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# Sediment Control During Instream Construction Using a Regression Analysis - Robert Service Way Reconstruction Project - City of Whitehorse, Yukon.

R. C. Snider, B.Sc., Eng.

Access Mining Consultants Ltd.
204D Strickland Street
Whitehorse, Yukon
Y1A 2J8

## ABSTRACT

During the Summer of 1997 the City of Whitehorse undertook reconstruction of the Robert Service Way, one of the two key access routes to the downtown core of Whitehorse, Yukon. Based on previous fisheries investigations, it was determined that the road embankment fill required for reconstruction would cover critical rearing, overwintering and spawning habitat for chinook salmon. A fisheries compensation agreement was reached whereby the City would construct three compensation channels within the Yukon River to provide spawning and rearing habitats for the salmon.

During instream fill placement and construction of the compensation channels, there was a requirement to monitor suspended solids levels on a daily basis, and more frequently during specific construction activities. An agreement was reached between the City of Whitehorse and the Department of Fisheries and Oceans (DFO) to monitor total suspended solids (TSS) daily using a portable turbidity meter based on a regression analysis of TSS and turbidity. The relationship was established through the collection of samples prior to and during construction with a total of 38 samples being collected. Two separate regression analyses were used to correlate TSS and turbidity measurements for varying sediment concentrations. A TSS to turbidity ratio of 1.5:1 was calculated for turbidity measurements from 0 to 80 NTU, while a ratio of 0.8:1 was determined for turbidity measurements over 80 NTU.

Suspended solids monitoring indicated that the total suspended solids limit of 25 mg/L (above background) was met on all occasions except for selected periods during compensation channel plug removals.

The use of a portable turbidity meter and regression of TSS and turbidity provided a valuable tool in monitoring and controlling upstream construction activities.

## INTRODUCTION

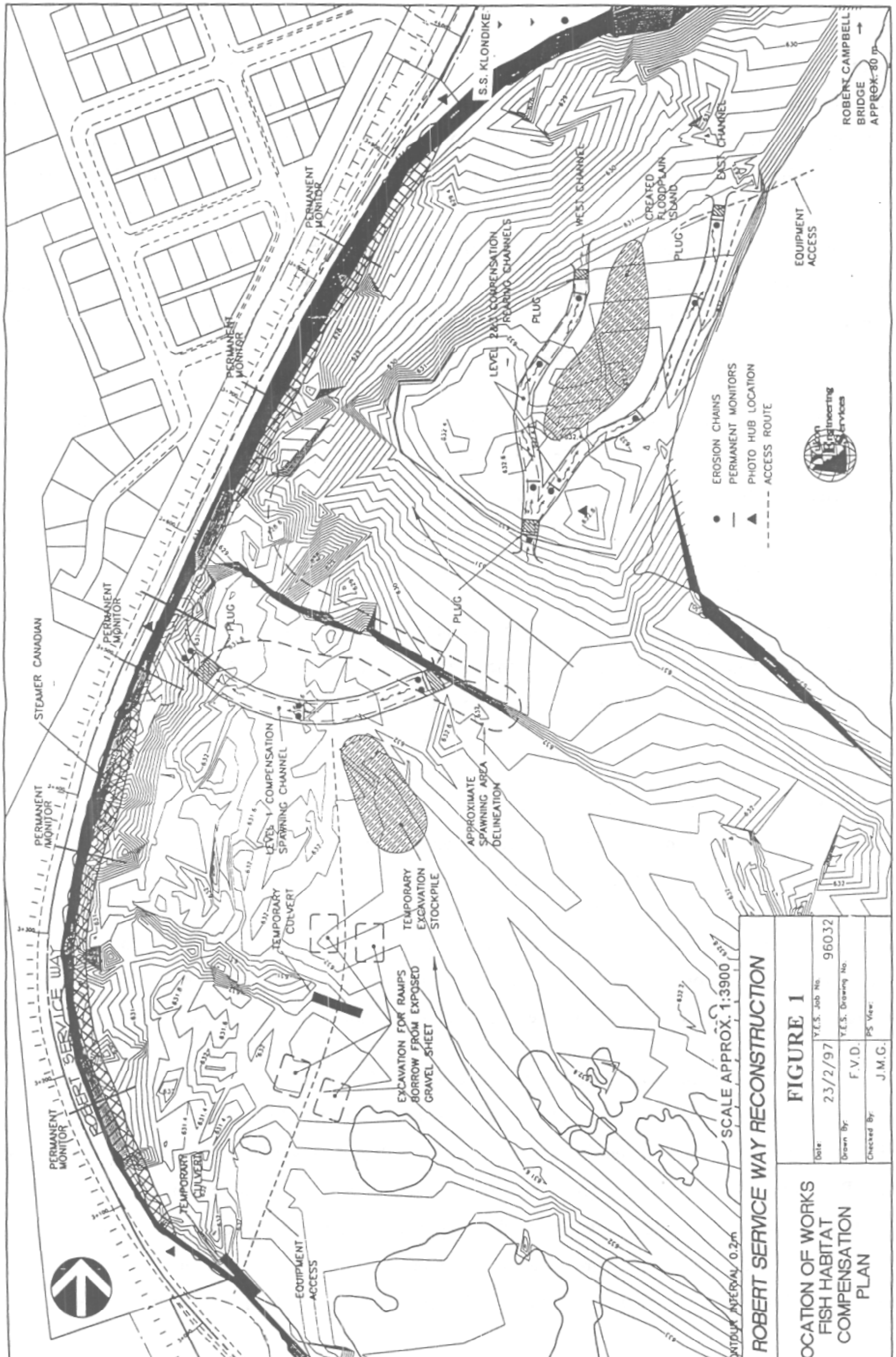
During the Summer of 1997 the City of Whitehorse undertook reconstruction of the Robert Service Way, one of the two key access routes to the downtown core of Whitehorse, Yukon. To accomplish route alignment widening, pathway development and more stable road slopes, it was necessary to conduct instream construction between 1.3 to 12.8 m into the Yukon River, for a distance of 1.2 km (City of Whitehorse, 1996). Access Mining Consultants Ltd. was retained by Yukon Engineering Services, the consultant responsible for the design and project management, to oversee the environmental permitting and monitoring.

Based on previous fisheries investigations, it was determined that the road embankment fill would cover critical rearing, overwintering and spawning habitat for chinook salmon. To compensate for the fill placement and habitat loss, a Fisheries Compensation Plan was negotiated with the Department of Fisheries and Oceans (DFO). As part of this plan, the City was required to construct three compensation channels within the Yukon River to provide spawning and rearing habitats for the salmon (Figure 1). The Level 1 Channel replaced spawning habitat while the Level 2 and 3 Channel provided rearing and overwintering habitat. The instream construction portion of the work was conducted between April 16 and June 1, 1997. The short period for the instream construction was required to protect fisheries resources and complete work prior to seasonal increases in flows from the upstream hydroelectric facility reservoir.

During instream fill placement and construction of the compensation channels, there was a requirement to monitor total suspended solids levels on a daily basis, and more frequently during specific construction activities. One of the unique aspects associated with the project, aside from the instream construction work ,within the Yukon River, was that a regression analysis was used to establish a relationship between turbidity (NTU) and total suspended solids (TSS) levels. Compliance limits were established for TSS, however this parameter is not easily measured in the field. Since turbidity can be measured using a portable meter, a decision to conduct turbidity !monitoring, to establish compliance with suspended solids levels during construction, was reached between DFO and the City of Whitehorse.

## SAMPLE COLLECTION

Prior to construction it was necessary to develop a correlation between turbidity levels and total suspended solid concentrations. For the purposes of this project suspended solids were defined as solids that can be filtered by a 0.45 um glass fiber filter disc (American Public Health Association, 1989). Turbidity was measured by reference to a chemical mixture that produces a reproducible refraction of light (Davis and Cornwall, 1991) and was measured in Nephlometric Turbidity Units (NTU).


S.S. KLONDIKE
ROBERT CAMPBELL BRIDGE APPROX. 80 m →
PERMANENT MONITOR
PERMANENT MONITOR
PERMANENT MONITOR
PERMANENT MONITOR
PERMANENT MONITOR
STEAMER CANADIAN
ROBERT SERVICE WAY
EAST CHANNEL
WEST CHANNEL
CREATED FLOODPLAIN ISLAND
PLUG
PLUG
PLUG
PLUG
LEVEL 2&3 COMPENSATION REARING CHANNELS
EQUIPMENT ACCESS
EQUIPMENT ACCESS
EROSION CHAINS
PERMANENT MONITORS
PHOTO HUB LOCATION
ACCESS ROUTE
LEVEL 1 COMPENSATION SPAWNING CHANNEL
APPROXIMATE SPAWNING AREA DELINEATION
TEMPORARY EXCAVATION STOCKPILE
TEMPORARY CULVERT
TEMPORARY CULVERT
EXCAVATION FOR RAMPS BORROW FROM EXPOSED GRAVEL SHEET
SCALE APPROX. 1:3900
CONTOUR INTERVAL 0.2m
ROBERT SERVICE WAY RECONSTRUCTION
FIGURE 1
LOCATION OF WORKS FISH HABITAT COMPENSATION PLAN
Date: 23/2/97
Y.E.S. Job No. 96032
Drawn By: F.V.D.
Checked By: J.M.G.

The turbidity measurement was correlated to a total suspended sediment equivalent using samples that were collected from the construction area, prior to and during the initial phase of construction. Each sample was sent to ASL Analytical Service Laboratories in Vancouver for analysis of turbidity and total suspended solids. The samples were collected in one litre plastic high density polyethylene (HDPE) bottles and sent to ASL the day of sample collection. Analysis was completed within 48 hours of sample collection. ASL used standard nephelometric and filtration/gravimetric analysis methods for the turbidity and suspended solids samples, respectively. The analyses were carried out in accordance with procedures described in the "Standard Methods for the Examination of Water and Waste Water" published by American Public Health Association (1989).

hi situ turbidity measurements were performed using a portable single cell EPA approved DRT-15CE Portable turbidimeter produced by HF Scientific Inc.. Calibration and standardization was performed as recommended in the operators manual. The complete sampling and analysis protocol is provided in "Robert Service Way Reconstruction Project - Monitoring and Sampling Protocols, Standards and Procedures- Working Document" (Access Mining Consultants Ltd., 1997b).

Samples were collected on a daily basis during instream construction activities to determine construction generated and background sediment levels in the river water. The samples were collected using a bottle on a pole extension, approximately one metre from the bank, to ensure representative samples were collected. The samples were obtained from each of the following areas:

- Upstream of the study area (background);
- A control upstream of the working face where water is present (background); and
- Immediately downstream of the working area (compliance)

Samples were also collected from ponded water within the constructed channels and ponded water within the embankment fill to obtain a range of suspended solids levels and sediment sources. These samples were use to assist in regression analysis development and were not used to determine compliance.

As noted, the downstream compliance point was defined as "immediately downstream of the working area". However through consultation with federal regulatory agencies between, including the Department of Fisheries and Oceans (DFO) and Department of Indian Affairs and Northern Development (DIAND) - Water Resources personnel, it was agreed that the downstream compliance stations should be established at designated locations. The objectives of establishing a set location for the compliance station were to not only ensure that the entire upstream work was monitored but that there be a minimum distance downstream of the works where the sediment would be monitored. Two downstream compliance stations were established, one at the SS Klondike Steamer site, a local tourist attraction, and another immediately downstream of the Robert Campbell Bridge, on the east side of the Yukon River (Figure 1). Uranine dye was introduced at upstream locations to verify that sediment generated during construction would flow to these stations.

The SS Klondike station was used to monitor compliance during embankment work and construction of the Level 1 Compensation Channel. The Robert Campbell Bridge site was used during construction and opening of the Level 2 and 3 Compensation Channels to the Yukon River.

**REGRESSION DEVELOPMENT**

As part of the Fisheries Compensation plan there was a requirement to collect approximately fifteen samples for both turbidity and suspended solids analysis at a certified laboratory (City of Whitehorse, 1997a). The samples were to be collected prior to and during the initial stages of construction and the relationship updated or verified periodically as concentrations change in the working area. A total of twenty samples were used to establish the initial regression analysis which provided a total suspended solids to turbidity ratio of 2.0:1. The turbidity meter and regression was then used to measure turbidity on a daily basis and correlate the reading to TSS in order to determine compliance using the upstream (background concentration) and downstream (compliance station) sites. Samples with correlated suspended solids values near the compliance limit were sent for laboratory analysis to verify TSS compliance.

A linear relationship between total suspended solids and turbidity was used in the regression analysis as the data followed a linear trend when graphed and non-linear relationships underestimated the total suspended solids values near the 25 nig/L (above background) compliance limit.

Throughout the construction work samples were collected from a variety of locations, with varying sediment loads, in order to update the regression. *A* total of 38 samples were submitted for laboratory analysis as part of the program. The final regression included samples collected from the Compensation Channels and the Yukon River after an increase in water level and flow caused an noticeable increase in the background TSS levels.

The updated regression for turbidity measurements from 0 to 80 NTU provided a TSS to turbidity ratio of 1.5:1, as shown on Figure 2. For turbidity measurements above 80 NTU a ratio of TSS to turbidity of 0.8:1 was used, as shown on Figure 3.

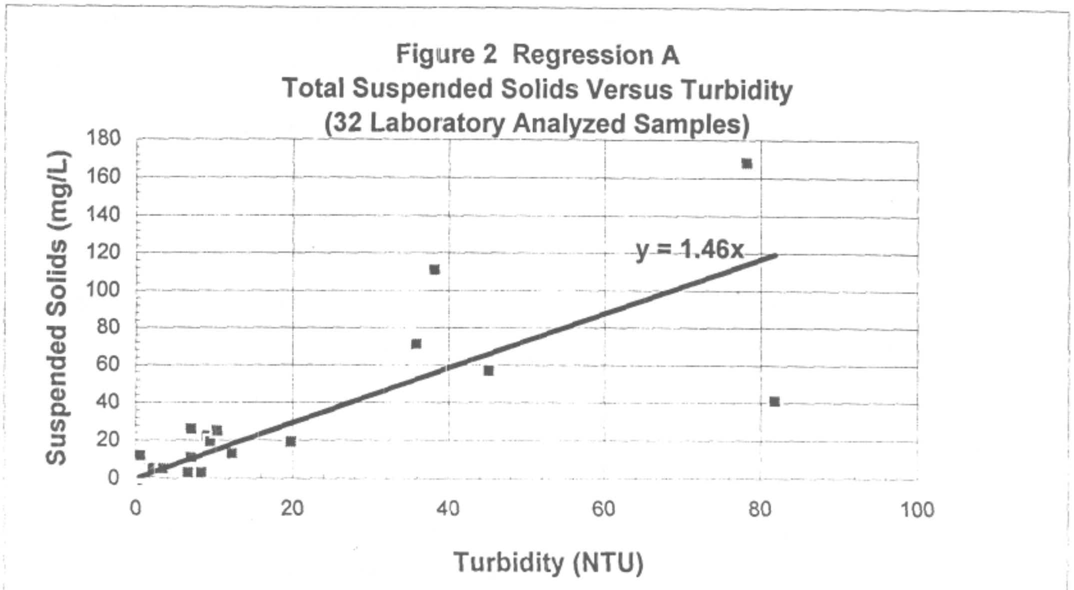


Figure 2 Regression A
Total Suspended Solids Versus Turbidity
(32 Laboratory Analyzed Samples)
Suspended Solids (mg/L)
180
160
140
120
100
80
60
40
20
0
y = 1.46x
0
20
40
60
80
100
Turbidity (NTU)

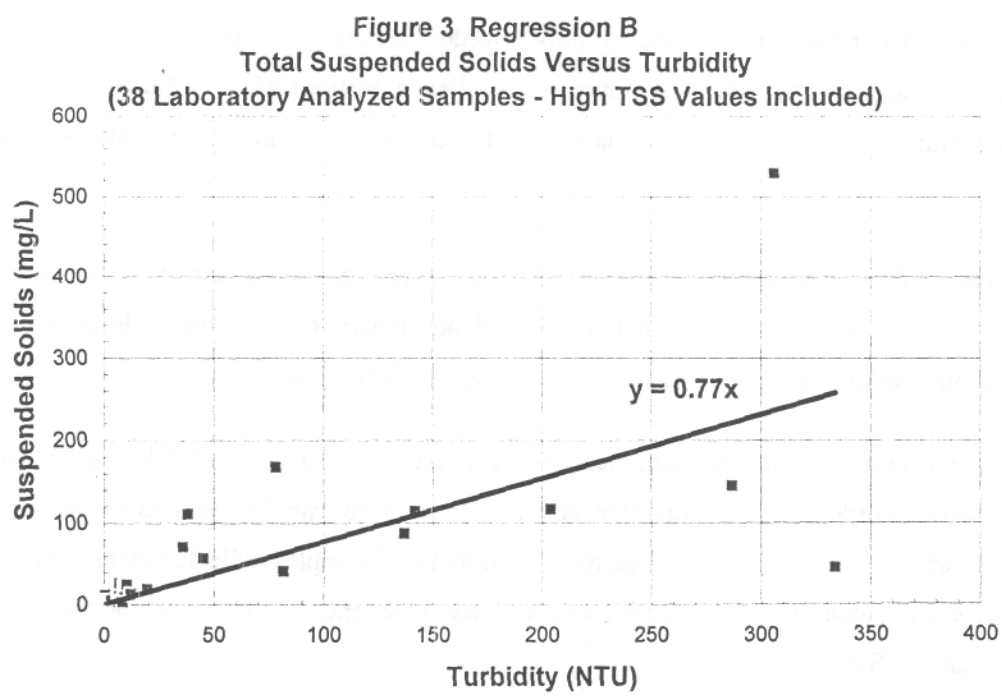


Figure 3 Regression B
Total Suspended Solids Versus Turbidity
(38 Laboratory Analyzed Samples - High TSS Values Included)
Suspended Solids (mg/L)
600
500
400
300
200
100
0
y = 0.77x
0
50
100
150
200
250
300
350
400
Turbidity (NTU)

Two different regression curves were used to determine TSS equivalents since the relationship between turbidity and TSS varied with higher turbidity measurements. The use of two regression analysis curves ensured that a conservative relationship between TSS and NTU, near the 25 mg/L (above background) compliance limit, was used. A detailed discussion on regression development, and data used in the analysis, is found in the "Final Water Quality Report, Robert Service Way Reconstruction Project" (Access Mining Consultants Ltd., 1997c).

There were also a few trends, with regards to the regression development which are notable. Laboratory analyses of samples from the constructed compensation channels indicated a TSS to turbidity ratio of 0.5:1, which varied from the previous trend developed using the other samples. It has been hypothesized that the channels have a higher concentration of very fine sediment (colloidal particles) which resulted in higher turbidity readings than total suspended solids levels. It was also observed that samples collected from the Yukon River, while the natural background turbidity levels were high, displayed a turbidity to TSS ratio of 1:1.

The TSS to turbidity ratios observed from the compensation channels and Yukon River samples, while the turbidity levels were high, indicates that the TSS values monitored and reported during compensation channel inlet and outlet removals were conservative. The values were conservative since a 1.5:1 ratio was used, unless the turbidity values rose above 80 NTU, when a 0.8:1 ratio was used.

## RESULTS AND OBSERVATIONS

The background suspended solids levels and compliance monitoring was conducted from April 17 to May 31, 1998 at either the SS Klondike and downstream of the Robert Campbell Bridge. This data was compared to the upstream stations to determine whether the TSS compliance limit was exceeded. The 25 mg/L TSS (above background) requirement was met during the entire daily routine sampling, with none of the samples exceeding 10 mg/L TSS (above background).

A rise in the natural background TSS levels in the Yukon River was observed in the middle to end of May. The background TSS levels started to rise in the middle of May and eventually peaked on May 26 at 79.4 mg/L. The rise in TSS has been attributed to an increase in the discharge from the hydroelectric facility and the associated rise in the water level contributing to an increase in sediment loads to the river. The suspended solids steadily declined from the May 26 peak to 12.4 mg/L at the end of the monitoring program on May 31. Compete data from the monitoring program, and noted observations are provided in the "Final Water Quality Report, Robert Service Way Reconstruction Project" (Access Mining Consultants Ltd., 1997c).

During the opening of the Level 1, 2 and 3 channels to the river, the TSS levels at the downstream compliance stations were elevated above background levels for very brief periods. The monitoring conducted during the channel inlet and outlet: removals is discussed in the following sections.

Level 1 Channel

The inlet and outlet barriers, preventing flow from entering or leaving the channels during construction, were removed from the Level 1 Spawning Channel on May 5, 1997. During this activity the TSS levels were monitored every 5 to 25 minutes using the portable turbidity meter. Work stoppage was ordered by the Environmental Monitor once during the removal of the upstream plug to allow the suspended solids levels to return to normal levels. The 25 mg/L (above background) TSS limit was not exceeded.

Level 2 (West) Channel

The removal of the west channel access road and outlet was performed on May 29, 1997. The TSS compliance monitoring results, downstream of the Robert Campbell Bridge, are shown on Figure 4. The figure also details the activities and actions undertaken. The highest TSS value (54.6 mg/L above background) was recorded after the road excavation had been completed. Over the course of the west channel access road and downstream outlet removal, suspended solids levels were above the 25 mg/L compliance level for a total period of approximately 2 hours. The rise in TSS levels has been attributed to the discharge of silt and fine sand which had settled within the channel substrate during excavation of the channel and placement of the substrate material suited for fish rearing habitat. The lack of thorough mixing of the Yukon River with the channel outflow prevented rapid dissipation of suspended solids on the east side of the Yukon River.

Level 3 (East) Channel

The TSS monitoring conducted during the removal of the inlet and outlet of the east channel is shown on Figure 5. The work was conducted throughout May 30, 1997. As can be observed from the figure, three peaks in TSS levels were observed. The first peak of 128.9 mg/L occurred approximately 15 minutes after the Environmental Monitor (EM) instructed the hoe operator to cease work. The next two peaks were observed after the removal of the inlet and check dam was completed. Suspended solids levels exceeded 25 mg/L for a total of approximately 3.5 hours during the inlet, east channel outlet, access road and check dam removal. The rise in TSS levels after the completion of the two activities is a result of the discharge of sediment which had settled in the channel substrate during excavation and substrate placement and the increased flow through the channel.

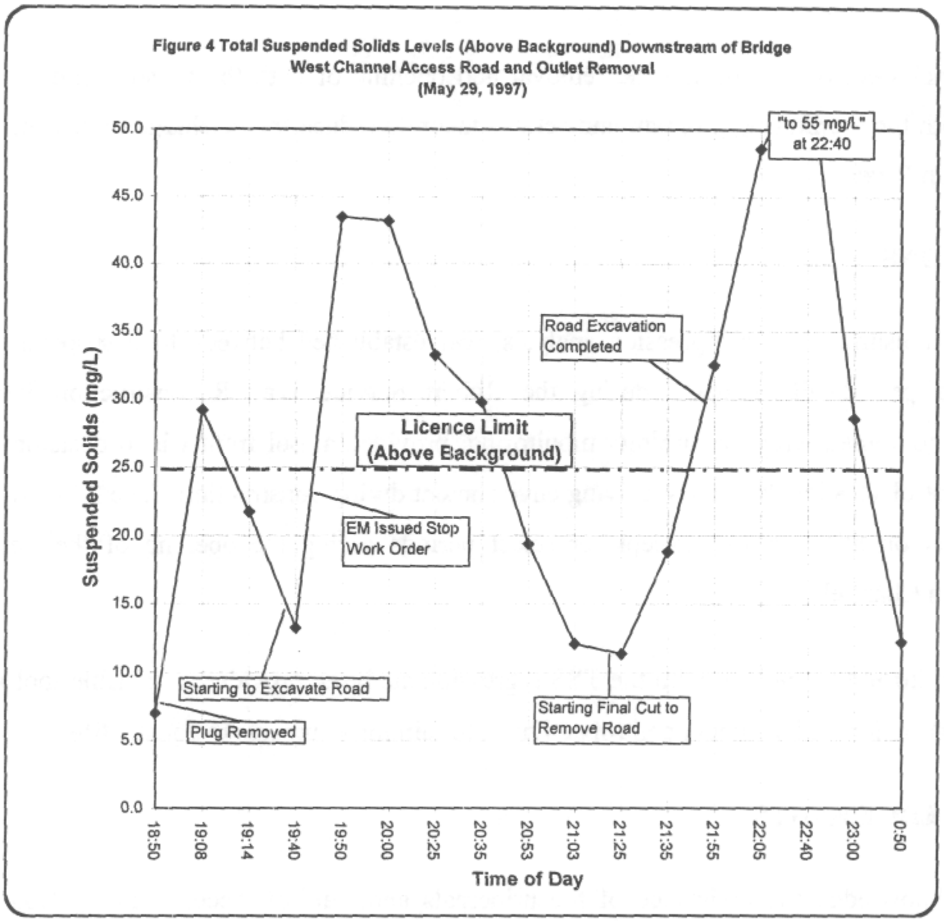


Figure 4 Total Suspended Solids Levels (Above Background) Downstream of Bridge
West Channel Access Road and Outlet Removal
(May 29, 1997)
Suspended Solids (mg/L)
Time of Day
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
18:50
19:08
19:14
19:40
19:50
20:00
20:25
20:35
20:53
21:03
21:25
21:35
21:55
22:05
22:40
23:00
0:50
"to 55 mg/L" at 22:40
Road Excavation Completed
Licence Limit (Above Background)
EM Issued Stop Work Order
Starting to Excavate Road
Plug Removed
Starting Final Cut to Remove Road

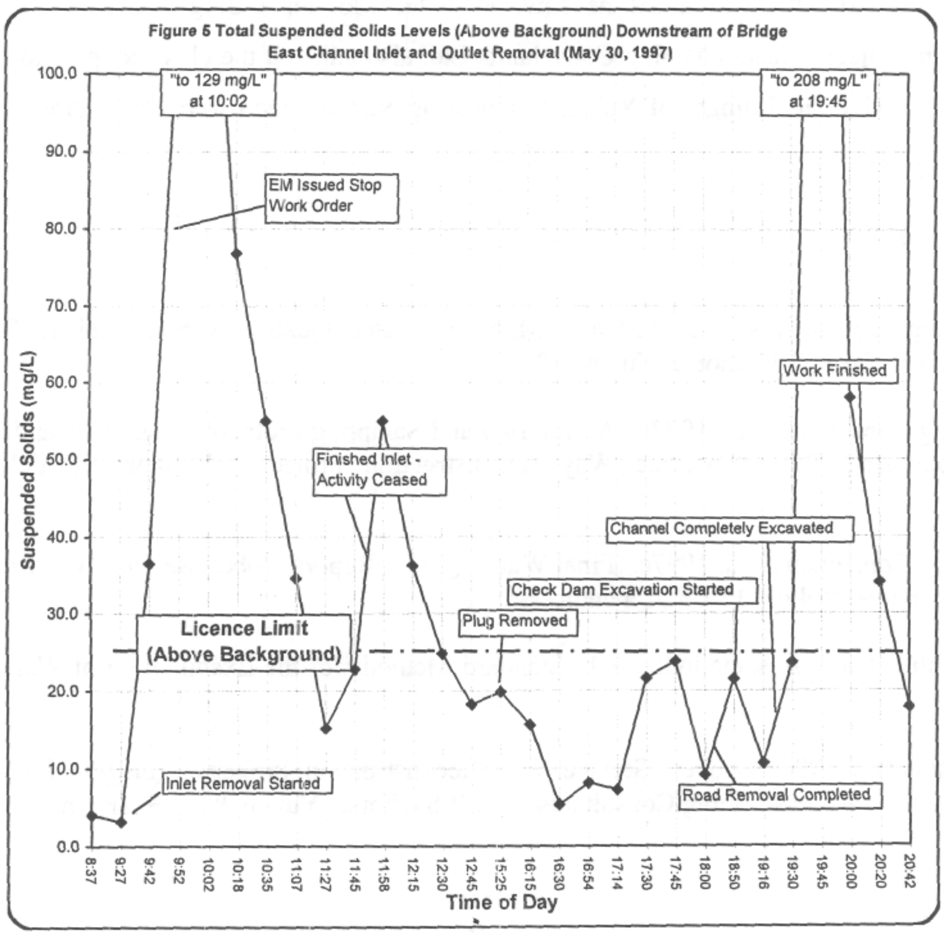


Figure 5 Total Suspended Solids Levels (Above Background) Downstream of Bridge
East Channel Inlet and Outlet Removal (May 30, 1997)
Suspended Solids (mg/L)
Time of Day
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
8:37
9:27
9:42
9:52
10:02
10:18
10:35
11:07
11:27
11:45
11:58
12:15
12:30
12:45
15:25
16:15
16:30
16:54
17:14
17:30
17:45
18:00
18:50
19:16
19:30
19:45
20:00
20:20
20:42
"to 129 mg/L" at 10:02
"to 208 mg/L" at 19:45
EM Issued Stop Work Order
Work Finished
Finished Inlet - Activity Ceased
Channel Completely Excavated
Check Dam Excavation Started
Plug Removed
Licence Limit (Above Background)
Inlet Removal Started
Road Removal Completed

DFO personnel were on site during the removal and opening of both the Level 2 and 3 channels and concurred with the monitoring program and actions taken to reduce the discharge of suspended sediment into the Yukon River.

**CONCLUSIONS**

A linear relationship, using a regression analysis, was established between total suspended solids and turbidity and periodically updated during the Robert Service Way Reconstruction Project. This relationship, combined with the turbidity monitoring, provided a tool from which decisions were made rapidly to control TSS levels in the receiving environment during construction. The 25 mg/L compliance limit was met on all occasions except for select periods during the opening of the Level 2 and 3 Compensation Channels.

Turbidity monitoring, combined with the TSS regression analysis, provided a valuable tool for directing instream construction and sediment control activities to minimize impacts to aquatic life.

**ACKNOWLEDGEMENTS**

I wish to acknowledge the assistance of the principals and staff of Access Mining Consultants Ltd, particularly Dan Cornett, who acted as Environmental Monitor during the Robert Service Way Reconstruction Project. Access Mining Consultants Ltd. also enjoyed the close cooperation and support of Rob Harvey and John Grainger of Yukon Engineering Services who were responsible of the overall design of the project.

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