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DESIGN FOR THE RENATURALIZATION OF THE PARMENTER CREEK FLOOD HAZARD REDUCTION PROJECT

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TABLE OF CONTENTS

I. INTRODUCTION

WestWater Consultants, Inc. and Water Consulting, Inc. were retained by Lincoln County to develop and oversee the implementation of a stream relocation and re-naturalization project on Parmenter Creek. This report and the attached maps and diagrams is the final design for this project and is sufficient for public review and comment, permitting review, and construction. Preliminary information and conceptual designs were originally submitted to Lincoln County in a report titled Summary of Data Collection and Conceptual Designs for Stabilization of Flower and Parmenter Creeks near Libby, Montana. Project goals and objectives derive from a multitude of sources and include landowner concerns, Lincoln County issues (development, flooding, and infrastructure), public safety, educational value, hydrologic processes, fluvial geomorphic process, and fishery concerns. Project complexity is an understandable result of the number and diversity of the project goals and objectives.

We have summarized the channel design criteria, other information related to the design, and performance of the proposed channel system. This design is based wholly on the concepts of natural channel design philosophy and incorporates recent developments in design techniques pioneered by Mr. David Rosgen, Hydrologist with Wildland Hydrology, Inc., Pagosa Springs, CO. Furthermore, some of the proposed techniques were jointly pioneered and developed by WestWater Consultants, Inc. and Water Consulting, Inc. and are proprietary information. The objectives of the new channel design are to:

- Reduce the flood hazard to adjacent homeowners;
- Reduce excessive sediment sources upstream by incorporating stabilization techniques that function naturally with the stream while decreasing the amount of stress on the stream banks (near-bank shear stress);
- Convert the channelized portions of the stream into a channel type that is self maintaining and will accommodate floods without major changes in channel pattern or profile;
- Use natural stream stabilization techniques that will allow the stream to adjust slowly over time and be representative of a natural stream system;
- Improve fish habitat, particularly for native fish, and improve the aesthetics of the river and adjacent riparian ecosystem;
- Reduce bank erosion and sediment loads to the stream below Dome Mountain Bridge

- Provide adequate bridge capacity for the 100 year flood without creating backwater at the three proposed bridges;

- Minimize construction and maintenance costs.

Following this section are sections dedicated to specific topics (ex. Flood Risk Analysis). Following the formal report is a section detailing all references and the Appendices. For the purposes of brevity, conciseness, and to facilitate document review, we have intentionally placed some specific and detailed information in the Appendices. Also included with this report is a maps and diagram packet which includes large format plan views, longitudinal profile, and cross-sections. These were not included in the bound report because of their size.

II. EXISTING CONDITIONS

Due to local geology and climate, the streams of this area of Montana have naturally evolved under an above average bedload availability and a high runoff regime with relatively frequent rain-on-snow events. This has lead to stream systems that are very dynamic. They naturally adjust to facilitate the deviations in flow and sediment produced within the watershed. However, most indications lead to a conclusion that the stream systems within the Libby area, including Parmenter Creek, are currently functioning far below their historic potential relative to their ability to maintain their dynamic equilibrium.

The Parmenter Creek watershed is primarily wilderness formed in pre-cambrian meta-sedimentary formations. Most of the headwaters have been glaciated and includes cirque basins and glacial trough valleys. Downstream from the glaciated headwaters, the stream has carved a narrow, relatively steep canyon until it exits the canyon at the upstream terminus of the project area. At that point, the valley opens up onto a broad relic alluvial fan formed during past glacial melt periods. The fan is not active at the present time, and the stream has entrenched into this landform to some degree. There is a subtle gradient reduction as the stream exits the canyon, and the gradient continues to decrease throughout the project area. Gradients upstream from the mouth are 2 to 4 percent, while downstream reaches range from 2.9 percent on the upper reaches of the project area to about 2 percent at the Dome Mountain Bridge. Downstream from the bridge, the gradient is reduced to about 0.5 percent.

The headwaters have a relatively low level of development until it exits the valley. Subjected to over a century of residential and industrial encroachment, removal of riparian vegetation, and inadequate bridge capacities, Parmenter Creek has been channelized, encroached upon, and manipulated extensively. The result is a substantial reduction in floodplain and streamside vegetation, and an alteration of the stream's natural dimension and meander pattern. This stream is therefore much less stable than it would be naturally. The stream has been straightened, widened, bermed on both sides, and streambanks destabilized through manipulation and reduction of the riparian vegetation. Parmenter Creek now has a much higher bedload supply and the sediment transport capacity is less than it would be naturally. The result is heavy bedload deposition during all peak streamflow events and a channel that is unable to adequately transport stream flow and bedload supply and still maintain a stable channel.

A narrow bridge was constructed at the Dome Mountain road that is a serious constriction of even the normal annual peak flow. This bridge further reduces sediment transport efficiency and has caused backwater and upstream deposition of bedload by as much as 5 feet in elevation. Past attempts at cleaning the channel has resulted in dredging the channel with dozers and building higher gravel berms without stabilization to prevent erosion. This backwater deposition is evident even with the original FIRM accepted in 1980.

The reach of existing channel downstream from the Dome Mountain Bridge for about 1000 feet has not been dredged for a considerable time and is completely filled with bedload sediment. The channel at that point is not transporting water or sediment and is simply spreading the water in both the east and west directions.

Currently, the stream typically goes dry during base flow conditions due to its location on the alluvial fan, deep bedload deposits and lack of a properly functioning floodplain.

III. HYDROLOGY AND FLOOD FLOW ANALYSIS

This section will evaluate all available data and analysis procedures to estimate bankfull and flood flow discharges for the Parmenter Creek watershed. There are no streamgages on Parmenter Creek. Therefor, flood flow and bankfull discharges will be estimated using the USGS regional equations (Omang, 1992), and evaluation of a USGS streamgage on Flower Creek (an adjacent, similar drainage) and one method developed by the Kootenai National Forest (Johnson, 1985).

The watershed area of Parmenter Creek is about 17.8 square miles, with elevations ranging from 2100 feet at the project area to over 7500 feet at the watershed divide. Almost the entire watershed originates on the Kootenai National Forest with the headwaters of the drainage occurring in the Cabinet Wilderness Area. This area produces some of the highest annual precipitation zones in Montana. Mean annual precipitation was estimated on an area-weighted basis using the most recent precipitation data from the Kootenai National Forest (GIS maps available upon request). Annual precipitation ranges from over 86 inches at the highest elevations to about 20 inches at the project area. Basin average annual precipitation is estimated to be about 53.5 inches. Most of the precipitation occurs as snow, which melts between April and June on most years.

A. USGS Regional Equations

Omang (1992) developed regression equations for Montana using the peak flow peak flow gaging network. The equations are based on area weighted mean annual precipitation and basin size. Parmenter Creek lies within the West Region (see map). The equations applied to Parmenter Creek are as follows:

$Q_2 = 0.042\ A^{0.94}\ P^{1.49} = 240$ cfs

$Q_{10} = 0.235\ A^{0.90}\ P^{1.25} = 444$ cfs

$Q_{25} = 0.379\ A^{0.87}\ P^{1.19} = 532$ cfs

$Q_{50} = 0.496\ A^{0.86}\ P^{1.17} = 625$ cfs

$Q_{100} = 0.615\ A^{0.85}\ P^{1.15} = 695$ cfs

Q500 = 0/874 A0.84P1.14 = 900 cfs

where A is basin area in square miles and P is the mean annual precipitation for the basin. The average standard error of the prediction ranges from 45 to 52 percent (see attached tables).

B. Flower Creek Gage Evaluation

Flower Creek is adjacent to Parmenter Creek to the south and is a similar gaged watershed. It originates in the same mountain range, is similar size and has the same orientation, surficial geology, precipitation ranges and morphology. However, the gaged watershed is somewhat smaller (11.1 square miles vs. 17.8 square miles) and the gage is higher in the watershed than the project area of Parmenter Creek. Mean basin precipitation is 67 inches for Flower Creek and more of the watershed is at higher elevation. Mean basin elevation is equal to about 5290 feet for Flower Creek and about 4490 feet for Parmenter Creek. For these reasons, the water yields are proportionally higher for Flower Creek than for Parmenter Creek. The following table will summarize the analysis made by the USGS for Flower Creek, then the USGS regression equations will be shown for the Flower Creek gage. The unit discharges for Flower Creek will then be applied directly to Parmenter Creek (cubic feet per second per square mile- or CSM).

	Flower Creek			
Recurrence Interval	USGS Discharge by recurrence interval	Predicted Discharge using USGS equations	Gaged CSM	CSM applied to Parmenter Creek
Q_2	240	212	21.6	378
Q_{10}	413	384	37.2	651
Q_{25}	503	457	45.3	793
Q_{50}	572	537	51.5	901
Q_{100}	642	599	57.8	1012
Q500	810	778	70.1	1300
Q_{max}	709 (1974)			

The annual peak flow frequency analysis is plotted on the attached chart for the Flower Creek gage. The maximum flow for the 29 year period of record occurred during 1974 at 709 cfs. 1974 was known as one of the largest flows on record on most gages in Northwest Montana and occurred from a large rain on snow event. Based on the frequency analysis, this maximum flow was approximately equal to the Q_{200} discharge. Refer to the Peak Flow Frequency Analysis in the Appendix.

Based on this analysis, it appears that the USGS regional regression equations underestimate flood discharges varying from about 7 to 12 percent. Also, the unit discharges of Flower Creek result in an over estimate for Parmenter Creek of about 20 percent (mean basin precipitation of 53.5/67=0.80) due to the higher basin precipitation and elevation. However, these CSM estimates provide another verification for the USGS regional equations.

C. Kootenai National Forest Equations

The Kootenai National Forest developed a number of flood flow prediction equations based on watershed and channel characteristics (Johnson, et al, 1985). The forest-wide procedure is also displayed here for comparison with the other more standardized methods.

Q10	= 1.013(log Area)	+ 1.449	(log ppt)	- 1.057 =	522	cfs
Q25	= 0.984 "	+ 1.525	"	- 1.025 =	699	cfs
Q50	= 0.953 "	+ 1.595	"	- 1.028 =	839	cfs
Q100	= 0.932 "	+ 1.671	"	- 1.058 =	998	cfs

While the estimates are somewhat higher than other methods, they offer some comparison to the more standardized methods.

D. Selected Flood Discharges

The gaged data on Flower Creek indicate that the USGS regional equations may underestimate flood discharges varying by about 7 to 12 percent. The Kootenai NF method also indicates somewhat higher flood discharges than the USGS regional equations. However, the Flower Creek unit discharges may not be extrapolated directly to Parmenter Creek because of the greater mean annual precipitation and mean elevation. For these reasons, the following flood discharges are predicted for Parmenter Creek:

Q2	=	290 cfs
Q10	=	510 cfs
Q25	=	615 cfs
Q50	=	710 cfs
Q100	=	810 cfs
Q500	=	1050 cfs

IV. PROPOSED CHANNEL DESIGN

A. Introduction

The study area can be segmented into three stream reaches starting from the downstream terminus of the project:

Reach One
Reach 1 is bounded on the downstream by Station 0+00 and the upstream Dome Mountain Bridge Crossing at Station 15+00.

Reach Two
Reach 2 is bounded on the downstream by the Dome Mountain Bridge at Station 15+00 upstream to Station 36+65, which is the upstream terminus of the detailed survey data.

Reach Three
Reach 3 extends upstream from Station 36+65 to the mouth of the canyon at approximately Station 59+00.

The proposed design incorporates three primary considerations:

- Construct a stable channel and floodplain that incorporates natural channel design consistent with the natural geomorphology of the site;
- Reduce sediment sources such that the designed channel can transport the remaining supply;
- Change the location of the bridge crossing on the Dome Mountain Road to the low point in the area and construct a bridge with a span that will pass the 100 year event without backwater deposition of sediment. The existing bridge will remain as an overflow for extreme events and to promote wetlands creation in the downstream reach.

The most stable natural stream type found on relic alluvial fans of this gradient are "B" stream types (Rosgen, 1996). These single-thread channel systems have relatively low width/depth ratios, moderate sinuosity, gradients between 2 and 4 percent and a predominantly cobble substrate with smaller proportions of small boulders and gravel. The channel morphology is primarily a riffle/pool type with frequent step/pool reaches interspersed. Restoring the stream so that it is self maintaining and provides habitat will involve constructing a two-stage channel that is built to the natural dimension, meander pattern, and gradient of a B3 channel type (Rosgen,1996) upstream from the Dome Mountain Road bridge and a C4 channel downstream from the bridge as the gradients flatten and the floodplain broadens.

A two-stage channel consisting of a natural channel to carry the normal annual flows constructed within a floodplain to carry the flood events is proposed. In order for the channel to maintain itself (transport bedload, debris and stream flow) through normal runoff events, it must have a consistent, specific cross-sectional area. The width/depth ratio and other hydraulic parameters are balanced with the gradient to provide enough sediment transport capacity to transport the available sediment. For the channel to maintain it's cross-sectional area during flood events, it must have a sufficient floodplain so that all flow is not confined within the normally active channel.

Since Parmenter Creek currently has excessive bedload available due to upstream bed and bank erosion, it will be necessary to reduce these sediment supplies through bed and bank stabilization. The majority of the gravel bedload is produced from within the active channel and originates from the mouth of the canyon downstream. During the peak annual runoff events, the stream has continually eroded streambanks and deposited the material within the over-widened channel. The gravel deposits within the active channel locally reduce the channel's needed cross-sectional area, thereby elevating the near bank shear stresses, and promoting additional bank erosion on adjacent banks through an acceleration of the natural lateral migration processes.

The two stage channel design and a reduction of bed and bank erosion is essential for the stream to maintain stability and reduce flood hazards. Given the correct channel shape, meander, gradient, and floodplain, the stream will be able to transport bedload and flow efficiently. Lateral stream migration and sediment supply is greatly reduced through channel and bank stabilization as described in another section. Flood stage is also reduced because the sediment is being transported downstream rather than depositing on the streambed and causing elevated water surfaces. Aquatic habitat will also be improved since lateral migration tendencies are reduced and less bedload from eroding stream banks is made available to the stream.

Floodplains also provide most of the wetland and riparian habitat associated with these valleys and are particularly important for the natural re-generation processes. Floodplains are essential to spread and dissipate flood flows, deposit fine sediment, and provide water storage for late season release of water during the low flow time periods. It is critical to design and construct an adequate floodplain with the stream design.

B. Channel Design Dimensions and Methods

Several methods were used to arrive at channel design dimensions, including:

- using a "reference reach" upstream from the project area in the mouth of the canyon where the stream remains in a stable, functioning condition;
- data from other similar stable reference streams in the vicinity provided by the Kootenai National Forest;
- cross section channel hydraulics for the reference and proposed channel dimensions and ultimately the HEC-RAS model to verify channel dimensions.

Natural channel design is based on sizing the active channel to the bankfull flow conditions and providing an adequate floodplain to accommodate flood events, including the 100 year flood event (Rosgen and Silvey, 1996 and Leopold, et. al. 1964). Bankfull flow conditions are commonly approximated with the 1.5 year return interval flood event. The bankfull flow can be estimated in the field by using indicators such as the tops of recent point bars, channel shape, vegetative growth patterns, etc. (Rosgen and Silvey, 1996 and Leopold, et. al, 1964). The bankfull flow, which is sometimes referred to as the "dominant discharge" is responsible for forming and maintaining the channel system over time. This discharge transports the greatest amount of sediment over time and in general does the most work in maintaining the channel over time (Andrews, 1980).

Most channel dimensions are related to the Bankfull Discharge, and in particular, the width of the channel and floodplain and the meander pattern. The dimensions shown in Table 1 are related to bankfull discharge and the bankfull width. The designed channel provides adequate sediment transport capacity due to the relatively low width to depth ratio and gradient, especially when compared to the existing conditions. The floodplain is designed to spread the flood flows similar to the natural streams in this geomorphic setting.

Typical cross-sections for reaches 1 and 2 are in the enclosed map and drawings packet. Typical cross-sections for Reach 3 are in located in Appendix 2 of this document.

Table 1 – Design Dimensions

Draft Design Dimensions (in feet)
Average Value (± in parentheses)

Dimension	Reach One	Parmenter Creek Reach Two	Reach Three
BF Discharge (CFS)	250 (30)	250 (30)	250 (30)
BF Width – straight	30 (2)	27 (2)	27 (2)
- meander	32 (2)	30 (2)	30 (2)
BF Depth – avg	2.4 (0.2)	1.6 (0.2)	1.6 (0.2)
- max	4.0	4.0	4.0
BF Velocity	4.5 (1.0)	5.5 (1.0)	5.5 (1.0)
BF Area (SF)	44 (5)	41 (4)	41 (4)
BF Width/Depth	18	18	18
Meander Length	300 (100)	300 (100)	300 (100)
Radius Curvature	100 (22)	95 (25)	95 (25)
Belt Width	120 (70)	70 (20)	70 (20)
Meander Width Ratio	> 3.0	> 2.5	>2.5
Floodplain Width (minimum)	70	56	56
Sinuosity	> 1.3	> 1.2	> 1.2
Gradient	0.012 (0.007)	0.025 (0.005)	0.035 (0.007)

C. Pattern & Profile

The longitudinal profile for Reaches One and Two for the proposed channel is included in the map and drawings packet. The longitudinal profile for Reach Three is located in Appendix Two of this report.
The pattern and profile of the design are fit to the site conditions to minimize construction costs and disturbance while constructing the channel and floodplain in the lowest possible

point in the terrain. The overall gradient is held relatively constant where possible to avoid discontinuities which will tend to deposit bedload. The gradients are varied within short reaches between the meander pools and the straight riffles. In general the pool slopes much less (about 50 percent) than the average gradient and the riffle slopes are much steeper (about 150 percent) than the average gradient. The overall gradient of the channel is gradually decreased in a downstream direction to fit the overall terrain.

Where possible, existing vegetation will be left in place to provide a vegetated floodplain and the channel is excavated within the floodplain. This occurs in areas of dense riparian vegetation. Where the dense riparian vegetation will be removed to excavate the channel, it will be transplanted elsewhere in combination with other bank stabilization structures.

D. Stream Gradient and Grade Control

It should be noted that because a less detailed survey was performed in this area, the gradients in Reach Three are approximate and need to be verified during the staking phase.

Natural stream gradient varies in the longitudinal profile from pools to riffles. Typically, stream gradient decreases in the meanders associated with pools, and steepens in the straight riffles. This undulation in the bed profile dissipates energy and maintains the vertical stability of the riffle as well as providing a variety of habitat. To help maintain vertical stability and the riffle/pool gradients, it is important to provide some form of grade control in the restoration design. Natural rivers are able to maintain this grade control through scour along a stable streambank and deposition at the end of the meander at the pool tailout. In a reconstructed river, however, it is necessary to incorporate grade control structures that will maintain the designed longitudinal profile until the channel can maintain itself.

For this project, rock weirs are proposed for grade stabilization. These weirs have no effect on base flood elevations or velocities, but do stabilize the bed material at key locations, primarily at the downstream terminus of meanders at the pool tailout and also at extended riffle sections. The grade control structures include a rock sill at floodplain height that extends laterally across the floodplain perpendicular to the flow to prevent downcutting until adequate vegetation can become established. These rock structures are specifically designed and constructed to pass bedload are <u>not</u> sediment traps which could potentially lead to bed aggradation. Rock vanes, vortex weirs, cross vanes and modifications of these structures are proposed. Please refer to the Appendix for example diagrams of these structures.

E. Bridges

Three new bridges are proposed for the project area: a road bridge on Dome Mountain Avenue at Station 15+00, one foot bridge downstream at Station 0+50 and a shorter bridge over an intermittent side channel to the west of the footbridge crossing Parmenter Creek. All bridges are being designed by a separate contractor (Ray Engineering, Inc. of Libby, MT). The span of both bridges crossing Parmenter Creek is 60 feet with a minimum of two feet of freeboard to pass debris at the 100 year flood water surface elevations. The 60 foot span was selected because it has a minimal effect on 100 year flood hydraulics and should not create backwater deposition of bedload sediment. The exact location of the shorter footbridge has not been determined in the field, but it will have a span of 30 feet and a minimum freeboard of 2 feet to pass the 100 year flood. The low stringer elevations are 2104.5 for the new Dome Mountain Road Bridge and 2102.4 for the two new foot bridges.

F. Sediment Transport Considerations

Parmenter Creek currently has excessive bedload supply and a channel with inadequate geometry to transport this sediment supply. Based on studies of similar streams, most of the gravel-sized sediment is derived from the streambanks and streambed from the mouth of the canyon downstream. There are no data available to calibrate sediment transport through the project area and no bedload data available for similar, nearby streams. Bedload sediment was not modeled for this project because of the highly dynamic nature of the stream itself. Since most of the bedload is derived from stream bed and banks and the stream is highly mobile in its current condition, actual sediment transport is almost completely controlled by sediment supply (supply controlled function). These conditions are very difficult to model accurately given the highly variable nature of sediment transport in this stream. Instead of a theoretical model, pre- and post-project sediment transport conditions are evaluated on an empirical basis. An evaluation of shear stress and unit streampower will provide an indication of sediment transport efficiency of the current and proposed channel. Table 1 will display these variables for several reaches of the stream.

Table 2 - Estimated Shear Stress and Unit Streampower for selected reaches of Parmenter Creek

Reach/Station	Flow Range	Existing Shear Stress (psf)	Proposed Shear Stress (psf)	Existing Unit Streampower (#/sec-ft)	Proposed Unit Streampower (#/sec-ft)
Reference Reach/	$Q_{1.5}$	3.8	--	23.7	--
5800 approx	Q_{100}	6.6	--	72.9	--
XS3/ 4340 approx	$Q_{1.5}$	1.8	3.1	8.9	15.5
	Q_{100}	3.4	3.6	30.7	29.3
XS4/ 3135 approx	$Q_{1.5}$	1.5	3.1	5.8	15.5
	Q_{100}	2.2	3.6	12.3	29.3
XS5/ 2800 approx	$Q_{1.5}$	1.6	2.5	8.2	15.5
	Q_{100}	2.3	2.4	17.1	19.0
930 approx *	$Q_{1.5}$	---	1.1	---	6.5
	Q_{100}	---	0.8	---	5.1
620 approx *	$Q_{1.5}$	---	0.7	---	3.2
	Q_{100}	---	0.6	---	3.3

* The existing channel downstream is completely filled with sediment and has very little sediment transport capacity.

The upstream part of the proposed project (Reach 3) would reconstruct a stable channel that would have a much higher sediment transport capability than the existing channel. The bank and bed stabilization treatments described previously would substantially reduce sediment supplies. The combination of greatly decreased sediment and increased sediment transport capability will greatly improve the streams ability to maintain itself during all flood conditions, however, some maintenance may be required in the future, as described in the Section XII.

G. Bank Stabilization and Baseflow Habitat Conditions

In order to maintain bank stability and allow the stream to maintain pools on bends, bank stabilization measures developed by Rosgen (1996) over the last 13 years are recommended. These measures involve interlocking tree rootwads, logs and boulders into a stable structure, then capping the structure with whole, massive sod and shrub transplants. The purpose of these rootwad composites is to provide stability over a period of a couple of decades to allow the vegetative root masses to become established, which will eventually provide long term natural stability. These structures have successfully withstood floods from 25 year to 300 year events (Rosgen, 1992 and personal experience of WestWater Consultants, Inc. and Water Consulting, Inc.)

In areas of high concern or increased shear stress against the streambanks, such as near the bridge crossings and the channel divergence at Station 17+00, additional rock rip rap will be used along with the root wad and log structures to provide a measure of security. These areas will sacrifice some aesthetics and habitat for increased durability and ability to withstand flood events.

The rootwad composites appear natural, dissipate stream energy, and also provide superior fish habitat and food sources by providing cover, slow holding water, and deep pools. Other techniques can be used including rip rap, gabions, concrete retaining walls, etc., but these methods do not meet many of the restoration objectives. Costs for installing any of these other treatments tend to be higher than rootwad composites. In addition, because these other treatments generally do not provide for natural stream structure and function, they can actually inhibit stability and may require maintenance of the structure itself, or create other channel maintenance as a result of the structure's destabilizing effects.

The new streambed will be 4 to 6 feet in elevation lower than the existing stream through the area that the stream currently goes dry. It is thought that the excessive bedload deposition is one reason the stream goes subsurface. It emerges downstream at a point that the deposition diminishes. By lowering the streambed, there is a higher probability that perennial flows will occur. Re-establishing the natural width/depth ratio and bedload transport capacity of the stream would significantly improve the capability of the active stream channel to maintain consistent perennial flows during base flow conditions. In addition, a properly functioning floodplain will store water for late season release. These factors will lead to higher instream base flow conditions, or at least shorter duration of dry channel conditions, which will be more favorable for fish..

V. FOOTPATHS

The proposed footpaths as shown on the plan view maps located in Reaches One and Two constructed outside the floodplain will be built with excess excavated soil and gravel material. Basic dimensions are 12 foot wide top width with a face of rock rip-rap as shown in the sketches located in the Appendix. The proposed rock rip-rap is necessary to protect the footpaths from flood flows in excess of the 100-year flood event.

VI. EXISTING CHANNEL

We have proposed three different treatments for the existing channel. Upstream of the current Dome Mountain Road Bridge, the existing channel will be completely filled with excess excavated material to the appropriate floodplain elevation. Fill material will consist of a gravel base and, if possible, a top layer of soil. Construction techniques utilizing the transport vehicles should provide for adequate compaction of the fill material. Subsequent to placement of the fill material, the area will be revegetated. Revegetation efforts will include seeding and, if possible, some transplanting of grass sod mats and large mature plants. Sod mats should be laid in linear strips perpendicular to flood flows and span the entire width of the fill material. These strips and the transplants will help prevent a large-scale flood from downcutting through the unconsolidated fill material prior to the establishment of a dense vegetated riparian community.

Immediately above the current Dome Mountain Road bridge, the new channel leaves the existing channel and passes under Dome Mountain Road at the new bridge location. At the point where the new channel leaves, the existing channel will be filled to a height approximately 0.5 feet above the bankfull or floodplain elevation. Thus creating a low terrace. This will allow larger flood events to access the historic channel for flood flows. Although the new channel and floodplain have the capacity for a 100-year flood event, this will provide added capacity for these and higher flood events. In addition, subsurface water from the stream should seep through the gravels and flow down the abandoned channel, which will help maintain wetlands downstream.

Below the Dome Mountain Road bridge the existing channel will be left largely alone. Wetland plugs have been proposed in three locations to increase total wetland acreage as discussed in the following section (VII. Wetlands Enhancement).

VII. WETLANDS ENHANCEMENT

The design calls for three wetland plugs to be placed in the existing (to be abandoned) channel. Approximate location of the proposed plugs is shown on the plan view diagram. The exact location will be determined during staking. Material for the plugs will be produced during the excavation of the new channel. Plug height will be tied to the existing floodplain to allow for the plugs to be overtopped by sheet flow during a flood event. The plugs will hold and capture water, creating more wetland acreage and allowing subsurface irrigation of adjacent wetlands. Wetland vegetation can easily be transported from the lower donor site (area immediate to and adjacent of the proposed channel).

The existing channel that will be filled and converted (enhanced) to woody herbaceous and sedge wetlands is currently grass and upland-wetland mosaic. The total acreage of existing channel that will be converted is about 1.2 to 1.4 acres from near the point that the new channel will exit the existing channel down to the confluence of the existing and new channel. From Station 1800 to 1100 on the new channel, an additional 0.5 to 0.6 acres of existing upland-wetland mosaic will be enhanced and converted to woody herbaceous and sedge type wetlands. From Station 2000 to 3600 of the new and existing channel that is currently upland and riverine gravels will be enhanced and converted to woody-herbaceous and sedge type wetlands for a total of about 1.1 acres. The total acreage of wetlands that will be enhanced or created will be about 2.8 to 3.2 acres.

VIII. FLOOD RISK ANALYSIS

The proposed project will have positive impacts to the water surface elevations during flood events. A detailed flood risk analysis was prepared and submitted to FEMA as part of the CLOMR (Conditional Letter of Map Revision) process. For specifics, please refer to the CLOMR report for a detailed flood risk analysis. A previous study of Parmenter Creek was used as the basis for a comparison between historic and proposed water surface elevations. The comparison is not as straightforward as one might suspect for several reasons. One, the vertical datum has been revised in the time between the original study on our latest analysis which made direct correlation of the two studies more involved. Two, the scale of the mapping for the original model is not as detailed as our project and made correlation of horizontal points and cross-section locations more difficult. Three, the historic model was performed using HEC-2 and our hydraulic model used HEC-RAS which has updated hydraulic algorithms. Four, there is a discrepancy in some of the thickness of the bridge decks. Five, we believe there are several theoretical problems with the historic model.

We have compared the water surface elevations associated with a 100 year flood event for the effective FIRM (Flood Insurance Rate Model) and our proposed channel.. Following is a tabular summary of this type of comparison. It is quite obvious that the proposed project is lowering water surface elevations throughout the project area and is thereby beneficial in comparison to the effective FIRM.

Station #	Proposed Change to Water Surface Elevations	Elevational Difference	Comments
37+60	Lower	0.6 feet	Upstream terminus of detailed mapping
29+00	None	0.0 feet	
16+50	Lower	0.9 feet	Existing bridge
16+00	Lower	0.5 feet	
15+00	Lower	1.10 feet	New bridge
06+75	Lower	1.2 feet	
05+25	Lower	0.2 feet	
02+25	Lower	0.3 feet	
01+25	None	0.0 feet	
0+50	Lower	0.10 feet	New Footbridge
0+00	Lower	0.2 feet	

This type of analysis does not indicate the project's full benefits in regards to the existing conditions. The current situation is radically different from the historic model and has even higher water surface elevations. Therefore, a comparison of actual existing conditions to proposed conditions would show an even larger reduction in water surface elevations during floods. In fact, the existing channel creates flooding of adjacent properties even by 5 to 10 year flood events.

IX. IMPLEMENTATION PLAN & CONSTRUCTION SEQUENCING

We have developed the implementation plan based on the project and design and our past experience with projects of this type. For construction purposes, we have divided the project into the following 12 individual steps or phases:

1. <u>Build New Dome Mtn Road Bridge</u>

The construction of the new Dome Mtn Road bridge is relatively independent of the stream construction process. The bridge can be constructed prior to the new stream construction, but the bridge must be in place prior to diverting Parmenter Creek into the new channel. Dome Mtn Road is an important conduit for both vehicular and pedestrian traffic and is particularly important during the school year for school buses and student foot traffic. Therefore, the town of Libby, is proposing beginning new bridge construction immediately after the close of the 98/99 school year to allow for the bridge to be completed prior to the beginning of the 99/00 school year.

2. <u>Build Reach Two</u>

Reach Two will be constructed in the dry with Parmenter Creek remaining in its present location. A narrow plug will be left in place to separate the new channel from the current channel. This narrow plug would be easily removed when it was appropriate to introduce water to the newly constructed stream channel. The entire reach will be excavated from upstream to downstream. The channel and floodplain (where necessary) will be "rough" shaped while emphasizing proper elevations and the efficient movement of mass materials. All excess material (spoil) will be distributed on-site along the southwestern edge of the existing channel. Once rough channel and floodplain shaping along with mass material movement has been completed a second pass will be made from upstream to downstream. During this second pass, final channel and floodplain shaping will occur and all bank stabilization, grade control, and fish habitat structures will be installed. Efforts will be made to reduce the impacts to and disturbance of existing vegetation. However, when existing riparian vegetation must be disturbed, it will be transplanted to a new location at an appropriate elevation on the new floodplain. Stated differently, upland transplants will be placed on future upland sites and wetland/riparian transplants will be placed in wetland/riparian locations on the floodplain or in conjunction with the bank stabilization structures.

There is a potential additional cost associated with the fine materials discovered near the proposed Dome Mountain Bridge. Initial soils investigations by Land and Water

Consulting, Inc. (Environmental Analysis, December, 1998) indicated that the soils in the project area were deep alluvial gravel and cobble with a thin layer of topsoil. However, recent core sampling by Ray Engineering, Inc. near the new proposed bridge locations discovered that the subsurface materials were silty, sandy loams to depths of up to 9 feet. Additional core sampling is recommended for the entire new channel location to better predict depth to gravel. Because the soils in this area are finer than required for a stable stream bottom, it may be necessary to over-excavate the new channel by about 3 feet and backfill with imported gravel from elsewhere in the project. This potential additional task and cost is included in the cost analysis.

3. Build Reach One & Transplant Reach Two

Like Reach Two, Reach One will be built largely in the dry. For the purposes of discussing construction, it is probably easiest to discuss Reach One in two sub-reaches: new channel and current channel. The largest sub-reach is the new channel construction which goes from the new Dome Mtn Road bridge to approximately L.P. Station #3+00. At this point the new channel rejoins with the current channel. The smaller, current channel subreach goes from L.P. station #3+00 to the downstream project terminus. Construction of the new channel sub-reach will be similar to Reach Two construction methodology. During the initial "rough" pass from upstream to downstream, a great deal of transplantable riparian and wetland plant material will be removed from the new channel's location. Careful excavation and handling will allow for this material to be taken and transplanted upstream in Reach Two. Therefore, ideally, the final work on Reach Two should occur coincident with the initial phase of Reach One's new channel sub-reach. All excess material (spoil) will be distributed on-site in two locations: along the southwestern edge of the existing channel and on School District Property. Excess soil and gravel will be placed along the existing channel near the locations where the wetland plugs will be constructed.

There is a potential additional task and cost associated with the finer than predicted material as described in Task 2. This potential additional task involves over excavating the portions of channel that have finer than required bed material and importing coarse gravel and cobble from elsewhere in the project.

Divert Water (if necessary)

If Parmenter Creek is flowing water, then it may be necessary to divert the water into the newly constructed channel. During construction, a plug will be left at the upper end of the new channel. When the system is finished and ready for water, removing the plug and blocking the old channel will divert the water into the new channel.

Build & Transplant Reach Three

Work in Reach Three consists of constructing a stable stream channel inside what is the currently active channel. There is the potential that this would be "wet" work. Construction should be timed to perform this work after the stream has gone dry. The channel will be excavated, then all bank stabilization and grade control structures can be installed.

Fill Existing Channel & Construct Wetlands

After the water has been diverted into the newly constructed channel, the existing channel can be filled with the stockpiled fill material. For further information, please refer to the Existing Channel section (Section VI) and the wetlands enhancement section (Section VII).

Build Foot Path

The walk path can be constructed at almost anytime during the project. We would suggest that this occur at a later stage when the bulk material movement has been finished. It is understood and acknowledged that it would be optimal to have the walk path completed prior to the school year.

Build Foot Bridge

The foot bridge can be built and installed at any point during construction. It would make sense to install the bridge when the footpath in that vicinity is being constructed.

Re-Vegetation

Re-vegetation of the disturbed areas including both the historic and the new channel is of paramount importance. For further information regarding this effort, please refer to the Re-Vegetation section (Section XI). Re-vegetation efforts will be performed throughout project implementation as any section or task is completed.

Erosion and Sediment Control

Since all of Reach Two and most of Reach One will be constructed in a dry condition, the potential for sedimentation is greatly reduced. For Reach Three, the lower section is generally dry for about two months during August and September. However, in the event of a large rainstorm during construction, several measures will be implemented to reduce the potential for stormwater sediment. First, a sediment filter fence will be constructed between any gravel stockpiles or any new construction and live water. Secondly, when construction will occur near live water, every practical effort will be made to temporarily divert the water away from the site during construction. This will occur in the lower end of Reach One and upper part of Reach Three. If water is flowing in the lower part of Reach Three, there is the potential to divert all of the water into a diversion ditch and around the construction area.

There will be short time periods when discharge of fine sediment and turbid water is unavoidable, particularly when the water is diverted into the newly constructed channels. Our experience in constructing many of these projects is that the turbidity is high for about one hour, then decreases to normal levels within five to six hours. There may be additional periods of increased turbidity during the first rainstorm or snowmelt runoff event, but that is typically unnoticeable and not detected.

Weed Control

Weed Control measures will need to be implemented during and immediately after construction. Noxious weeds are invaders and can be disturbance-induced. The area disturbed in association with this project is not insignificant and the potential for weed infestation is very real. Equipment used in conjunction with this project should be cleaned and be as close to "weed free" as possible. Daily care should be taken by the contractor(s) to eliminate the unnecessary introduction or proliferation of weeds into or out of the project area. Obviously, weed control is directly related to the re-vegetation effort. Post construction chemical treatment of problematic areas may be necessary. The County should be able to handle the weed control issues with their local personnel.

Monitoring

After the project has been implemented, it is important that the entire project be monitored. A rigorous monitoring program is suggested for a couple of years immediately following construction. This monitoring will allow for and indicate areas in need of a "tune-up". For specifics regarding the monitoring, please refer to the Maintenance section (Section XII).

X. COST ANALYSIS AND MATERIAL SPECIFICATIONS

The estimated costs of project implementation is detailed in Appendix 3. The costs are based on standard production rates from past projects with experienced crews. Actual contract bids may vary due to local conditions, experience and competition. The following assumptions were made in the cost analysis:

- Rock rip rap is provided by the US Army Corps of Engineers and estimated costs only include hauling the rock to the site.

- Many trees of appropriate size are available on site. The additional trees necessary are assumed to be donated and estimated costs only include the cost associated with hauling the trees to the site.

- Excess excavated material will be used for the footpath construction and will not need to be stored or stockpiled elsewhere.

There is a potential additional cost associated with the fine materials discovered near the proposed Dome Mountain Bridge. Initial soils investigations by Land and Water Consulting, Inc. (Environmental Analysis, December, 1998) indicated that the soils in the project area were deep alluvial gravel and cobble with a thin layer of topsoil. However, recent core sampling by Ray Engineering, Inc. near the new proposed bridge locations discovered that the subsurface materials were silty, sandy loams to depths of up to 9 feet. Additional core sampling is recommended for the entire new channel location to better predict depth to gravel. Because the soils in this area are finer than required for a stable stream bottom, it may be necessary to over-excavate the new channel by about 3 feet and backfill with imported gravel from elsewhere in the project. This potential additional task and cost is included in the cost analysis as a line item.

The total estimated cost of the project is summarized in the following table. For specific costs and detailed information, please refer to the Cost Analysis Spreadsheets located in Appendix Three.

Table 3 – Estimated Project Implementation Costs

Reach One	$ 81,300
Reach Two	$ 132,800
Reach Three	$ 69,500
Staking/Supervision	$ 30,430
Subtotal	$ 314,030
Contingency	$ 31,403
Total with Contingency	$ 345,433
Potential Additional Cut/Fill	$ 33,000
Total with Potential Costs	$ 378,433

XI. RE-VEGETATION EFFORT

One of the challenges of a large-scale stream relocation project is the adequate re-vegetation of all disturbed areas. Long-term stability of the newly constructed channel and the floodplain requires that these areas' vegetation function naturally. Therefore, we have proposed a rather rigorous re-vegetation effort that incorporates three distinct components: transplanting of large mature shrubs and sod mats, establishment of new small shrubs, and the establishment of good dense riparian and upland grasses.

Grass sod mats and large mature riparian shrubs will be harvested from donor sites located throughout and adjacent to the project area. These harvested plants and sod mats will be transplanted throughout the disturbed portion of the project area in critical locations. Typically, these types of transplantable materials are utilized in the immediate vicinity of the newly constructed channel particularly on the outside of the meanders. Experience has shown the need for and importance of having firmly established riparian vegetation in these locations due to the higher shear stresses and resulting potential for erosion. Transplanted material will be set at an elevation such that the depth to groundwater and the stream's water surface elevation are adequately matched between the donor site and the transplanted site. For example, if a red-osier dogwood is being transplanted and it is currently located on or near a streambank at floodplain elevation, it would be transplanted to a similar environment. In all cases, harvested materials will be transplanted to an appropriate site to provide the highest probability of survival. We would not recommend transplanting wetland sod mats composed of sedges, rushes, and wetland grasses onto an upland terrace because survival would be improbable. Other locations of particular importance would be where the new channel takes off from the existing channel; it is critical that this area be well-vegetated from the onset to prevent the stream from eroding the fill material which will be placed in the abandoned channel.

Unfortunately, construction costs and budgetary constraints preclude transplanting all disturbed areas and other less costly measures must be utilized in lower risk areas. These areas would include the newly constructed floodplain, existing floodplain that was disturbed during construction, and donor sites for transplantable material. These areas will be re-vegetated using two methods: small shrub "sprigging" and broadcast grass seeding.

Other possible options might include the use of lightweight erosion control fabric on particularly sensitive floodplain areas. Sod mats laid in a linear fashion perpendicular to the flow direction across the newly excavated floodplain.

For further information on the monitoring and maintenance of the re-vegetation effort, please refer to the long-term maintenance section.

XII. PROJECT MAINTENANCE

This project has been carefully designed to reduce long-term maintenance and its associated cost to an absolute minimum. In the initial stages, multiple options were considered and dismissed because they included and required expensive long-term maintenance. Given the dynamic nature of riverine systems, the chosen option addressed the problem by providing the greatest likelihood of long-term success and stability through the use of sound hydrologic and fluvial geomorphic principles. However, in any project of this nature, it is impossible to wholly eliminate maintenance and repair. We have attempted to estimate the reasons for and the amount of maintenance and the potential costs for this work in the following paragraphs.

Maintenance is largely a function of several factors: degree and duration of flood events, establishment and health of riparian transplants, plantings, and seeding, and gravel deposition. In projects like this, the first few years are the most critical because of the disturbed condition of the project site. During this time period, large-scale flooding (flooding associated with a high recurrence interval) can be particularly damaging to the re-vegetation effort. Although we cannot predict the actual occurrence of these types of flooding events, their statistical likelihood is low. This type of flooding has the potential to scour the recently transplanted and established grasses and shrubs. Obviously, the degree or magnitude of the flood event and the duration are linearly related to the amount of damage these events can produce. If a large flood event were to occur, the damaged areas would need to be re-vegetated. The costs associated with this type of re-vegetation could be minimized by utilizing students as an educational project. If this is possible, the only costs would be associated with the purchase of appropriate seed mixes and should not be significant. If students are not available, a crew of professionals would have to perform the work with their associated costs.

Unfortunately, bio-engineering and re-vegetation efforts are not an exact science. Even under the best of circumstances, there is a natural and unavoidable loss of vegetation. These losses will occur to transplanted mature shrubs and sod mats as well as grass seeding and small shrub sprigs. In previous projects, with proper treatment, we have experienced a survival rate over the first three years of greater than 70% with our large mature shrub transplants and sod mats. The entire project will need to be systematically monitored to determine how much of the non-surviving transplanted material need to be replaced. A trained professional can help set up the monitoring methodology with implementation by local personnel. The success of grass seeding is typically measured as a percent of ground coverage and coverage density. The grasses will need to be monitored to determine the degree of loss. If surface coverage (area) or the density of grasses needs to be increased, additional seed will need to be broadcast. This is a relatively simple procedure which could be accomplished by any trained individual in a short period of time. The costs would be directly related to seed cost. Small shrub sprigging has the lowest probable success rate of any of the proposed re-vegetation efforts. Additional shrub sprigging may be required. As previously discussed, with supervision, this task could be performed by students. A donor site could be located in or adjacent to the project area which would supply the plant material at no cost.

Great effort has been expended to ensure that the newly constructed stream channel is capable of transporting the sediment made available to it by its watershed. Specifically, the channel was designed to create shear stresses high enough to mobilize and transport material larger than the D50 size particle. However, there are at least two active debris/landslides located upstream of the project in the watershed. These slides and other events could temporarily provide sources of material in exceedance of the channel's ability to transport during a large flood event. Therefore, it would be prudent to plan for gravel removal as a long-term requirement. Gravel removal from the channel is the most probable, but removal of gravel from the floodplain might be required after a large flood event. Obvious locations for potential gravel deposition are upstream of the New Dome Mountain Road Bridge and at gradient transitions (stations 36+00, 22+00, 11+00 and 5+00).

It is important to understand that these streams are difficult to restore given the amount of disturbance that they've been subjected to and their current state. They are very dynamic systems and a significant amount of the developed land is located at the valley mouths. Some amount of carefully, designed channel maintenance is likely after major flood events. To accommodate monitoring and maintenance, the nearby homeowners are forming a Conservancy District and have created a tax base from which to generate needed maintenance funding The Conservancy District in cooperation with the County have agreed to maintain the stream system over time. There will be a maintenance plan developed that will direct maintenance work to essentially maintain the stream in its originally constructed state. Most of the maintenance work would be associated with dredging of bedload sediment in areas where deposition has been shown to occur through monitoring. Also some bank and bed stabilization structures may need to be maintained over time. The revegetation effort will be an ongoing process and will be accomplished in cooperation with the School system as an educational tool.

Estimated Maintenance Costs

First Year

For newly constructed channels, it is reasonable to expect that approximately 5% of the total construction budget will be required for maintenance after the first year. This money would be utilized to "fine-tune" the project area and repair any and all damage that the first runoff might cause to the structures and the re-vegetation effort. For the Parmenter Creek project, this cost is estimated to be approximately $15,000.

Every 10 Years

We estimate about a ten-year frequency, the entire project area may require maintenance and "fine-tuning". For the Parmenter Creek project, this cost is estimated to be approximately $10,000 to $15,000. In response to repeated large-scale flood events corresponding to 20 year or longer recurrence intervals, bed aggradation may occur as a result of gravel deposition. During the ten year period, the deposited gravel may need to be removed after such a flood event. However, the cost of this gravel removal is included in the 10-year estimated maintenance costs.

amended

XII. PROJECT MAINTENANCE

This project has been carefully designed to reduce long-term maintenance and its associated cost to an absolute minimum. In the initial stages, multiple options were considered and dismissed because they included and required expensive long-term maintenance. Given the dynamic nature of riverine systems, the chosen option addressed the problem by providing the greatest likelihood of long-term success and stability through the use of sound hydrologic and fluvial geomorphic principles. However, in any project of this nature, it is impossible to wholly eliminate maintenance and repair. We have attempted to estimate the reasons for and the amount of maintenance and the potential costs for this work in the following paragraphs.

Maintenance is largely a function of several factors: degree and duration of flood events, establishment and health of riparian transplants, plantings, and seeding, and gravel deposition. In projects like this, the first few years are the most critical because of the disturbed condition of the project site. During this time period, large-scale flooding (flooding associated with a high recurrence interval) can be particularly damaging to the re-vegetation effort. Although we cannot predict the actual occurrence of these types of flooding events, their statistical likelihood is low. This type of flooding has the potential to scour the recently transplanted and established grasses and shrubs. Obviously, the degree or magnitude of the flood event and the duration are linearly related to the amount of damage these events can produce. If a large flood event were to occur, the damaged areas would need to be re-vegetated. The costs associated with this type of re-vegetation could be minimized by utilizing students as an educational project. If this is possible, the only costs would be associated with the purchase of appropriate seed mixes and should not be significant. If students are not available, a crew of professionals would have to perform the work with their associated costs.

Unfortunately, bio-engineering and re-vegetation efforts are not an exact science. Even under the best of circumstances, there is a natural and unavoidable loss of vegetation. These losses will occur to transplanted mature shrubs and sod mats as well as grass seeding and small shrub sprigs. In previous projects, with proper treatment, we have experienced a survival rate over the first three years of greater than 70% with our large mature shrub transplants and sod mats. The entire project will need to be systematically monitored to determine how much of the non-surviving transplanted material need to be replaced. A trained professional selected by Lincoln County can help set up the monitoring methodology with implementation by local personnel. The success of grass seeding is typically measured as a percent of ground coverage and coverage density. The grasses will need to be monitored to determine the degree of loss. If surface coverage (area) or the density of grasses needs to be increased, additional seed will need to be broadcast. This is a relatively simple procedure which could be accomplished by any trained individual in a short period of time. The costs would be directly related to seed cost. Small shrub sprigging has the lowest probable success rate of any of the proposed re-vegetation efforts. Additional shrub sprigging may be required. As previously discussed, with supervision, this task could be performed by students. A donor site could be located in or adjacent to the project area which would supply the plant material at no cost.

Great effort has been expended to ensure that the newly constructed stream channel is capable of transporting the sediment made available to it by its watershed. Specifically, the channel was designed to create shear stresses high enough to mobilize and transport material larger than the D50 size particle. However, there are at least two active debris/landslides located upstream of the project in the watershed. These slides and other events could temporarily provide sources of material in exceedance of the channel's ability to transport during a large flood event. Therefore, it would be prudent to plan for gravel removal as a long-term requirement. Gravel removal from the channel is the most probable, but removal of gravel from the floodplain might be required after a large flood event. Obvious locations for potential gravel deposition are upstream of the New Dome Mountain Road Bridge and at gradient transitions (stations 36+00, 22+00, 11+00 and 5+00).

It is important to understand that these streams are difficult to restore given the amount of disturbance that they've been subjected to and their current state. They are very dynamic systems and a significant amount of the developed land is located at the valley mouths. Some amount of carefully, designed channel maintenance is likely after major flood events. To accommodate monitoring and maintenance, the nearby homeowners are forming a Conservancy District and have created a tax base from which to generate needed maintenance funding The Conservancy District in cooperation with the County have agreed to maintain the stream system over time. There will be a maintenance plan developed that will direct maintenance work to essentially maintain the stream in its originally constructed state. Most of the maintenance work would be associated with dredging of bedload sediment in areas where deposition has been shown to occur through monitoring. Also some bank and bed stabilization structures may need to be maintained over time. The revegetation effort will be an ongoing process and will be accomplished in cooperation with the School system as an educational tool.

Estimated Maintenance Costs

First Year
For newly constructed channels, it is reasonable to expect that approximately 5% of the total construction budget will be required for maintenance after the first year. This money would be utilized to "fine-tune" the project area and repair any and all damage that the first runoff might cause to the structures and the re-vegetation effort. For the Parmenter Creek project, this cost is estimated to be up to $15,000. Lincoln County will budget up to this amount the first year after completion.

Every 10 Years

We estimate about a ten-year frequency, the entire project area may require maintenance and "fine-tuning". For the Parmenter Creek project, this cost is estimated to be up to $15,000. In response to repeated large-scale flood events corresponding to 20 year or longer recurrence intervals, bed aggradation may occur as a result of gravel deposition. During the ten year period, the deposited gravel may need to be removed after such a flood event. However, the cost of this gravel removal is included in the 10-year estimated maintenance costs. Up to $15,000 will be available in this 10 year period for the estimated costs.

Approved 5/27/99

Rita P. Windom
Lincoln Co. Commissioner
Dist #1

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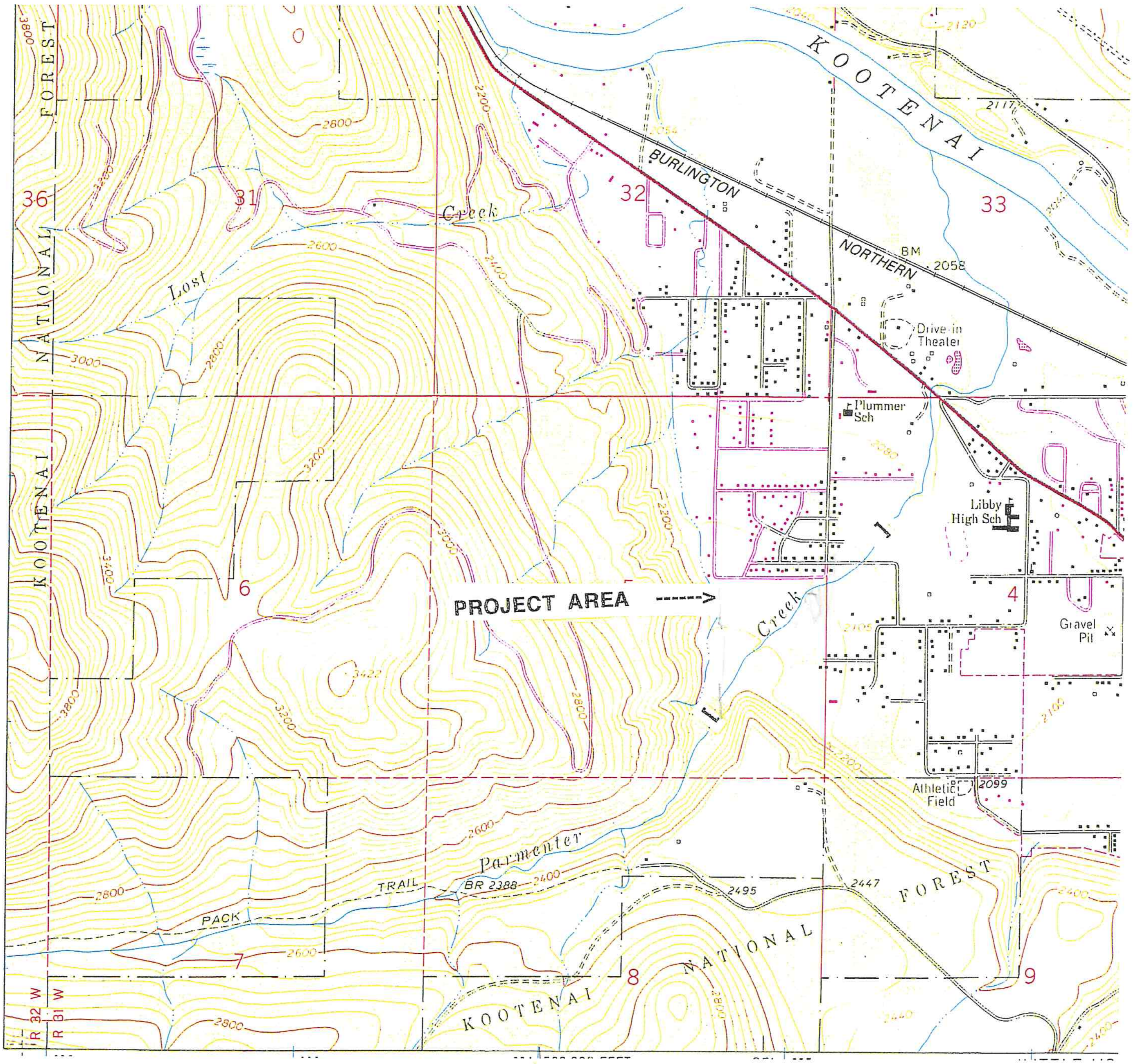
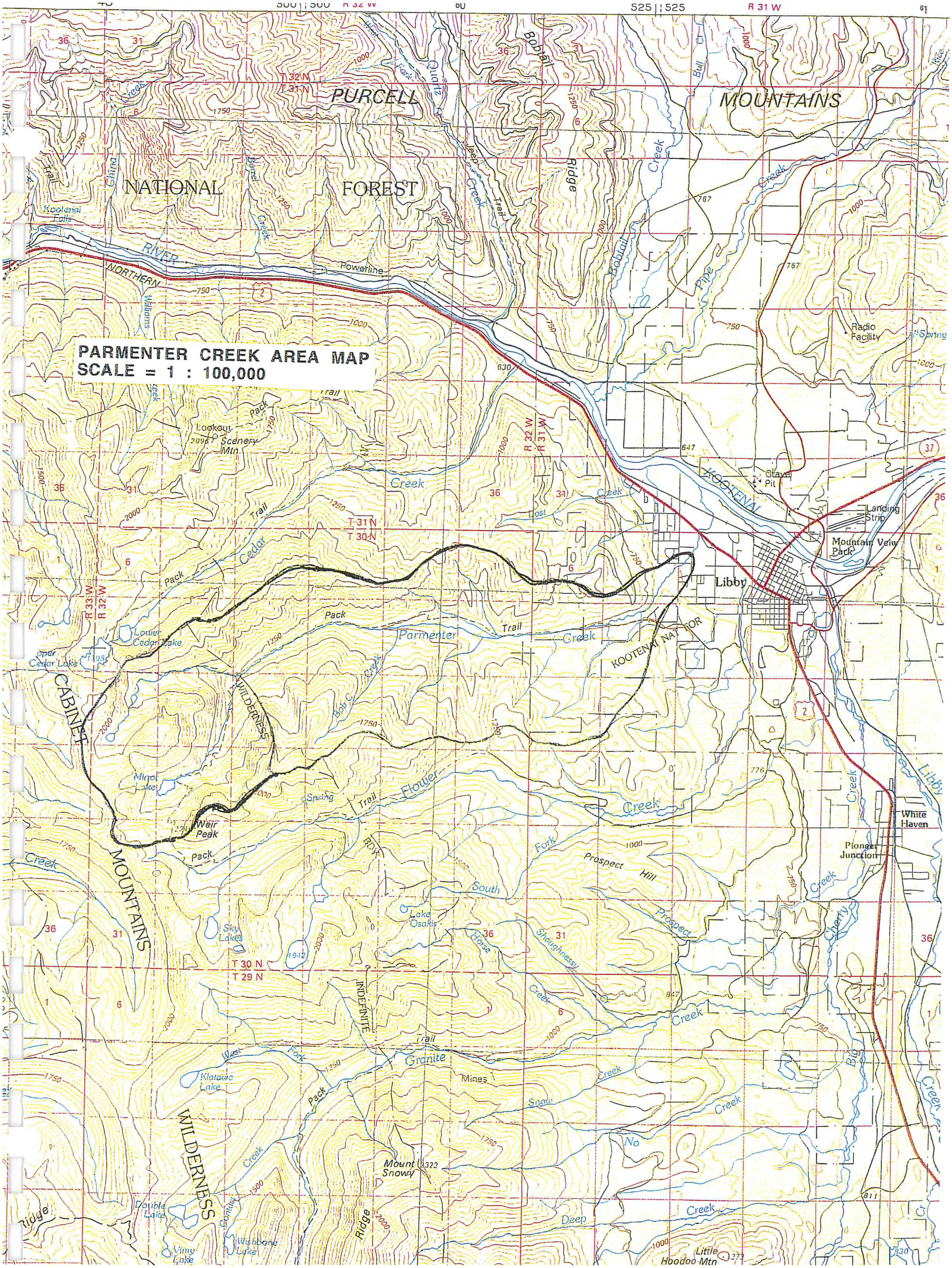
APPENDICES

1. Site Maps
2. Reach 3 Information including typical cross-section, plan view photomap, and longitudinal profile
3. Detailed Cost Analysis Spreadsheets
4. Proposed Structure Sketches
5. Map & profile package

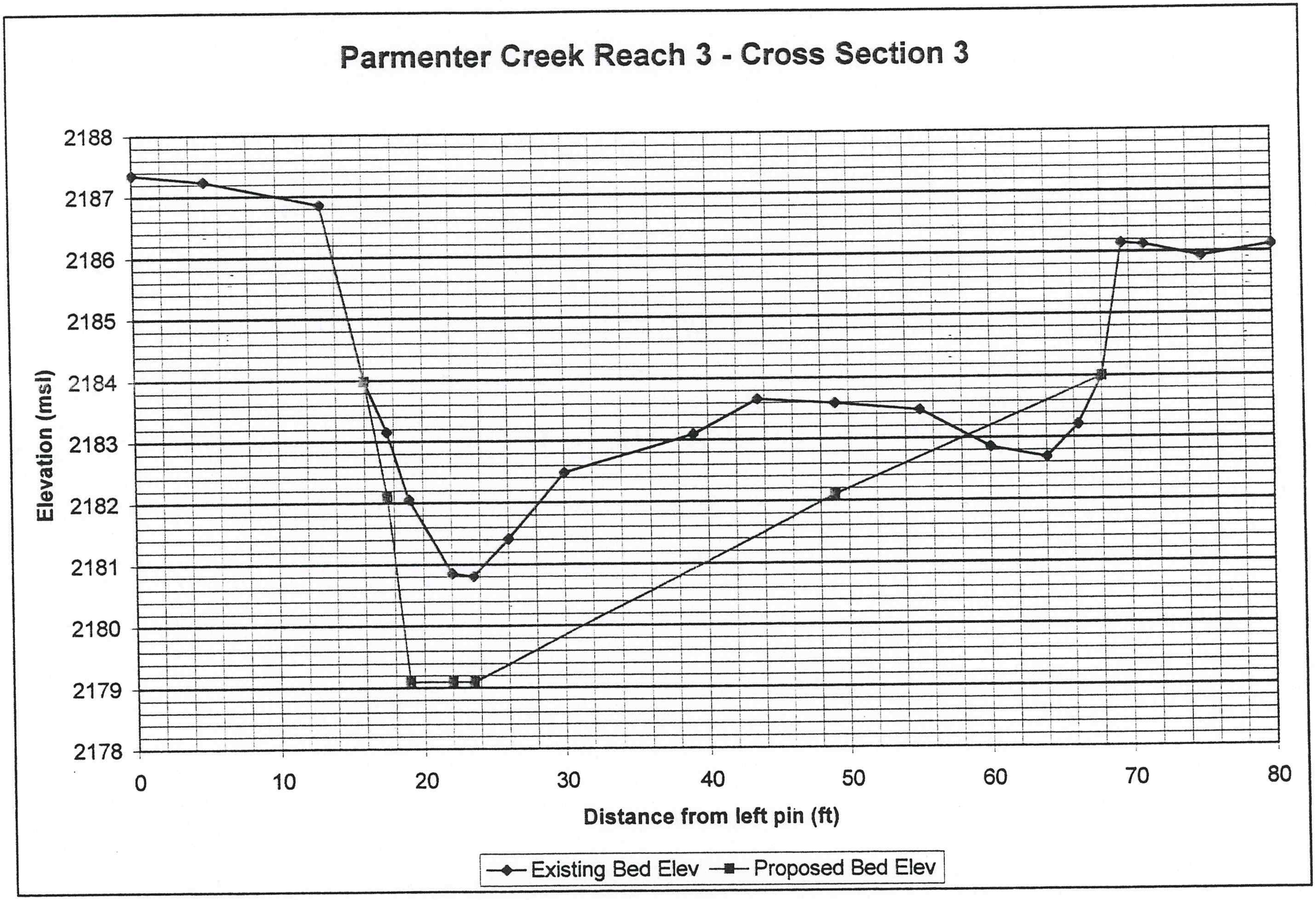
<u>APPENDIX 1</u>
Site Maps



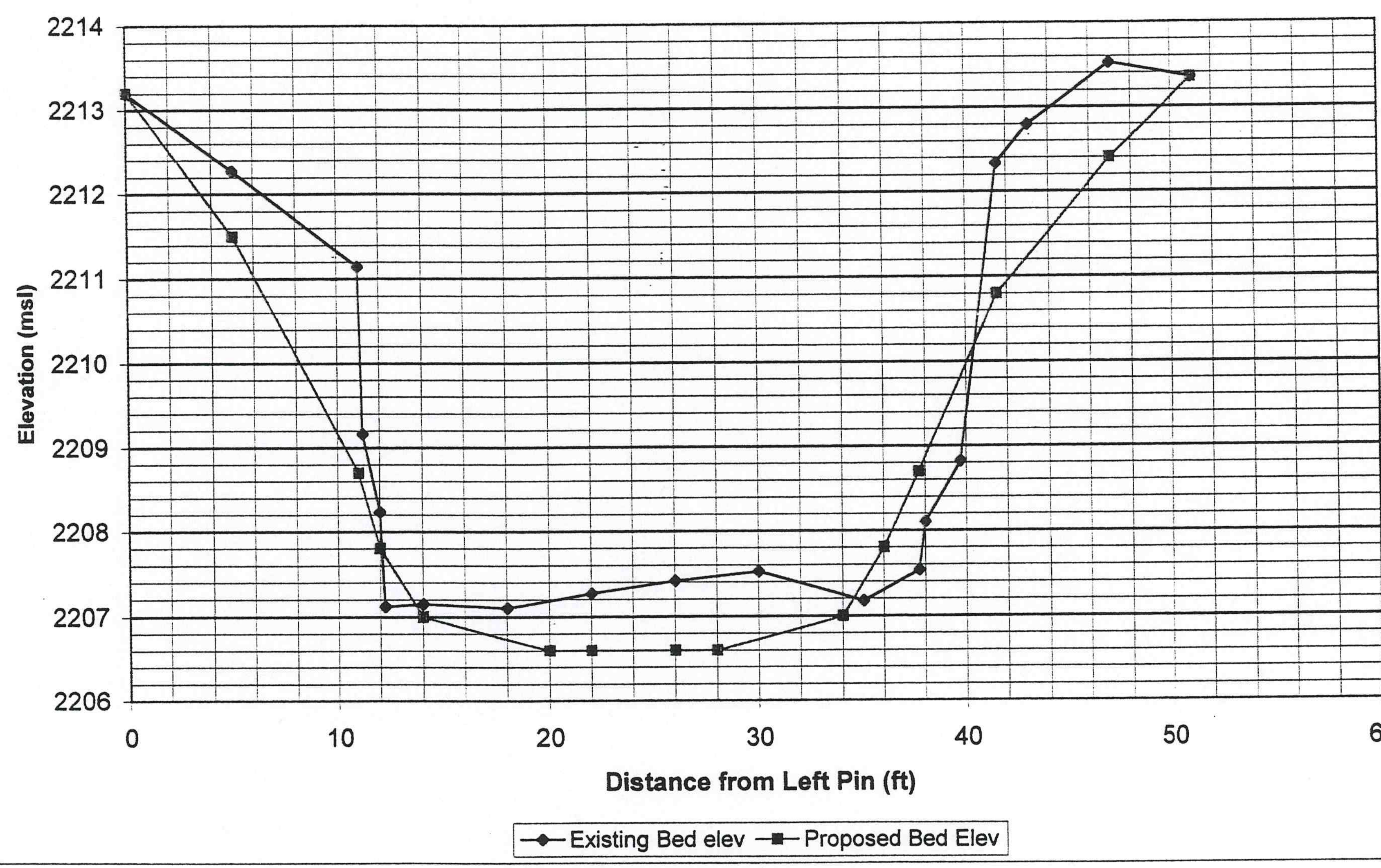
PROJECT AREA
KOOTENAI
BURLINGTON
NORTHERN
BM 2058
Drive-in Theater
Plummer Sch
Libby High Sch
Gravel Pit
Athletic Field
Lost Creek
Parmenter
PACK TRAIL
BR 2388
KOOTENAI NATIONAL FOREST
R 32 W
R 31 W
36
31
32
33
6
4
7
8
9


PARMENTER CREEK AREA MAP
SCALE = 1 : 100,000
PURCELL
MOUNTAINS
NATIONAL
FOREST
R 32 W
R 31 W
T 32 N
T 31 N
T 30 N
T 29 N
R 33 W
Kootenai Falls
RIVER
NORTHERN
Powerline
KOOTENAI
Lookout
Scenery Mtn
Pack
Trail
Cedar
Creek
Lost
Parmenter
KOOTENAI NAT FOR
Lower Cedar Lake
Cedar Lake
CABINET
MOUNTAINS
WILDERNESS
Bob C.
Minor Lake
Weir Peak
Flower
Spring
South
Fork
Prospect Hill
Prospect
Sky Lakes
Lake Osakis
Horse
Shaughnessy
INDEFINITE
BDY
Granite
Mines
West
Fork
Klatawa Lake
Snow
No
Mount Snowy
Double Lake
Wishbone Lake
Vimy Lake
Ridge
Deep
Little Hoodoo Mtn
Libby
Gravel Pit
Landing Strip
Mountain Veiw Park
Radio Facility
Spring
White Haven
Pioneer Junction
Cherry
Big
Bobtail
Ridge
Quartz
Jeep
Bull Cr
Pipe
China
Burrel
Williams

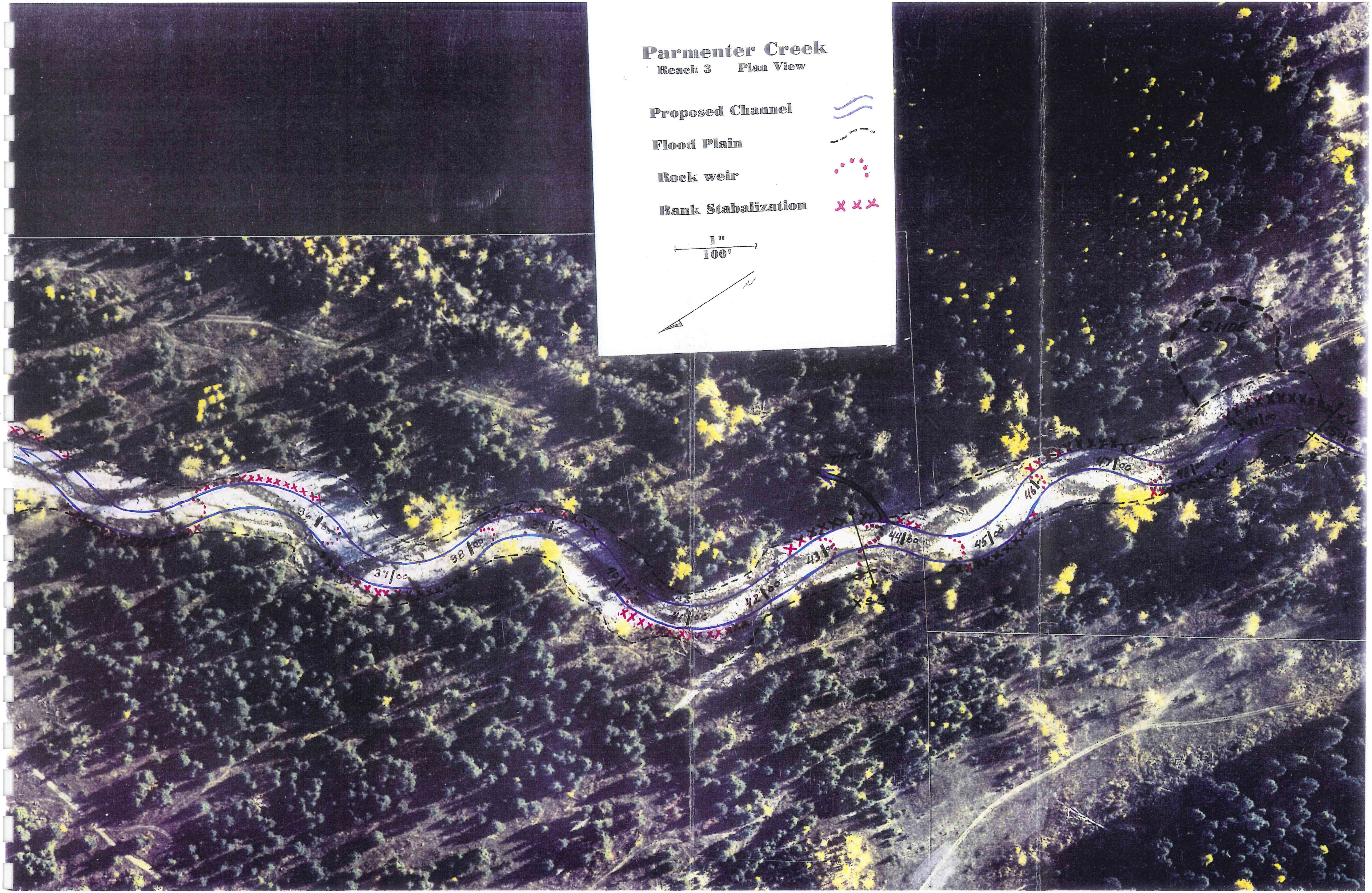
APPENDIX 2
Reach Three Information
(including Typical Cross-Sections, Plan view, and Longitudinal Profile)


Parmenter Creek Reach 3 - Cross Section 3
2188
2187
2186
2185
2184
2183
2182
2181
2180
2179
2178
Elevation (msl)
0
10
20
30
40
50
60
70
80
Distance from left pin (ft)
Existing Bed Elev
Proposed Bed Elev

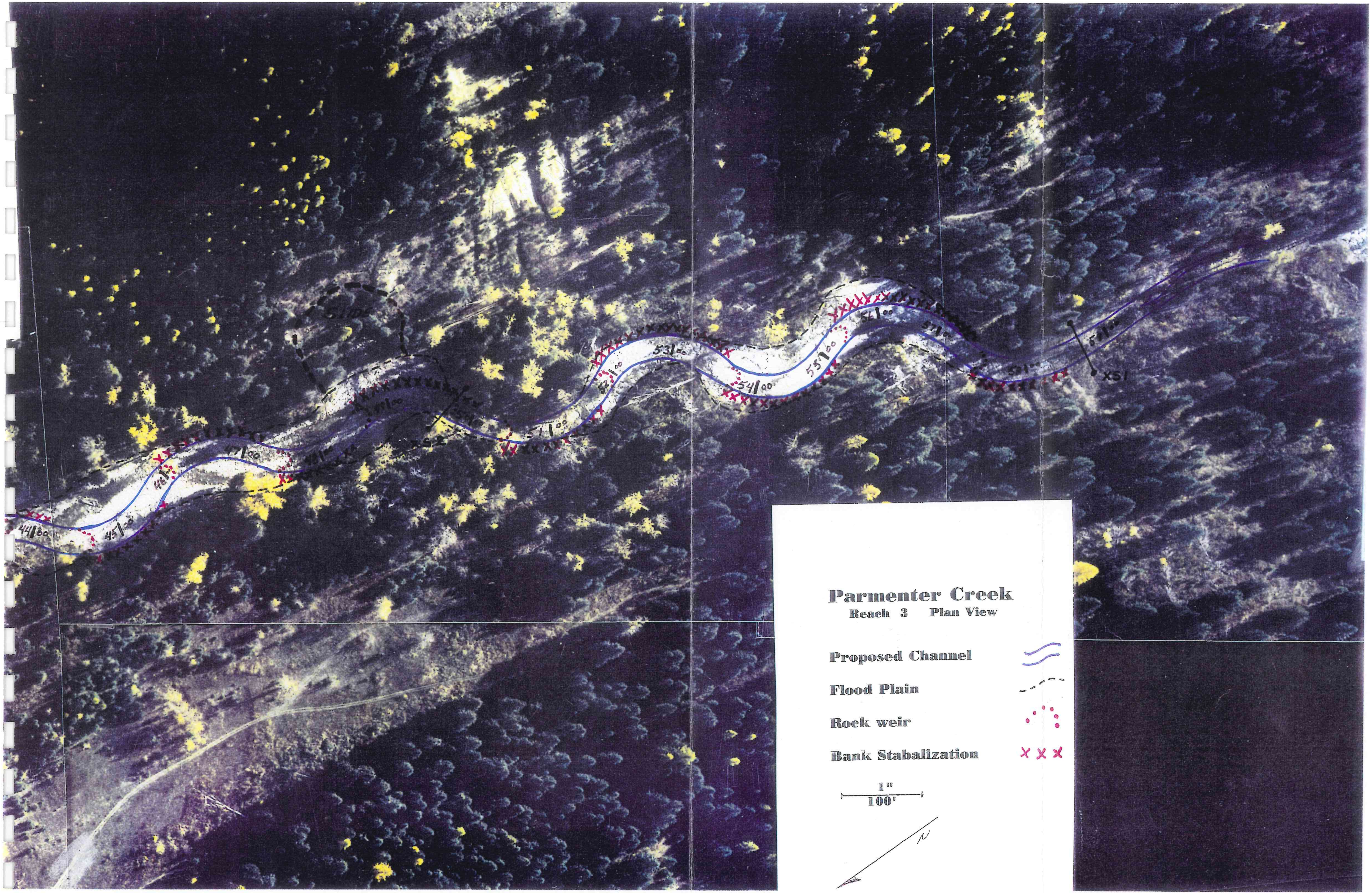
Parmenter Creek Reach 3 - Cross Section 2

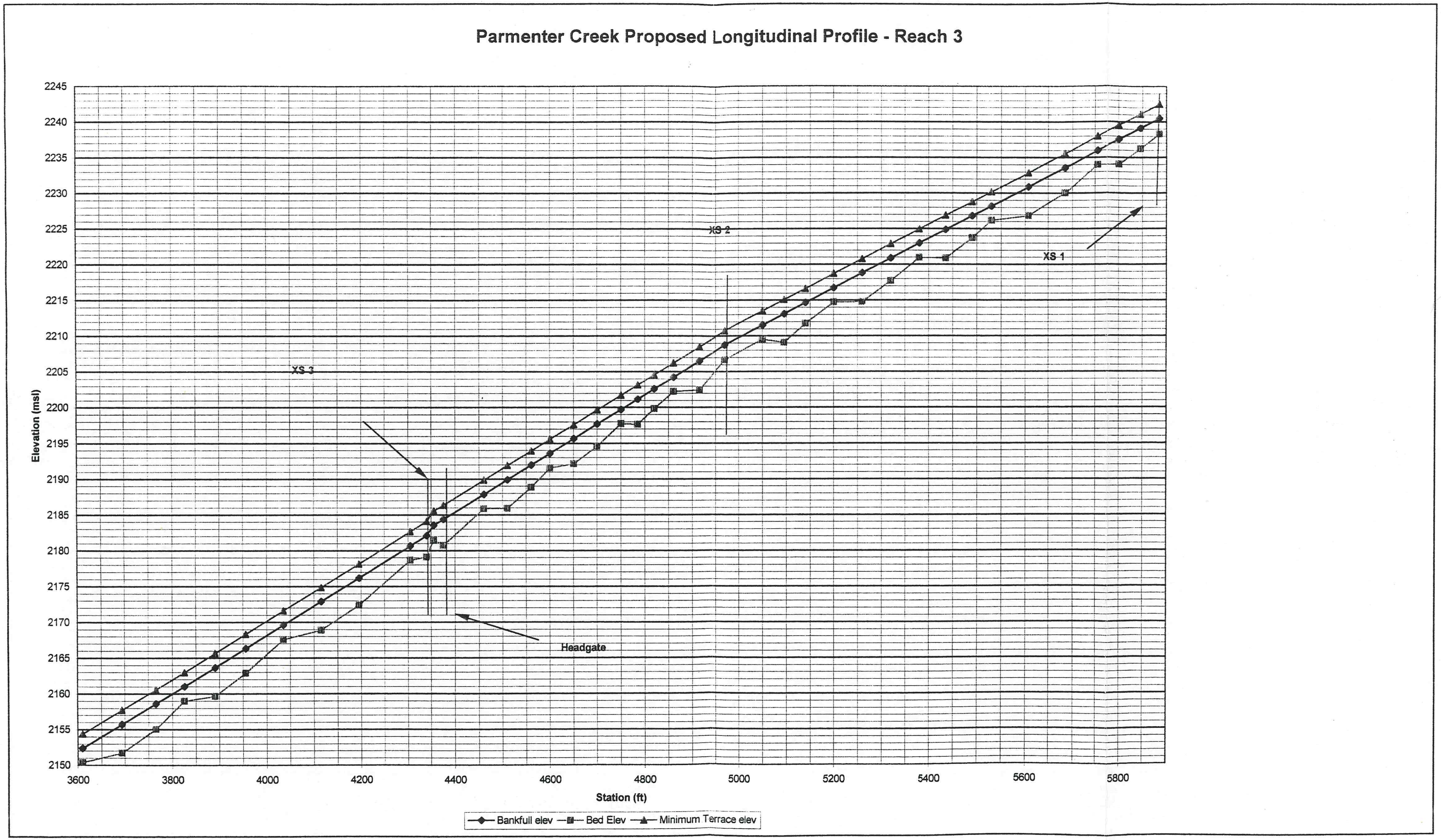


WestWater Consultants, Inc.

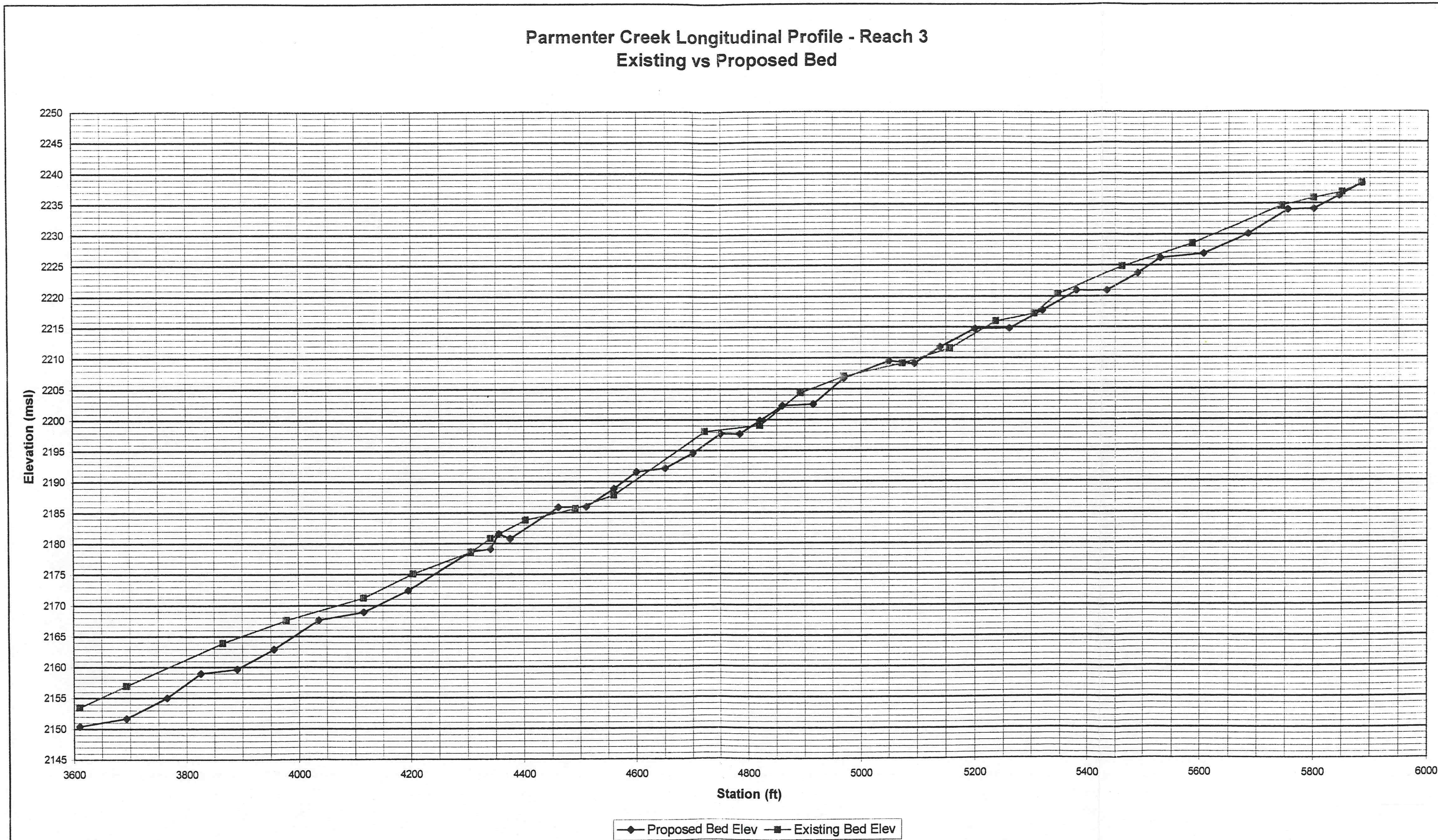


Parmenter Creek
Reach 3 Plan View
Proposed Channel
Flood Plain
Rock weir
Bank Stabalization
1"
100'
N
SLIDE


Parmenter Creek
Reach 3 Plan View
Proposed Channel
Flood Plain
Rock weir
Bank Stabalization
1"
100'
N



WestWater Consultants, inc.



WestWater Consultants, Inc.

APPENDIX 3
Detailed Cost Analysis Spreadsheets

Estimated Implementation Costs

REACH ONE 0+00 to 14+70

<u>Channel & Floodplain Excavation</u>

Excavation of approximately 4,800 cubic yards of gravel and end haul 4,000 yards to stockpile including equipment costs. Potential cut and fill would only occur if materials are too fine for the channel bed (please see write-up).

	Volume	Rate	Cost	Potential Cost
Excavate	4,800 yds	$2.00/yd	$9,600	
Fill	800 yds	$2.00/yd	$1,600	
End Haul	4,000 yds	$3.00/yd	$12,000	
Potential Fill	4,000 yds	$5.00/yd		$20,000
		Subtotal	$23,200	$20,000

<u>Floodplain & Channel Finish</u>

Bank Stabilization & Transplanting-1,050 linear feet of bank stabilization

	Days	Hours/Day	Rate/Hour	Cost
Excavator	9	10	$90	$8,100
Loader	9	10	$70	$6,300
Structures				
Excavator	6	10	$90	$5,400
Loader	4	10	$70	$2,800
Footpath- Stockpile Material, Construct, & Rip-rap				
Excavator	6	10	$90	$5,400
Loader	3	10	$70	$2,100
Dozer	5	10	$80	$4,000
			Subtotal	$34,100

<u>Materials</u>

Large Rock (Average 1.5 cubic yards/rock)		
	450 cubic yds @$20/cubic yd	$9,000
Rip-Rap 12" to 24" Gradation	800 cubic yds @ $10/cubic yd	$8,000
Cost is for haul only (Includes Path/Stockpile)		
Whole Trees	90 @ $50/tree	$4,500
Cost is for haul only (Refer to Specs in Report)		
Silt Fence		
500 feet of silt fence @ $2.00/foot installed		$1,000
Re-vegetation - Seed/Mulch/Fertilizer		
	3 acres $500/acre	$1,500
	Subtotal	$24,000

Reach One Estimated Total Implementation Cost = $81,300

Reach One Total Cost w/Optional Gravel Excavation and Fill = $101,300

Estimated Implementation Costs

REACH TWO 15+00 to 36+00

Channel & Floodplain Excavation

Excavation of approximately 13,00 cubic yards of material, end haul and placement of approximately 7,200 yards including equipment costs. Potential cut and fill would only occur if materials are too fine for the channel bed (please see write-up).

	Volume	Rate	Cost	Potential Cost
Excavate	13,000	$2.00/yd	$26,000	
Fill	5,000	$2.00/yd	$10,000	
End Haul	7,200	$3.00/yd	$21,600	
Potential Fill	2,000 yds	$5.00/yd		$10,000
		Subtotal	$57,600	$10,000

Floodplain & Channel Finish

Bank Stabilization & Transplanting-1,150 linear feet of bank stabilization

	Days	Hours/Day	Rate/Hour	Cost
Excavator	9	10	$90	$8,100
Loader	9	10	$70	$6,300
Dozer	5	10	$80	$4,000
Structures				
Excavator	8	10	$90	$7,200
Loader	4	10	$70	$2,800
Footpath- Stockpile Material, Construct, & Rip-rap				
Excavator	9	10	$90	$8,100
Loader	4	10	$70	$2,800
Dozer	5	10	$80	$4,000
			Subtotal	$43,300

Materials

Large Rock (Average 1.5 cubic yards/rock)		
	500 cubic yds @ $20/cubic yd	$10,000
Rip-Rap 12" to 24" Gradation	1,200 cubic yds @ $10/cubic yd	$12,000
	Cost is for haul only (Includes Path/Stockpile)	
Whole Trees	100 @ $50/tree	$5,000
	Cost is for haul only (Refer to Specs in Report)	
Silt Fence		
	1200 feet of silt fence @ $2.00/foot installed	$2,400
Re-vegetation - Seed/Mulch/Fertilizer		
	5 acres $500/acre	$2,500
	Subtotal	$31,900

Reach Two Estimated Total Implementation Cost = $132,800

Reach Two Total Cost w/Optional Gravel Excavation and Fill = $142,800

Estimated Implementation Costs

REACH THREE (36+00 to 58+85)

Channel & Floodplain Excavation

Excavation of approximately 4,100 cubic yards of gravel and fill of 4,100 cubic yards of gravel. Includes equipment costs.

	Volume	Rate	Cost	Potential Cost
Excavate	4,100	$2.00/yd	$8,200	
Fill	4,100	$2.00/yd	$8,200	
		Subtotal	$16,400	$0

Floodplain & Channel Finish

Bank Stabilization & Transplanting-1,350 linear feet of bank stabilization

	Days	Hours/Day	Rate/Hour	Cost
Excavator	11	10	$90	$9,900
Loader	11	10	$70	$7,700
Dozer	5	10	$80	$4,000
Structures				
Excavator	10	10	$90	$9,000
Loader	5	10	$70	$3,500
			Subtotal	$34,100

Materials

Large Rock (Average 1.5 cubic yards/rock)		
	550 cubic yds @ $20/cubic yd	$11,000
Rip-Rap 12" to 24" Gradation	200 cubic yds @ $10/cubic yd	$2,000
Cost is for haul only (Includes Path/Stockpile)		
Whole Trees	110 @ $50/tree	$5,500
Cost is for haul only (Refer to Specs in Report)		
Re-vegetation - Seed/Mulch/Fertilizer		
	1 acre $500/acre	$500
	Subtotal	$19,000

Reach Three Estimated Total Implementation Cost = $69,500

Estimated Implementation Costs

Project Supervision & Training

	Days	Hours/Day	Rate/Hour	Cost
Hydrologist/Engineer	34	10	60	$20,400
Travel/Per Diem/Misc.				$4,030
			Subtotal	$24,430

Project Staking

3 person crew (staking channel margins, cut/fill, & elevations)

Reach 1	2 days/reach	$1,000/day	$2,000
Reach 2	2 days/reach	$1,000/day	$2,000
Reach 3	2 days/reach	$1,000/day	$2,000
		Subtotal	$6,000

Estimated Total Project Supervision & Training Cost = $30,430

Estimated Implementation Costs

SUMMARY OF ESTIMATED COSTS

	Planned	Potential Cut/Fill
Implementation - Reach 1 =	$81,300	$101,300
Implementation - Reach 2 =	$132,800	$142,800
Implementation - Reach 3 =	$69,500	
Project Supervision & Training =	$30,430	

Summary of Estimated Costs =	$314,030	
Estimated Costs w/Optional Gravel Excavation and Fill =		$344,030

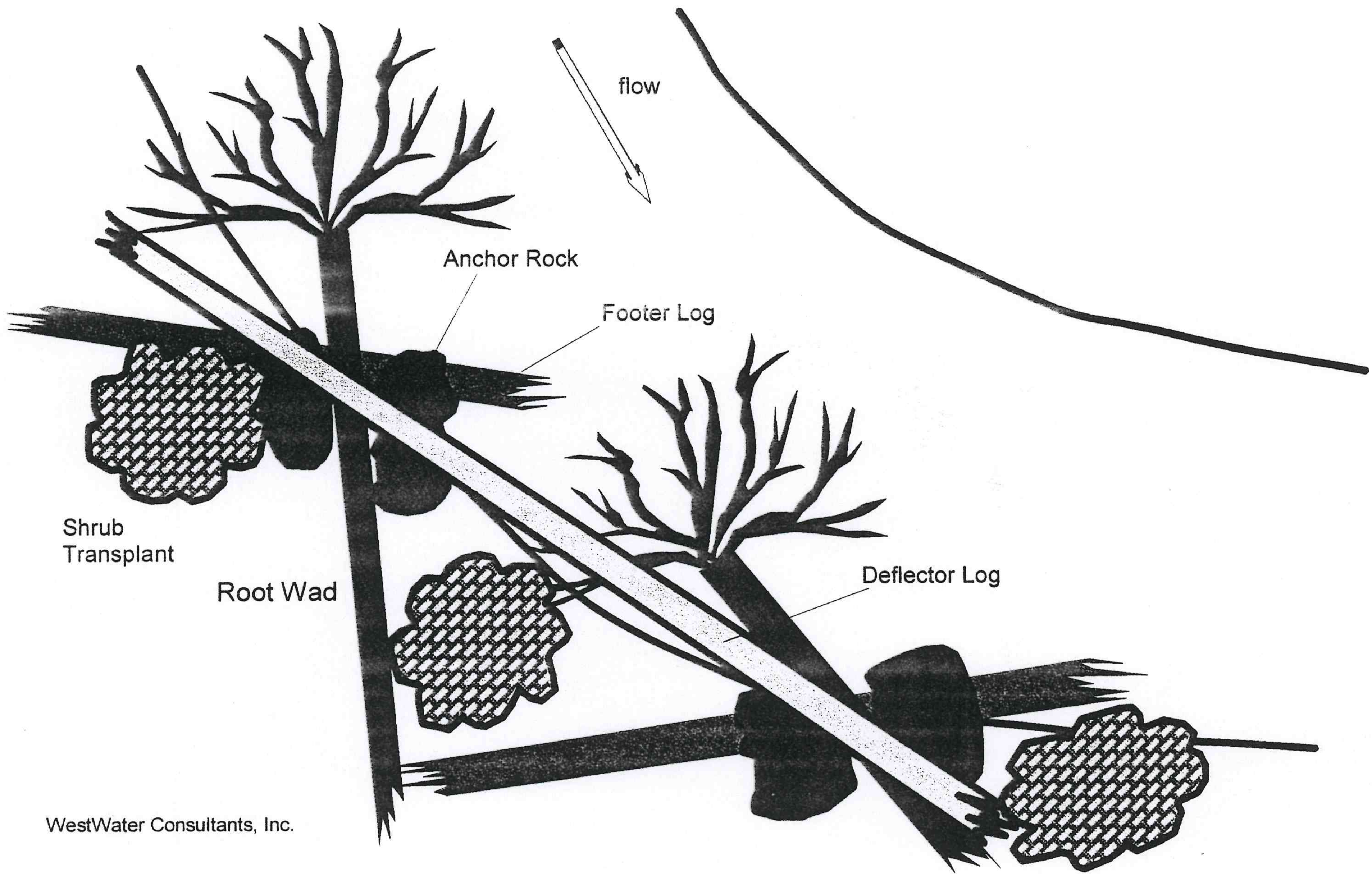
Contingency of 10% =	$31,403	$34,403

Estimated Grand Total Cost w/Contingency =	$345,433	
Estimated Grand Total Cost w/Optional Gravel w/Contingency =		$378,433

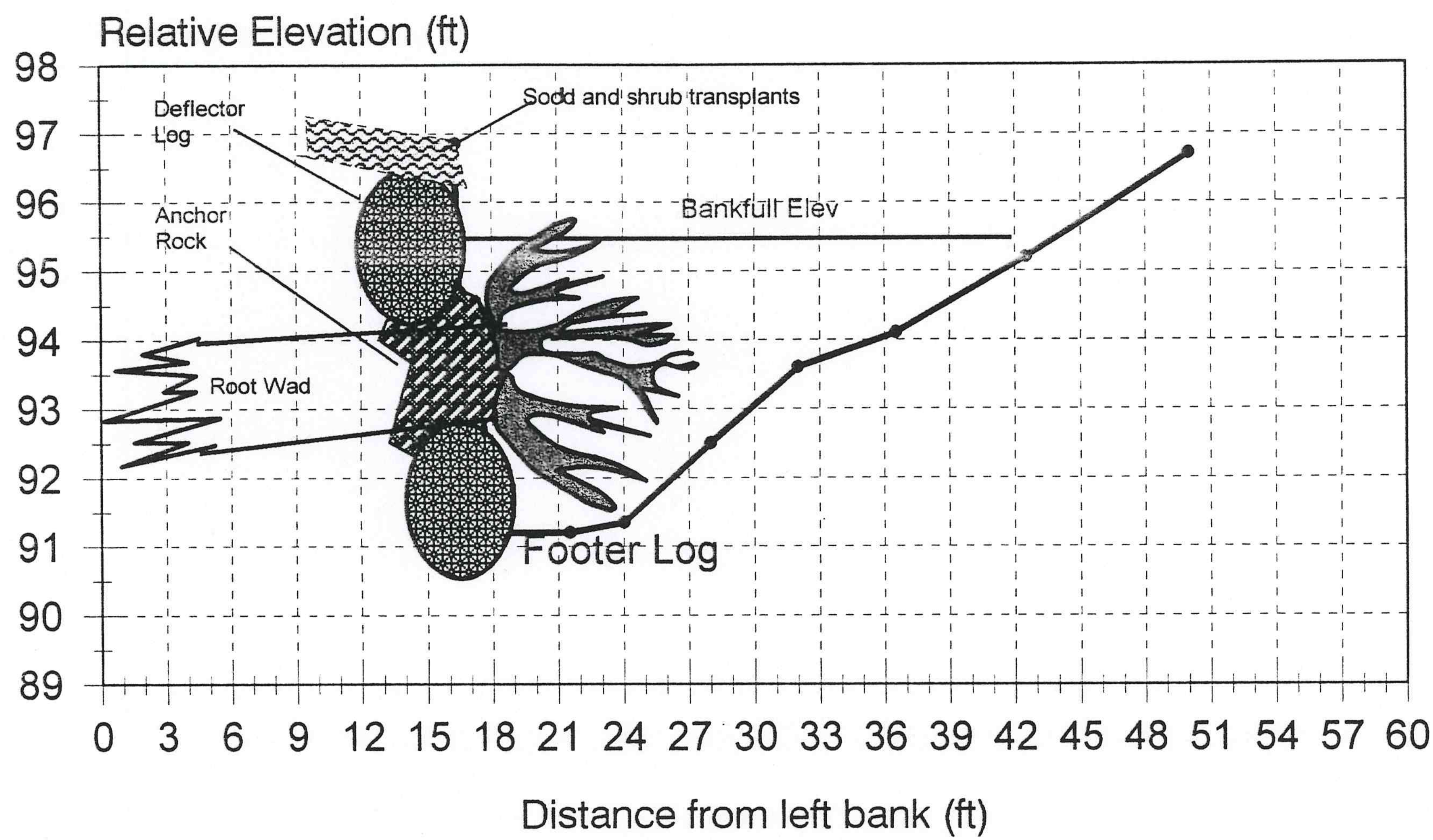
Grand Total Materials	
Large Trees	300
Large Rock	1,500 cubic yds
Rip-Rap	2,200 cubic yds

APPENDIX 4
Proposed Structure Sketches

Typical Root Wad Installation

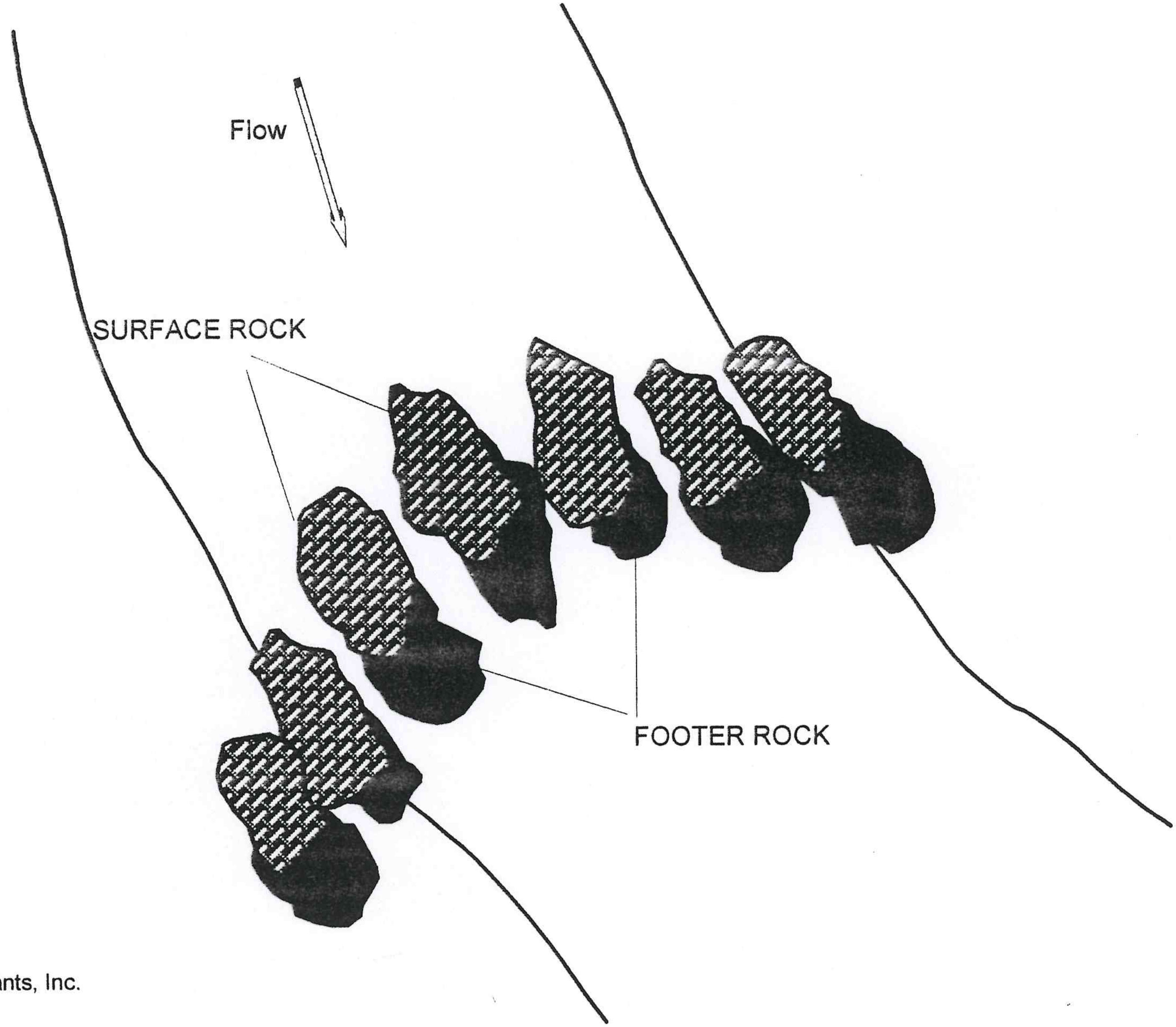


Typical Root Wad Installation



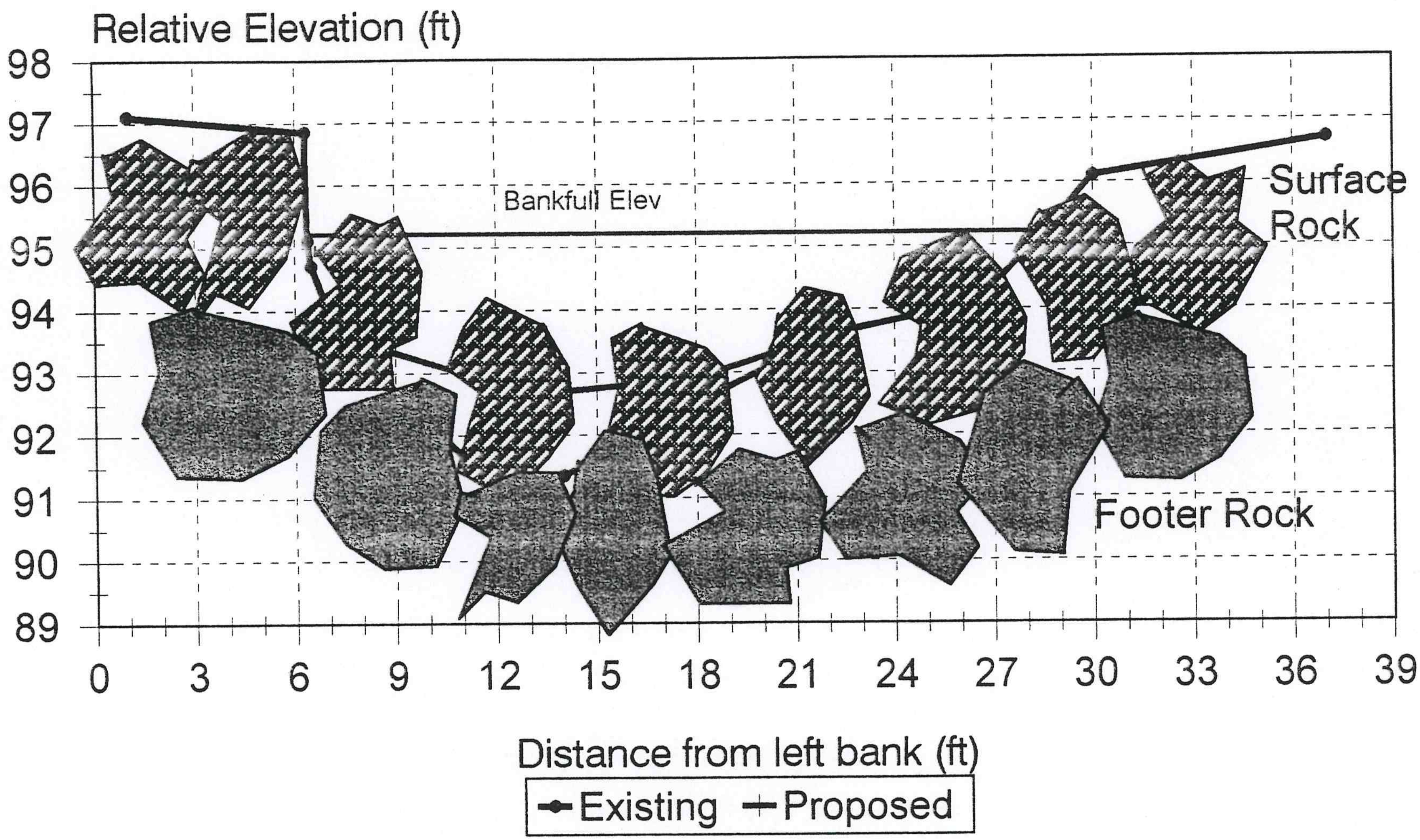
WestWater Consultants, Inc.

Typical Vortex Rock Weir Installation



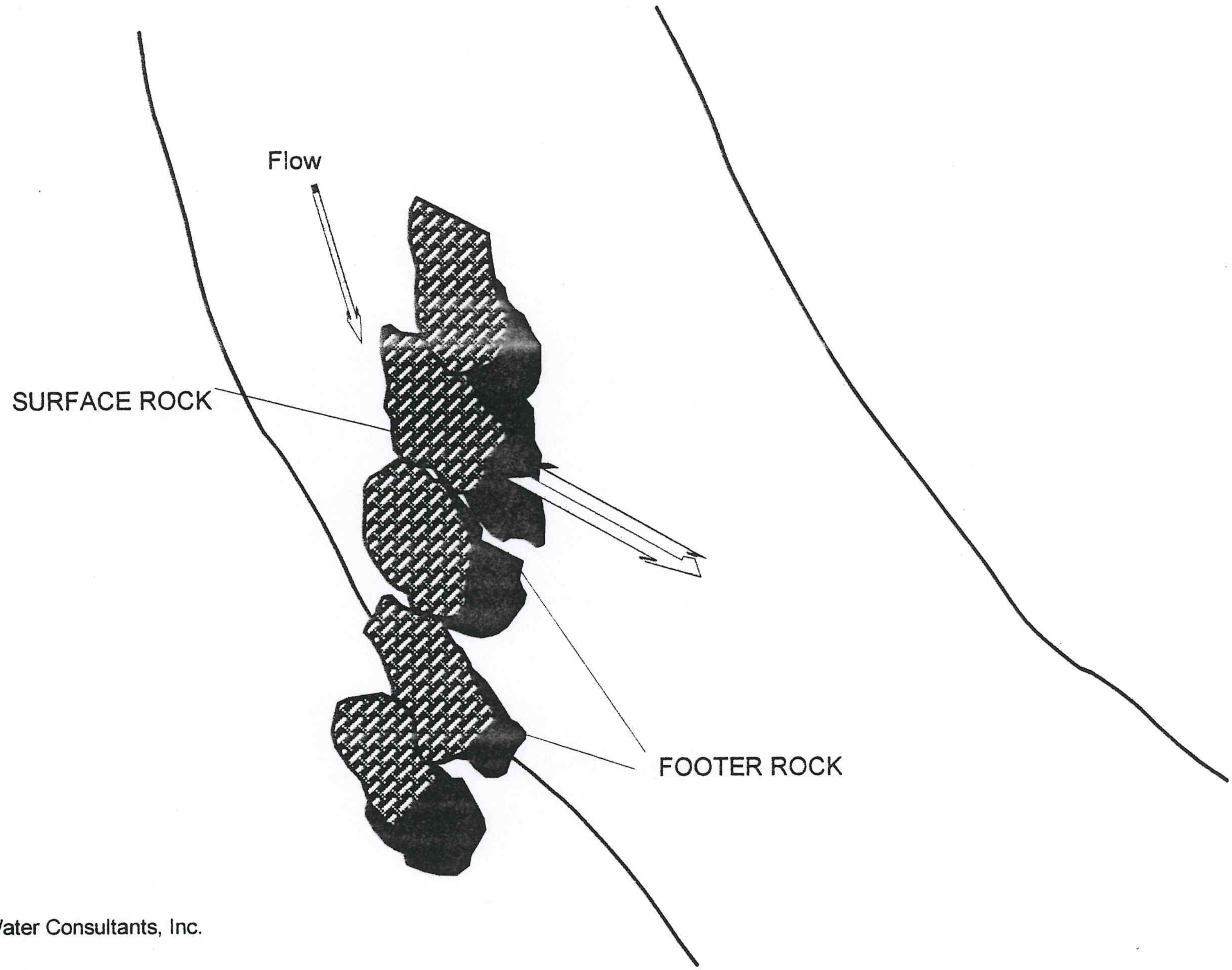
WestWater Consultants, Inc.

Typical Vortex Weir Installation



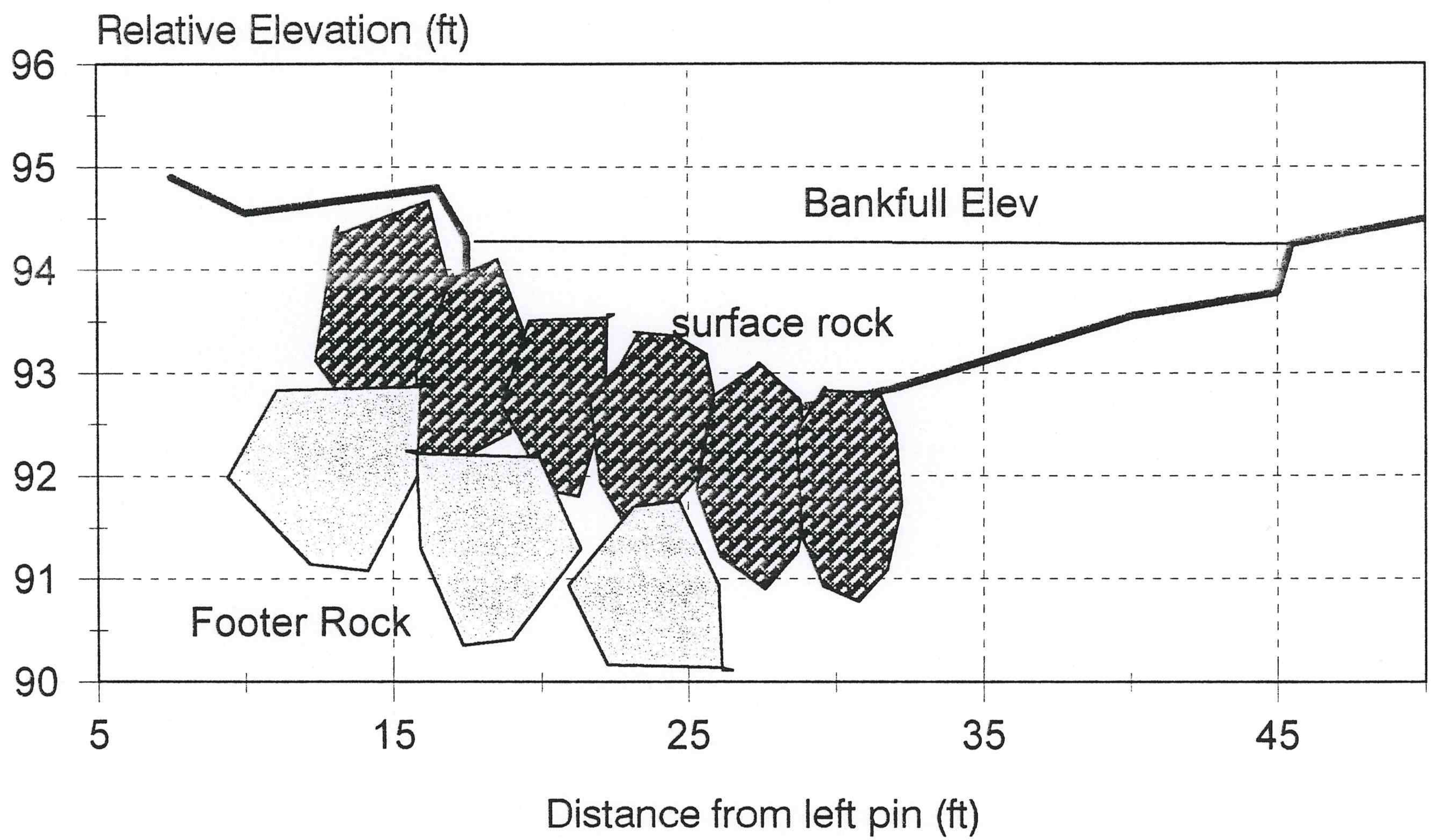
WestWater Consultants, Inc.

Typical Rock Vane Installation



WestWater Consultants, Inc.

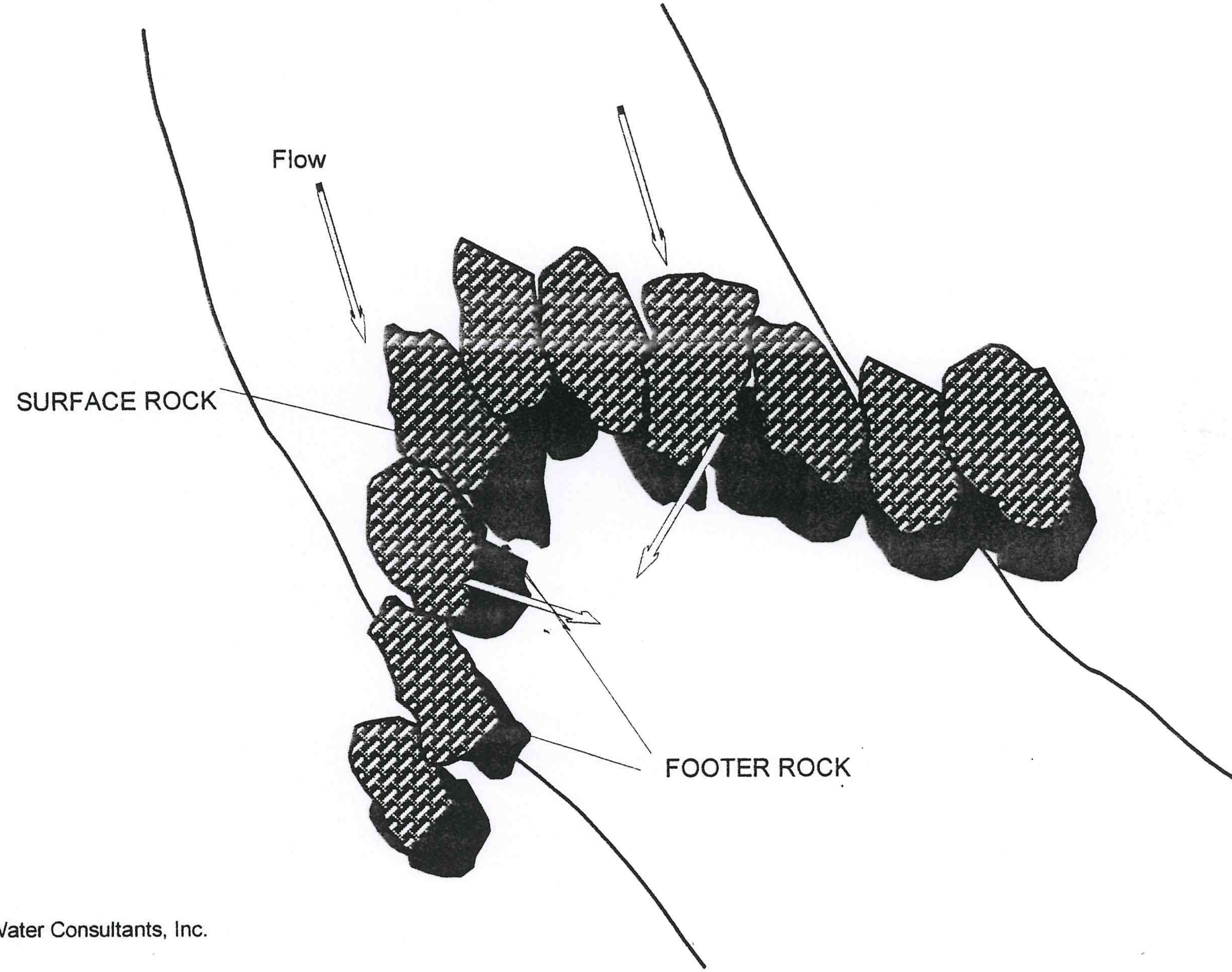
Typical Rock Vane Installation



WestWater Consultants, Inc.

Typical Cross Vane Installation

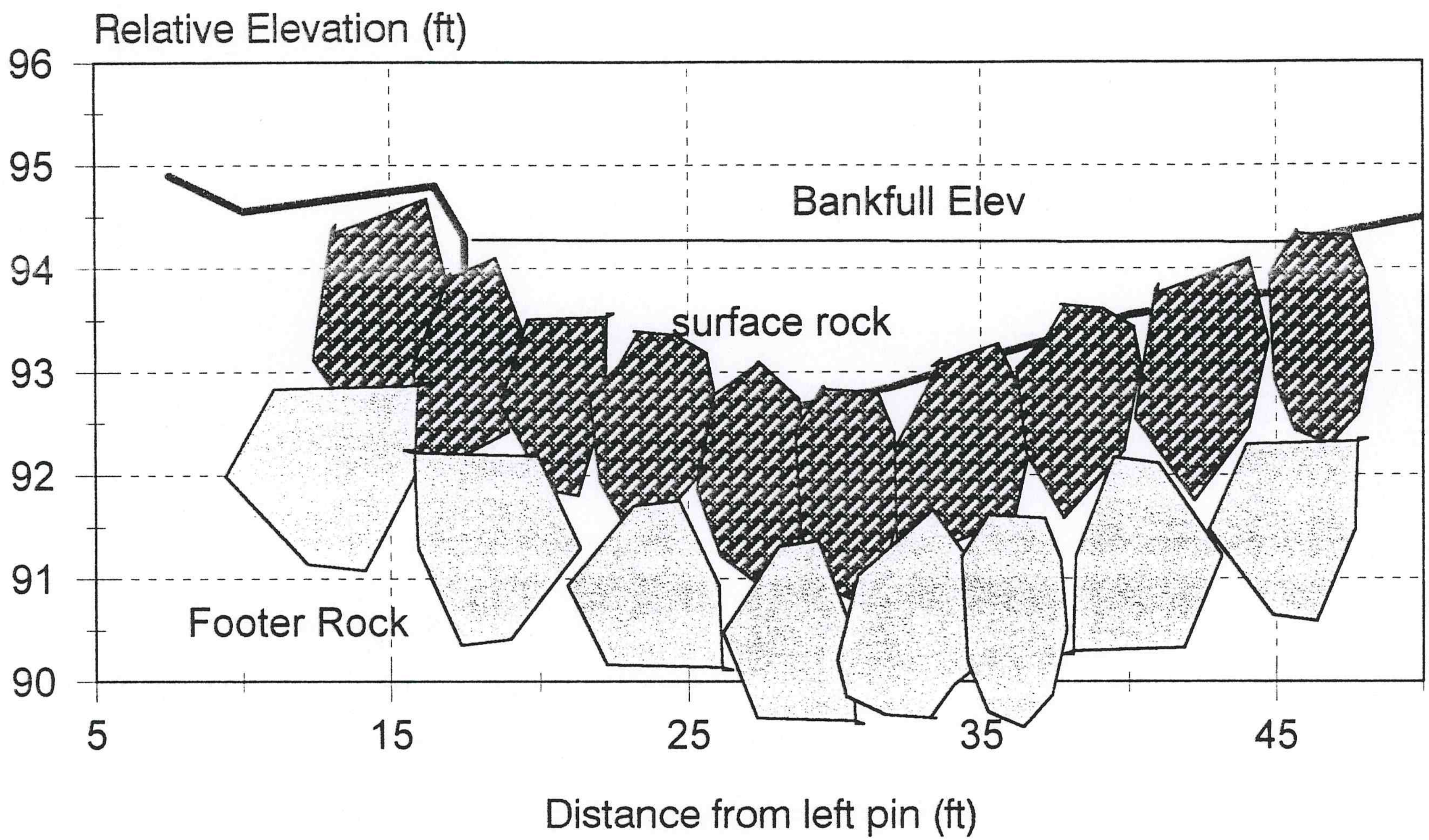
For Diversion Structure at Station 43+75



WestWater Consultants, Inc.

Typical Cross Vane Installation

For Diversion Structure at Station 43+75



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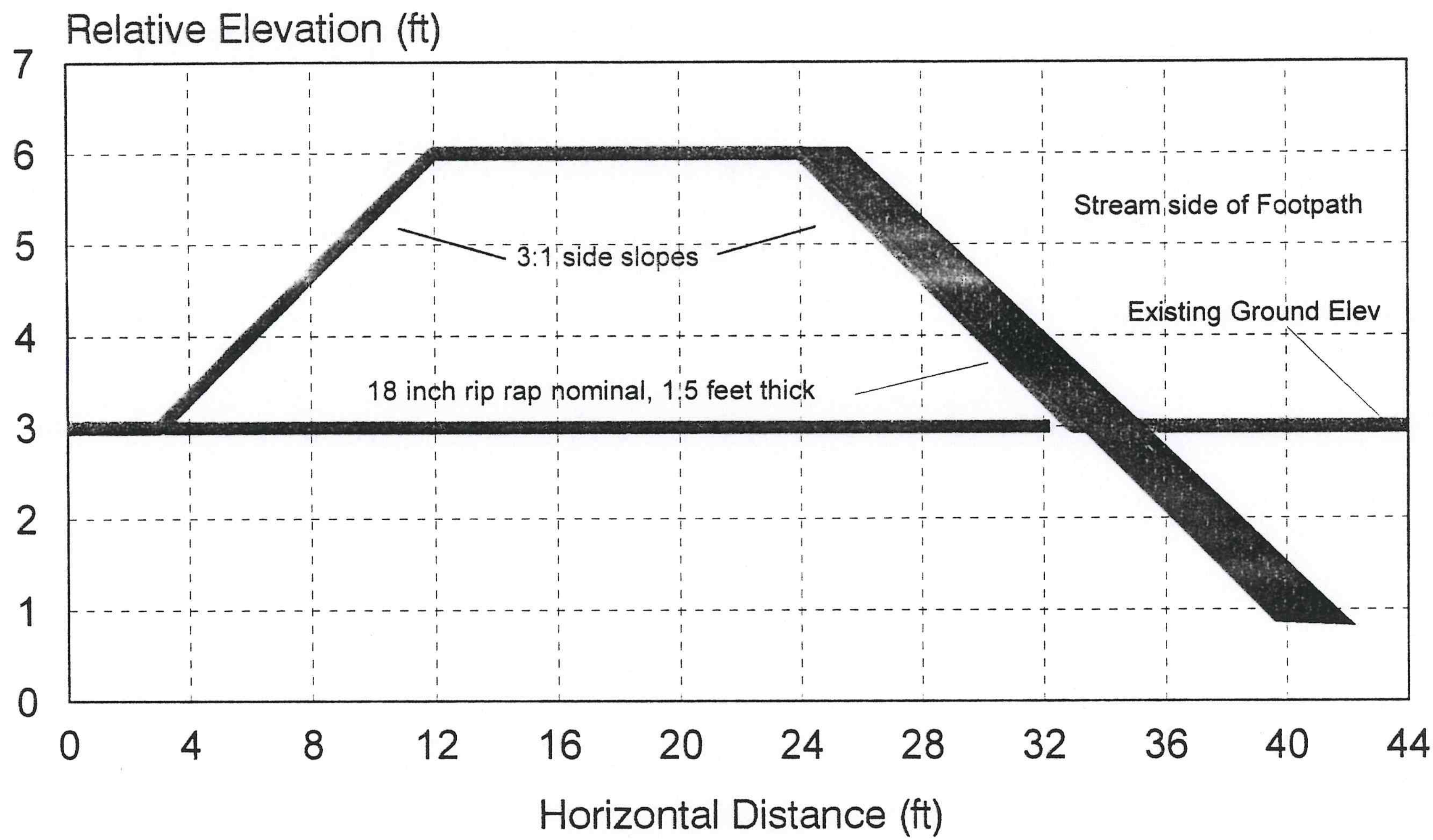
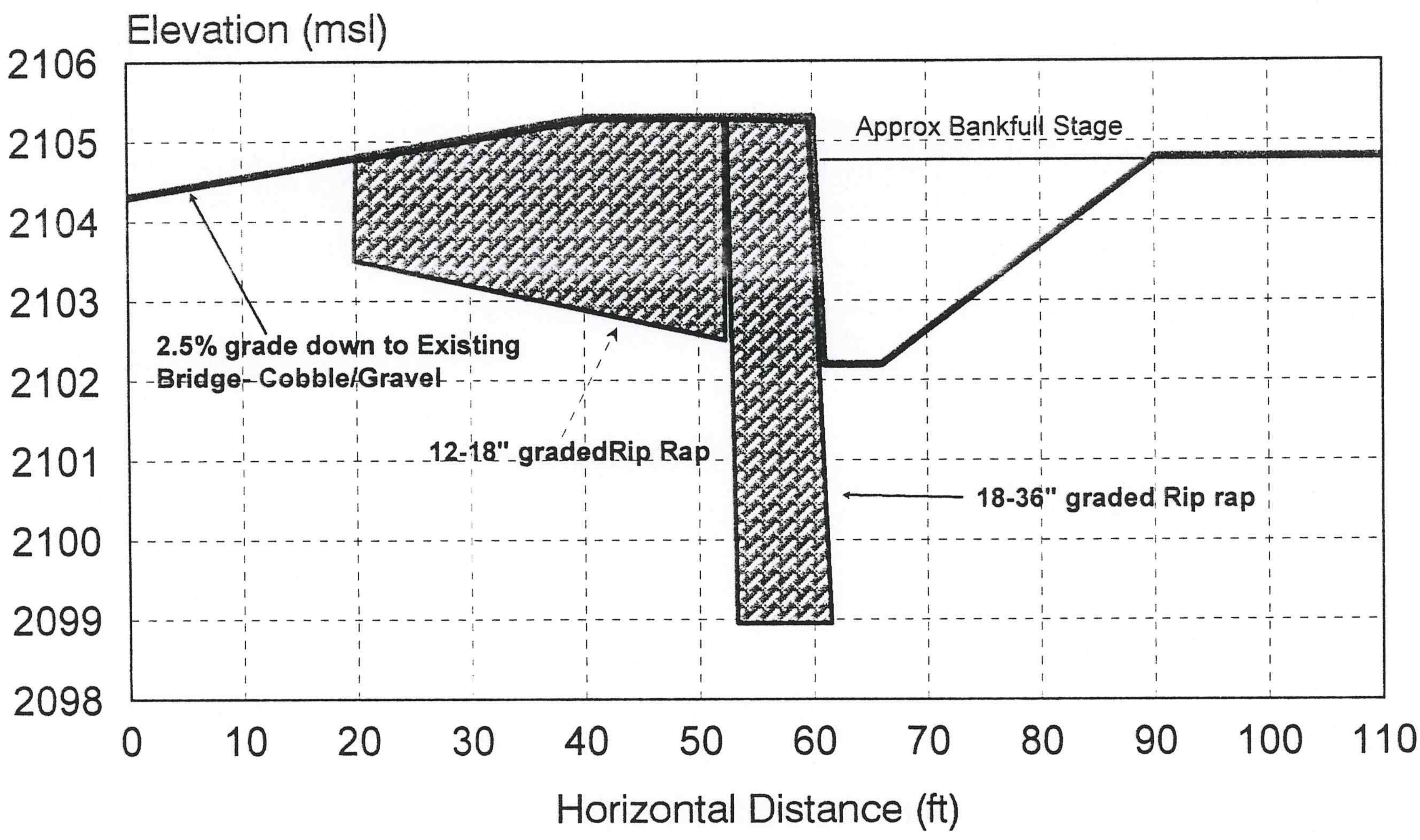
Parmenter Creek Border Footpath

Typical Cross section and Dimensions



Parmenter Creek Sill at Station 17+25



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