

FRASER VALLEY REGIONAL DISTRICT

ENGINEERING STUDY OF THE CASCADE/CARRATT CREEK FLOOD PROTECTION WORKS

FINAL REPORT

E5917

MARCH 1999



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**ENGINEERING STUDY
OF THE CASCADE/CARRATT CREEK
FLOOD PROTECTION WORKS**

Sigma Engineering Ltd is pleased to submit this Final Report for the Engineering Study of the Cascade/Carratt Creek Flood Protection Works to the Fraser Valley Regional District.

The report discusses the condition and effectiveness of the existing flood protection works, identifies needed improvements, and establishes a creek monitoring and maintenance program to maintain an acceptable standard of flood protection to adjacent properties.

Thank you for the opportunity to work on this project. Should you have any questions or wish to discuss any aspect of this report, please contact the undersigned at ext. 385.

Yours truly,
SIGMA ENGINEERING LTD

Brian R Samson, PEng
Project Manager



Encl.

Report Addendum

This addendum relates to items discussed in Section 5.1.1 (page 11) of the report. Following the completion of the final report, further information was obtained from BC Environment indicating that the existing Cascade Creek dyke would not be considered a “standard dyke”, for the following reasons:

- The Fraser Valley Regional District does not have permanent right of access for maintenance of the flood protection works. BC Environment normally requires statutory rights-of-way over the dyke, flood corridor and stream channel (where not owned by the crown).
- Downstream of approximately station 1+070 the dyke is not protected from potential erosion during an extreme flood. To meet BC Environment requirements, an analysis of potential erosion during a 200 year flood would be needed. If this analysis shows that any portion of the dyke could fail by erosion, riprap would be required along that portion. Based on the hydraulic analysis done as part of this study, it is estimated that an additional 300 to 500 metres of the Cascade Creek dyke could require riprapping. The required layer of riprap would cover approximately the lower two vertical metres of the dyke slope.

The issue of whether the Cascade Creek dyke is “standard” is significant only if the owner of a protected property applies for subdivision. As it stands, BC Environment would not consent to a subdivision of property in the protected area.

In future, if provincial or federal funding is available for upgrading of flood protection works, it is recommended that the FVRD consider applying for funds to extend the riprap protection on the Cascade Creek dyke.

1. SUMMARY

The existing flood protection works along Cascade and Carratt Creeks consist of a setback dyke to the west of Cascade Creek and berms along both banks of Carratt Creek (Figure 1). The flood protection works are located along reaches that have tended to gradually fill with sediment, reducing the standard of flood protection provided. The purpose of this study is to evaluate the condition and effectiveness of the existing flood protection works, identify needed improvements, and establish a creek monitoring and maintenance program that will maintain an acceptable standard of flood protection to adjacent properties.

The Cascade Creek dyke was found to be in generally good structural condition, requiring only trimming of vegetation on the side slopes. The Carratt Creek berms are also in generally good structural condition, although in some places the berms should be widened to reduce the likelihood of a breach during high water.

The Cascade Creek dyke was generally found to provide adequate protection against a 200 year flood, with the exception of a 40 metre section just upstream of Sylvester Road that needs to be raised by between 0.1 and 0.5 metres. The Carratt Creek berms were also generally found to be of sufficient height to convey the 200 year flood, with the exception of the lower 100-200 metres of the north berm. However, the Carratt Creek berms lack erosion protection and would likely sustain significant erosion damage during large floods. Adding a layer of riprap to the banks and berms of Carratt Creek would provide erosion protection, but the cost would be significant. Reconstructing the Carratt Creek berms a distance from the creek would decrease the likelihood of a berm failure, and would also permit re-vegetation of the stream banks, but again the cost would be high.

The banks of Cascade Creek require attention in some locations to improve erosion protection, rebuild eroded sections and raise relatively low areas where bank overtopping could initiate.

The beds of both creeks were generally found to be at relatively low levels, the result of an extensive gravel removal operation in 1998. There is considered to be no need for

further gravel removal from either creek at this time. It is recommended that gravel removal be undertaken once the stream bed is more than 1.0 metres above the target levels defined in this report, which generally correspond to the 1999 bed levels. This will preserve an acceptable amount of freeboard along the Cascade Creek dyke, provide a reasonable degree of flood protection to property east of Cascade Creek, and reduce the likelihood of a berm breach along Carratt Creek. The most critical area for stream bed monitoring and maintenance is the lower portion of Cascade Creek, as this is where the dyke freeboard is the lowest.

Five monitoring sections have been established along each of the two creeks for future monitoring of changes in the stream bed levels. Procedures for measuring the mean bed elevations at the monitoring sections have been developed, and maximum allowable bed levels are recommended. Guidelines for sediment excavation are provided to minimize negative impacts to habitat and stream stability.

2. BACKGROUND

This study was undertaken in February and March of 1999 by Sigma Engineering Ltd (Sigma) for the Fraser Valley Regional District (FVRD). The key objectives of the study were to assess the condition and effectiveness of existing flood protection works, identify needed improvements, and establish a creek monitoring and maintenance program. The cost of the study was shared by the FVRD and the province of BC. The provincial share of the study cost was funded under the Flood Protection Assistance Program.

Most of the existing dyking along Cascade Creek and Carratt Creek was constructed following a severe flood in 1984. Both creeks transport significant volumes of sediment and the reaches along which the dykes have been constructed are generally deposition zones. Without periodic excavation of accumulated sediment from the creek beds, the standard of flood protection tends to diminish from year to year as the bed profile rises. Although sediment removal has taken place over the years, there have been no specific guidelines or procedures for monitoring the sediment build-up or excavating the sediment.

Following a series of meetings between FVRD and the advisory committee for the flood mitigation service area, in late 1998 responsibilities for monitoring and maintaining the creeks and flood protection works were established. A draft Operation and Maintenance Manual for the flood mitigation works was prepared in 1998 by FVRD staff.

This report:

- describes the current condition of the creek beds, dykes and riprap bank protection, and identifies maintenance requirements;
- assesses the standard of flood protection provided by the existing works and recommends upgrades for any relatively weak areas;
- identifies design profiles and maximum allowable levels for both creek beds;
- provides procedures for monitoring the creek beds and excavating accumulated sediment.

Existing documents, reports, maps, drawings and other information used in carrying out this study included:

- Cascade/Carratt Creek Flood Mitigation Works, Draft Operation and Maintenance Manual, June 1998, Fraser Valley Regional District.
- Cascade & Carratt Creeks – Channel & Dyke Cross Sections, Ministry of Environment, Lands and Parks, 1988.
- Dewdney-Alouette Regional District, Cascade-Carratt Creek Flood Control Outline Report, A. A. McPherson, Rivers Section, Water Management Branch, Ministry of Environment, Lands and Parks, March 1983.
- Technical Report and Recommendations, Bland Engineering, November 1996.

3. HYDROLOGY

A peak flow analysis was carried out for Cascade and Carratt Creeks using regional peak flow mapping completed by BC Environment in 1998. The mapping is based on a statistical analysis of large flows in nearby creeks and rivers having flow records. The mapping can be used to estimate flood magnitudes for creeks with no flow record, such as Cascade and Carratt Creeks. The resulting instantaneous peak flows are summarized in the table below. The term “instantaneous” means the highest value that the flow could reach for a short period of time, as opposed to a value averaged over some time period such as 24 hours.

Table 3.1: Peak Flow Estimates

Creek / Location	Drainage Area	200 Year Peak Instantaneous Flow
Cascade Creek upstream of confluence with Carratt Creek	20.1 km ²	157 m ³ /s
Cascade Creek at Sylvester Road	23.7 km ²	178 m ³ /s
Carratt Creek upstream of confluence with Cascade Creek	3.6 km ²	40 m ³ /s

The drainage area is the area of land contributing runoff to a given point along the creek. The flows provided in the above table are for a “return period” of 200 years. This means that the flows in the creeks are expected to exceed these values on average once every 200 years. Another way of expressing these results is in terms of probabilities. For example, for Cascade Creek there is a 0.5% (1 in 200) chance each year that the flow (at Sylvester Road) will exceed 178 m³/s.

The above 200 year peak flow estimates are 15-18% larger than the estimates done by the Water Management Branch in 1983. This difference is not surprising given the inherent uncertainty in this type of analysis. In addition, some extreme flows have been recorded in the general area over the past 15 years, and this may have increased statistical peak flow estimates for recorded streams.

Sediment transport rates are significant in both Cascade and Carratt Creeks, and have likely increased in the last 20 years or so due to past logging in the drainage basins. Evidence of bedload¹ deposition during the 1984 flood appears to be present along the upper reaches of the Cascade Creek study area. Gravel terraces present along the creek channel indicate that bedload deposition during extreme floods could be as high as two metres near the upper Cascade Creek fan. Bedload deposition during extreme floods appears to decrease with distance down the fan.

4. SURVEY

The purposes of the survey were to:

- Determine the current crest profile of the Cascade Creek dyke;
- Determine current bed levels and cross sections of the two creeks for use in the hydraulic analysis;
- Establish cross sections for future monitoring.

4.1 Survey Methods

4.1.1 Cascade Dyke Crest Profile

The crest of the Cascade Creek dyke was surveyed to identify any differences from the 1985 as-constructed profile. The survey started at the monument on the Sylvester Road bridge deck (elevation 96.090 m Geodetic Survey of Canada - see data sheet in Appendix C), proceeded along the crest of the Cascade Creek dyke, and then looped back along Ridgeview Drive and Sylvester Road. The berm stationing starts at the centreline of Sylvester Road and follows a baseline approximately along the centerline of the dyke crest. The stationing along the berm is essentially the same as that shown on the BC Environment drawing 88-43-1. In addition to the crest elevation, typical crest widths and side slopes along the dyke were also measured.

¹ Bedload refers to the sediment (silt, sand, gravel and boulders) that moves along the bed of the creek. Bedload movement is usually minor during low and moderate flows, but often increases dramatically at very high flows. During floods, the stream bed can build up quickly at locations where the stream slope decreases, because the bedload tends to deposit or slow down at these locations.

4.2.2 Creek Cross Sections

Five cross sections of each creek were surveyed to determine current bed levels. The following criteria were used for selecting locations of cross sections:

- at locations previously surveyed by the Water Surveys Unit of BC Environment in 1984, 1985 and 1988, to allow direct comparison;
- ease of access for future monitoring;
- even spacing along the creek to get a good representation of the bed profile;
- at relatively straight sections of creek or near inflection points, because the banks are likely to be relatively stable and the bed level may be more representative of the overall profile than at bends where scour holes and bars tend to form.

The 1999 creek cross sections were compared with the previous surveys to evaluate changes in the bed level.

At each cross section (other than the two bridge sections), a 36" long, 1" diameter galvanized steel pipe was driven into the ground to serve as a reference elevation for future monitoring of the creek bed. The locations and elevations of these reference pins are shown in Drawings 101 and 111.

4.2 Survey Results

4.2.1 Cascade Dyke Crest Profile

In general, the Cascade Dyke crest is at or above the as-constructed profile surveyed in 1985. Drawing 101 shows the 1985 and 1999 crest profiles. A comparison of the two profiles follows:

- For a total length of about 930 metres along the lower and middle reaches of the dyke (station 0+030 to 0+450, and station 0+670 to 1+180), the crest has been raised by typically about 1.0 metres.
- Along one relatively short section of dyke (190 metres long from station 0+480 to 0+670), the crest has been lowered by typically about 0.5 metres.

- The upper 420 metres of the dyke (station 1+180 to 1+600) has the same crest profile as in 1985.

4.2.2 Cascade Creek Cross Sections

Comparisons of the 5 surveyed cross sections with earlier surveys (1984, 1985 and 1988) are detailed below. Drawings of the cross sections are included at the back of this report. Photographs of the cross sections are contained in Appendix A.

In general, the cross sections reflect the large excavation of gravel in 1984-85, followed by several years of aggradation (build-up) and then another extensive excavation in 1998. The change in bed level from 1985 to 1988 indicates the natural trend in bed aggradation or degradation (downcutting) at each cross section, as no channel excavation is believed to have taken place in these years. No channel surveys were done between 1988 and 1998, hence there is no record of the change in bed level over this period. However, a rough estimate of the net change can be made by allowing for an average depth of excavation in 1998.

A total of 18,000 m³ of gravel was removed from Cascade Creek in 1998. This gravel removal operation extended from Sylvester Road to approximately XS-4 (i.e. no excavation was done at XS-1 and XS-3). Averaged over the length and width of the excavated area, this represents a depth of roughly one metre. Between 1988 and 1998, gravel was also periodically excavated from the lower reach of Cascade Creek (downstream of Carratt Creek), but no records of quantities are available.

Although the width of the channel varies (typically decreasing in the downstream direction), for reasons of consistency, mean bed elevation has been calculated for the deepest 25 metre portion of each cross section.

XS-1

The mean bed elevation at this section has dropped 1.6 metres since 1985, even though no sediment has been artificially removed in that time period. The earlier cross sections and evidence at the site indicate that a significant depth of sediment can be deposited in this reach during extreme peak flows when large volumes of sediment are transported from the watershed. It appears that at more moderate flows the channel naturally

downcuts as bed material is sorted and transported downstream to lower gradient reaches. Between 1985 and 1988 the mean bed level at this section dropped by about 0.6 metres, and there were also changes in the section shape as material was deposited and subsequently eroded. The bankfull width of the channel has not changed significantly since 1985.

XS-3

The bed at this cross section has been generally building up since 1985. As with XS-1, no sediment has been artificially removed from this reach since 1985. Between 1985 and 1988 the mean bed elevation rose by approximately 0.7 metres. Since 1988, the mean bed elevation of the normal channel has not changed significantly, but sediment deposition has increased the height of a large mid-channel bar by about one metre. Since 1985 the bankfull width of the channel has increased by approximately 7 metres due to bank erosion on both sides of the channel.

XS-5

Between 1985 and 1988 the mean bed level rose by approximately 0.3 metres. Currently the bed is approximately 0.4 metres below the 1985 level, due to the 1998 gravel removal. The bankfull width of the main channel has not changed since 1985.

XS-7

Between 1985 and 1988 the mean bed level rose by approximately 0.8 metres. Currently the bed is approximately 0.7 metres below the level it was in 1985, due to the 1998 gravel removal. The bankfull width of the main channel has increased by approximately 3 metres since 1985 due to bank erosion.

XS-10

Between 1985 and 1988 the mean bed level rose by approximately 0.6 metres. Currently the bed is approximately 0.4 metres below the level it was in 1985, due to the 1998 gravel removal. The bankfull width of the main channel has not changed significantly since 1985.

The key characteristics of the Cascade Creek cross sections are summarized in the table below, with sections listed from upstream to downstream.

Table 4.1: Cascade Creek Cross Sections

Cross Section	Mean Bed Elevation			Bankfull Width	
	Current	1985-88 Change	1988-99 Change	Current	1985-99 Change
XS-1	118.7 m	-0.6 m	-1.0 m	50 m	0
XS-3	109.4 m	+0.7 m	0 m	70 m	+7 m
XS-5	99.4 m	+0.3 m	-0.7 m	40 m	0
XS-7	93.2 m	+0.8 m	-1.5 m	27 m	+3 m
XS-10	91.0 m	+0.6 m	-1.0 m	25 m	0

Typically, the creek bed aggraded by 0.6 metres between 1985 and 1988, with the exception of XS-1 which degraded 0.6 m. The net change in bed level between 1988 and 1998 appears to have been relatively small, since the average depth excavated in 1998 (1.0 metres from XS-5 to XS-10) is roughly equal to the net change in mean bed level from 1988 to 1999. The reasons for the relatively rapid aggradation of the stream bed from 1985 to 1988, compared to relatively little build-up from 1988 to 1998, are not clear. Possible explanations are as follows:

- Sediment yield from the watershed is decreasing as hydrologic recovery from logging progresses.
- There were more large flows in the 1985 to 1988 period compared to the 1988 to 1998 period, resulting in greater sediment transport.
- Sediment accumulates more rapidly when the channel bed is relatively low.

None of these possible explanations was investigated as part of this study. Future monitoring of the channel beds and correlation with flows could be used to better understand the factors affecting sediment deposition rates.

4.2.3 Carratt Creek Cross Sections

The changes in the mean bed elevation are summarized in the table below, with sections listed from upstream to downstream. Although the width of the channel varies (typically

decreasing in the downstream direction), for reasons of consistency, mean bed elevation has been calculated for the deepest 10-15 metre portion of each cross section.

Table 4.1: Carratt Creek Cross Sections

Cross Section	Mean Bed Elevation			Bankfull Width	
	Current	1985-88 Change	1988-99 Change	Current	1985-99 Change
XS-22	125.4 m	-0.2 m	-0.4 m	17 m	0
XS-20	110.5 m	+1.4 m	-2.7 m	17 m	0
XS-17	101.1 m	+1.5 m	-1.0 m	13 m	0
XS-15	96.1 m	+0.8 m	-0.7 m	19 m	0
XS-14	94.2 m	+0.5 m	-0.5 m	10 m	0

The results in the above table indicate significant sediment aggradation between 1985 and 1988, particularly in the middle reach of the study area. The exception is the uppermost section (XS-22), which shows a net downcutting of the channel bed from 1985 to 1999, although it is expected that sediment is deposited here during very large flows. As with Cascade Creek, extensive removal of gravel occurred in 1985 (prior to the 1985 survey) and in 1998. Other gravel removal operations were carried out in the intervening years, although there is no available record of volumes or dates. The channel bed is generally slightly lower now than in 1985. The bankfull width of the channel has not changed significantly since 1985, although this width is largely dictated by the periodic gravel excavations and the locations of the training berms.

5. CURRENT CONDITION OF FLOOD MITIGATION WORKS

The dykes and creeks were inspected for the following:

- Location, size gradation and condition of riprap on dykes and creek banks
- Erosion of creek banks
- Vegetation growth on the dykes
- Damage or instability in the dyke crest or side slopes
- Low spots or inadequate width in the dyke crests

- Debris or obstruction in the creek channels

Photographs of the dykes are contained in Appendix A.

5.1 Cascade Creek

5.1.1 Dyke

The Cascade Creek dyke is set back 50 to 150 metres from the right bank of Cascade Creek. Since its initial construction in 1985, there have been no floods large enough to produce a significant flow of water along the base of the dyke. Since 1985, additional lifts of fill have been placed on the top of the dyke, so that the lower and middle reaches of the dyke are now generally 0.5 to 1.0 metres higher than in 1985 (see Section 4.2.1 and Drawing 101 for additional details). The dyke appears to be in as-constructed condition, with the exception of vegetation growing on the side slopes, mostly alders up to 10 cm diameter (Photos 11 and 12). The width of the crest varies between 7 and 14 metres, which is considered adequate. Side slopes are typically 1.5:1 or slightly flatter, which is also considered acceptable. Upstream of approximately station 1+070 the creekside slope of the dyke is protected with riprap, which is adequately sized and in good condition. The riprap has been placed with the larger sizes (typically 1.0 m) near the base of the slope. It is not known whether the riprap is trenched-in at the base of the dyke, hence the ability of the berm to resist scour at the toe is unknown.

A “standard” dyke is one that meets the provincial requirements for flood protection, which are summarized as follows:

- High enough to provide the required freeboard above the estimated 200 year flood level. Required freeboard is usually 0.3 metres above the instantaneous peak flood level or 0.6 metres above the daily peak flood level, whichever is higher.
- Cross sectional dimensions in accordance with provincial standards, which typically include a minimum crest width of 3.6 metres and maximum side slopes of 1.5 to 1.
- Erosion protection (typically riprap) to withstand estimated 200 year water velocities. Riprap is often not necessary if the dyke is adequately set back from the watercourse.

- Properly specified materials, including fill, filter and riprap.
- Proper construction methods, including adequate compaction of fill and proper placement of riprap.
- An approved maintenance program for the dyke and the creek, and an official commitment from an approved authority to carry out ongoing maintenance.

The Cascade Creek dyke generally meets the above definition, and therefore may be considered a standard dyke.

5.1.2 Riprap Bank Protection

Riprap has been placed along the outer banks of all of the major bends downstream of XS-4. Most of this riprap is believed to have been placed in 1985, and most of it appears to have survived the intervening peak flows. Not all of the riprap is currently visible for inspection as it has been partially covered with sediment, either through natural deposition or during gravel removal operations. In some locations the riprap layer appears to have deteriorated somewhat as a result of shifting and loss of rock (Photo 13). To be effective, the riprap should form a tight, cohesive layer, with a minimum amount of space between the rocks so they interlock as much as possible. The only major failure has been to the riprap located toward the downstream end of the riprapped bank downstream of XS-6 (Photo 14 and Drawing 101). The primary cause of the failure is believed to be erosion of the right bank upstream, which has allowed large flows to impinge more directly on the bank where the failure has occurred. Significant erosion has also occurred on the right bank downstream of XS-5, and on the left bank in the vicinity of XS-3. This bank erosion is believed to be largely the result of bed aggradation, which is tending to widen and straighten the channel in certain reaches.

5.1.3 Recommended Maintenance and Upgrading

Cascade Creek Dyke

It is recommended that the vegetation be removed in accordance with the Operation & Maintenance Manual being prepared by the Regional District. At a minimum, trees growing on the side slopes and crest of the dyke should be cut down when they reach a

trunk diameter of 5 cm. Large trees can create a weakness in the berm if they topple during a flood. Vegetation can also encourage animal burrowing, which can initiate piping through the dyke under flood conditions. Dense vegetation also obscures the dyke side slopes, making it difficult to inspect for any problems.

There is a low spot in the dyke crest at station 0+630 and this should be filled in. Even though the freeboard is estimated to be adequate at the low spot, it is a relatively weak point and the cost of filling it is minor.

The crest of the dyke near Sylvester Road needs to be raised by 0.5 metres in order to provide the required freeboard above the estimated 200 year flood levels (see Section 6.2.1).

Cascade Creek Bank Protection

It is recommended that the failed riprap downstream of XS-6 be replaced (Drawing 101). The bank where the riprap has failed is a relatively likely place for an avulsion² to occur, and further erosion of this bank will increase this likelihood. Recommended specifications for materials are provided in Appendix B. The riprap should be placed at a side slope of 1.5:1 or flatter (2:1 is preferred), and extend a metre below the minimum bed level to prevent undermining.

During future gravel removal operations, while trucks and excavators are working in the stream channel, any deterioration in the riprap layer should be repaired by rearranging the rock and adding new rock if necessary. Large boulders excavated from the stream bed may be used as riprap, provided that they meet the specification in Appendix B.

To reduce the likelihood of further erosion of the left bank at the bends downstream of XS-5 and XS-6, it is recommended that the eroded right banks at these locations be rebuilt. The locations requiring rebuilding are cross-hatched in Drawing 101. The objective of rebuilding the inside of these two bends is to direct the flow more smoothly through the bends and reduce the angle of impingement on the outside bank. During the

² An avulsion is when a creek or river suddenly changes course. This can happen during a flood if the normal channel becomes choked with sediment or debris. Avulsions are more likely to occur at locations where the bank is relatively low or where the channel is more likely to become blocked.

next major gravel removal operation, the right banks at the locations shown should be rebuilt using material excavated from the stream bed. Starting at the upstream end of the eroded zone, material should be added to obtain a channel bottom width of about 30 metres. Placed material should be compacted as much as practical with the equipment available, and should be armoured using the larger material from the stream bed (two layers if possible of rock 0.3 m diameter and up). The largest rock available should be used for armouring approximately the upstream one-third of each rebuilt section. The side slope of the rebuilt bank should be 2:1 or flatter. It should be noted that rebuilding the insides of these two bends is recommended only if the channel bed can be maintained as recommended in this report. If the channel is permitted to fill in to the extent that has occurred in the past, it will be difficult to prevent bank erosion from reoccurring.

A portion of the right bank between XS-2 and XS-3 is relatively low, and this appears to be a likely location for a channel avulsion. It is recommended that this low section of bank be raised by at least one metre and armoured. Material from the stream bed could be used during the next gravel removal operation.

5.2 Carratt Creek

5.2.1 Berms

The Carratt Creek berms are generally located with no setback from the creek bank (Photo 15). The crest width typically varies between 4 and 8 metres. Side slopes are typically 1.5:1, but are as steep as 1:1 in places (Photo 16). The berms appear to be generally in as-constructed condition, with the exception of vegetation growing on the side slopes and crest in some places (mostly alders up to 10 cm, Photo 17). The crest of the left berm in the vicinity of XS-20 appears to be about 0.8 metres lower than in 1985.

5.2.2 Riprap Bank Protection

Most of the banks and training berms along Carratt Creek have no erosion protection. Riprap is currently in place on the left bank between XS-20 and XS-24, and on the left bank between XS-11 and XS-14. At other locations where riprap has been placed in the past, the rock has either washed away or is buried with sediment (Photo 18).

5.2.3 Recommended Maintenance and Upgrading

The Carratt Creek berms in their current condition are prone to erosion and breaching, particularly if the stream bed level is allowed to build up. A layer of riprap erosion protection on the berms would improve their ability to withstand large flows, but the cost would be significant. The riprap layer would have to cover the bank from the stream bed to the berm crest, requiring a large volume of rock. The cost to riprap all of the banks and berms is estimated to be roughly \$500,000. A better solution would be to set the berms back from the creek bank. A minimum of 10 metres is recommended to allow for future shifting of the channel and to provide enough area for vegetation to establish. The cost of this option (including land costs) would also likely be prohibitive.

To reduce the likelihood of a berm failure, the berms should be widened where necessary to a minimum crest width of 6 metres and maximum side slopes of 1.5:1 (2:1 is preferred). Most of the existing berms meet these requirements, with the exception of the left berm downstream of the Carratt Road bridge (Photo 16). Recommended specifications for materials are provided in Appendix B.

Short of riprapping the berms or reconstructing them further from the creek bank, the most effective way to reduce the likelihood of a berm failure is to maintain the creek bed close to the target levels recommended in this report.

6. HYDRAULIC ANALYSIS

The objectives of the hydraulic analysis were to determine design bed levels and peak flood levels for the two creeks. The design bed level is the bed level used at each of the surveyed cross sections to calculate the flood levels along the creek. A design bed level consists of a “target bed level” plus an allowance for sediment that could be occupying a portion of the channel when the flood reaches its peak. The target bed levels must be practical in that they should not require an excessive amount of excavation to achieve or maintain.

6.1 Methods

6.1.1 Cascade Creek

A detailed survey of Cascade Creek was last conducted in 1988. The 1988 cross sections were used as the basis for a HEC-RAS (US Army Corps of Engineers Hydrologic Engineering Centre – River Analysis System) computer model of Cascade Creek. The 1988 cross sections were updated by using the 1999 channel survey to adjust the bed level to current conditions. The computer model uses the cross section data and other information about the channel (flow rate, channel slope and roughness, bridge locations, etc.) to estimate the flood level at each cross section. The flow rate with a return period of 200 years was used in the analysis because this is the provincial standard for flood protection.

In using HEC-RAS to calculate the 200 year flood levels, allowances were made for:

1. Bed build-up between sediment removal operations;
2. Bedload deposition that could accompany the peak flow.

The first allowance was selected to be 1.0 metres. Average annual rates of sediment build-up between 1985 and 1988 were between 0.1 and 0.3 metres per year at the sections surveyed. Since 1988, rates of sediment accumulation appear to have decreased. An allowance of 1.0 metres would therefore mean that intervals between clean out would typically be between 3 and 10 years or more. This will give the excavated reach some time for ecological recovery and should also facilitate the natural transport of sediment to downstream reaches. An excavation depth of 1.0 metres also permits reasonable economy in the excavation operation.

The second allowance was selected to be 2.0 metres at the upstream end of the Cascade Creek study reach, decreasing to 1.0 metres at the Sylvester Road bridge. This allowance was based on evidence at the site, and on the results of other studies indicating that bedload deposition during large floods is greatest just downstream of sudden changes in stream gradient (i.e. near the fan apex).

In the HEC-RAS model no provision was made for a blockage of the Sylvester Road Bridge, other than the sediment allowances described above.

The 1999 bed profile was generally selected as the “target bed level” for Cascade Creek, because:

- it is a smooth profile, i.e. without any dips or sudden gradient changes which could cause excessive local deposition;
- it is known to be readily achievable without significantly encountering layers of clay or other undesirable soil types (Jim Lund, Cascade Contracting Ltd, pers. comm.);
- it does not cause any obvious instabilities in the channel, such as bank sloughing;
- it is low enough that the existing dyke, with only minor upgrading, will provide protection against the estimated 200 year flood.
- it is low enough that the undyked property east of Cascade Creek will be afforded some degree of protection against large floods.

For cross section XS-1, the target bed level was selected to be somewhat higher than the 1999 level, because the bed has degraded naturally at this location, and it is not necessary for flood protection to maintain the bed at such a low level.

For cross section XS-3, the target bed level was selected to be approximately one metre lower than the 1999 bed level. No gravel removal was done here in 1998 and the current bed level is relatively high. The right bank just upstream of XS-3 is relatively low, and this appears to be a likely place for an avulsion to occur. A right bank avulsion at this location could be dangerous because a new channel could form along the dyke and cause undermining and erosion of the dyke fill.

In the HEC-RAS analysis, channel roughness factors (Manning equation “n” values³) were selected as follows:

³ The Manning equation is one of the key equations used in the estimation of flood levels, and uses factors such as the channel slope, shape, and roughness to calculate a water depth corresponding to any given flow rate. The “n value”

- For the main channel, the selected n value varied linearly from 0.06 at the upstream end to 0.04 at the downstream end. These values were based on the size of bed material, the shape and uniformity of the channel, and on keeping the state of flow subcritical⁴. Various studies have shown that flow in natural channels rarely becomes supercritical due to the extreme turbulence that characterizes large flows. Significant bedload movement accompanying extreme flows is also believed to increase the effective channel roughness.
- For the overbank area an n value of 0.15 was selected, corresponding to dense vegetation with underbrush.

6.1.2 Carratt Creek

The analysis for Carratt Creek was similar to that for Cascade Creek. However, instead of using HEC-RAS, individual uniform flow calculations⁵ were carried out at each of the 5 cross sections surveyed in 1999. This simpler analysis was selected because:

- the accuracy was reasonably good given the relative uniformity of the channel and the simple shape of the cross sections (i.e. no overbank area);
- a high level of accuracy in estimating flood levels was not as important since the existing berms are not designed or built to provincial standards.

Sediment allowances for Carratt Creek were selected as follows, using the same reasoning as for Cascade Creek:

- For year-to-year aggradation, 1.0 metres. Intervals between sediment excavation are expected to be between 2 and 7 years, with the more frequent maintenance required for the middle reach (XS-17 and XS-20).

refers to the channel roughness coefficient selected for use in the Manning equation. The roughness coefficient depends on the size of material lining the stream bed and banks, the presence of vegetation or other protrusions, etc.

⁴ The terms "subcritical" and "supercritical" refer to the relative speed of the flow (usually expressed in metres/second or feet/second) for a given flow rate and shape of cross section. Flowing water can reach supercritical velocities in smooth and/or steep channels, but it is uncommon in natural channels.

⁵ The water depth was estimated using the Manning equation and the channel characteristics (slope, cross section, roughness) at the cross section. The results are reasonably accurate provided the channel characteristics are fairly constant (or changing only gradually) with distance along the channel.

- For bedload deposition accompanying the design flood, 1.5 metres at XS-22, decreasing linearly to 1.0 metres at XS-14.

As for Cascade Creek, the 1999 bed profile was generally used as the target mean bed elevation for Carratt Creek. Maintaining the bed profile of Carratt Creek close to the 1999 levels will provide a reasonable degree of flood protection to adjacent properties and will reduce the likelihood of a berm washout.

In the hydraulic calculations, Manning n values varied from 0.078 at XS-22 to 0.046 at XS-14. The n-values were adjusted to maintain subcritical or near-critical flow at each cross section. There is no significant overbank area as the channel is bermed on both banks.

6.2 Results of Hydraulic Analysis

6.2.1 Cascade Creek

Right Bank

The 200 year water surface profile is shown on Drawing 101 together with the 1999 surveyed crest of the dyke west of Cascade Creek. The usual provincial standard for minimum acceptable freeboard is 0.3 metres above the estimated 200 year peak instantaneous flood level. The estimated freeboard provided by the Cascade Creek dyke is more than adequate at the upstream end of the dyke, but steadily decreases in the downstream direction. The following table summarizes the results.

Table 6.1: Estimated Cascade Dyke Freeboard

Cross Section	Berm Station	Freeboard	Comments
XS-1	1+492	2.9	
XS-2	1+326	1.6	
XS-3	1+154	2.2	
XS-4	0+947	1.9	
XS-5	0+780	1.8	
XS-6	0+580	1.7	
XS-7	0+417	1.6	
XS-8	0+250	1.4	
XS-9	0+148	1.3	
XS-10	0+077	0.5	
XS-11	0+029	0.2	
	0+014	-0.2	Overtops berm
XS-12	0+007	0.4	

Approximately 40 metres of dyke immediately upstream of Sylvester Road needs to be raised by up to 0.5 metres in order to provide a minimum of 0.3 metres of freeboard during a 200 year flood. Recommended specifications for materials are provided in Appendix B.

Left Bank

Provided the Cascade Creek channel is maintained as recommended in this report, most of the property east of the creek and upstream of the Carratt Creek confluence should be reasonably well protected from flooding. It is estimated that the 200 year flood would overtop the left bank somewhere between XS-6 and XS-7, which would impact a relatively small corner of the property situated between the two creeks. In addition, during the 200 year flood the freeboard on the left bank is estimated to be only about 0.3 metres at XS-5, and may be minimal at other locations in between the cross sections surveyed. However, during more frequent floods, such as a 50 year return period event, there should be little or no overtopping of the left bank except near the confluence with Carratt Creek.

The left bank between XS-6 and XS-7 is also a relatively likely place for an avulsion to occur, due to the potential bank overtopping as well as the bank erosion that has been

occurring at this location and just upstream (see Section 5.1.2). If an avulsion occurs at this location, then Cascade Creek would erode a new channel toward Carratt Creek, isolating the triangle of land situated between the two creeks.

It is also estimated that the 200 year flood would overtop the left bank by about one metre in the vicinity of XS-8, just downstream of the mouth of Carratt Creek. This conclusion is based on the 1988 survey, as the left berm was not resurveyed for this study. Unless the left berm has been raised since 1988, there appears to be a low spot in the berm extending approximately 100 metres upstream and downstream of XS-8 (see Ministry of Environment Drawing No. 88-43-2, Profile No. 4).

6.2.2 Carratt Creek

In its current excavated condition, the Carratt Creek channel was found to have sufficient capacity for the 200 year peak flow except along the lower 100-200 metres, where the right berm would be overtopped. Allowing for bed aggradation and bedload deposition as discussed in Section 6.1.2, approximately 0.5 metres of freeboard was provided at XS-22, XS-20 and XS-15 during the 200 year peak flow of 40 m³/s. At the Carratt Road bridge, allowing 1.0 metres for aggradation and 1.4 metres for bedload deposition, the 200 year flood level would be approximately 0.4 metres higher than the underside of the bridge structure. This lack of clearance, combined with the relatively short bridge span (13 metres) could result in debris jamming during floods. This could cause an increase in the water level just upstream of the bridge, resulting in berm overtopping.

The banks and berms along Carratt Creek are generally not protected against erosion, and it is expected that significant sloughing and erosion would occur during large floods. It is not possible to predict whether the berms in their current state would survive an event such as the 200 year flood, however it is considered unlikely. Maintaining the creek channel within 1.0 metres of the target levels will certainly decrease the likelihood of a berm failure during large floods.

7. CREEK BED MONITORING

Due the extensive gravel removal operation in 1998, it is expected that gravel removal will not be necessary for a few years. The cross section drawings at the back of this report show previous, current (1999) and target bed levels. With the exception of XS-3, where no gravel was removed in 1998, the beds of both creeks are at or below the target bed levels. At XS-3 the bed level in 1999 was 1.0 metres above the target level, which would normally mean that gravel removal is required. However, it is recommended that XS-3 be monitored for at least another year before gravel removal is undertaken, as this reach may be downcutting as the result of the recent excavation downstream.

Five cross sections on Cascade Creek and five cross sections on Carratt Creek have been established for ongoing monitoring of the creek bed. At each of the ten cross sections, a reference point has been established for measuring the elevation of the stream bed. The locations of the monitoring sections and the reference points are shown in Drawings 101 and 111.

Monitoring and maintaining stream bed levels is most important toward the lower end of Cascade Creek (XS-11), because this is where the dyke freeboard is the smallest. Cross sections XS-5 and XS-7 are also important because sediment build-up here will increase the flood risk to property east of the creek, which is relatively unprotected. Sediment build-up along the upstream portion of Cascade Creek is less critical because of the generous amount of freeboard provided by the dyke. Channel maintenance upstream of approximately XS-4 (particularly between XS-2 and XS-3) is recommended primarily to reduce the chance of an avulsion that could undermine or erode the dyke. Sediment deposition near XS-3 is also contributing to erosion of the left bank, which is a significant source of sediment due to its height and steepness (Photo 2; note unstable slope and fallen trees in background).

The Visual Method and measurements at the two bridge section should be carried out at least once a year, during late summer low water conditions and also following large flows which may have deposited significant volumes of sediment. If these methods indicate a significant build-up of gravel, the bed levels should be measured at all of the monitoring

sections to determine whether gravel removal is required. Even if the bed does not seem to be building up significantly, the bed level at the 10 monitoring sections should be measured at least every second year to establish a record of bed level changes.

7.1 Visual Method

A quick impression of the level of the stream bed can be obtained by comparing the current cross section to the photographs in Appendix A. The photographs are all taken from approximately 20 metres upstream of each of the 10 cross sections and show the bed at 1999 levels, which have generally been adopted as “target levels” for both creeks. The cross section drawings at the back of the report can be used to estimate bank heights relative to the 1999 bed level. If the bed appears to be noticeably (a metre or more) above the level shown in the photographs and the cross section drawings, then more accurate measurements of the bed levels should be made using the Survey Method or Stringline Method.

7.2 Bridge Sections

The two bridges (Sylvester Road and Carratt Road) provide convenient reference points for measuring changes in the stream bed level. The bed levels at the bridges can be used to indicate the general bed level near the bridges, but are not necessarily indicative of bed levels further upstream or downstream. Bed level measurements at the two bridges provide a quick way of determining whether measurements at other sections should be made.

At the upstream edge of the Sylvester Road Bridge, the distance from the upper surface of the bridge deck to the stream bed should be measured at 5 points spaced 5 metres apart, across the lowest 20 metres of the channel. The average of these 5 measurements should be 5.0 metres or more. If the average is less than 4.0 metres, then this is an indication that gravel removal is needed and measurements should be made at the other monitoring sections using the Survey or Stringline Method.

At the downstream edge of the Carratt Road Bridge, the distance from the underside of the bridge deck to the stream bed should be measured at two points spaced 5 metres apart,

across the lowest 5 metres of the channel. The average of these two measurements should be 3.0 metres or more. If the average is less than 2.0 metres, then this is an indication that gravel removal is needed and measurements should be made at the other monitoring sections using the Survey or Stringline Method.

7.3 Survey Method

For this method a surveyor's level is required to make the measurements. The procedure for using the surveyor's level is given in Appendix C. At each of the monitoring cross sections with the exception of the two bridge sections, a 1" diameter galvanized pin has been driven into the ground to be used as a vertical reference point (benchmark) for surveying the creek. The locations of the pins are shown in Drawings 101 and 111. In the field, the locations of the pins have been marked with surveyor's flagging and the pins have been painted bright orange. The elevation of the top of the pin at each cross section is provided in the table below and on Drawings 101 and 111.

Table 7.1: Elevations of Benchmarks at Monitoring Cross Sections

Cascade Creek		Carratt Creek	
Cross section	Elevation of Benchmark	Cross section	Elevation of Benchmark
XS-1	122.44 m	XS-22	121.16 m
XS-3	111.07 m	XS-20	113.40 m
XS-5	101.16 m	XS-17	104.10 (underside of bridge deck)
XS-7	95.92 m	XS-15	98.80 m
XS-11	96.09 m (top of bridge deck)	XS-14	95.14 m

At each of the monitoring cross sections, the elevation of the channel bed should be measured:

- for Cascade Creek, at five points spaced 5 metres apart (total distance 20 metres)
- for Carratt Creek, at three points spaced 5 metres apart (total distance 10 metres)

The distance between the points does not have to be exact (plus or minus one metre is acceptable), but the set of 5 or 3 points should cover the deepest part of the channel. For each cross section, the average of the 5 or 3 elevations is calculated. This is the mean bed elevation at the cross section. A detailed procedure for calculating the mean bed elevation is given in Appendix C. If it is more than 1.0 metres above the target bed elevation in Table 7.2 provided below, then *gravel removal is required in the vicinity of that cross section.*

Table 7.2: Target Mean Bed Elevations at Monitoring Sections

Cascade Creek		Carratt Creek	
Cross section	Target Mean Bed Elevation	Cross section	Target Mean Bed Elevation
XS-1	120.0	XS-22	125.5
XS-3	108.3	XS-20	110.8
XS-5	99.4	XS-17	101.0
XS-7	93.2	XS-15	96.1
XS-11	91.0	XS-14	93.7

7.4 Stringline Method

A horizontal stringline set at a known elevation could also be used to measure the bed elevation at the monitoring sections using only a survey rod or tape measure. At each of the monitoring cross sections, vertical posts anchored in concrete blocks could be placed to establish a horizontal reference line across the creek channel. At each cross section, a string would be tied between the tops of the two posts and stretched taut across the creek. A brightly coloured, lightweight but strong string is required so it can be easily seen and stretched tight to minimize sag. Once the posts are placed, the elevations of the tops (or some other point where the string will be attached) will need to be surveyed, using the reference pins as benchmarks. The distance from the stringline to the creek bed is measured at the 3 or 5 points as described above for the survey method, and the mean bed elevation calculated by averaging the measurements and subtracting the average from the elevation of the string.

8. GUIDELINES FOR SEDIMENT EXCAVATION

1. The measurements and calculations done as part of the creek monitoring program will indicate the required average depths of gravel removal. Between monitoring sections, the required depth of excavation should be estimated by interpolating linearly between the target mean bed elevations at the monitoring sections.
2. The average bed elevation of the excavated channel should match the target mean bed elevations provided in Table 7.2. The finished channel bed should have a gentle U or V shape in cross section, with the deepest part of the channel slightly below the target mean bed elevation and the outer edges of the bed slightly above it. Overexcavation is not permitted.
3. The stream bed should be left in a reasonably smooth state, with no depressions that could strand fish.
4. In most years Cascade and Carratt Creeks run dry for a period of time in late summer, and sediment removal should be undertaken at that time. There is sufficient freeboard incorporated into the Cascade Creek dyke height that it will generally be safe to postpone gravel removal until a year when the creek is dry.
5. If sediment removal must be undertaken while there is flow in the creeks, excavation must not be conducted in flowing water. The dry (higher) side of the channel should be excavated first, then the flow diverted to that side. This will leave the first side dry, and it can then be excavated.
6. The creek alignment (bends) and width should be maintained. Unless necessary for access, banks should not be disturbed. In no case should the excavation increase the overall width of the channel. The base width of the excavation should not exceed 20 metres for Cascade Creek and 10 metres for Carratt Creek. Where Cascade Creek is divided, one or both channels may be excavated but the total base width of the resulting channels should not exceed 25 metres and the left channel should remain larger than the right channel. The large bar near XS-3 should generally be left

undisturbed, although the left and right edges of the bar can be excavated to widen the channels to the allowable total width.

7. The side slopes of excavated areas should not be steeper than 2:1.
8. Environmental monitoring of the gravel extraction will be required under the Water Act (Section 9) approval. A fish salvage must be undertaken by a qualified biologist if there is any water present in a reach being excavated.
9. Only existing access roads should be used. Disturbance to vegetation along the creeks should be avoided.
10. Some large boulders should generally be left in the stream bed for fish habitat. The best location for the boulders is just upstream of bends.
11. Where Cascade Creek has been widening by eroding the inside bank at bends (see Drawing 101), the inside banks should be reconstructed using the larger material from the stream bed until the channel width is approximately 30 metres (see Section 5.1.3).
12. Care should be taken not to disturb monitoring posts and pins.
13. Any large wood debris should be left in the stream.
14. If fine-grained soils (clays and silts) are encountered in the stream bed, they should not be disturbed and the depth of excavation should be adjusted to maintain a layer of gravel covering these soils.
15. Excavated material should not be stockpiled between the creek and the dykes, other than on a short term basis (i.e. not extending into the flood season usually beginning in October).
16. Upon completion of the work, the creek area should be left in a clean condition. Access ramps should be removed and the creek banks restored to as-found condition.

Appendix A: Photos



Photo 1 - Cascade Creek Monitoring Section - XS-1



Photo 2 - Cascade Creek Monitoring Section - XS-3 (left channel)



(right channel)



Photo 3 - Cascade Creek Monitoring Section - XS-5

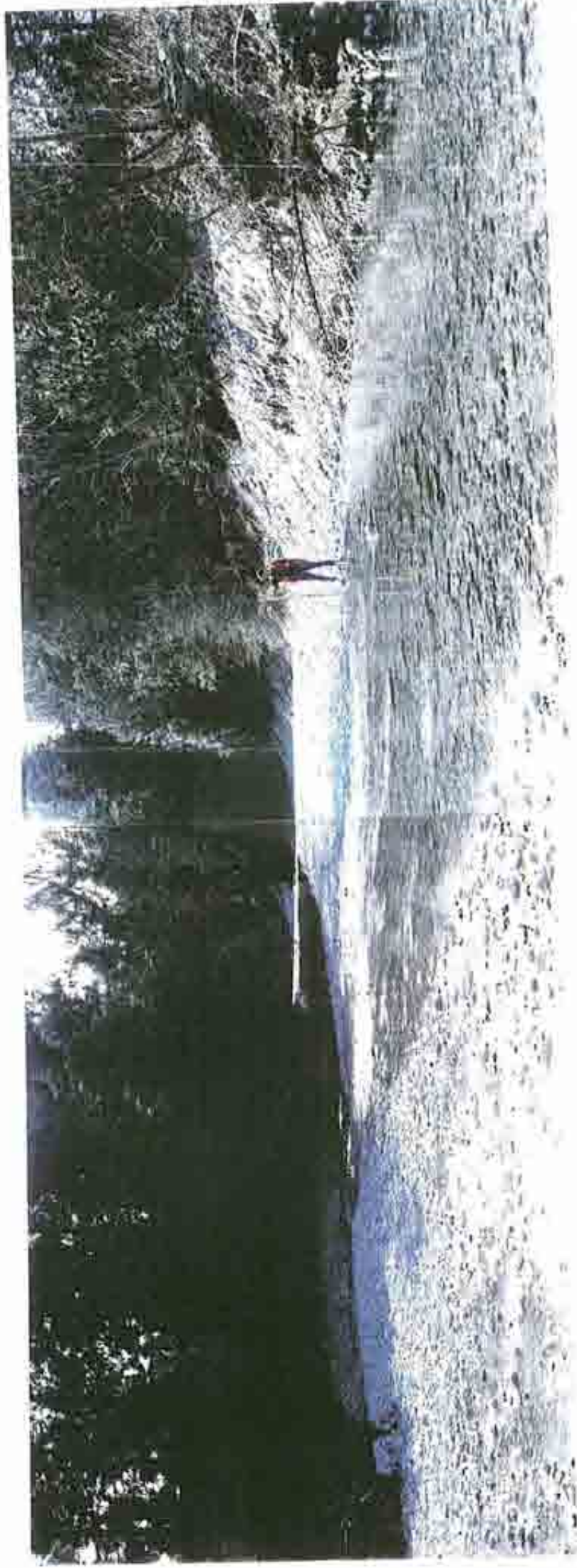


Photo 4 - Cascade Creek Monitoring Section - XS-7



Photo 5 - Cascade Creek Monitoring Section - XS-11 (Sylvester Road Bridge)



Photo 6 - Carratt Creek Monitoring Section - XS-22

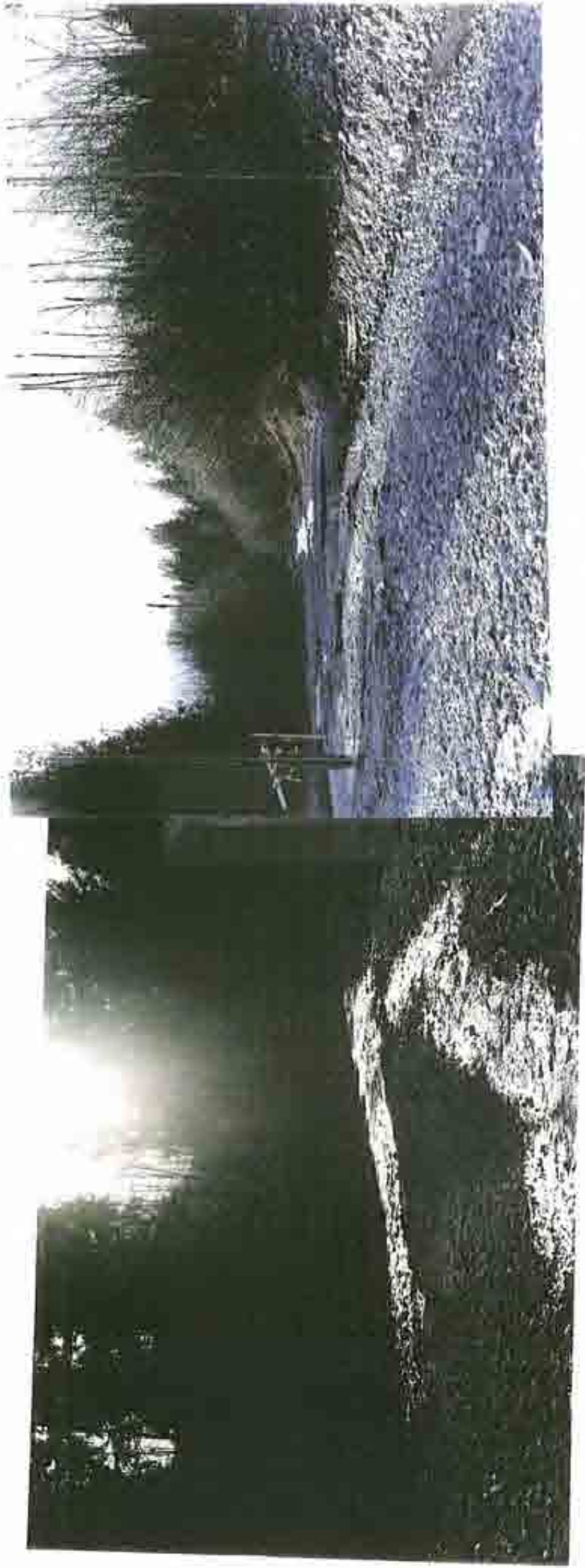


Photo 9 - Carratt Creek Monitoring Section - XS-15



Photo 10 - Carratt Creek Monitoring Section - XS-14A



Photo 11 - Cascade Creek Dyke looking upstream near XS-5.



Photo 12 - Cascade Creek Dyke looking upstream at XS-7.

Photo 13 - Cascade Creek looking at the left bank near XS-6. Riprap is shifting and losing integrity.



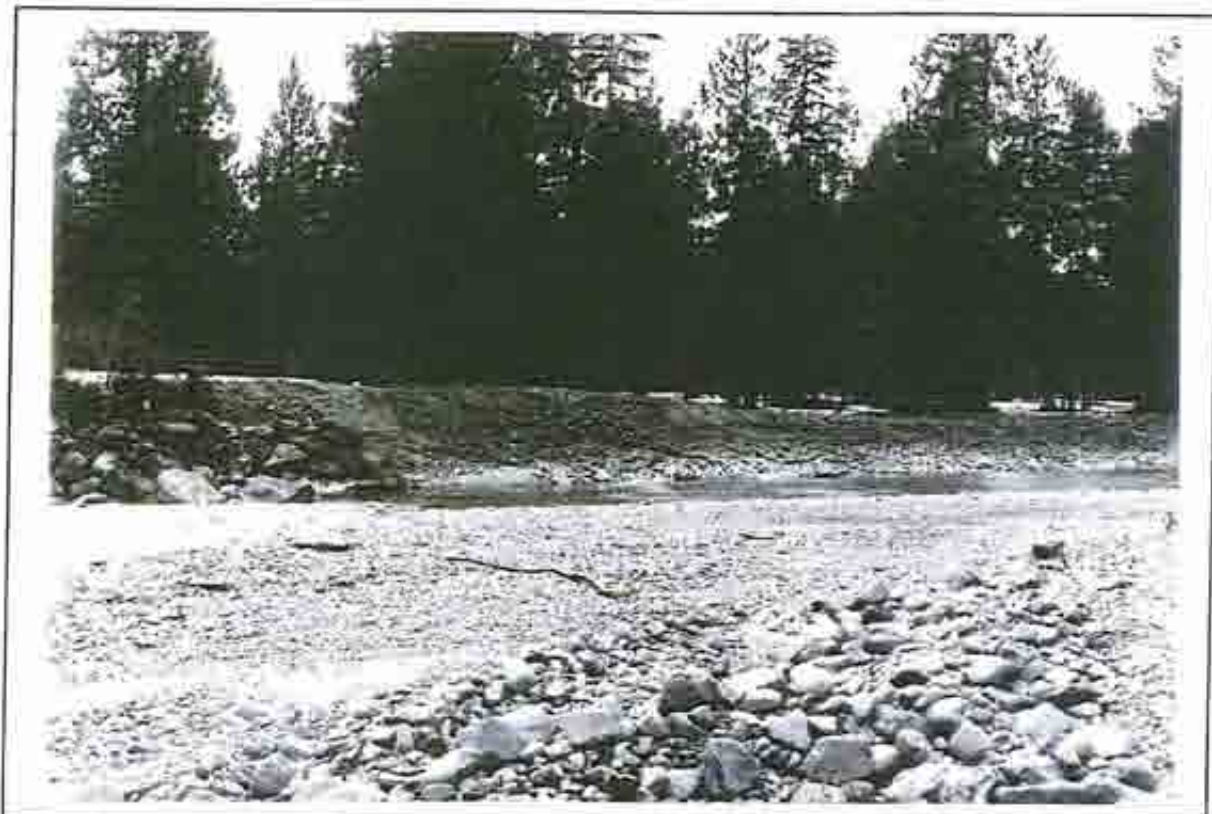


Photo 14 - Cascade Creek looking at the left bank downstream of XS-6. Riprap is required here.



Photo 15 - Carratt Creek looking upstream from XS-15.



Photo 16 - Left Carratt Creek Berm looking upstream between XS-15 and XS-16.



Photo 17 - Right Carratt Creek Berm looking downstream near XS-15.



Photo 18 - Carratt Creek looking downstream from about XS-21. This bank was previously riprapped.

Appendix B: Material Specifications

MATERIALS SPECIFICATIONS FOR FLOOD PROTECTION WORKS

Rock Riprap

Riprap is a layer of rock pieces used to protect creek banks and dykes from erosion by flowing water. The riprap layer is composed of a range of rock sizes placed tightly together, with a minimum amount of air space between the rocks so that each rock is held in place by the other rocks around it. The required size of the rock will depend largely on the slope of the creek channel, with steeper creeks generally requiring larger riprap. Riprap should be hard, durable, roughly equidimensional, angular quarry (blasted) rock of a quality that will not disintegrate on exposure to water or the atmosphere. The two recommended classes of riprap and the general locations where each should be used are as follows:

250kg class riprap

- 100% smaller than 1000mm average dimension
- at least 15% larger than 900mm average dimension
- at least 50% larger than 600mm average dimension
- at least 85% larger than 300mm average dimension

1000kg class riprap

- 100% smaller than 1500mm average dimension
- at least 15% larger than 1350mm average dimension
- at least 50% larger than 1000mm average dimension
- at least 85% larger than 450mm average dimension

Cascade Creek:

The 1000kg class riprap should be used upstream of XS-7 due to the relatively steep nature of the creek. Downstream of XS-07 the 250kg class riprap may be used.

Carratt Creek:

Upstream of XS-15 the 1000kg class riprap should be used and downstream of XS-15 the 250kg class riprap may be used.

The thickness of the riprap layer should generally be two times the average (50%) size of the rock pieces. The recommended side slope is 2 horizontal to 1 vertical, although 1.5:1 is permitted if there are space constraints. The riprap should be placed in such a manner as to produce a well graded mass of rock with the minimum practical percentage of air spaces.

Filter Layer

If the material behind the riprap is silt or sand, it can be washed out by the flowing water or by groundwater seeping through the bank. This can cause shifting or settling of the riprap, and may eventually result in a riprap failure. To prevent this process, a layer of gravel is placed on the bank or dyke before placing the riprap. The filter layer should be a well-graded gravel, free

of clay lumps, organic matter and other extraneous material, screened to remove all stones in excess of 150mm. The thickness of the filter layer should be at least 0.3 metres. Although the size gradation of the material is not critical, as a general guide no more than about 30% by weight should be smaller than 5mm. In most cases gravel from either Cascade or Carratt Creek would probably be satisfactory for the filter layer. If this creek bed material is being used as dyke or bank fill, then no separate filter layer would be required over the fill.

Dyke Fill

Fill should be a well-graded granular material, free of clay lumps, organic matter and other extraneous material. The size gradation should conform approximately to the following table:

<u>Sieve Designation</u>	<u>Percent Passing</u>		
450 mm	100		
100 mm	60	to	100
20 mm	35	to	100
10 mm	25	to	75
1 mm	10	to	35
0.1 mm	5	to	20

Sand and gravel excavated from either Cascade or Carratt Creek will generally be satisfactory for use as fill. There may be areas along the creek where deposits of silty/fine material may be encountered, which are unsuitable for use as fill because they can lose strength under saturated conditions. Fill should be placed in 1 metre (or smaller) lifts and compacted with at least 4 passes of a 10 ton vibratory drum roller. The fill should be placed in a slightly damp condition to achieve good compaction.

Appendix C: Survey Information

PROCEDURE FOR USING THE SURVEYOR'S LEVEL FOR MEASURING THE MEAN BED ELEVATION OF THE CREEK

Required Equipment:

Surveyor's Level

Tripod

5 metre telescopic leveling rod

Pencil

Paper

Drawing showing the location and elevation of the reference pins

(note: 2 people are required to carry out this task)

Procedure:

Set up the tripod at a place where both sides of the creek and the reference pin are visible. The top of the tripod must be above the elevation of the reference pin, but no more than 5 metres above the lowest elevation of the creek. Place the surveyor's level on the tripod and secure. Level the surveyor's level using the fisheye bubble on the instrument.

1. Determine Elevation of Surveyor's Level

Have one person hold the telescopic leveling rod (fully extended) on the reference pin while the second person sights through the surveyor's level and takes a reading on the telescopic leveling rod. To determine the elevation at which the surveyor's level is set, add this initial reading to the elevation of the reference pin.

2. Determine Average Elevation of Creek Bed

Have one person hold the telescopic leveling rod (fully extended) at each of the required number of locations across the creek bed (5 for Cascade Creek, 3 for Carratt Creek). Take readings with the surveyor's level at each of the five locations and write these numbers down. Average these five readings and subtract the average from the elevation of instrument determined in step 1 above.

The tables on the next page can be used for recording the data.

Cascade Creek

Cross Section #

1) Reference Pin Elevation

2) Reference Pin Reading

3) Elevation of Level
(add #1 and #2)

3)

Creek Bed Readings

1	<input type="text"/>
2	<input type="text"/>
3	<input type="text"/>
4	<input type="text"/>
5	<input type="text"/>

4) Average Creek Bed Reading

4)

Mean Bed Elevation metres
(subtract #4 from #3)

Carratt Creek

Cross Section #

1) Reference Pin Elevation

2) Reference Pin Reading

3) Elevation of Level
(add #1 and #2)

3)

Creek Bed Readings

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2	<input type="text"/>
3	<input type="text"/>

4) Average Creek Bed Reading

4)

Mean Bed Elevation metres
(subtract #4 from #3)

DOCUMENT NO. 200802

ENV 2043-A

MONUMENT DATA SHEET

MONUMENT NO. B5BN003

PROJECT NO. B5BN003	PROJECT Cascade/Carratt Creeks	REGION 2
ESTABLISHED BY: T. Dignan	DATE: June 1985	
COMPUTED BY: J. Duncan	CHECKED BY:	AIR PHOTO NO.
NRS MAP # 5208		
DESCRIPTION: B5BN003 - Rock bolt set vertically in U/S R/R corner of Carratt Rd. bridge over Carratt Creek. Bolt is in concrete bridge seat at deck level.		
CONTROL ORIGINS - LOCAL SURVEY METHODS - ORDERS OF ACCURACY		
HORIZONTAL: Control Origin Stations 4 & 5 (TD BANYON) Order 4 Existing Origin Mon. Elev. Method Geodimeter 140 total station Order 4 Right Hand Merit B/RN Page No. B/RN		
VERTICAL: Control Origin Bolt L/RN XS-3 Legare Ch. (HARDELL) Order 4 Datum Geodetic Survey of Canada Date: Mer. Elev. Method Wild Na 2 - Double run Order 4 Field Read Merit 2431 Page No. as indicated		
COORDINATES GEOGRAPHICAL: Lat. Long. U.T.M. Zone 10 N E Poly. Lat. Dep. Rect. PLANE: Lat. 5 456 766.413 Dep 556 976.449		
ELEVATION: 105.089 Meters Feet		
Province of British Columbia Ministry of Environment		WATER MANAGEMENT BRANCH

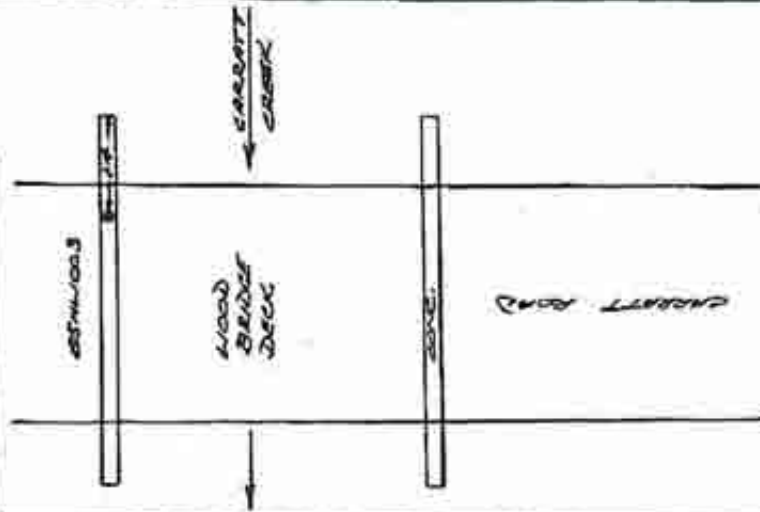
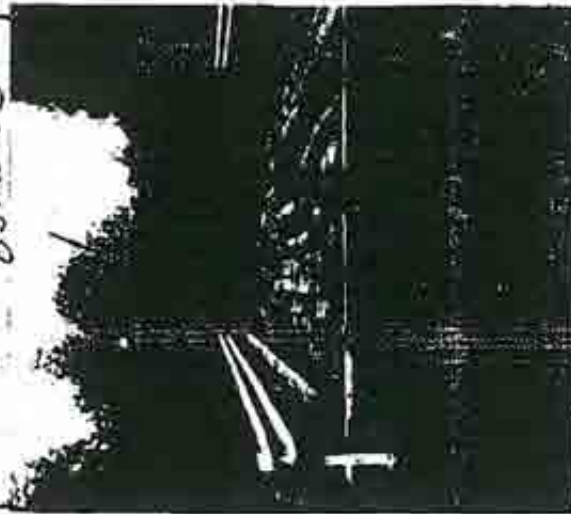


PHOTO NEG. NO.

4 - 22

85HW003

SKETCHES: TIES AND LOCAL DETAILS



MONUMENT DATA SHEET

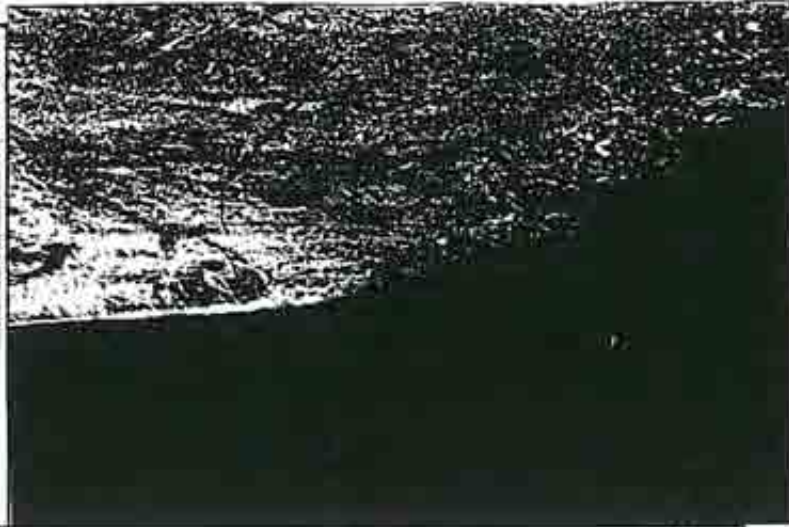
MONUMENT NO. 1039

PROJECT NO. B5RPP8 PROJECT CASCADE/Carratt Creeks REGION 12
 ESTABLISHED BY T. Dignan DATE June 1985
 COMPUTED BY J. Duncan CHECKED BY AIR PHOTO

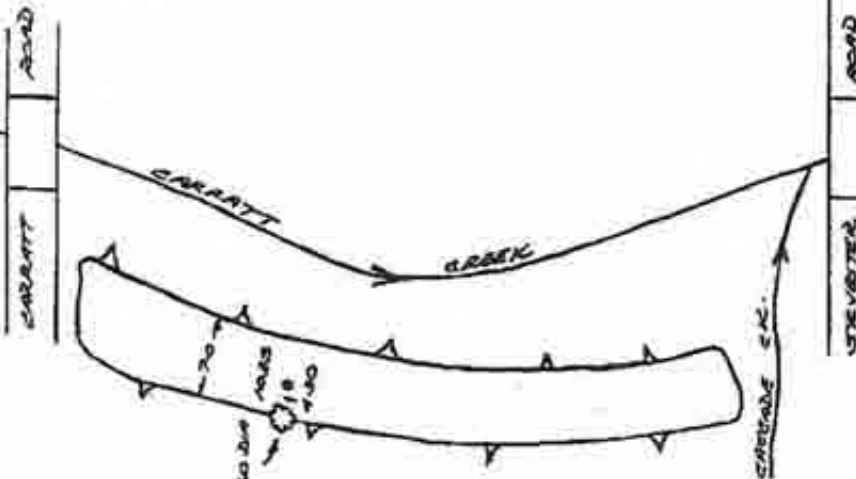
MONUMENT INSCRIPTION



PHOTO REF. NO. 4 - 3)



SKETCHES: TIES AND LOCAL DETAILS



DESCRIPTION: 1039 - Pipe post set vertically on C/L of 7m. wide dyke on S/B Carratt Creek. Pipe post is opposite lone tree and is located at point where both Carratt and Sylvester Rd. bridges can be seen. Post is set in concrete and is 0.06m. above top of dyke.

CONTROL ORIGINS - LOCAL SURVEY METHODS - ORDERS OF ACCURACY

HORIZONTAL:
 Control Origin Stations 4 6 3 (TD 84RPP9) Order 4
 Bench Origin
 Mon. Dyke Method Geodimeter 140 total station Order 4
 Field Book Not N/A Page Not
VERTICAL:
 Control Origin Bolt 1/8 XS - 3 Lejacre Cx. (84RPP13) Order 4
 Datum Geodetic Survey of Canada Date
 Mon. Dyke Method Wild M2 - Double run Order 4
 Field Book Not 2431 Page Not as Indexed

COORDINATES

GEOGRAPHICAL: Lat. Long
 U.T.M. Zone 10 N E
 Poly. Lat. DAP
 Rect. PLANE Lat. 5 456 856.127 DAP 556 785.003

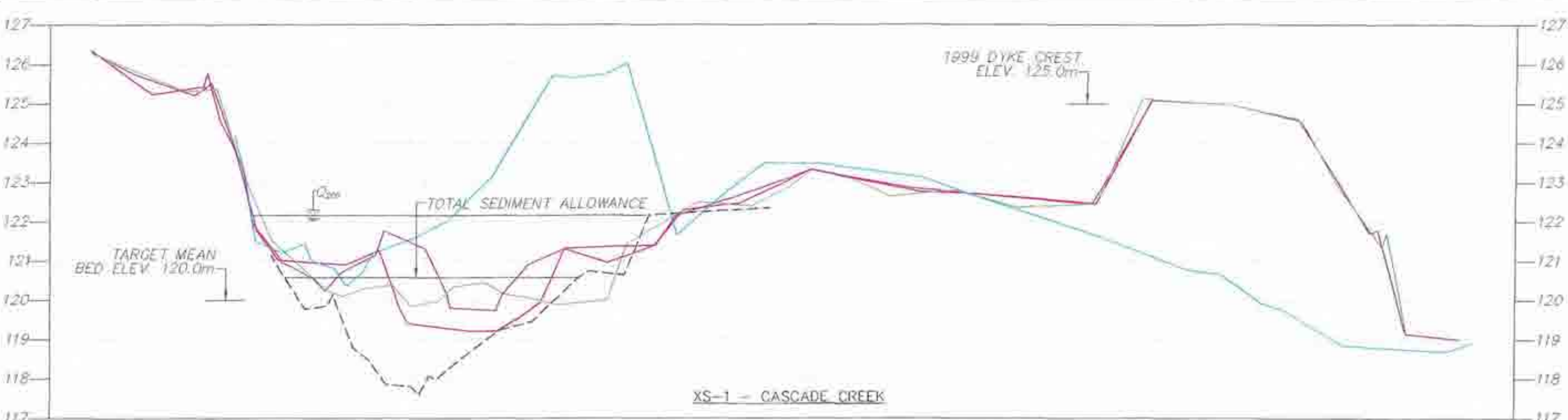
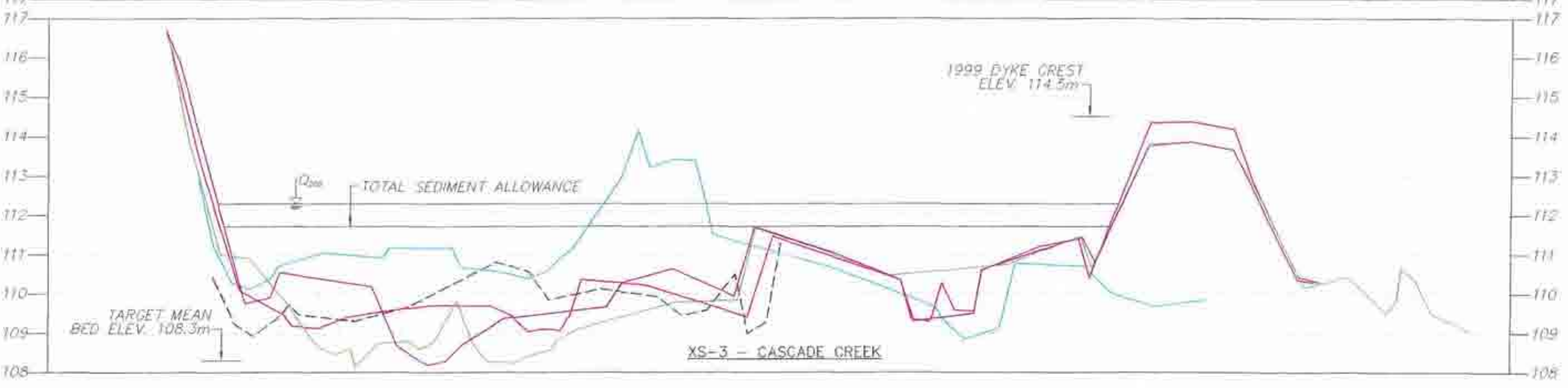
ELEVATION: 99.159 Meters Feet

Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH



ENV 2043-A

Drawings



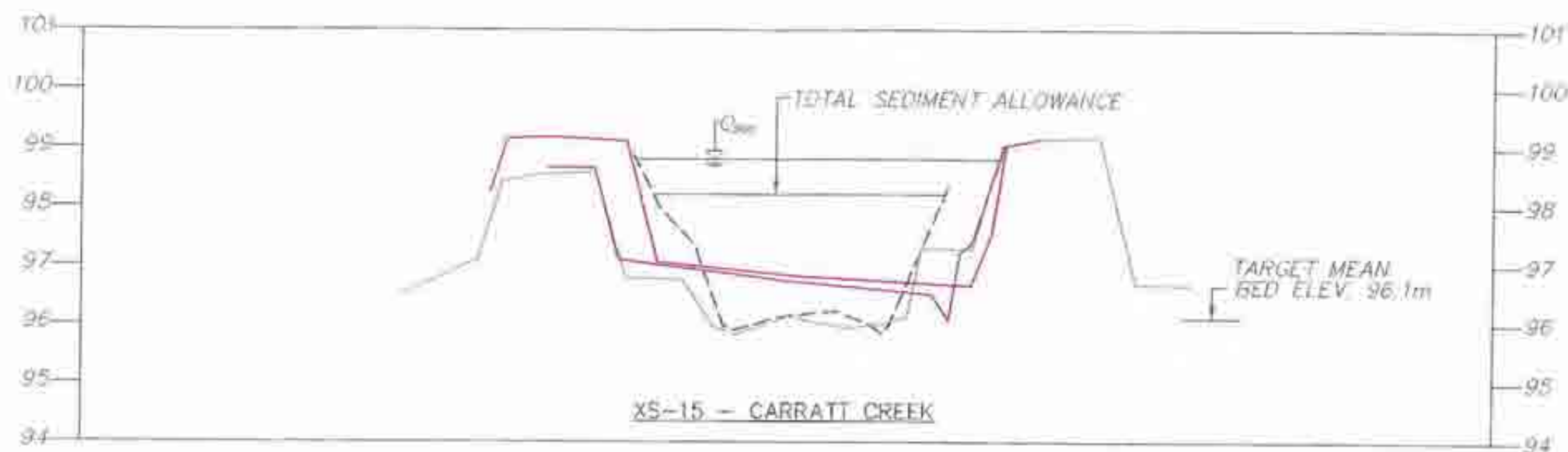
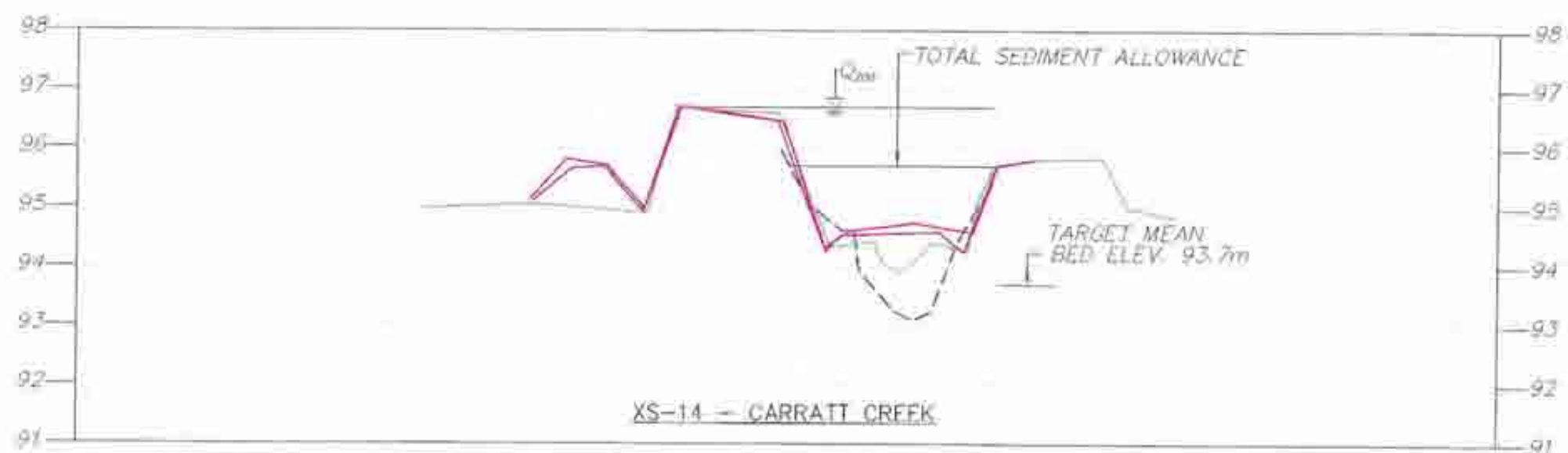
- 1984 SURVEY, PROJECT #84RPP09, STADIA
- 1985 SURVEY, PROJECT #85RPP08, STADIA
- 1986 SURVEY, CHAIN AND LEVEL
- 1988 SURVEY, PROJECT #88RPP01, TOTAL STATION
- 1999 SURVEY, SIGMA ENGINEERING LTD., TOTAL STATION

REFERENCE DRAWING: MINISTRY OF ENVIRONMENT,
LANDS, AND PARKS, RESOURCES INVENTORY BRANCH,
WATER SURVEYS UNIT - CASCADE AND CARRATT
CREEKS CROSS SECTION 1 AND 3.

HORIZONTAL SCALE 0 5 10 15 20 25 metres

VERTICAL SCALE 0 1 2 3 4 5 metres

												SIGMA ENGINEERING LTD				FRASER VALLEY REGIONAL DISTRICT CASCADE AND GARRATT CREEK CROSS SECTIONS 1 & 3		PROJECT ES917																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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LEGEND:

- 1984 SURVEY, PROJECT #84NPP09, STADIA
- 1985 SURVEY, PROJECT #85RPP05, STADIA
- 1986 SURVEY, CHAIN AND LEVEL
- 1988 SURVEY, PROJECT #88RPP01, TOTAL STATION
- 1999 SURVEY, SIGMA ENGINEERING LTD, TOTAL STATION

REFERENCE DRAWING

MINISTRY OF ENVIRONMENT, LANDS, AND PARKS, RESOURCES INVENTORY BRANCH,
WATER SURVEYS UNIT - CASCADE AND CARRATT CREEKS CROSS SECTION 15 AND 14.

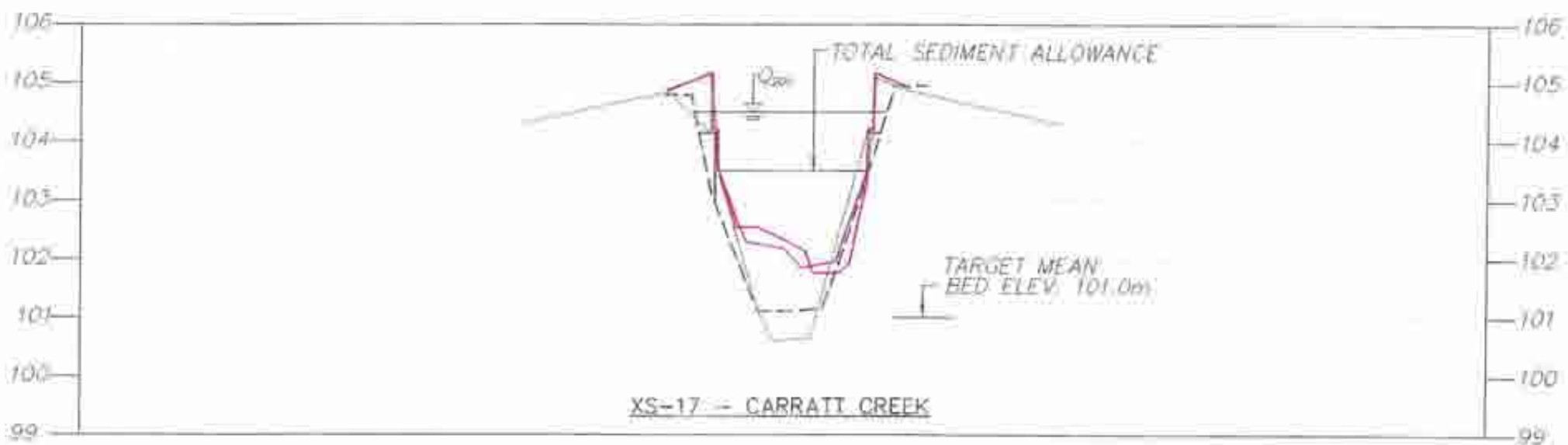
HORIZONTAL SCALE 0 5 10 15 20 25 metres

VERTICAL SCALE 0 1 2 3 4 5 metres

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FOR FINAL REPORT

JUNE 1999



												SIGMA ENGINEERING LTD				FRASER VALLEY REGIONAL DISTRICT				PROJECT E5017	
												DRAWN KV								SCALE AS SHOWN	
												DESIGNED BRS								DATE MAY 1999	
												CHECKED GSM								DRAWING NO.	
0 FOR FINAL REPORT <i>4/18/99</i>												INSPECTED								REV 0	
REV	ISSUE	DATE	REV	ISSUE	DATE	REV	DESCRIPTION	DWN	CHK	APVD	DATE	REV	DESCRIPTION	DWN	CHK	APVD	DATE	APPROVED	CROSS SECTIONS 20 & 17		SHEET OF

