DRAFT FINAL

SOUTH FORK OF THE SKOKOMISH RIVER
AND
VANCE CREEK

Hydraulic and Geomorphic Analysis
and
Recommendations for Action

June 1999
(Revised September 1999)

Project # S-C 99033

Prepared for:

Mason County Department of Community Development
411 North Fifth Street, Shelton, WA 98584 -1850

The preparation of this document was financially aided through FCAAP Grant Agreement No. G9900204 from the Washington State Department of Ecology with funds appropriated for the Flood Control Assistance Account Program.

Prepared by:

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and

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3528 JFK Parkway, Suite 1, Fort Collins, CO 80525

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Geomorphic and Hydraulic Analysis of the South Fork of the Skokomish River and Vance Creek Regarding Flood and Avulsion Hazards

Skillings~Connolly, Inc.
and
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(Revised 9/3/99)

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1.0 Introduction

1.1 Background

The Skokomish River and several of its main tributaries (the South Fork of the Skokomish River and Vance Creek) have experienced or may potentially experience a significant level of instability even to the point of possible avulsions and frequent overbank flooding. An evaluation of similar possibilities was made on a portion of the mainstem Skokomish River in the vicinity of the confluence of the North Fork and South Fork (see "Discussion of Skokomish River Valley Flood and Avulsion Hazards" by Skillings~Connolly and Simons & Associates, September, 1997). The previous evaluation provided warning of potential avulsion, recommended channel stabilization measures, inspected some of the placement of the stabilization measures, and provided Mason County with information that was a partial basis for a moratorium on new construction in the area. This previous analysis focused on the reach of river farther downstream in the vicinity of the confluence of the North Fork and South Fork. The following few paragraphs summarize this previous work.

1.2 Previous Studies

As discussed in the previous reports, the lower South Fork and upper Skokomish River is located downstream of the mountains of the upper watershed flowing over an alluvial plain. In this zone of the river system, the coarser sized sediments eroded and transported from the upper watershed tend to deposit on the bed of the river because the slope of the river is flatter in this reach compared to upstream. As the slope becomes flatter in the downstream direction, the velocity decreases thereby decreasing the energy of flow and its sediment transport capacity. The bed of the river in this area responds by aggrading as the coarser sizes of sediment tend to deposit. Over time, the channels capacity to convey flow decreases causing more frequent flooding and a tendency for the channel to erode banks enlarging the channel size or even to shift position seeking new alignments or paths to convey the flow. There are several areas of the river where the bed of the main channel is very high compared to the surrounding floodplain, which is called a perched river. Such a situation tends to lead to avulsions, which can be described as the flow in the river abandoning the old channel, and flowing over the floodplain, eventually finding or creating a new channel down the valley.

During the 1996/1997 high flow season, the Skokomish River experienced several significant flood events which seem to have exacerbated its dynamic nature. Surveys of channel sections conducted in 1997 when compared to the same sections taken in 1992 showed approximately 2 feet of aggradation. Thus, the channel continues to decrease in size and ability to convey flow. Based on the hydraulic analysis conducted using both the 1992 and 1997 data, the1997 water surface profile is on the order of 2 feet higher than the profile based on the previous data.

The short-term recommendations included protection of riverbanks against erosion in specific areas, construction of spur dikes, implementation of the proposed point bar and instream gravel traps, stabilization of the toe of slopes, and removal of two logjams at the upper end of the gravel bar just upstream of the confluence. The long-term recommendations included analysis of trade-offs and the cost-benefit of major alternatives such as dredging, continued coarse sediment trapping, continued buy-out of properties, and a joint flood control/sediment trapping facility on the South Fork. Also considered was allowing the dynamic nature of the Skokomish River system to run its course and make necessary responses as the need arises.

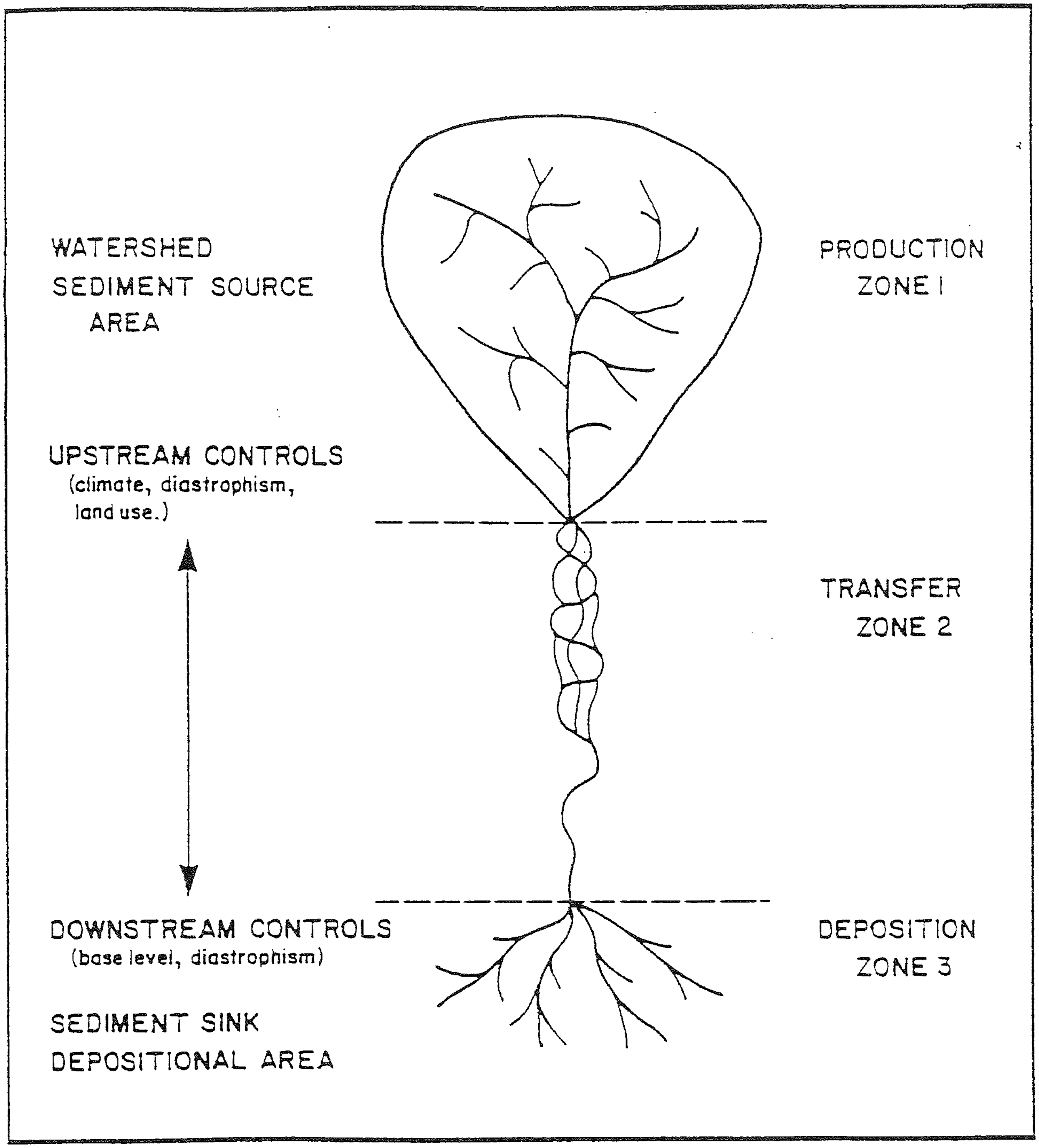
1.3 Reason For Study

Concern has now been raised over the same issues on the tributaries themselves (South Fork and Vance Creek) related to existing development and the pressure to continue future development in some areas of the valley. In order to evaluate the potential for avulsions, other channel instabilities, and flooding issues for these rivers, it is essential to understand the geomorphology and geomorphic trends governing the processes of water and sediment movement through them.

2.0 Geomorphic Analysis

2.1 Idealized Fluvial System

To place perspective on these processes, the geomorphic tool of the *"idealized fluvial system"* has been applied to the South Fork and Vance Creek. Most watershed and river systems fit the classic description of the "idealized fluvial system." The idealized fluvial system was developed by Schumm (1977, The Fluvial System, John Wiley & Sons) to better understand the key geomorphic zones (see Figure 1). The classic idealized fluvial system originates in an upper watershed area where most of the water is produced. This area generally has significant topographic relief consisting of mountains and valleys. This area, in addition to producing water in the form of surface runoff, also produces sediment because of the erosion process occurring in this portion of the basin and hence is called the production zone. Streams in the mountainous region of a watershed are generally steep and flow at relatively high velocity. Such streams have high erosive energy and are capable of transporting considerable amounts of sediment.



Idealized Fluvial System (after Schumm 1977)

Figure 1

After flowing out of the upper watershed area, the classic river system flows through a relatively flat, alluvial plains region where gradients or river slopes are significantly flatter and where energy to carry sediment eroded from the upper watershed is reduced. In this region, the coarser sediment load produced and transported by the steep upper rivers tends to deposit, causing the river to fill and shift, and fill and shift again, resulting in a wide multiple channel dynamic system, classified as a braided river. As the coarser material drops out through the braided reach, the classic river system undergoes a transition into a relatively stable meandering reach, with a narrower deeper river channel and sinuous path. Through this alluvial plains region most of the finer-sized sediment and some of the coarser material passes. This zone has been called the transfer zone.

As the river approaches the coastal zone (or lake or reservoir) it often splits into a number of channels in the classic delta formation. The river, its associated sediment load, and the interaction between the river and the sea form a deltaic formation. As a river transports sediment into the sea, the velocity of flow decreases and sediment is deposited. Gradually, over time the deposit builds out into the sea and the gradient of the river becomes flatter and flatter. More deposition of sediment occurs until at some point the channel becomes sufficiently flat and full of sediment that the river shifts to an alternate route to the sea. This process continues and results in the classic fan-shaped, multiple-channel delta configuration. This is the deposition zone.

2.2 South Fork Skokomish River and Vance Creek Relative to Transfer Zone

The reaches of the South Fork and Vance Creek being evaluated in this analysis are located in the upper end of the transfer zone, immediately downstream of the sediment supply zone. While these simple classifications indicate general trends, it is necessary to consider site specific tendencies at work in this transition area that goes from the supply to the transfer zone. In this transition area, the slope of these rivers changes from relatively steep to significantly flat in a short distance. The change in slope is demonstrated by plotting the longitudinal profile of these rivers based on USGS quad maps (see Figures 2 and 3).

While most sediment, in terms of quantity, passes through the transfer zone down through the idealized fluvial system to the deposition zone; in the transition from the supply to the transfer zone the coarsest fraction of sediment produced in the supply zone tends to deposit in the upper reaches of the transfer zone. There is also a tendency to deposit coarse sediment in any area where velocities decrease below critical levels required to transport such sizes of sediment.

2.3 Plan-form Concerns

South Fork Skokomish River

As the South Fork flows out of its canyon, the river is generally flowing in a southerly direction. Downstream of the USGS gage on the South Fork, the South

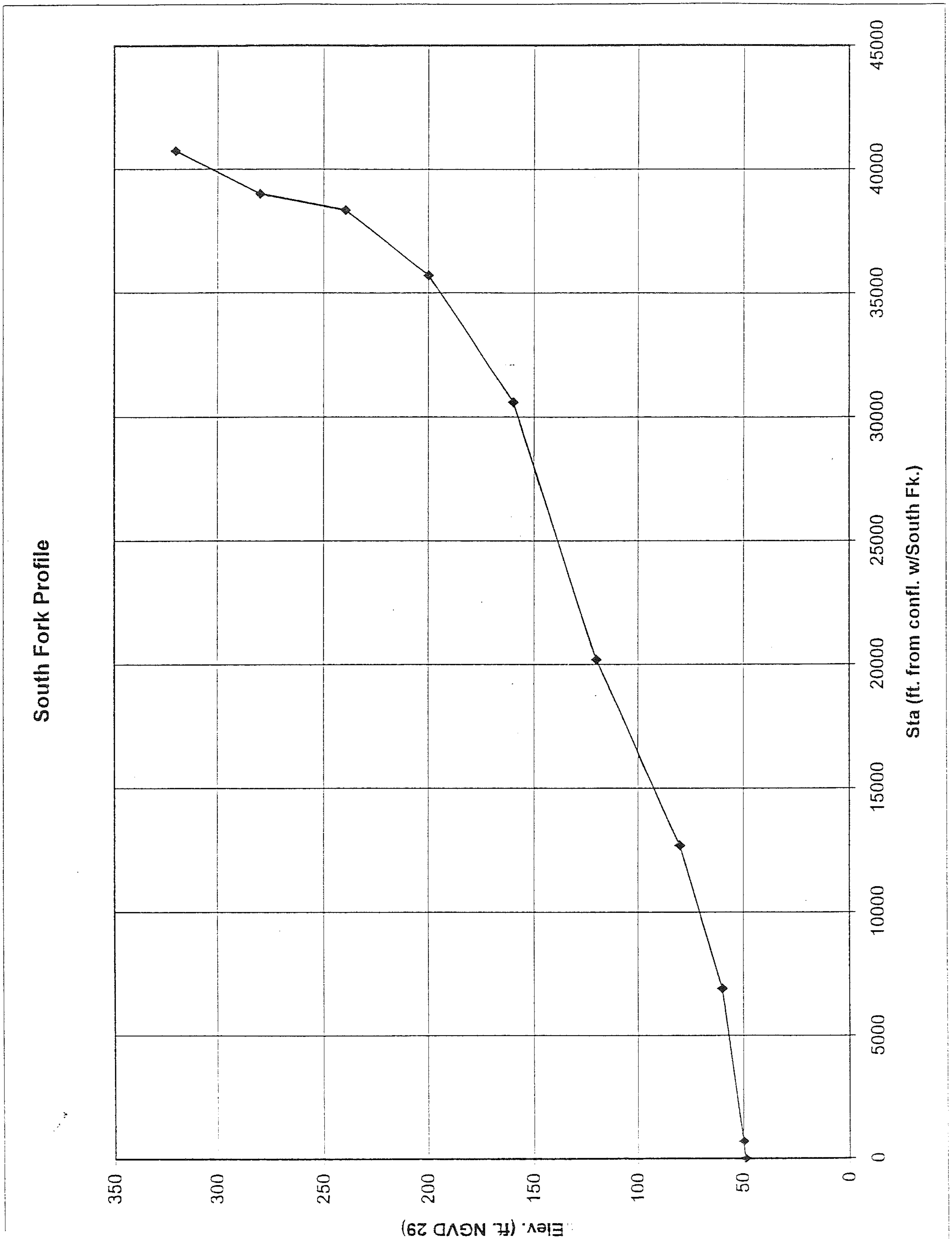

South Fork Profile
Elev. (ft. NGVD 29)
350
300
250
200
150
100
50
0
Sta (ft. from confl. w/South Fk.)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000

Figure 2

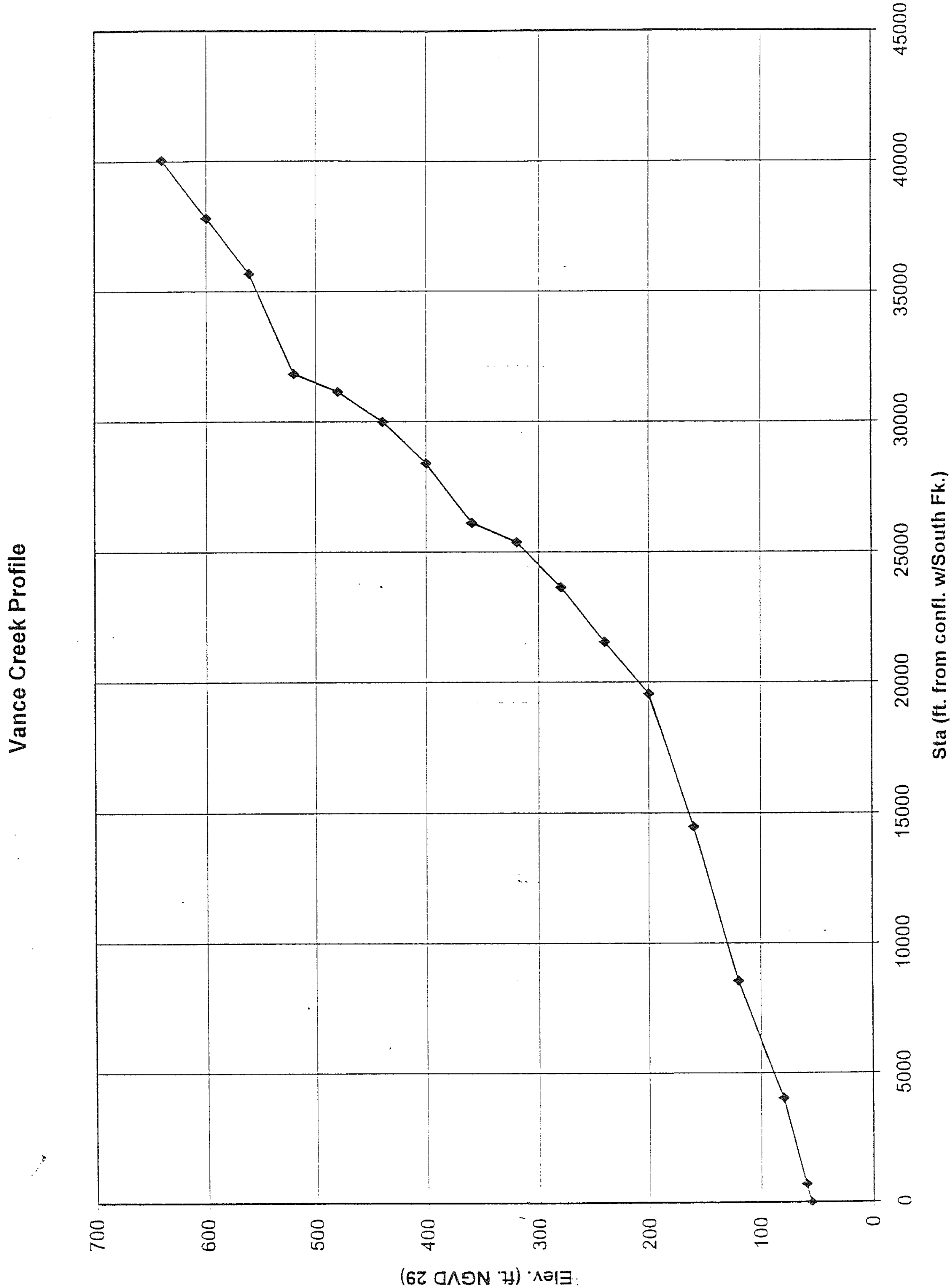

Vance Creek Profile
Sta (ft. from confl. w/South Fk.)
Elev. (ft. NGVD 29)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
0
100
200
300
400
500
600
700

Figure 3

Fork makes an abrupt turn to the east. After flowing in an easterly direction for about 1/2 mile, the river then makes another abrupt turn to the south. This turn is located in the vicinity of a high bluff or hillside that has experienced significant landslides into the river. More discussion on the landslides will be presented later. After flowing about another mile in a southerly direction, the South Fork again makes an abrupt turn to the east. Less than a mile downstream, the river then again turns abruptly to the south. Once again, in less than a mile (just downstream of the confluence with Vance Creek) the South Fork makes an abrupt turn to the east as the river flows adjacent to the road down the valley.

At each of the locations of the abrupt turns, a significant change in momentum of flow direction occurs such that the river tends to attack the outside of the bend. The velocity of flow and depths of flow are generally greater near the outside of bends than inside of bends. In addition, as a river makes a bend the phenomenon of super-elevation occurs resulting in higher water surface elevations along the outside of the bend than on the inside of the bend. All of these factors tend to destabilize the outside of bends resulting in riverbank erosion, lateral migration, and perhaps the potential for other significant changes.

Vance Creek

Similar plan-form characteristics are found on Vance Creek. Just as it flows out of the mountains and under a bridge, it makes a sharp turn from a southeasterly direction towards the east-northeast. After this turn, Vance Creek flows in an easterly direction as it leaves the mountains. After a distance of a little over a mile, Vance Creek makes an abrupt turn to the south. Approximately a half of a mile farther downstream, it turns abruptly to the east. After some gentler bends and over a mile farther downstream, Vance Creek turns sharply to the south. This bend is located a relatively short distance upstream from a bridge. Not far downstream of the bridge, Vance Creek again turns abruptly to the east. It then turns gently towards the southeast for about two miles, whereupon it turns sharply to the northeast. A relatively short distance downstream of this bend, Vance Creek flows under a bridge and then into the South Fork a few tenths of a mile downstream of the bridge.

2.4 Bridges

Three bridges have been constructed over Vance Creek. Bridges generally cause constrictions to the flow as the water must pass under the bridge deck and between the bridge abutments. Forcing the flow through such a constraint causes energy losses and can cause backwater effects upstream of the bridge. Energy losses and backwater effects are significantly greater when the flow is high enough to hit the bridge deck or flow over and around the bridge. Bridges also tend to collect debris such as logs, root wads, or other material, particularly during flood events. The existence of a bridge tends to exacerbate instabilities and dynamic behavior of a river. The bridge surveys conducted by S~C in June 1999 indicate the current size of the openings. At the bridge designated as V-1.82, the span of the bridge is 120 feet.

The maximum distance below the low chord of the bridge to the riverbed was 15.1 feet and the minimum distance (away from the abutments) was 12.6 feet. At the bridge designated as V-0.16, the span was 70 feet with minimum and maximum vertical clearance between the low chord and the bed of the river being 9.9 and 18.2 feet, respectively. At the upstream end of the reach of Vance Creek just as it leaves the mountain and canyon area there is another bridge where the Simpson Timber 800 Road crosses (approx. V-3.6). Near this location there is a tributary creek which has flowed through a culvert. This culvert has been plugged by sediment. Just upstream of the V-0.15 bridge there is a large tree with root wad large enough to seriously impede the ability of the bridge opening to function properly. Throughout the reaches of both Vance Creek and the South Fork of the Skokomish there is a large amount of woody debris and some log jams. Some of these are illustrated in the Photographs included in this report.

No bridges over the South Fork have been built in the reach of river between the confluence with the North Fork and the mouth of the canyon.

2.5 Sediment

Sediment loads produced by the South Fork and Vance Creek are considered to be significantly greater than would be expected under natural conditions. While fine sized sediment (clay, silt, and fine sand) is mostly transported through this reach of Vance Creek and the South Fork (since no appreciable quantities of fine sized sediment is found in the bed of these streams consistent with the concept of the transfer zone of the idealized fluvial system), there is evidence of increased supply and deposition of coarse sediment in these streams.

The following was stated by Simons & Associates [January 27, 1998, "Response to Comments Provided by the Consultants to the Skokomish Tribe: David R. Dawdy (September 9, 1996, David A. Jay (April 20, 1996), R2 Resources (June 18, 1997), Stetson Engineers (June 27, 1997), Thomas M. Watson (September 4, 1996)"]:

> Data from the South Fork, where timber harvesting has occurred, compared to data from the North Fork in Olympic National Park upstream of Lake Cushman, where timber harvesting has not occurred, clearly show that there has been a dramatic increase in bedload supply from the South Fork.

More information from this report confirms the significant increase in sediment supplied from the South Fork.

> The data discussed above are supported by observations of others. In the 1993 draft of the Skokomish River Comprehensive Flood Hazard Management Plan (KCM, 1993), the following is stated, *"Extensive clear-cut logging operations have been conducted in the upper basin. . . Almost 40 percent of the South Fork basin has been logged since 1935. The U.S.*

Forest Service (USFS) estimates soil erosion over the past few decades has increased sediment loading to the Skokomish River more than three times the natural, undisturbed rate. The Hood Canal ranger district has identified over 5,000 slope failures in the district. Of these, 90 percent result from road failures. . ." In addition, a 1988 version of a similar report entitled, "Skokomish River Comprehensive Flood Control Management Plan Preliminary Draft Plan," by the Washington Department of Ecology (March, 1988) stated, *"Based on field reconnaissance, there is no sediment source in the Skokomish Valley sufficient to account for the degree of aggradation which has occurred, nor is the North Fork a sediment contributor due the reduced flows in that tributary. Therefore, the source of the aggrading sediments must lie in the South Fork basin above the Skokomish Valley - - that is, from within the Olympic National Forest."* This 1988 report contains an appendix supporting this statement. The appendix is a report entitled, "Skokomish River Investigation," by Dr. Donald R. Reichmuth (June 25, 1987). The report states, *"The aerial observation of the upper south fork drainage revealed that large quantities of sediment are being released from the heavily logged areas that cover large portions of the basin."* In discussing these observations of the South Fork, the report states, *"The gravel moving down this drainage is clearly seen in the photograph. The tree buffer which separates the logging area from the river bottom has not been able to filter out and trap the gravel from the upper areas. . . These gravels are flushed down the stream and passed through the steeper gorge areas without causing significant deposition or bank erosion, because this section is confined by bedrock. However, once the river leaves this gorge, large quantities of gravel are immediately deposited." Regarding solution measures and with the author considering the potential effect of the diversion of the North Fork which he states limits sediment carrying capacity, he states, "Because the upper drainages are contributing so much material and show no signs of reaching stability, it is expected that this downstream migration of large quantities of gravel will continue until something is done to control the material nearer its source. This will require either limiting future logging, or carefully controlling the areas where logging occurs, so that sediment releases are minimized. Additionally, control structures should be placed in the upper drainage to trap as much gravel as possible, before it reaches the canyon area."* In further discussion of solutions, he does not mention flow related solutions and does not support work in the lower valley except as temporary measures because, *"the money will be largely wasted, because these efforts are only dealing with symptoms and not the root cause of the instability which has been observed on the river."*

Although no detailed information is available regarding Vance Creek, it is known that similar activities are occurring there suggesting that Vance Creek is experiencing a similar increase in sediment supply.

An increase supply of coarse sediment from the sediment production zone of the Vance Creek and South Fork watersheds coupled with the tendency for coarse sediment to deposit in the transition from the supply zone to the transfer zone provides another area of concern regarding issues of continued decrease in flood conveyance capacity and potential channel instabilities.

2.6 Landslides

In addition to the generally increased sediment load from the watersheds of the South Fork and Vance Creek, landslides can potentially supply sudden increases of sediment and can alter channel geometry and hydraulics. An existing landslide was observed in the portion of Vance Creek being evaluated in this analysis between River Mile 2.0 and 2.4 opposite and upstream from the Robinson-Goddings property.

There is also an existing landslide area that has affected the South Fork. It is located on the outside of a bend at approximate river mile 2.4 (S 2.4 on Figure 7 in this report) in Sec.1 T21N R5W W.M. Photo #7 in Appendix B gives a good view of the face of the most recent slide activity at this location. This area has been producing landslides for at least the recent past several years, with a significant event reported by the local residents to have occurred in early February 1995. At that time, a significant portion of the slope broke away and slid into the South Fork. There was sufficient volume of material to cause a partial blockage of the South Fork, at least to the extent that it caused a portion of the flow of water to back up and pond for a period of a couple of days. The blockage eroded away quickly and the effects of the ponding were mostly gone within a week. This landslide raised the water level upstream and slowed the velocity of flow. By so doing it raised the base level of this temporary hydraulic control causing water to raise on the banks making the river upstream more susceptible to flooding. In other words the landslide could have caused more flooding, but it was fortunate that it happened when the river was not at flood stage. That Spring the slide material washed away prior to any further flooding. To the extent that the landslide raised the water level, it increased the chances of water to leave the river and flow out over the flood plain with increased potential for erosion and possible avulsion. If a landslide of sufficient magnitude occurred at the same time as a major flood, the river could be diverted out of its path and be forced to take a different route by forming and eroding a new channel on the south side of the existing channel thereby causing a sudden avulsion.

The USGS (personal conversation with Bill Wiggins 6-3-99, USGS, Tacoma, WA) has also reported an active landslide on the South Fork upstream from their gage at the mouth of the canyon, S 3.24 on Figure 7. Also, their gage notes indicate another landslide and trees that came down sometime prior to 1995 that destroyed their aerial line immediately upstream from their gage. As noted in the material quoted above, there are many landslides that have occurred in this area.

2.7 Debris

There is evidence of significant quantities of woody debris being transported through and deposited in both the South Fork and Vance Creek. This is demonstrated by photographs included in this report. While in some cases woody debris piles up adjacent to riverbanks providing some limited degree of protection against the erosive effects of flow, adverse affects of debris include raising resistance to flow in the main channel (causing increased water levels, decreased velocities, and sediment deposition), and cause the main path of the river to shift direction causing the flow to more vigorously attack the riverbanks. In those reaches affected by bridges, woody debris may become trapped either upstream or under bridges that can greatly exacerbate backwater effects and can significantly reduce flow conveyance capacity through the bridge. Although the existence of woody debris being produced by the South Fork and Vance Creek watersheds presents excellent fish habitat, from a hydraulic efficiency perspective it represents another factor of concern regarding river instabilities and potential for adverse consequences.

2.8 Analysis of South Fork Dynamics Based on Aerial Photographs

In observing the areas of Vance Creek and the South Fork, information was provided showing the dynamic nature of the South Fork based on interpretation of aerial photography by Tom Schreiber (1999). On an aerial photograph dated 7/9/85 and based on a series of aerial photographs from the 1960's to more recent times, as well as personal observations, Mr. Schreiber marked the locations of the path of the main channel of the South Fork as it has shifted during this time period within or beyond the recent historic limits of the overall area of active river. The result of his work is presented in Figure 4. In evaluating this figure two key observations are noted. First, the main channel of the river has shifted continuously and significantly during this period of time. Second, in recent years, significant erosion of the south bank of the river has occurred moving the bank line southward over 100 feet destroying over 3.28 acres of previously forested flood plain (see Figure 5, after Schreiber).

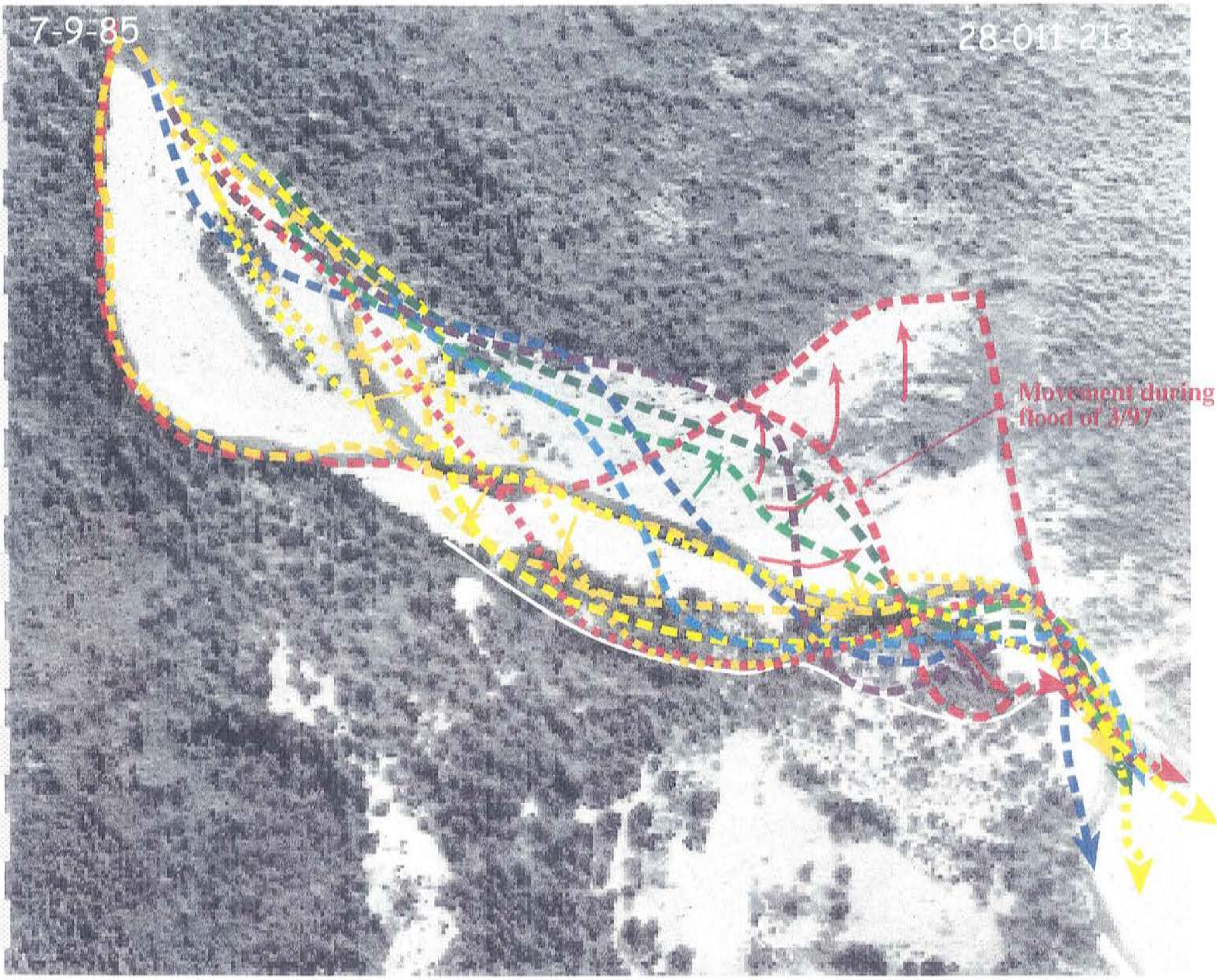
Based on Schreiber's observation of the shifts in the main channel of the South Fork, as shown in Figure 4, several concepts are presented regarding the behavior of the river. At the beginning of this time period(1970's), the river flowed directly south, as it came out of the canyon at approximate River Mile S 3.1 hugging the western and southern edge of the active channel boundary and flowing on the western and southern side of the vegetated island in the vicinity of this major bend in the river. As the river reaches the point where it turns to the east, its riverbank transitions from a hill several hundred feet high to a region where the riverbanks become much lower, being classified as alluvial valley floor/flood plain terrace. It is in this area where the South Fork leaves the lower canyon leaving the confinement of this area and arriving at the freedom of movement on the alluvial plain with its lower banks and erodable material.

After making the sharp bend to the east, the main channel then swung to the far northern side of the active channel boundary whereupon it made a sharp turn to the

1985 Photo Showing Recent Channel Locations of the South Fork Skokomish River, Mason Co., WA

Sections 1 & 2, Township 21North, Range 5 West, Willamette Meridian

Prepared by Tom Schreiber, 401 Bambi Farms Rd., Shelton, WA 98584, 360-426-4827



Channel during mid to late 70's and limits of northward migration

Channel during mid 1980's

Channel during summer of 1991

Channel during summer of 1992

Channel during summer of 1993

Channel during summer of 1994

Channel during summer of 1995

Channel during summer of 1996

Channel during summer of 1997

Channel during summer of 1998

Channel location 1999

Figure 4

Bank Erosion on the South Fork Skokomish River

Section 1, T21N, R5W, Mason Co., WA

Tom Schreiber - property owner

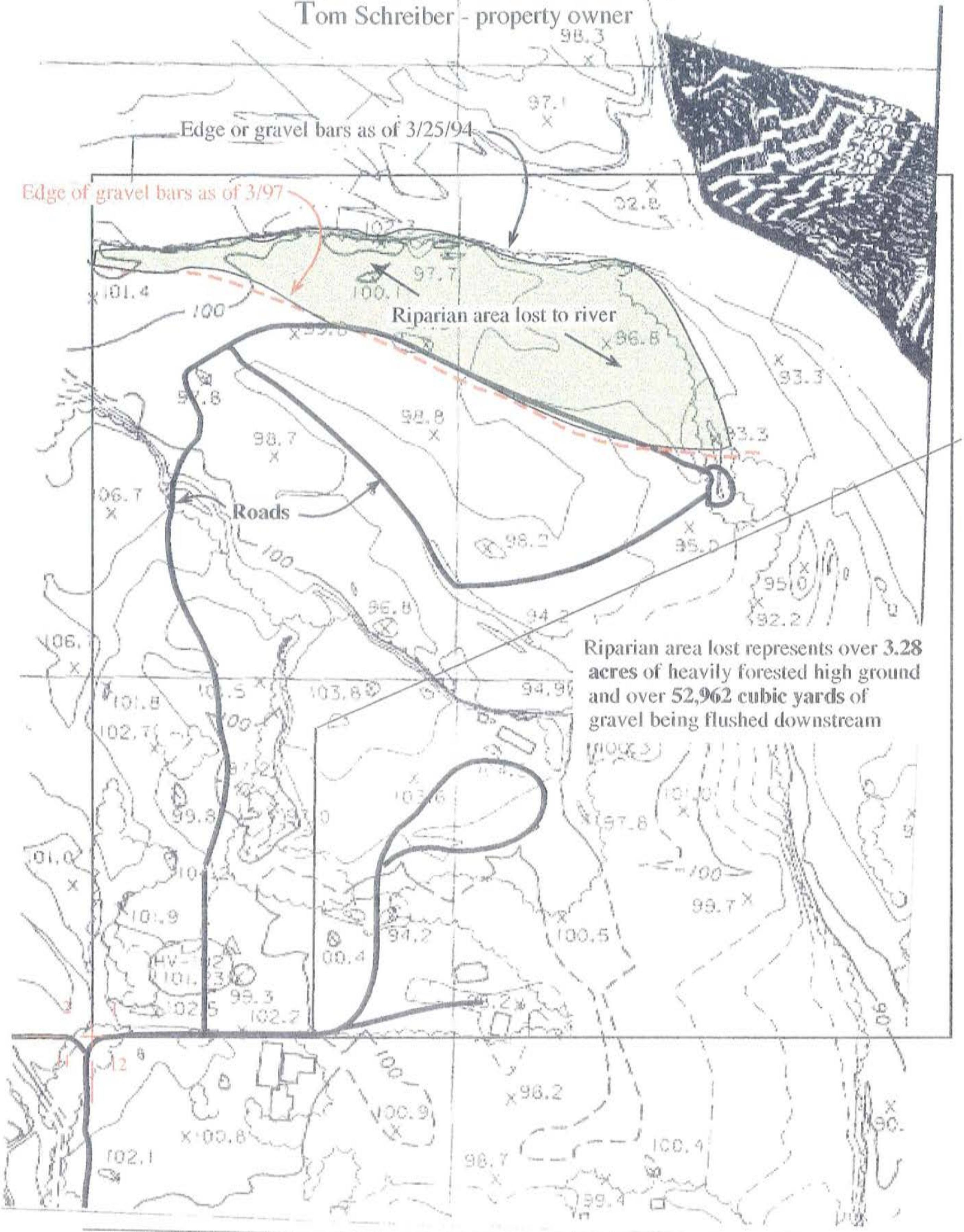


Figure 5

south and flowing in a southerly direction through the narrow reach adjacent to the hill where landslides have occurred. This path kept the main current of the river away from the southern bank of the river most of its length through this reach. On the 1985 photograph (Figure 4), the main channel of the river shifted significantly hugging the northern side of the active zone on the northern side of the vegetated island. The main channel then gradually crossed over to the southern bank just upstream of the narrow area by one last hill on the north side of the river (known locally as the "red cliff" – this is the location where landslides have recently occurred) before making a sharp turn to the south. In the flood of 11/91 the channel made a major shift to the north side of the active channel farther downstream than it did in 1985 before swinging fairly sharply to the south, hitting the south bank almost directly, resulting in erosion of the south bank and loss of some riparian forest land on the flood plain. In subsequent years of 1992, 1993, 1994, 1995, 1996, and 1997, the main channel remained on the north side farther and farther downstream before again swinging to the south and attacking the southern bank. During this time, progressively more of the riverbank and forested flood plain was eroded. As a result of the 3/97 flood, the point at which the main channel began swinging to the south moved quite a ways upstream. As a result, the main current attacked the southern bank farther upstream than in previous years. Again, more erosion of the southern riverbank occurred with additional loss of forested flood plain.

In May of 1999, the main channel followed a path close to the 1985 photograph when the river flowed on the north side of the vegetated island and crossed gradually across the active channel towards the red cliff before turning sharply to the south. Thus, at this point in time the direct attack of the southern bank is not occurring as it has it recent years.

2.9 Analysis of Recent Flood Plain Overflow Events

South Fork Skokomish River

The occurrence of flood overflow events in the Bambi Farms area is available based on observations of water on the flood plain in this area (Schreiber, 1999b). The Bambi Farms area is located on the south side of the South Fork downstream of the first bend below the USGS gaging station and upstream of the red cliff. Schreiber showed overflow channels based on his historic observations on a 6/28/95 aerial photograph. Based on this information, overflow events occurred during November of 1991, December of 1994, and March of 1997. All of these overflow events followed essentially the same path out of the South Fork channels across the flood plain, entering an existing perennial channel that is fed by ground water. These overflow paths are shown on a figure prepared by Schreiber using the 6/28/95 photograph and represented by us on Figure 8 in this Report. The location of the exit point of the overflow is in the vicinity of the direct attack of the current on the south bank as previously described based on the location of the main channel as it existed in the mid- to late 1990's. On the figure, Schreiber also shows the location of other possible overflow channels that supposedly have been dry for over 60 years. The basis for length of time that these channels have been dry is based on Schrieber's analysis of the location of old growth stumps, logging practice knowledge, forest ecology and reports from long-term residents of the area.

It is appropriate to consider some material written by Schreiber regarding the overflow channels.

> It is my understanding that a century ago a number of overflow channels existed throughout the neighborhood. These channels would run when the river flooded but were probably dry most of the year. Early homesteaders felt these flood channels were a hazard. . . The settlers filled the upstream portions of these channels and through the activities of logging and land clearing substantial portions of these channels were filled, blocked and obliterated.

Schreiber explains that water has entered one of these overflow channels three times in the fifteen years he has lived in the area. The first occurred in 1991 as a result of a flood event, where the water overtopped a low spot in an existing gravel bar or berm located in Sec 2 T21N R5W WM which also served as the river bank. Flow at this time was higher than any previously recorded event at the South Fork gage. The highest previously recorded flow was 21,600 cfs occurring two times in the record (1/22/35 and 11/26/49). Flow farther downstream on the mainstem Skokomish River on 11/23/91 was 36,600 cfs after receiving contributing flow from Vance Creek, the North Fork, and other smaller tributaries. Flooding occurred in various places in the neighborhood but dried up and absorbed into the ground shortly after the event. Immediately after this event, the landowner built up the low spot in the gravel bar/berm in an attempt to prevent this from happening again.

The December 1994 event, according to Schreiber, exceeded 22,000 cfs. The South Fork gage was not operating at this time but the flow on the mainstem Skokomish River was 30,000 cfs on 12/20/94. It washed out the soft plug that had been replaced after the 1991 flood. For both the 1991 and 1994 events some flooding and ponding occurred temporarily, but the overflow infiltrated into the ground and did not flow back into the river. At this point in time, the opening in the gravel bar/berm was replaced with large rock in an attempt to prevent erosion of the plug.

Regarding the 1997 event, Schreiber provides the following description of conditions associated with this flood. According to the USGS in a discussion of one of their flow measurements, their slope area approach yielded a peak flow of 25,700 cfs while a peak stage indicator yielded a flow of 24,400 cfs. The flow on the mainstem Skokomish on March, 1997 was listed provisionally as 37,000 cfs.

> The third time water came through was March of 1997. While this was not as large an event (24,400 cfs) as the 12/94 event enough bank had eroded away that the blockage was less than 100 feet from the river and the bank was significantly lower than it had been in the past since the land

> had sloped upwards as it approached the river. This allowed more water than ever before to hit the blockage which then went around and through the rocks.

He then describes the flow and ponding of water as well as for the first time in recent history, the overflow reconnected to the river farther downstream as shown on his figure. He describes ponding on the order of 2 feet deep and generally shallow flow without sufficient velocities to cause significant erosion damage on the flood plain.

Schriebers observations above have been corroborated by another Bambi Farms Road resident, Mr. Loren Lampley.

Vance Creek

There are several areas of potential concern on Vance Creek where abrupt bends in the path of the river are located and where constrictions in the channel may occur due to bridges. Just as Vance Creek flows out of the mountainous zone, it flows under a bridge. Just downstream of the bridge a short distance, Vance Creek makes an abrupt right-hand bend. There are some roads in this vicinity that could serve as a cleared path of potential overflow in the direction of the momentum of flow in the vicinity of the bend. As indicated by the geomorphic analysis showing the tendency for coarse material to deposit in the transition area between the production zone and the transfer zone, coarse sediment tends to deposit in this portion of Vance Creek. Skillings~Connolly observed on a tributary of Vance Creek, that a culvert had been plugged by the deposition of coarse sediment in this area, confirming the concepts of the geomorphic analysis applied to this particular location. Due to additional constriction as coarse sediment deposition or blockage due to debris, overflow from Vance Creek could occur and follow existing roads into the forest along the direction of the momentum of flow before the sharp bend (bend 1). The momentum of the flow at bend 2 would take any overflow into the valley wall that would force the water back into the channel. At bend 3, however, the momentum of any overflow would tend to flow southward across the valley if there was any gradient in that direction. Bend 4, located upstream of a bridge, presents an opportunity for any overflow to flow eastward, down the valley. Any constriction, backwater, or blockage at the bridge would exacerbate this condition. At bend 5, there does not appear to be any significant chance for flow to leave the channel without it again being forced back into the channel by the southern valley wall. Bend 6 is located upstream of another bridge. Again, any backwater, constriction, or blockage by debris would increase chances for flow to leave the channel and flow in a southeasterly direction down the valley between the road and the southern valley wall. Some overflow occurred this past year that flowed down the valley with sufficient force to erode pavement from the road to the trout hatchery.

3.0 Hydraulic Analysis

Cross-section surveys of the South Fork and Vance Creek were conducted by Skillings~Connolly in May 1999. Some preliminary discussion of the results of the survey is presented prior to the hydraulic analysis. Cross-section locations are shown on Figure 6.

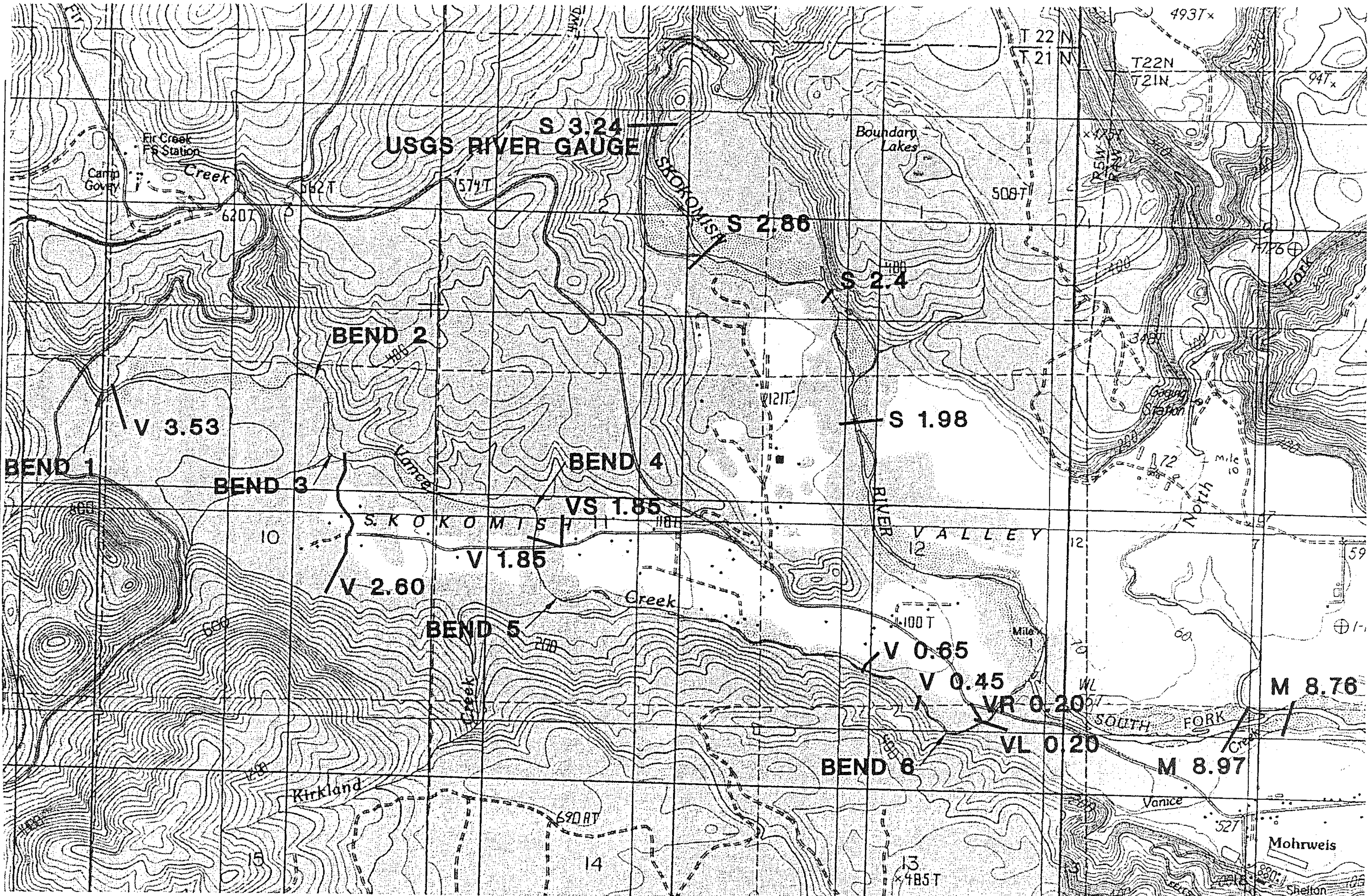
3.1 South Fork/Mainstem Skokomish River

Cross-sections were surveyed at the following locations on the South Fork at mile: 2.86, 2.39, 1.98, and on the mainstem Skokomish River at mile 8.97 and 8.76. The mileage designations come from a previous survey conducted by Simons & Associates in 1992. At mile 2.86, the bank to bank top width of the South Fork is almost 800 feet with a maximum cross-sectional depth of about 6.4 feet (comparing thalweg to the lowest bank height). The river narrows considerably at mile 2.39 in the vicinity of the red cliff. At this location the top width is about 250 feet with a depth of about 6.5 feet. At mile 1.98, the river again widens to a width of about 700 feet with a depth of about 5.5 feet. On the Skokomish River at mile 8.97, the width is about 840 feet and a depth of about 11.7 feet. Just downstream at mile 8.76, the width is about 420 feet with a depth of about 5.5 feet. A discussion of cross-sectional changes is found in Appendix A.

The cross-section surveys reflect the relatively wide channel that exists on the South Fork upstream of the red cliff where significant bank erosion has been experienced over recent years. They also show that a significant constriction occurs at mile 2.39. Although erosion has occurred along the south bank of the South Fork, most of this erosion occurred upstream of mile 2.39. This area remains much narrower than the river either upstream or downstream of this area in this reach of the South Fork. This part of the South Fork (the narrow area in the vicinity of mile 2.39 and the red cliff) serves as hydraulic control for the cross-sections upstream from this location. This means that the water levels upstream of this location are controlled to a significant degree by this area of the river. Farther downstream of the red cliff, the river again widens and is more free to adjust laterally without significant constraint.

Hydraulic analysis shows that the flow is well contained within the South Fork channel at the USGS gage at mile 3.24. In going downstream, however, the channel size and slope dictate that high flows approach and exceed bank height in the vicinity of mile 2.8 and for most of the rest of the South Fork down to the mainstem, where overbank flooding continues. The flow accelerates as it approaches mile 2.39 where a relatively high spot in the bed profile exists that provides hydraulic control to upstream reaches and lateral constriction due to the narrowing at the red cliff.

The 100-year flood peak exceeds the capacity of the South Fork channel. In addition, there are several overflow paths that are fed by low areas in the river banks which allow high flows to spill on to the floodplain at lower magnitudes of flow than



RIVER CROSS-SECTION LOCATIONS

FIGURE 6

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the channel in general. Given that aggradation has been occuring and is expected to continue in the future, both from upstream sources and local landslide activity, the hydraulic conveyance capacities are expected to continue to decrease over time with a commensurate increase in overbank flooding.

3.2 Vance Creek

On Vance Creek, the hydraulic analysis shows that overbank flows would be expected for a range of high flow conditions along much of the river. The bridge sections, however, appear to provide adequate conveyance capacity at this time, assuming no blockage due to woody debris or significant aggradation occurs. Similar to the South Fork, the 100-year flood peak exceeds the capacity of the Vance Creek channel. Likewise, low bank areas will allow flow to spill overbank in several areas at lower magnitudes of flow than the channel in general. Aggradation is also expected to decrease the capacity of Vance Creek to convey flood flows in the future.

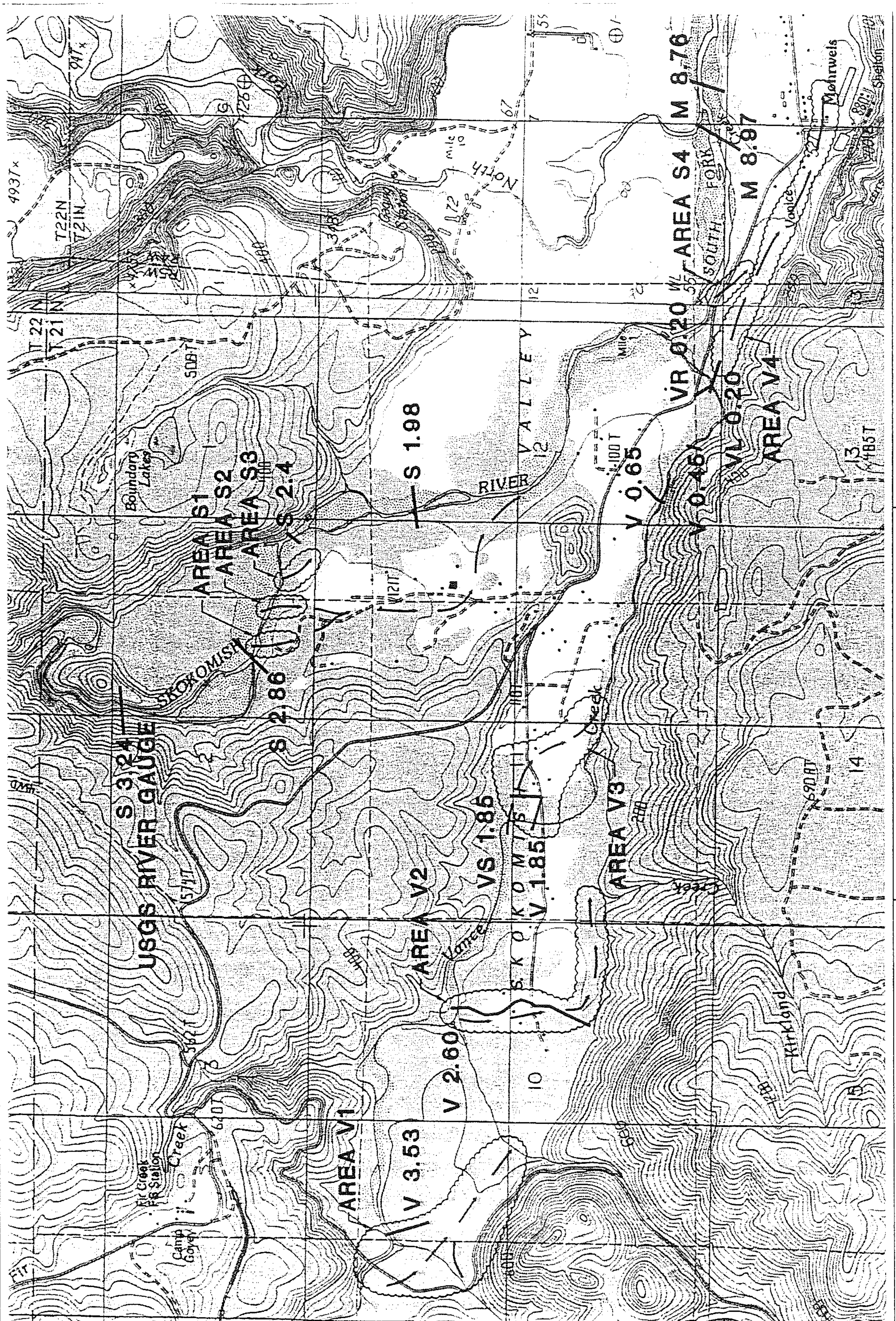
4.0 Possible Avulsion Locations

Figure 7 pictorially shows the locations of possible avulsion locations. It must be pointed out that the Upper Skokomish River System is aggrading at an accelerated rate due to the increased supply of sediment and the decrease in slope of the river bed in the downstream direction; furthering the possibility of avulsions which may route the South Fork and Vance Creek tributaries to new locations on lower ground within their respective river valleys. Also, Vance Creek has become perched (the river bed is higher than the surrounding valley floor) in a portion of its upper reach, which also furthers the probability of avulsions.

4.1 South Fork of the Skokomish River

There are at least three possible avulsion locations in the upper Bambi Farms Road reach of the South Fork (Approx. River Mile S-2.5 to 2.8, Areas S-1, S-2, and S-3 show on Figure 8) and one at the "dips" (Approx. River Mile S-0.6, Area S-4 also shown on Figure 8).

In the upper Bambi Farms Road area, the avulsion potential is largely brought about by the narrowing of the river at the "red cliff" area, just downstream (located approximately at river mile S-2.4). The possible avulsion locations originate at low bank areas, where flood waters have entered in at least the last three major floods, 11/91, 12/94, and 3/97 and at other historical times. The potential for avulsion will be greatest if a landslide in the active slide area in the "red cliff" area were to occur at the same time as a major flood event. The slide could block or partially block the river channel causing increased water surface elevations upstream, hence heighten overbank flows and/ or widening of the existing channel at the river bend opposite of



POTENTIAL AVULSION LOCATIONS

FIGURE 7

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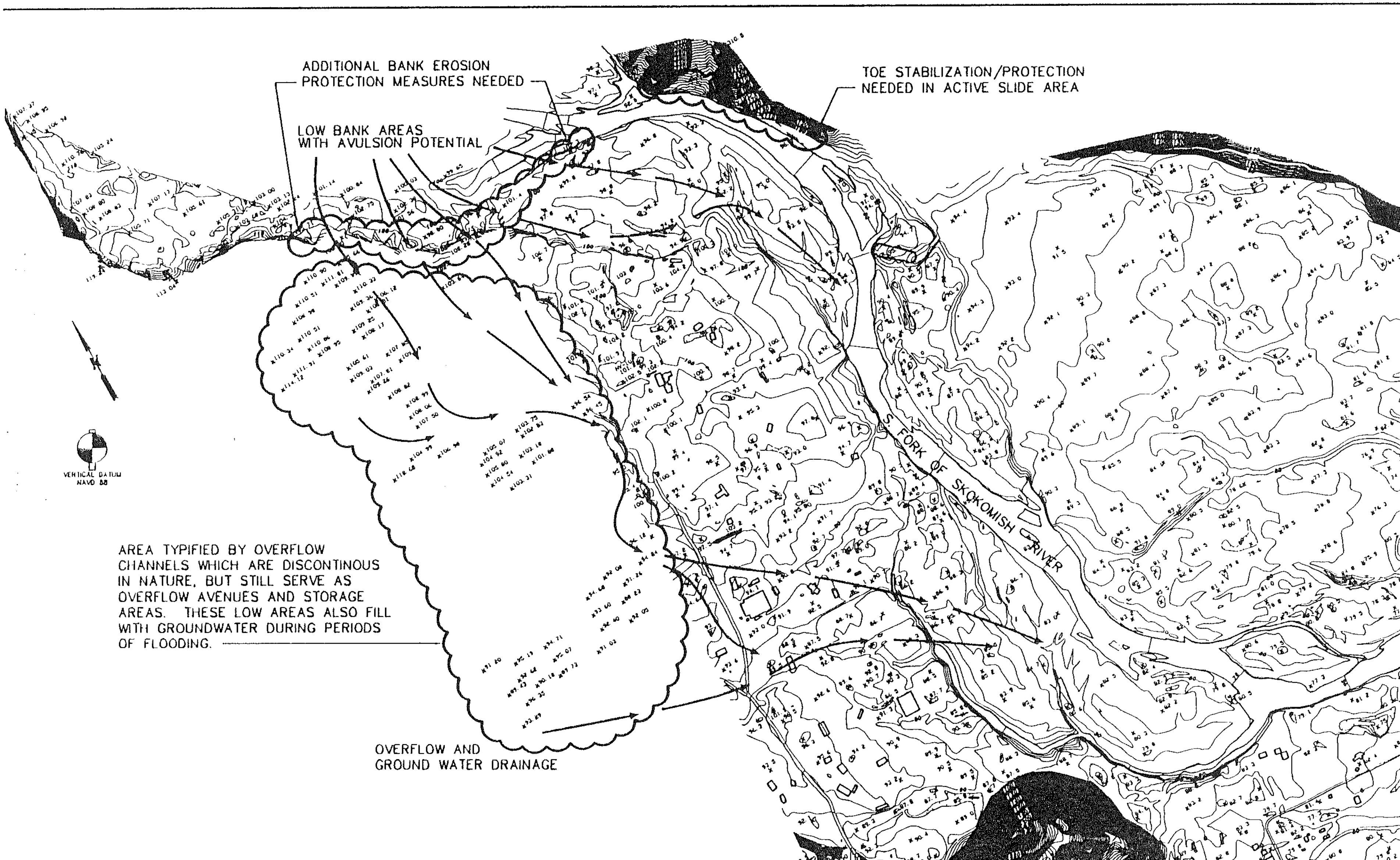
the "red cliff". The potential also remains for future overflows to occur during flooding. It is believed the potential is greatest nearer the "red cliff" since a significant constriction occurs at this location and the river will probably try to widen the existing channel before it will cut an entirely new channel further to the west. The old overflow channels located to the west will undoubtedly carry overflow waters, but due to their discontinuous nature and the existing vegetation, they probably will not facilitate sufficient velocities to achieve cutting a new river channel unless a long duration high flow event occurs and/or if headcutting occurs from the downstream end of the overflow starting where the over flow re-enters the South Fork. These overflow channels will also continue to fill with groundwater during periods of heavy rainfall causing ponding and subsequently channeling of the runoff. Based on Schreiber's analysis of historic overflows, there is a path for the water to return to the river. Such a path typically provides a pilot channel that can erode, expand, and sometimes headcut in the upstream direction; connecting it back as far upstream as the beginning of the overflow.

The avulsion potential at the "dips", Area S-4 was assessed in our previous study, and will be addressed again in this report. This area remains as the first location where the South Fork overflows its banks during periods of flooding. The overflows proceed in a southeasterly direction, causing Swift Creek (shown as Vanice Creek on the USGS Base Map) to overflow its banks, and continue southeasterly between Skokomish Valley Road and the Trout Hatchery, entering the Weaver Creek drainage, eventually overflowing to Purdy Creek, and re-entering the main Skokomish River below Highway US-101. During recent flooding, sufficient velocities of over flow were observed by some in the valley to have lifted and removed the asphalt pavement from the access road to the Trout Hatchery south of the Skokomish Valley Road (observation of this damage was confirmed by Skillings~Connolly on one of the visits to the study area). If such velocities were to remain in effect over an extended period a new channel could be formed.

4.2 Vance Creek

At Area V1 the avulsion potential is largely dependent on maintenance of the waterway opening under the bridge where the 800 Road crosses Vance Creek. If this opening were to be blocked the Creek would be forced to find a route around it. Based on a review of the topography, the water could proceed around the southern approach and may not re-enter the existing channel, but could follow the existing road and old logging roads in a southeasterly direction towards the southerly valley wall and points east. It was noted that a tributary creek south of the bridge, which has historically crossed under the 800 Road in a culvert, has been plugged by sediment. Overflow water will seek the path of least resistance and typically follows old roadways gaining enough velocity to cause significant erosion, if not a new channel. These old roadways should at least be water barred to keep velocities down, and consideration should be given to an even more substantial barrier such as an erosion protected earth berm. If the bridge opening is kept open Vance Creek is expected to stay in its present channel in this area for the foreseeable future. The



SOUTH FORK SKOKOMISH RIVER
BAMBI FARMS AREA
FIGURE 8

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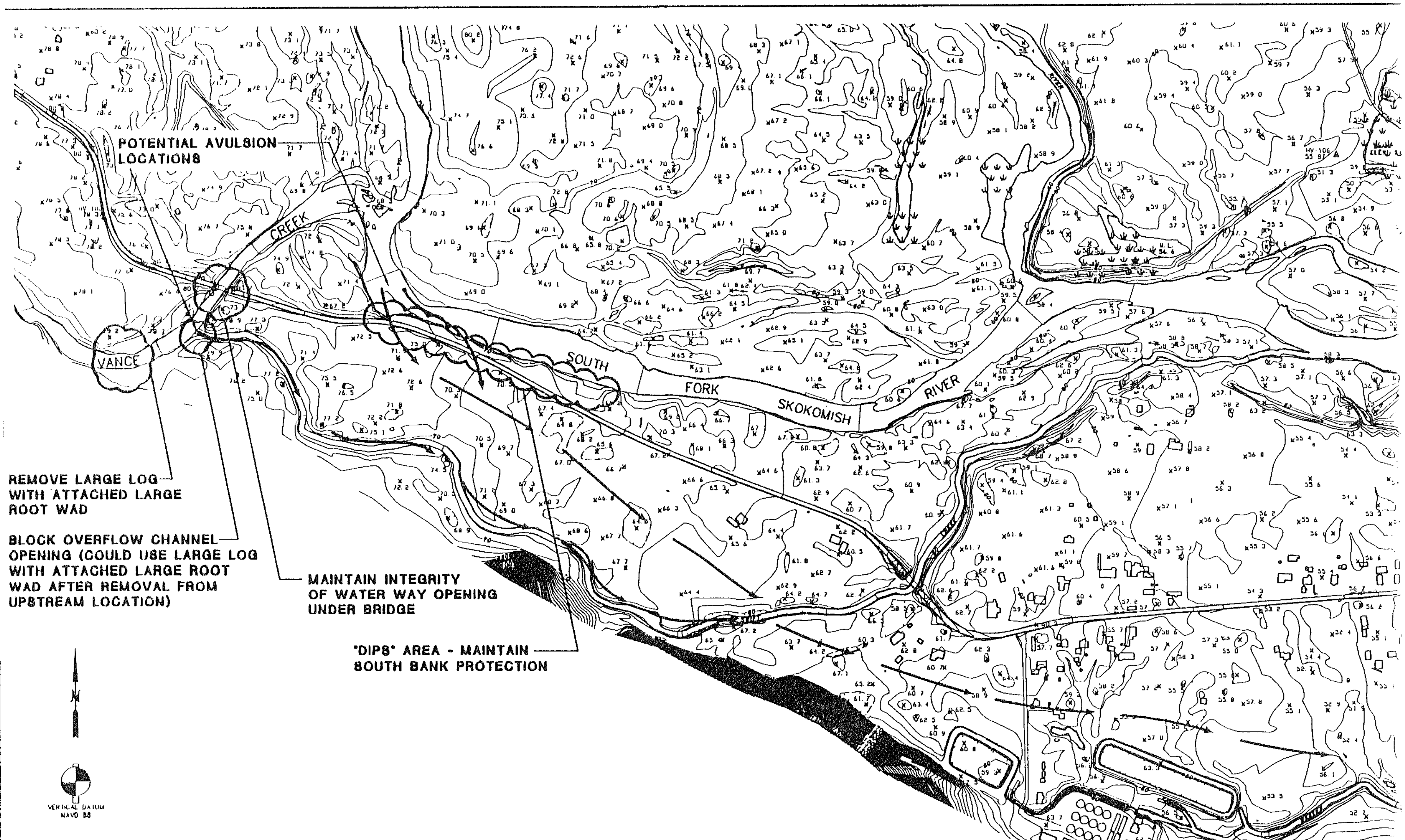


LOWER SOUTH FORK SKOKOMISH RIVER "DIPS" AREA FIGURE 9	Skillings - Connolly Inc. Consulting Engineers CIVIL TRANSPORTATION ENVIRONMENTAL	MASON COUNTY DEPT. OF COMMUNITY DEVELOPMENT AND WASHINGTON STATE DEPT. OF ECOLOGY FCAAP GRANT NO. G9900204

existing channel is quite wide with high banks and no existing slides to provide blockages. Area V2 presents an interesting situation. Vance Creek is perched in this location (the Creek bed is higher than the flood plain to the south). Based on observation, there is ample south bank height to contain recent flood flows, however, there are active slides on the north bank just downstream. If these slides were to cause a blockage and the water were to overflow the south bank, it would very likely continue southerly or southeasterly to the south valley wall and points east. If these flows lasted for an extended period, a new channel could be formed by the erosion process.

At Area V3 an avulsion is already beginning. The east bank of the Creek has been breached, just where the Creek takes a sharp bend to the south and upstream from the bridge at approximate River Mile V 1.8. A channel has been eroded to the east, which is several feet deep and continues until it daylights and flows out over the field to the southeast. Left unattended this erosion will undoubtedly continue and could cause rerouting of the Creek where it crosses Skokomish Valley Road. To keep the Creek in its present location and crossing under Skokomish Valley Road at the present bridge site, the breach must be repaired.

The scenario at Area V4 is quite precarious. There is a very large log with root wad attached laying across part of the Creek bed several hundred feet upstream from the bridge at approximate River Mile V 0.18. This log could block the waterway opening under the bridge, if it floated up against it during flood flows. It should be removed. If water flowing under this bridge is impeded in any way, the overflow will undoubtedly proceed to the east in the existing overflow channel, join overflows from the "dips", and proceed easterly as described above in the S4 paragraph and also shown in Figure 9. The existing overflow channel on the east bank above the bridge should also be blocked to alleviate avulsion potential at that location. The large log with root wad that should be removed from Vance Creek and could be utilized to block the opening for this existing overflow channel on the east bank.

5.0 Recommendations

5.1 Continue Moratorium

Mason County should continue their existing moratorium for the Zone A floodplains of the Skokomish River, including the South Fork and Vance Creek drainages. The County should also consider expanding the moratorium to include those additional areas subject to flooding and/or avulsions as described in this report. Additional mapping would be required to specifically detail the limits of this expanded area. The rationale for this position is that there is a general tendency for the South Fork and Vance Creek to aggrade, especially since there is a significantly increased supply of coarse sediment being produced by the upstream watersheds compared to natural conditions. There is also considerable woody debris being produced by the upstream watersheds that can block and divert flow, and there are existing landslides that can potentially block and divert the channels in several locations. There is substantial risk associated with living within these flood zones and adjoining areas subject to flooding and/or avulsions.

5.2 Mitigation Measures

There are appropriate mitigation measures that should be taken that may be able to alleviate the current conditions at locations shown in the drawings contained in this report. These are discussed below:

1. Additional protection is needed beyond the end of the Bambi Farms Road along the southerly bank of the South Fork from about River Mile S2.5 to S2.8. Specific attention should be directed to the low bank areas and to locations where previous erosion has occurred and where overflow begins to occur from the river onto the flood plain. If woody material is used, it should be secured with cables or other methods to prevent it from floating away during flood flows.
2. The toe of the active slide in the vicinity of the "red cliff" on the South Fork near River Mile S2.4 should be protected to prevent further erosion and exacerbation of the slide area. Consideration should be given to stabilize the active slide areas above the toe protection as well as to alleviating drainage issues from upslope areas that may contribute to destabilizing the slide area. Toe protection and stabilization of other slide areas discussed in the report should also be done.
3. We had considered a recommendation to widen and deepen the South Fork channel at a point of constriction in the vicinity of mile 2.4 to reduce the hydraulic control at this point, thereby reducing upstream water levels; however, due to likely downstream impacts, we no longer recommend such action..
4. The old roadways downstream from the 800 road in Area V1 should at least be water barred to keep velocities down, and consideration should be given to even more substantial barriers such as erosion protected earth berms.
5. Repair the breach at the east bank of Vance Creek just where the Creek takes a sharp bend to the south and upstream from the bridge at approximate River Mile V 1.8. Left unattended, this erosion will undoubtedly continue and could cause rerouting of the Creek where it crosses Skokomish Valley Road. To keep the Creek in its present location and crossing under Skokomish Valley Road at the present bridge site, the breach must be repaired.
6. Remove the large log with attached large rootwad from its location on Vance Creek just upstream from the Bridge at approximate River Mile V0.18. The existing overflow channel on the east bank above the bridge should also be blocked to alleviate avulsion potential at that location. The large log with root wad that should be removed from Vance Creek could be utilized to block the opening for this existing overflow channel on the east bank. This log and/or rootwad could be used to assist with repair of the breach at the east bank described in the previous paragraph.

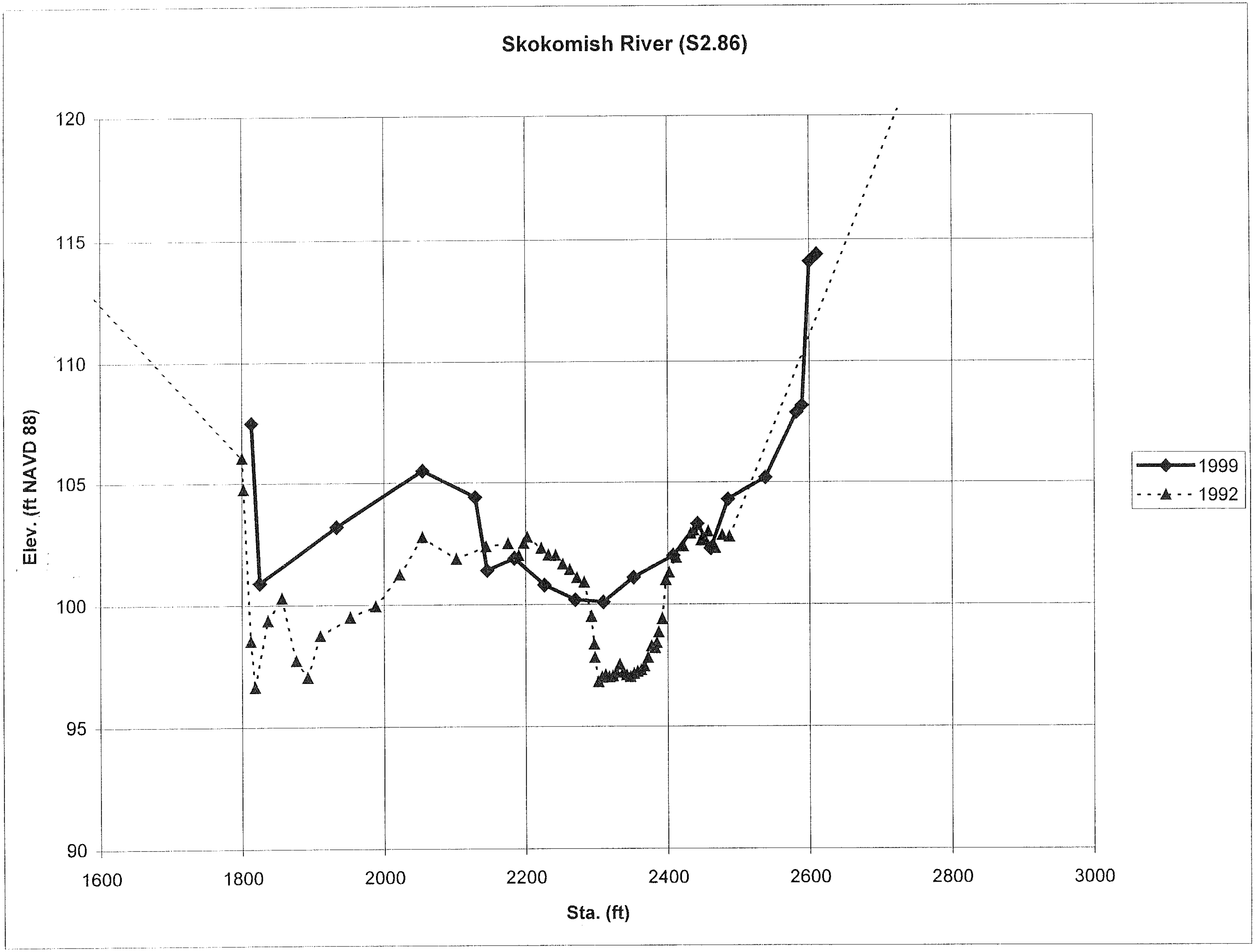
7. Maintain the armor protection of the south bank of the South Fork at the "dips"(approximate River Mile S0.6). Maintenance of this bank protection is imperative to preventing an avulsion at this location. Additional bank protection may be required as a part of this maintenance.
8. Consider trapping and removing coarse sediment from the upstream sections of the South Fork and Vance Creek to reduce aggradation and flooding.

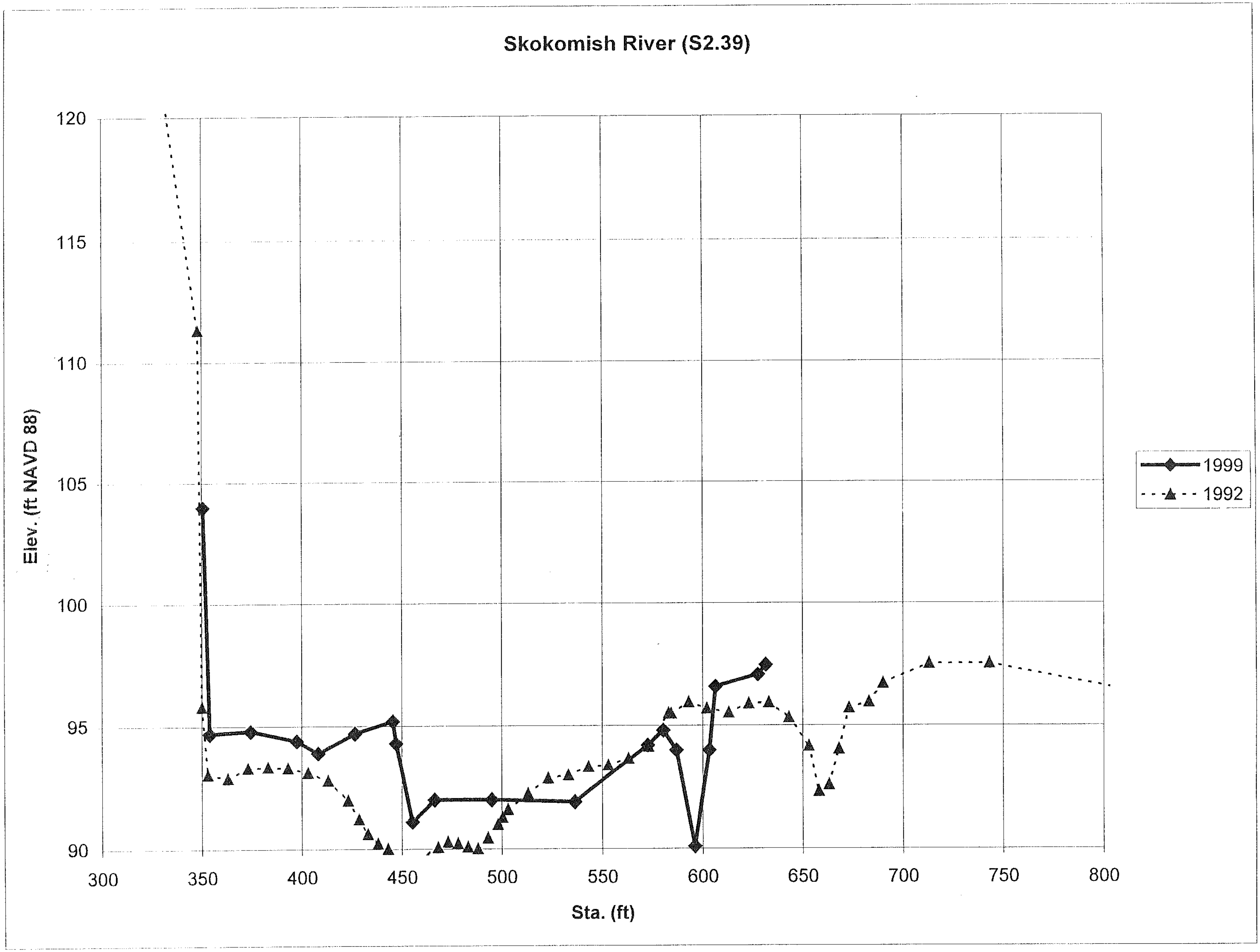
5.3 Continuing and Future Actvities

1. Monitor the progression of riverbank erosion, cross-sections, condition of erosion protection works, and landslides periodically in the future to re-evaluate conditions as they change. Several permanent cross-section locations should be established and monumented. These monuments would insure measurements could readily be taken to monitor scour or aggradation and hydraulic capacity of the channels. These cross-sections should be measured at least every two years to establish trends and rates of scour or aggradation.
2. The geomorphology and potential avulsions analysis conducted and reported above relied on available data as well as some limited survey of specific areas. While some fairly detailed mapping exists of the floodplain for significant portions of the Skokomish River, the upper reaches have not been adequately surveyed to provide sufficiently detailed information to better define areas of potential hazard. In addition, detailed analysis of the potential for flooding based on a more complete database has not been conducted. The following steps are proposed for consideration in better defining flood and avulsion hazard areas along the South Fork and Vance Creek.
   - Conduct a floodplain survey of missing areas not yet surveyed.
   - Conduct a detailed riverbank survey to define all low bank areas that have potential for overflow, as well as defining some additional river cross-sections at key locations.
   - Apply geomorphically correct terrain modeling procedures to develop an appropriate set of topography for detailed modeling of potential flooding.
   - Conduct detailed hydraulic modeling using refined data to better define flood hazard areas.
   - Refine geomorphic analysis based on the updated data and hydraulic modeling.

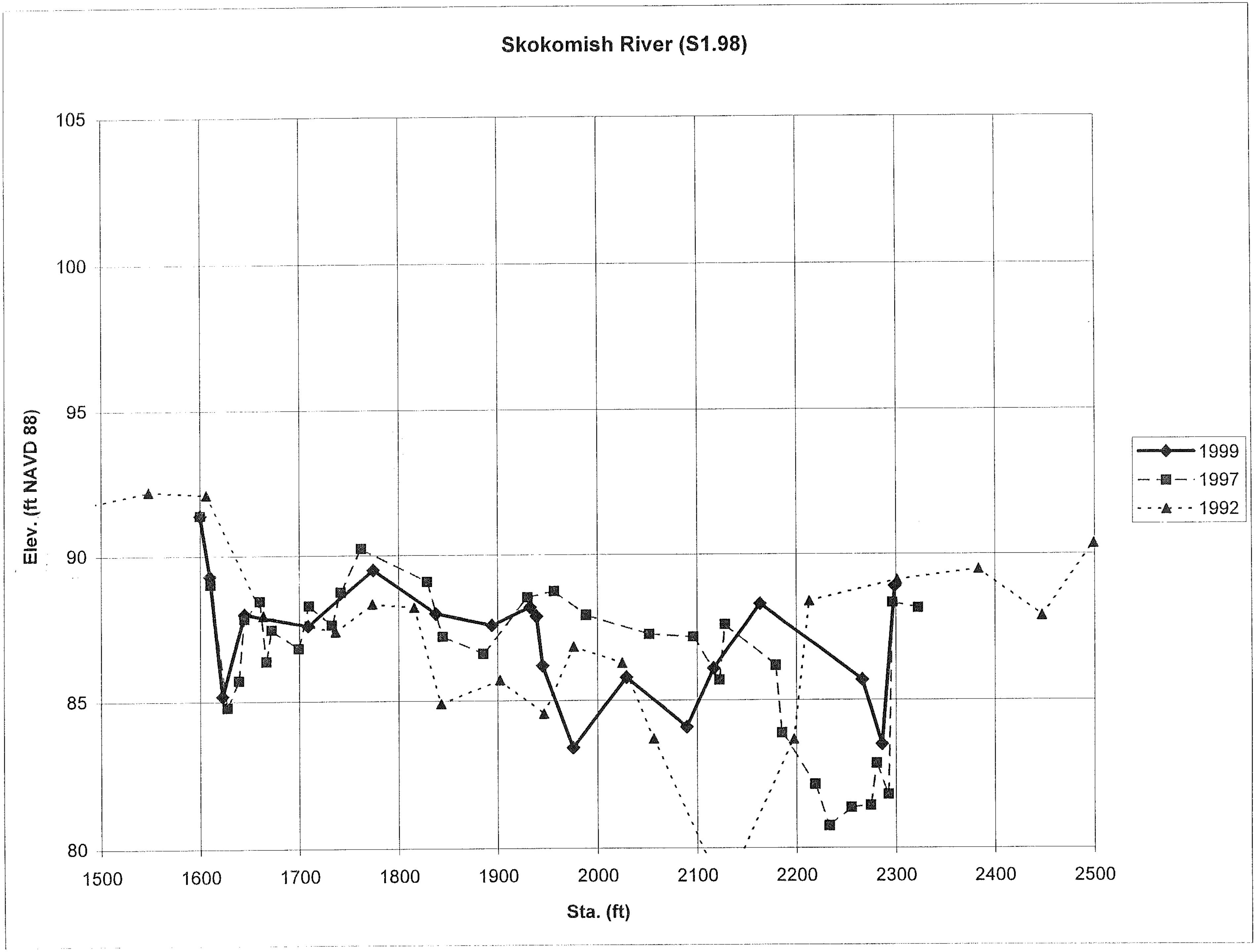
Appendix A

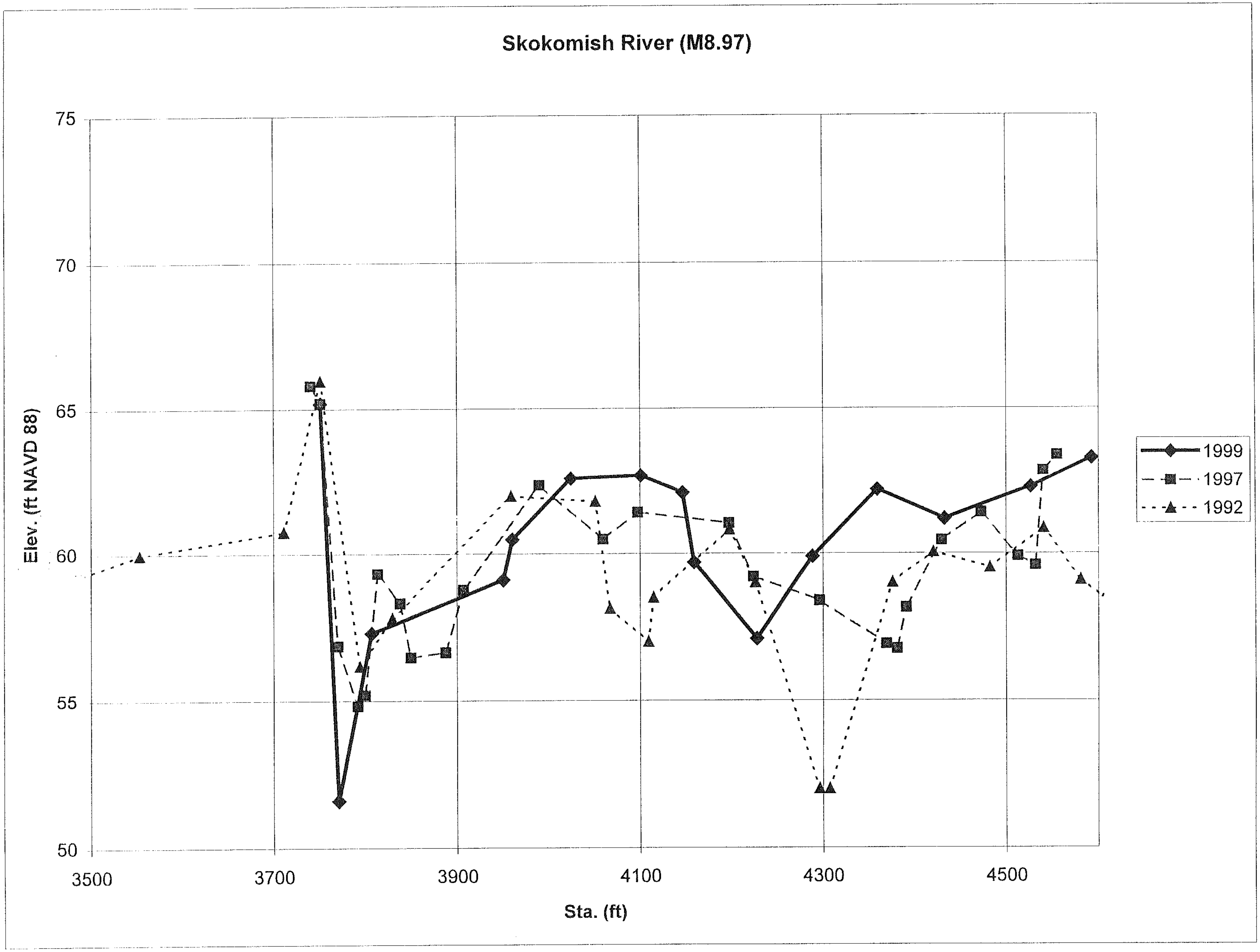
Survey data collected at several cross-sections in the South Fork and mainstem Skokomish River allow some limited comparison of changes from 1997 to 1999. Graphs of the cross-sections showing the visual comparisons are presented in this appendix. From 1997 to 1999 the maximum aggradation calculated from the data was 0.86 feet. The average aggradation during this time period was 0.33 feet. These data indicate a general trend of aggradation is continuing along the South Fork and mainstem Skokomish River during the time period from 1997 to 1999. These values should be considered as approximations only, as they are based on a very limited set of data.


Skokomish River (S2.86)
120
115
110
105
100
95
90
1600
1800
2000
2200
2400
2600
2800
3000
Elev. (ft NAVD 88)
Sta. (ft)
1999
1992

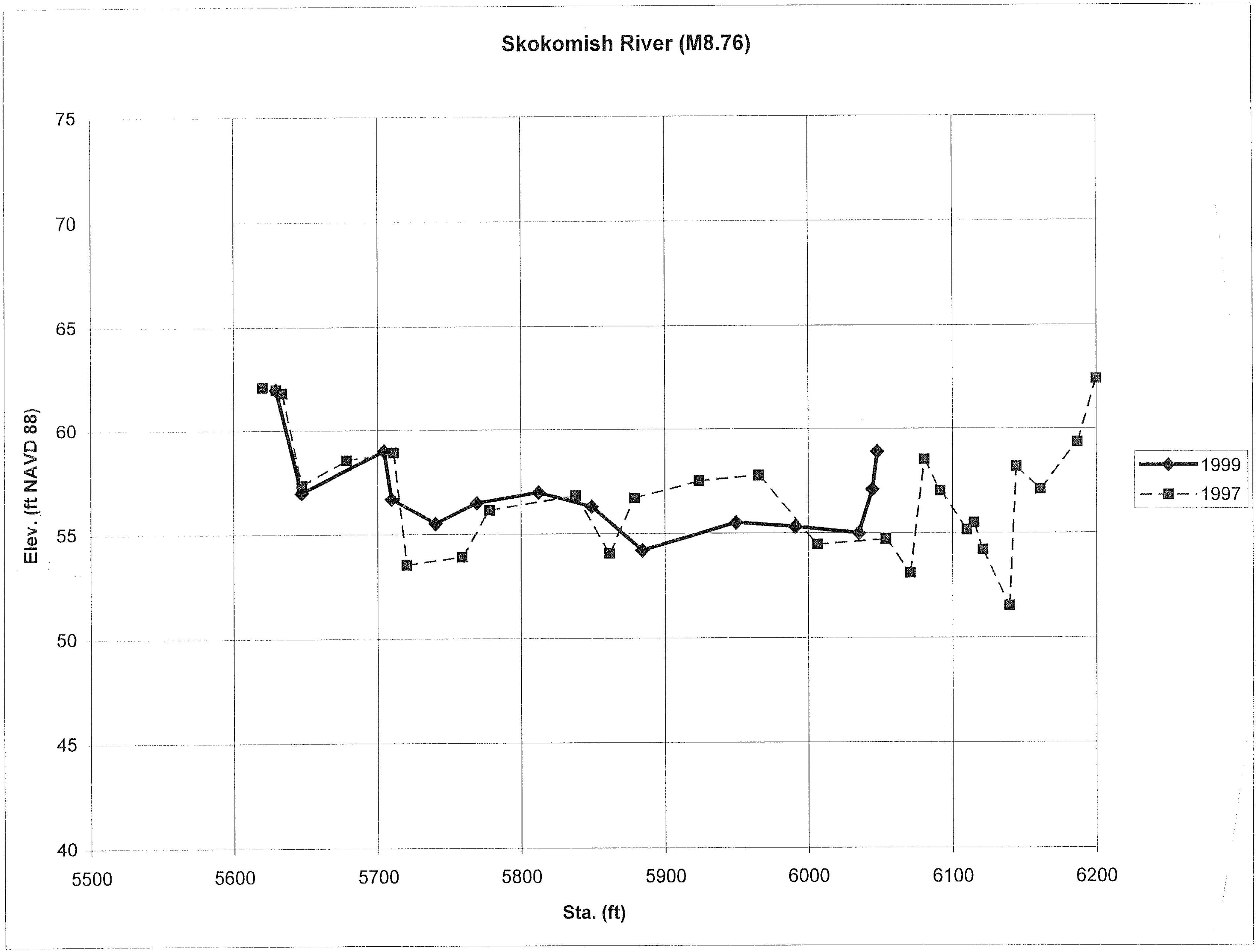


Skokomish River (S2.39)
Elev. (ft NAVD 88)
120
115
110
105
100
95
90
300
350
400
450
500
550
600
650
700
750
800
Sta. (ft)
1999
1992


Skokomish River (S1.98)
105
100
95
90
85
80
Elev. (ft NAVD 88)
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
Sta. (ft)
1999
1997
1992

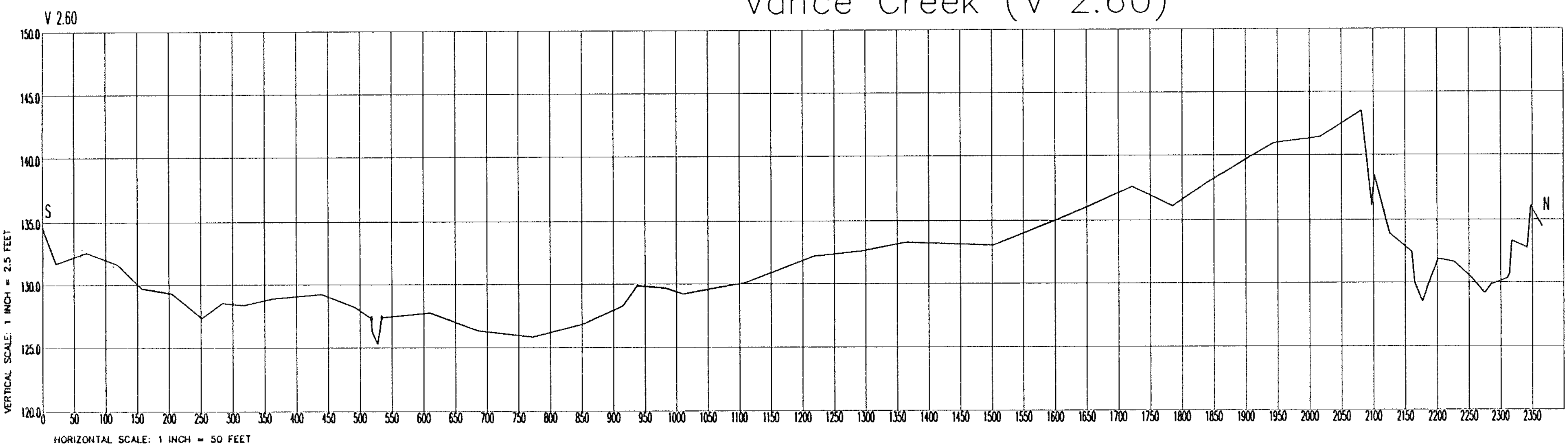


Skokomish River (M8.97)
Elev. (ft NAVD 88)
75
70
65
60
55
50
3500
3700
3900
4100
4300
4500
Sta. (ft)
1999
1997
1992

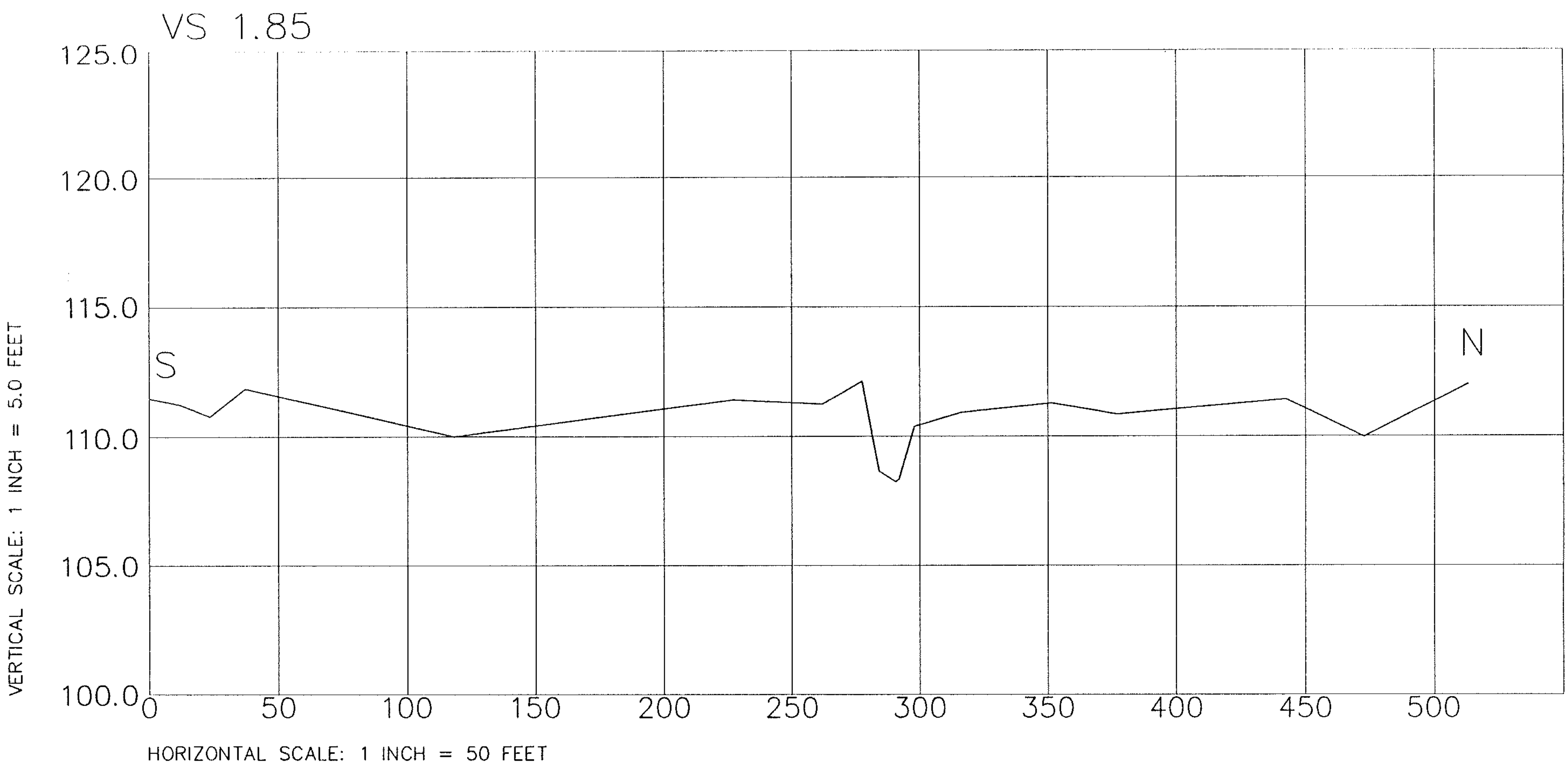


Skokomish River (M8.76)
Elev. (ft NAVD 88)
Sta. (ft)
75
70
65
60
55
50
45
40
5500
5600
5700
5800
5900
6000
6100
6200
1999
1997

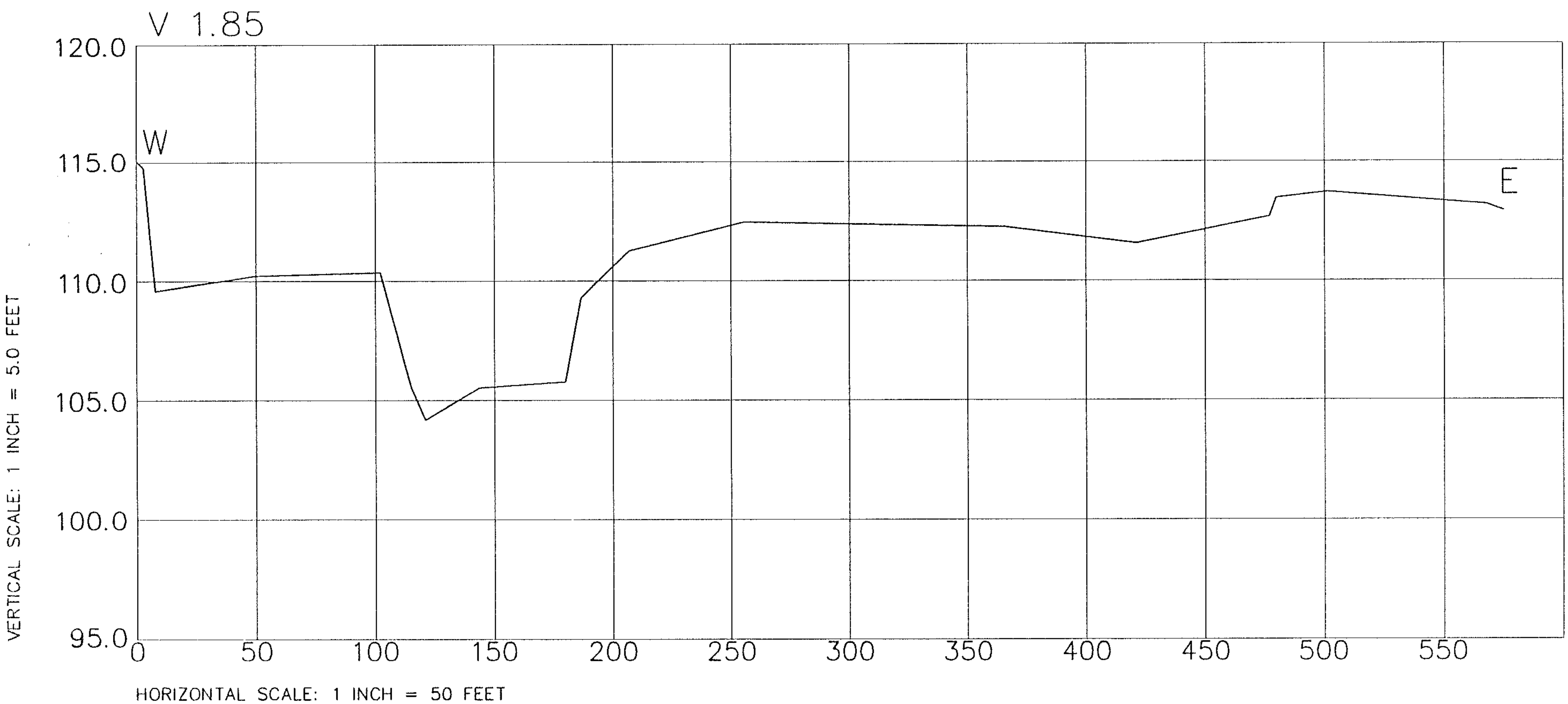
Vance Creek (V 2.60)



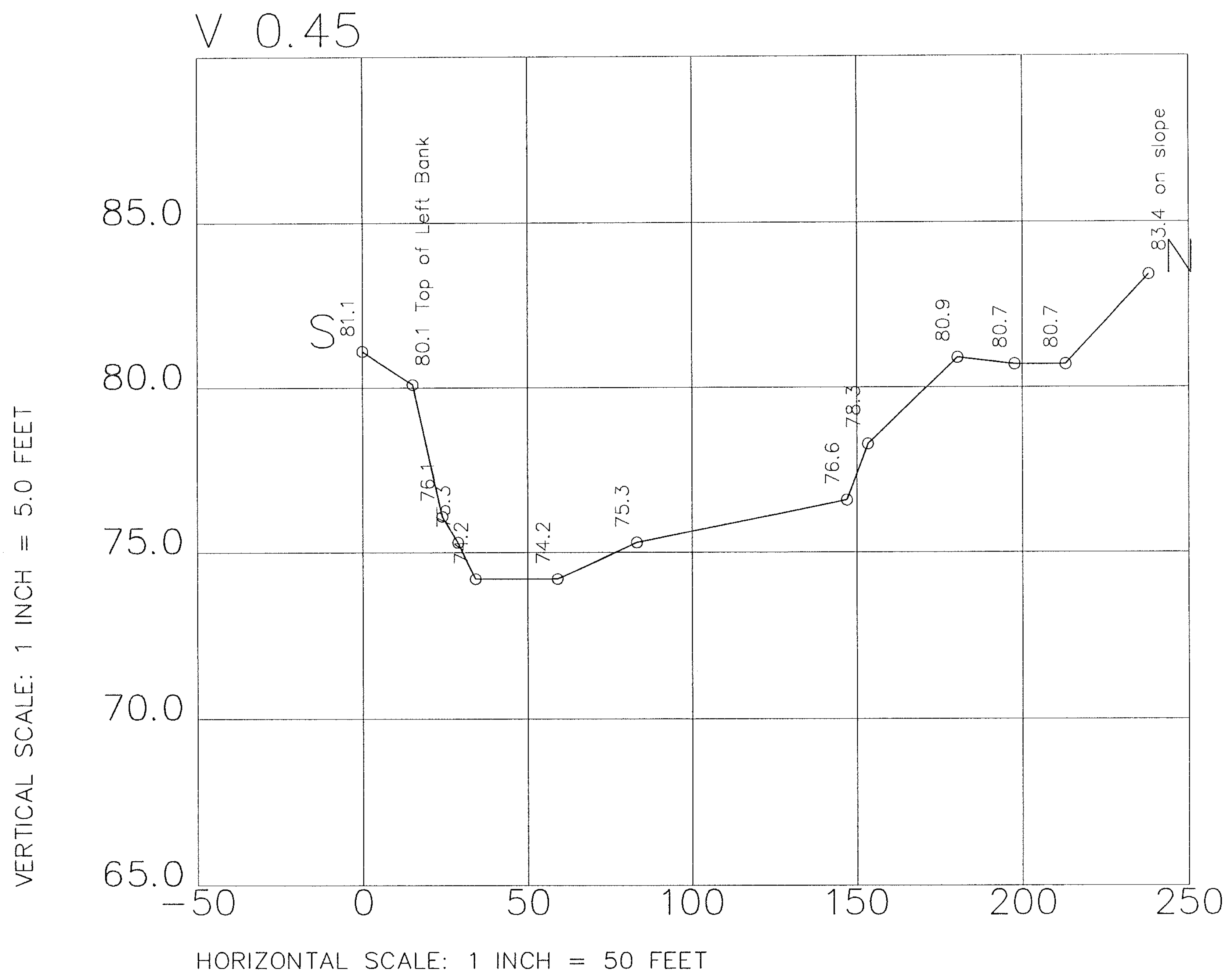
Vance Creek (VS 1.85)



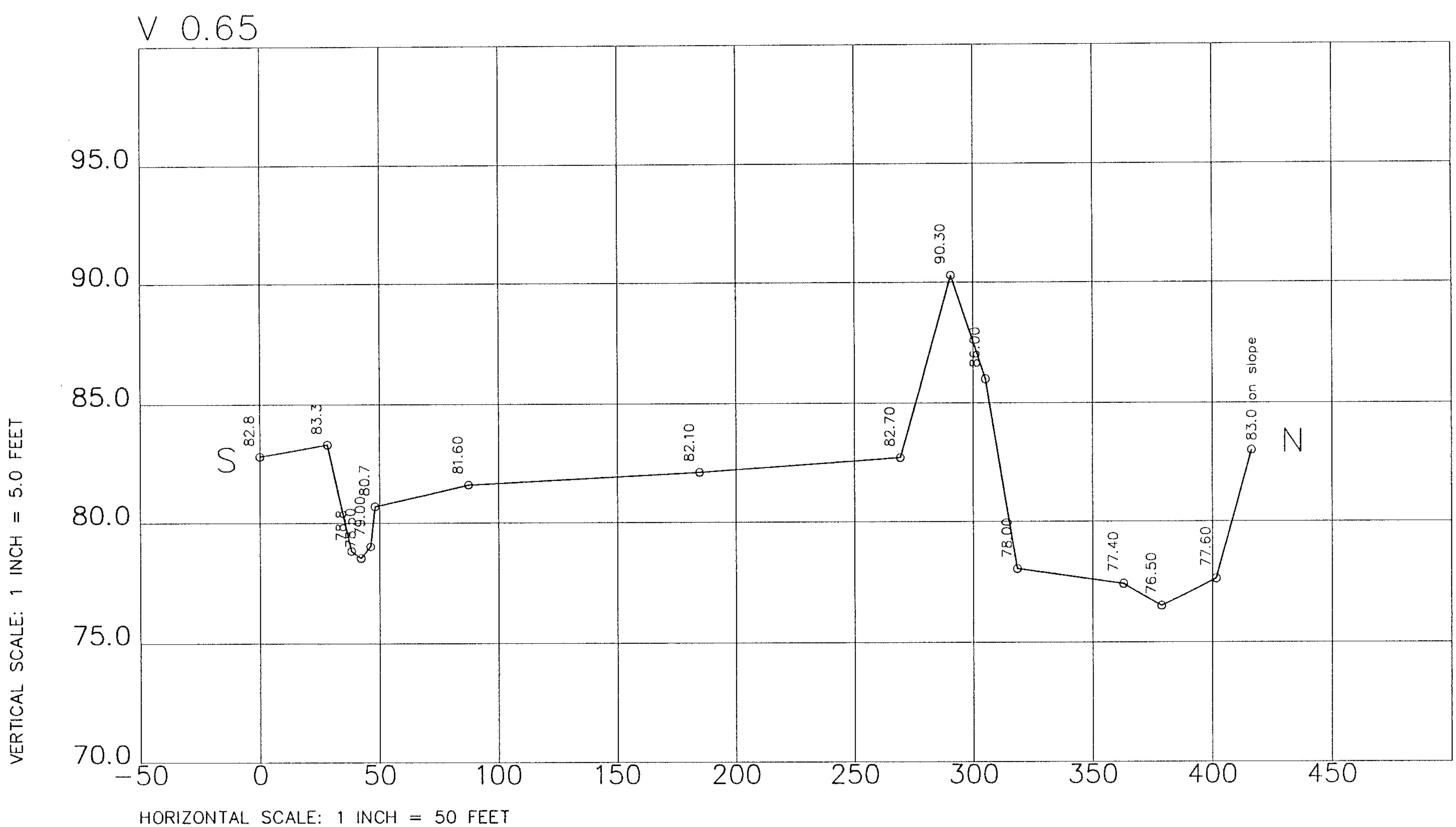
Vance Creek (V 1.85)



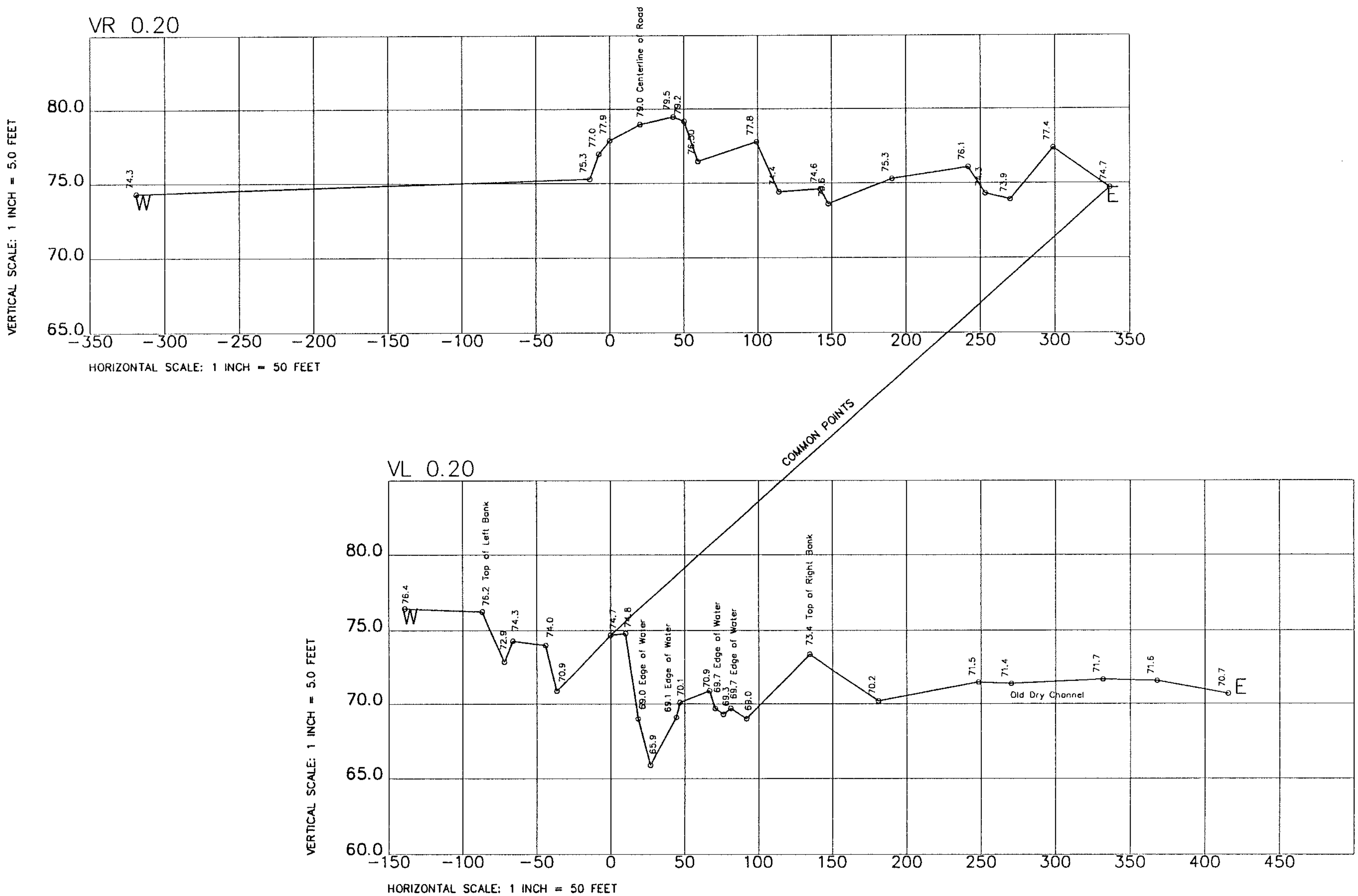
Vance Creek (V 0.45)



Vance Creek (V 0.65)

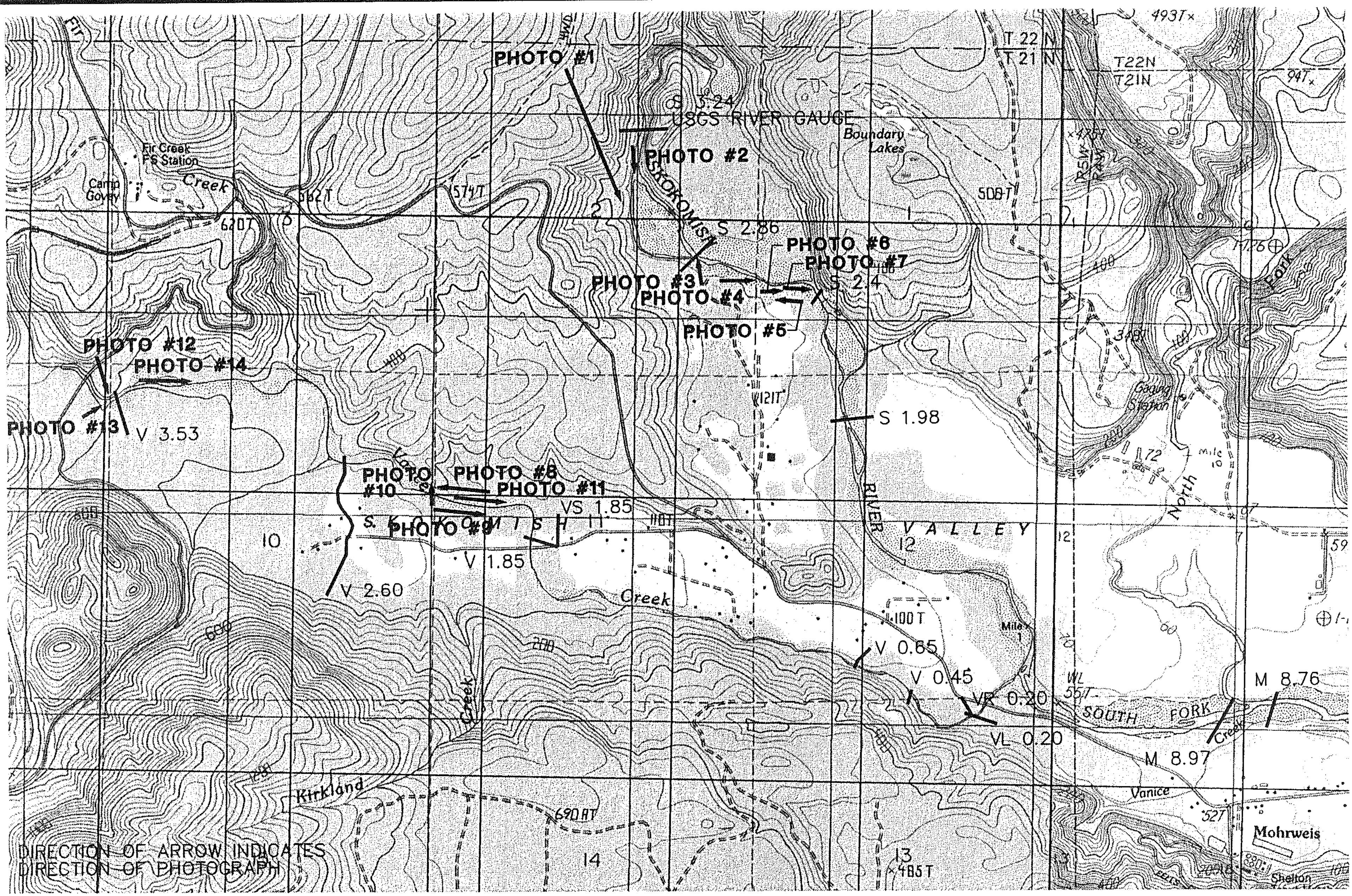


Vance Creek (VR 0.20 and VL 0.20)



Appendix B

Photographs taken during the Study period in May and April 1999 follow:



PHOTOGRAPH LOCATIONS

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PHOTO – 1: South Fork Skokomish River – McKay Flats
looking southeast between RM-S 2.36 and RM-S 3.18

PHOTO – 2: South Fork Skokomish River – Where River
comes out from the canyon approximately at RM-S 3.18 –
Log Jam on the right

PHOTO – 3: South Fork Skokomish River – Terry Bence's property at approximately 500 feet from RM-S 2.86 looking upstream

PHOTO – 4: South Fork Skokomish River – Terry Bence's property at approximately 500 feet from RM-S 2.86 looking downstream

PHOTO – 5: South Fork Skokomish River – Tom Schreiber's property at approximately 500 feet from RM-S 2.4 looking upstream

PHOTO – 6: South Fork Skokomish River – Tom Schreiber's property at approximately 500 feet from RM-S 2.4 looking downstream

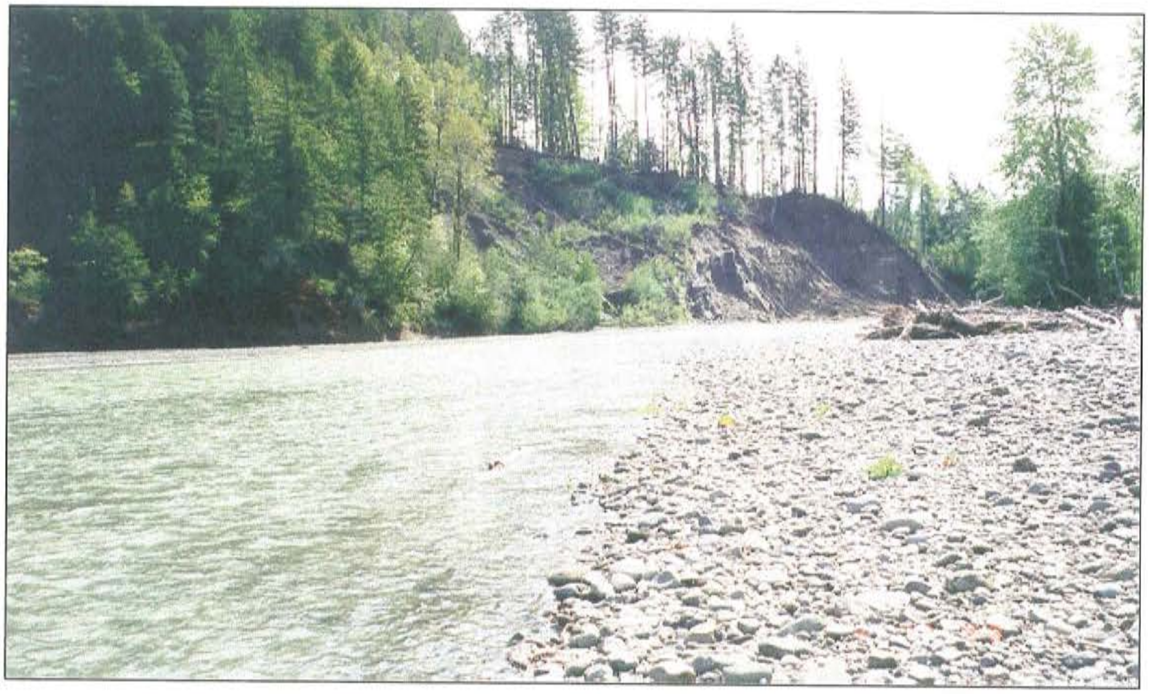

PHOTO – 7: South Fork Skokomish River – Tom Schreiber's property at approximately 500 feet from RM-S 2.4 at pointout on bar, looking downstream. Red cliff and active slide downstream is in the background.

PHOTO – 8: Vance Creek – Robinson & Godding's property looking upstream from high bank towards slide between RM-V 2.03 and RM-V 2.20

PHOTO – 9: Vance Creek – Robinson & Godding's property
looking downstream from high bank between RM-V 2.03 and RM-V 2.20

PHOTO- 10: Vance Creek – Robinson & Godding's
property upstream slide face across river between
RM-V 2.03 and RM-V 2.20

PHOTO – 11: Vance Creek – Robinson & Godding's property looking downstream from channel edge between RM-V 2.03 and RM-V 2.20

PHOTO – 12: Vance Creek – RM-V 3.53 at cross section location: Note bank height

PHOTO 13: Vance Creek – RM-V 3.53
looking downstream

PHOTO – 14: Vance Creek –
approximately RM-V 3.4 looking downstream