmented Blocks, In Place Complete	325	Each	$325	$105,475
7.0	Imported Rock Rip-rap Boulder Fill, In Place Complete	876	CY	$400	$350,400
8.0	Concrete Culvert Headwall, In Place Complete	2	Each	$12,500	$25,000
9.0	Corrugated Metal Pipe Culvert, In Place Complete	52	LF	$250	$13,000
10.0	Rock Rip-rap Energy Dissipator, In Place Complete	67	CY	$600	$40,000
11.0	Rock Vane, In Place Complete	1	Each	$12,000	$12,000
12.0	Rock Bank Spur, In Place Complete	3	Each	$12,000	$36,000
13.0	Restoration	1	LS	$50,000	$50,000
	Sub-Total				$965,975
	Contingencies (@ 10%)				$96,598
	Total Construction Cost				$1,062,573
				Rounded	$1,100,000

Table 6-2: Estimated Construction Cost for Alternative No. 1, Option B

Item No.	Item	Approximate Quantity	Unit	Unit Price	Amount
1.0	Mobilization/ De-mobilization (15% of all items)	1	LS	$155,000	$155,000
2.0	Installation, Maintenance, Monitoring, and Removal of BMPs	1	LS	$125,000	$125,000
3.0	Clearing and Grubbing	10,000	SF	$3	$30,000
4.0	Temporary Coffer Dam	1	LS	$40,000	$40,000
5.0	Excavation	262	CY	$50	$13,100
6.0	Driven Sheet Piles, In Place Complete	1,404	SF	$215	$301,860
7.0	Grouted Rock Fill (onsite dredging materials), In Place Complete	876	CY	$400	$350,400
8.0	Concrete Culvert Headwall, In Place Complete	2	Each	$12,500	$25,000
9.0	Corrugated Metal Pipe Culvert, In Place Complete	52	LF	$250	$13,000
10.0	Rock Rip-rap Energy Dissipator, In Place Complete	67	CY	$600	$40,000
11.0	Rock Vane, In Place Complete	1	Each	$12,000	$12,000
12.0	Rock Bank Spur, In Place Complete	3	Each	$12,000	$36,000
13.0	Restoration	1	LS	$50,000	$50,000
	Sub-Total				$1,191,360
	Contingencies (@ 10%)				$119,136
	Total Construction Cost				$1,310,496
				Rounded	$1,300,000

Table 6-3: Estimated Construction Cost for Alternative No. 2, Option A

Item No.	Item	Approximate Quantity	Unit	Unit Price	Amount
1.0	Mobilization/ De-mobilization (15% of all items)	1	LS	$120,000	$120,000
2.0	Installation, Maintenance, Monitoring, and Removal of BMPs	1	LS	$125,000	$125,000
3.0	Clearing and Grubbing	10,000	SF	$3	$30,000
4.0	Temporary Coffer Dam	1	LS	$40,000	$40,000
5.0	Excavation	262	CY	$50	$13,100
6.0	Precast Concret Block, In Place	325	Each	$325	$105,625
7.0	Imported Rock Rip-rap Boulder Fill, In Place Complete	712	CY	$400	$284,800
8.0	Concrete Culvert Headwall, In Place Complete	2	Each	$12,500	$25,000
9.0	Corrugated Metal Pipe Culvert, In Place Complete	52	LF	$250	$13,000
10.0	Rock Rip-rap Energy Dissipator, In Place Complete	111	CY	$600	$66,600
11.0	Rock Vane, In Place Complete	1	Each	$12,000	$12,000
12.0	Rock Bank Spur, In Place Complete	3	Each	$12,000	$36,000
13.0	Restoration	1	LS	$50,000	$50,000
	Sub-Total				$921,125
	Contingencies (@ 10%)				$92,113
	Total Construction Cost				$1,013,238
				Rounded	$1,000,000

Table 6-4: Estimated Construction Cost for Alternative No. 2, Option B

Item No.	Item	Approximate Quantity	Unit	Unit Price	Amount
1.0	Mobilization/ De-mobilization (15% of all items)	1	LS	$150,000	$150,000
2.0	Installation, Maintenance, Monitoring, and Removal of BMPs	1	LS	$125,000	$125,000
3.0	Clearing and Grubbing	10,000	SF	$3	$30,000
4.0	Temporary Coffer Dam	1	LS	$40,000	$40,000
5.0	Excavation	262	CY	$50	$13,100
6.0	Driven Sheet Piles, In Place Complete	1,404	SF	$215	$301,860
7.0	Grouted Rock Fill (onsite dredging materials), In Place Complete	712	CY	$400	$284,800
8.0	Concrete Culvert Headwall, In Place Complete	2	Each	$12,500	$25,000
9.0	Corrugated Metal Pipe Culvert, In Place Complete	52	LF	$250	$13,000
10.0	Rock Rip-rap Energy Dissipator, In Place Complete	111	CY	$600	$66,600
11.0	Rock Vane, In Place Complete	1	Each	$12,000	$12,000
12.0	Rock Bank Spur, In Place Complete	3	Each	$12,000	$36,000
13.0	Restoration	1	LS	$50,000	$50,000
	Sub-Total				$1,147,360
	Contingencies (@ 10%)				$114,736
	Total Construction Cost				$1,262,096
				Rounded	$1,300,000

7.0 PERMITTING REQUIREMENTS

While developing and assessing alternatives to meet the project goals is challenging, getting a project ready for construction also requires meeting the regulatory requirements through preparation and submittal of all required permits. The following section provides an overview for the anticipated permits required for construction of the Hanalei Valley Irrigation Intake Protection/Streambank Stabilization Project.

7.1 FEDERAL

7.1.1 Environmental Assessment/Environmental Impact Statement

The purpose of the National Environmental Policy Act (NEPA) as implemented by the Council on Environmental Quality Regulations (40 Code of Federal Regulations Parts 1500–1508 [1997]) is to ensure that adequate analysis of potential environmental impacts of proposed Federal actions projects and public disclosure of how this information is used in decision making. Environmental Assessments (EA) and Environmental Impact Statements (EIS) are the documents prepared in order to assist in disclosure and decision making. The State of Hawaiʻi has enacted a parallel system for the documentation and disclosure of environmental impacts (known as “Hawaii Revised Statutes Chapter 343”), however, since this project will use federal funding, and falls within a NWR, a NEPA-compliant (Federal) document would need to be prepared.

An EA is a document that is prepared to determine whether the various alternatives considered for the project will have any significant adverse impacts to the environment. Various studies are commissioned (biological, archaeological, etc). The public and various agencies are consulted through a public review process. An EA ends in one of three ways: 1) Finding of No Significant Impact (FONSI), 2) commitments to mitigation for impacts accompanied by a FONSI, or 3) a requirement to prepare an EIS. The EIS document is much more robust, and includes an in-depth analysis of the various alternatives, and fully discloses the impacts (short-term, long -term, and cumulative) for each of the alternatives. The end result, after public and agency input, is a Record of Decision, indicating what alternative is chosen. An agency may elect to proceed directly with an EIS if significant adverse impacts are anticipated with the implementation of the proposed action.

The preparation of an EA, including associated studies requires 10-12 months, whereas the minimum time to prepare an EIS is 18 months.

http://www.epa.gov/compliance/nepa/

7.1.2 Department of the Army Permit

The purpose of a Department of the Army (DA) Permit is to determine a project’s probable impact on the public interest and to identify possible environmental consequences. The first step in obtaining a DA Permit is to obtain a jurisdictional determination (JD) from the USACE.

Under the Clean Water Act (CWA) and Rivers and Harbors Act, the USACE regulates activities in waters of the United States, which generally includes coastal and inland waters, as well as rivers and streams feeding these water bodies. In the case of rivers, the horizontal extent (width) of the USACE’s jurisdiction extends to the ordinary high water mark. Jurisdiction is also extended to wetlands adjacent to any of these water bodies.

In the State of Hawaiʻi, given the proximity of the ocean, rivers and nearly all streams (intermittent and perennial) come under the jurisdiction of the USACE. Further, for this project it has already been determined by the USACE that a Wetland Delineation will be required prior to the commencement of any construction activities.

Any project that places materials into the waters of the United States (temporarily or permanently) requires both a DA Permit and more than likely a Section 401 Water Quality Certification (WQC) (discussed below). If projects are limited in size, routine maintenance, emergency repairs, etc., a less rigorous review of the application is possible by following the JD process, but is not likely in this situation.

The DA permit involves describing the potential dredged and/or fill material that could be discharged with implementation of the proposed activity, describing the structures to be constructed, and identifying environmental effects, alternatives considered, and mitigation measures. After the permit is submitted, a public notice is issued and a 30-day comment period begins. A public hearing may be required. A completed application must be submitted to the USACE at least 45 days prior to breaking ground at the project site.

http://www.usace.army.mil/CECW/Documents/cecwo/reg/eng4345a.pdf

7.1.3 National Historic Preservation Act Section 106 Consultation

National Historic Preservation Act (NHPA) Section 106 requires consultation with the State of Hawaii Department of Land and Natural Resources (DLNR) State Historic Preservation Division (SHPD) when a proposed project may affect historic properties included on the National Register of Historic Places, properties located on tribal lands, or when a Native Hawaiian organization places religious or cultural significance to a property. Most projects undertaken in the State of Hawaii must go through the Section 106 Consultation process (or State equivalent), given the cultural significance of locations throughout the archipelago. Hanalei is no exception.

With its rich history both pre- and post-Western contact, a letter to the SHPD must be prepared explaining the proposed project and its possible effects on the above stated items. SHPD will respond with a letter that may include a number of conditions and suggestions that would need to be followed during construction activities. It is important to request a response within 30 days.

http://www.achp.gov/106summary.html

7.1.4 Endangered Species Act Section 7 Consultation

The Endangered Species Act (ESA), Section 7, requires consultation with the National Marine Fisheries Service (NMFS) and/or USFWS when an action may affect listed species, or surrounding endangered species habitat. Almost all waterbirds and all seabirds are afforded protection under the ESA or the Migratory Bird Treaty Act. In addition, protected fish and invertebrates may use the waterway.

A biological assessment must be prepared to disclose the projects potential effects on listed species and their surrounding habitat. It is very likely that the project area is considered habitat for a number of these protected species, thereby necessitating this study and consultation.

After the biological assessment is submitted, NMFS or USFWS will respond with a biological opinion that may include a number of project alternatives. It is important to request a response within 30 days.

http://www.nmfs.noaa.gov/pr/consultation/

7.2 STATE OF HAWAII

7.2.1 Coastal Zone Management Federal Consistency Review

All federally licensed and/or permitted activities must be consistent with state coastal management policies as required by Section 307 of the Coastal Zone Management (CZM) Act. Federally licensed or permitted activities must be consistent with state coastal management policies (e.g., land use planning statutes, marine spatial planning, and water quality standards). A *Consistency*

Determination is the process used to implement this requirement for federal permits and licenses. Because Hawaii is composed entirely of islands with no point of land more than 30 miles from shore, Hawai‘i’s coastal zone encompasses the entire state. Accordingly, Hawai‘i’s CZM Program coordinates the various resource authorities throughout the state so that they function as a network in implementing the CZM Program.

The basic application submittal for a CZM Federal Consistency review includes the following materials: CZM application form; detailed project description; CZM assessment form; site location map; project plan or drawings; copy of the federal permit or license application; copy of the application for the Section 401 WQC and any additional information that will assist the review (e.g., EA or EIS, surveys, study and monitoring plans, etc.).

The Department of Business, Economic Development and Tourism (DBEDT) Office of Planning (OP) is the lead agency for the review process Within 6 months of a complete consistency certification submission, the OP reviews the application and notifies the federal action agency and the applicant of its concurrence or objection to the consistency determination. A Consistency Determination is issued when the applicant and the project reviewers concur with the state’s consistency determination, including any stipulations. An objection to a consistency determination may be appealed to the Secretary of Commerce.

http://hawaii.gov/dbedt/czm/program/fed_con/fed_con_assess.pdf

7.2.2 Special Management Area Permit

A Special Management Area Permit (SMAP) assesses proposed coastal development projects to ensure consistency with SMA guidelines. In the State of Hawaii, each County has drawn its SMA boundaries, ranging from as few as 100 yards to multiple miles inland. Between the shoreline and this boundary, Counties regulate development.

A SMAP is designated as either minor or major. A minor SMAP is issued for projects that have a construction appraisal of less than $125,000. The review process is shorter and a public hearing is not required for minor SMAPs. A major SMAP is required for construction appraisals greater than $125,000 and a public hearing may be required.

SMAPs are regulated by each County through their Department of Planning and Permitting. A $500 filing fee must be submitted with the completed application. Processing usually takes approximately 6 months but can take up to 12 depending on public involvement. Similar to the CZM Consistency Review, while this project falls outside the SMA boundary, a formal request for concurrence with this determination must be made with the County of Kaua‘i Planning Commission who will facilitate the Public Hearing.

http://hawaii.gov/dbedt/czm/program/sma/sma_use_app.pdf

http://hawaii.gov/dbedt/czm/program/sma/sma_instructions.pdf

7.2.3 Conservation District Use Application

The State of Hawaii has designated various lands (both public and private) throughout the Islands as set aside for Conservation District Use. Within the Conservation District, areas are divided into subzones that are afforded escalating levels of protection (General, Resource, Limited, Protected, and Special). Only certain activities are permitted within the Conservation District, and the list becomes progressively restrictive depending on the subzone.

A project is required to submit a Conservation District Use Application (CDUA) when any Conservation District land is used that is not permitted by the State Land Use Law. All ocean water and submerged lands (sea floor) in Hawaii are part of the Conservation District.

The DLNR Office of Conservation and Coastal Lands (OCCL) is the accepting authority for the CDUA. To confirm that a CDUA is necessary, the project proponent must submit a Request for Information to OCCL. OCCL will respond within 30 days with a determination if a CDUA is required. A CDUA can take up to 12 months for processing and requires $500-$1,000 in filing fees. This project lies within the resource possibly the protective subzones of the Conservation District. At a minimum, a formal request for concurrence with this determination must be made.

http://hawaii.gov/dlnr/occl/documents-forms/applications-forms

http://hawaii.gov/dlnr/occl/documents-forms/applications-forms/CDUA-marine.pdf

7.2.4 Stream Channel Alteration Permit

A Stream Channel Alteration Permit (SCAP) is issued in order to “protect, enhance, and reestablish, where practical, beneficial in-stream uses of water including the creation of a permit system to regulate the alteration of stream channels.”

A SCAP is necessary when substantive changes are proposed to the waterway, including, but not limited to changes causing hydrological and biological impacts. Channelization, diversion (alteration of flow), and realignment of waterways are common examples of types of projects requiring a SCAP.

The DLNR Commission on Water Resource Management (CWRM) will determine if a SCAP is required for the proposed project and will administers the permit. A $25 filing fee must be submitted with the completed application. After CWRM approves the SCAP, they will publish a public notice and solicit comments. The total time frame is approximately 6 months.

http://hawaii.gov/dlnr/cwrm/resources_permits.htm

http://hawaii.gov/dlnr/cwrm/forms/SCAP.pdf

http://www.state.hi.us/dlnr/cwrm/permitdiagrams/dgscap.pdf

7.2.5 Water Quality Certification, Section 401

A WQC ensures that State Water Quality standards are upheld, and further sources of pollution are not created throughout a project. Should the USACE take jurisdiction over the proposed project, a Section 401 (of the CWA) WQC must be obtained from the State of Hawaii Department of Health (DOH) Clean Water Branch (CWB). Any project that places materials into the water requires both a DA Permit and a Section 401 WQC. BMPs and a Mitigation/Compensation Plan must be thoroughly defined to ensure that the subject waters are not adversely impacted. The completed application and $1,000 filing fee are submitted to the DOH CWB. After the application is submitted, a Public Notice of Proposed Action is issued and a 30-day comment period begins (publication of notice in the newspaper is an additional $1,400). A public hearing may be required. The WQC process can take 12 months to complete, depending on the complexity of the project. CWB is now more closely reviewing and commenting on recent WQC submittals.

http://hawaii.gov/health/environmental/water/cleanwater/forms/pdf/wqcguide.pdf

http://hawaii.gov/health/environmental/water/cleanwater/forms/pdf/cwb-wqc.pdf

7.2.6 National Pollutant Discharge Elimination System General Permit for Storm Water Associated with Construction Activities

The purpose of the National Pollutant Discharge Elimination System (NPDES) permit is to control water pollution by regulating point sources that discharge pollutants into waters of the United States. The NPDES permit is authorized under the CWA, and reviewed and approved by the State of Hawaii DOH CWB. Because this project falls within a wildlife sanctuary, it is not eligible for coverage under the State's General Permit, and must apply for a project-specific Individual Permit.

The requirement for the NPDES Individual Permit arises from the need to allow either one of two types of discharge to return to the regulated waterbody (Hanalei River): 1) construction dewatering effluent, and 2) site stormwater runoff.

An example of the first (construction dewatering effluent) for this project might include a requirement to "work in the dry." A temporary cofferdam may need to be built around the existing intake and water removed in order to successfully make the repair. The action of pumping water out of the work area back to the river requires a permit.

The second discharge (construction site stormwater runoff) also requires permitting to ensure that construction activities are performed in such a way as to minimize rainfall from coming into contact with pollutants (which include lose soil, for example) and to prevent water from leaving the site until all pollutants have been removed.

A Signatory and Certification Statement, Individual Application Form must be completed and filed with CWB along with a $1,000 permit application filing fee. The application involves detailing the sources of water (rainfall and/or any waters pumped from the work site to create a dry workspace) and measures that will be taken to prevent the introduction of pollution prior to the waters' return (discharge) to the waterbody. Testing for water quality parameters may also be required. BMPs must be submitted for review. Submitting Site-Specific BMPs with the initial application will expedite the review process.

After the application is submitted, a Public Notice of Proposed Action is issued and a 30-day comment period begins (publication of notices in the newspaper are an additional $1,400). A public hearing may be required. After a completed permit is submitted to DOH, a response is usually given within 4-6 months.

http://hawaii.gov/health/environmental/water/cleanwater/forms/indiv-index.html

7.3 KAUA'I COUNTY

7.3.1 Grading & Grubbing Permits

A grading permit is required by the County for projects that meet the following criteria, all of which apply to the proposed project:

- Planned excavation is more than 100 cy.
- Project will alter the general drainage pattern to the detriment of abutting properties.
- Exceeds 5 feet at its deepest height or depth.

A grubbing permit is required by the County for projects that meet the following criteria, all of which also apply to the proposed project:

- Planned grubbing exceeds one acre.
- Project will alter the general drainage pattern to the detriment of abutting properties.

The applicant must submit design of the proposed project to the County of Kaua‘i, Department of Public Works, Engineering Division for review and approval by the County Engineer. Applicable documents include site plans and cross sections showing the extent of the work, BMPs and Sediment and Erosion Control plans, and an Engineer’s soils report. A purpose of the grading permit is to ensure BMPs to be employed are incorporated to prevent damages by sedimentation to streams, watercourses, natural areas and the property of others to the maximum extent practicable. A public hearing is not required. The County often waives the Grading Permit requirements for State owned projects where earthwork is less than 100 cy.

http://www.kauai.gov/Government/Departments/PublicWorks/Engineering/DesignampPermitting/tabid/133/Default.aspx

8.0 PROJECT IMPLEMENTATION AND FUNDING OPPORTUNITIES

A search for potential funding programs and sources for implementation of any proposed improvements was conducted. The search considered the multiple land parcels with different owners and lessees, multiple project purposes, and governmental programs.

Potential funding opportunities are described below, categorized by government level or as Non-Governmental Organization.

8.1 FEDERAL

8.1.1 U.S. Department of Agriculture Natural Resources Conservation Service

The NRCS administers programs created by two federal acts that can provide technical and financial assistance.

8.1.1.1 WATERSHED AND FLOOD PREVENTION ACT, PUBLIC LAW 83-566

The Watershed Programs provide assistance to communities by evaluating the water resources problems and opportunities in a watershed-scale evaluation. The Hanalei project will be evaluated as a component of the larger Hanalei Watershed. Eligible purposes include agricultural water management, water quality improvement, and watershed restoration.

The Watershed Surveys and Planning (WSP) Program can fund technical studies, development of project plans, and preparation of EAs or EISs for authorized water resources projects. Generally, up to 100% of the study and planning costs can be provided through the WSP Program. The local sponsors will be responsible for funding nonfederal requirements, such as unique aspects of the state EIS process. The request for study or planning authorization is submitted by the sponsoring local organization to the NRCS Director for the Pacific Islands Area. Funding for the WSP Program has not been appropriated by Congress since 2008.

http://www.nrcs.usda.gov/programs/watershed/Surveys_Plng.html

The Watershed Operations (WO) Program can fund installation of completed Watershed Plans and, potentially, other complying water resources projects. Generally, the WO Program will fund between 50% and 100% of the design, construction, and engineering costs of structures, depending on the project purpose, and the local sponsor will be responsible for the remainder of design, construction, and engineering costs. In addition, the local sponsors are responsible for acquisition of landrights, permits and approvals, and operation, maintenance, and replacement for the life of the project. The request for authorization of a project is submitted by the sponsoring local organization to the NRCS Director for the Pacific Islands Area. Funding for the WO Program has declined sharply in the past decade with an authorized project backlog of approximately $1 billion.

http://www.nrcs.usda.gov/programs/watershed/protect-and-prevent.html

The Emergency Watershed Protection Program is a disaster recovery program, which authorizes NRCS to immediately assist with and provide funding for situations involving threats to life and property caused by natural disasters. While an emergency declaration is not necessary for the application, a singular, identifiable natural disaster event is needed to trigger the application process. Applications for assistance need to be submitted within 60 days of the event. NRCS can reimburse up to 75% of the project costs and up to 90% in certain limited-resource situations. Contact with any NRCS Office can start the assistance process following a disaster event.

http://www.nrcs.usda.gov/programs/ewp/

8.1.1.2 2008 Farm Bill Conservation Programs

The 2008 Farm Bill provides NRCS with authority and funding for several programs that may be applied to portions of the Hanalei project. These programs are delivered to individual agricultural producers and landowners and managers.

The Environmental Quality Incentives Program (EQIP) provides technical and financial assistance to agricultural producers to reduce erosion, improve air and water quality, and improve natural habitat for at-risk wildlife. The EQIP program will likely be limited to the privately-leased parcels of the Hanalei project area. Assistance through EQIP can be requested by the landowner or manager from the NRCS Office at the Lihu‘e Service Center.

http://www.nrcs.usda.gov/programs/eqip/

The Wildlife Habitat Incentives Program (WHIP) provides technical and financial assistance to land owners for improvement of habitat for nationally and locally important wildlife species. While the land does not have to be in agricultural production, the land must be privately owned. Improvements can include wetland creation and enhancement for native waterfowl habitat. Assistance through WHIP can be requested by the landowner or manager at the NRCS Office at the Lihu‘e Service Center.

http://www.nrcs.usda.gov/programs/whip/

Other Farm Bill Programs may apply to the Hanalei Project area. Contact the NRCS Office at the U. S. Department of Agriculture’s Lihu‘e Service Center for further information about Farm Bill Programs.

8.1.2 U.S. Fish and Wildlife Service

The USFWS has many Divisions administering diverse programs, including the Wildlife Refuge Division which manages the Hanalei Wildlife Refuge. While the breach on the Hanalei River directly impacts the volume of water reaching their agricultural and wildlife pond water delivery system, the refuge managers state that they have no authority to fund projects outside of the refuge boundary.

The USFWS’ Fisheries and Habitat Conservation Division administers programs and participates in partnerships that may assist with implementation of repairs to the breach. Purposes for the involvement of the Division will include protection and improvement of habitat for native stream organisms, such as the four species of ‘o‘opu. The USFWS offers a financial assistance program through the National Fish Habitat Action Plan. The maximum grant is $250,000. Application for the grant should be made through the Hawaii Fish Habitat Partnership.

http://fishhabitat.org/index.php?option=com_content&view=category&layout=blog&id=35&Itemid=27

http://fishhabitat.org/index.php?option=com_content&view=article&id=182:hawaii-fish-habitat-partnership&catid=44:partner-profiles&Itemid=37

8.1.3 U.S. Army Corps of Engineers

The USACE administers programs to assist communities with water resources problems. The Planning Assistance to the States Program can provide USACE technical assistance to prepare a planning-level analysis and documents. Federal funding is limited to $500,000 annually, although most projects receive considerably less in funding, and must be cost-shared at a 50% federal-local ratio. This program would be valuable if the current breach repair project is expanded to include other stream and watershed areas in Hanalei.

The USACE provides water resources project implementation assistance through the Continuing Authorities Program. The Program is a collection of water resource project authorities provided in various congressional acts. The program can be used for streambank modifications and improvements and ecosystem restoration. The process for project implementation will require Congressional authorization of the project and appropriation of funds.

USACE assistance can be requested from the Civil and Public Works Branch located at Fort Shafter, Hawaii.

http://www.poh.usace.army.mil/CW/CW.htm

Hawaii Congressional Delegation

Hawaii's Congressional delegation has taken a strong interest in solving the water resources problems that exist in the state. They are able to direct federal technical and financial resources to assist local governments and organizations. Contacts with Senator Daniel Inouye, Senator Daniel Akaka, and Representative Mazie Hirono (2nd Congressional District) should be made whenever major program requests are made to federal agencies.

http://inouye.senate.gov/

http://akaka.senate.gov/

http://hirono.house.gov/

8.2 STATE OF HAWAII

8.2.1 Department of Health

The DOH's CWB administers the federal CWA, Section 319(h) grants program. Grants are provided to local governments and other organizations to prevent and/or reduce nonpoint source pollution to improve water quality of receiving water bodies. A wide range of activities can be funded by the 319 grant, including management or improvements to reduce nutrient or sediment runoff, control of invasive alien species and restoration of native vegetation in critical areas of the watershed, and modification of watershed improvements to include nonpoint source pollution controls.

The Hanalei Watershed is included in the list of priority watersheds, which can improve the ranking of a proposal in Hanalei. The CWB accepts applications for 319 grants until late June of each year.

http://hawaii.gov/health/environmental/water/cleanwater/prc/environmental/water/cleanwater/prc/index.html

http://www.epa.gov/owow_keep/NPS/cwact.html

8.2.2 Department of Land and Natural Resources

The DLNR owns most of the property affected by the current project. For those parcels not leased to other private parties, the DLNR Division of Land Management has primary responsibility to comply with federal and state regulations and policies for floodplain management, nonpoint source pollution control, aquatic habitat, and wetlands. Repairs to comply with any of the regulations or policies will normally be funded from their operating budget. If funds are inadequate or authorities for use of the funds are exceeded, a funding request for the project is made in the DLNR legislative budget request. The budget is submitted at the start of the biennial legislative session.

The DLNR administers many state and federal programs to assist landowners and land managers with land management issues. A listing of the programs is found on the Division of Forestry and Wildlife website, which also includes a link to a detailed listing for federal and state incentives programs for land management on private lands. Due to the DLNR ownership of much of the area included in this project, many of the programs are unavailable.

http://hawaii.gov/dlnr/divisions/offices/aso/aso/

http://www.state.hi.us/dlnr/dofaw/lap/index.html

8.2.3 Coastal Zone Management Program

The Hawaii CZM Program is located in the DBEDT's Office of Planning. While the CZM Program does not directly administer funding assistance programs, the CZM program engages in partnerships for protection and enhancement of coastal and watershed resources. These partnerships are important sources of legislative funding requests. The CZM program also can serve as a pathway to National Oceanic and Atmospheric Administration technical and financial resources.

http://hawaii.gov/dbedt/czm/index.php

http://www.csc.noaa.gov/regions/pacific.html

8.2.4 Department of Agriculture

The Hawaii Department of Agriculture (DOA) is involved in many aspects of taro production and marketing in the Hanalei Valley. However, the DOA is not involved in the irrigation water supply to the farms. The DOA's Agricultural Resources Management Division (ARMD) manages and operates the State's ten agricultural parks and five Irrigation water systems throughout the state. An association of the Hanalei irrigation system with the DOA can make available the technical and financial resources of the ARMD. The ARMD receives legislative appropriations for capital improvements and emergency repairs for its land and water facilities.

http://hawaii.gov/hdoa/arm

8.2.5 State Legislature

Many capital improvement and significant repair projects on state-owned land will require a separate line item appropriation by the Legislature. The operating and capital improvement budget requests are submitted by the departments at the beginning of the legislative session. If the improvement is included in the department budget request, contact with State Representatives and Senators who are in a position to advocate or vote upon the request is important. As the rules for legislative action and the committee structure are often complicated, guidance from the requesting department and community lobbying organizations should be sought.

http://hawaii.gov/lrb/capitoli/dirguide/ (link to Legislative directory)

8.3 COUNTY OF KAUAʻI

Due to the State ownership of the project area, it is unlikely that the County of Kauaʻi will provide financial assistance for project implementation. The County may have interest in water quality effects of the project on the Hanalei Watershed and might partner with associated projects for water quality improvement such as with the County Road. Contact with the Mayor, key County Council members, and Director and leadership staff at the Department of Public Works and Planning Department can be made to inform them of the project and to seek partnership relations.

8.4 NON GOVERNMENTAL ORGANIZATIONS

8.4.1 Hanalei Watershed Hui

The Hanalei Watershed Hui (HWH) is a nonprofit organization focused on environmental and cultural enhancement of the watersheds that flow into Hanalei Bay. The HWH has partnered with federal projects and other grant-funded projects to improve water quality and cultural awareness in Hanalei. The HWH's network of contacts with other organizations and funding programs might provide opportunities for implementation financial and technical assistance.

http://www.hanaleiwatershedhui.org/

8.4.2 Garden Island Resource Conservation and Development

The Garden Island Resource Conservation and Development (GIRC&D) program states that it is “an independent, nonprofit, nonpartisan, community-based organization focused on the prudent use of natural and human resources on the Island of Kaua‘i. It is sponsored by the U.S. Department of Agriculture, administered by the NRCS—a federal agency—and locally managed.”

The GIRC&D has been a nonprofit 501(3)(c) since 1993 and has the capacity to apply for and administer government and private grants. They have partnered with a long list of government agencies and nongovernmental organizations. Their Five-Year Area Plan includes support “requesting projects that practice erosion and sediment control” and “improvement of agricultural water management and improvement.”

To receive GIRC&D assistance, a project application is made to the RC&D Council which decides on approval and further steps to identify funding sources.

http://www.gircd.org/index.html

9.0 REFERENCES

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Rosgen. D. 2006. *Watershed Assessment of River Stability and Sediment Supply.* Fort Collins, CO: Wildland Hydrology.

Moffatt and Nichol, 2007, *Preliminary Feasibility Assessment Hanalei River Diversion*.

United States Geologic Survey (USGS) 1999. *Description of Gage Station on Hanalei River near Hanalei, Kauai. Station Number 16103000*. Revised September 28, 1999.

Appendix A
Stakeholder Meeting Notes

Hanalei Valley Irrigation Intake Protection
/ Streambank Stabilization Preliminary Investigation
Hanalei Kauai, Hawaii

MEETING SIGN-IN SHEET

DATE: 7/1/10

NAME	ORGANIZATION	ADDRESS	PHONE NUMBER	EMAIL ADDRESS
BRANDON WEAVER	AECOM	1001 BISHOP ST. #1600, HONOLULU 96813	808 529 7214	brandon.weaver@AECOM.com
ARDALAN NIKOU	"	"	808 (551-4150)(C) 808 396 4163	ardalan.nikou@AECOM.com
Dudley Kubo	KuboEng.	99-1010 Kalua Pl. Aiea 96701	808 722 9376	dykubohi@yahoo.com
LEX RIGGLE	USDA-NRCS	4334-RICE ST., LIHUE 96766	808-245-9014 x101	lex.riggle@hi.usda.gov
Marj Stanphill	EKSWCD	#334 Rice St Lihue 96766	808 245-6513 x 27	marjorie.stanphill@hi.nacdnet.net
Ted Inouye	"	"	"	"
Sharon Sawdey	NRCS	on file	808-541-2600 x125	sharon.sawdey@hi.usda.gov
Rodney + Karol Haraguchi	Kauai Taro Growers Assn			
Ga[illegible]	taro farm			
EUGENE HARRELL	AECOM	1001 BISH St STE 1600 96813	529-7208	
CARL IMPARATO	Hanalei-to-Haena Community Association	P.O. Box 1102, Hanalei 96714	826-1856	CARL.IMPARATO@JUNO.COM
STEPHEN BLANTON	AECOM		503.312.9339	STEPHEN.BLANTON@AECOM.COM

Hanalei Valley Irrigation Intake Protection
/ Streambank Stabilization Preliminary Investigation
Hanalei Kauai, Hawaii

MEETING SIGN-IN SHEET

DATE: 7/1/10

NAME	ORGANIZATION	ADDRESS	PHONE NUMBER	EMAIL ADDRESS
Makaala Kaaumoana	HWtt		346-5458	makaala@hawaiian.net
Barbara Robeson	HWtt		826-9370	robeson b 999@hawaii.rr.com
Mina Morita	property owner	PO Box 791 Hanalei	256-5076	repmorita@capitol.hawaii.gov

Hanalei Valley Irrigation Intake Protection / Streambank Stabilization Preliminary Investigation Hanalei, Kauai, Hawaii

Meeting Minutes

Date: **July 1, 2010**

Location: **Laney/Morita residence, Hanalei, Kauai**

Subject: **Stakeholders Meeting concerning the Hanalei Valley Irrigation Intake Protection/Streambank Stabilization Preliminary Investigation**

- Attendees:

Lance Laney/Mina Morita	Landowners and DLNR Lessees
Makaala Ka'aumoana	Hanalei Watershed Hui
Barbara Robeson	Hanalei Watershed Hui
Carl Imparato	Hanalei to Haena Community Association
Rodney and Karol Haraguchi	Hanalei Taro Growers Assn
Gary Koga	Hanalei Taro Growers Assn
Ted Inouye	East Kauai SWCD
Marjorie Stanphill	Kauai SWCDs
Lex Riggle	NRCS
Sharon Sawdey	NRCS
Stephen Blanton	AECOM
Ardalan Nikou	AECOM
Brandon Weaver	AECOM
Eugene Harrell	AECOM
Dudley Kubo	Kubo Engineering

- The meeting began at 10 AM with a welcome by Inouye and self-introductions by attendees. Kubo described the objectives of the project which include stabilization of the river bank at the breach, restoration of consistent streamflow to the FWS intake, maintenance of flow in the cutoff channel, and community stakeholder satisfaction. The product of the study will be a conceptual alternative and design that can be implemented in a subsequent phase of the project.

- Blanton described the methodologies involved in analysis and preparation of the project alternatives. He discussed the surveying process, development of a hydraulic model, and geomorphological investigation. Analysis will cover 1500 'downstream of breach and 2500' upstream of breach (close to the old China ditch).

- Sawdey discussed the project's background which began with a request by the Taro Growers to the East Kauai SWCD and NRCS. NRCS granted the funding to the East Kauai SWCD through the Conservation Technical Assistance Program.

- Morita described the history of the breach which first occurred in 1995 when a series of three major floods, in a 90-day period, forced the river over its banks. She recounted that an emergency repair of the breach using boulders failed in a following storm creating safety concerns and enlarging the cutoff channel. She is concerned that each failure at the breach has been repaired using a short-cut emergency process without environmental and engineering review. Sawdey stated that the current project will incorporate environmental review and risk and stability investigation.

- Morita also stated that additional problems for their property include floodwater from mauka areas to the west and flows in portions of the abandoned ditch system. She pointed out the drainage ditch that was dug. She also described mosquito problems due to stagnant water.

- R. Haraguchi said that he was told about portions of the old ditch system below the breach that provided water to taro field in the interior of the river oxbow. He also said that the present cutoff location was a swamp. He also expressed his appreciation of the support to taro farmers to solve their water problem.

- Environmental concerns and issues were discussed.

- There was agreement that native aquatic organisms, especially o'opu, needed to be protected – no invasive species, ensure passage and protect habitat. Don Heacock, DAR, and Gordon Smith, USFWS, should be contacted.

- Maka'ala stated that hydro-mulching should not be used (wants to prevent introducing invasive species such as fire-weed).

- The project should not increase sediment or bacterial pollution as Hanalei River is a 308(d) listed stream. The project should complement TMDLs and 319 projects for the Hanalei River.

- Laney mentioned the heating of the water in the cutoff channel during dry, hot summer months and loss of habitat for o'opu. R. Haraguchi added that water supplies are short for everyone during summers and droughts. Taro farmers are unable to get needed water volumes. A comment was made that FWS use of water in their ponds reduce water available to farmers.

- Use of ha'u in vegetating the project improvements was discouraged by the Hanalei Watershed Hui.

- Pursuit of other alternatives to provide water to the China Ditch was questioned. Sawdey responded that the current project can bring the quickest solution.
  R. Haraguchi added that the old China Ditch could only handle half of the capacitiy of the current system, and requires more maintenance.

- Ka'aumoana mentioned that privately owned properties to the west of the refuge are in need of water to convert them from pasture to cropland. She asked whether additional water could be made available throught the China Ditch. She also stated that many planning decisions need a valley-wide water budget to evaluate effects of an action to other water users.

- Laney and Morita were asked to indicate the amount of water that they would like to see flowing in the cutoff channel after the breach is repaired. They responded that they were not interested in stating an amount of flow or fraction of total flow, but wanted an appropriate amount to manage the mosquito problem and prevent warming of the stream. They were also wanting to reduce bank erosion and repair their eroded banks. They wanted to assure that the farmers also received the water required for their fields. They said that they had opposed the notion of a concrete wall to repair the breach as earlier proposed.

- If rock was to be brought in as a part of the repair, the Hanalei Watershed Hui would like it to be well washed to reduce sediment and pest contamination. A source for large, dense, angular rocks should be located.

- Ka'aumoana asked for the cost of the current contract. Blanton replied that is was in the range of $100,000 to $175,000 (?). The study is ecpected to be completed by May 2011. Sawdey stated that the contract work must be invoiced by September 30, 2011.

- Blanton described the next steps for the project:
    1. Survey of river cross-sections
    2. Hydraulic modeling of flood conditions
    3. Analysis geomorphic changes and function of structures
    4. Formulation of preliminary alternatives

- Several of the meeting participants followed Morita on a trail to the breach location to examine the river, breach and temporary repair. It was estimated that up to one-third of the streamflow was directed to the cutoff channel.

Hanalei Valley Irrigation Intake Protection
/ Streambank Stabilization Preliminary Investigation
Hanalei Kauai, Hawaii

MEETING SIGN-IN SHEET

DATE: 7/2/10

NAME	ORGANIZATION	ADDRESS	PHONE NUMBER	EMAIL ADDRESS
BRANDON WEAVER	AECOM	1001 BISHOP ST. #1600 HONOLULU, HI 96813	(808) 529-7214	brandon.weaver@AECOM.com
STEPHEN BLANTON	AECOM	" " "	503.312.9839	STEPHEN.BLANTON@AECOM.COM
Rodney Haraguchi	KTGA		826-6202	
Carl Imparato	Hanalei-Haena Cmty Assn	Box 1102, Hanalei 96714	826-1856	carl.imparato@juno.com
Kelly Bynum	USFWS			
Tasia Chase	USFWS			
Charles Spencer				
Dawn Spencer				
Eden Wynd	USFWS/YCC		[illegible]	edenwynd@gmail.com
Mason Chock	USFWS/YCC			klmachoc@ksbe.edu
Dudley Kubo	KE	99-1010 Kahua Pl Aiea, HI 96701	8087229376	dykubohi@yahoo.com

Hanalei Valley Irrigation Intake Protection
/ Streambank Stabilization Preliminary Investigation
Hanalei Kauai, Hawaii

MEETING SIGN-IN SHEET

DATE: 7/2/10

NAME	ORGANIZATION	ADDRESS	PHONE NUMBER	EMAIL ADDRESS
Alex Diego	Diego Farms		651-8558	
Bobby Watari		P.O. Box 38 Hanalei	826-6395	
Lauren Esaki	USFWS		822-0214	
Azurae Burdett	USFWS			
Mike Mitchell	USFWS	P.O. Box 1128	828-1413	michael_mitchell@fws.gov
Gary Koga	taro farmer	P.O. Box 323 Kilauea		
Kaioli Brun	USFWS			

Hanalei Valley Irrigation Intake Protection / Streambank Stabilization Preliminary Investigation Hanalei, Kauai, Hawaii

Meeting Minutes

Date: **July 2, 2010**

Location: **Wai`oli Hui`ia Church, Hanalei, Kauai**

Subject: **Hanalei Community Meeting concerning the Hanalei Valley Irrigation Intake Protection/Streambank Stabilization Preliminary Investigation**

- Attendees: See attached sign-in sheet.

- Introductions:
  The meeting began at 1:00 PM with an introduction by Dudley Kubo. Kubo described the objectives of the project which include stabilization of the river bank at the breach, restoration of consistent stream flow to the FWS intake, maintenance of flow in the cutoff channel, and community stakeholder satisfaction. The product of the study will be a conceptual alternative and design that can be implemented in a subsequent phase of the project.

- Project Background:
  The project's background was explained as that it began as call for help by the Taro Growers Association to the East Kauai SWCD and NRCS. NRCS granted the funding to the East Kauai SWCD through the Conservation Technical Assistance Program.

- Project Approach:
  Stephen Blanton of AECOM described the methodologies involved in analysis and preparation of the project alternatives. He discussed the surveying process, development of a hydraulic model, and geomorphological investigation. Analysis will cover 1500 'downstream of breach and 2500' upstream of breach (close to the old China ditch).

  Blanton described the next steps for the project:
  1. Survey of river cross-sections
  2. Hydraulic modeling of flood conditions
  3. Analysis geomorphic changes and function of structures
  4. Formulation of preliminary alternatives

- R. Haraguchi expressed his appreciation of the support to taro farmers to solve their water problem. He explained that the taro growers have dealt with this issue for over 15 years.

- Questions and Answers:
  1. *What flood events are will the design alternatives be based on?* Tentatively, the design alternatives presented in this study will be based on 10 year and 25 year storm events.
  2. *When did the problem with the breach first begin to occur?* The earliest recorded breach occurred in 1995.

3. *Hurricane Iniki produced many felled trees in the Hanalei watershed. This led to accelerated soil erosion. Could this have contributed to the breach?* Possibly. The study will involve geomorphology to help determine why the breach has occurred. The repair will be designed to withstand the forces of water and debris (ie. boulders) that commonly mobilize during storm events.
4. *Will the project widen the river to accommodate debris flow?* The study will determine what river geometry is best suited for the breach location.
5. *If stream channel is not designed to handle the correct velocity, will the channel overtop?* Mother Nature seems to always overtop anything that is built in her path. It may be possible to overtop the repair structure, however the repair would be design to withstand overtopping.
6. *Why not move the intake structure to a location that would work better, perhaps upstream of the breach location?* The existing intake structure irrigation network is contained within the USFWS property. Moving the intake offsite would require agreements with the other landowners for both construction and maintenance of the system.
7. *Why not use the old China Ditch?* The old China Ditch requires extensive repairs to bring it back on line. The old China ditch has been reported to have only ½ of the capacity of the current system. Furthermore, the old China ditch requires more maintenance because it is an earthen lined channel.
8. *Why design a repair that is only a midterm solution?* Construction costs and available funding are the main factors. The duration will be looked at further during the study.
9. *Will the repairs be in the million dollar price range?* Possibly. This study will consider at least one low tech/low cost design alternative.
10. *Will other options be considered?* Other options have been examined under previous studies (ie. hydraulic pump), and were determined require huge construction, maintenance, and operational costs.
11. *How is this study being funded?* The study is being funded by the USDA NRCS. The funds do not cover the cost for construction. The study will identify possible sources to obtain construction funding.
12. *Will the final decision be a joint decision?* Yes, the final method of repair will be jointly decided on by the stakeholders. The community has the opportunity to participate in the study through community meetings.

Appendix B
Alternative Designs

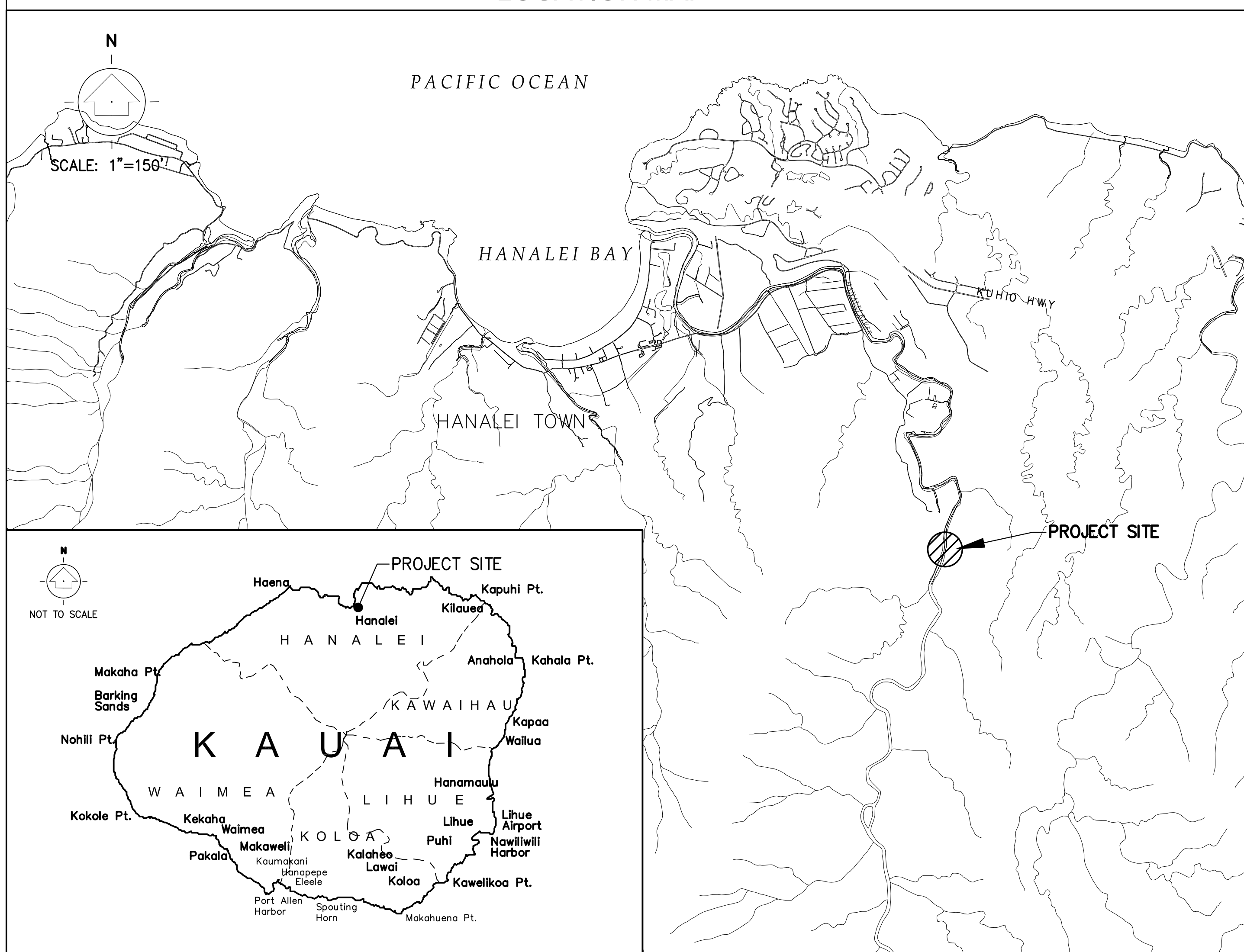
UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

HANALEI VALLEY IRRIGATION INTAKE PROTECTION AND STREAM BANK RESTORATION PRELIMINARY INVESTIGATION

HANALEI, KAUAI, HAWAII
TAX MAP KEY 454002034

PREPARED BY: AECOM
1001 BISHOP ST, SUITE 1600
HONOLULU, HAWAII 96813

LOCATION MAP



INDEX TO DRAWINGS

SHT NO.	DESCRIPTION
1	TITLE SHEET
2	SITE ACCESS AND STAGING PLAN
3	SITE PLAN AND GRADING PLAN
4	ALTERNATIVES NO. 1 AND NO. 2, PROFILE AND CROSS SECTIONS
5	STRUCTURAL ALTERNATIVES
6	ROCK VANE LAYOUT
7	DETAILS

APPROVALS

Designed	S. BLANTON	Date —
Drawn	B. WEAVER	—
Checked	A. NIKOU	—
Approved		

TITLE SHEET

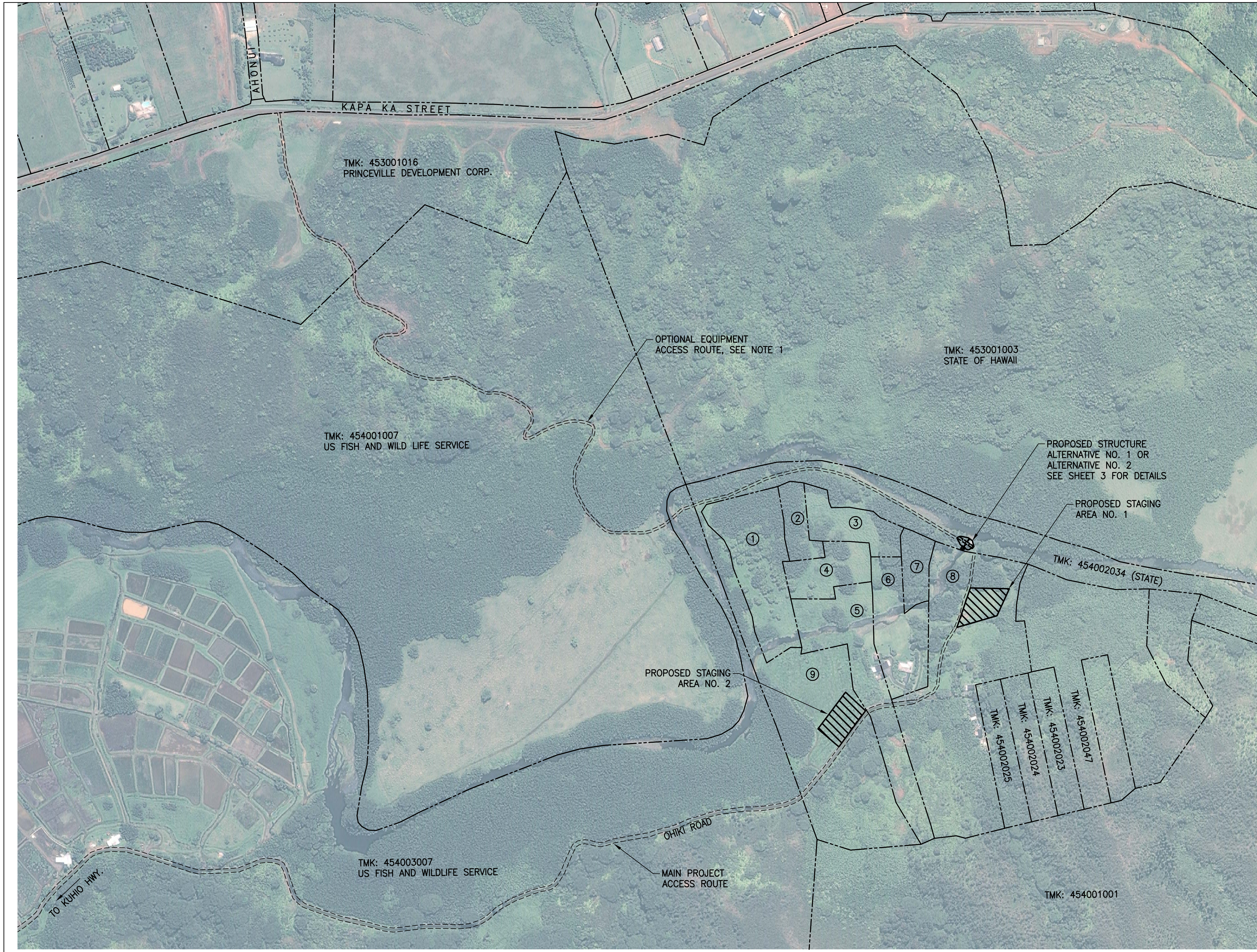
HANALEI VALLEY IRRIGATION INTAKE PROTECTION/STREAMBANK STABILIZATION PRELIMINARY INVESTIGATION
HANALEI, KAUAI, HAWAII

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

File Name

Drawing Name

Sheet 1 of __



STAGING PLAN

SCALE: 1"=60'

GRAPHIC SCALE

0 500 1000

SCALE: 1"=500'

NOTES:

1. CONTRACTOR MAY USE OPTIONAL ACCESS ROUTE FOR EQUIPMENT MOBILIZATION AND DEMOBILIZATION ONLY. THE CONTRACTOR SHALL BE RESPONSIBLE TO RESTORE AFFECTED AREAS TO ORIGINAL CONDITIONS OR BETTER.

LEGEND:

- PROPOSED STAGING AREA
- ACCESS ROAD
- PROPERTY LINE

NO.	TMK	OWNER
①	454002038	STATE
②	454002044	PRIVATE
③	454002042	STATE
④	454002045	PRIVATE
⑤	454002033	STATE
⑥	454002032	PRIVATE
⑦	454002031	STATE
⑧	454002026	STATE
⑨	454002034	STATE

Designed	S. BLANTON	Date
Drawn	B. WEAVER	
Checked	A. NIKOU	
Approved		

SITE ACCESS AND STAGING PLAN

HANALEI VALLEY IRRIGATION INTAKE
PROTECTION/STREAMBANK STABILIZATION
PRELIMINARY INVESTIGATION
HANALEI, KAUAI, HAWAII

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United States Department of Agriculture

File Name

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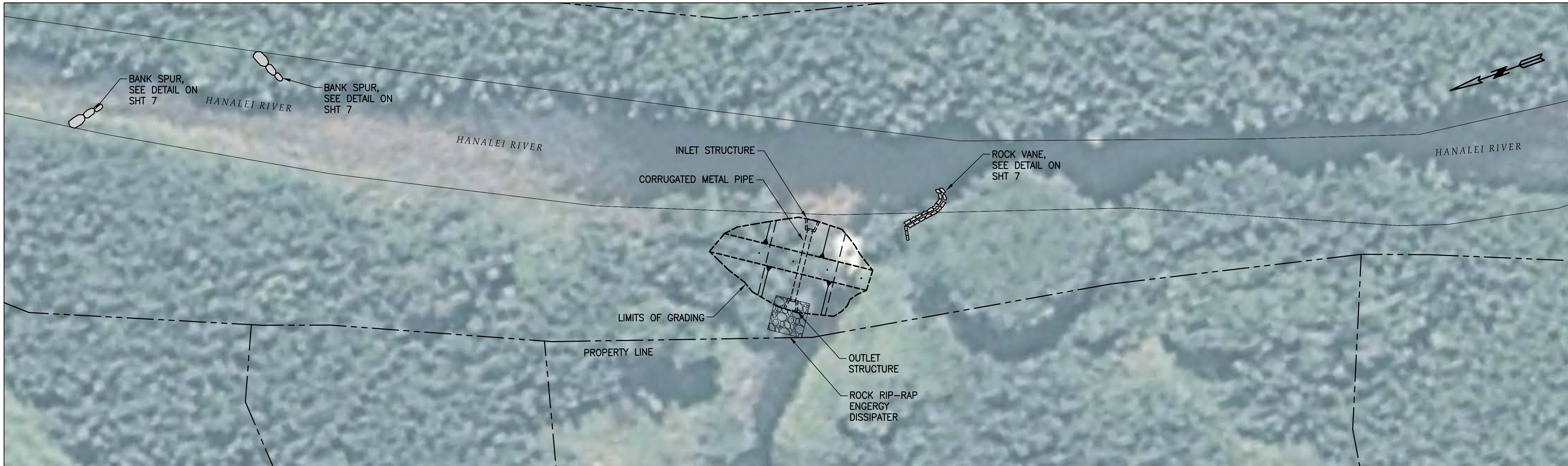
Sheet 2 of __



SITE PLAN

SCALE: 1"=60'

GRAPHIC SCALE
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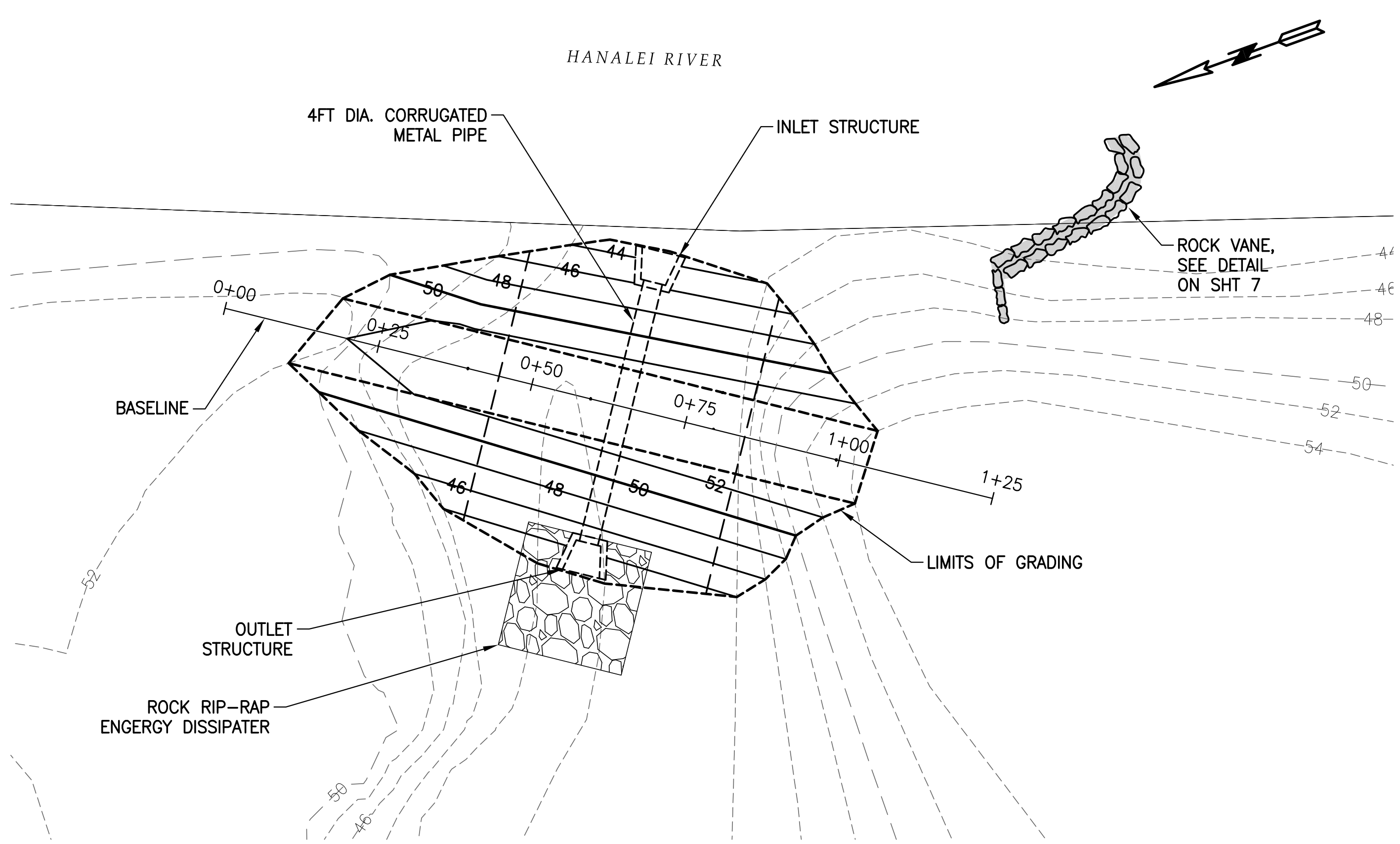
SCALE: 1"=60'



GRADING PLAN (ALTERNATIVE NO. 1)

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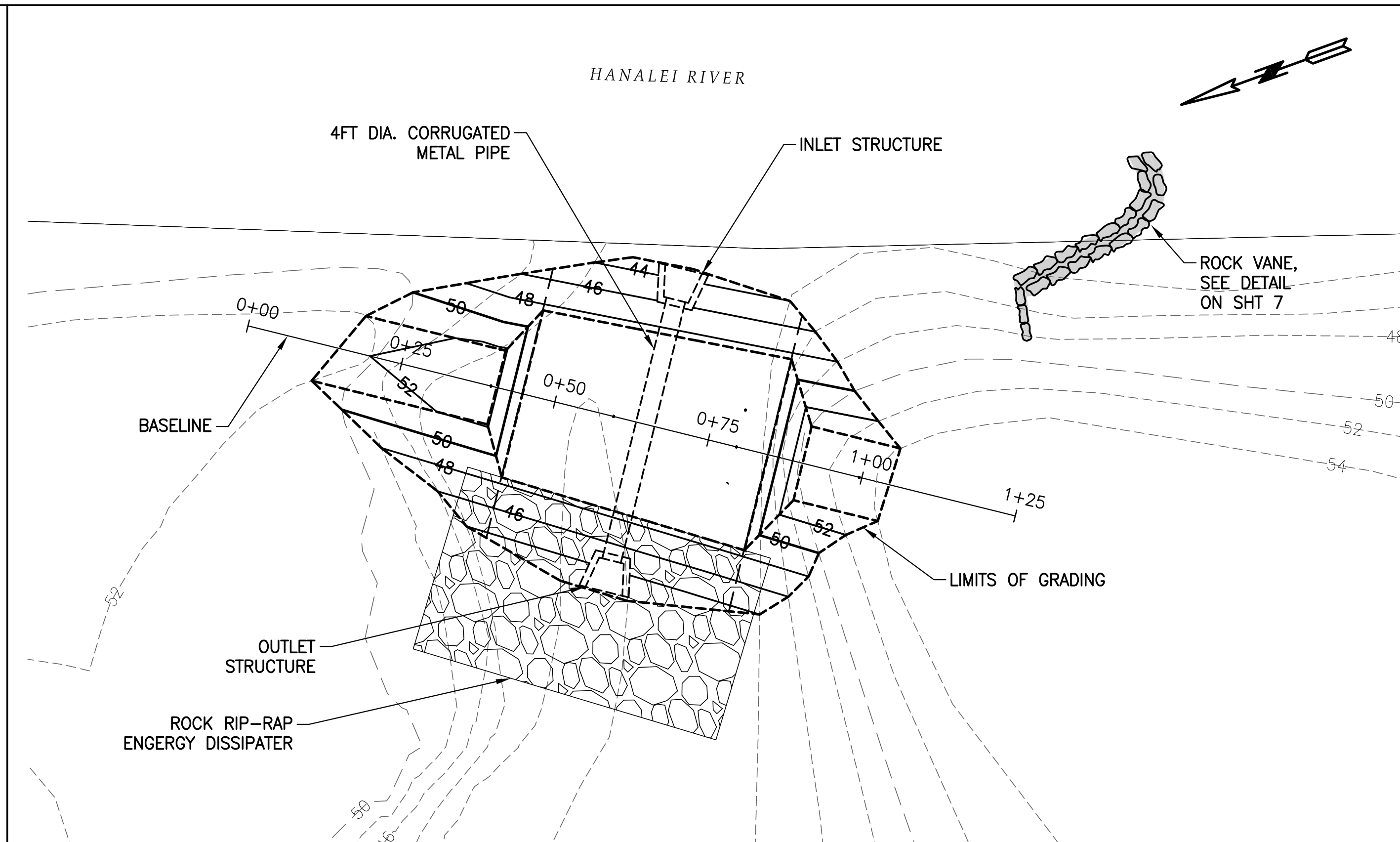

GRADING PLAN (ALTERNATIVE NO. 2)

SCALE: 1"=30'

GRAPHIC SCALE
30 0 30
SCALE: 1"=30'

Designed S. BLANTON
Drawn B. WEAVER
Checked A. NIKOU
Approved
Date

SITE PLAN AND GRADING PLAN

HANALEI VALLEY IRRIGATION INTAKE
PROTECTION/STREAMBANK STABILIZATION
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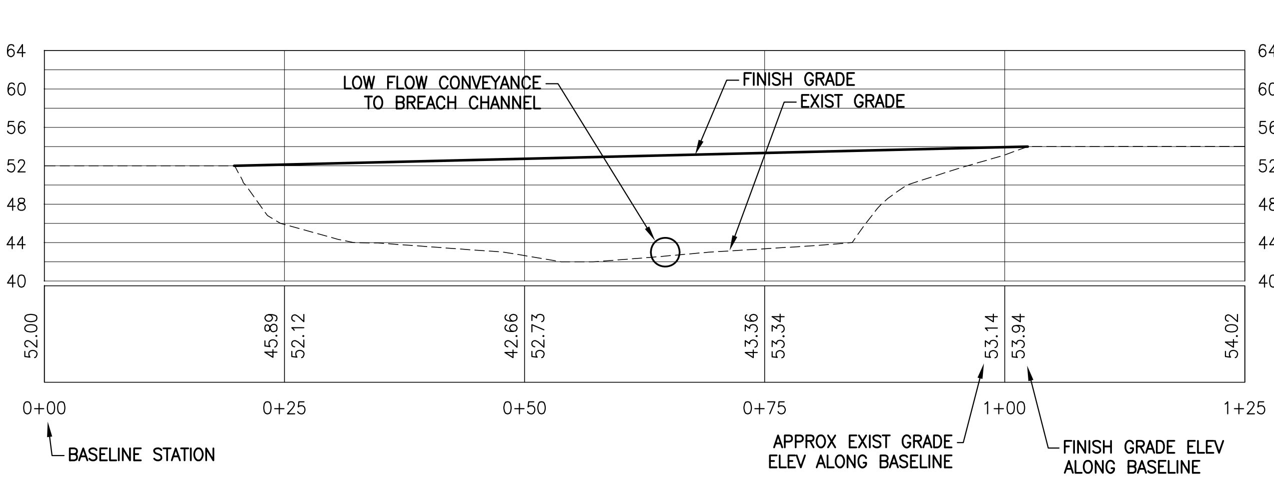
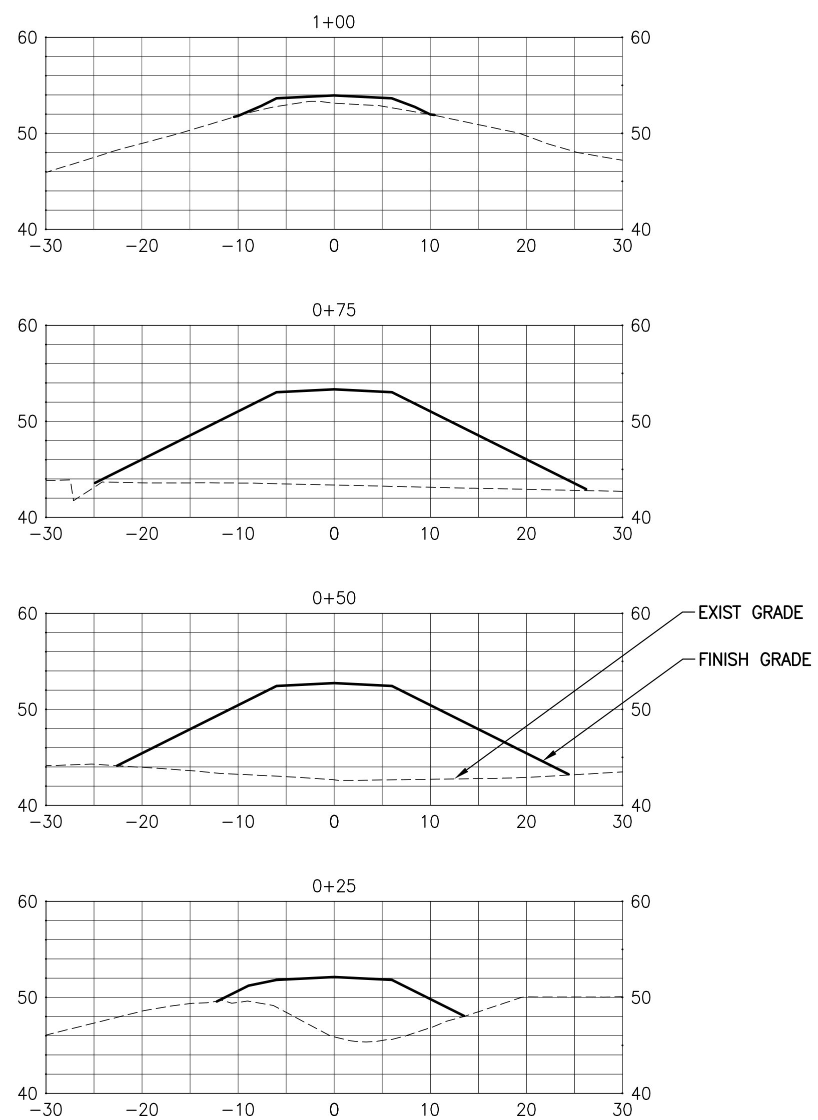
Sheet 3 of __



PROFILE

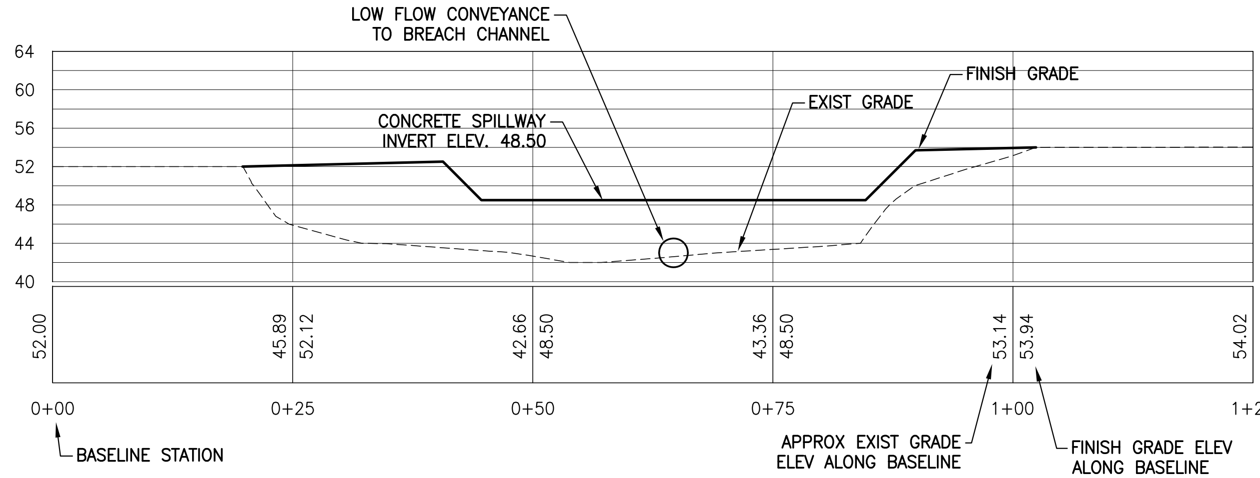
SCALE: 1"=20'



CROSS SECTIONS

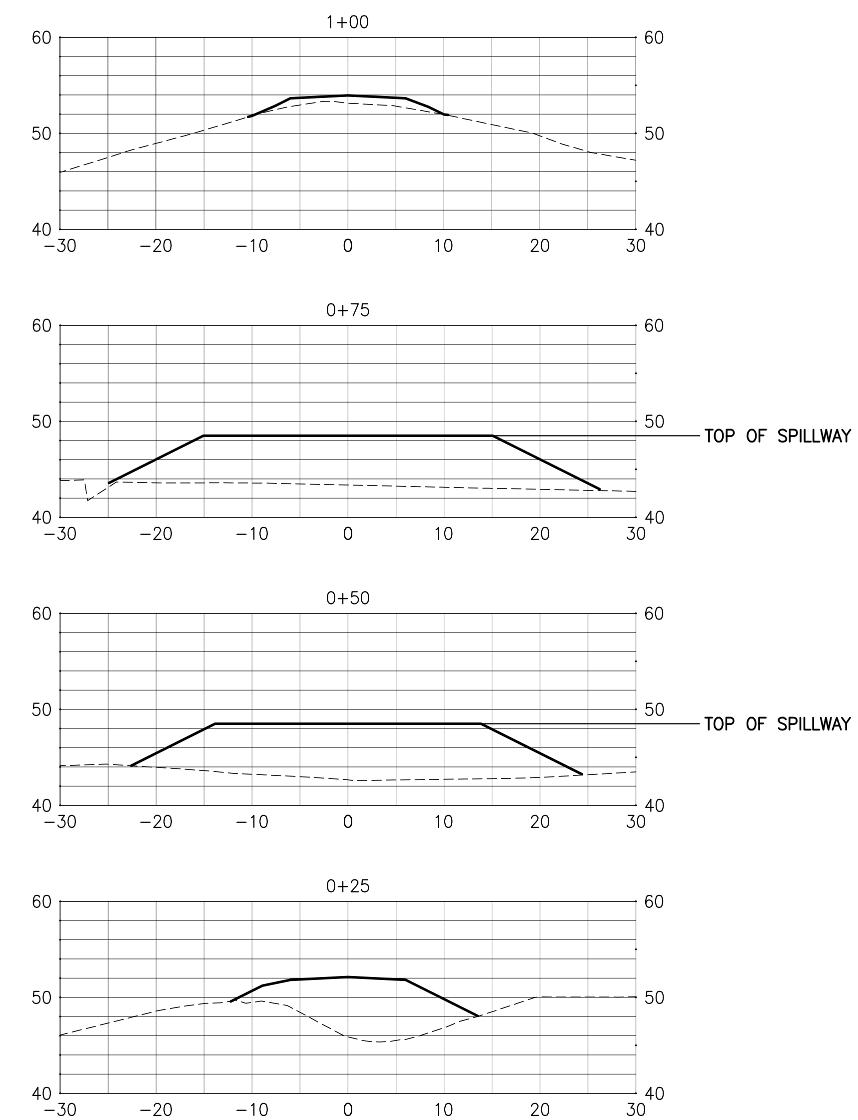
SCALE: 1"=20'

ALTERNATIVE NO. 1



PROFILE

SCALE: 1"=20'



CROSS SECTIONS

SCALE: 1"=20'

ALTERNATIVE NO. 2

GRAPHIC SCALE

20 0 20

SCALE: 1"=20'

Designed	S. BLANTON	Date —
Drawn	B. WEAVER	—
Checked	A. NIKOU	—
Approved		

ALTERNATIVE NO. 1 AND NO. 2, PROFILES AND CROSS SECTIONS

HANALEI VALLEY IRRIGATION INTAKE PROTECTION/STREAMBANK STABILIZATION PRELIMINARY INVESTIGATION HANALEI, KAUAI, HAWAII

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Natural Resources Conservation Service
United States Department of Agriculture

File Name

Drawing Name

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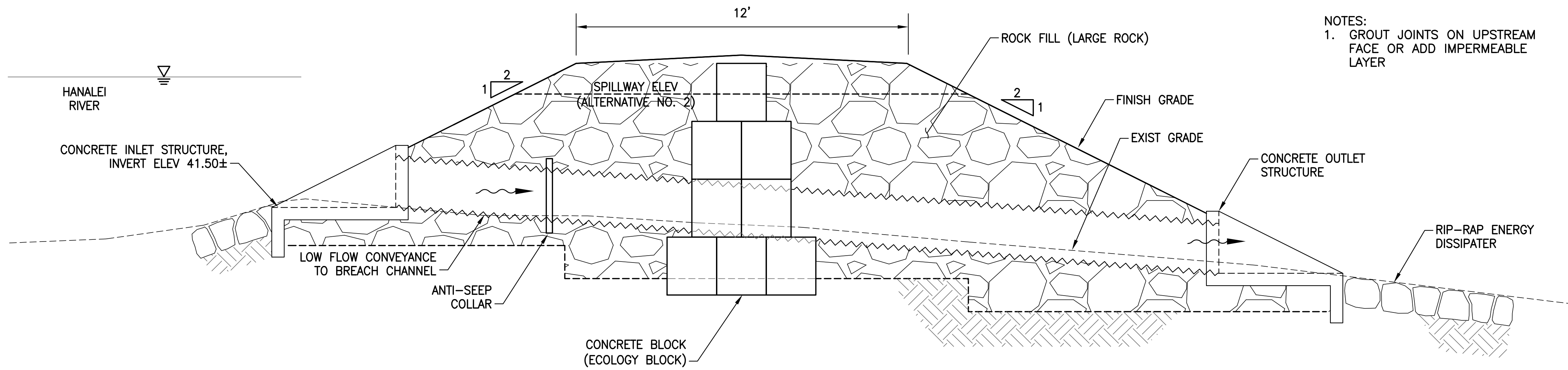
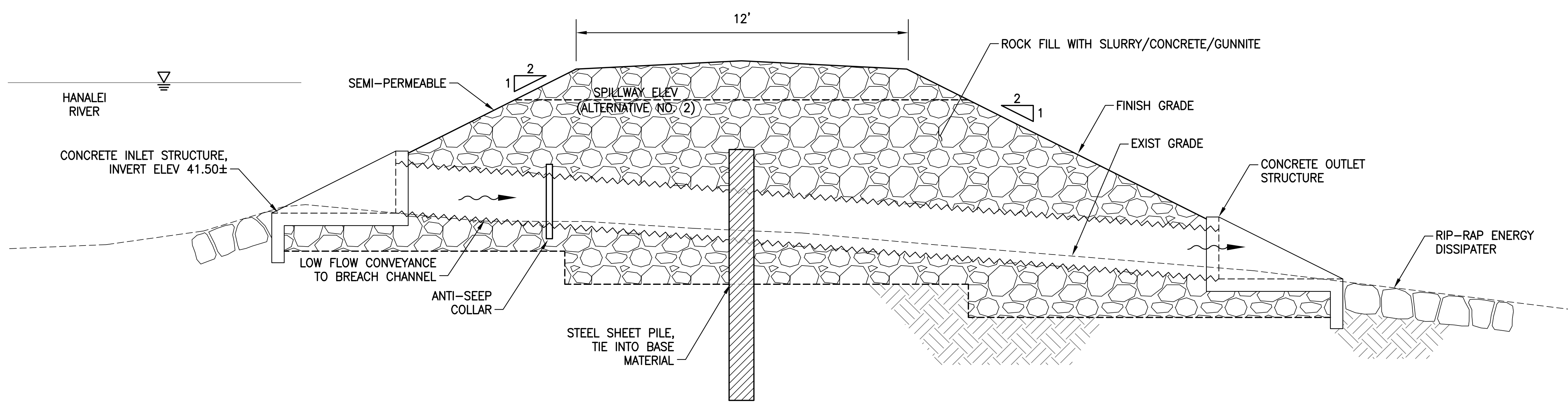


NOTES:
1. GROUT JOINTS ON UPSTREAM FACE OR ADD IMPERMEABLE LAYER

OPTION A - PERMEABLE STRUCTURE

NOT TO SCALE



OPTION B - SEMI-PERMEABLE STRUCTURE

NOT TO SCALE

Designed	S. BLANTON	—
Drawn	B. WEAVER	—
Checked	A. NIKOU	—
Approved		

Date

STRUCTURAL ALTERNATIVES

HANALEI VALLEY IRRIGATION INTAKE
PROTECTION/STREAMBANK STABILIZATION
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HANALEI, KAUAI, HAWAII

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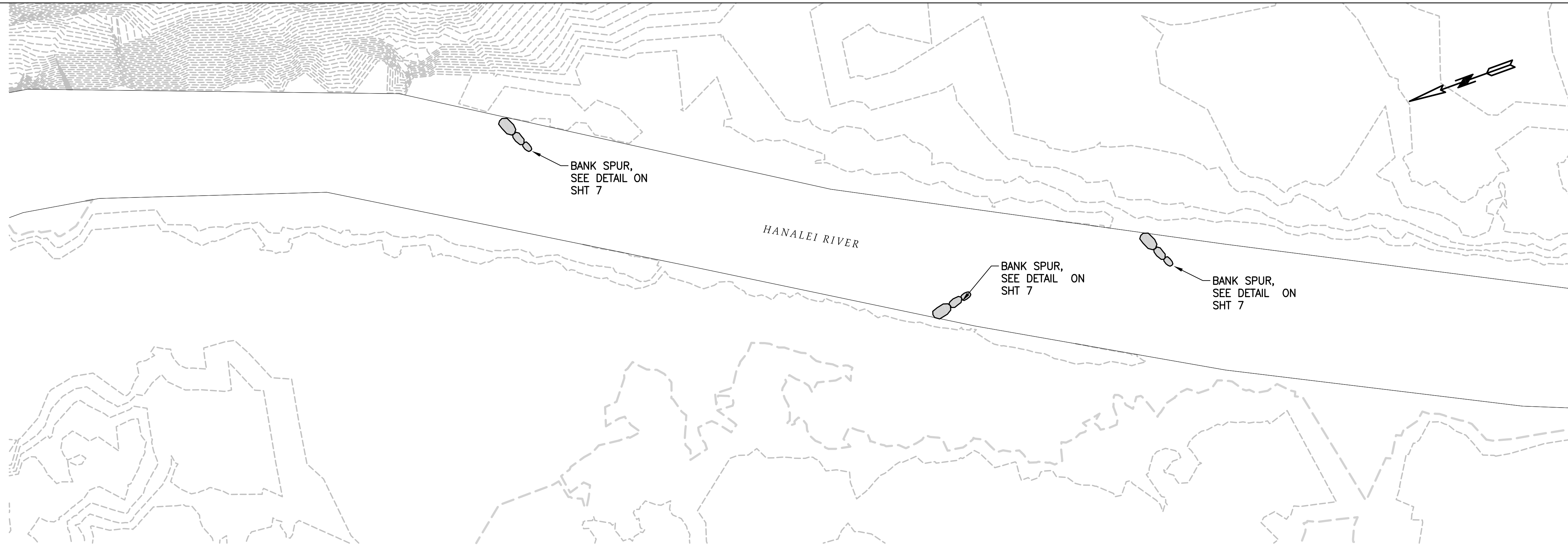

DOWNSTREAM

SCALE: 1"=60'

UPSTREAM

SCALE: 1"=60'

GRAPHIC SCALE

60 0 60

SCALE: 1"=60'

		Date
Designed	S. BLANTON	
Drawn	B. WEAVER	
Checked	A. NIKOU	
Approved		

ROCK VANE LAYOUT

HANALEI VALLEY IRRIGATION INTAKE
PROTECTION/STREAMBANK STABILIZATION
PRELIMINARY INVESTIGATION
HANALEI, KAUAI, HAWAII

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File Name

Drawing Name

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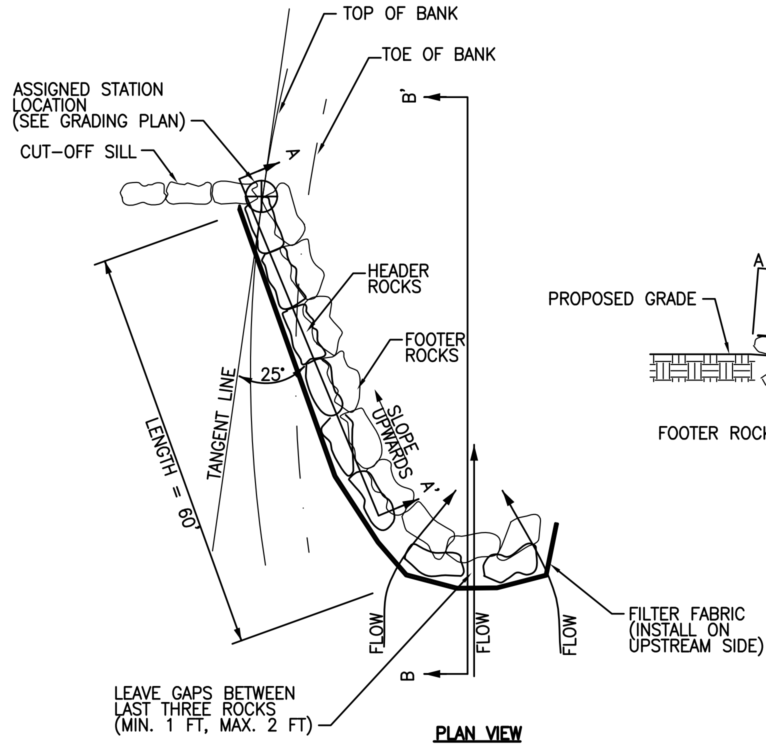
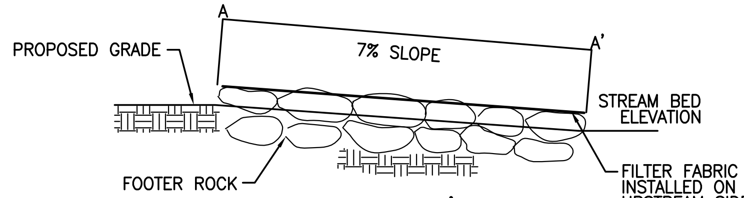
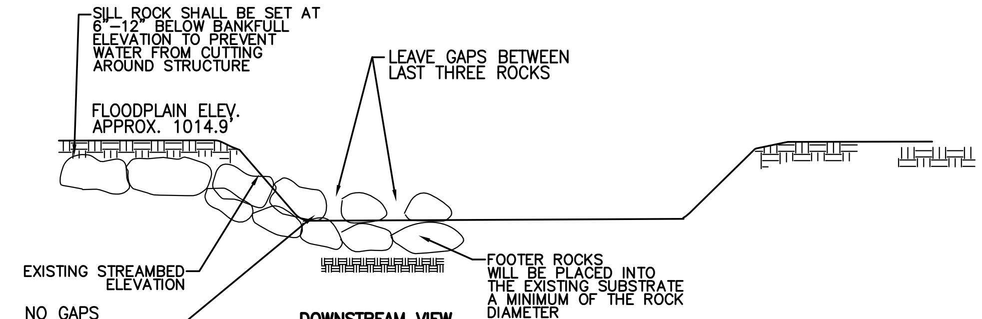


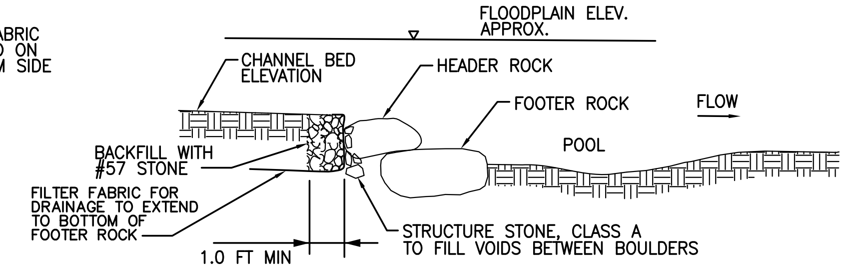
PLAN VIEW



SECTION A–A'



DOWNSTREAM VIEW



SECTION B–B' (PROFILE VIEW)

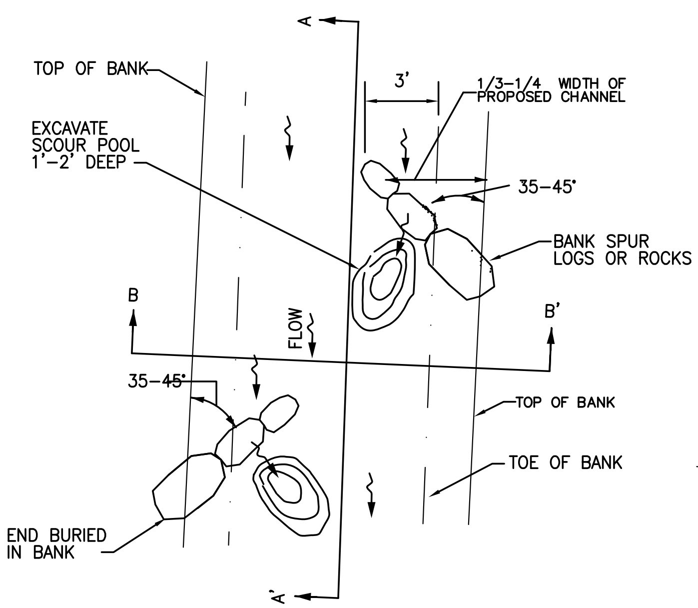
NOTES:

HEADER, FOOTER, AND SILL ROCKS TO BE STRUCTURE STONE, CLASS BOULDER.

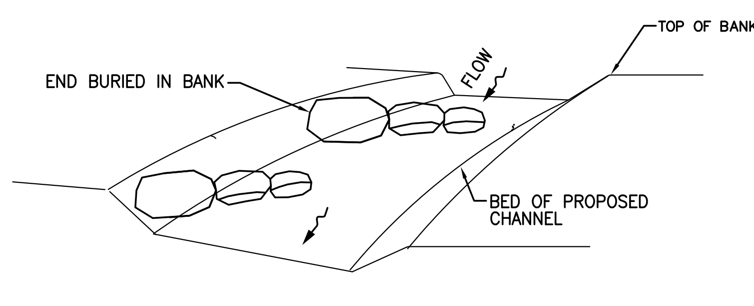
AT THE DISCRETION OF THE ENGINEER, SURGE STONE MAY BE USED IN LIEU OF #57 STONE AND CLASS 'A' USED TO FILL VOIDS.

ROCK VANE DETAIL

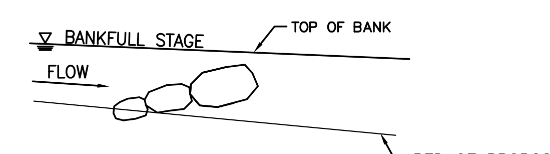
SCALE: NTS



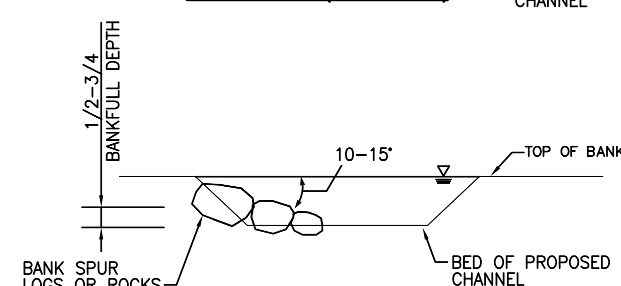
PLAN VIEW



ISOMETRIC VIEW



SECTION A–A' (PROFILE VIEW)



SECTION B–B' (SECTION VIEW)

NOTE:

ROCKS TO BE STRUCTURE STONE, CLASS BOULDER, 18"–30".

BANK SPUR DETAIL

SCALE: NTS

Role	Name	Date
Designed	S. BLANTON	–
Drawn	B. WEAVER	–
Checked	A. NIKOU	–
Approved		

DETAILS

HANALEI VALLEY IRRIGATION INTAKE PROTECTION/STREAMBANK STABILIZATION
PRELIMINARY INVESTIGATION
HANALEI, KAUAI, HAWAII

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