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Steelhead Haven Landslide:

The Steelhead Haven Landslide (SHL) is located at approximately river mile (RM) 20 on the North Fork Stillaguamish (NFS) river. Investigations into the cause and effects of

(1969) documented the massive failure of January 7, 1967 that damned the NFS for approximately 4 hours. Williams (1975) noted the implications of the slide on the fisheries in a catalog of Washington streams and salmon utilization. The following is an excerpt from that report.

> "The principal factor limiting salmon production within the section is sedimentation resulting from a major mud and clay slide on the river's right bank, at approximately mile 20.4. Below that point, heavy silt deposits cover most of the gravel riffles, making them unsuitable for successful spawning and egg incubation. This condition also inhibits natural cycles of aquatic insect growth, reducing food production, and consequently lowering the rearing capacity of the stream below".

The factors affecting SHL have also been the subject of more recent reports (Benda 1988, Miller and Sias 1997). Benda (1988) identified the groundwater recharge area of the slide and providing timber harvest recommendations within these areas. Miller and Sias (1997) more rigorously identified the factors affecting the slide and documented historical changes. Miller (1999) provided an update on the status of the slide and estimated the current failure potential of the slide.

A summary of status quo conditions for the landslide is listed below. For detailed analyses, please see the afore-mentioned reports.

Status Quo:

- Slope instability
- Fine sediment source
- Turbidity and temperature concerns: ie 303(d) list
- Located within an area considered habitat limited
- Downstream pool filling and redd entombing
- Catastrophic failure concerns
- Floodplain encroachment

Overview:

Steelhead Haven landslide is primarily composed of lacustrine clays underlying glacial-fluvial outwash. Post-glacial fluvial incision through these deposits has resulted in large-scale mass wasting over time and is the precursor to the landslide's current unstable conditions. Near vertical scarp faces can be seen sandwiched between intact slumps of forest as a result of multiple failure planes within the slide (figure 1). There are 3 main spring-fed streams that drain the slide as well as several other significant seeps. These streams deliver a steady flux of fine sediment to the river, which is promptly integrated into the river's flow and transported downstream. Turbidity is greatly increased downstream of the slide which can lead to an increase in temperature during summer months and smothering of salmon eggs due to fine sediment intrusion into redds. Turbidity has also prevented monitoring efforts from conclusively determining habitat use below the slide. The NFS has been characterized as "habitat limited" through the Hazel Watershed Analysis (1996). This designation suggests that any and all in-stream work on the NFS should be completed in a fashion consistent with habitat rehabilitation efforts. Hence, projects must address the current limiting factors to salmonid stock recovery.

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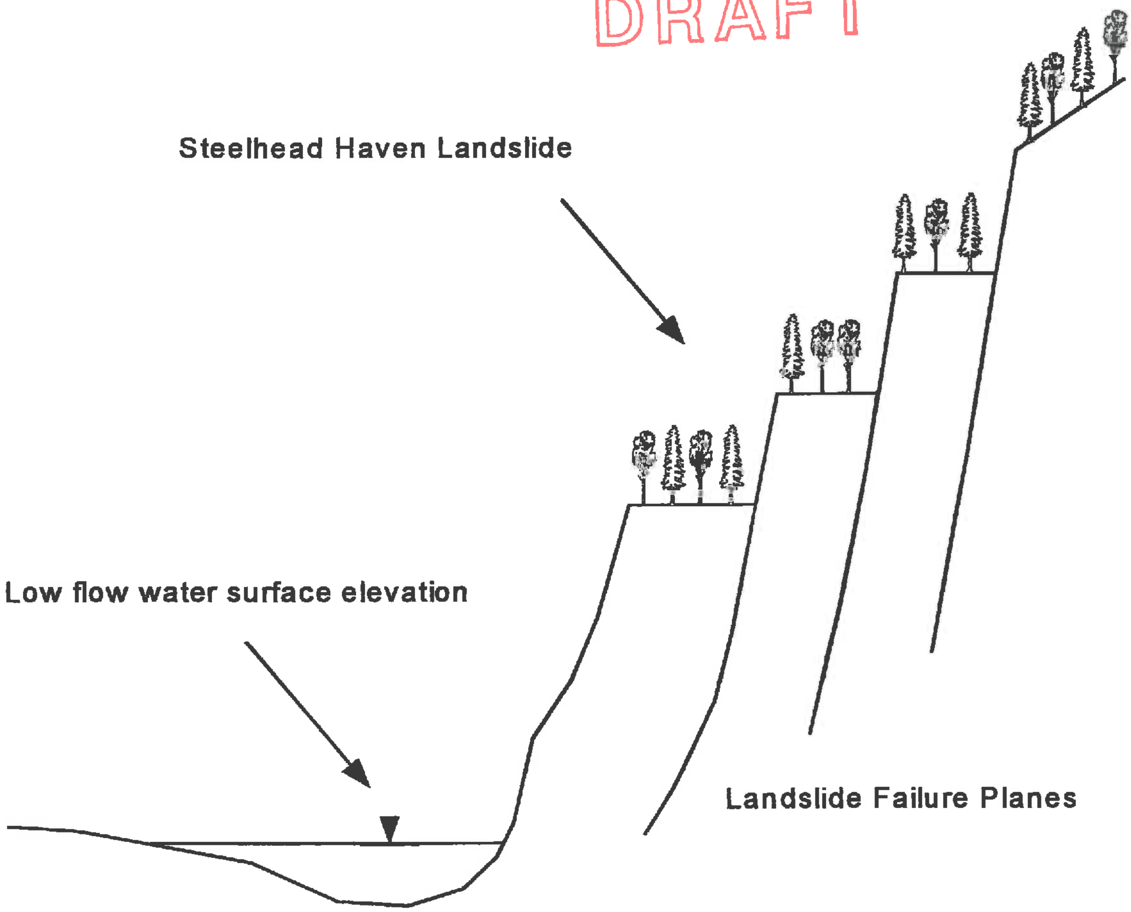

Figure 1: status quo for Steelhead Haven Landslide.

The current interaction of the river and SHL raises concerns about catastrophic failure. The river is currently located at the base of the slide and is actively cutting the toe. This toe cutting removes materials currently buttressing the slide and promoting the dormant state of several failure planes within the slide (figure 1). Continued toe cutting will undoubtedly result in reactivation of one or more of these failure planes. Miller (1999) estimated the current runout potential of the slide to be 900 ft south from the toe of the slide through an area which is currently owned and occupied by private citizens. The development of the floodplain has encroached on the river's natural channel migration and places current residents at risk. Prior to 1967, the river's location and landslide's condition were remarkably similar to the current state. The failure event of 1967 temporarily damned the river and runout from the landslide extended several hundred feet south of the rivers current location. This resulted in a new river channel running through the historical floodplain. Based on the available data, and assuming the future resembles the past, SHL poses a significant risk to human lives and private property, since human development of the floodplain in this area has steadily increased since the 1967 event. The persistence of this landslide, failure potential, and detrimental effects it induces emphasizes the assertion that immediate attention is given to addressing the current conditions.

The objectives developed for potential project remedies range from interruption of the imminent geomorphic processes and rehabilitation aimed at historical reconstruction to alteration of embedded human demographic patterns. These objectives aim to address the overall goal of restoring salmonids to healthy harvestable levels. Objectives are summarized below.

Objectives:

a. Eliminate toe cutting of slope
b. Reduce slope failure hazard
c. Stabilize slope
d. Create local holding habitat and increase cover
e. Create off-channel rearing habitat
f. Reduce fine sediment inputs
g. Reduce floodplain encroachment

Five alternative courses of action are evaluated based upon: ability to meet objectives, technical merit, and feasibility of implementation. Alternatives are labeled 1 through 5 and are listed below.

Alternatives:

1. No action
2. Stabilize toe of the slide
3. Provide storage area for landslide materials
4. Protect area equivalent to landslide runout potential
5. Floodplain buyout

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Alternative 1: no Action.

Selecting the "No Action" alternative implies that status quo conditions are deemed acceptable or that no other alternative possesses technical merit and feasibility of implementation. In considering the acceptability of status quo conditions one must take into consideration that:

- Large, persistent, deep-seated landslides don't just go away
- Current slide activity has a detrimental effect on fisheries habitat
- Listing of Chinook under the Endangered Species Act mandates action
- Catastrophic failure potential places human lives and properties at risk

The remaining alternatives should be judged individually on the basis of technical merit and feasibility.

Alternative 2: stabilize toe of the slide.

Stabilization would be achieved by installing large wood debris at the base of the slide. The configuration of this debris would be in the form of a large wood revetment. This revetment would isolate the river from the toe of the landslide and would be constructed in a manor where scour pool development of the active channel would be acceptable (figure 2). Additional revetment components would be placed to promote entrainment of landslide materials within and behind the revetment. The immediate results of this installation would be the elimination of the toe cutting of the slide and the development of pools and cover for fisheries habitat. However, slopes are near vertical and cannot be maintained in their current form. Mass wasting and fluvial sediment transport would continue and the expected habitat benefits may be short lived. Landslide materials would quickly overrun this structure resulting in status quo fine sediment delivery to the river. Any medium or large scale slumping of the slide would be delivered directly to the river similar to status quo conditions. Further development of the existing failure potential may be curtailed, but this alternative does not address long-term major failure concerns.

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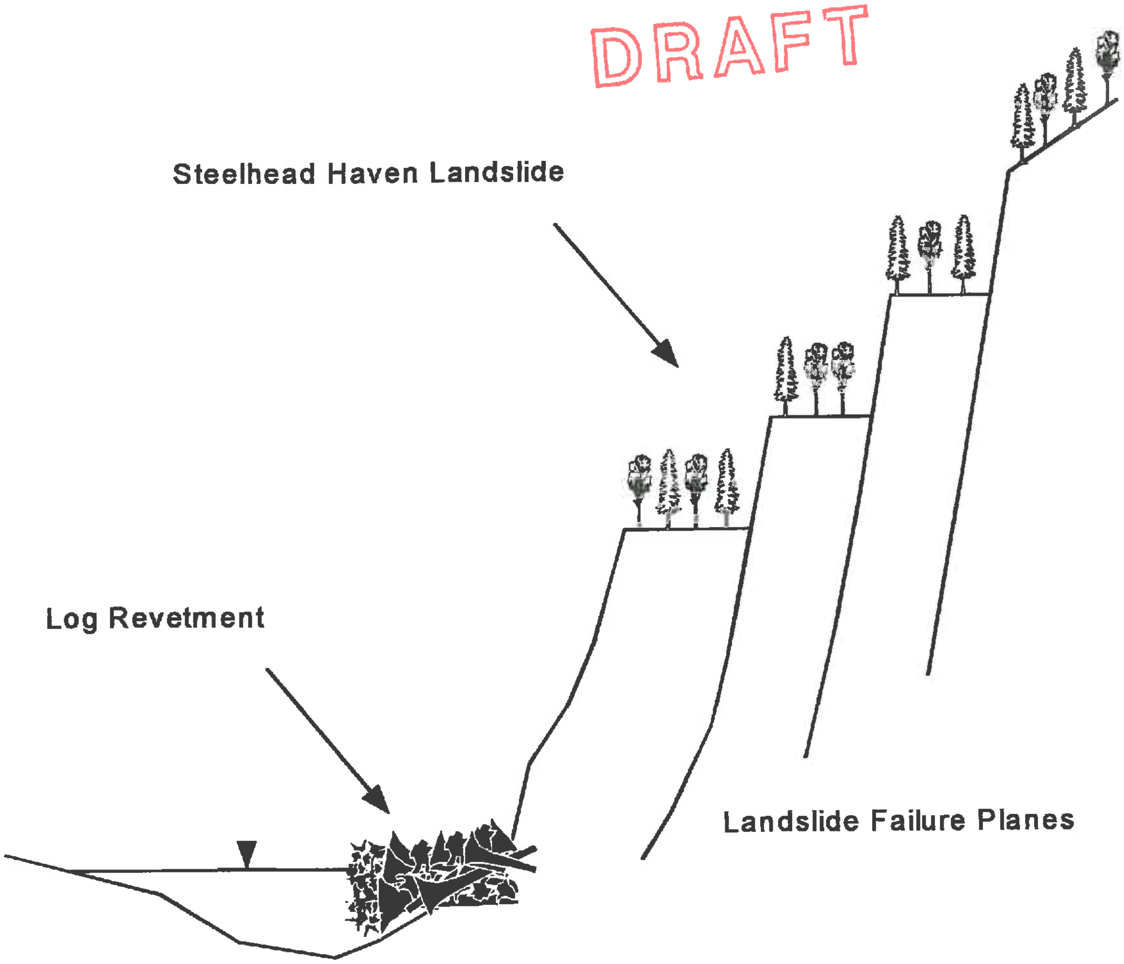

Figure 2: log revetment designed to eliminate toe cutting of the slide.

Alternative 3: provide storage area for landslide materials.

This alternative proposes a series of revetments to eliminate toe cutting of the slide and create settling ponds for fine materials that would otherwise be delivered to the mainstem from the multiple streams that drain the slide area. In addition, these structures will create adult Chinook holding habitat similar to that of the NFS Engineered Log Jams (ELJs) and mainstem off-channel habitat currently lacking in the NFS. Revetment A would isolate the landslide from the mainstem NFS and eliminate the toe cutting (Appendix A). The interaction of this structure with the NFS will also create deep pools critical for adult Chinook holding. Revetments B, C, and D will create a series of settling ponds to help decrease the magnitude of fine sediments delivered to the mainstem NFS. These revetments will also create a pseudo beaver-pond network providing mainstem off-channel habitat. Initially the area created between the landslide and revetment A will be quite expansive and largely a habitat component. As the creeks drain the slide and deliver fine sediment, an increasing volume of this area will be converted to fine sediment storage. Over time it is possible that the entire area between revetment A and the landslide will be converted to fine sediment storage. It is also possible that stabilization of the landslide will occur prior to filling the entire storage area and that some off channel habitat will remain over time. Uncertainty remains with respect to the eventual equilibrium condition as well as the time frame of development. An additional habitat component that will develop is a log raft in the stagnation point that will be created by the interaction of the river and revetment A. This will result in an excellent feeding zone with cover for juveniles and adult stream fishes.

Alternative 4: protect area equivalent to landslide runout potential.

Miller (1999) estimated the current runout potential of the slide to be 900 ft from the toe. The design for alternative 3 can be altered to accommodate the full runout potential of the slide. This alternative would provide very similar habitat benefits as alternative 3, while providing greater storage area for mass wasting materials. Theoretically, even a worst-case failure scenario would be captured within the storage area.

Alternative 5: floodplain Buyout.

This alternative suggests floodplain buyout and excavation of a new channel through the floodplain. This would move the river approximately 2000 ft away from the slide effectively isolating the slide from the river. Revetments discussed in alternatives 3 and 4 would not be constructed. However one revetment would be constructed across the current channel to insure that re-occupation of the current channel did not occur (Appendix A). Construction of the new channel would include the installation of several LWD structures similar to those built on the NFS during 1998 and 1999. These structures would assist in initial channel training and provide in-stream habitat components. The new channel could be multi-threaded providing both mainstem and off-channel habitat.

Discussion:

As a first order evaluation, the ability of these alternatives to meet the designated objectives was considered. For purposes of clarity, objectives and alternatives were compiled into a decision matrix where inputs into the matrix represent fulfillment of the objective (table 1).

Table 1: objectives meet by alternatives.

Alternatives \ Objectives	a	b	c	d	e	f	g
1							
2	X			X			
3	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X
5	X	X	X	X	X	X	X

From this matrix it can be seen that Alternatives 3, 4, and 5 meet all objectives. Therefore only these alternatives will be further evaluated for technical merit.

Technical Merit:

Alternative 3: provide storage area for landslide materials.

Initially, a first order approximation of the cross-sectional width currently being used by the river was delineated. From figure 3 it can be seen that the river currently uses approximately 500 ft and an additional 500 ft of floodplain is available before a floodplain terrace is encountered. Private properties, including some full time residences, are located on this floodplain terrace. It would be the objective of this alternative to isolate SHL from the river without increasing the frequency and magnitude of flood inundation on the floodplain terrace. Hence, it is suggested that the log revetment be located 500 ft from the slide (figure 3).

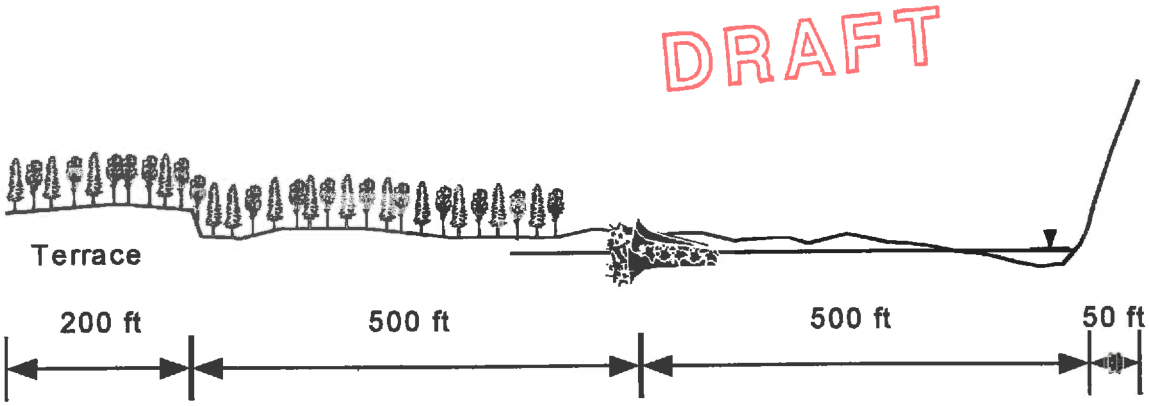

Figure 3: existing conditions and proposed log revetment placement.

This provides the river with approximately 500 ft of cross-sectional width matching its current use. The post construction expected conditions are shown in figure 4.

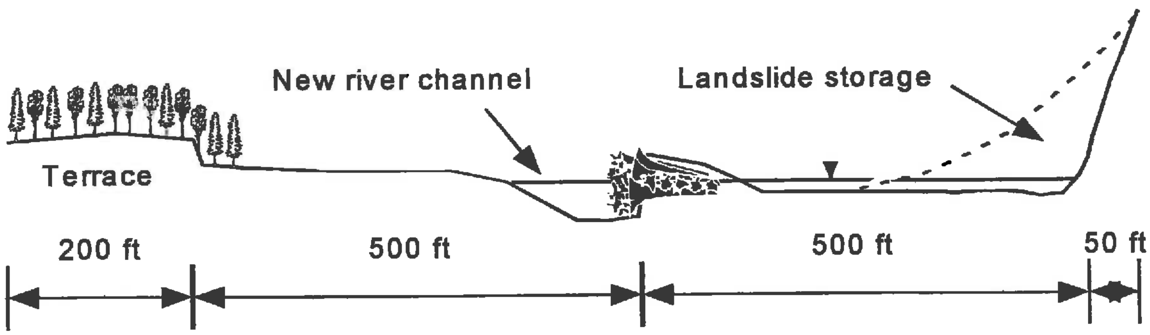

Figure 4: expected post project conditions.

In order to provide a more technical justification for this alternative's configuration, data collected and results determined through the study of the 1998 NFS ELJ project (Drury 1999) will be drawn from and applied to this site. The 1998 NFS ELJ project site is located approximately 1.0 miles upstream (approx. RM 21) from SHL. For purposes of this analysis, it is assumed that hydrologic and hydraulic conditions at the 1998 NFS ELJ project site are representative of conditions at Steelhead Haven. In addition, the effects induced by the installation of the 1998 NFS ELJ project can be drawn from when forecasting the expected post project conditions at Steelhead Haven.

Figure 5 shows actual conditions for the cross-section depicted in figures 3 and 4 from the base of the landslide (on the right of figure 5) to the edge of the vegetated floodplain. These data were collected August 1999 during low flow conditions.

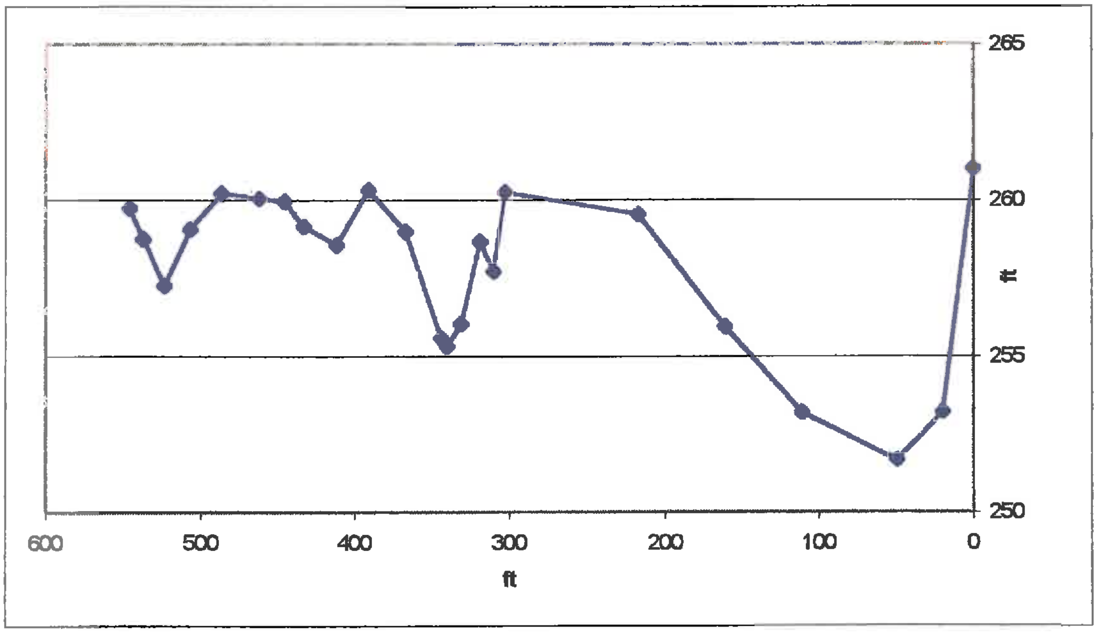

Figure 5: actual current conditions of NFS at Steelhead Haven Landslide.

It is shown that the actual cross-sectional width currently used by the river during high flow conditions is approximately 550 ft. It is also shown that the high-energy core of the river is located at the base of the slide. Figure 6 shows cross-sections for pre and post project conditions associated with the installation of ELJ #4 of the 1998 NFS ELJ project. The translation of the left bank of the river, from left to right in figure 6, is due to placement of ELJ #4. The deepening of the thalweg is a direct result of ELJ installation and can be expected in the proximity of log revetment A, suggested as part of this alternative. The width of ELJ #4 was approximately 34 ft while the width of the cross-section was 410 ft. This reduced the width of the channel 8.3%, but no effects of this reduction were felt on the right bank. In fact, it is shown that effects were only felt approximately 200 ft from ELJ placement and that conditions at the right bank were not altered. In addition, data collected suggests no detectable change in water surface elevation for a given flow between pre and post ELJ placement conditions once channel alterations occurred.

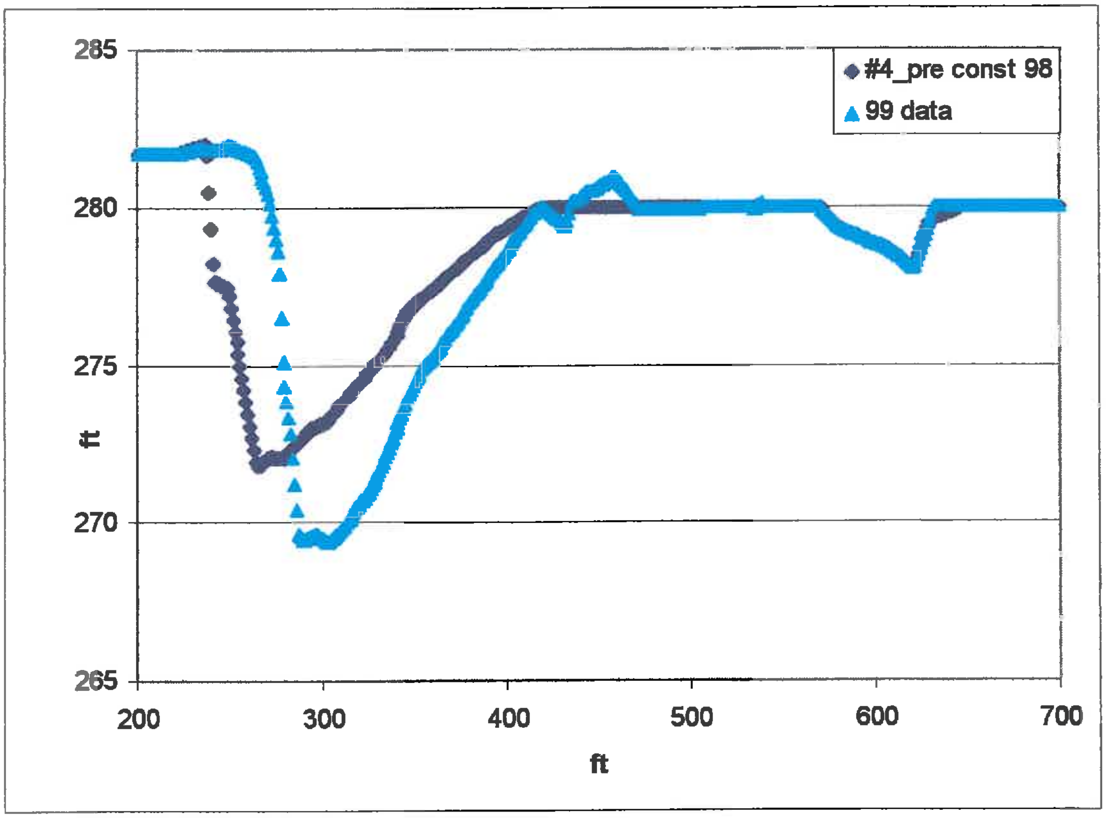

Figure 6: pre construction and 1-year post construction at ELJ 4, 1998 NFS ELJ project.

If one applies this 8.3% reduction in cross-section width observed at ELJ #4 to the current width at Steelhead Haven, one could infer that a post project channel width of approximately 504 ft would be sufficient to insure conveyance without impacting the far bank. It can also be inferred that water surface elevation will not detectable be altered do to project installation. Therefore the 1999 cross-section data for Steelhead Haven was analyzed to determine water surface elevation for post project conditions.

Using data from the 1998 NFS ELJ project and the Manning's Equation (simplified using the wide channel approximation):

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$$Q = \frac{1.486\ A\ Y^{2/3} S^{1/2}}{n}$$

a value for roughness (Manning's n) of 0.022 was derived. The appropriate values and results are shown in table 2.

Table 2: determination of Manning's n.

Depth (Y) (ft)	Slope (S)	Discharge (Q) (ft^3/s)	Area (A) (ft^2)	n
4.10	0.0023	16339	1962	0.022

Using this roughness value and other site-specific parameters, the average depth of flow at Steelhead Haven was determined. These data are shown in table 3.

Table 3: average flow depth at Steelhead Haven.

n	Slope (S)	Discharge (Q) (ft^3/s)	Area (A) (ft^2)	Depth (Y) (ft)
0.022	0.0023	16339	2073	3.77

This resulted in a water surface elevation of 261.2 ft for this particular discharge. Keep in mind that this is for the largest flow recorded during the study period of the 1998 NFS ELJ project. Referring back to figure 4, the elevation of the terrace is approximately 264 ft. Therefore, post project conditions for this alternative at the given flow would result in a water surface elevation approximately 3 ft below that of the floodplain terrace. Since there are full time residences located on this floodplain terrace, the magnitude of flow required for inundation is of interest. Using a water surface elevation of 264 ft and backing out the other parameters, Manning's equation was used again to solve for the discharge that would induce the results. The discharge required was found to be in excess of 40,000 cfs. Results are shown in table 4.

Table 4: discharge resulting in floodplain terrace inundation.

Discharge (Q) (ft^3/s)	Slope (S)	n	Area (A) (ft^2)	Depth (Y) (ft)
40461	0.0023	0.022	3571	6.50

The likelihood of a discharge of this magnitude at Steelhead Haven is poor. Based on a 66-year hydrologic record at the NFS gauge near Arlington (USGS 12167000), the 100-year reoccurrence discharge at Arlington is 40300 cfs. This gauge is located approximately RM 5 compared to Steelhead Haven at approximately RM 20. The basin area at Arlington is approximately 262 square miles compared to 144 at Steelhead Haven (Drury 1999). In summary, deriving a reoccurrence interval for a 40,000 cfs discharge at Steelhead Haven would be speculation, but it can be shown that it would be in excess of 100 years.

Alternative 4: protect area equivalent to landslide runout potential.

As shown previously in this document, the specifications of this alternative are very similar to those of alternative 3 although the location is different. Therefore, technical evaluation and results would be like those for alternative 3, but would be translated an additional 400 ft away from the toe of the slide. One difference between the two alternatives is the location and quantity of private properties that would need to be purchased in order to accommodate the proposed actions. This distinction is discussed in the feasibility section.

Alternative 5: floodplain buyout.

Alternative 5 involves the translation of the river south approximately 2000 ft and would require the excavation of a new river channel. This new channel could be designed with multiple threads and incorporate vegetated islands into the plan form. A specific design would be developed once all barriers to implementation are overcome and would be subject to a more detailed topographic map than currently available. In order to approximate the cross-sectional width of the new channel, a single thread channel was evaluated using similar methods as previously outlined. An average flow depth of 5.5 ft and discharge of 30,000 cfs were assumed. Roughness and slope were assumed to be identical to previously used values. The approximate channel width to accommodate this flow was 540 ft. Results are shown in table 5.

Table 5: width of new excavated channel.

Discharge	Slope	Depth	n	Area	Width
(ft^3/s)		(ft)		(ft^2)	(ft)
30,000	0.0023	5.50	0.022	2960	538

This channel width provides a first order approximation of the area that should be designated for a new channel. The results most likely oversize the channel and are to be used to delineate the appropriate properties that would need to be purchased in order to implement this alternative. More detailed analysis including justification of design flow is needed for final channel sizing.

Feasibility:

It has been shown that in order to successfully address the problems that Steelhead Haven landslide presents, the NFS river's course must be altered to some degree. In any case, private citizens own the majority of land in the vicinity of the slide. Therefore, the feasibility of implementing an alternative is evaluated based upon ability to secure the private properties required for each installation. There are approximately 100 separate properties local to SHL. Many of these properties have common owners, but it may still be necessary to secure properties from over 30 landowners for a given alternative. Appendix B provides a summary of properties, landowners, landuse, and assessed values for these properties. In addition, each property has been given a buyout priority level. These levels represent the following:

I. Purchase property: no action required
II. Purchase required for alternative 3
III. Purchase required for alternative 4
IV. Purchase required for alternative 5

Level I buyout priority is given to land that is currently interacting with the river. Much of this land is host to the active channel at low flow, while some is floodplain with high connectivity and is within the ordinary high water mark. In all cases properties with level I buyout status are considered vacant, undeveloped, unused land and purchase of these properties most likely would be met with little resistance. Level II buyout includes property that would need to be purchased in order to implement alternative 3. In each case buyout requirements are cumulative in that level II requires that level I property be acquired. Level III requires that levels I and II properties are secured and so on. Therefore, level III priority adds the additional property needed for alternative 4 and level IV for alternative 5.

Alternative 3: provide storage area for landslide materials.

As noted prior, implementation of this alternative is contingent on securing the rights to properties with buyout priorities 1 and 2. The approximate cost to purchase level 1 properties is $181,500. Level 2 properties are estimated at an additional $94,500. Total buyout costs for this alternative are estimated to be $276,000. Construction related costs are approximately $1.0 million. (Appendix C). Therefore, the total cost estimate for this alternative is $1.3 million.

Alternative 4: protect area equivalent to landslide runout potential.

This alternative requires the additional purchase of level III properties at a cost of $832,500. Construction related costs are approximated to be on the order of $1.0 million. This brings the total cost of this course of action to approximately $2.1 million.

Alternative 5: floodplain buyout.

The additional cost to purchase level IV properties is estimated at $547,500, making total land purchases $1,656,000. However, construction related costs for this alternative are reduced to $586,760. Grand total for this alternative is approximately $2.2 million.

Cost estimates are summarized in table 6.

Table 6: cost estimates for alternatives 3, 4, and 5.

Alternative	3	4	5
Construction Costs	$1.0	$1.0	$0.6
Land Acquisition Costs	$0.3	$1.1	$1.6
Total Cost (million)	$1.3	$2.1	$2.2

In can be seen from table 6 that alternative 3 is the most cost effective of the three remaining alternatives. Perhaps more important is that securing properties required for implementing this alternative requires that the rights to only vacant, undeveloped, unused land be purchased. Each of alternatives 4 and 5 require that properties used as fulltime residences be bought out. The probability that all property owners within the areas needed for alternative 4 or 5's plan form are willing sellers is low. Therefore the feasibility of implementation of alternatives 4 and 5 is low.

Hence, it is recommended that implementing alternative 3 be pursued.

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Appendix A

Schematic Plans for Alternatives 3, 4, and 5

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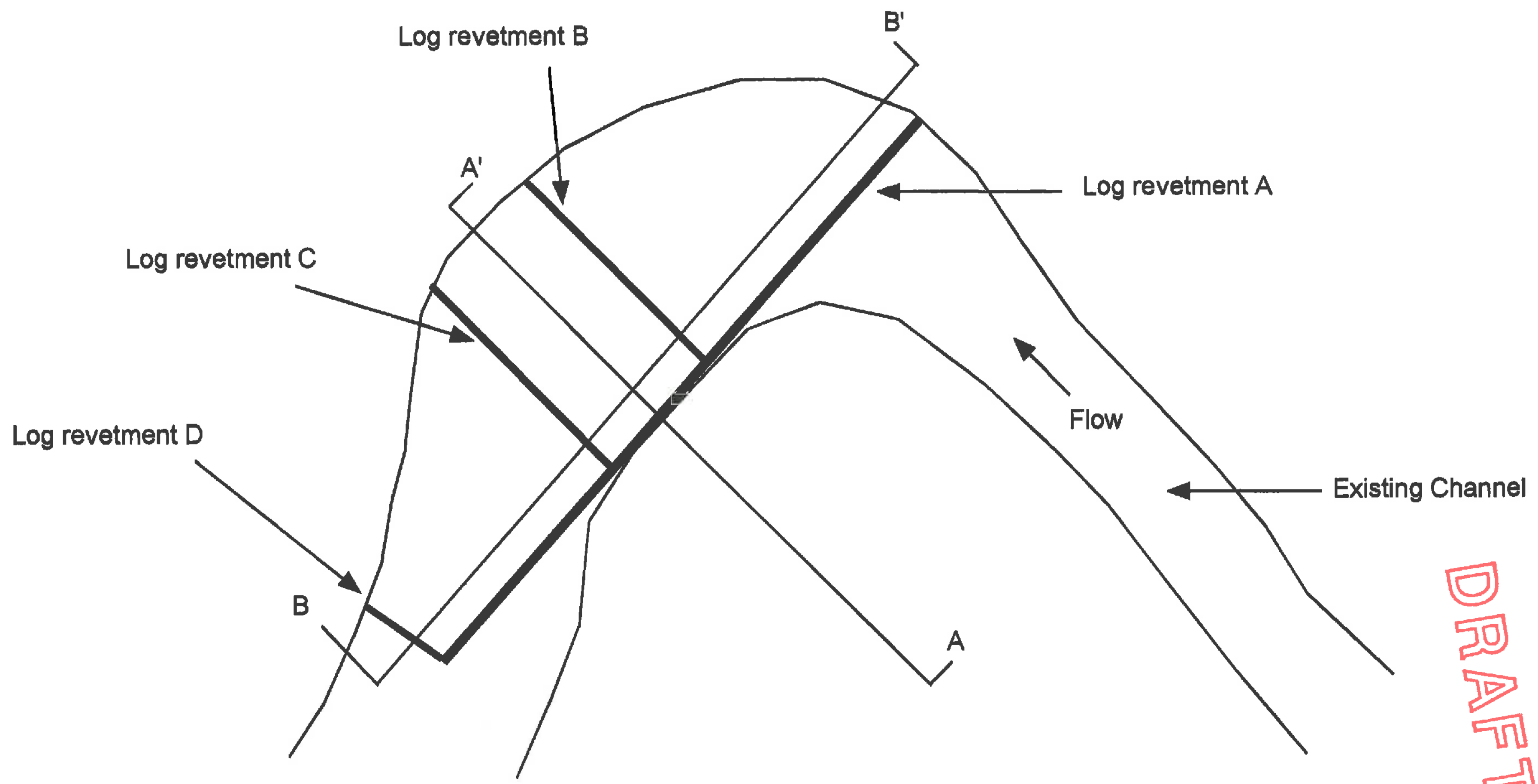
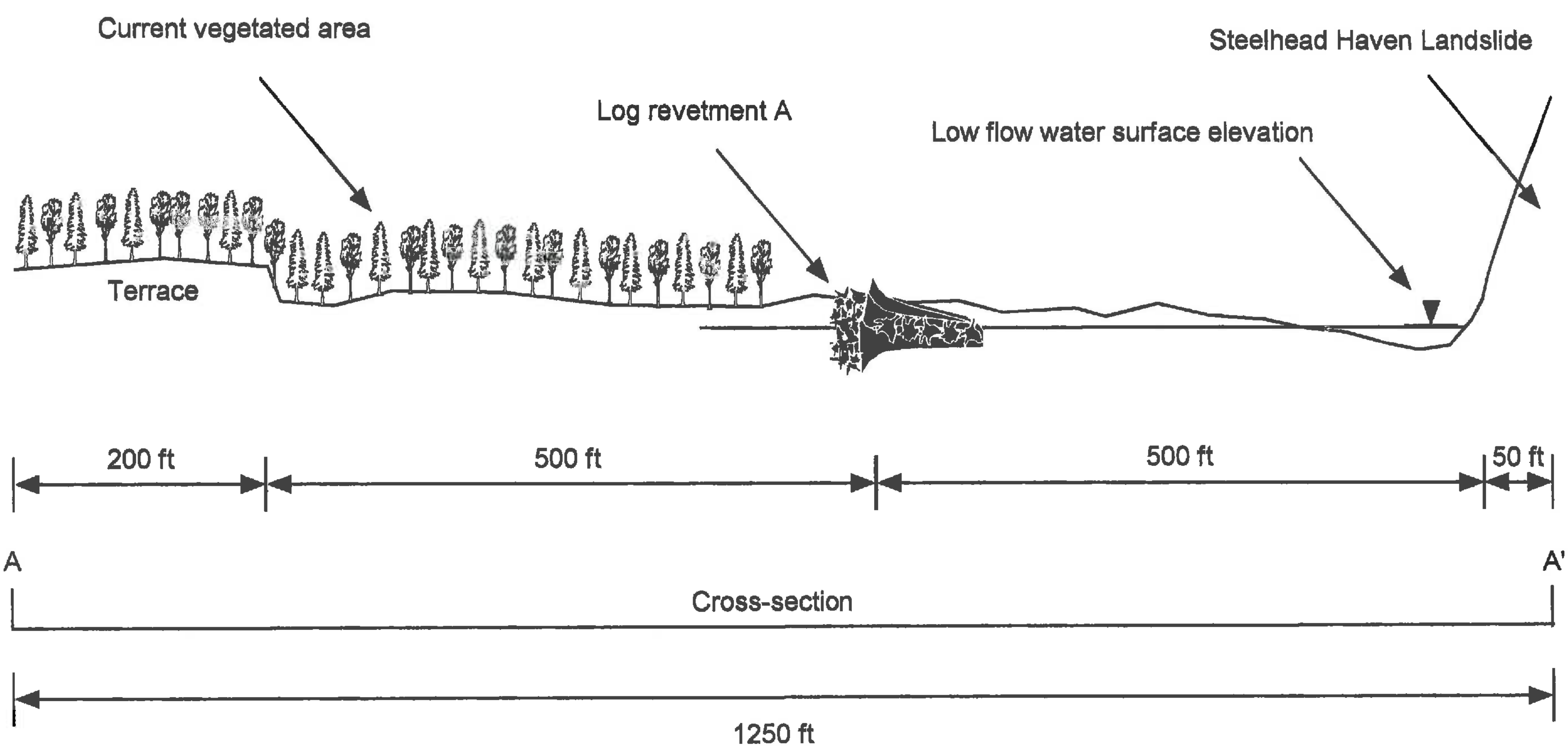
Alternative 3



Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Plan view of existing conditions and proposed project placement: Alternative 3.		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		1/19/00



Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Proposed placement of log revetment A and existing conditions for cross-section A - A'		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		1/19/00

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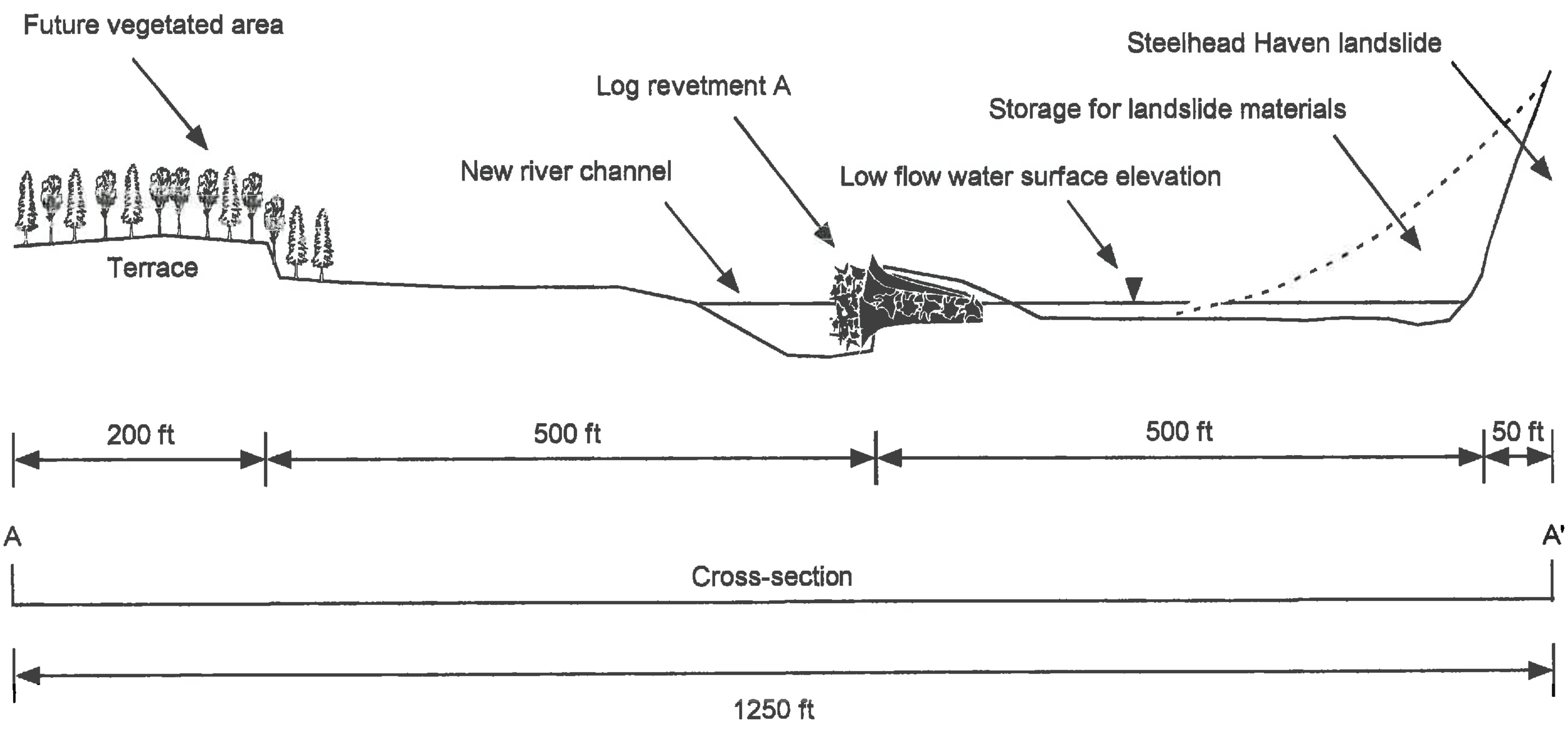

Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Expected post project conditions for cross-section A - A'		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		1/19/00

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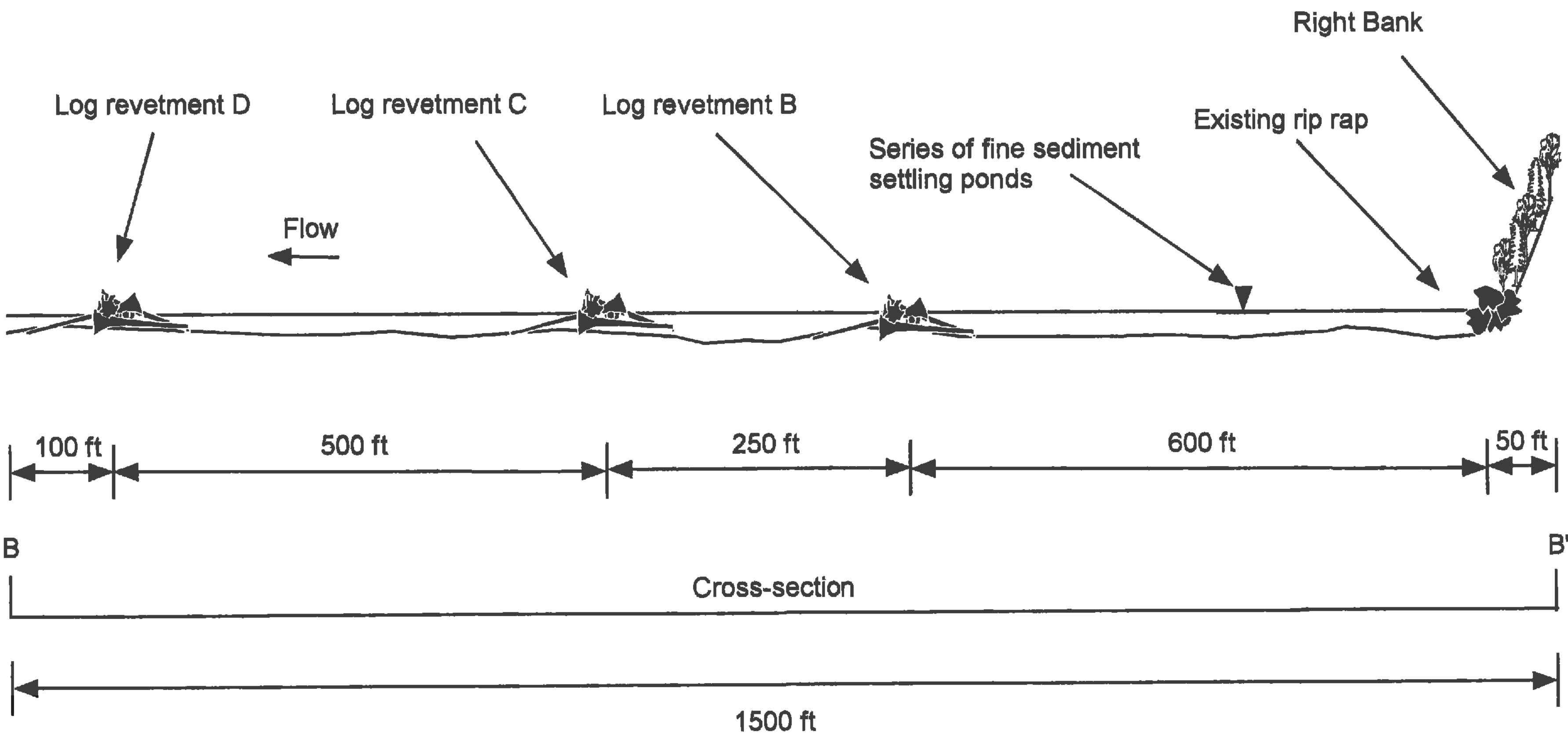

Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Placement of log revetments B, C,and D and expected conditions for cross-section B - B'		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		1/23/00

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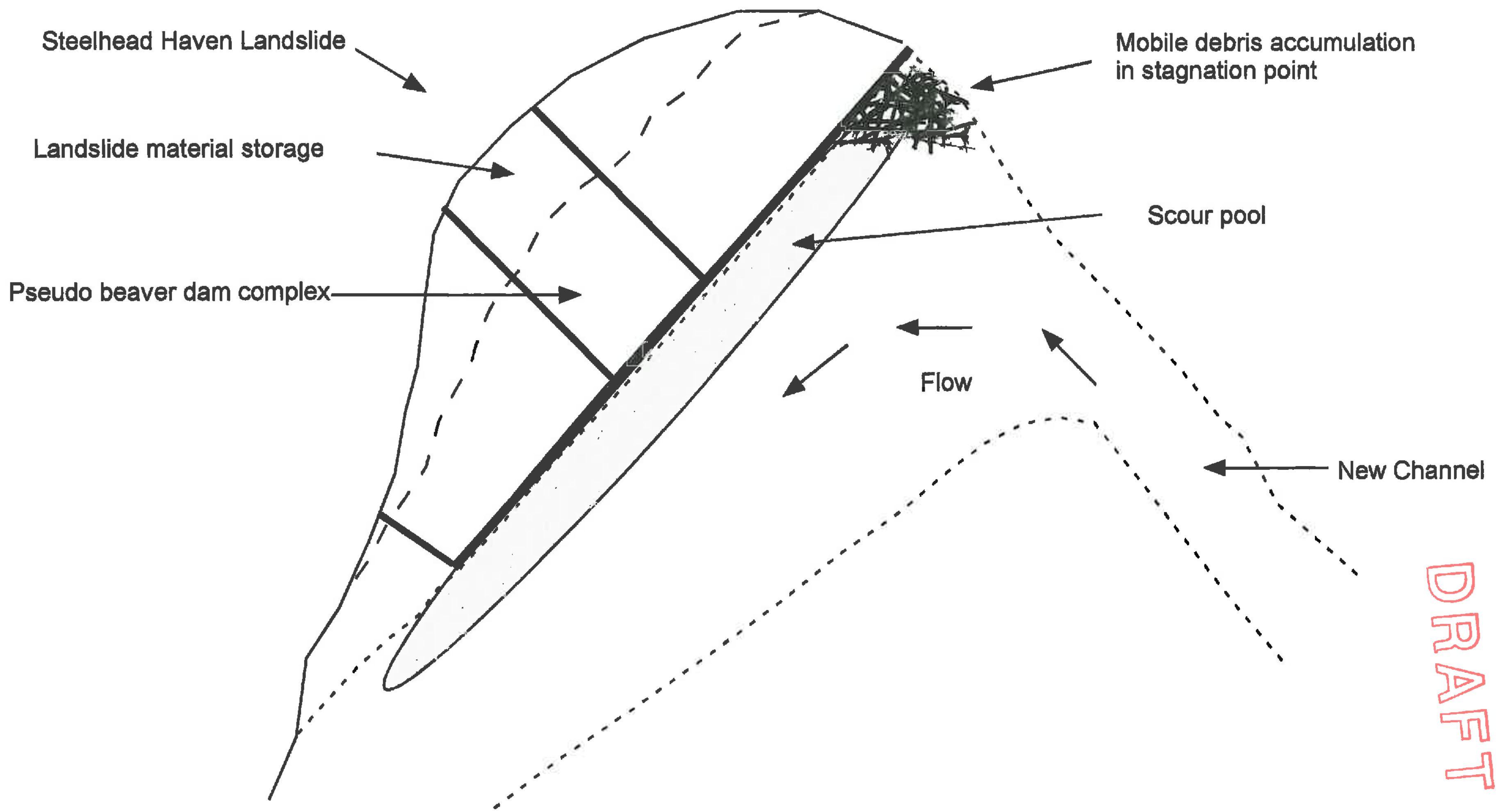

Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Plan view of expected post project conditions		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		1/19/00

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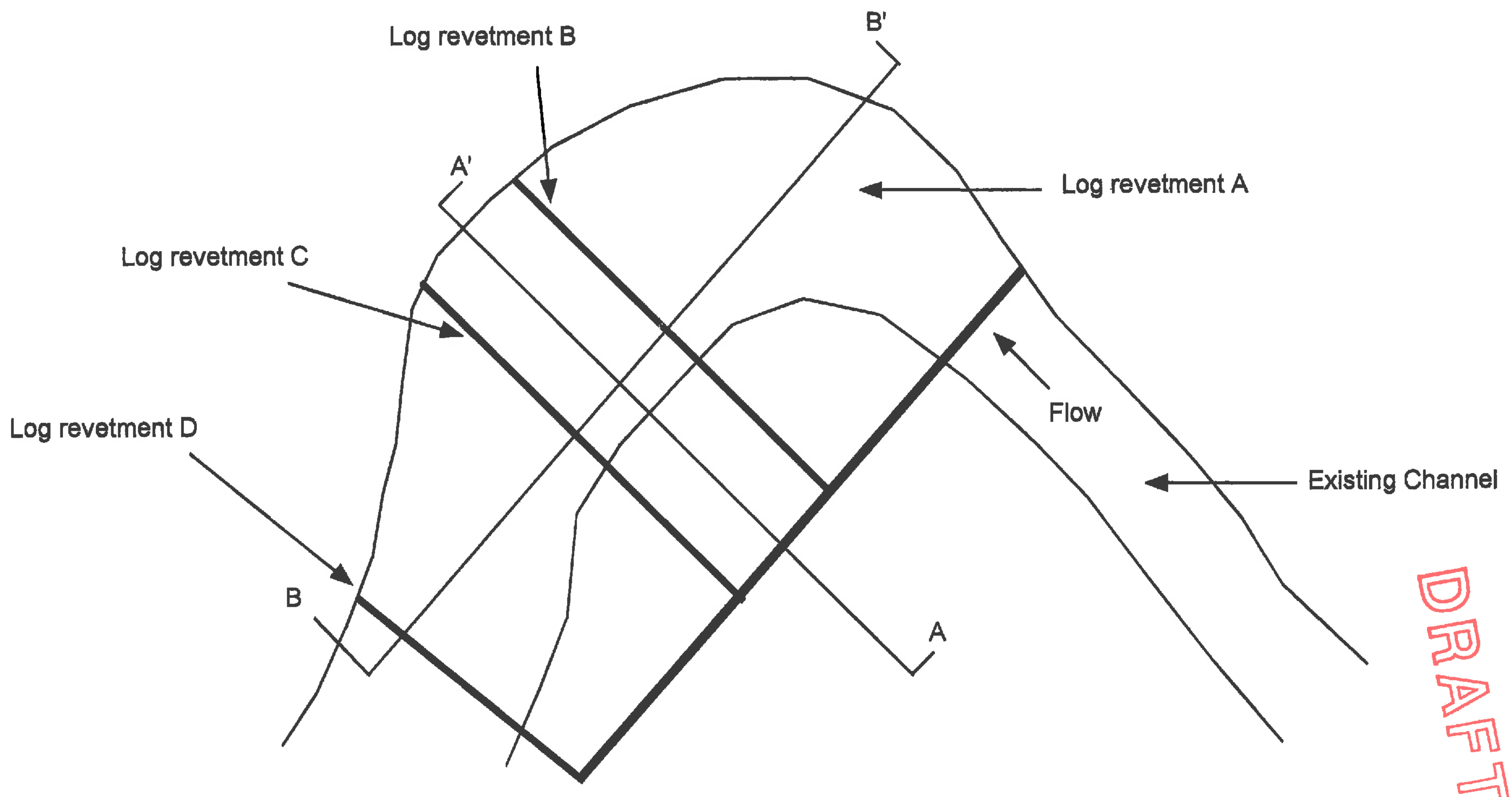
Alternative 4



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Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Plan view of existing conditions and proposed project placement: Alternative 4		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		4/22/00

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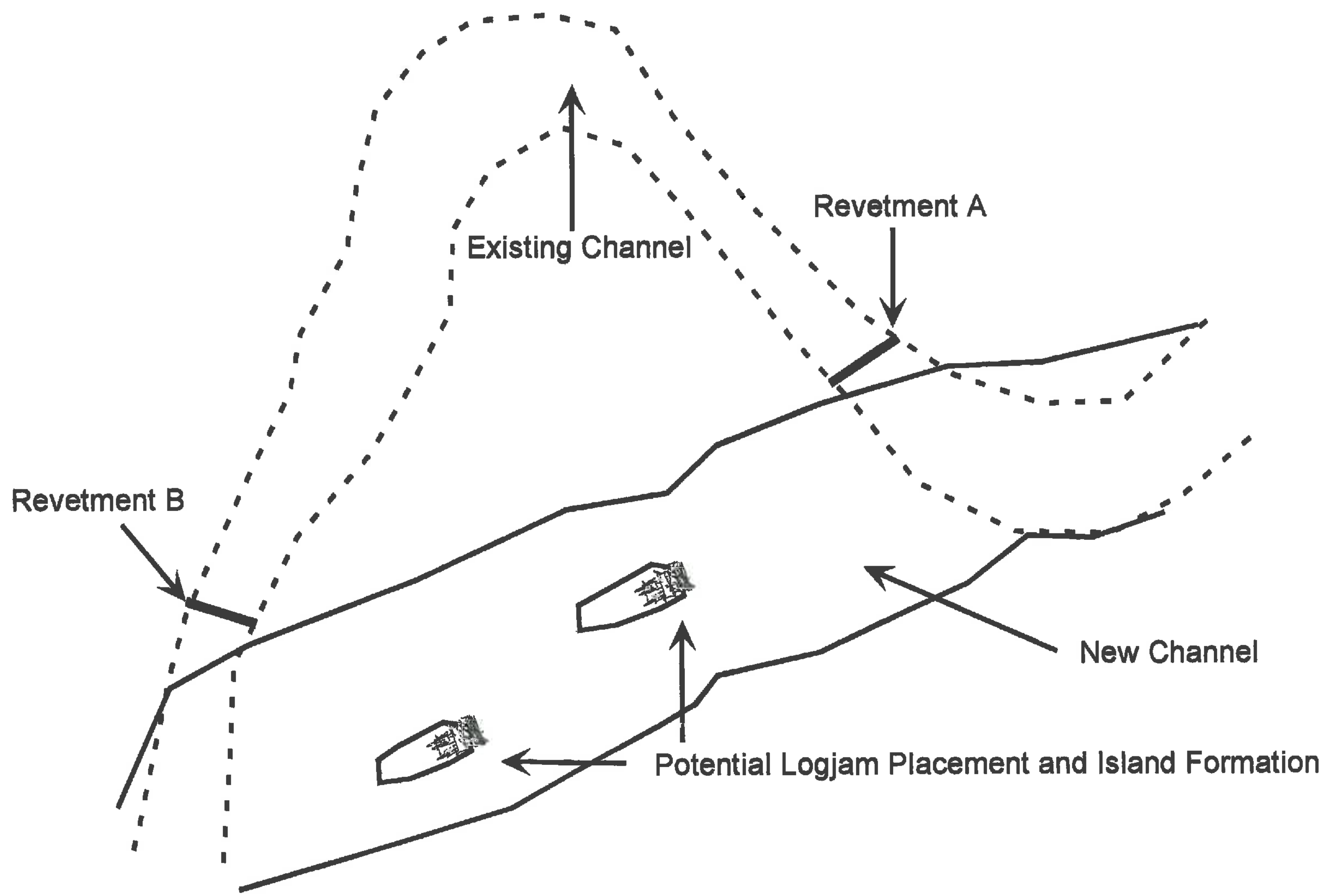
Alternative 5



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Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Plan view of existing conditions and proposed project placement: Alternative 5.		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		4/25/00

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Appendix B

Property Information for Steelhead Haven

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Summary of Properties, Landowners, Landuse, Assessed Value, and Buyout Priorities

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Landuse Key

VUU:	Vacant, Unused, Undeveloped Land
Res:	Residential
Forest:	Designated Forest
MOSG:	Miscellaneous, Open Space, General

Lot #	Owner	Landuse	Assessed Value	Estimated Buyout Cost	Buyout Priority Level	Priority 1	Priority 2	Priority 3	Priority 4
0 017	Thompson, John	VUU	$1,000	$1,000	1	1,000			
0 018	Moore, Carlos	VUU	$100	$1,500	1	1,500			
0 019	Cheffer, Kim & Sue	VUU	$100	$1,500	1	1,500			
0 021	Hopkins, Sally	VUU	$100	$1,500	1	1,500			
0 022	Braden, William	VUU	$100	$1,500	1	1,500			
0 023	Welch, Isabel	VUU	$100	$1,500	1	1,500			
0 024	Cohen, Norma & Mansfield	VUU	$100	$1,500	1	1,500			
0 025	Mursar, Altura	VUU	$100	$1,500	1	1,500			
0 026	Cohen, Norma & Mansfield	VUU	$100	$1,500	1	1,500			
0 027	Cohen, Norma & Mansfield	VUU	$100	$1,500	1	1,500			
0 028	Cohen, Norma & Mansfield	VUU	$100	$1,500	1	1,500			
0 029	Winstead, Leslie	VUU	$100	$1,500	1	1,500			
0 030	Harris, John	VUU	$100	$1,500	1	1,500			
0 031	Click, Edith	VUU	$100	$1,500	1	1,500			
0 032	Cohen, Norma & Mansfield	VUU	$100	$1,500	1	1,500			
0 033	Anderson, Fritz	VUU	$100	$1,500	1	1,500			
0 034	Anderson, Fritz	VUU	$100	$1,500	1	1,500			
0 035	Sparecho	VUU	$100	$1,500	1	1,500			
0 036	Sparecho	VUU	$100	$1,500	1	1,500			
0 037	Harb, Alice	VUU	$100	$1,500	1	1,500			
0 039	Francis, Jay	VUU	$100	$1,500	1	1,500			
0 042	Harb, Alice	VUU	$100	$1,500	1	1,500			
0 043	Howell, walter	VUU	$100	$1,500	1	1,500			
0 044	Phillps, Anthony	VUU	$100	$1,500	1	1,500			
1 001	Hawkins, Larry	VUU	$1,900	$1,900	1	1,900			
1 008	Larsen, James	VUU	$2,700	$2,700	1	2,700			
1 009	Hawkins, Larry	VUU	$36,300	$36,300	1	36,300			
1 015	Read, Rodney	VUU	$35,300	$35,300	1	35,300			
1 023	Larsen, James	VUU	$25,900	$25,900	1	25,900			
2 006	Keller, Ward	VUU	$100	$1,500	1	1,500			
2 008	Lavender Moon Society	Res	$42,400	$42,400	1	42,400			
0 012	James, Morris	VUU	$4,500	$4,500	2		4,500		
0 013	James, Morris	VUU	$4,500	$4,500	2		4,500		
0 014	Sparecho	VUU	$4,500	$4,500	2		4,500		
0 015	Taylor, Genevieve	VUU	$4,000	$4,000	2		4,000		
0 016	Thompson, John	VUU	$1,500	$1,500	2		1,500		
0 055	Phillps, Anthony	VUU	$4,000	$4,000	2		4,000		
0 056	Woods, James	VUU	$4,000	$4,000	2		4,000		
0 057	Norman, Leon	VUU	$100	$1,500	2		1,500		

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0 058	Slauson, Lon	VUU	$400	$4,000	2		4,000		
0 059	Slauson, Donald	VUU	$400	$4,000	2		4,000		
0 060	Slauson, Donald	VUU	$400	$4,000	2		4,000		
0 061	Slauson, Donald	VUU	$400	$4,000	2		4,000		
0 062	Slauson, Donald	VUU	$400	$4,000	2		4,000		
0 063	Kilian, John	VUU	$400	$4,000	2		4,000		
0 064	Kilian, John	VUU	$400	$4,000	2		4,000		
0 065	Kilian, John	VUU	$400	$4,000	2		4,000		
0 066	Kilian, John	VUU	$400	$4,000	2		4,000		
0 067	Kilian, John	VUU	$400	$4,000	2		4,000		
0 068	Kilian, John	VUU	$400	$4,000	2		4,000		
0 069	Thompson, John	VUU	$400	$4,000	2		4,000		
0 070	Thompson, John	VUU	$400	$4,000	2		4,000		
0 071	Thompson, John	VUU	$400	$4,000	2		4,000		
0 072	Thompson, John	VUU	$400	$4,000	2		4,000		
0 073	Thompson, John	VUU	$400	$4,000	2		4,000		
2 007	Reed, Clyde	VUU	$2,000	$2,000	2		2,000		
0 007	Munsch, Twyla	VUU	$15,000	$15,000	3			15,000	
0 008	Munsch, Twyla	VUU	$13,000	$13,000	3			13,000	
0 009	Wood, Irvin	VUU	$11,000	$11,000	3			11,000	
0 010	Brennan, Michael	VUU	$9,000	$9,000	3			9,000	
0 011	Oster, Herbert	VUU	$7,000	$7,000	3			7,000	
0 045	Phillps, Anthony	Res	$62,600	$62,600	3			62,600	
0 046	Forsman, Larry	Res	$74,900	$74,900	3			74,900	
0 047	Parker, Lewis	VUU	$12,000	$12,000	3			12,000	
0 048	Sewell, Emma	Res	$48,300	$48,300	3			48,300	
0 049	Lee, Bruce	Res	$17,000	$17,000	3			17,000	
0 050	Goodrich, Donald	Res	$63,200	$63,200	3			63,200	
0 051	Pearson, Michael	Res	$75,200	$75,200	3			75,200	
0 052	Hargrave, J Davis	Res	$67,800	$67,800	3			67,800	
0 053	Gustafson, Mark	Res	$20,300	$20,300	3			20,300	
0 054	Gustafson, Mark	Res	$20,300	$20,300	3			20,300	
1 004	Slauson, Donald	Res	$117,000	$117,000	3			117,000	
1 005	Gustafson, Mark	VUU	$11,500	$11,500	3			11,500	
1 017	Kilian, John	Res	$144,300	$144,300	3			144,300	
1 018	Lee, Bruce	VUU	$43,100	$43,100	3			43,100	
0 001	Harrell, Kenneth	Res	$81,700	$81,700	4				81,700
0 002	Jefferds, Seth	Res	$122,300	$122,300	4				122,300
0 003	Sullivan, John	Res	$23,600	$23,600	4				23,600
0 004	Dunshee, Dale	VUU	$16,000	$16,000	4				16,000
0 005	Dunshee, Dale	Res	$25,600	$25,600	4				25,600
0 006	Dunshee, Dale	Res	$29,800	$29,800	4				29,800
0 074	Miller, Reed	Res	$47,200	$47,200	4				47,200
0 075	Bird, Carrol	VUU	$4,500	$4,500	4				4,500
0 076	Bird, Carrol	VUU	$4,500	$4,500	4				4,500
0 077	Bird, Carrol	VUU	$4,500	$4,500	4				4,500
0 078	Bird, Carrol	VUU	$4,500	$4,500	4				4,500
0 079	Bird, Carrol	VUU	$4,500	$4,500	4				4,500
0 080	Bird, Carrol	VUU	$4,500	$4,500	4				4,500
1 007	Larsen, James	VUU	$43,000	$43,000	4				43,000
1 019	Bird, Carrol	VUU	$42,900	$42,900	4				42,900

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1 022	Larsen, James	Res	$75,900	$75,900	4				75,900
2 003	Paulson, Thomas	MOSG	$100	$1,500	4				1,500
2 004	Dix, Douglas	VUU	$6,500	$6,500	4				6,500
2 010	Paulson, Wesley	MOSG	$100	$1,500	4				1,500
2 011	Paulson, Thomas	MOSG	$100	$1,500	4				1,500
2 012	Paulson, Ethel	MOSG	$100	$1,500	4				1,500
0 020	NO INFO ???								
0 038	NO INFO ???								
				Totals		181,500	94,500	832,500	547,500

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Vacant, Undeveloped, Unused Land

Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0			
Typical:	Property listed as "Vacant, Undeveloped, Unused land"			
Drawn By	Tracy Drury	Notes	Date	3/14/00

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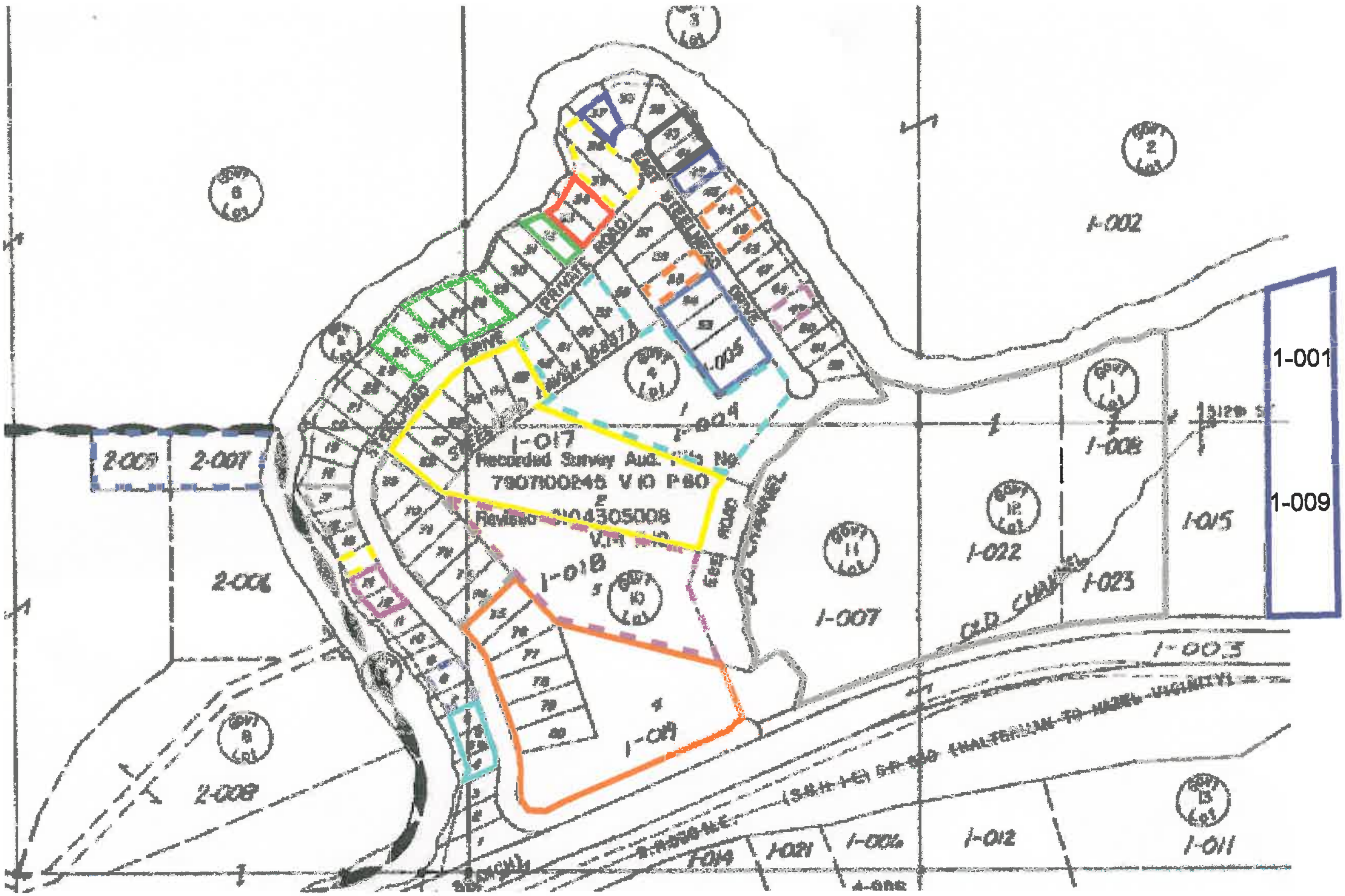
Multiple Properties with Common Owners



Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0			
Typical:	Multiple properties with common owners			
Drawn By	Tracy Drury	Notes	Date	3/13/00

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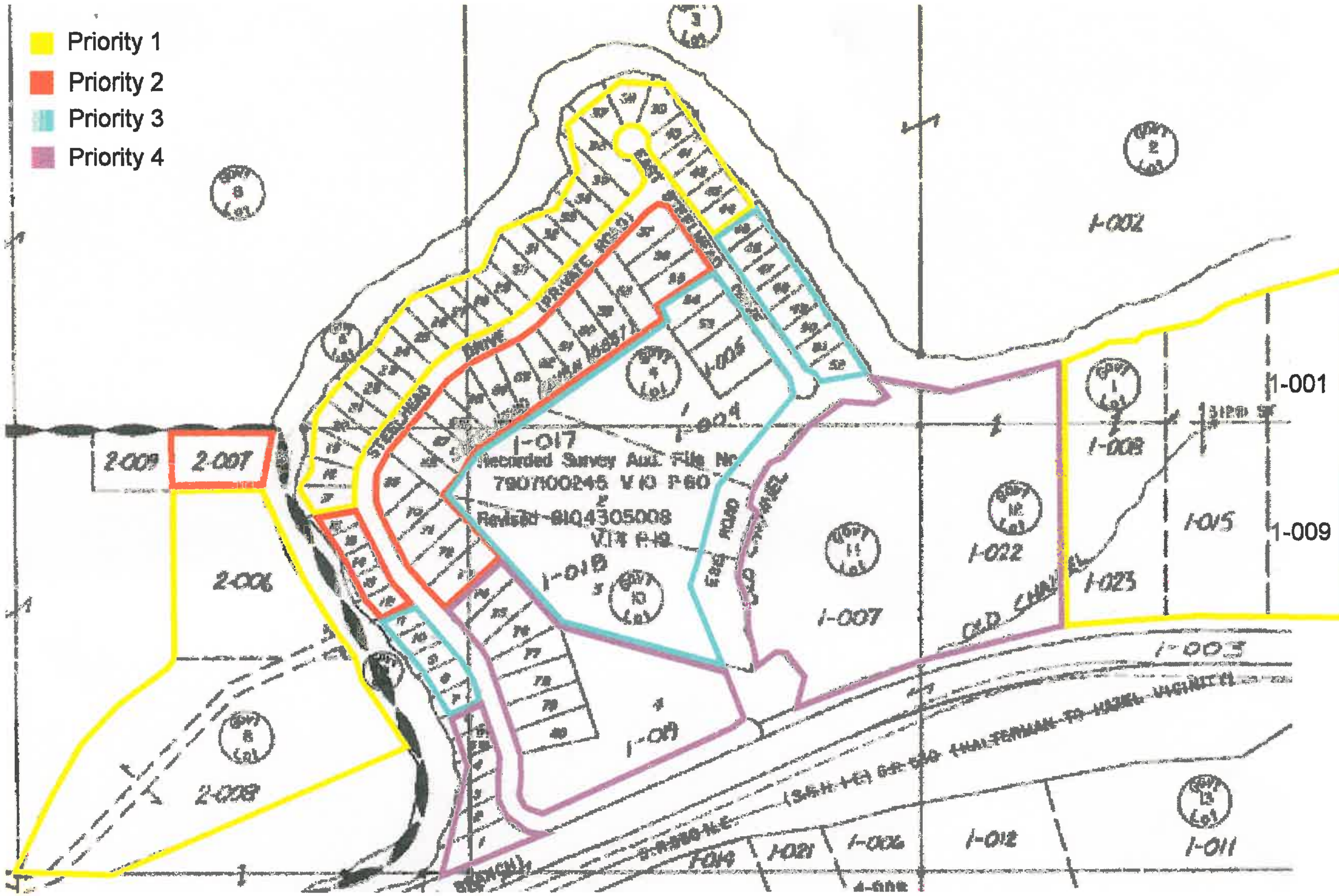
Property's Buoyout Priority



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Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0
Typical:	Property designated by buyout priority

Drawn By	Tracy Drury	Notes	Date	4/3/00

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Appendix C

Cost Estimates / Quantity Takeoffs

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Alternative 3

Steelhead Haven Cost Estimates

Material Costs:

Cost of Key members	2500		Cost of Stackers	2000	Cost of Rackers	250	
	Length (ft)	# of Key members	# of Stackers	# of Rackers	Total Cost: Key members	Total Cost: Stackers	Total Cost: Rackers
Revetment A	1200	80	240	240	200,000	480,000	60,000
Revetment B	500			85	0	0	21,250
Revetment C	500			85	0	0	21,250
Revetment D	100			18	0	0	4,500
					200,000	480,000	107,000
					Total Material Costs		$787,000

Equipment and Labor:

	Units	Cost per hour	Cost per month	Estimated Hours	Estimated Months	Cost
D8 Dozer	1	145		240		34,800
Track Grapple 1	1	140		240		33,600
Track Grapple 2	1	140		240		33,600
Track Grapple 3	1	100		240		24,000
Track hoe	1		8600		1.5	12,900
Skidder	1		8000		1.5	12,000
Tubs	3	49		240		35,280
Laborers	3	30		240		21,600
		Total Equipment and labor costs				207,780

Total Project Costs $994,780

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Alternative 4

Steelhead Haven Cost Estimates

Material Costs:

Cost of Key members	2500		Cost of Stackers	2000	Cost of Rackers	250	
	Length (ft)	# of Key members	# of Stackers	# of Rackers	Total Cost: Key members	Total Cost: Stackers	Total Cost: Rackers
Revetment A	1200	80	240	240	200,000	480,000	60,000
Revetment B	900			150	0	0	37,500
Revetment C	900			150	0	0	37,500
Revetment D	500			85	0	0	21,250
					200,000	480,000	156,250
					Total Material Costs		$836,250

Equipment and Labor:

	Units	Cost per hour	Cost per month	Estimated Hours	Estimated Months	Cost
D8 Dozer	1	145		240		34,800
Track Grapple 1	1	140		240		33,600
Track Grapple 2	1	140		240		33,600
Track Grapple 3	1	100		240		24,000
Track hoe	1		8600		1.5	12,900
Skidder	1		8000		1.5	12,000
Tubs	3	49		240		35,280
Laborers	3	30		240		21,600
		Total Equipment and labor costs				207,780

Total Project Costs $1,044,030

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Alternative 5

Steelhead Haven Cost Estimates

Material Costs:

Cost of Key members	2500		Cost of Stackers	2000	Cost of Rackers	250	
	Length (ft)	# of Key members	# of Stackers	# of Rackers	Total Cost: Key members	Total Cost: Stackers	Total Cost: Rackers
Revetment A	450	30	90	100	75,000	180,000	25,000
Revetment B	450	0	0	50	0	0	12,500
Log Jam #1		5	15	50	12,500	30,000	12,500
Log Jam #2		5	15	50	12,500	30,000	12,500
					100,000	240,000	62,500
					Total Material Costs		402,500

Equipment and Labor:

	Units	Cost per hour	Cost per month	Estimated Hours	Estimated Months	Cost	
D8 Dozer	1	145		240		34,800	
Track Grapple 1	1	140		240		33,600	
Track Grapple 2	1	140		240		33,600	
Track Grapple 3	1	100		240		24,000	
Track hoe	1		8600		1.5	12,900	
Skidder	1		8000		1.5	12,000	
Tubs	3	49		80		11,760	
Laborers	3	30		240		21,600	
		Total Equipment and labor costs				184,260	
						Total Project Costs	586,760

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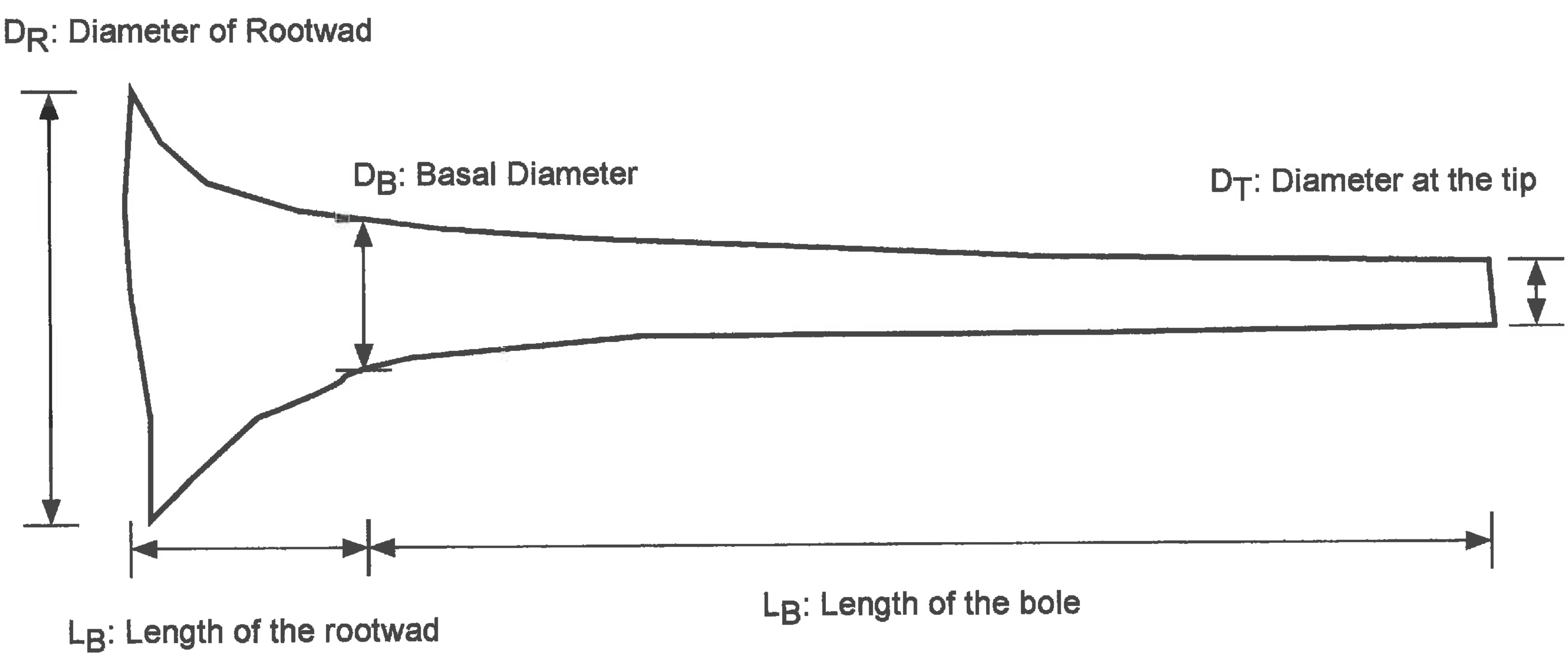
Log and Revetment Parameters



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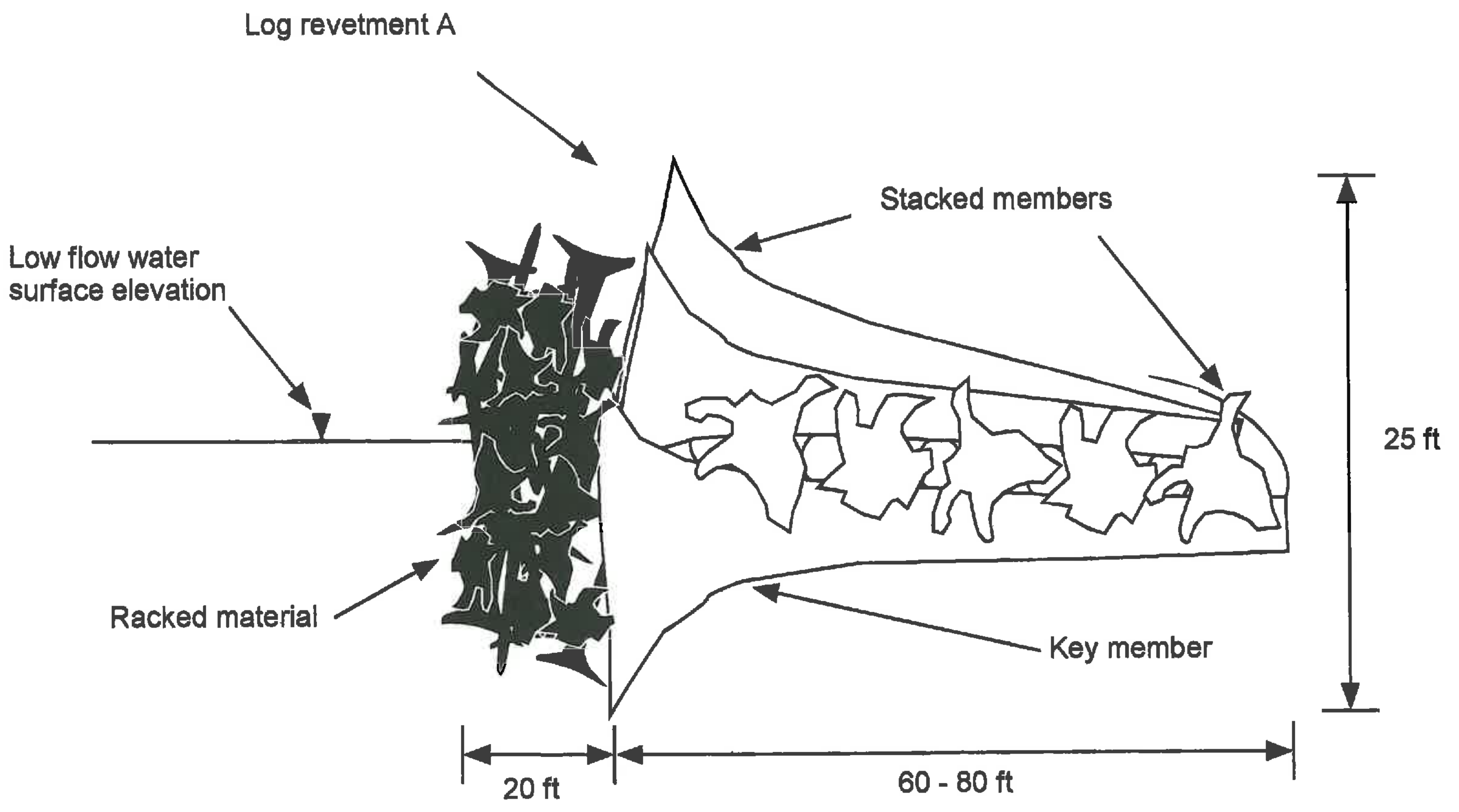
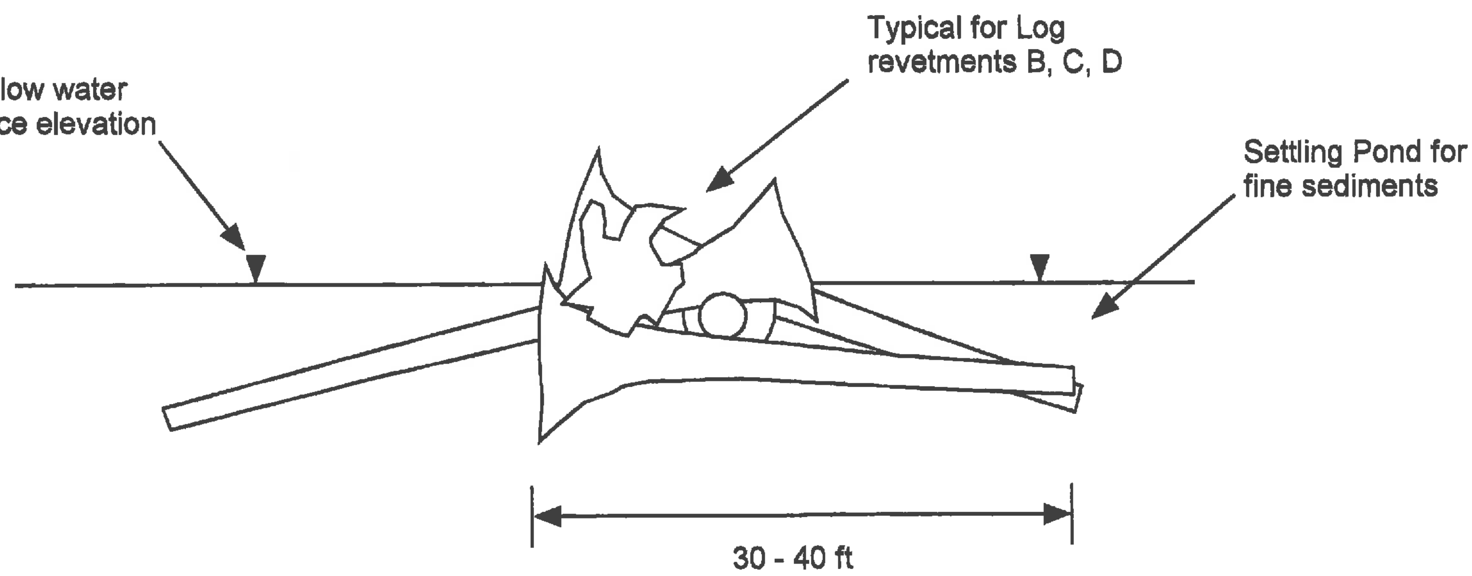
Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Definition of log characteristic metrics		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		1/25/00



Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Cross-section of revetment A		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		1/19/00



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Project:	Steelhead Haven Landslide, North Fork Stillaguamish river approximately RM 20.0		
Typical:	Cross-section of revetments B, C, and D		
Design By	Tracy Drury	Notes	Date
Drawn By	Tracy Drury		6/17/00

Log Specifications for revetment A and Log Jams

	Key Members		Stacked Members		Racked materials	
	Max	Min	Max	Min	Max	Min
D_R (ft)	16	8	12	6	8	2
D_B (in)	42	32	31	24	23	12
Total Length (ft)	80	60	60	30	40	20

Log Specifications for revetment B, C, D

	Key Members		Stacked Members		Racked materials	
	Max	Min	Max	Min	Max	Min
D_R (ft)	0	0	5	1.5	0	0
D_B (in)	0	0	18	10	0	0
Total Length (ft)	0	0	40	30	0	0

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