

INVESTIGATION OF SEDIMENTATION
AND FLOOD CONTROL ON LAGACE CREEK
FINAL REPORT

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ABSTRACT

This study investigates the causes of sedimentation and channel instability on the Lagace - Pattison Creek fan. The overall objective of the study was to assess the feasibility of constructing sediment basins to protect against channel shifting and aggradation on the fan and to reduce aggradation on the Hatzic Slough flooding. It was found that the proposed sediment basins would have only limited effectiveness for reducing aggradation or flooding even for relatively small floods.

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1.0 INTRODUCTION

1.1 Problem Statement

Lagace Creek originates in the Douglas Forest 15 km northeast of Mission and flows southwards approximately 10 km before entering Hatzic Lake. Runoff from the creek and from adjacent Hatzic Slough is eventually discharged into the Fraser River through the Hatzic pump station and outlet works (Figure 1).

Lagace Creek has experienced persistent flooding problems over the last 50 years due to two main causes:

- channel aggradation and sedimentation on the Lagace - Pattison Creek fan (Figure 1);
- flooding on Hatzic Prairie and Lower Lagace Creek from the backwater of Hatzic Lake.

In the past five years, flooding has occurred in December 1979, December 1980, June 1981, July 1983 and January 1984.

In January 1985, the Water Management Branch, B.C. Ministry of Environment (MOE), requested Northwest Hydraulic Consultants (NHC) to investigate the flooding and sedimentation problems on Lagace Creek, and to provide conceptual designs for flood protection works and sediment control structures. Authorization to proceed with the study was received by NHC on January 23, 1985.

1.2 Terms of Reference

The overall objective of the study was to examine the feasibility of constructing sedimentation basins and ancillary training works to protect against channel shifting and flooding on the fan and to reduce sedimentation and flooding on the Lower Lagace Creek - Hatzic Slough floodplain.

Specifically, the objectives of the study were as follows:

1. To investigate the feasibility of constructing sediment basins to contain bedload and control channel instability on the Lagace - Pattison Creek alluvial fan for hydrological events up to the 200-year return period;
2. To investigate the feasibility of constructing sediment basins in conjunction or separate from 1. to reduce sedimentation and flooding on the Lower Lagace Creek - Hatzic Slough floodplain;
3. To assess the effect of the proposed works on reducing the duration of summer flooding on the Lower Lagace Creek - Hatzic Slough floodplain;
4. To estimate average annual bedload that will be trapped in the proposed basins and to comment on the viability of commercial extraction;
5. To provide preliminary cost estimates including right of way acquisition costs and probable annual maintenance costs of the basins.

2.0 METHOD OF APPROACH

2.1 General Approach

Flooding and sedimentation problems on alluvial fans are often difficult to solve and are not amenable to assessment with sophisticated mathematical modelling programs. However, engineering solutions to sedimentation problems can be achieved by using a combined geomorphic/river engineering approach to identify the main processes governing channel instability and sedimentation.

In this study two different flooding problems are considered:

- the channel instability and flooding on the fan;
- the summer flooding on Lower Lagace Creek - Hatzic Slough due to backwater from Hatzic Lake and sedimentation in Lagace Creek channel.

These problems will be discussed separately.

2.2 Flooding on Lagace - Pattison Creek Fan

Geomorphic studies were conducted to document the history of channel instability on the fan and to identify the major causes of rapid sedimentation. Field studies were conducted to assess site conditions and to collect bed material samples for grain size analysis.

A regional flood frequency analysis was carried out to estimate discharges for various return periods up to the 200-year flood. Hydraulic calculations were made to estimate channel properties and discharge capacities along the creek. These calculations were based on channel cross sections surveyed by the Ministry of Environment in July 1984.

Sediment transport rates were computed from theoretical equations to estimate annual volumes of bedload transport. Transport volumes for various flood conditions were also computed. These results were compared with estimates of historical aggradation rates on the fan.

Alternative sites for a sediment basin were identified and compared. Bedload transport calculations were repeated to estimate the trap efficiency of the alternative schemes and conceptual designs were prepared. The overall feasibility of the alternatives was then assessed.

2.3 Flooding on Lower Lagace Creek - Hatzic Slough

A regional hydrology analysis was carried out to develop summer (May 1 - August 31) flood inflow hydrographs for the lake and outlet works. It was assumed that during the summer period, high water levels in the Fraser River would prevent floodbox relief at the outlet of Hatzic Slough. Under these conditions, the outflow from the lake is governed by the discharge capacity of Hatzic pump station. The design inflows were routed through Hatzic lake to estimate the variation in lake levels during the summer floods.

Backwater calculations were then performed using the computer program HEC-2 to estimate flood profiles along the creek. The backwater calculations were repeated with modified bed evaluations to determine the sensitivity of the flood levels to amounts of sediment deposition in the channel. This allowed some conclusions to be drawn on the effectiveness of upstream sedimentation basins on reducing the duration of flooding on the floodplain.

3.0 FLOOD HYDROLOGY

3.1 Basin Characteristics

Lagace Creek originates in the mountainous Douglas Forest north of Dewdney Peak. Above its confluence with Pattison Creek, the stream drains an area of 11 km² with Pattison Creek contributing an additional 6 km². In the 7.5 km between Pattison Creek and Hatzic Lake, the drainage area increases from 17 km² to 54 km². Hatzic Lake and Hatzic Slough drain an additional 36 km² of uplands and low floodplain so that the area drained by Hatzic Slough totals 90 km².

The basin is almost entirely mountainous at the Pattison - Lagace Creek confluence. However, at Hatzic Lake, the basin consists of 61 percent mountains, 22 percent forest covered uplands and 17 percent flat-lying lowlands and floodplain areas.

500 - 1500
3400 - 1050
7760 - 2400

Most extreme floods have occurred in the months of December and January as a result of intense frontal precipitation. Rainstorm generated flooding has also occurred in the summer but is usually substantially lower in magnitude.

3.2 Winter Flood Hydrology

For the purposes of this study, winter floods include any events that occurred in the period between September 1 and April 30. There are no discharge measurements on Lagace Creek so that a regional analysis had to be carried out to generate flood flows. Table 1 summarizes the available Water Survey of Canada gauging stations that were used in the analysis. Although all selected stations have operated for more than 20 years there are no long-term stations available.

The following procedures were used to estimate flood discharges on Lagace Creek:

1. A flood frequency analysis was carried out for each station listed in Table 1 using the annual maximum daily flow in the period September 1 - April 30. All data were fitted to log-normal probability distributions;
2. The mean annual flood was computed for each station and an envelope curve of discharge versus drainage area was plotted;
3. A non-dimensional flood frequency relation was obtained by plotting the ratio of flood magnitude to mean annual flood for various return periods for each station.

Mean annual winter floods were estimated for two locations on Lagace Creek - downstream of the Pattison Creek fan and downstream of the Farms Road bridge (Figure 1). Maximum instantaneous discharges were estimated by multiplying the daily values by a factor of 2.5. Design hydrographs for estimating total sediment loads associated with a particular flood were developed by examining recorded hydrographs on other similar-sized streams during extreme floods in 1963, 1979 and 1980. The adopted flood hydrographs for return periods up to the 200-year flood are summarized in Figure 2 and Table 2.

The return periods associated with some of the recent winter floods in the Fraser Valley can be estimated from the discharges recorded on some of the nearby gauged streams. Based on measurements from Norrish Creek, Kanaka Creek and North Alouette River it appears that the 1979 and 1980 floods had return periods of roughly 25 years and 10 to 20 years, respectively.

3.3 Summer Flood Hydrology

Summer floods on Lagace Creek were estimated at Hatzic Lake and at Hatzic Slough pumping station in order to provide inflows for lake routing. The summer floods magnitudes were estimated using the same procedures as for the winter floods except that the period of maximum daily discharges were restricted between period May 1 to August 31. Instantaneous summer flows were estimated by multiplying the mean daily flows by a factor of 2.0.

Table 3 summarizes the estimated daily and instantaneous flood discharges.

Flood levels in Hatzic Lake were estimated by routing the inflows through the lake. Outflows from Hatzic Slough were assumed to be limited to the capacity of Hatzic pumping station, which is only $6 \text{ m}^3/\text{s}$ (Water Management Branch, 1983). The stage - volume relation for the lake was based on previous studies on Hatzic Lake (Water Management Branch, 1983). As in these previous studies, the initial pre-flood summer lake level was assumed to be 2.438 m (8.0 feet) geodetic. During the severe summer flood of July 1983, stage levels on Hatzic Slough were recorded by the Ministry of Environment. Based on an examination of summer flood and rainfall frequency data at adjacent recording stations, it was estimated that the 1983 flood had a return period of greater than 100 years. For the purposes of this study, the 1983 flood has been adopted as the 200-year summer flood. However, in terms of the winter flood series, the July 1983 event probably was close to a mean annual flood.

Figure 3 shows lake level variations for 25-year and 200-year inflows. During the 1983 flood, the maximum lake level reached 3.95 m geodetic and the level exceeded its flood stage of 3.35 m for 16 days. In this flood event, the duration of inflows lasted only five days. Therefore over most of the period of flooding the discharge in Lagace Creek was near its normal summer baseflow level. This indicates that flooding on Hatzic Slough and Lower Lagace Creek is governed more by backwater from Hatzic Lake than by hydraulic conditions in Lagace Creek.

4.0 SEDIMENTATION ON LAGACE CREEK FAN

4.1 General Characteristics

The Lagace - Pattison Creek alluvial fan occupies an area of 2.1 km² and has its apex in the vicinity of Sylvester Road bridge on Pattison Creek (Figure 1). The fan length averages 2.0 km and the total relief is about 55 m which provides an overall gradient of about 0.0275. Lagace Creek flows along the northern limit of the fan and occasionally passes off the fan boundary and flows across non-alluvial glacial sediments. It is apparent that Pattison Creek has provided the main source of sediment to Lagace Creek over geological times. The downstream limit of the fan extends to the 5 m contour line along Hatzic Prairie. This places the lower fan boundary approximately 800 m downstream of the Farms Road bridge.

Figure 4 and Table 4 illustrate the variation in bed-material characteristics along the fan and Figure 5 summarizes the bed profile and channel properties. Based on this data the following points were noted:

1. Both the bed slope and bed-material size decreases rapidly downstream of the Pattison - Lagace confluence, which indicates that the coarse fraction of the bedload is being selectively deposited along the creek. The most rapid sorting and hence greatest deposition is occurring downstream of Seux Road bridge;

2. Virtually all of the gravel load in the stream is deposited when the slope is less than 0.006. As a result, the creek flows in a predominately sand-bed channel at the lower end of the fan.
3. The Lagace - Pattison channel is partially incised between Sylvester Road bridge and Seux Road bridge. Under existing channel conditions, the bankfull discharge in this reach had a return period of between 25 and 200 years.
4. The channel's discharge capacity decreases rapidly downstream of the Seux Road bridge. At the time of the 1984 cross-section surveys the bankfull capacity varied from $60 \text{ m}^3/\text{s}$ (close to a mean annual flood) upstream of Farms Road bridge to less than $20 \text{ m}^3/\text{s}$ between the bridges on Farms Road and Dale Road.

Downstream of the fan, Hatzic Prairie consists of flat lying floodplain sediments that were originally deposited by the Fraser River. The prairie is dissected by a number of prominent channels which drain low-lying areas on either side of Lagace Creek. These areas are up to 2 m lower than natural levees around the lake and creek, which means that substantial areas of Hatzic Prairie can be inundated before bankfull conditions are reached in either the lake or the creek.

4.2 History of Channel Instability

Table 5 lists the maps and airphotos that were reviewed to assess past channel shifting on the fan. The earliest detailed maps were prepared from legal surveys in May 1920. These maps, and airphotos from May 1930, showed that Lagace Creek flowed in a small, meandering channel as far upstream as Farms Road bridge (Figure 6). The stream appeared similar to other inactive drainage channels and was not transporting large quantities of gravel bedload.

By 1940, Lagace Creek had changed to a wider braided channel downstream of Pattison Creek and had shifted out of its former course approximately midway between Seux Road and Farms Road (Figure 6). This dramatic change resulted from a landslide on the south side of Pattison Creek basin which introduced a large slug of sediment into Lagace Creek (Figure 7). It is likely that this slide took place in January 1935 when the Fraser Valley was hit by one of the most severe winter storms of the century (Won, 1971). According to newspaper accounts, this storm produced a number of major landslides throughout the Valley (The Province, January 27, 1935). At the time of this first slide there was no logging or road construction in Pattison Creek watershed.

Ministry of Environment records indicate rapid sedimentation was occurring along the entire extent of the fan in 1951 and that annual dredging was necessary.

By 1952, Lagace Creek had been diverted back to its former course and was straightened downstream of Farms Road bridge.

A second major slide took place on the north side of Pattison Creek basin between 1952 and 1962 below a recently constructed logging road (Figure 7). This slide was visited by Dr. A.G. Mercer, P.Eng., of Northwest Hydraulic Consultants Ltd. in October, 1982. Dr. Mercer's description of the slide follows:

"The slide is about 75 m wide, its head is at el. 600 m and its foot is at el. 460 m. The creek slope is at about 0.25 below the slide.

The slide is very dramatic in appearance but is more of a head cutting erosion area than a slide. It appears that the stream flowing into the steep gully has been cutting back into the gravel and boulder bed causing the gully sides and ends to collapse. A comparison with 1968 airphotos shows the slide has cut back about 10 m since then. This represents about 100,000 cubic metres of material eroded in 14 years." (NHC, 1982)

This second slide worsened aggradation problems along Lagace Creek throughout the 1960's. Ministry files recorded that in 1968 the creek aggraded up to 1.5 m in a single flood event, and that between Seux Road and Farms Road bridge, the channel (between its natural levees) was up to 1.0 m above the surrounding floodplain.

Serious flooding problems appear to have decreased throughout the 1970's until the flood of December, 1979. This flood caused the creek to shift out of its channel at Farms Road bridge and flow into Bouchier Creek (MOE, 1980).

In the long term, future channel instability and sedimentation problems on Lagace Creek will depend largely on the sediment volumes supplied from Pattison Creek basin. Sediment production in Pattison Creek will be governed mainly by:

- future occurrences of extreme precipitation events;
- future landslide and surface erosion activity.

Given that there are now a number of active slides in the basin and that some areas have been de-stabilized by logging activities, it seems likely that large sediment volumes will continue to be supplied from Pattison Creek over the next few decades.

4.3 Sediment Transport Rates on Lagace Creek

Annual bedload transport volume estimates are required for assessing the size required for a sedimentation basin on the creek. Unfortunately, there has been no direct measurements of sedimentation rates along the fan. In view of the lack of reliable direct measurements, estimates were made using theoretical bedload formulae. The following equations were used in the study.

- Parker
- Modified Einstein
- Ackers - White
- Bagnold
- Meyer - Peter & Muller

Previous studies have demonstrated that bedload formulae can give a wide range of predictions especially when the equations are used outside of their limits of initial calibration. However, it was felt that the formulae could be used to bracket the actual transport rates and could also provide information on the relative variation in transport along the creek.

Transport rates were estimated at two locations (Figure 1):

- 350 m downstream of Seux Road bridge;
- at the lower limit of the fan, 800 m downstream of upper Farms Road bridge.

At the first site, the creek transports mainly gravel sediment while at the second site, bedload consists mainly of sand or fine pea gravel. Input data for the equations were based on the 1984 survey data and on the bed-material data reported above.

Figure 8 shows the bedload transport rate - discharge relation at Seux Road. It can be seen that the formulae predictions range over a factor of about 3. It was decided to adopt the predictions from the Parker equation for the gravel-bed site. The Parker equation was developed from field measurements in a small coastal gravel-bed stream with similar bed-material size and channel slope as Lagace Creek. This equation was also calibrated against field measurements of the Vedder River near Chilliwack (Parker et al, 1982).

Table 6 summarizes the transport volumes associated with various flood-return periods. These volumes were computed using the adopted transport relations and the hydrographs in Figure 2. In addition, the long-term annual transport rate was estimated by developing a flow-duration curve for Lagace Creek using measured discharge data from the North Alouette River and Kanaka Creek. Figure 9 shows the expected variation in annual gravel transport rates at Seux Road bridge.

The main results from the calculations at Seux Road were as follows:

1. The mean annual gravel transport rate is about $7,500 \text{ m}^3/\text{year}$;
2. The year to year variation in gravel transport can be very high with annual volumes ranging from virtually zero to $30,000 \text{ m}^3/\text{year}$. This range occurred over a simulated 22-year period when the largest single flood had a return period of 25 years;
3. The gravel transport during a 200-year flood was estimated to be $74,000 \text{ m}^3/\text{year}$ or about 10 times the annual average.

These estimates represent the transport of predominately gravel-sized materials. Additional sand and fine gravel will be carried past Seux Road bridge as washload; however this component can not be computed since its transport rate is governed by sediment supply rather than local hydraulics.

Figure 10 shows the computed bedload rates in the sand bed reach at the downstream limit of the fan. Predictions from the Ackers - White equation were adopted for the calculations of annual sand loads. Previous studies have shown the Ackers - White equation to be one of the most reliable relations available for predicting bedload in sand-bed channels.

The calculations at the lower end of the fan indicated the channel has a capacity to transport about $2,000 \text{ m}^3/\text{year}$ of predominately sand-sized material. However, the amount of sand entering this reach is substantially greater than $2,000 \text{ m}^3/\text{year}$ since rapid sedimentation has been going on.

McPherson (1980) estimated the average rate of infilling in the 4 km reach downstream of Farms Road bridge to be $0.3 \text{ m}/\text{year}$ which corresponds to a volume of $8,000 \text{ m}^3/\text{year}$. An alternative estimate of deposition was made by computing the volume of sediment stockpiled along the channel below Farms Road bridge. The cross section of the spoil piles were obtained from the 1984 MOE channel surveys. Based on the available airphotos, these spoil piles were first constructed in about 1962. This calculation indicated an annual deposition rate of about $3,000 \text{ m}^3/\text{year}$. However, since some of the spoil has been removed and spread on the floodplain, this estimate is probably low.

The total sand load transported into the lower reach will equal the sum of the volume transported through the reach (approximately $2,000 \text{ m}^3/\text{year}$) plus the volume deposited within the reach ($3,000$ to $8,000 \text{ m}^3/\text{year}$). These figures give a total sand inflow of between $5,000$ to $10,000 \text{ m}^3/\text{year}$.

5.0 CHANNEL STABILIZATION AND SEDIMENT CONTROL

5.1 Objectives and Design Constraints

The main objectives of a sediment control scheme on Lagace Creek should be:

1. To reduce the chance of major avulsion such as the shift of 1935 - 1940;
2. To reduce the extent of aggradation along the fan, especially on the lower half where sedimentation is seriously reducing the creek's channel capacity.

This study considered only the use of sediment basins to control aggradation on the fan. However, hydraulic calculations have shown that the discharge capacity of Lagace Creek is less than a 10-year flood over most of its length (Section 4.1). Therefore a sediment basin would not prevent overbank flooding on the fan even during relatively minor floods. Prevention of overbank flooding would require additional channel improvements (such as channel widening or deepening) or construction of a set-back dyke. In order to prevent flooding on the south side of the creek, a set-back dyke would have to tie into high ground near the fan's apex and extend 1,800 m downstream to the end of the fan downstream of Farms Road bridge. A second 1,500 m long set-back dyke would have to be constructed on the north side of the creek if it was considered necessary to protect developments along the right bank. A set-back dyke

scheme could be implemented either in conjunction with a sediment basin or with a regular channel maintenance program. A set-back dyke scheme for Lagace Creek would represent a much more extensive and costly undertaking than the proposed sediment basin. Further consideration of set-back dykes is considered beyond the terms of reference for this present study.

In this study, the proposed sediment basin consists simply of an enlarged channel with a flattened slope to promote sediment deposition. This type of sediment storage channel is believed to be acceptable to environmental authorities, subject to restrictions on times of excavation and provision for fish passage. (In order to minimize disturbances to fish eggs, excavation will be allowed only in the months of July and August.)

The 200-year flood is usually adopted for flood studies in British Columbia. However, it is not practical to design a sediment basin for such an extreme event. In this study, it was felt that the basin should be sized to trap sediment from a 25-year flood event and significantly reduce the volume of sediment carried during more extreme floods. The selection of the 25-year sediment inflow volume was based on the following considerations:

1. During more extreme floods, extensive overbank flooding would occur along Lagace Creek regardless of any sediment deposition in the channel. Therefore the basin would have little, if any, impact on reducing flood damages during such extreme events;
2. The estimated sediment inflow volumes increase very rapidly with flood magnitude (Table 6). Therefore the cost of constructing a basin with a 200-year inflow capacity would be substantially greater even though the benefits of the larger basin would be minor;
3. If the basin was entirely filled during an extreme flood, the basin's trap efficiency would simply decline to a point where virtually all of the incoming sediment load was passed through the channel. Therefore the basin would not fail catastrophically or contribute to further instability on the fan.

The 25-year flood event was estimated to transport 21,000 m³ of predominately gravel-sized bedload at Seux Road bridge. However, there are too many uncertainties involved in these bedload calculations to ensure that a reasonably conservative estimate of the sediment load has been achieved. Therefore, the volume of the basin was set to be 30,000 m³ or approximately 50 percent more than the estimated 25-year inflow volume. This should provide some allowance for trapping some of the sand load that is transported in suspension. Also, this size of basin would reduce the sedimentation downstream of the basin associated with more extreme floods.

5.2 Alternative Sites

There are a number of possible sites for sediment basins on the Lagace - Pattison Creek fan including:

- downstream of Sylvester Road bridge on Pattison Creek;
- upstream of Seux Road bridge on Lagace Creek;
- between Farms Road and Seux Road bridges;
- downstream of Farms Road bridge.

The locations of these sites is shown in Figure 11. A very brief account of each site will be made.

5.2.1 Pattison Creek Downstream of Sylvester Road Bridge (Photo 1)

Advantages

1. Will trap sediment near fan apex;
2. Undeveloped land available for stockpiling gravel.

Disadvantages

1. Bed material very coarse so the value of trapped sediment will be low;
2. Very steep channel slope (0.044) which will reduce the trap efficiency of the basin;
3. Degradation above the basin could undermine Sylvester Road bridge;
4. Bank erosion downstream of the basin could introduce large sediment volumes to the lower channel.

This site was considered impractical and was not investigated further.

5.2.2 Lagace Creek Upstream of Seux Road Bridge (Photo 2)

Advantages

1. Will trap sediment near fan apex and limit the chance of an avulsion;
2. Undeveloped land available for stockpiling gravel.

Disadvantages

1. Relatively steep channel slope (0.021) which will reduce the trap efficiency of the basin.

This site was recommended previously by McPherson (1981) for construction of a sediment basin.

5.2.3 Lagace Creek Between Seux Road and Farms Road Bridges (Photo 3)

Advantages

1. The lower slope in this reach (0.017) is promoting deposition;
2. Partial basin already constructed.

Disadvantages

1. Avulsion may occur on the upper fan upstream of the basin;
2. Degradation upstream of the basin may undermine Seux Road bridge;
3. Surrounding land partially developed.

This site was also described as a possible basin location by McPherson (1981).

5.2.4 Lagace Creek Downstream of Farms Road Bridge (Photo 4)

Advantages

1. Slope is low (0.006) so the trap efficiency for sand would be higher than on the upper fan.

Disadvantages

1. Would not prevent an avulsion or reduce aggradation on the upper fan;
2. Degradation upstream of the basin may undermine Farms Road bridge;
3. Surrounding land is developed.

5.2.5 Summary

The sites above and below Seux Road both are feasible locations for sediment basins. Therefore, conceptual designs were prepared for both alternatives. The site below Farms Road bridge is located too far downstream to prevent a future avulsion on the fan, but could be more effective than the upstream sites in reducing sand deposition on the Hatzic Slough floodplain. Therefore consideration was given to constructing a second basin near the lower limit of the fan below Farms Road bridge.

5.3 Conceptual Design of the Sediment Basin

Appropriate dimensions for the sediment basin were estimated from tractive force theory and from bedload transport equations. Tractive force theory was used to estimate the minimum size of sediment that could remain stable in the channel. The calculations were based on Shield's equation for incipient motion:

$$D_{\min} = \frac{RS}{1.65 T_c}$$

where $D_{\min}$ is the bed-material size, R is the hydraulic radius, S is the slope and T_c is the Shield's parameter.

The calculations were repeated for trapezoidal-shaped channel with bottom widths ranging from 30 m to 50 m and slopes ranging from 0.015 to 0.002. The relation between stable stone size and slope at a 25-year flood condition is illustrated in Figure 12. These calculations demonstrate that it is impractical to design a basin that will trap all the gravel and sand material entering from upstream. For example, a channel with a bottom width of 50 m and a slope of 0.002 will still be capable of transporting gravel up to 40 mm in diameter. Similar calculations based on critical velocity demonstrated that the velocity would have to be reduced from 3 - 4 m/s in the approach channel to only 0.2 m/s in the basin in order to trap the creek's suspended sand load. This would require excavating a basin at least 4 m below the existing bed level. As a result, it does not appear practical to construct a basin at the lower end of the fan solely for the purpose of trapping the creek's sand load.

The bedload equations of Parker and Ackers - White were used to compare the transport rates in basins having different bottom widths and slopes with the computed loads in the existing channel at Seux Road bridge. The calculations showed that a trapezoidal channel having 3 to 1 side slopes, a base width of 40 m and a slope of 0.012, would have a trap efficiency for gravel of 75 percent to 95 percent during a 25-year flood. This basin would have roughly twice the width and half of the

slope as the existing channel near Seux Road. Under actual operating conditions, the trap efficiency of the basin would be considerably less than the theoretical predictions. For example, over the course of a flood, sediment aggradation will cause an increase in the channel slope in the basin and hence an increase in transport capacity. Therefore, the overall trap efficiency for gravel bedload during a major flood might be in the order of 50 percent to 70 percent.

Based on these considerations, the following basin dimensions were adopted:

- Volume below existing grade = 30,000 m³
- Bottom slope, downstream end = 0.006
- Bottom slope, upstream end = 0.012
- Basin side slopes = 1V:2H
- Bottom width = 50 m

The side slopes of the basin would have to be protected with riprap to prevent bank erosion and channel shifting within the basin. Preliminary calculations indicate the following gradation of riprap would provide adequate protection for flows up to the 200-year flood:

- 100% smaller than 1,200 mm or 2,300 kg
- 20% larger than 900 mm or 1,100 kg
- 50% larger than 800 mm or 700 kg
- 80% larger than 500 mm or 200 kg

A rough estimate of the basin's performance at either of the two alternative sites is summarized in Table 7. It should be realized that these figures are intended for comparing the effects of different flood conditions and that the actual transport rates and deposition volumes could be substantially different from the predictions.

Due to the flattened slope in the basin, the bed level at the upstream end of the trap will be substantially lower than the existing channel. The depth below existing grade would be 3.2 m at the upstream basin site and 2.5 m at the lower site.

In the conceptual designs, it has been assumed that a 100 m long transition slope was excavated upstream of the basin to blend into the undisturbed channel bed. Since this slope would be approximately double the existing channel slope, this would produce a knickpoint in the stream profile and would induce degradation upstream until the bed developed a stable armour layer. Degradation could also promote bank sloughing upstream of the basin since the height of the banks would be more than doubled. These effects would increase transport rates in the channel which would increase the rate of infilling in the basin.

At the lower site the end of the basin would be only 250 m downstream of Seux Road bridge. This structure, which is supported on pipe piles, could be undermined by up to 2.5 m. As a result, some consideration would have to be given for

either replacing or protecting the bridge. Protection against undermining could be achieved by placing a riprap apron around the piles and the abutments. Further consideration of this problem would have to be given if the project went ahead. In this preliminary study, a contingency cost of \$10,000 for bridge protection has been included in the capital cost of the Farms Road basin. Temporary degradation upstream of the Seux Road site would probably be of less concern since there are no nearby structures that would be affected.

Table 8 compares the approximate annual costs of the two alternative basins. Annual costs have been estimated by considering both capital costs amortized over a 25-year period and annual maintenance costs. Land acquisition costs were based on current prices for undeveloped land in Hatzic Valley. Construction and annual maintenance costs were estimated from discussions with local contractors. These costs consider both excavation and stockpiling; however, in practice some double handling of the material would be required. The total volume of excavation required for the basin was estimated at roughly 40,000 m³. This includes 30,000 m³ for sediment storage and 10,000 m³ for cutting back banklines and providing a transition slope. For the purposes of this study, it has been assumed that some of the costs of construction could be partially offset by the sale of the material. Riprap cost estimates were provided by the Ministry of Environment, Abbotsford Office and are based on current experience in the Dewdney District.

Based on the sediment transport calculations, approximately 6,800 m³ of sediment would be trapped in the basin on an average annual basis. Some additional deposition of suspended sand will also occur, although the actual amount is difficult to quantify. For the purposes of costing, it has been assumed that the total amount of bedload and suspended load trapped in the basin averages 10,000 m³/year. The trapped material will range in size from large cobbles and boulders up to 400 mm down to pea gravel and sand. Without screening or separating, this material is only suitable for bulk fill. Discussions with local residents indicated that gravel between Seux Road and Farms Road bridge has sold for about \$1.10/m³.

The results indicate the total annual cost of the basin would be \$37,900 per year for the site upstream of Seux Road bridge and \$43,400 per year for the site upstream of Farms Road bridge.

In addition to costs, the upper site has the following technical advantages over the lower site:

1. It will produce less impact on existing structures;
2. It will be more effective in preventing a major channel shift such as the 1935-1940 event;
3. It is located in a reach that is partially incised, so bankfull conditions will be exceeded very rarely. Therefore the basin has a greater chance of continuing to operate during an extreme flood event.

The main disadvantages of the upper site are:

1. It will be less effective in trapping suspended sand than the lower basin since the upper site is shorter and has higher approach velocities;
2. It is located upstream of existing spoil piles in the Farms Road area that are being eroding by bank attack and are supplying gravel and sand to the lower reach (Photo 3).

Based on these considerations, the site above Seux Road appears more advantageous than the lower site. A conceptual layout of the Seux Road basin is shown in Figure 13.

6.0 EFFECT OF THE SEDIMENT BASIN ON LOWER LAGACE CREEK - HATZIC SLOUGH FLOODPLAIN

6.1 Effect of Aggradation on Summer Flooding

The transition between the lower limit of the fan and Hatzic Slough floodplain occurs at about el. 5 m. This places the lower boundary of the fan about 800 m downstream of the Farms Road bridge. Sand deposition continues to occur in the channel of Lagace Creek downstream to about the Dale Road bridge (Figure 1). Channel cross sections surveyed in July 1984 showed that aggradation had reduced the mean depth below bankfull stage to only 0.5 to 1.0 m in this area (Figure 5).

However, flooding along Lower Lagace Creek is strongly controlled by the backwater from Hatzic Lake. The effect of sedimentation on the extent and duration of flooding was investigated by computing water surface profiles from Hatzic Lake to Farms Road bridge using the computer program HEC-2. The calculations were carried out for two different channel conditions:

- an aggraded channel as surveyed in July 1984;
- a channel with its bottom deepened by 1.0 m.

The deepened channel was intended to represent conditions following sediment removal. The profiles were computed for three different days during a 25-year summer flood (Figure 3).

These days included the following combinations of creek discharges and lake levels:

<u>Creek Discharge (m³/s)</u>	<u>Lake Level (m)</u>
21 (flow peak)	2.6 (lake rising)
12 (flow falling)	3.1 (lake rising)
5 (flow near baseflow)	3.3 (lake peak)

The results of the flood level analysis showed:

1. Extensive flooding would occur to low-lying areas on Hatzic Slough during a 25-year flood for both deepened and aggraded channels. Flooding occurred as a result of the backwater from Hatzic Lake through the numerous drainage channels and sloughs that intersect the creek.
2. Some of the highest land is found around the north end of the lake and on natural levees adjacent to Lagace Creek. Therefore extensive flooding from the lake can take place without the creek ever exceeding its bankfull level.
3. At the time of the peak lake stage, the creek discharge had dropped to near baseflow conditions.
4. Effective lake control ends in Lagace Creek upstream of the Dale road bridge during a 25-year flood. Upstream of this point, the highest water levels in the channel occurred on the day of the peak river flow when the lake was still rising.

5. Channel deepening reduced water levels in the creek upstream of the point where lake control ended. The difference in water levels in the aggraded and deepened channels reached up to 1.0 m at a point 500 m upstream of the Dale Road bridge. However, land adjacent to Hatzic Slough would continue to be flooded by the lake for a distance of up to 1,000 m upstream of Dale Road bridge.

These results demonstrate that deepening Lagace Creek by up to 1 m would have a near negligible impact on summer flooding over most of Hatzic Slough. During a more extreme flood such as in 1983, Hatzic Lake would rise to el. 4.0 m, which would extend the area of lake control further upstream. This would reduce the effectiveness of a deepened channel even further.

6.2 Effect of Sediment Basin on Aggradation in Lower Lagace Creek - Hatzic Floodplain

The proposed sediment basin would have relatively little effect on reducing sand deposition on the Hatzic Slough floodplain, partly a consequence of the basin's expected low efficiency for trapping sand. Also, substantial quantities of sediment are probably now being supplied to the channel from erosion of the large spoil piles that confine the channel between the Farms Road and Dale Road bridges (Photo 4). During a major flood large volumes of sediment would be supplied directly to the channel from erosion of these slopes, which are very steep and unprotected. As a result, some of the ongoing annual maintenance in this reach may involve re-excavation of eroded materials from the slopes.

7.0 ASSESSMENT OF OVERALL FEASIBILITY

It is technically feasible to construct a 30,000 m³ sediment basin on Lagace Creek. However, the basin could produce some significant upstream impacts by inducing degradation and bank collapse. These effects would temporarily increase bedload transport above present conditions which would hasten the infilling of the basin.

It does not appear technically feasible or practical to design a basin for more extreme flood than a 25-year event.

The proposed basin would be most effective in reducing gravel aggradation between Seux Road bridge and the bend below Farms Road bridge. It would have a very limited effect on reducing aggradation or flooding on the Hatzic Slough floodplain. There would be little advantage in constructing a second basin below Farms Road bridge as long as the existing spoil piles along the creek continue to supply large volumes of sediment through bank erosion.

In the long term, more cost effective improvements could probably be achieved by upgrading the annual channel maintenance operations that have been carried out in the past. This type of program could include:

1. Upgrade the existing gravel mining operation upstream of Farms Road bridge and remove up to 7,500 m³ of gravel per year;
2. Remove the spoil piles downstream of Farms Road bridge that are actively supplying sediment to the channel;
3. Monitor bed levels along the channel and excavate material after significant aggradation has occurred;
4. Widen the confined sections of channel such as in the below Seux Road bridge and between the bridges on Farms Road and Dale Road.

This program would improve conditions during smaller floods, but would not prevent flooding during extreme events.

Floodproofing land on the fan against extreme floods will require construction of set-back dykes in conjunction with a sediment basin or a program of regular channel maintenance. Further considerations of these improvements is beyond the scope of this study.

8.0 CONCLUSIONS

Based on this study, the following conclusions can be drawn:

1. A sediment basin would have only a limited effectiveness for reducing aggradation and flooding on Lagace Creek and Hatzic Slough even for relatively small floods with return periods less than 25 years. Much more extensive measures such as construction of set-back dykes would be required to prevent overbank flooding to lands on the Lagace - Pattison Creek fan.
2. It is not practical to design a basin to trap the bedload volume associated with an extreme flood such as a 50-year or 200-year event.
3. Overall, a site upstream of Seux Road bridge would be the best location for placing a 30,000 m³ sediment basin. This location would have less impact on existing structures and would reduce the chance of an avulsion near the upstream end of the fan.
4. On average, the basin would trap about 10,000 m³ of sediment each year. This material would range from 400 mm boulders to sand. Without screening or separating, this material could be sold only as bulk fill.

5. The approximate annual cost of the basin would be \$37,900/year.
6. The basin would be most effective in trapping coarse gravel bedload and would be less effective for trapping sand. As a result sand deposition would continue to occur on the Lagace Creek - Hatzic Slough floodplain.
7. Channel aggradation between Farms Road bridge and Dale Road bridge is being aggravated by erosion of unprotected spoil material that encroaches into the channel. Some of the ongoing annual maintenance dredging that is required in this reach could be reduced if the spoil were to be removed and the banks stabilized.
8. The sediment basin will have very little impact on reducing summer flooding over most of Hatzic Slough since in this area flooding is mainly governed by backwater from Hatzic Lake.

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- Northwest Hydraulic Consultants Ltd., 1982. "Hazard of Lagace-Pattison Creek System to Proposed Sub-division", Letter Report to Mr. Frank Kokoska.
- Parker, G., Klingeman, P., McLean, D., 1982. "Bedload and Size in Paved Gravel-bed Rivers", Journal of the Hydraulics Division, American Society of Civil Engineers.
- Won, T.K., 1971. "Meteorology in British Columbia: A Centennial Review", Atmospheric Environment Service, Pacific Region.

TABLE 1

Gauging Stations in Regional Flood Frequency Analysis

<u>Station</u>	<u>Name</u>	<u>Years of Record</u>	<u>Drainage Area (km²)</u>
08MH76	Kanaka Creek Near Webster's Corner	24	47.7
08MH18	Mahood Creek Near Newton	22	18.4
08MH20	Mahood Creek Near Sullivan	24	34.4
08MH58	Norrish Creek Near Dewdney	25	117.0
08MH06	North Alouette River Near Maple Ridge	25	37.3
08MH91	Silverdale Creek Near Mission	24	17.1
08MH29	Sumas River Near Huntingdon	29	149.0

TABLE 2

Adopted Winter Flood Discharges, Lagace Creek

Return Period (Years)	Below Pattison Creek (D.A. = 17 km ²)		Below Farms Road Bridge (D.A. = 24 km ²)	
	Daily Discharge m ³ /s	Instantaneous Discharge m ³ /s	Daily Discharge m ³ /s	Instantaneous Discharge m ³ /s
Mean Annual	27	68	35	88
5	41	103	55	138
10	50	125	65	163
25	60	150	80	200
50	70	175	90	225
200	90	225	115	290

Note: Winter period = September 1 - April 30

TABLE 3

Adopted Summer Flood Discharges, Lagace Creek and Hatzic Slough

Return Period (Years)	Lagace Creek at Hatzic Lake (D.A. = 54 km ²)		Hatzic Slough Pump Station (D.A. = 90 km ²)	
	Daily Discharge m ³ /s	Instantaneous Discharge m ³ /s	Daily Discharge m ³ /s	Instantaneous Discharge m ³ /s
Mean Annual	12	24	15	30
5	15	30	20	40
10	18	36	23	46
25	21	42	28	56
50	24	48	31	62
200	30	60	35	70

Note: Summer period = May 1 - August 31

TABLE 4

Bed-material Characteristics on Lagace Creek

<u>Sample</u>	<u>Location</u>	<u>Distance from Hatzic Lake (m)</u>	<u>Average Channel Slope</u>	<u>Bed-material Size (mm)</u>			
				<u>D_{max}</u>	<u>D₈₄</u>	<u>D_{mean}</u>	<u>% Sand</u>
6	Seux Road Bridge	6500	0.021	400	125	57	-
5	Farms Road Bridge	5800	0.017	230	98	21	13.5
4	Farms Road Bend	5200	0.006	110	26	2.7	55
3	Hatzic Slough	4300	0.0015	18	6.5	1.8	45
2	Dale Road Bridge	3550	0.001	16	2.6	0.8	79
1	Lower Farms Road Bridge	700	-	8	1.8	0.6	90

TABLE 5

Historical Maps and Airphotographs

<u>Date</u>	<u>Source</u>
May 1920	Legal Survey
May 1930	Federal Airphoto
June 1940	Provincial Airphotos
June 1952	Provincial Airphotos
June 1962	Provincial Airphotos
June 1963	Provincial Airphotos
June 1968	Provincial Airphotos
June 1979	Provincial Airphotos
June 1981	Provincial Airphotos
June 1984	Provincial Airphotos

TABLE 6

Bedload Volumes During Flood Events

Return Period (Years)	Bedload Transport (m ³ /year)	
	Seux Road	Lower Fan
Mean Annual Flood	7500	2000
10	16000	4000
25	21000	5000
50	47000	6000
200	74000	8000

Note: Based on Parker Equation.

TABLE 7

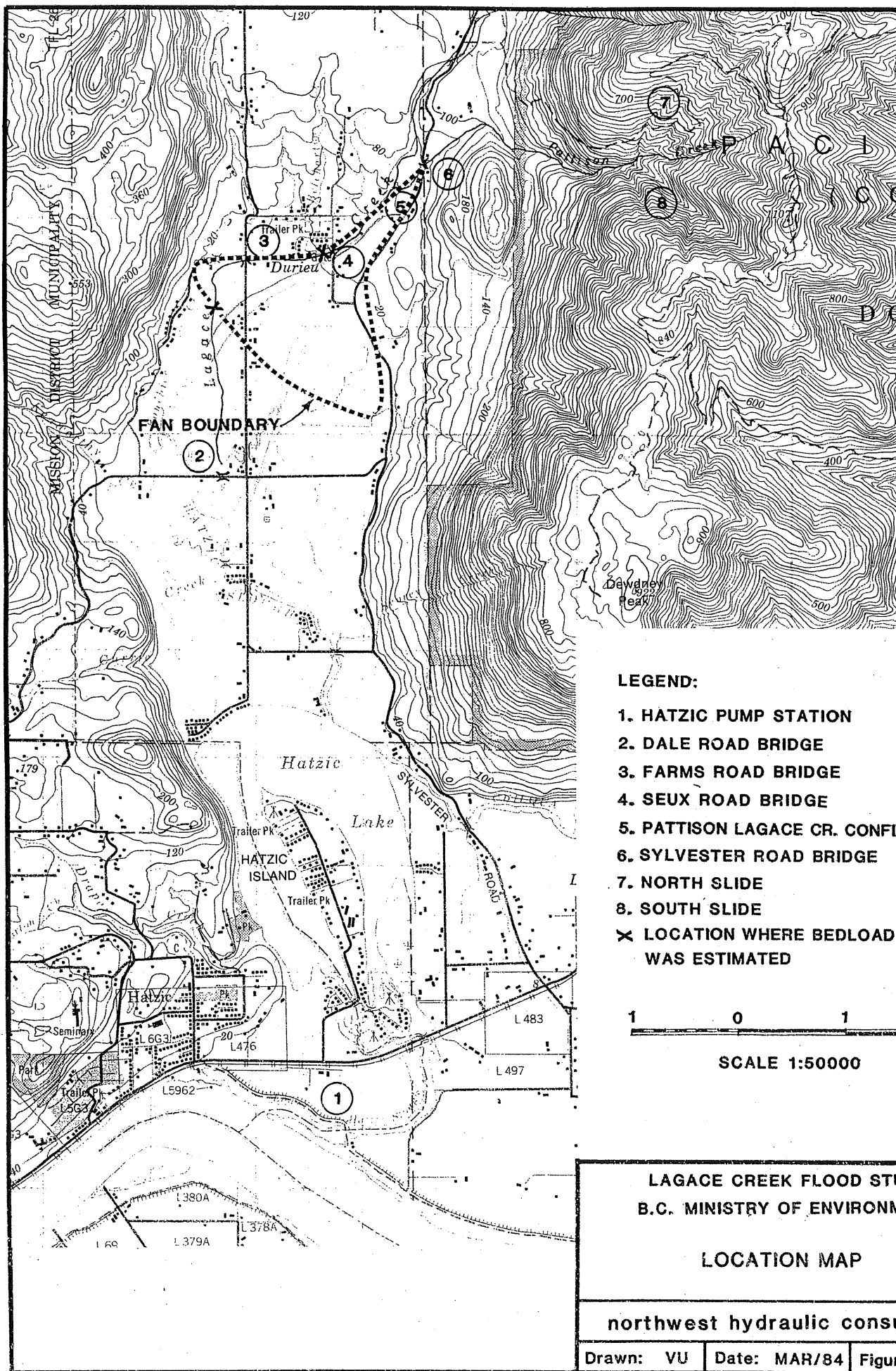
Estimated Volumes of Trapped Sediment

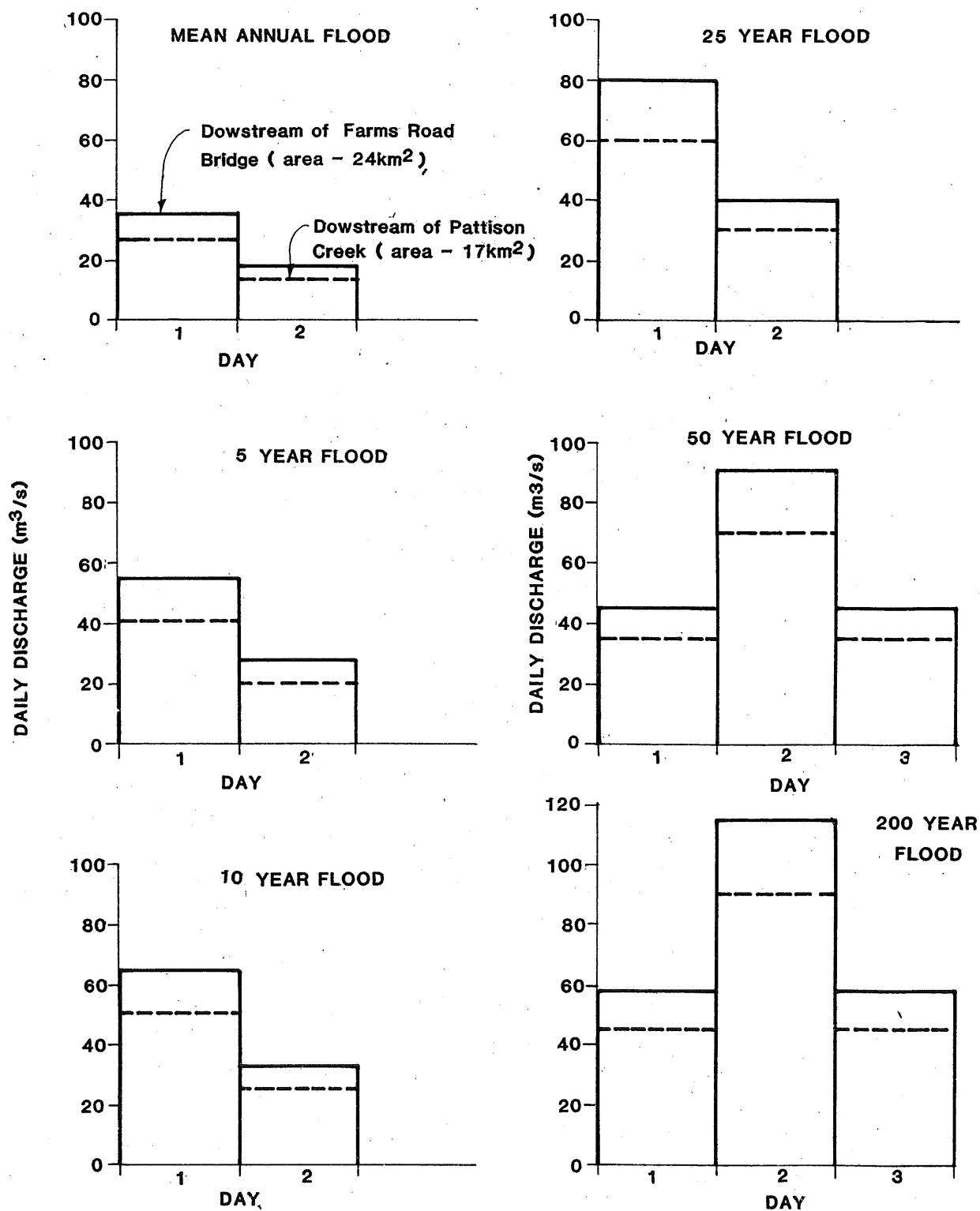
<u>Flood</u>	<u>Mean Annual Flood</u>	<u>25-year Flood</u>	<u>200-year</u>
Bedload Inflow (m ³)	7500	21000	75000
Bedload Trap Efficiency	0.9	0.7	0.4
Volume Passed (m ³)	700	6400	45000
Volume Trapped (m ³)	6800	14700	30000
% Gravel	75	75	75
% Sand	25	25	25

TABLE 8

Summary of Basin Costs

Item	Upstream of Seux Road Bridge	Upstream of Farms Road Bridge
<u>Capital Cost</u>		
Land Acquisition	12 acres @ \$5,000 = \$60,000	15 acres @ \$5,000 = \$75,000
Excavation	(40,000 m ³ @ \$2.30/m ³) \$92,000	\$92,000
Less Sales	(30,000 m ³ @ \$1.10/m ³) \$33,000	\$33,000
Bridge Pier Protection	Nil	\$10,000
Riprap	(7,000 m ³ @ \$12.00/m ³) <u>\$84,000</u>	(8,500 m ³ @ \$12) <u>\$102,000</u>
Total Capital Cost	\$203,000	\$246,000
Amortized Cost over 25 Years		\$25,900
		\$31,400
<u>Annual Maintenance Cost</u>		
Basin Excavation	(10,000 m ³ @ \$2.30/m ³) \$23,000	\$23,000
Less Gravel Sales	(10,000 m ³ @ \$1.10/m ³) <u>\$11,000</u>	<u>\$11,000</u>
Total Maintenance	\$12,000	\$12,000
<u>TOTAL ANNUAL COST</u>	\$37,900	\$43,400





NOTE:

WINTER PERIOD = SEPTEMBER 1 - APRIL 30.

LAGACE CREEK FLOOD STUDY
B.C. MINISTRY OF ENVIRONMENT

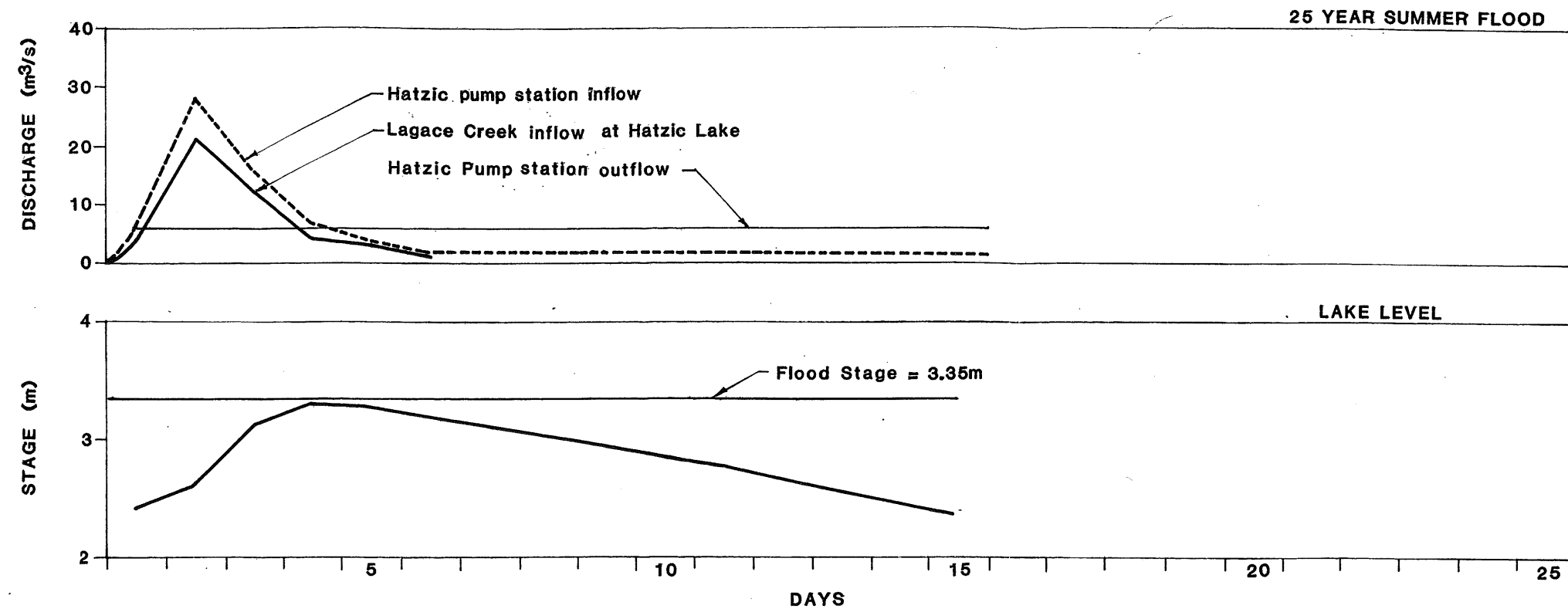
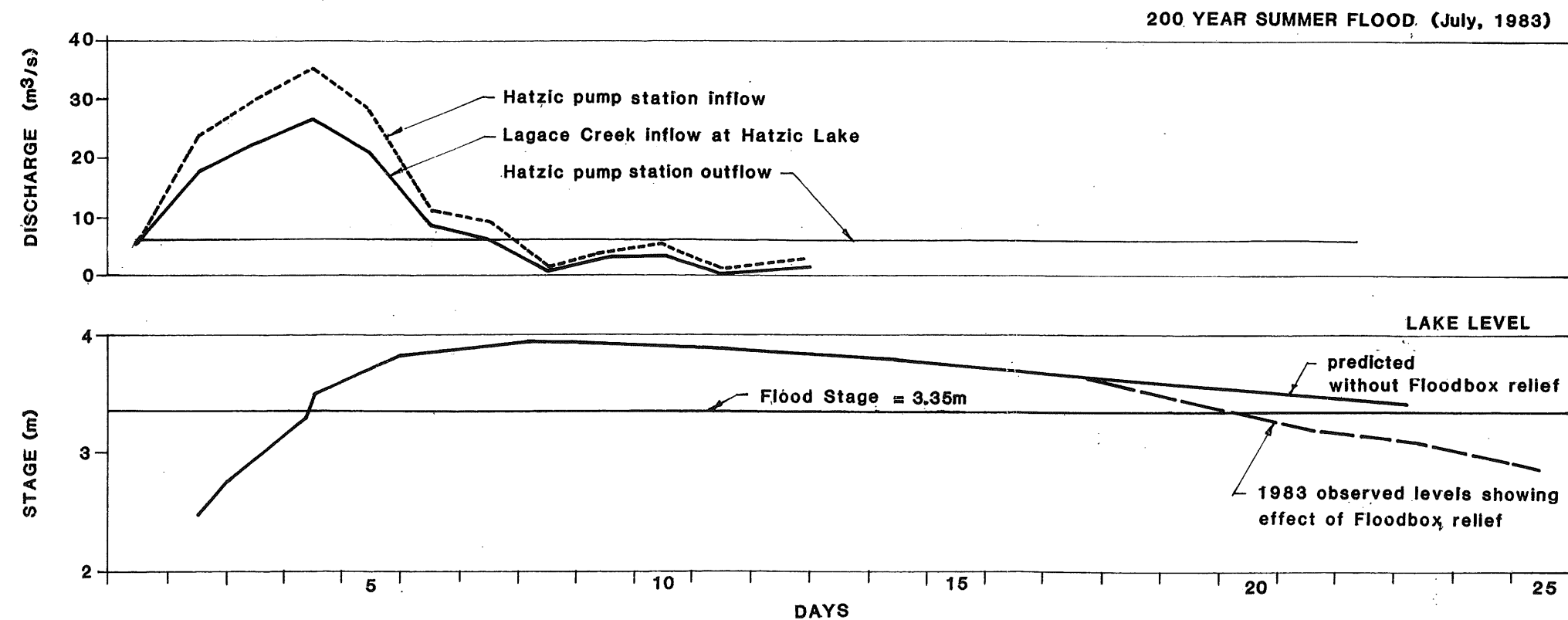
ADOPTED WINTER
FLOOD HYDROGRAPHS

northwest hydraulic consultants

Drawn: VU

Date: MAR/85

Figure: 2



NOTES :

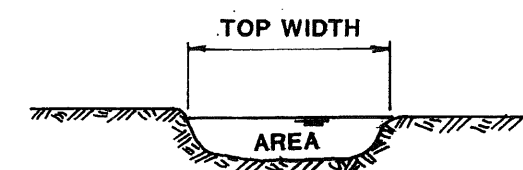
1. SUMMER PERIOD EXTENDS FROM MAY 1. TO AUG. 31.
2. ASSUMES NO FLOODBOX RELIEF DUE TO HIGH FRASER RIVER STAGE.
3. HATZIC PUMPING STATION CAPACITY = $6m^3/s$

LAGACE CREEK FLOOD STUDY
B.C. MINISTRY OF ENVIRONMENT
HATZIC LAKE ROUTING ANALYSIS
FOR SUMMER FLOODS

northwest hydraulic consultants

Drawn: VU Date: MAR/85 Figure: 3

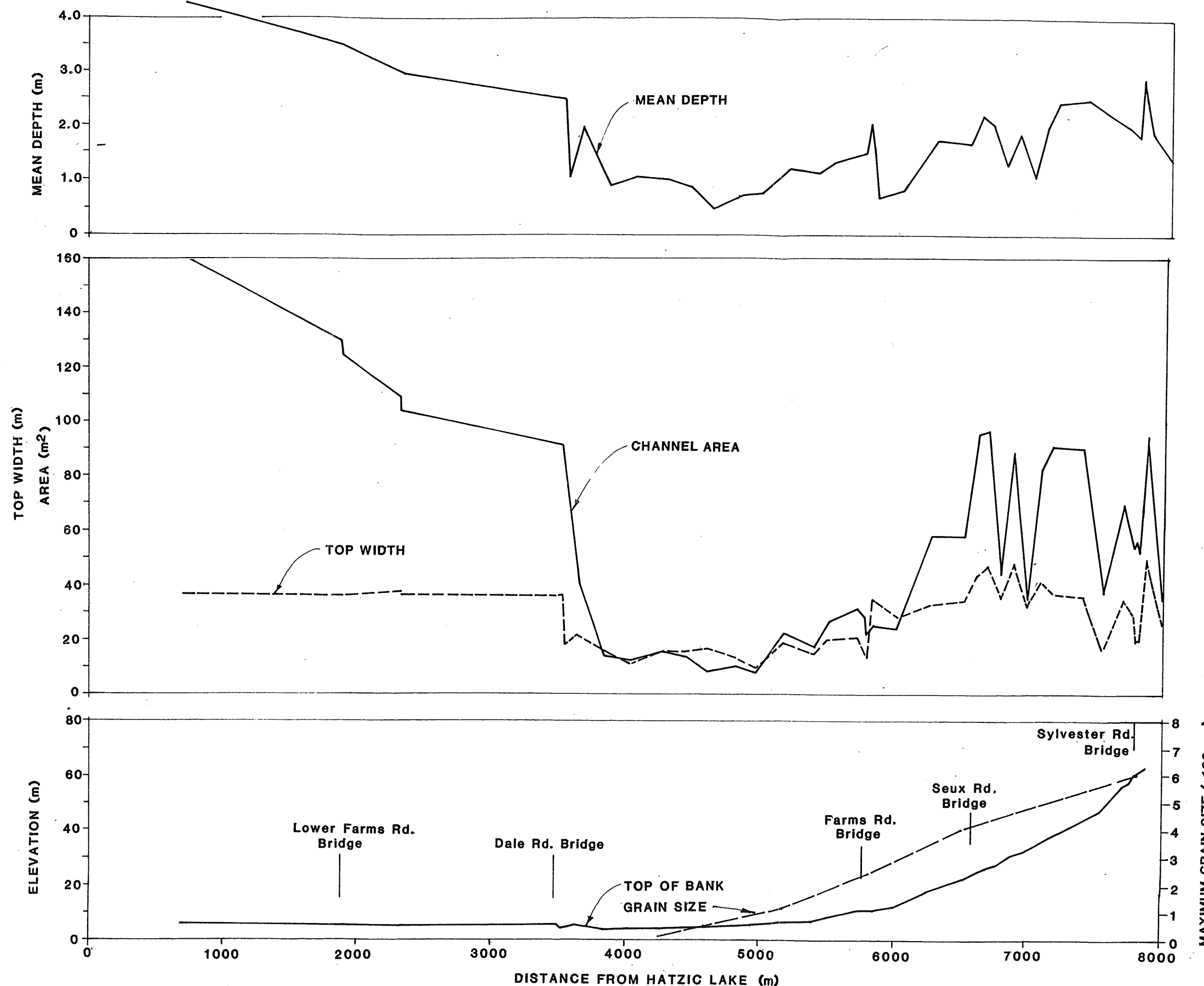
HYDRAULIC GEOMETRY AT BANKFULL STAGE



$$\text{MEAN DEPTH} = \text{AREA} / \text{TOP WIDTH}$$

NOTES:

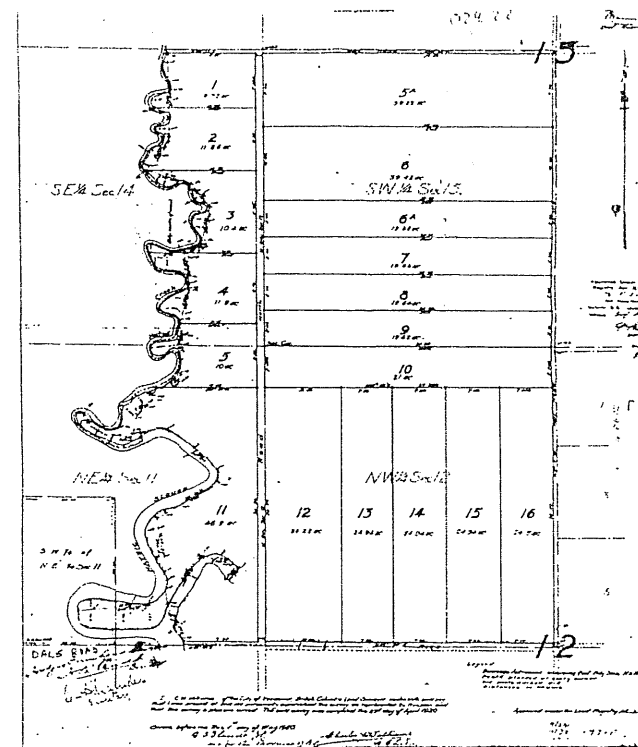
- BANKFULL GEOMETRY MEASURED FROM B.C. MINISTRY OF ENVIRONMENT CROSS SECTIONS SURVEYED IN JUNE, 1984



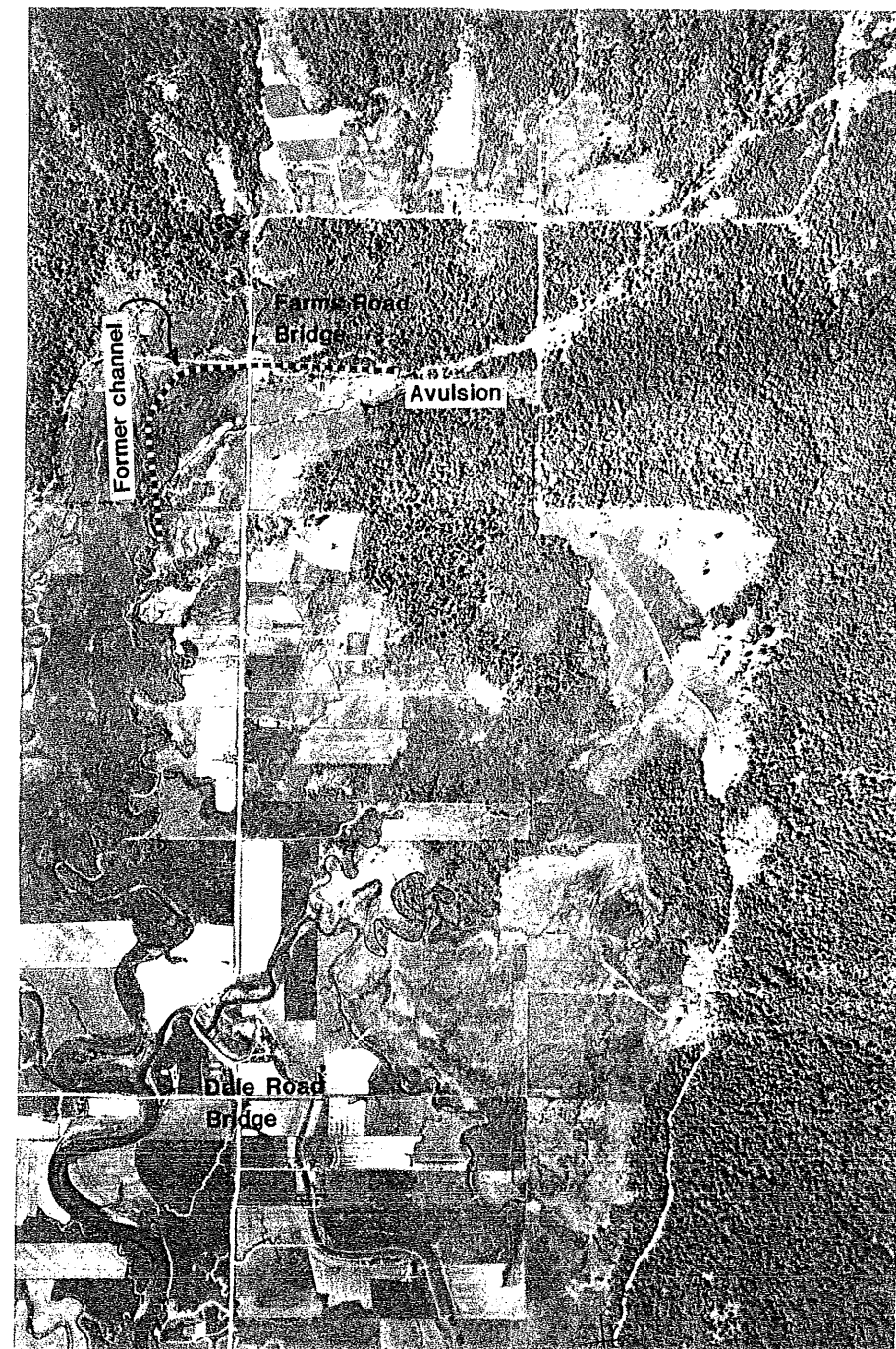
LAGACE CREEK FLOOD STUDY
B.C. MINISTRY OF ENVIRONMENT
BANKFULL CHANNEL GEOMETRY
ALONG LAGACE CREEK

northwest hydraulic consultants

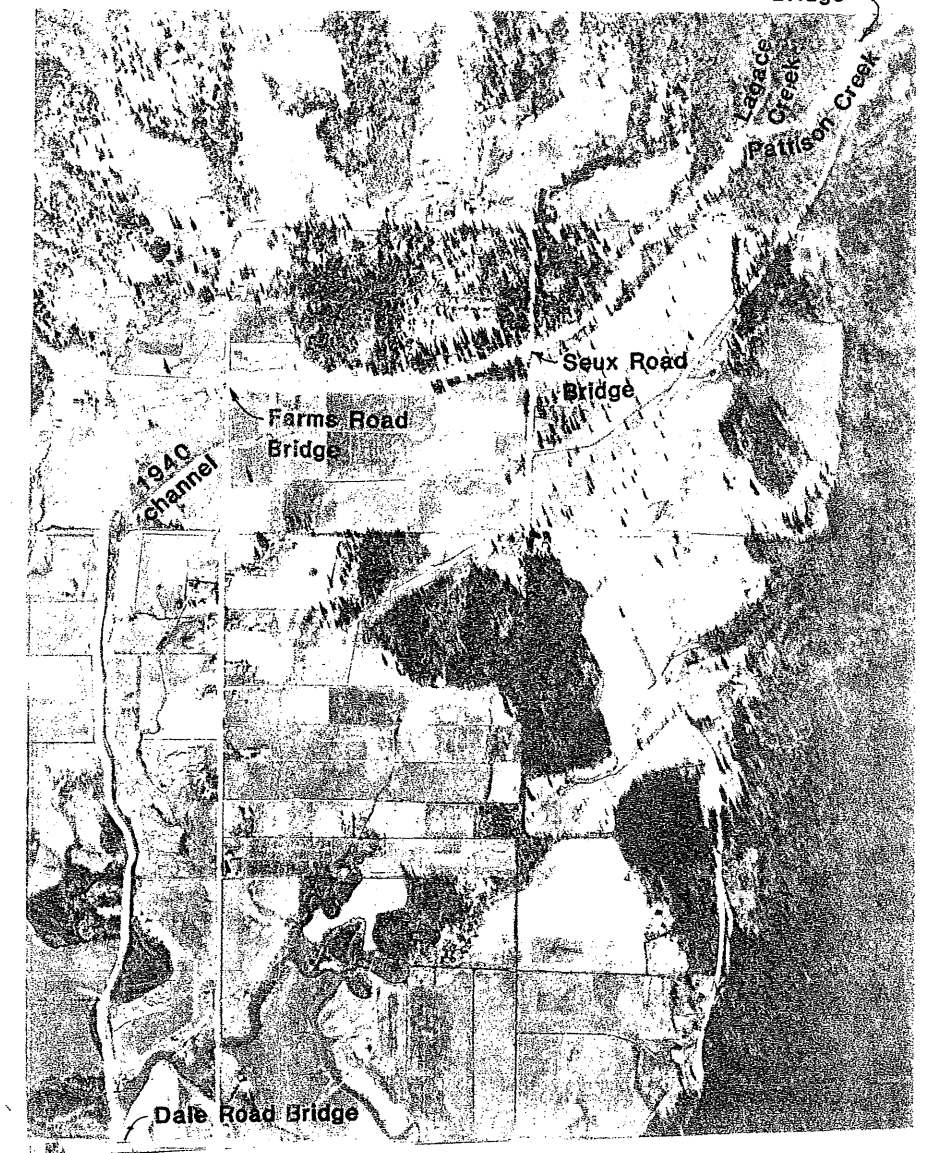
Drawn: VU Date: MAR/85 Figure: 5



MAY 1, 1920



JUNE, 1940



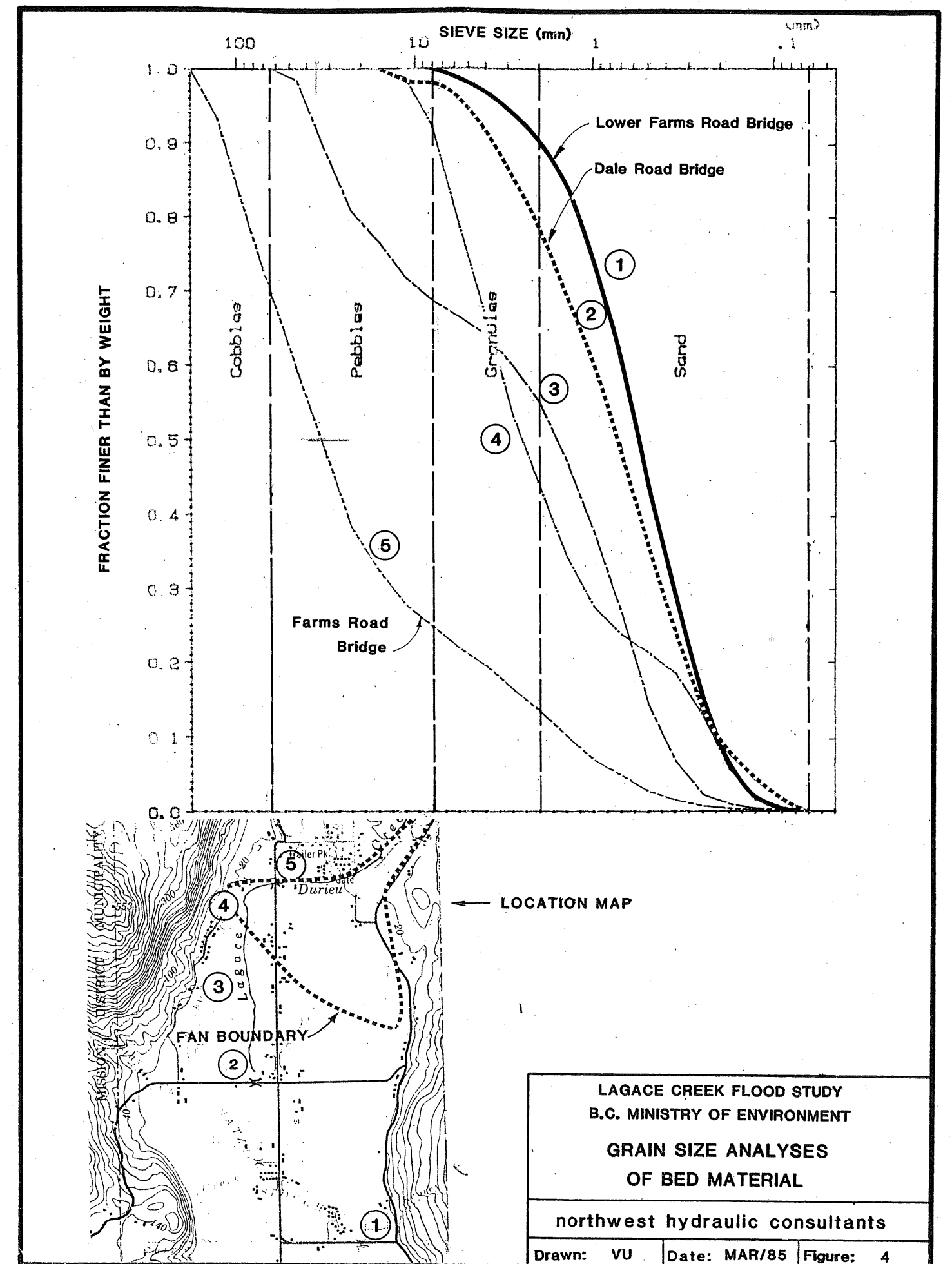
MARCH 11, 1981

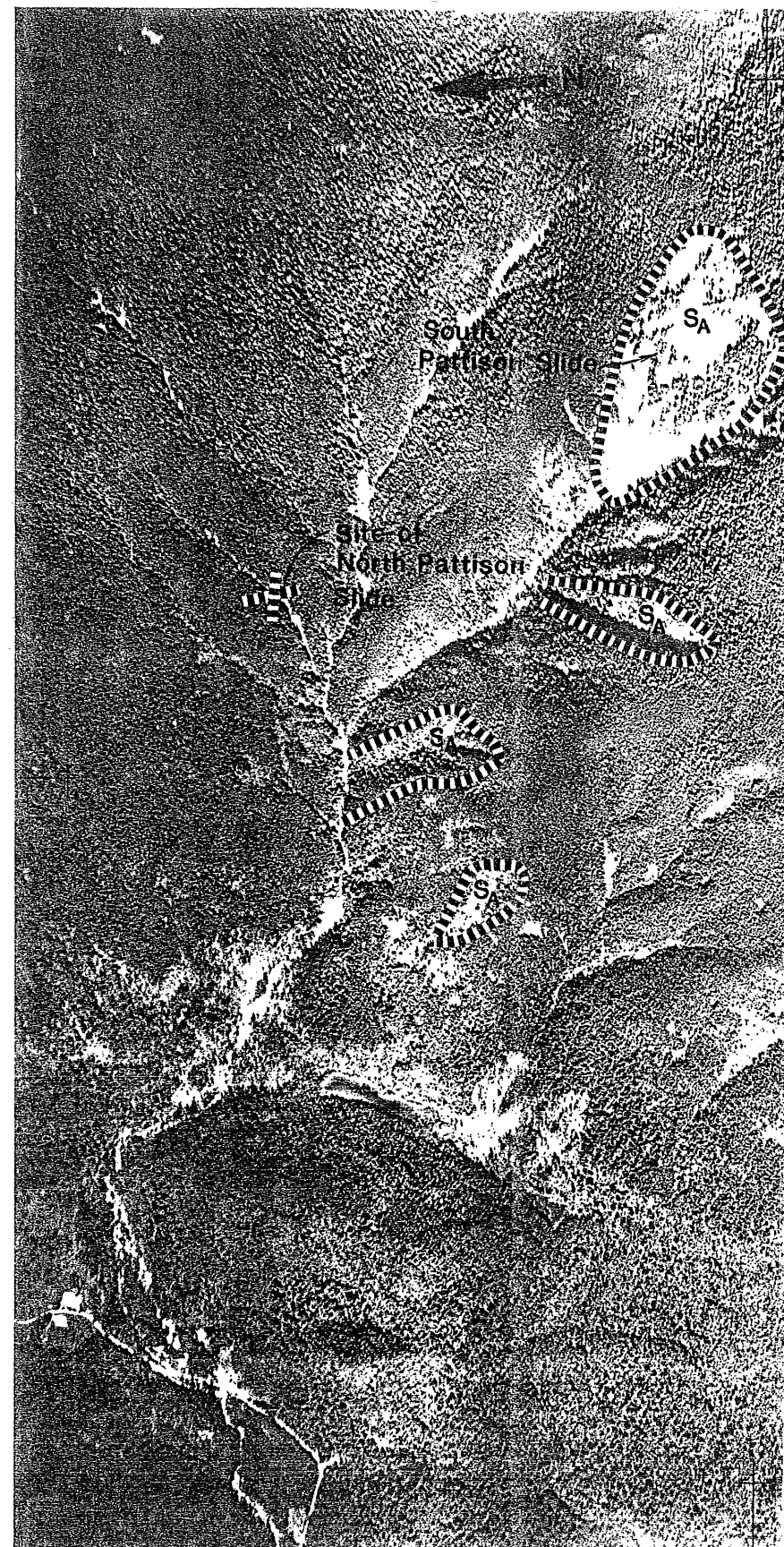
LAGACE CREEK FLOOD STUDY
B.C. MINISTRY OF ENVIRONMENT

CHANNEL CHANGES
ALONG LAGACE CREEK

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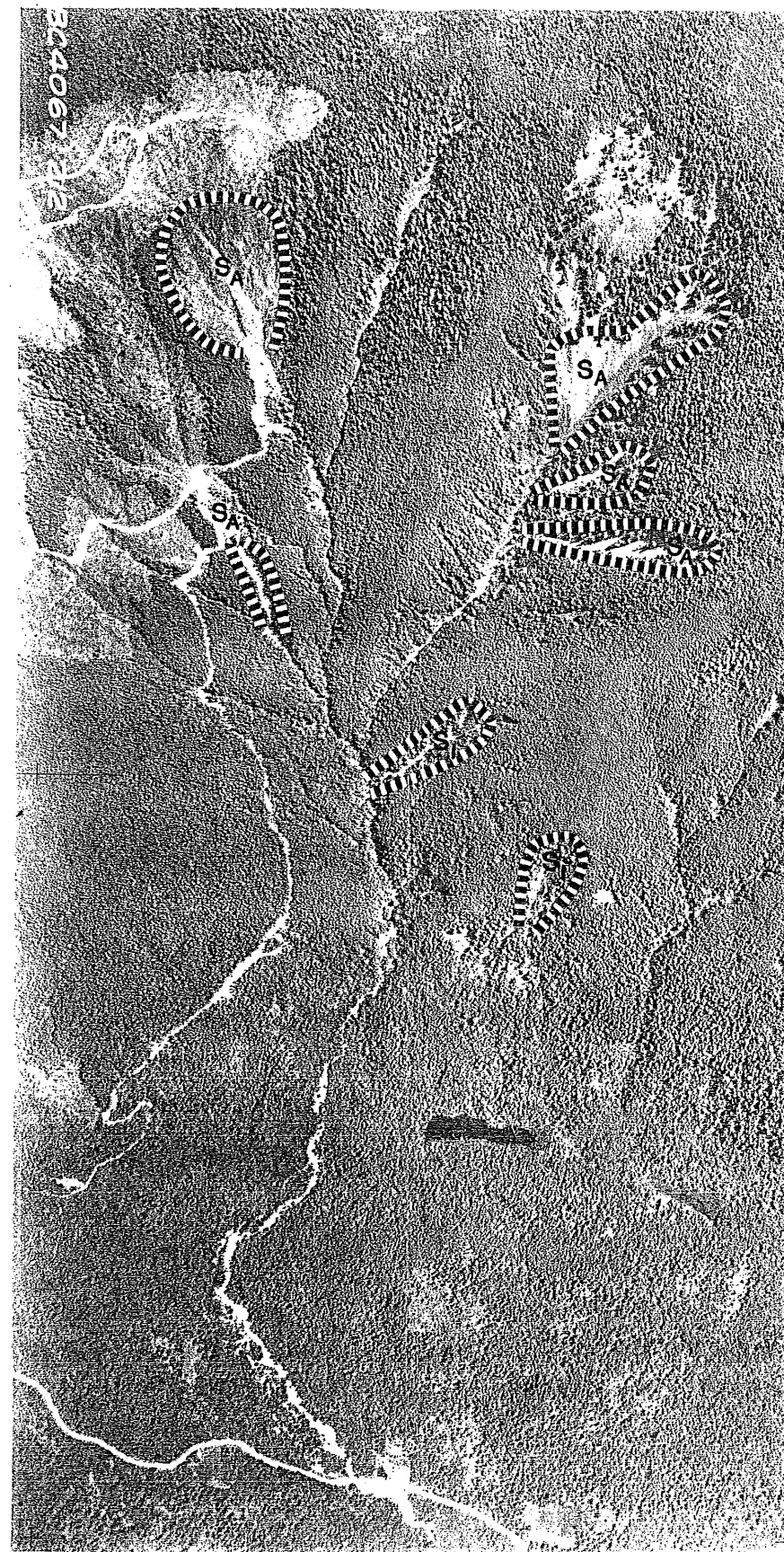
Drawn: VU Date: MAR/85 Figure: 6



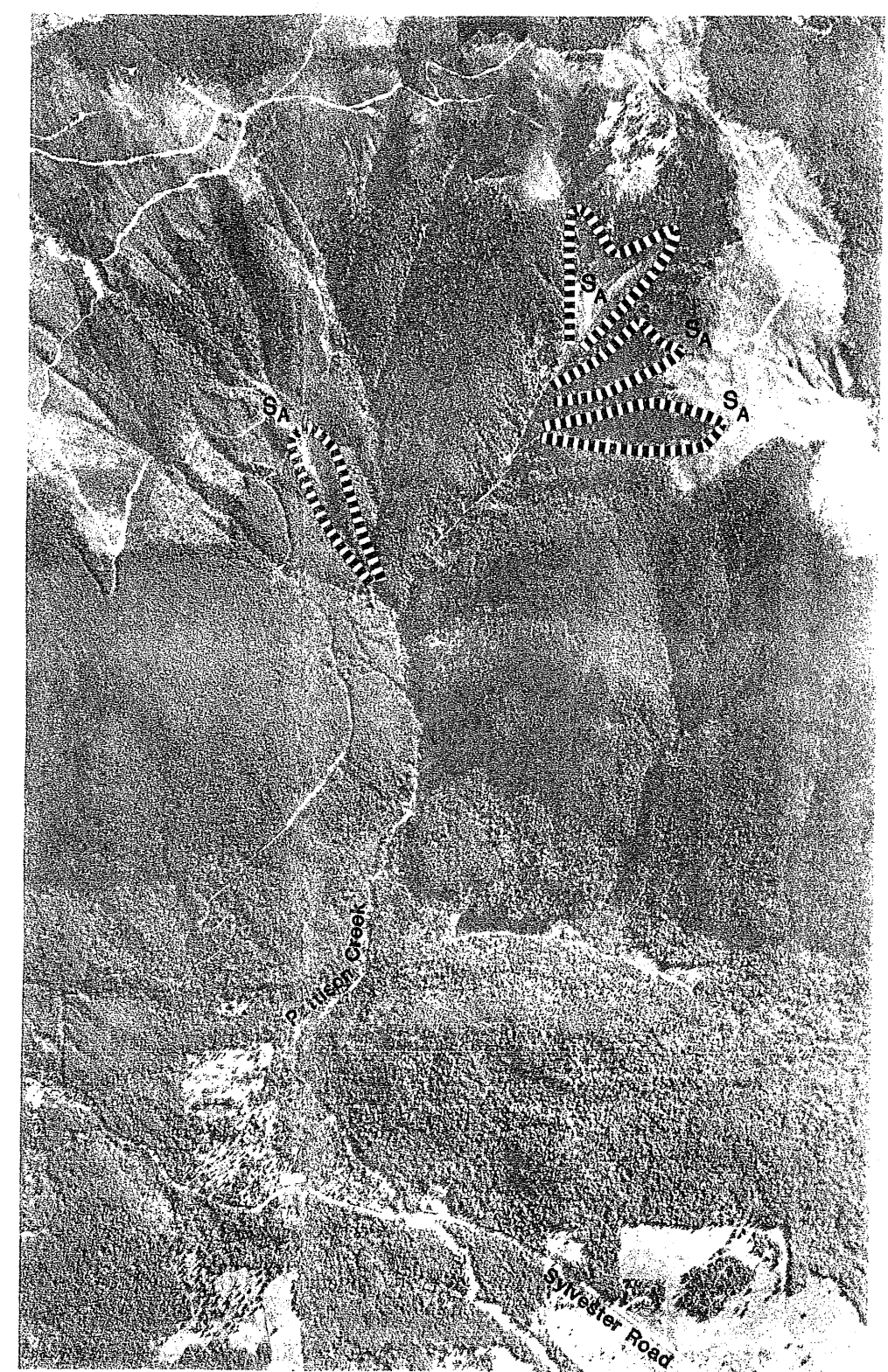


JUNE, 1940

SCALE:
0 1km (Approximate)



JULY 21, 1962



SEPTEMBER 11, 1979

NOTES :

S_A - ACTIVE SLIDE SCAR

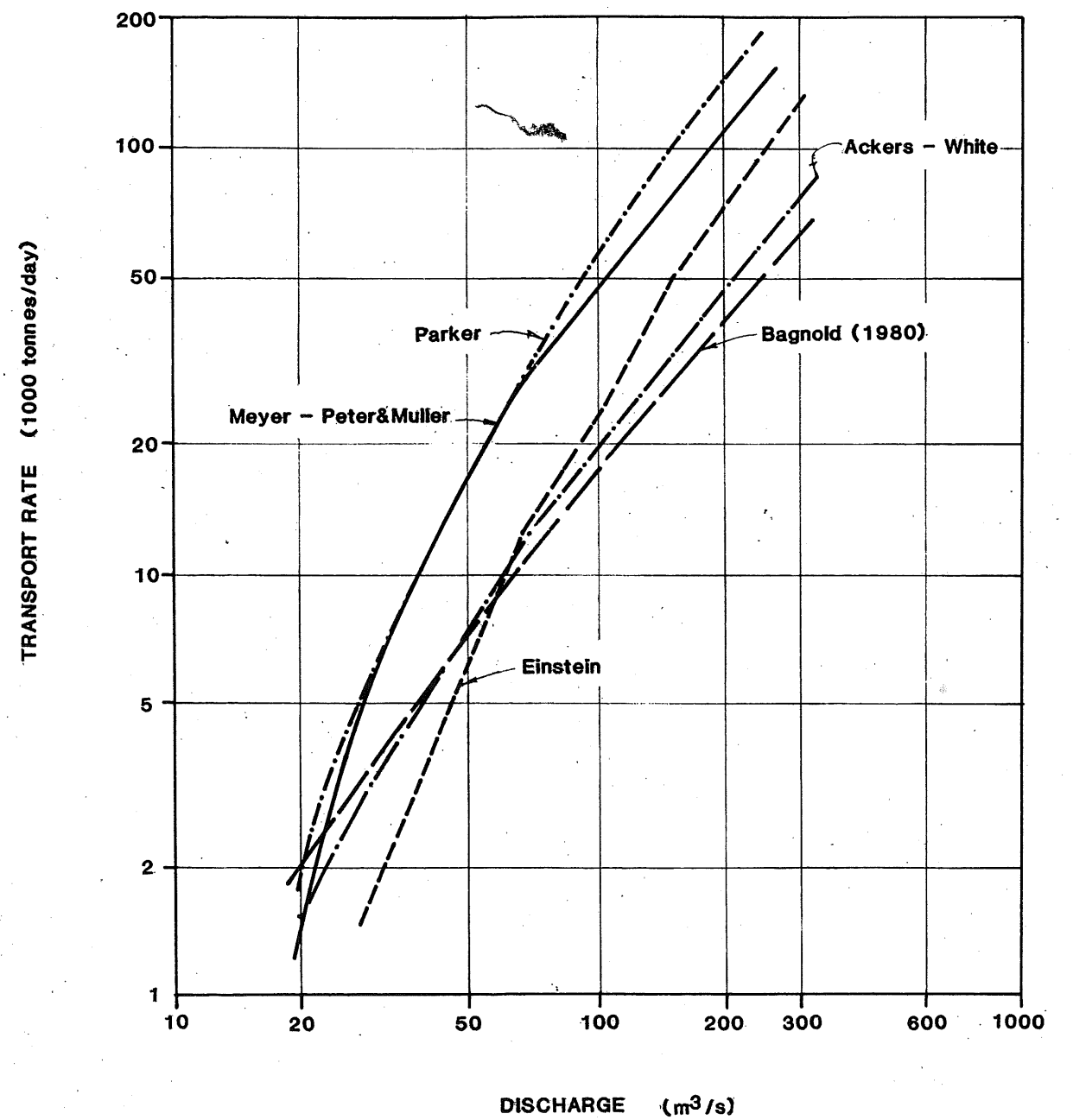
S_I - INACTIVE SLIDE SCAR

LAGACE CREEK FLOOD STUDY
B.C. MINISTRY OF ENVIRONMENT

LANSIDE ACTIVITY IN
PATTISON CREEK BASIN

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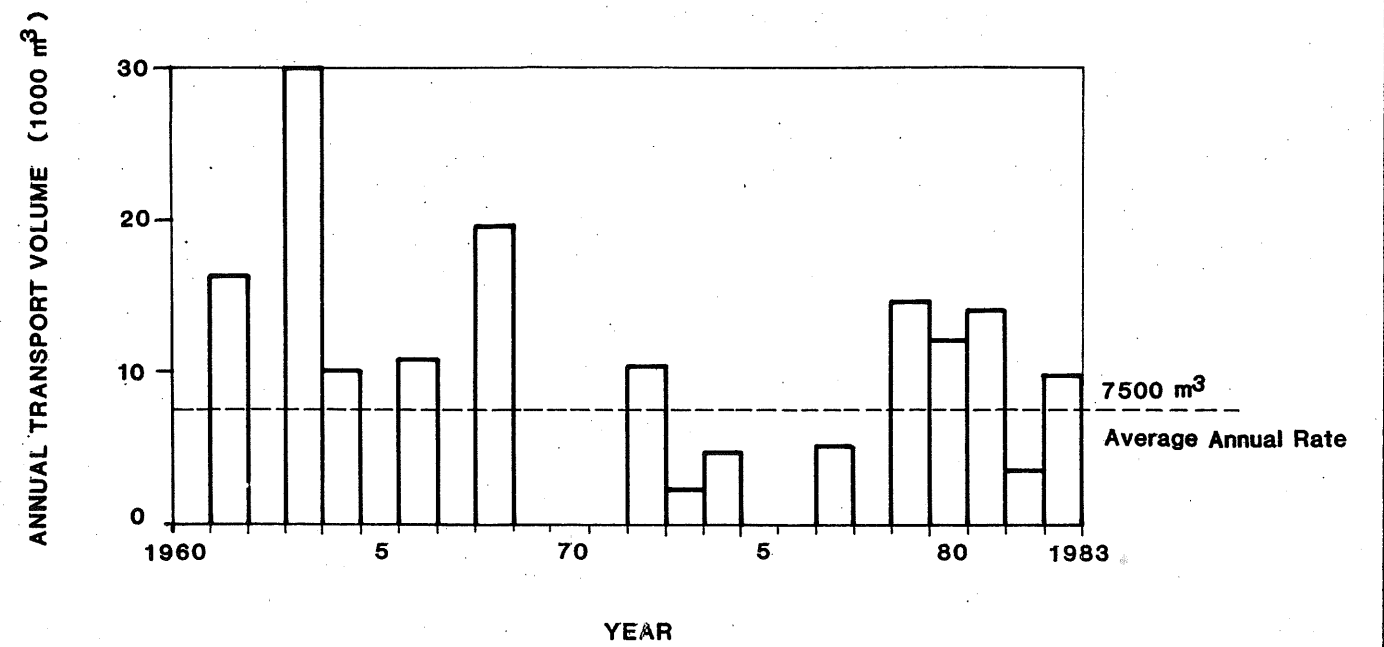
Drawn: VU Date: MAR/85 Figure: 7



LAGACE CREEK FLOOD STUDY
B.C. MINISTRY OF ENVIRONMENT
BEDLOAD TRANSPORT ESTIMATES
AT SEUX ROAD BRIDGE

northwest hydraulic consultants

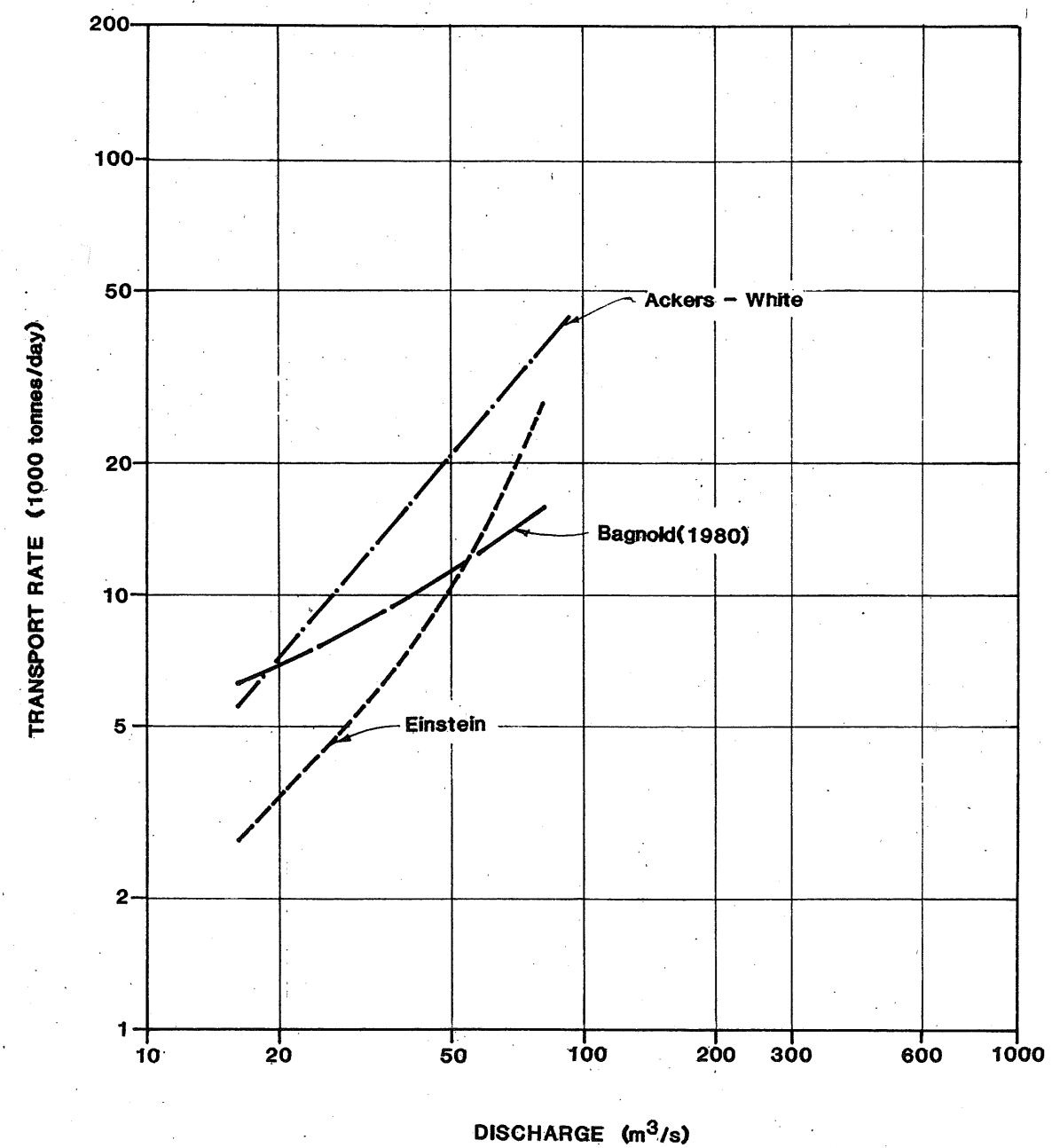
Drawn: VU Date: MAR/85 Figure: 8



LAGACE CREEK FLOOD STUDY
B.C. MINISTRY OF ENVIRONMENT
ANNUAL BEDLOAD TRANSPORT
ESTIMATES AT SEUX BRIDGE

northwest hydraulic consultants

Drawn: VU Date: MAR/84 Figure: 9



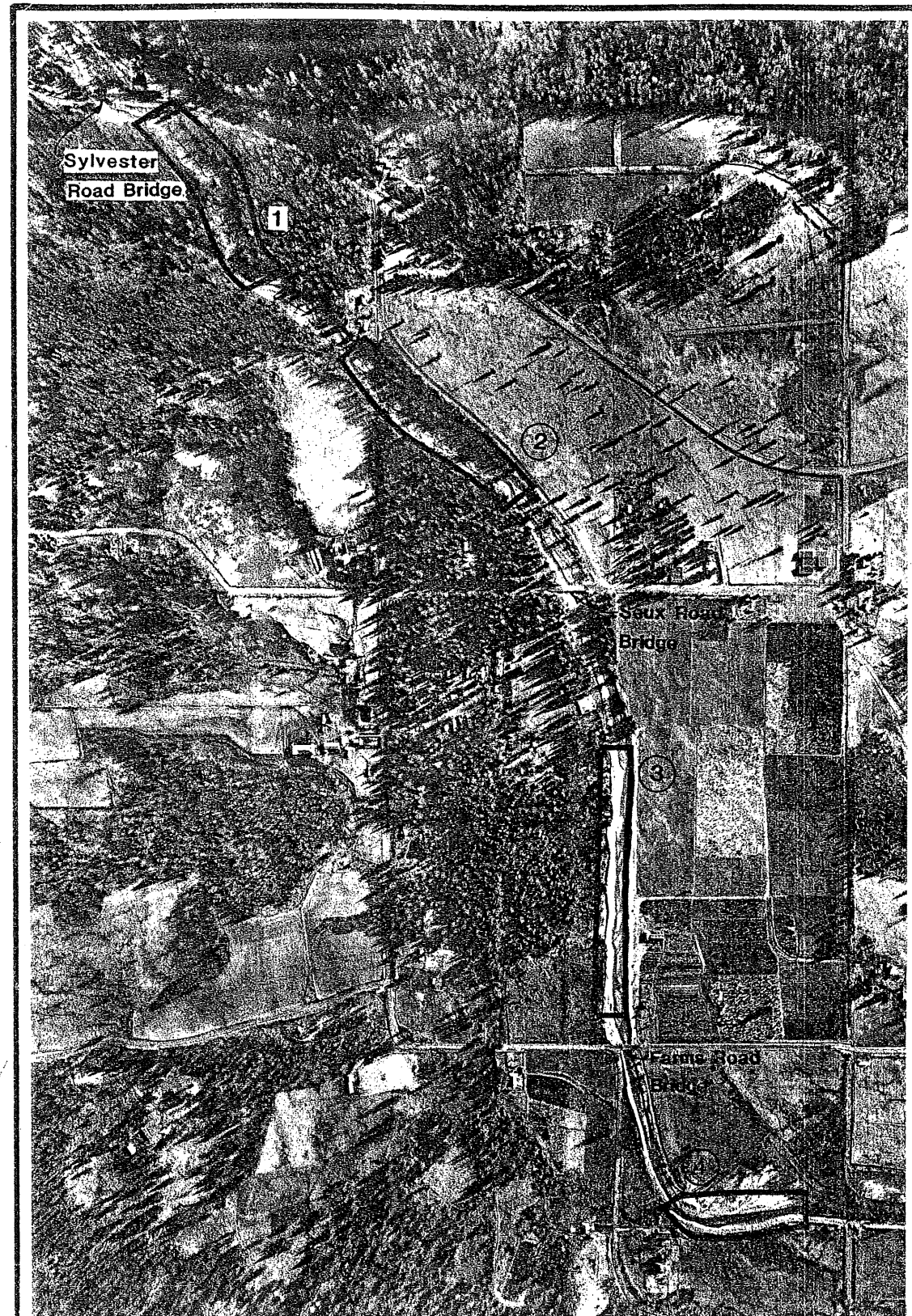
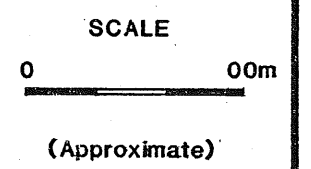


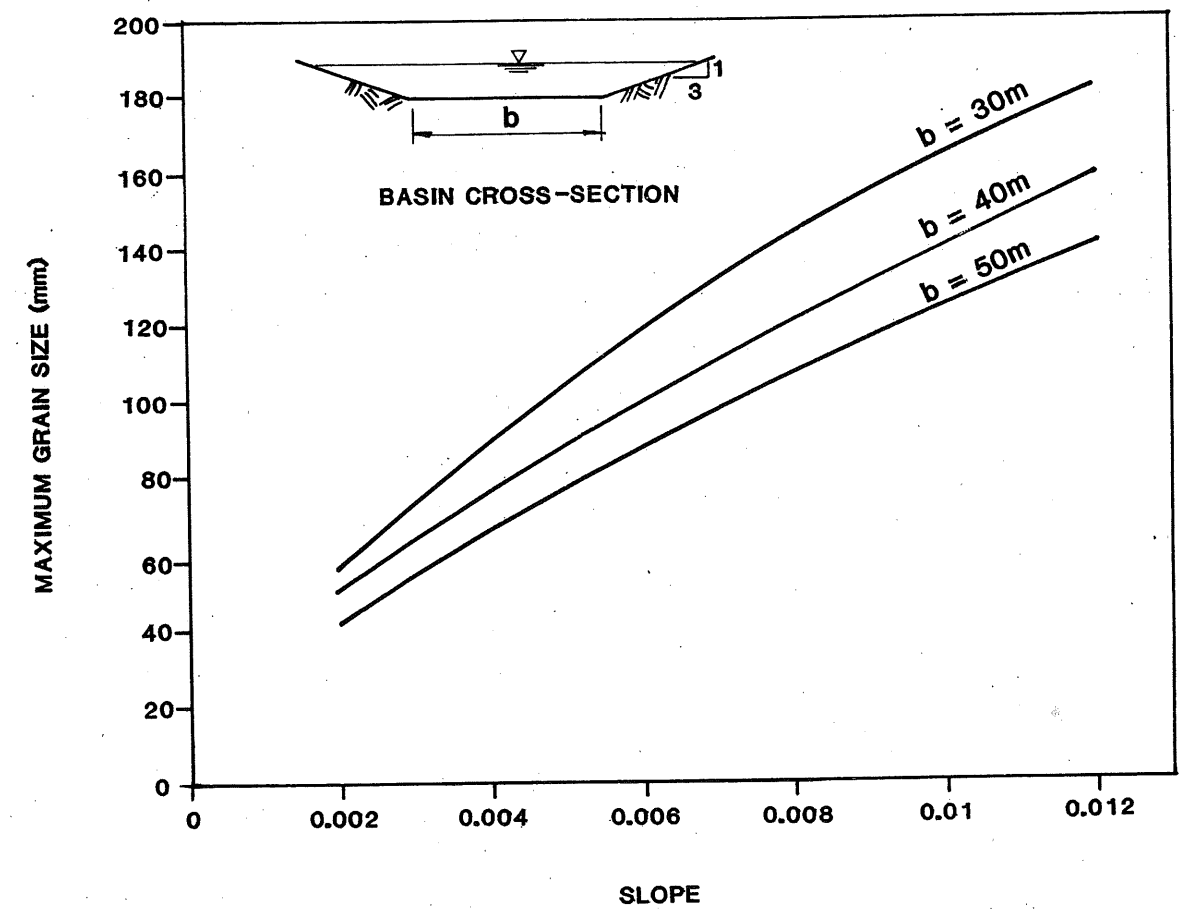
Photo date 1984



SEDIMENT BASIN SITES

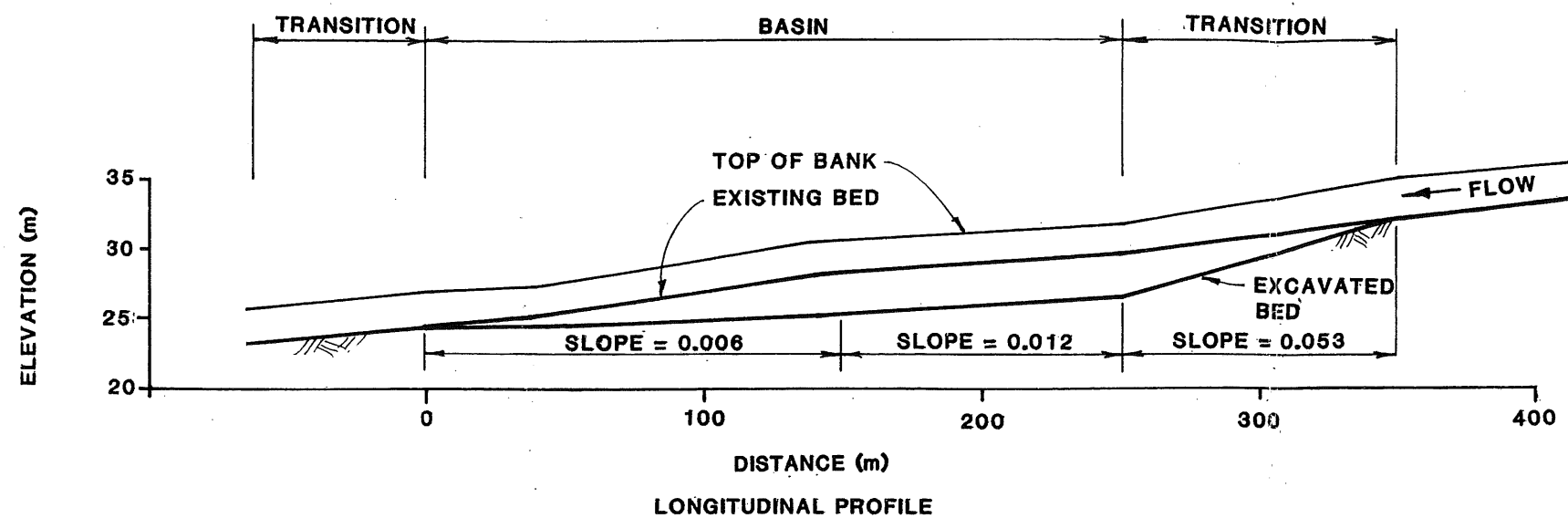
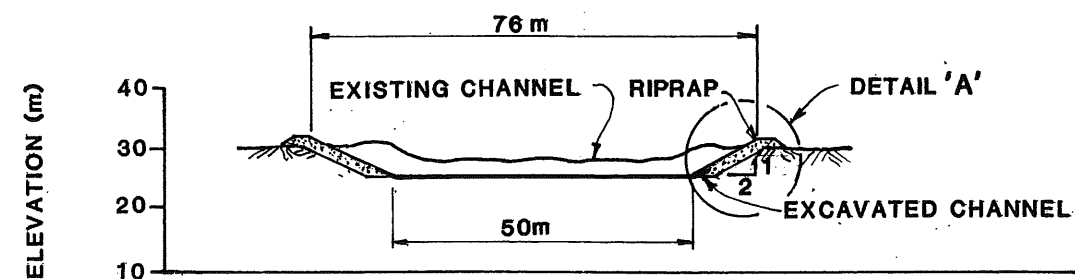
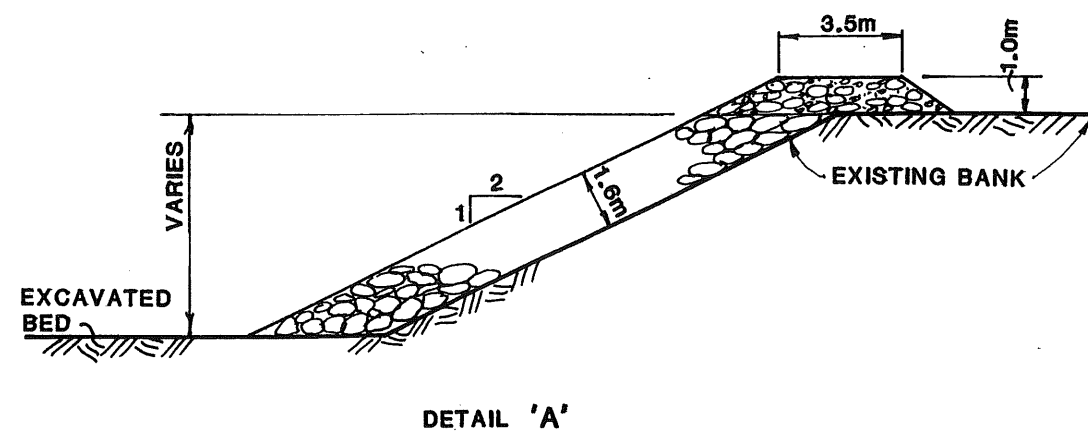
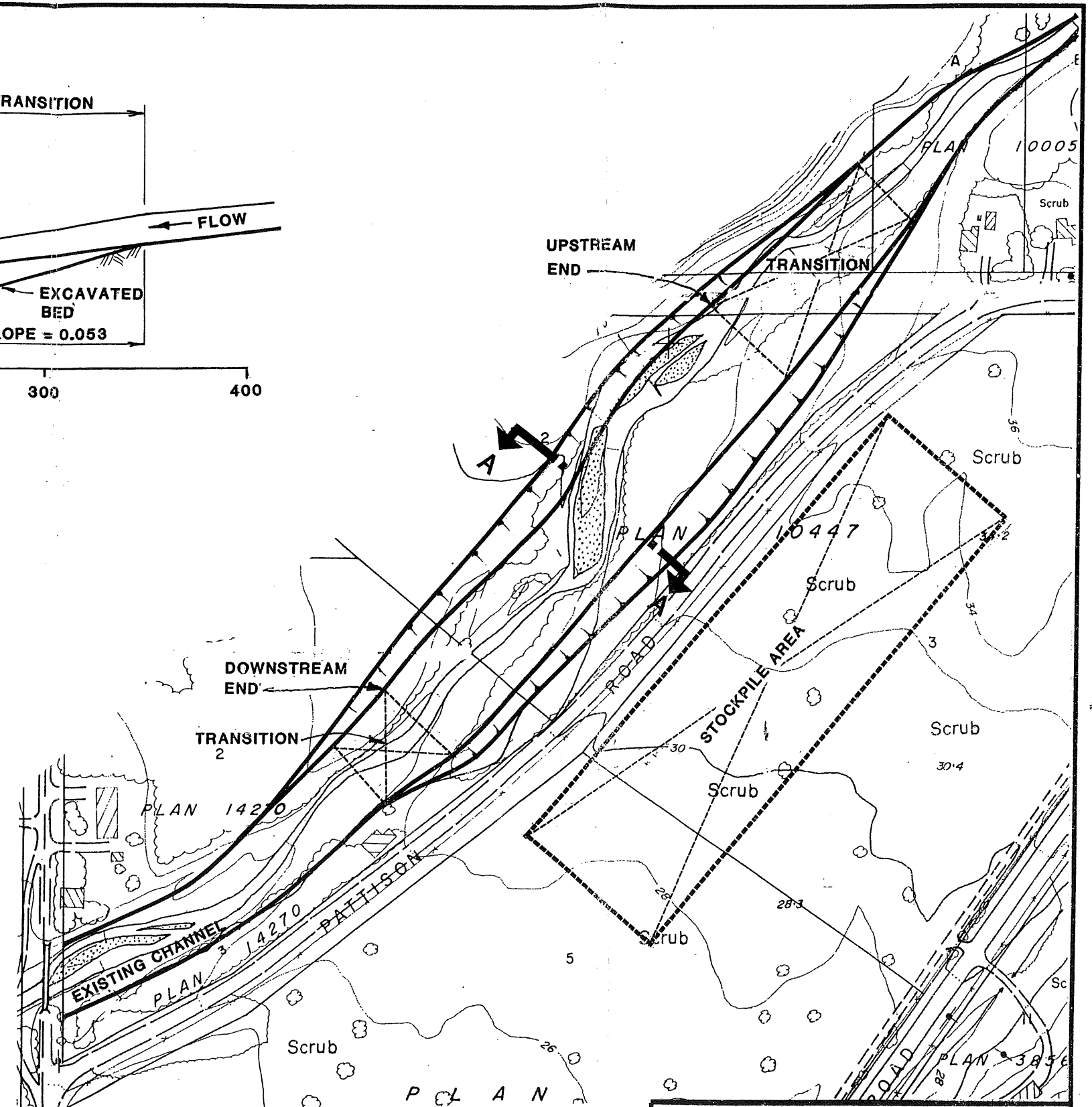
- 1 - BELOW SYLVESTER RD. BRIDGE
- 2 - ABOVE SEUX RD. BRIDGE
- 3 - BETWEEN SEUX RD. AND FARMS RD. BRIDGE
- 4 - BELOW FARMS RD. BRIDGE

LAGACE CREEK FLOOD STUDY B.C. MINISTRY OF ENVIRONMENT		
SEDIMENT BASIN SITE LOCATIONS		
northwest hydraulic consultants		
Drawn: VU	Date: MAR/85	Figure: 11



NOTE :

FOR 25 YEAR FLOOD $Q = 60\text{m}^3/\text{s}$



LAGACE CREEK FLOOD STUDY B.C. MINISTRY OF ENVIRONMENT CONCEPTUAL DESIGN OF SEDIMENT BASIN ABOVE SEUX ROAD BRIDGE northwest hydraulic consultants		
Drawn: VU	Date: MAR/85	Figure: 13



Photo 1. View upstream on Pattison Creek near confluence with Lagace Creek.



Photo 2. View upstream from Seux Road bridge showing site of the proposed basin.

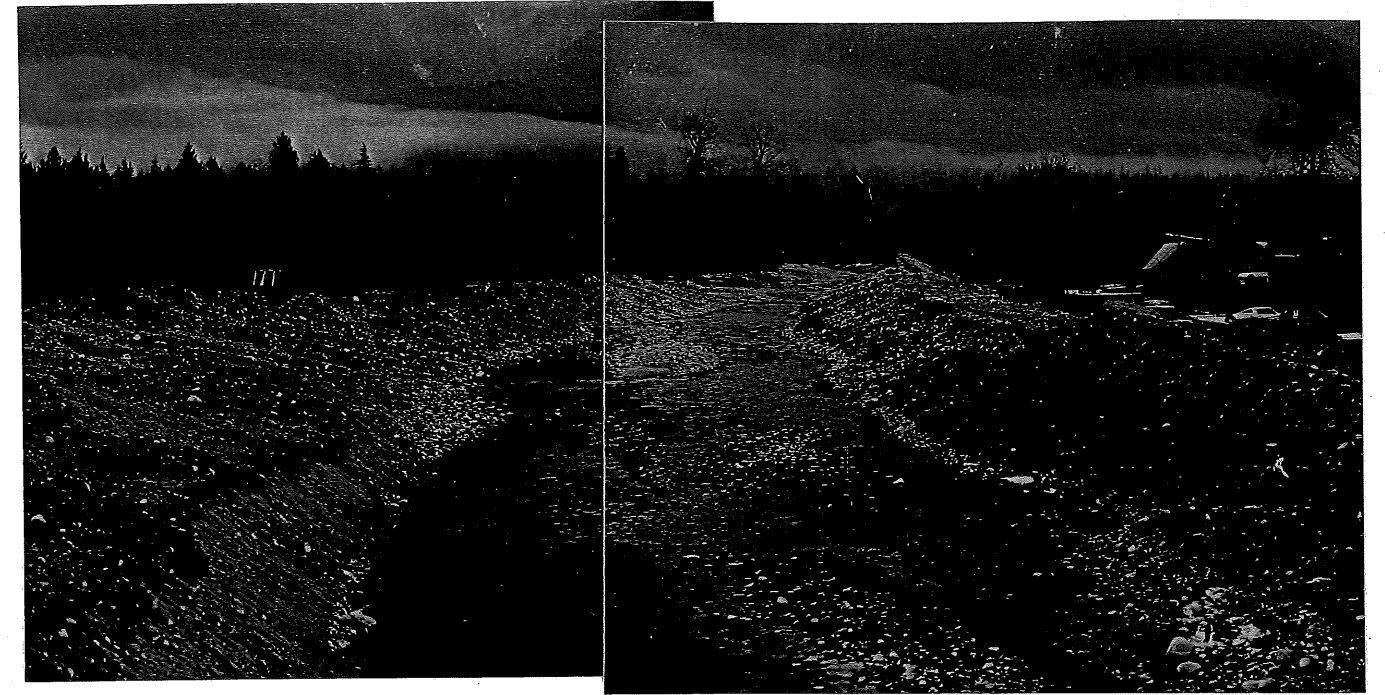


Photo 3. View upstream from Farms Road bridge showing existing gravel removal operations.



Photo 4. View downstream from below Farms Road bridge showing spoil piles along channel.