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DATE PERFORMED: AUGUST 11-28, 1992 **DATE FILED:** MARCH 25, 1993

LOCATION: **LAT.:** 62°16'N **AREA:** CARMACKS

LONG.: 136°41'W **VALUE $:** 51,450

CLAIM NAME & NO.: W 81-102, WAR 38-50, WC 1-76, X 1-4, X 5F-7F

WORK DONE BY: P.A. HARDER & ASSOCIATES

WORK DONE FOR: WESTERN COPPER HOLDINGS LIMITED

DATE TO GOOD STANDING:

REMARKS: BIOPHYSICAL ASSESSMENT OF WILLIAMS CREK

Western Copper Holdings Limited

Biophysical Assessment Of Williams Creek

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093083

P.A. Harder and Associates Ltd.

This report has been examined by the Geological Evaluation Unit under Section 53 (4) Yukon Quartz Mining Act and is allowed as representation work in the amount of $ 51,450.

for Regional Manager, Exploration and Geological Services for Commissioner of Yukon Territory.

WESTERN COPPER HOLDINGS LIMITED

BIOPHYSICAL ASSESSMENT OF THE WILLIAMS CREEK MINE SITE

Prepared for:
WESTERN COPPER HOLDINGS LIMITED

Prepared by:

P.A. Harder and Associates Ltd.

March, 1993

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J. Richard Janowicz, M.Sc. Northern Affairs Program, Indian and Northern Affairs Canada Whitehorse, Yukon

Glenn R. Ford Northern Affairs Program, Indian and Northern Affairs Canada Whitehorse, Yukon.

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LIST OF APPENDICES

1.0 INTRODUCTION

1.1 Study Area

Western Copper Holdings Limited (WCHL) is proposing to develop the Williams Creek copper oxide property located 38 km northwest of the town of Carmacks, Yukon (Figure 1.1.1). The property has estimated ore reserves of approximately 13.6 million tonnes. The ore body is located in the upper reaches of Williams Creek approximately nine km upstream from the Yukon River confluence between elevations 717 and 770 m. Williams Creek is a small tributary originating in the Dawson Range and draining northeast into the Yukon River downstream (north) of Carmacks. The creek has a total drainage area of approximately 89 km^2 with a mainstem length of approximately 11 km. The site is accessed from Carmacks via the Mt. Freegold Road and a 13 km seasonal access road at Mile Post 22 on the Mt. Freegold Road.

1.2 Mine Plan Overview

Development of the property would entail an open pit mine, ore crushing facility and a solvent extraction-electrowinning process facility on site. Extracted ore would be crushed to 2.5 cm and stacked in lifts of 6 m on leach pads to an ultimate height of 36 m. The leach pads would be situated adjacent to the ore body in the upper watershed; two alternative pad locations are being investigated (Figure 1.2.1). Sulphuric acid would then be irrigated on the heaps and collected for processing in the cathode extraction plant. Sulphuric acid would be produced on-site. Raw materials for the acid

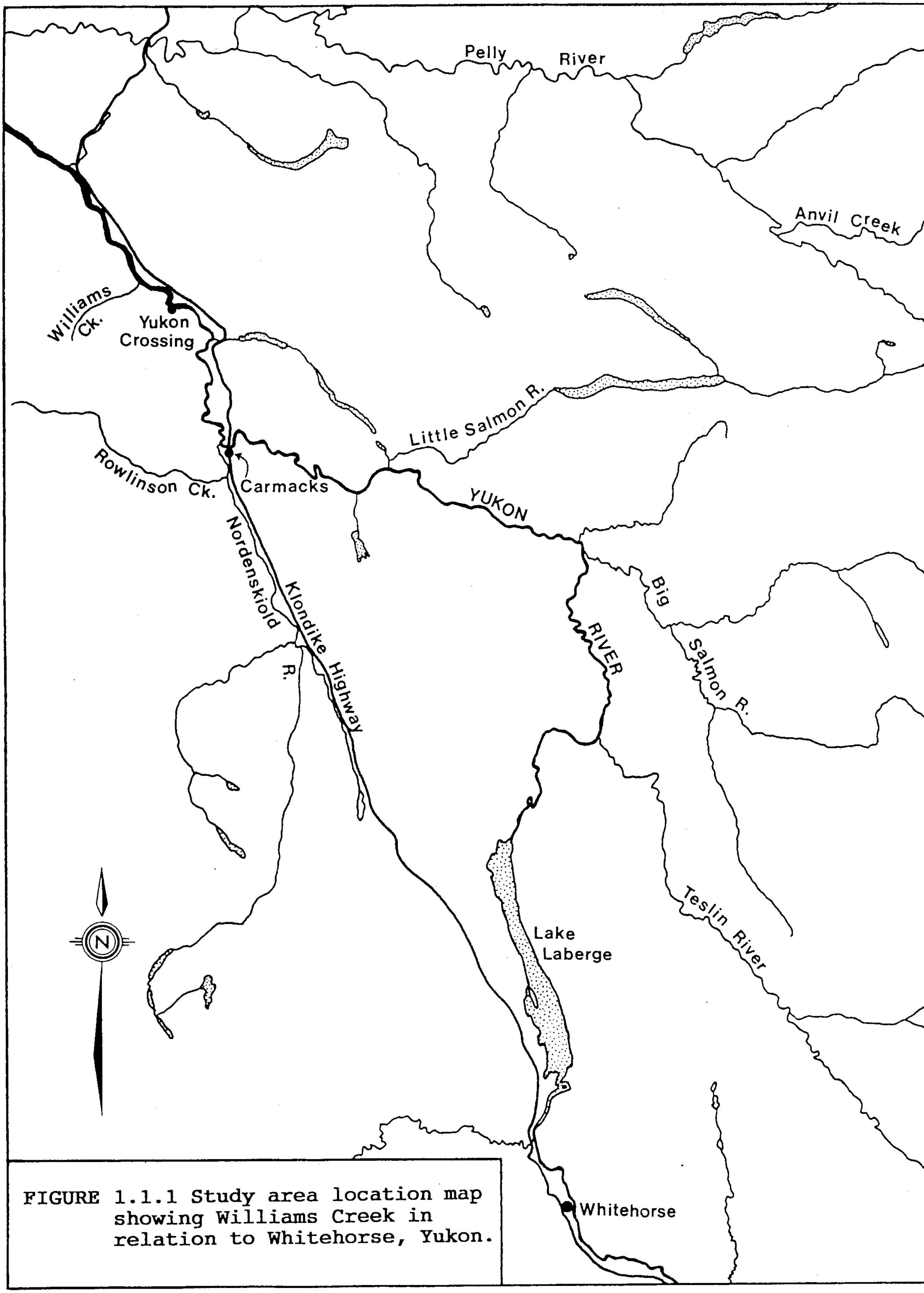

FIGURE 1.1.1 Study area location map showing Williams Creek in relation to Whitehorse, Yukon.

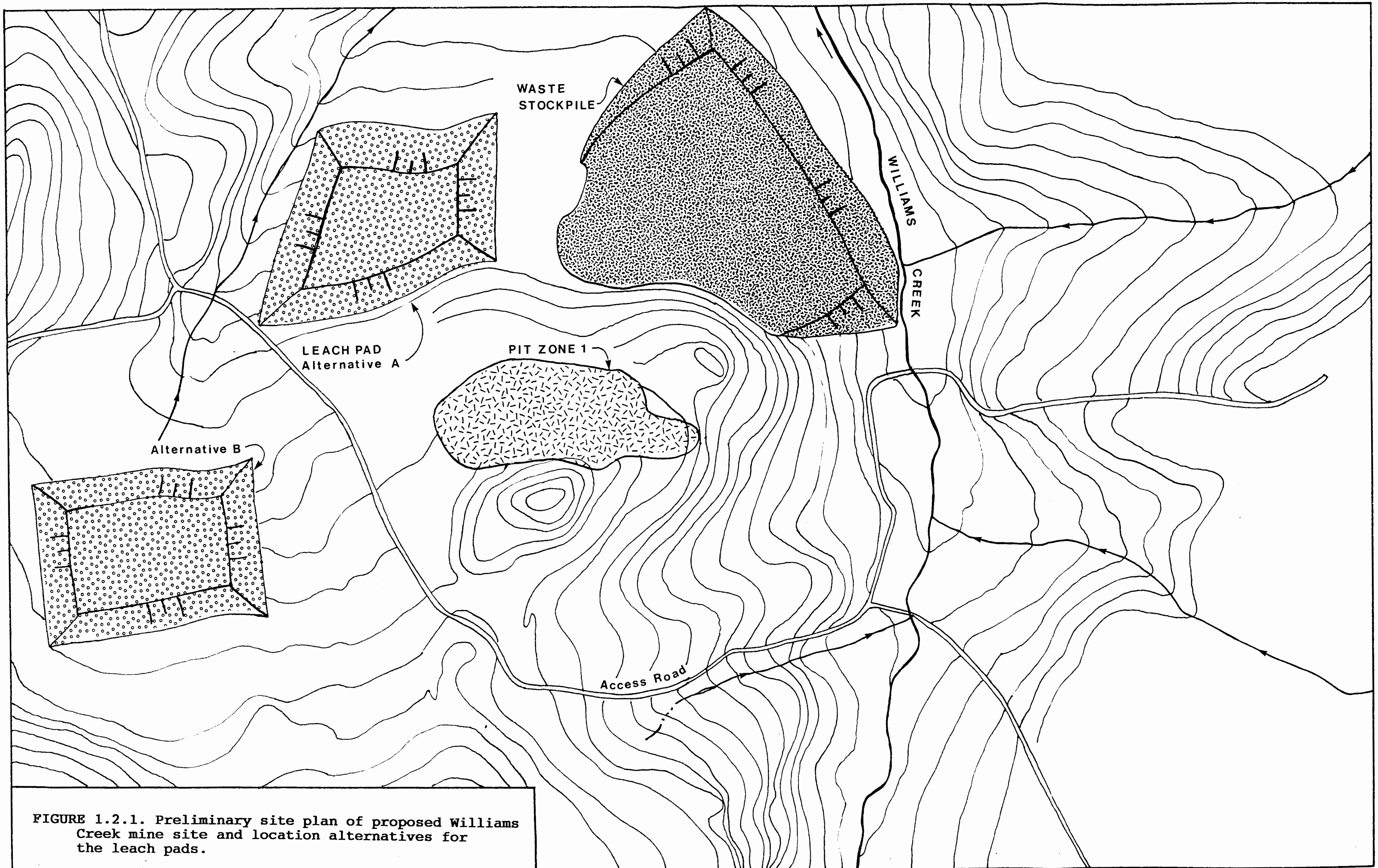

FIGURE 1.2.1. Preliminary site plan of proposed Williams Creek mine site and location alternatives for the leach pads.

generation plant would be transported to the mine site by road. Process waters would be pumped from the Yukon River or from a fresh water pond to be located near the mine. Extraction solvents would be recycled in the process. Any waste water discharge would enter the upper reaches of Williams Creek. The mine site would be serviced by a new power transmission line from the town of Carmacks. Copper would be recovered by an on-site electrolysis process and moved by truck from the mine site through to Carmacks and the Alaska Highway via the existing Mt. Freegold Road. The mine access road would be upgraded to an all-weather road. A detailed description and discussion of the mine will be presented in Volume 1 of the Initial Environmental Evaluation (IEE). Additional details of the preliminary mine development plan have been presented in the initial submission made to the Regional Environmental Review Committee (Archer Cathro and Associates 1991).

1.3 Study Objectives and Scope

P.A. Harder and Associates Ltd. were retained in June 1991 by WCHL to conduct the initial assessment of aquatic resources in the study area and develop recommendations for a detailed environmental assessment. An interim report of this study was prepared and submitted to the regulatory agencies. Following this initial study, WCHL instructed us to conduct further baseline environmental studies during the summer of 1992 and prepare a study on environmental baseline conditions for the IEE.

The scope of this report includes assessments of:

1. Terrain and vegetation characteristics;
2. Wildlife habitat capabilities;
3. Surficial hydrology and climate;
4. Water quality;
5. Aquatic resources; and
6. Natural resource use.

The assessments of surface water hydrology, water quality and aquatic resources have been based on field data collected since 1989. Field work for the other study components was conducted in the summer of 1992.

This report and accompanying maps, have been prepared in support of the Initial Environmental Evaluation being conducted for the proposed heap leach open pit copper mine referred to as the Williams Creek Copper Oxide Project. Socio-economic and heritage resource issues have been presented in a separate report prepared by Hallam, Knight and Piedsold Consultants Ltd.

2.0 METHODS

2.1 Terrain and Vegetation Assessment

The terrain mapping program consisted mainly of aerial photographic interpretation augmented with limited field checking. Aerial photos used were 1:24,000 black and white and colour flown in August 1992. The 1:12,000 black and white photos were also used in some areas.

Field work was done August 10-12, 1992. Two days of ground traversing visited most of the area accessible by road. One day of helicopter support provided access to the remainder of the area where transects were walked.

Terrain mapping was done according to acceptable standards (B.C. Ministry of Environment 1988). The base data (terrain units) were derived from aerial photographic interpretation. A terrain interpretive map was derived from the base data. It is plotted at 1:20,000 scale, and contains the general study area as well as the proposed heap leach pad area.

The interpretive map shows selected units of generalized terrain and vegetation features and conditions and potential geomorphic hazards which may have geotechnical and/or environmental considerations with regard to access road construction and mine site development.

2.2 Wildlife Resources

The wildlife field reconnaissance was conducted between August 10 and 2, 1992. This reconnaissance entailed an overview flight of the entire Williams Creek watershed by helicopter. Observations on habitat types were made and a collection of colour photographs taken at this time. Ground surveys were then conducted to obtain a description (notes and photos) of vegetation and wildlife sign and to assess the wildlife importance of representative sites on the ground. This involved helicopter access to the lower part of the watershed and truck access along exploration roads in the upper watershed. Notes were also made on wildlife sightings and or sign throughout the study area.

Additional wildlife information was obtained from the following sources:

1. Yukon Wildlife Branch staff.

2. Report of J. Gibson and Associates (1991) on wildlife sightings, October, 1989 to May, 1991.

3. Wildlife observations made by exploration camp staff, Fisheries Consultants, and others associated with the project.

4. Reports and publications on Yukon wildlife.

Terrain units mapped by Westland Resource Group (Walmsley 1993) were interpreted for their wildlife use or importance, based on physical features and on vegetation plots and wildlife sign described in the field. Wildlife habitat capability ratings were determined on the basis of this information and aerial photo interpretations.

The preliminary impact assessment was based on the approximate extent and importance of habitats that would be altered or lost as a result of the mine project, on preliminary review of mine-related activities, and experiences with similar projects in other areas.

2.3 Climate

Western Copper Holdings Ltd. measured temperature and precipitation in the vicinity of the Williams Creek Ore Body during the summer of 1991. These limited data, along with longer-term information from nearby stations operated by the Atmospheric Environment Service, were used to characterize the climatological characteristics of the Williams Creek watershed. Three snow courses were also operated at Williams Creek during 1992 and these data, supplemented with information collected by Indian and Northern Affairs Canada, were used to estimate the potential snow cover variation in the vicinity of the proposed mine site.

2.4 Surface Water Hydrology

Water level measurements were obtained at two sites on Williams Creek during the summers of 1991 and 1992. These data, which were obtained by J. Gibson and Associates Ltd., were used in conjunction with longer-term information from stream gauging sites operated by Indian and Northern Affairs Canada and the Water Survey of Canada to characterize the stream flow characteristics of the Williams Creek watershed. Potential peak and low-flow stream discharge were estimated for various locations within Williams Creek on the basis of regional flood frequency and low flow analyses prepared by Indian and Northern Affairs Canada.

2.5 Water and Sediment Quality

Water samples have been collected from the Williams Creek drainage between October 1989 and October 1992. Sediment samples were collected during the August 1992 survey. Sample techniques and site locations are described below.

2.5.1 Water Sampling

2.5.1.1 Sample Site Locations

Eleven water quality sampling stations were established in the Williams Creek drainage at the onset of the studies in 1989 (Figure 2.5.1). Location of these sites are described below.

- W-1 Located on an east flowing intermittent tributary to Williams Creek draining the south east hill side of the ore deposit situated approximately 50 m downstream of the slope toe and 30 m below the new access road.

- W-3 Located on an east flowing tributary to Williams Creek draining the north facing hill side of the deposit and situated approximately 20 m upstream of the new access road crossing.

- W-4 Mainstem of Williams Creek approximately 100 m downstream of the W-3 tributary confluence.

- W-5 Northeast flowing tributary to Williams Creek draining the hill side across the valley from the ore deposit This tributary is spring fed.

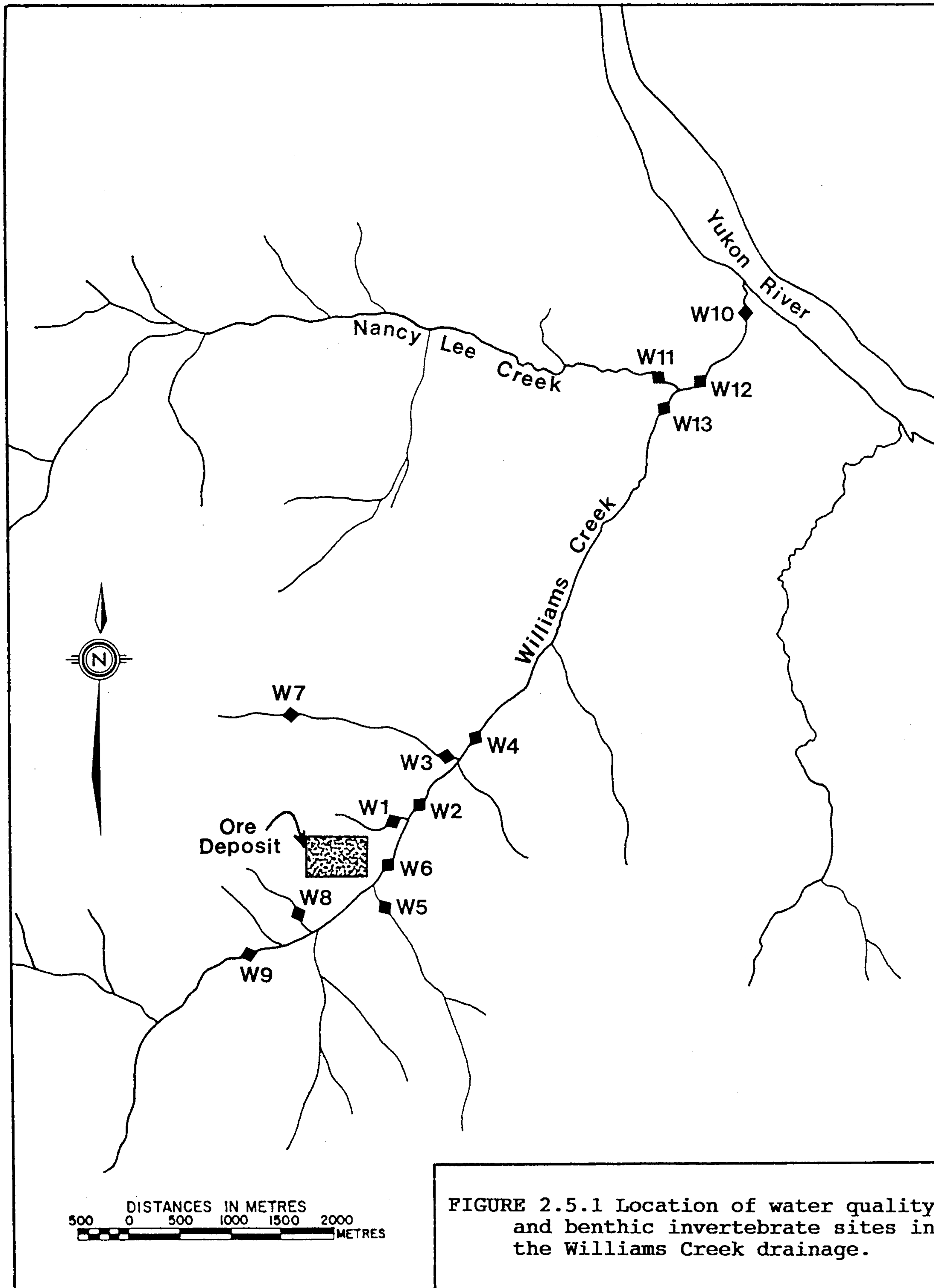

FIGURE 2.5.1 Location of water quality and benthic invertebrate sites in the Williams Creek drainage.

W-7 East flowing tributary draining the north face of the ore deposit located approximately 2 km upstream of sample station W-3.

W-8 Southeast intermittent tributary to Williams Creek draining the south hill side adjacent to the ore deposit. Stream flow occurs during peak of snow melt run off.

W-9 Mainstem of Williams Creek approximately 500 m upstream of the mine access road crossing.

W-10 Mainstem of Williams Creek located approximately 150 m upstream of the Yukon River confluence.

W-11 Mainstem of Nancy Lee Creek located approximately 200 m upstream of the Williams Creek confluence.

2.5.1.2 Sample Collection

Water samples were collected from Sites W-1, W-5, W-7 and W-9 on six occasions between October 1989 and October 1992. Sites W-3 and W-10 where sampled twice during this period while single samples (October 1989) were collected from Sites W-2 and W-6. Site W-11 on Nancy Lee Creek was sampled four times. Additional samples were collected from two sites in lower Williams (W-12 and W-13) during the August 1992 fish survey (Figure 2.5.1).

At each site, samples were collected in a two litre plastic bottle for suspended solids, turbidity, Ph, conductivity, alkalinity, total hardness, nitrate, nitrite, sulphate, ammonia and total phosphorus; and two 250 ml plastic bottles for total and dissolved metals. Collection bottles were supplied by Quanta Trace Laboratories. All sample bottles, with the exception of the dissolved metals sample, were partially filled and rinsed three times prior to collecting sample waters. During periods of open water, samples were collected in mid-channel at mid-depth upstream of any disturbance from other sampling activity. For samples collected under ice cover, a hole was chopped or augured through the ice to the flowing water. The hole was baled out three times before the sample was collected to reduce the effect of stream bed material disturbance. Samples from tributary sites were collected far enough upstream to avoid mainstem influence. Similarly, mainstem samples were collected far enough downstream of tributary confluences to ensure that the samples were representative of completely mixed waters.

The filtration method for dissolved metals samples varied slightly between sample years. The July and October 1992 samples were filtered in the field using 60 ml disposable syringes with an in - line 45 micron filter. This system was used to reduce the risk of sample contamination suspected in some cases when the Nalgene vacuum filter flask method was used. The August and December 1991 and May 1992 samples were collected and then filtered latter on the same day of collection using a dissolved metals filter train method to establish sample integrity. The filter train method entailed filtering deionized water before and after the sample water was filtered through a Nalgene 250 ml vacuum filter flask with 45 micron filters. The deionized water samples were then analyzed as separate samples for dissolved metals. Prior to the filtration procedure, the sample was re-mixed by shaking and the apparatus rinsed with a weak nitric acid/deionized water solution followed by two deionized water rinses. New filters were installed for each filter train using rinsed forceps. Filtered samples were collected in new collection bottles. Triplicate samples for all analyses were collected from Station W-10 during May 1992 as a further QA/QC measure. The October 1989 samples were un-filtered and were analyzed for total metals only.

All sample bottles were labelled prior to collection including project name, sample station number, data and time of collection and analysis required. Labels were double checked and verified with the log book entries in the field and again during the filtration procedure.

Dissolved and total metals samples were preserved with 0.5 ml of nitric acid per 100 ml of sample using a disposable pipette. Ammonia samples were preserved with 0.5 ml of sulphuric acid. Samples were kept cool prior to shipment to Quanta trace Laboratories in Vancouver.

2.5.1.3 Laboratory Analysis

Methods used by Qaunta Trace Laboratories are based on Standard Methods for the Examination of Water and Wastewater (17^{th} Edition) and U.S. EPA protocols and include 20% duplicates and SRM's with each sample shipment. Parameters of analysis and detection limits for water samples collected in Williams Creek are listed in Table 2.5.1.

TABLE 2.5.1. Parameters of analysis and detection limits for water samples collected in Williams Creek.

PARAMETER	DETECTION LIMIT (mg/L)	PARAMETER	DETECTION LIMIT (mg/L)
Nitrogen NH_3	0.05	Molybdenum	0.003
Sulphate	5.0	Sodium	0.05
Total Hard	5.0	Nickel	0.001
Aluminum	0.005	Phosphorous	0.02
Arsenic	0.05	Lead	0.004
Barium	0.001	Antimony	0.02
Beryllium	0.0002	Selenium	0.02
Bismuth	0.02	Silicon	0.05
Calcium	0.01	Tin	0.01
Cadmium	0.0003	Strontium	0.001
Cobalt	0.001	Tellurium	0.001
Chromium	0.001	Titanium	0.001
Copper	0.001	Thallium	0.001
Iron	0.09	Vanadium	0.001
Potassium	0.05	Zinc	0.002
Magnesium	0.001	Zirconium	0.001
Manganese	0.001		
Boron	0.001		

Note: Detection limits varied between years in some cases (As, Sb, Be, Bi, Pb, Se and Th) due to changes in laboratory procedures and regulatory guidelines.

2.5.2 Sediment Sampling

Sediment samples were collected from 6 stations (W-4, W-9, W-10, W-11, W-12 and W-13) during the July 1992 survey. Duplicate sediment samples were collected from Sites W-11, W-12 and W-13. Samples were collected from exposed portions of the bank, selecting the finest grained sediments available. A composite sample was collected for three points of the channel cross section at Site W-10. The W-4 and W-9 samples were collected by selecting a composite of available sediments within a 10 m stretch of the stream bank.

Samples were collected using a disposable perforated plastic scoop for each site and placed into a plastic or glass container and packed on ice before shipment to Quanta Trace Laboratories in Vancouver. The samples were dried and then run through an ICAP analysis using methods found in Clesceri et al., (1989).

2.6 Aquatic Resources

Aquatic resource of the study area were investigated in 1991 and 1992. These studies included juvenile and adult fish sampling, habitat assessment work and collection of baseline benthic invertebrate data.

2.6.1 Fisheries

The fisheries assessment has been based on two years of field studies. The Year 1 study included an assessment of habitat capabilities in Williams Creek, fish sampling to determine fish distribution and seasonal abundances in the creek and a survey of the Yukon River during the fall of 1991 during the chum salmon spawning period. Additional fish sampling was conducted in Williams Creek and tributaries crossed by the Mt. Freegold mine access road during August, 1992.

2.6.1.1 Habitat Assessment

Habitat types within the Williams Creek drainage were assessed from high level aerial photo interpretation (North West Survey Corporation Ltd. 1977; Scale: 1:60,000), helicopter reconnaissance and ground sampling. Stream habitat types were classified into homogeneous reaches on the basis of valley wall and channel processes and instream bio-physical characteristics. These data were collected and stored on DFO/MOE Stream Survey Forms following the methodology developed by the B.C. Ministry of Environment (Chamberlain 1986).

2.6.1.2 Fish Sampling

Fish samples were collected from Williams Creek and the Yukon River in August and October, 1991. The 1992 fish sampling program was conducted in August and included sites in lower Williams Creek, lower Nancy Lee Creek, Crossing and Merrice creeks on the Mt. Freegold mine access road.

2.6.1.3 Sample Sites

A total of seven fish sample sites fish were established on Williams Creek during the August 1991 survey (Figure 2.6.1). One site was established on the Yukon River immediately downstream of the Williams Creek confluence. Repetitive fish sampling was conducted at Sites #5 and #6 in Williams Creek during the October 1991 survey. Sampling was also conducted during the October sample in a side channel habitat of the Yukon River (Site Y1) located approximately 2 km upstream of the Williams Creek confluence (Figure 2.6.1). Fall sampling was not conducted at Site Y1 due to high flow conditions. The 1992 fish sampling included two sites in lower Williams Creek, a new site in lower Nancy Lee Creek and new

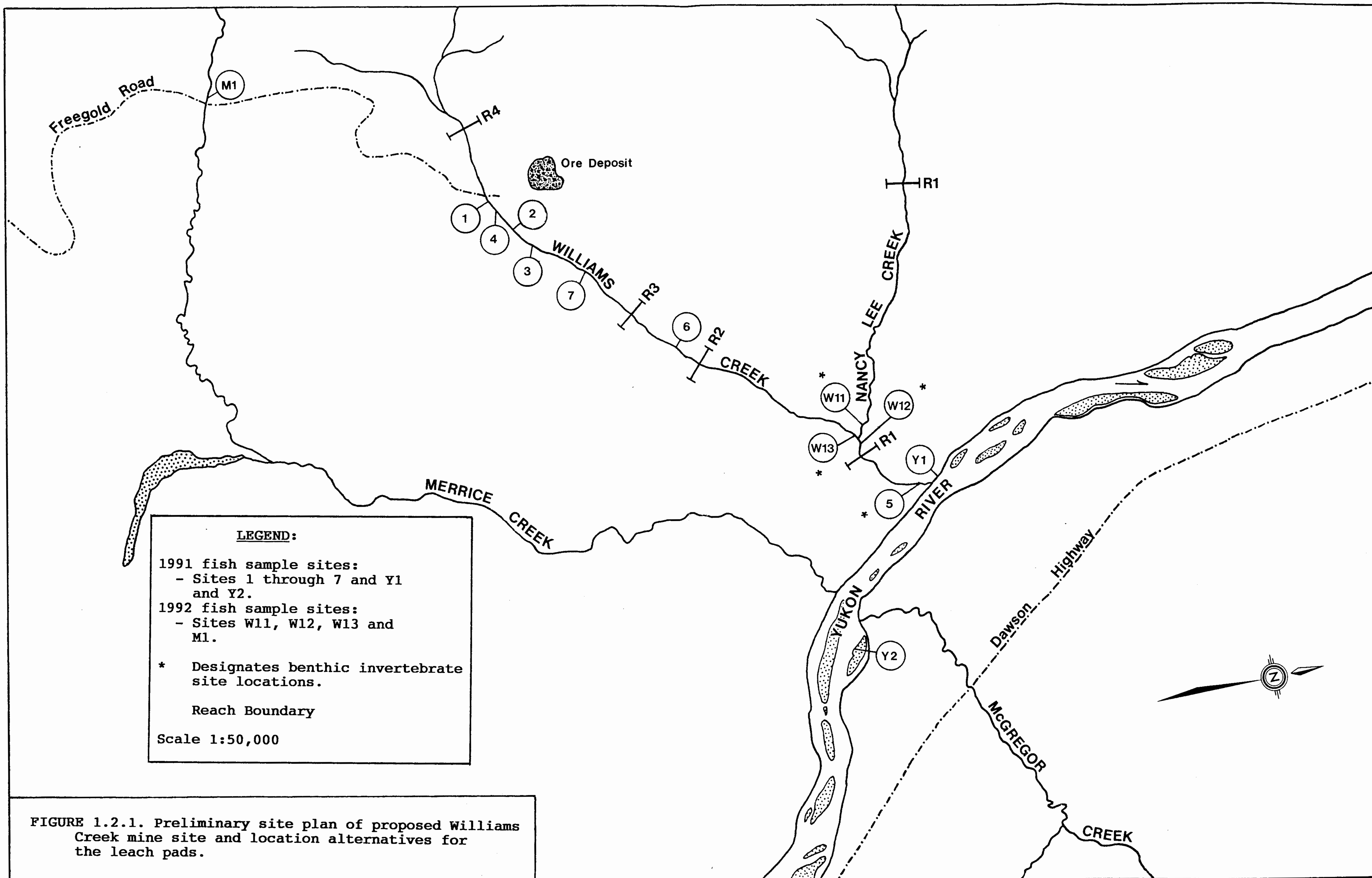

FIGURE 1.2.1. Preliminary site plan of proposed Williams Creek mine site and location alternatives for the leach pads.

sites at the Mt. Freegold Road crossings of Crossing and Merrice creeks (Figure 2.6.1).

2.6.1.4 Sample Techniques

Samples were collected using an electrofisher, baited minnow traps (August, 1991 sample only) and visual observations. The electrofishing was conducted using upstream and downstream stop nets enclosing the sample area. Sample areas varied between approximately 100 and 120 m^2. In most cases the electrofisher was moved up and down the enclosed sample area two times. Individual fish catches from each pass were kept in separate collection buckets to demonstrate the effectiveness of each sample. Captured specimens were identified to species and a measured for fork length. Specimens were anaesthetized using CO_2 prior to handling. Fish were revived and released in an area of slow, protected water. All mortalities were recorded and retained for future reference.

2.6.1.5 Spawner Surveys

A spawner survey was conducted in 1991 over selected sections of the Yukon River during the October spawning period for chum salmon. The survey extended downstream of the Williams Creek confluence for approximately 5 km and upstream for 10 km. The survey was concentrated along the channel margins of side channel areas where water clarity was adequate for aerial observations. The survey was conducted from a helicopter at a speed of approximately 70 km/hr, 50 to 100 m above ground level.

2.6.2 Benthic Invertebrate Study

Benthic invertebrate samples were collected from one site (W-10) in lower Williams Creek approximately 250 m upstream of the Yukon River confluence during the 1991 study. This site was relocated approximately 1.2 km further upstream (W-12) during the 1992 study and two additional sites were also established; one site (W-13) was upstream of the Nancy Lee Creek confluence and the other site in the lower reach of Nancy Lee Creek (W-11). Locations of the benthic invertebrate sites are presented in Figure 2.6.1.

Benthic invertebrate samples were collected using three wire mesh basket samplers set at each site. Each basket was filled with cleaned rocks collected from the stream bottom. The baskets were secured in a deep run along an under-cut bank. The baskets were left to colonize over a five week period and then retrieved (Table 2.6.1). Field preparation of the samples entailed removing all invertebrates with a wash bottle and brush. Collected specimens were preserved in 5% formalin and sent to Vancouver for analysis.

Preserved samples were sorted and screened using 5, 10 and 40 micron meshes. Debris was removed and specimens identified to genus level when possible. Analysis was conducted on the entire sample volume and a constant effort was maintained for each sample.

TABLE 2.6.1. Basket installation and collection dates for benthic invertebrate sampling conducted in the Williams Creek watershed during 1991 and 1992.

SITE #	SITE LOCATION	SAMPLE YEAR	INSTALLATION DATE	COLLECTION DATE
W-10	Lower Williams Cr	1991	August 8	September 6
W-13	Williams Cr above Nancy Lee	1992	July 7	August 11
W-12	Williams Cr below Nancy Lee	1992	July 7	August 11
W-11	Lower Nancy Lee Creek	1992	July 7	August 11

3.0 BASELINE ENVIRONMENTAL CONDITIONS

3.1 Terrain and Vegetation Characteristics

The purpose of the information is to assist in the planning for the mine development and to provide information to the multi-disciplinary team addressing environmental issues (in particular, the wildlife component).

The majority of the effort spent on this task is represented by the information displayed on the Terrain Interpretive Map contained in Appendix 1. This section has been kept brief, in that it is intended mainly as a supporting document to the map and legend.

3.1.1 Physiographic and Ecological Setting

The area around the project site is part of the Pelly River Ecoregion (Oswald et.al. 1977). The Pelly River Ecoregion is comprised of portions of the Stewart, Macmillan, Lewes and Klondike Plateaus and Tintina Valley physiographic subdivisions (Bostock, 1970). The study area generally falls with the Klondike Plateau.

Surface drainage flows both north and east from the study area. A number of valley streams, of which Williams Creek is the largest, drain northeastward to the Yukon River.

A broadly rolling till plain forms the dominant glacial landform. Isolated pockets of fluvial and glaciofluvial sands and gravels, glaciolacustrine silts and organic deposits mantle the subdued till in places. Surface till is variable in colour, moderately stony and has a silty sandy matrix. Volcanic ash forms a veneer varying from 5 to 30 cm thick in various locations throughout the area.

The area features a broad valley and rounded ridge crests. Relief is 480 to 900 m within the study area. Late Wisconsin ice covered the majority of the landscape east of the project area during glacial maxima. As deglaciation commenced and the ice sheet retreated and downwasted, glaciers remained in the valleys while ridge crests and upper slopes were ice-free. Till deposits in the valley bottoms and on lower slopes are the result of direct glacial deposition. Tills with a silty sandy matrix reflect the regional glaciation; in the upper valleys a coarser, looser till may be found which reflects deposition from ablating valley glaciers. The higher elevation areas were likely not glaciated during the Wisconsin. However, these areas were probably influenced by an earlier, pre-Wisconsin advance.

Large volumes of meltwater emanated from the retreating ice. Loose, surficial deposits were eroded from slopes, transported by meltwater streams and deposited as glaciofluvial terraces, outwash plains and ice-contact kames and eskers. These granular sediments infilled much of the valley lowlands. In places, they are associated with silt deposits laid down in glacial lakes formed by temporary ponding of meltwater.

In post-glacial time, deposition and erosion continues. Colluvial deposits are gravity-transported materials common to sloping ground. Angular bedrock fragments with interstitial sand and silt are ubiquitous on ridge crests and upper and mid-slope positions. Fluvial sediments and organic materials accumulate on floodplains, fans and adjacent valley lowlands. Fluvial erosion, lateral and vertical cutting through existing surface materials, is an on-going but generally imperceptible process; it is usually most dynamic in steeper-gradient channels and where unstable bank materials exist. Landsliding and debris flows are rapid mass movement processes which are modifying some areas of sloping terrain. Where surficial deposits are overlain by a blanket of organic materials, and on many north facing slopes, permafrost tends to occur. In these areas, ground-ice was encountered at depths of 10 to 50 cm.

3.1.2 Terrain Features

Landforms

Williams Creek valley and its tributaries are the dominant landform features of the study area. The main valley is characterized generally as a broad floodplain containing sands and silts that are covered by a blanket of organic accumulation. Ground ice occurs throughout this area at depths of 10 to 20 cm and peat plateaus are common. The Williams Creek channel becomes more confined downstream of the mine site area, where it has cut through bedrock and extensive deposits of fluvioglacial sands and gravels.

Near its confluence with Yukon River, Williams Creek is tightly confined in a canyon comprised of bedrock outcrop and steeply sloping outwash terraces. Due to the fact that much of the western portion of the study area was unglaciated during the Wisconsin Advance, the common surficial materials occurring upslope of Williams Creek are a combination of coarse textured colluvium and medium textured glacial till, and minor fluvioglacial materials. Weathered bedrock is a dominant feature throughout much of the upland area, where soils exhibit a coarse sandy and rubbly texture. Minor side-slope drainages are usually incised into bedrock and exhibit infilling by fluvial sediments, capped by a veneer of organic accumulation. Extensive areas of the landscape, where slopes are generally less than 20% are poorly drained and covered by a veneer of organic accumulation. Loess and volcanic ash deposits (White River source) cover extensive portions of the study area.

Erosion

Slope erosion processes are generally confined to minor gully erosion and landsliding. These processes are predominant on the terraces and steep slopes occurring on the north side of Williams Creek. The majority of the gulleys on the side-slopes are stable and exhibiting little erosion. The steeply sloping face on the south side of Williams Creek, upstream of its confluence with the Yukon River is exhibiting minor gullying and debris flow activity.

The extensive terrace face at the confluence is undergoing continuous mass movement by gully and surface erosion processes.

The area for the proposed heap leach pad is generally a moderately sloping area characterized by a blanket of moderately well drained glacial till overlying bedrock. There are no erosional processes affecting this area.

Permafrost

The study area lies within the discontinuous widespread permafrost subzone. During field examination, ground ice was encountered at depths of 40 to 50 cm on most north facing slopes where glacial till or medium textured colluvium is present. As previously mentioned, ground ice is widespread in the main Williams Creek floodplain as well as the north facing tributary gullies.

3.1.3 Vegetation Characteristics

White and Black Spruce are the common tree species. Black Spruce is dominant in poorly drained areas whereas White Spruce tends to occur mainly in better drained areas, and in particular, near the Yukon River. Birch is present throughout the forest stands with Aspen and Poplar often occurring on disturbed sites. Lodgepole Pine occurs throughout the study area, particularly on areas that have been influenced by fire.

Where Black Spruce occurs as a continuous forest stand, feathermoss tends to dominate the understorey and form a complete ground cover. Willows and ericaceous shrubs occur where the stands of trees are less dense. In floodplain and poorly drained areas, sedge and spagnum tussocks are common. On south facing slopes, sagewort, grasses and forbs occur as a continuous cover with Aspen stands occupying protected draws and gulleys.

On moderately well and well drained sites, brunisolic soil development predominates. These soils are often lithic due to the thin nature of the soil cover. Gleysolic soils occur throughout the study area on poorly drained sites. Fibrisols tend to be the common organic soil occurring in floodplain and poorly drained locations.

3.2 Climate

3.2.1 Climatological Setting

Wahl et al. (1987) divide Yukon into nine climatic regions on the basis of latitude, topography, elevation, scales of atmospheric motion, etc. As illustrated on Figure 3.2.1, the Williams Creek watershed is within the so-called "Central Yukon Basin". This area, which has the most continental climate of any area in Yukon, is typified by moderate annual precipitation totals (300 to 400 mm) and extreme variations in temperature. For example the North American record minimum temperature of -62.8°C was observed at Snag and both Mayo and Ross River have been nearly as cold. The maximum observed temperature in Yukon of 36.1°C was observed at Mayo.

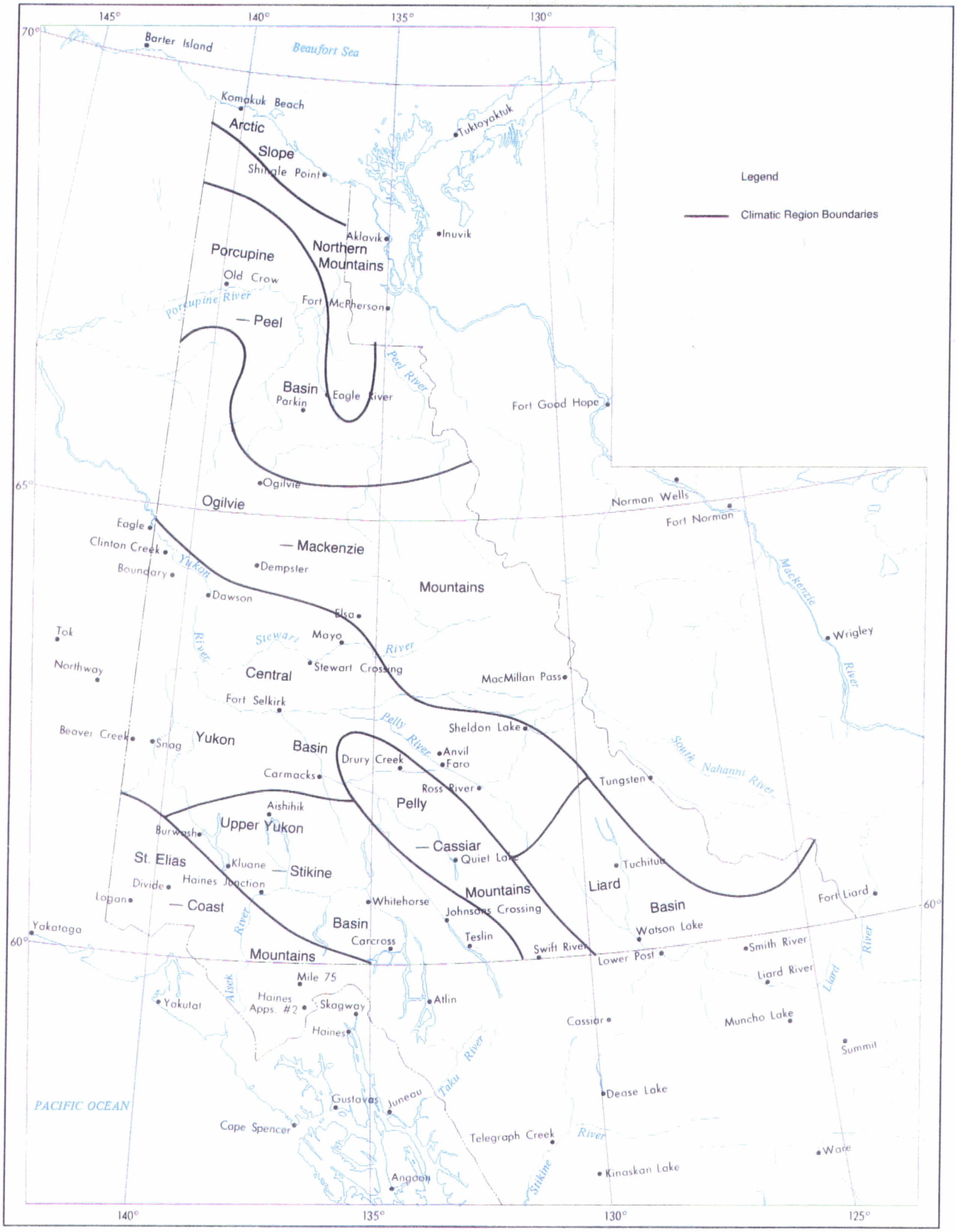

FIGURE 3.2.1. Climatic Regions of Yukon and Atmospheric Environment Service climate stations (from Wahl et al., 1987).

The Atmospheric Environment Service (AES) operates a number of climatological stations within or adjacent to the Central Yukon Basin (Table 3.2.1). Data from these sites has been obtained and used to estimate conditions within the Williams Creek watershed. As indicated on Figure 3.2.1, the closest long term AES stations are located 35 km to the southeast at Carmacks and 60 km to the northwest at Fort Selkirk and Pelly Ranch. [1] Carmacks and Fort Selkirk are located at an elevation of 525 m and 454 m, respectively. In comparison the Williams Creek watershed ranges in elevation between approximately 490 m and 1,070 m. Data from Carmacks and Fort Selkirk may therefore not be representative of conditions within higher elevation portions of the Williams Creek basin and analyses of regional data has therefore been undertaken to determine typical variations with elevation.

3.2.2 On-site Climatological Data

Temperature and precipitation data were collected in the vicinity of the proposed Williams Creek mine site during the summer of 1992 (Tables 3.2.2 to 3.2.4). This information, along with data collected in Carmacks by the Highway Department, suggest that Williams Creek is substantially wetter and slightly colder than Carmacks. However some of the readings seem anomalously different (e.g. the August 17 precipitation at Williams Creek was 30.0 mm

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[1] AES has combined data from the station Pelly Ranch with that from Fort Selkirk as the stations are in close proximity and have a similar elevation. All data from these two sites have, for convenience, been referred to as "Fort Selkirk".

AES STATION NUMBER	AES STATION NAME	ELEVATION (m)	PERIOD OF RECORD	YEARS OF RECORD	RELEVANT DATA						
					TEMP	PRECIP	RATE OF PRECIP	WIND	SUN	EVAP.	NIPHER
2100100	AISHIHIK A	966	1943-66		X	X		X			
2100J00	AISHIHIK LAKE UPPER	1,160	1976-								
2100120	ANVIL	1,158	1967-		X	X		X			
2100300	CARMACKS	525	1984-		X	X					
2100302	CARMACKS TOWER	1,234	1964-76		X	X					
2100400	DAWSON	320	1897-79		X	X		X			X
2100402	DAWSON AIRPORT	369	1976-		X	X	X				X
2100460	DRURY CREEK	609	1970-		X	X					
2100516	FARO	694	1971-77		X	X	X	X			X
2100517	FARO A	712	1977-		X	X					X
2100880	FORT SELKIRK/PELLY RANCH	454	1898-		X	X	X		X	X	
2100700	MAYO A	504	1924-		X	X	X			X	X
2101030	STEWART CROSSING	480	1963-		X	X	X				
2100940	ROSS RIVER A	705	1961-		X	X	X				
2100948	SHELDON LAKE	884	1970-		X	X	X				
2101000	SNAG A	587	1943-66								

FROM: Atmospheric Environment Service, 1989

Abbreviations:

TEMP	Temperature
PRECIP	Precipitation
RATE OF PRECIP	Rate of Precipitation
SUN	Sunshine
EVAP	Evaporation
NIPHER	Nipher Snow Gauge
1986-	Station still operating in 1993

TABLE 3.2.1 Selected Atmospheric Environment Service Climate Stations located within or adjacent to the Central Yukon Basin.

DATE JUNE	PRECIPITATION		TEMPERATURE					
	WILLIAMS CREEK (mm)	CARMACKS (mm)	WILLIAMS CREEK			CARMACKS		
			MAXIMUM (oC)	MINIMUM (oC)	AVERAGE (oC)	MAXIMUM (oC)	MINIMUM (oC)	AVERAGE (oC)
1		4.8				17.5	3.0	10.3
2						19.0	2.0	10.5
3						19.5	5.0	12.3
4						17.0	5.0	11.0
5							7.0	7.0
6								
7						17.0		17.0
8						17.0	0.0	8.5
9			26.0	-2.0	12.0	21.0	1.0	11.0
10			26.0	-1.0	12.5	21.5	3.0	12.3
11			27.0	6.0	16.5	26.0	5.0	15.5
12	1.0		28.0	4.0	16.0		6.0	6.0
13	9.8		21.0	5.0	13.0			
14	1.0	6.2	23.0	5.0	14.0	28.0		28.0
15	2.0	trace	23.0	7.0	15.0	21.0	7.0	14.0
16		0.6	22.0	3.0	12.5	19.5	8.0	13.8
17	2.0		21.0	1.0	11.0	19.0	7.0	13.0
18			24.0	2.0	13.0	22.0	4.0	13.0
19			18.0	2.0	10.0		6.0	6.0
20	10.0		17.0	3.0	10.0			
21	18.0	2.4	15.0	2.0	8.5	20.5		20.5
22	2.0	1.2	20.0	-1.0	9.5	16.0	7.0	11.5
23	1.0	trace	14.0	0.0	7.0	18.5	8.0	13.3
24		1.4	21.0	-2.0	9.5	13.5	4.0	8.8
25	2.0	1.4	20.0	-2.0	9.0	17.0	3.0	10.0
26			22.0	-1.0	10.5		4.0	4.0
27			27.0	-1.0	13.0			
28			30.0	2.0	16.0	30.5		30.5
29			31.0	4.0	17.5	31.0	7.0	19.0
30			28.0	5.0	16.5		10.0	10.0
TOTAL	48.8	18.0						
MEAN			22.9	1.9	12.4	20.6	5.1	12.9

TABLE 3.2.2 Preliminary Temperature and Precipitation Data-June, 1992

DATE	PRECIPITATION		TEMPERATURE					
			WILLIAMS CREEK			CARMACKS		
JULY	WILLIAMS CREEK (mm)	CARMACKS (mm)	MAXIMUM (oC)	MINIMUM (oC)	AVERAGE (oC)	MAXIMUM (oC)	MINIMUM (oC)	AVERAGE (oC)
1			29.0	8.0	18.5	29.0	13.0	21.0
2			28.0	9.0	18.5	29.0	14.0	21.5
3	6.0	2.0	21.0	8.0	14.5	29.0	13.0	21.0
4	1.0		22.0	8.0	15.0		13.0	13.0
5	10.0	7.0	21.0	7.0	14.0	21.0		21.0
6	14.0	17.4	22.0	6.0	14.0	16.5	12.0	14.3
7	2.0	5.2	21.0	7.0	14.0	17.0	12.0	14.5
8		trace	24.0	8.0	16.0	22.0	11.0	16.5
9	3.0		21.0	8.0	14.5	22.0	8.0	15.0
10	16.0		20.0	4.0	12.0		8.0	8.0
11	11.0		21.0	4.0	12.5			
12	4.0	8.2	20.0	6.0	13.0	25.0		25.0
13		14.0	18.0	8.0	13.0	13.0	10.0	11.5
14		0.5	18.0	8.0	13.0	18.0	10.0	14.0
15	2.0		22.0	4.0	13.0	18.0	9.0	13.5
16	3.0		23.0	3.0	13.0	19.5	6.0	12.8
17		trace	24.0	4.0	14.0	21.5	6.0	13.8
18			20.0	4.0	12.0	24.0	10.0	17.0
19		trace	21.0	5.0	13.0	21.0	10.0	15.5
20	3.0	1.4	20.0	2.0	11.0	20.0	8.0	14.0
21		3.0	22.0	3.0	12.5	19.5	9.0	14.3
22			21.0	2.0	11.5	21.0	8.0	14.5
23	4.0		20.0	4.0	12.0	23.0	8.0	15.5
24	6.0		21.0	4.0	12.5		9.0	9.0
25			23.0	5.0	14.0			
26		4.0	19.0	5.0	12.0	23.5		23.5
27	2.5	trace	20.0	1.0	10.5	18.5	6.0	12.3
28			22.0	3.0	12.5	21.0	6.0	13.5
29	2.0	2.8	23.0	4.0	13.5	18.0	6.0	12.0
30	4.0	2.8	22.0	3.0	12.5	16.5	7.0	11.8
31	10.0	0.4	23.0	5.0	14.0	23.5	9.0	16.3
TOTAL	103.5	68.7						
MEAN			21.7	5.2	13.4	21.2	9.3	15.4

TABLE 3.2.3 Preliminary Temperature and Precipitation Data-July, 1992

DATE	PRECIPITATION		TEMPERATURE					
	WILLIAMS CREEK		WILLIAMS CREEK			CARMACKS		
AUGUST	WILLIAMS CREEK (mm)	CARMACKS (mm)	MAXIMUM (oC)	MINIMUM (oC)	AVERAGE (oC)	MAXIMUM (oC)	MINIMUM (oC)	AVERAGE (oC)
1	5.0		24.0	4.0	14.0	23.5		23.5
2		0.4	21.0	2.0	11.5	23.5		23.5
3			23.0	6.0	14.5	22.0	5.0	13.5
4			23.0	14.0	18.5	24.5	5.0	14.8
5	6.0		21.0	9.0	15.0	23.0	11.0	17.0
6		3.5		10.0	10.0	22.0	10.0	16.0
7	8.0		22.0		22.0		11.0	11.0
8	1.0		21.0	9.0	15.0			
9		9.0	20.0	8.0	14.0	22.0		22.0
10			22.0	6.0	14.0	23.0	12.0	17.5
11			20.6	6.0	13.3	22.0	8.0	15.0
12			18.0	5.0	11.5	21.0	8.0	14.5
13			11.0	6.0	8.5	20.0	6.0	13.0
14			11.0	0.0	5.5		6.0	6.0
15			12.0	0.0	6.0			
16			10.0	0.0	5.0			
17	30.0	3.0	14.0	0.0	7.0	19.5		19.5
18	2.0	1.2	14.0	2.0	8.0	14.0	3.0	8.5
19			19.0	2.0	10.5	17.0	5.0	11.0
20			18.0	-1.0	8.5	19.5	5.0	12.3
21			20.0	1.0	10.5		0.0	0.0
22			21.0	1.0	11.0			
23			19.0	7.0	13.0	23.0		23.0
24			18.0	11.5	14.8	20.0	0.0	10.0
25	4.0		17.0	13.0	15.0	18.0	10.0	14.0
26	14.0	trace	14.0	3.0	8.5	18.0	6.0	12.0
27	46.0	2.8	12.0	5.0	8.5	18.0	3.0	10.5
28	3.0		13.0	7.0	10.0		3.0	3.0
29			16.0	-2.0	7.0			
30	24.0		12.0	3.0	7.5	16.0		16.0
31		8.0		5.0	5.0	17.0	0.0	8.5
TOTAL	143.0	27.9						
MEAN			17.5	4.7	11.1	20.3	5.9	13.7

TABLE 3.2.4 Preliminary Temperature and Precipitation Data-August, 1992

while that at Carmacks was 3.0 mm). Thus it would be desirable to base a thorough comparison between these sites on verified data (which were not available at the time this report was written).

3.2.3 Air Temperature

The seasonal variation in temperature at Carmacks (elevation 525 m) and Fort Selkirk (elevation 454 m) are shown on Figure 3.2.2 and are tabulated on Table 3.2.5. These data indicate that extreme minimum temperatures typically occur in December, January or February and have historically reached values of -58 to -60°C. Extreme maximum values typically occur between May and August and values of up to 30°C have been observed. Mean monthly temperatures typically exceed 0°C in the period between April and September, although greater than 0°C temperatures have historically occurred in all months of the year. The data on Tables 3.2.2 to 3.2.5 suggest that Williams Creek temperatures are approximately 0.5°C, 2.0°C and 2.6°C colder than at Carmacks during the months of June, July and August.

The historical variation in average annual air temperature at Carmacks and Fort Selkirk is shown on Figure 3.2.3. The residual mass curve indicates that annual mean air temperatures were generally colder than average between 1952 and 1975 and have subsequently been generally warmer than average. Statistical analyses (described in Buishand, 1982), indicate that there is a 95 per cent probability that a statistically significant shift in the mean

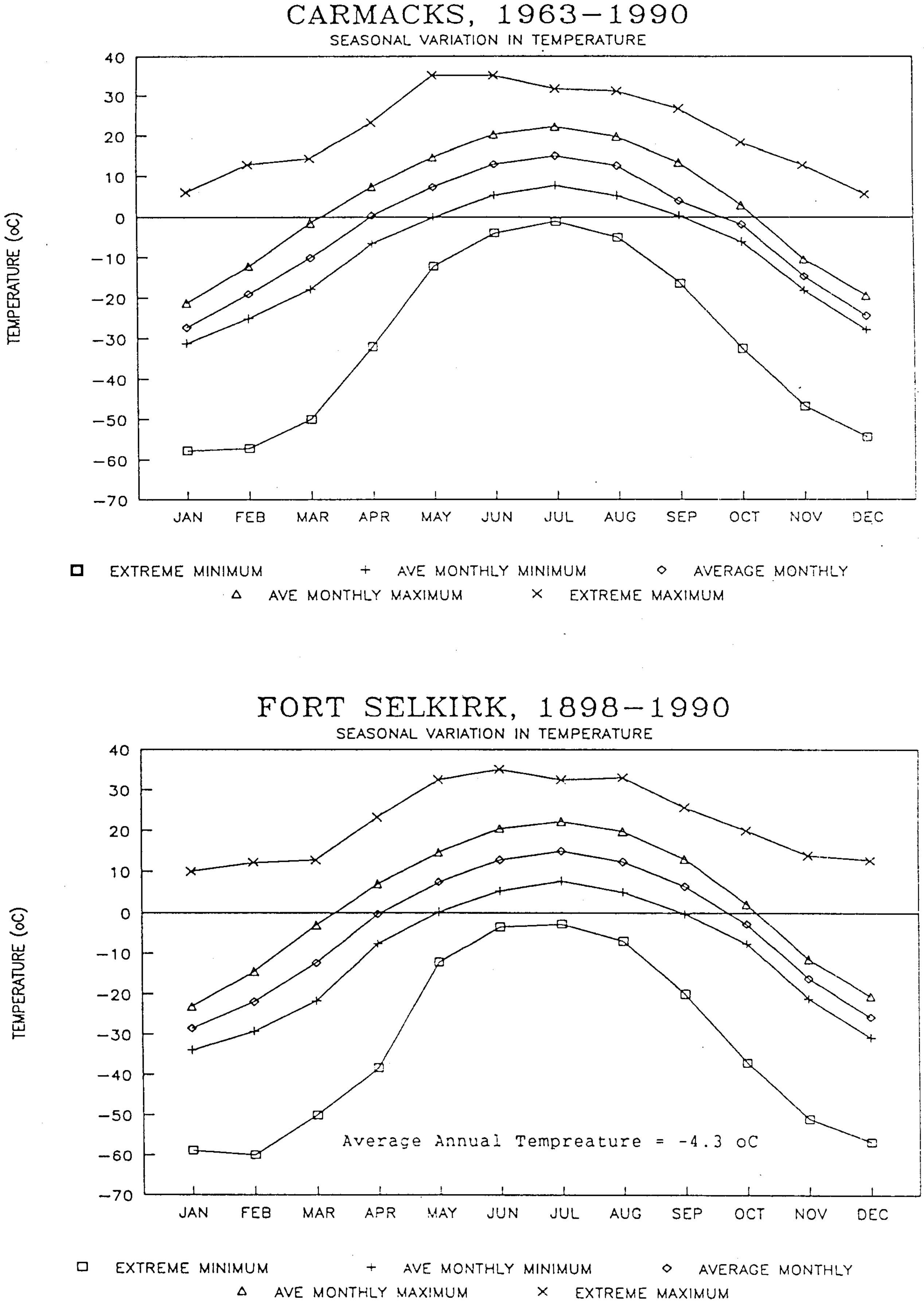
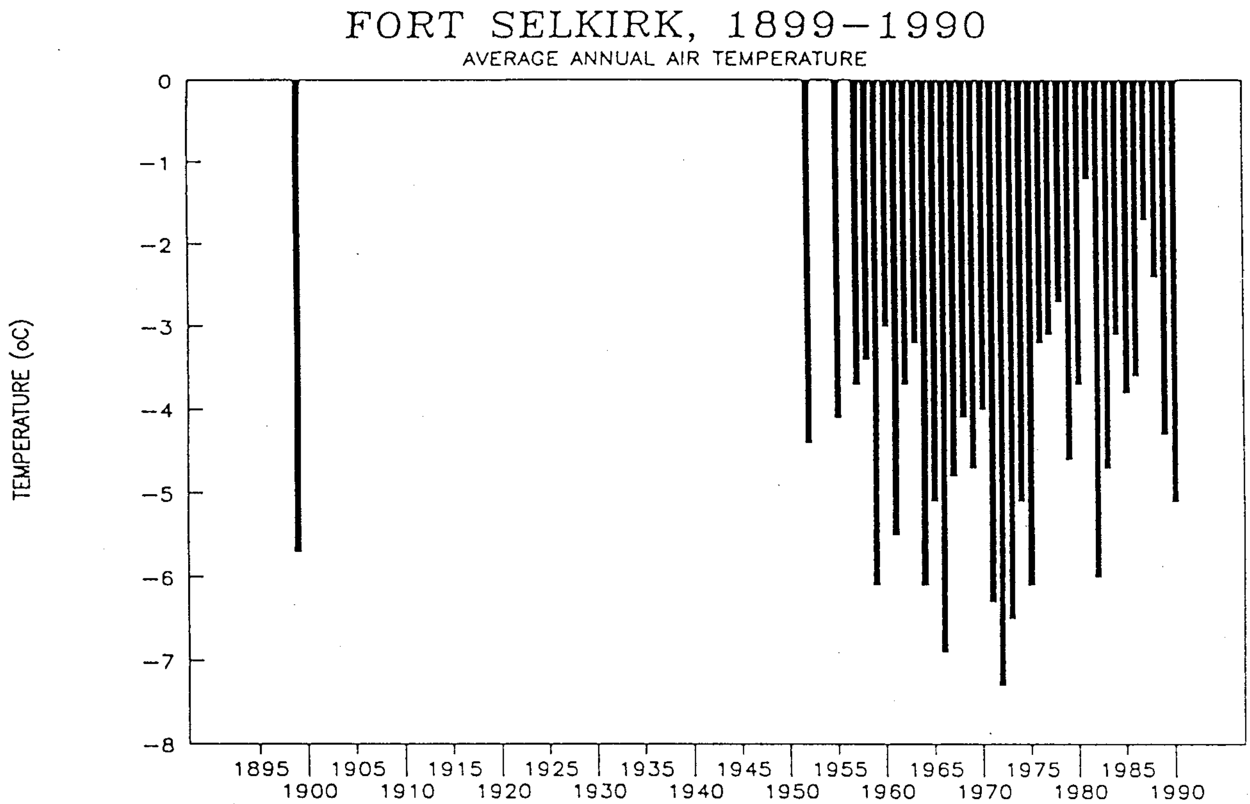


FIGURE 3.2.2 Seasonal variation in temperature at Carmacks and Fort Selkirk.



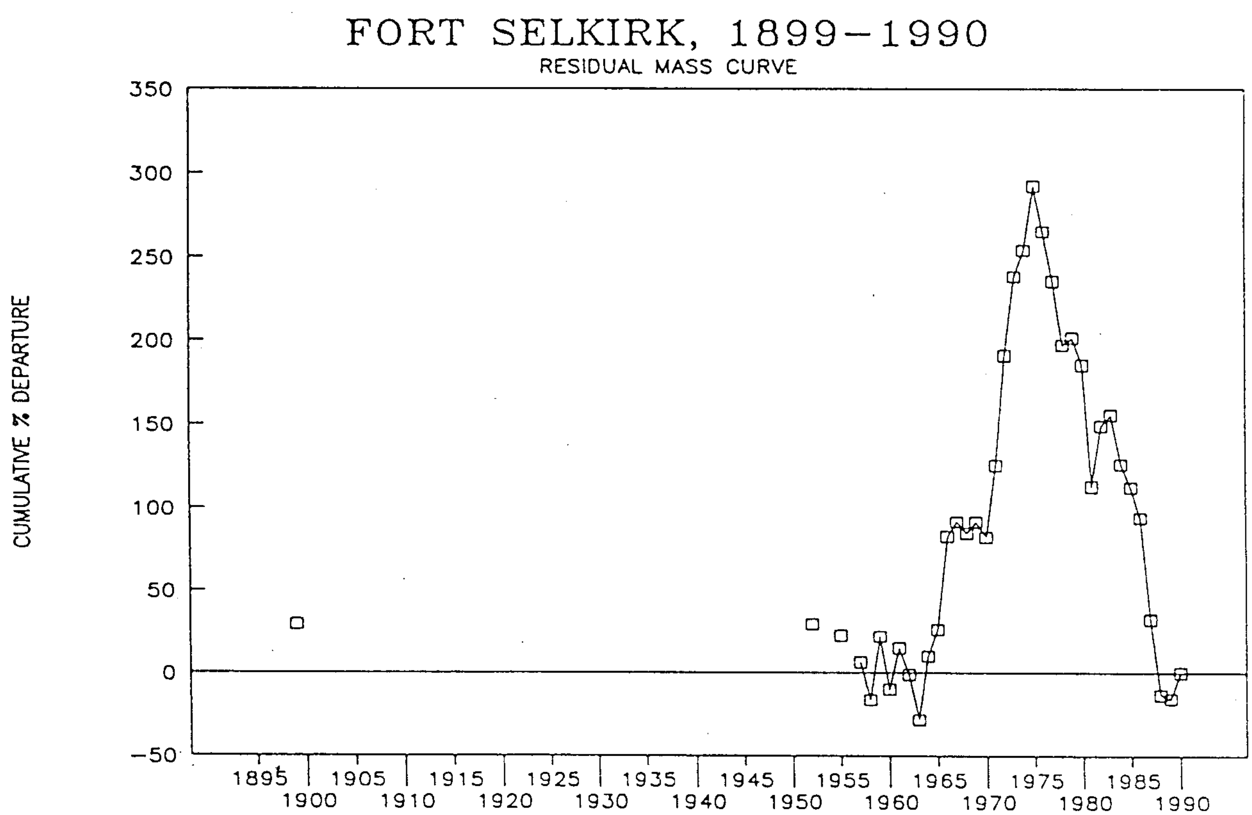


FIGURE 3.2.3 Historical variation in average annual air temperature, Carmacks and Fort Selkirk.

A: CARMACKS

MONTH	EXTREME MINIMUM TEMP (oC)	MEAN MONTHLY MINIMUM (oC)	MEAN MONTHLY TEMP (oC)	MEAN MONTHLY MAXIMUM (oC)	EXTREME MAXIMUM TEMP (oC)
JAN	-58.9	-33.9	-28.5	-23.1	10.0
FEB	-60.0	-29.3	-21.9	-14.5	12.2
MAR	-50.0	-21.7	-12.4	-3.1	12.8
APR	-38.3	-7.7	-0.3	7	23.3
MAY	-12.2	0.2	7.5	14.7	32.5
JUN	-3.5	5.3	12.9	20.5	35.0
JUL	-2.8	7.7	15.0	22.3	32.5
AUG	-7.0	5.0	12.4	19.8	33.0
SEP	-20.0	-0.3	6.4	13.1	25.6
OCT	-37.0	-7.7	-2.8	2.1	20.0
NOV	-51.0	-21.1	-16.2	-11.5	14.0
DEC	-56.7	-30.8	-25.7	-20.5	12.8

B: PELLY RANCH/FORT SELKIRK

MONTH	EXTREME MINIMUM TEMP (oC)	MEAN MONTHLY MINIMUM (oC)	MEAN MONTHLY TEMP (oC)	MEAN MONTHLY MAXIMUM (oC)	EXTREME MAXIMUM TEMP (oC)
JAN	-57.8	-31.2	-27.3	-21.3	6.0
FEB	-57.2	-25	-19.1	-12.2	12.8
MAR	-50	-17.9	-10.1	-1.5	14.4
APR	-32	-6.6	0.3	7.4	23.3
MAY	-12.2	-0.1	7.3	14.7	35.0
JUN	-3.9	5.3	13.0	20.3	35.0
JUL	-1.1	7.7	15.1	22.2	31.7
AUG	-5	5.2	12.6	19.8	31.1
SEP	-16.5	0.3	3.9	13.4	26.7
OCT	-32.5	-6.1	-1.8	2.9	18.3
NOV	-46.7	-18.2	-14.7	-10.4	12.8
DEC	-54.4	-27.9	-24.4	-19.5	5.6

NOTE: Data from AES computer files for the period up to 1990

TABLE 3.2.5 Seasonal variation in temperature at Carmacks and Fort Selkirk.

annual air temperature regime has occurred at Fort Selkirk over the period of record. Without further regional analyses it is not known if a similar pattern occurs in other areas of the Central Yukon Basin or if this trend results from the amalgamation of data from Pelly Ranch and Fort Selkirk.

3.2.4 Ground Temperature

The average annual temperature at Carmacks and Fort Selkirk is -3.8 and -4.4°C, respectively. On the basis of the criterion presented in Brown (1967), the mean annual ground temperature (at the depth of zero annual amplitude) should be approximately 3.3°C warmer or -0.5 to -1.1°C. Continuous permafrost is associated with mean annual ground temperatures of -5°C or colder and thus only discontinuous or scattered permafrost is therefore expected.

The regional variation in mean annual air temperature as a function of elevation is shown on Figure 2.3.4 on the basis of the data compiled on Table 2.3.6. This analysis indicates that there is a poor regional correlation between mean annual air temperature and elevation, likely reflecting varying periods of record, winter inversions and cold air drainage down valley bottoms. In general, air temperature is expected to decrease by approximately 1°C per 100 m increase in elevation and therefore a mean annual air temperature of -8.3°C (corresponding to a ground temperature of -5°C) is roughly estimated to occur at an elevation of approximately 900 to 1,000 m. Thus conditions suitable for continuous permafrost

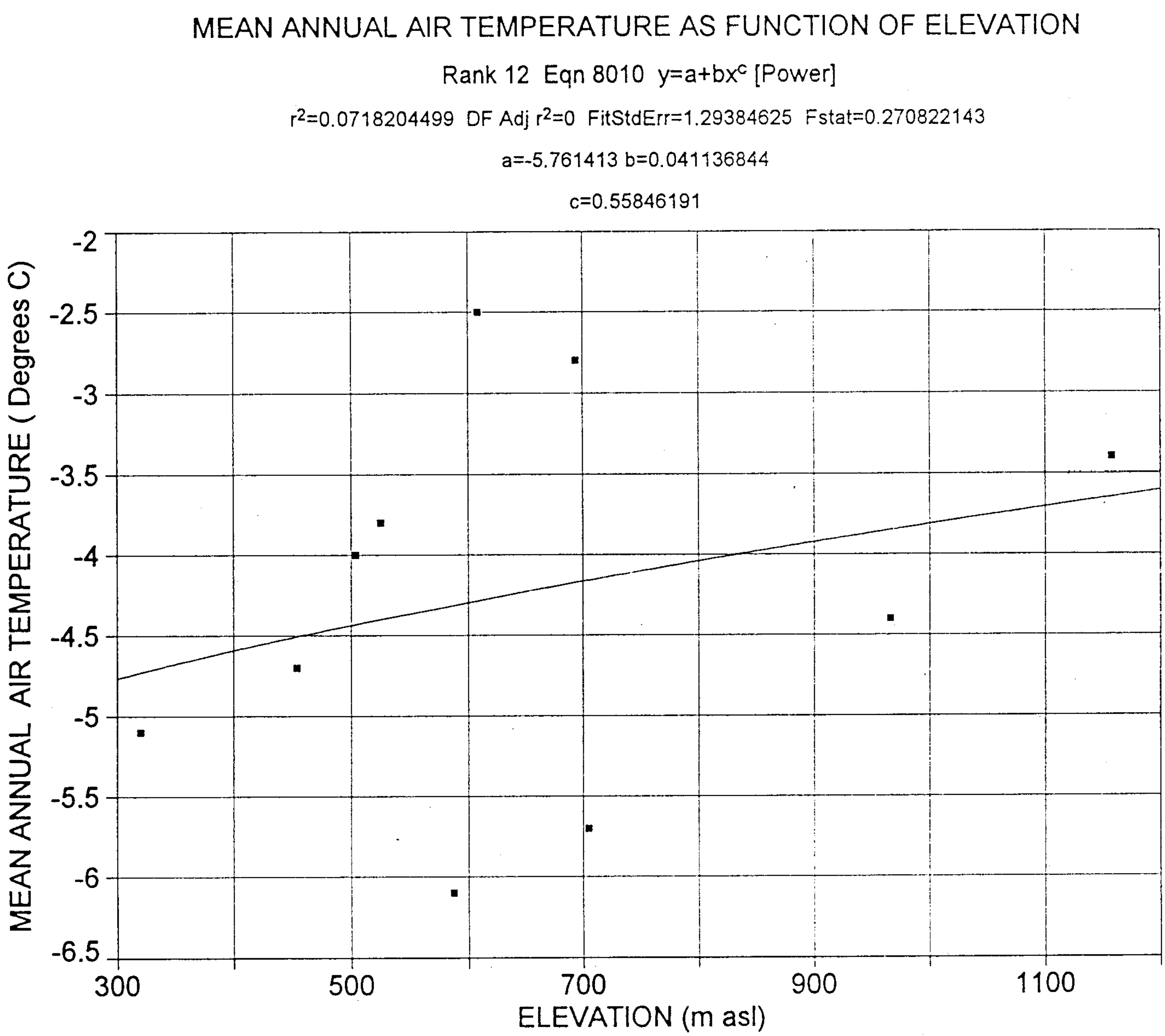


FIGURE 3.2.4 Mean annual air temperature as a function of elevation.

AES STATION NUMBER	AES STATION NAME	ELEVATION (m)	PERIOD OF RECORD	MEAN ANNUAL AIR TEMP (oC)	MEAN ANNUAL PRECIPITATION (mm)
2100100	AISHIHIK A	966	1943-66	-4.4	256.3
2100J00	AISHIHIK LAKE UPPER	1,160	1976-		
2100120	ANVIL	1,158	1967-	-3.4	367.7
2100300	CARMACKS	525	1984-	-3.8	254.3
2100302	CARMACKS TOWER	1,234	1964-76		
2100400	DAWSON	320	1897-79	-5.1	306.1
2100402	DAWSON AIRPORT	369	1976-		
2100460	DRURY CREEK	609	1970-	-2.5	394.4
2100516	FARO	694	1971-77	-2.8	287.7
2100517	FARO A	712	1977-		
2100880	FORT SELKIRK/PELLY RANCH	454	1898-	-4.7	286.4
2100700	MAYO A	504	1924-	-4.0	306.3
2101030	STEWART CROSSING	480	1963-		
2100940	ROSS RIVER A	705	1961-	-5.7	263.5
2100948	SHELDON LAKE	884	1970-		
2101000	SNAG A	587	1943-66	-6.1	338.5

NOTE: Data from Atmospheric Environment Service 1982A and 1982B

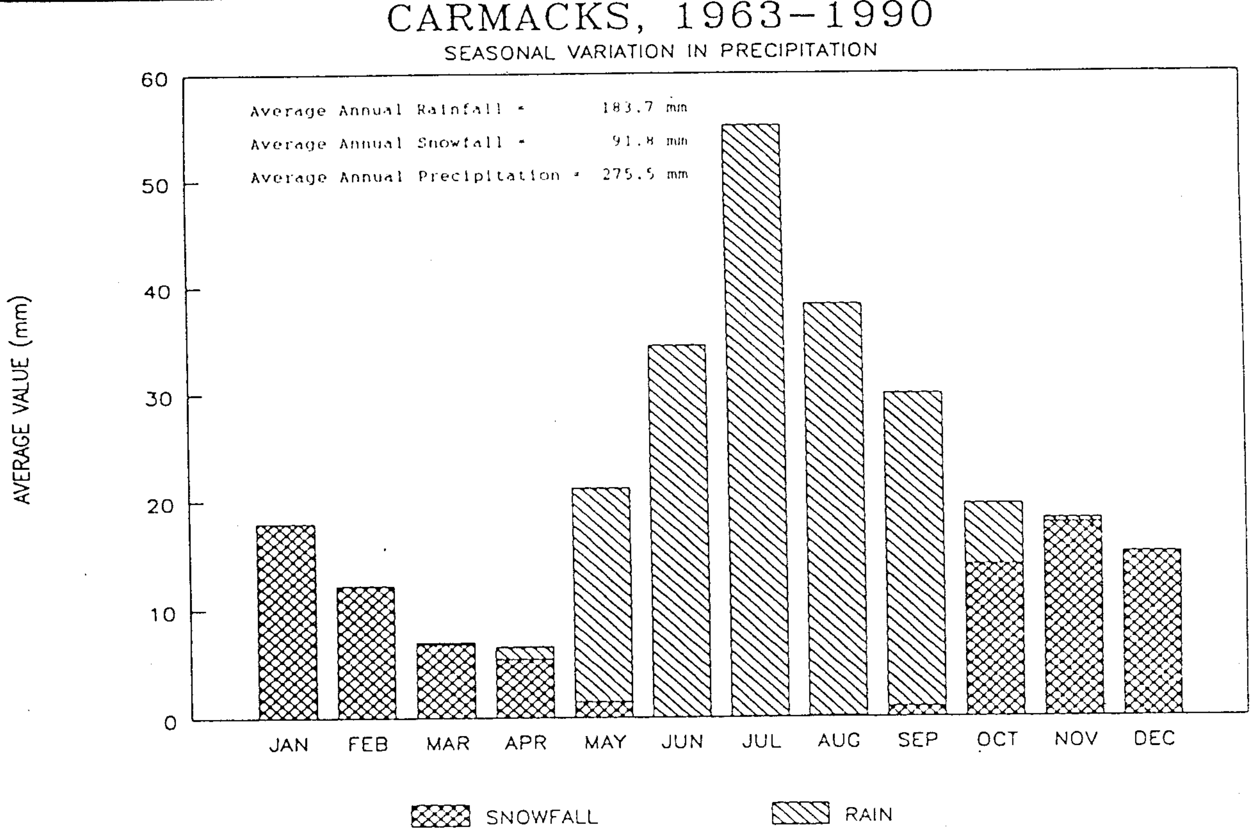
TABLE 3.2.6 Compilation of regional mean annual air temperature and mean annual precipitation data.

occurrence are predicted to occur only in the extreme upper elevations of the Williams Creek watershed. Historical variation in air temperatures, uncertainties in the relationship between air temperature and elevation and effects of varying ground cover will all however affect local ground temperatures. If required, the actual distribution of permafrost in the vicinity of the mine site infrastructure should therefore be confirmed by on-site measurements.

3.2.5 Precipitation

The seasonal variation in rainfall at Carmacks and Fort Selkirk is shown on Figure 3.2.5. Data summaries are shown on Table 3.2.7. This analysis indicates that approximately 60 to 65 per cent of the annual precipitation total (170 to 179 mm) occurs as rainfall in the period between May and September. The maximum monthly rainfall total typically occurs in July and, on average, is approximately 50 to 55 mm. The seasonal variation in the number of days per month with observed rainfall or snowfall is shown on Figure 3.2.6 and indicates that the greatest frequency of precipitation (11 to 14 days/month) occurs in June, July and August. Minimum values of 3 to 6 days per month occur in March and April.

The historical variation in annual precipitation at Fort Selkirk is shown on Figure 3.2.7. These data indicate that values have historically ranged between 219 and 370 mm with an average of 295.5 mm. There is no statistically-significant trend or shift in



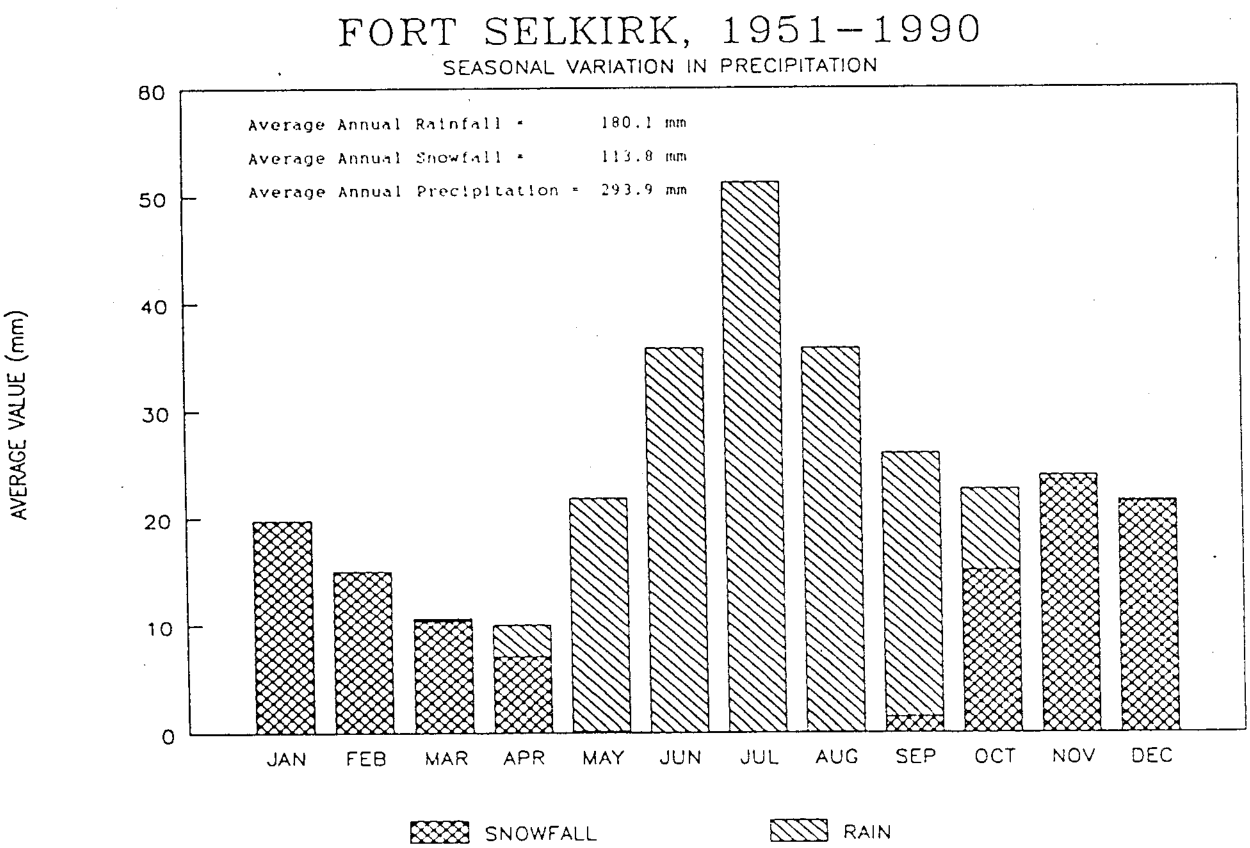
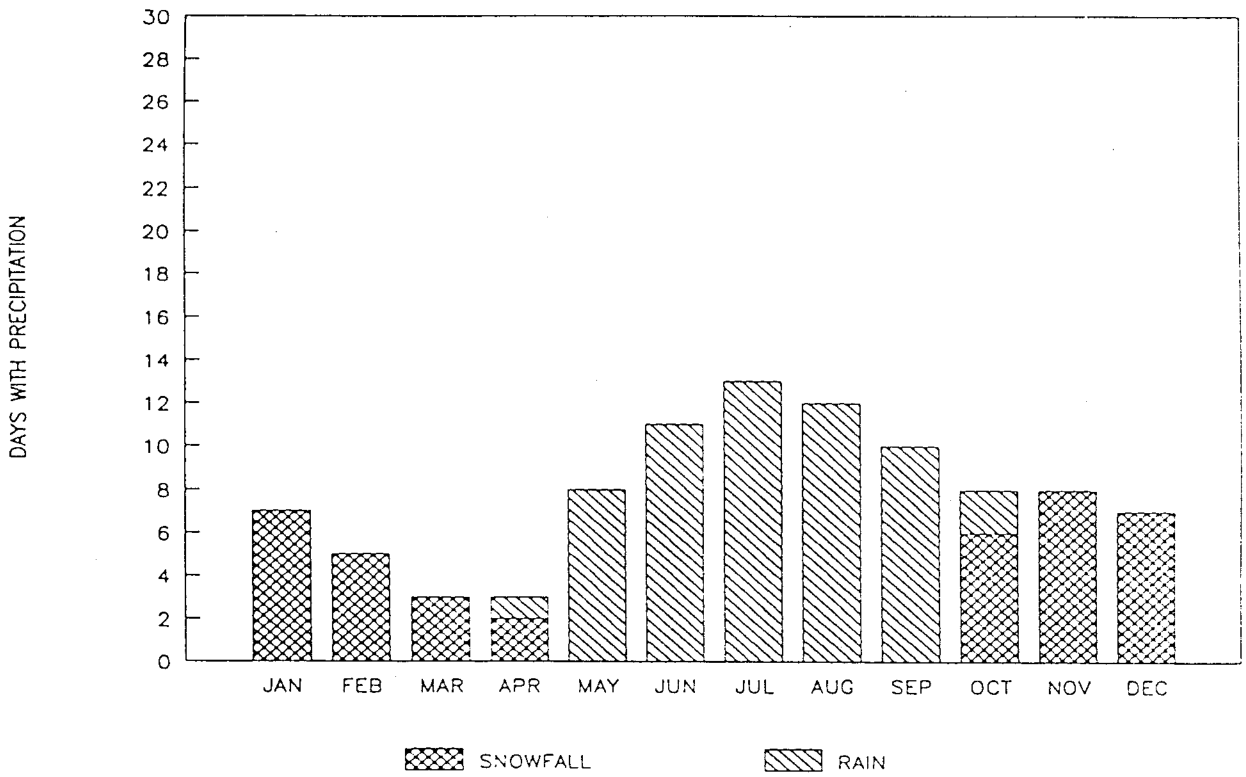


FIGURE 3.2.5 Seasonal variation in precipitation at Carmacks and Fort Selkirk air temperature as a function of elevation.



FORT SELKIRK, 1898–1990

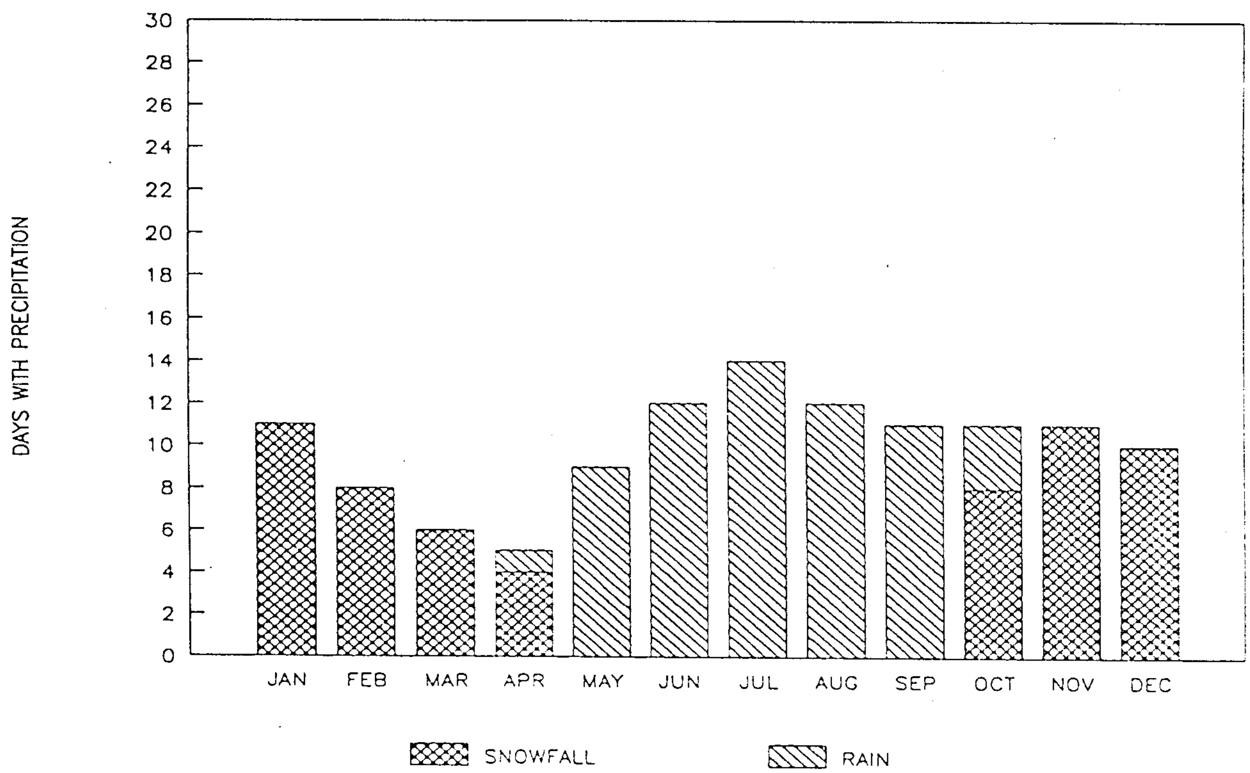


FIGURE 3.2.6 Seasonal variation in number of days with rainfall or snowfall at Carmacks and Fort Selkirk.

A: CARMACKS

MONTH	TOTAL RAINFALL (mm)	TOTAL SNOWFALL (mm)	TOTAL PRECIPITATION (mm)
JAN	0.0	17.9	17.9
FEB	0.0	12.2	12.2
MAR	0.2	6.8	7.0
APR	1.1	5.4	6.5
MAY	19.7	1.5	21.2
JUN	34.5	0.0	34.5
JUL	55.1	0.0	55.1
AUG	38.2	0.1	38.3
SEP	28.9	1.0	29.9
OCT	5.6	14.0	19.6
NOV	0.4	17.8	18.2
DEC	0.0	15.1	15.1
TOTAL	183.7	91.8	275.5

B: FORT SELKIRK

MONTH	TOTAL RAINFALL (mm)	TOTAL SNOWFALL (mm)	TOTAL PRECIPITATION (mm)
JAN	0.0	19.8	19.8
FEB	0.0	15.0	15.0
MAR	0.2	10.4	10.6
APR	3.0	7.0	10.0
MAY	21.6	0.2	21.8
JUN	35.7	0.0	35.7
JUL	51.2	0.0	51.2
AUG	35.7	0.0	35.7
SEP	24.6	1.4	26.0
OCT	7.5	15.1	22.6
NOV	0.5	23.4	23.9
DEC	0.1	21.5	21.6
TOTAL	180.1	113.8	293.9

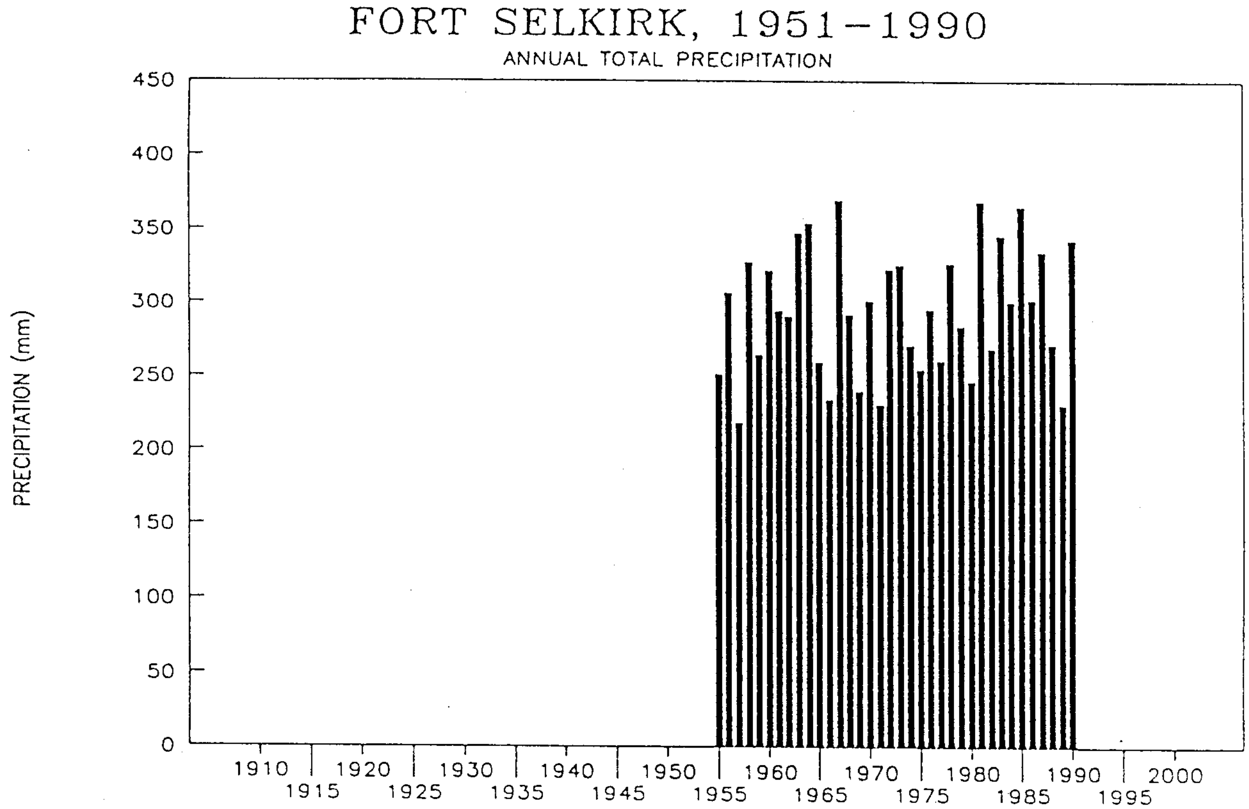
Data from AES computer listing for period of record up to 1990

TABLE 3.2.7 Seasonal variation in precipitation at Carmacks and Fort Selkirk

regime over the period of record.

The regional relationship between average annual precipitation and elevation is shown on Figure 3.2.8. This analysis, which indicates that there is a poor correlation between elevation and annual precipitation, suggests that precipitation in the headwaters of Williams Creek may be on the order of 5 per cent greater than that observed at lower elevation sites, such as Carmacks and Fort Selkirk. Comparison of June, July and August, 1992 data from Williams Creek and Carmacks (Tables 3.2.2 to 3.2.5) suggest that differences during these summer months might be as large as 260 per cent (based on seasonal totals of 295.3 vs. 114.6 mm). However additional (verified) data are required in order to confirm this preliminary result.

The seasonal variation in maximum 24-hour rainfall and total precipitation at Carmacks and Fort Selkirk is shown on Figure 3.2.9. This analysis indicates that maximum rates of 24-hour precipitation occur as rainfall events in June or July. Maximum observed rates of 24-hour rainfall (32 to 36 mm) are however relatively modest. A frequency analysis of short-duration rainfall data from Pelly Ranch is shown on Figure 2.3.10. This information provides a basis to estimate precipitation-derived streamflows for specific return periods (Section 2.4.5).



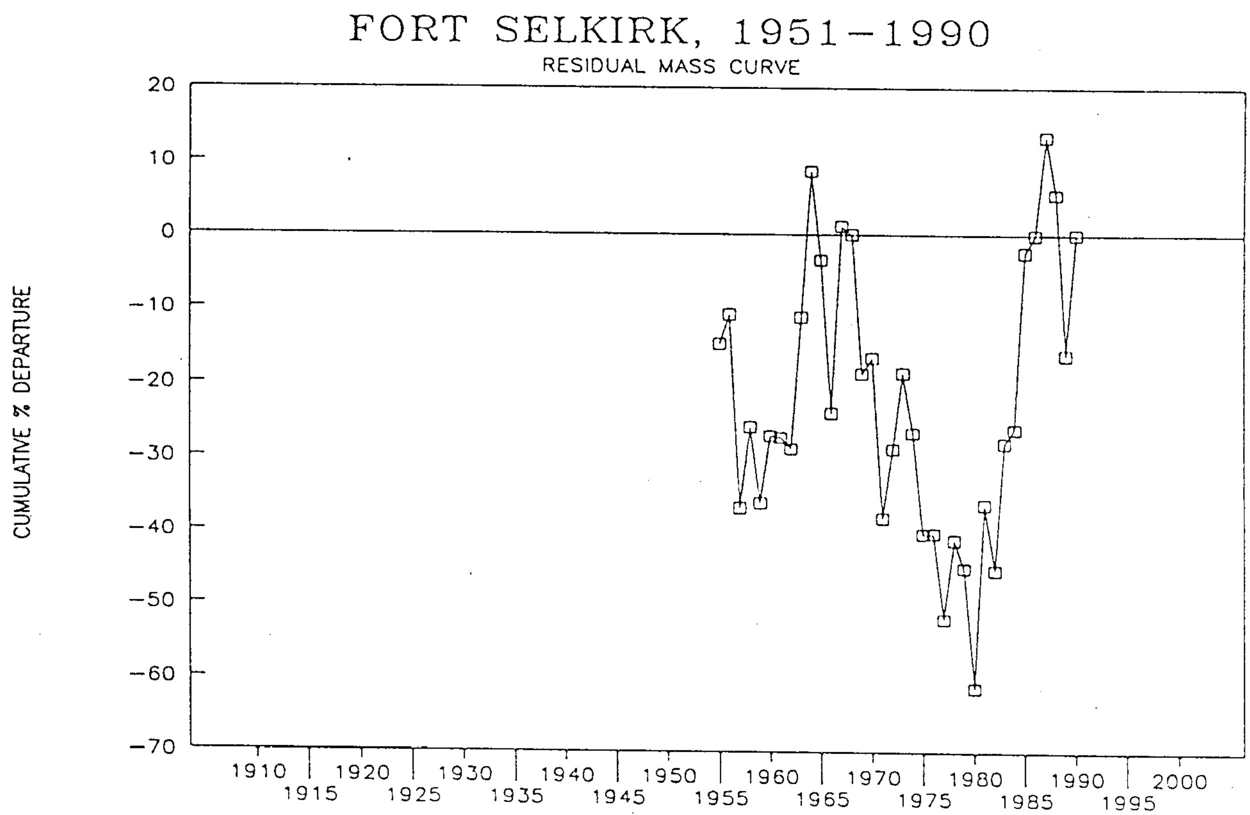


FIGURE 3.2.7 Historical variation in annual total precipitation at Carmacks and Fort Selkirk.

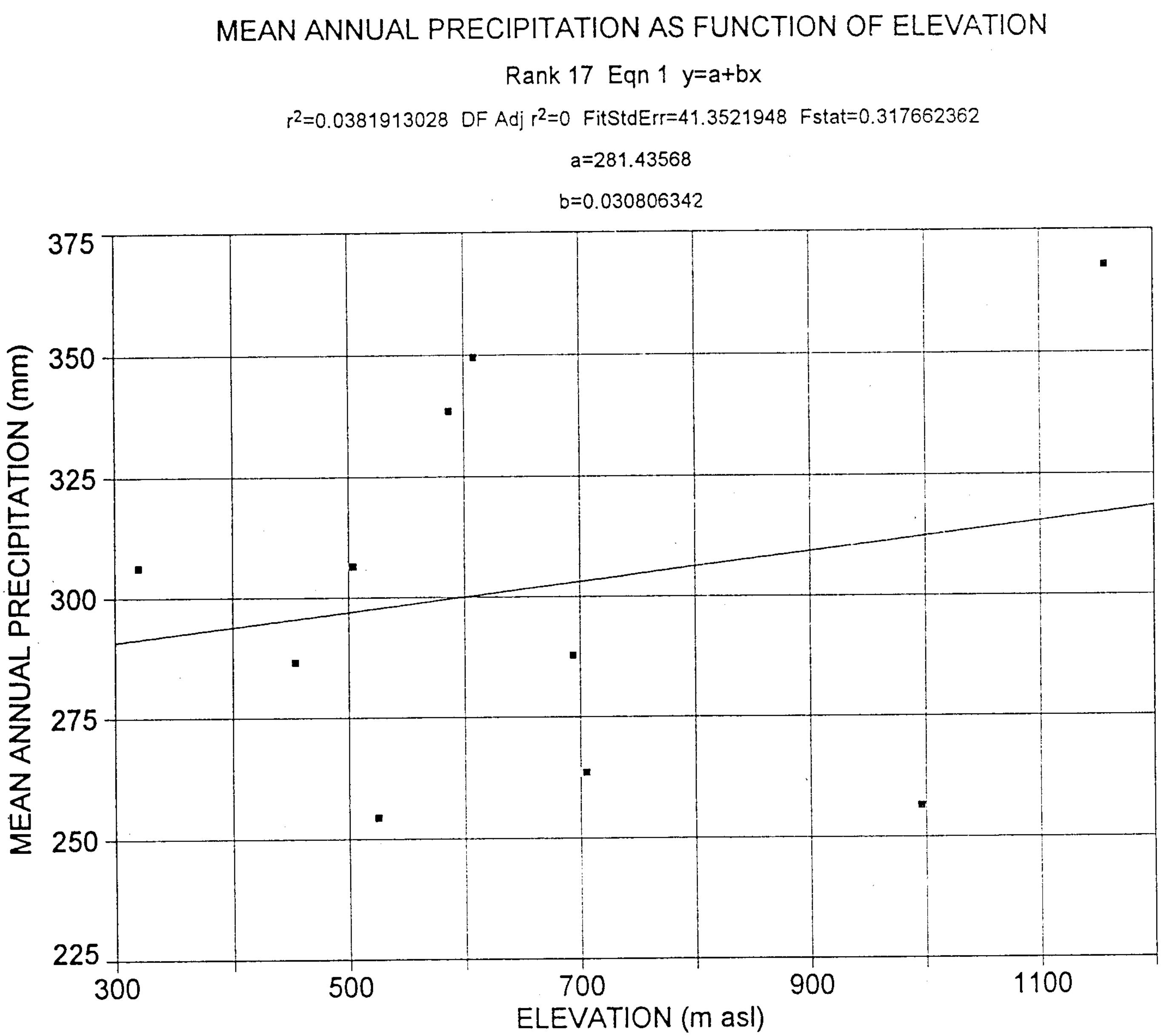
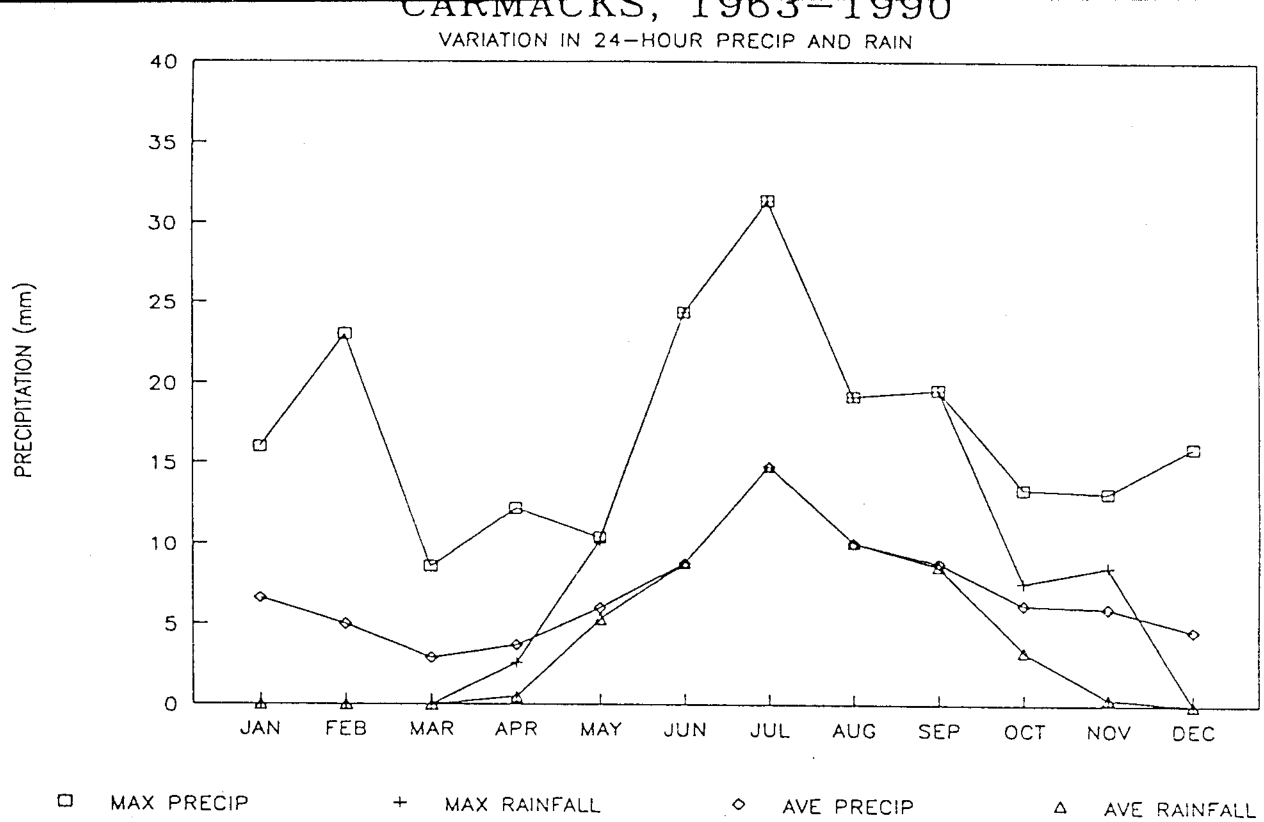


FIGURE 3.2.8 Mean annual precipitation as a function of elevation.



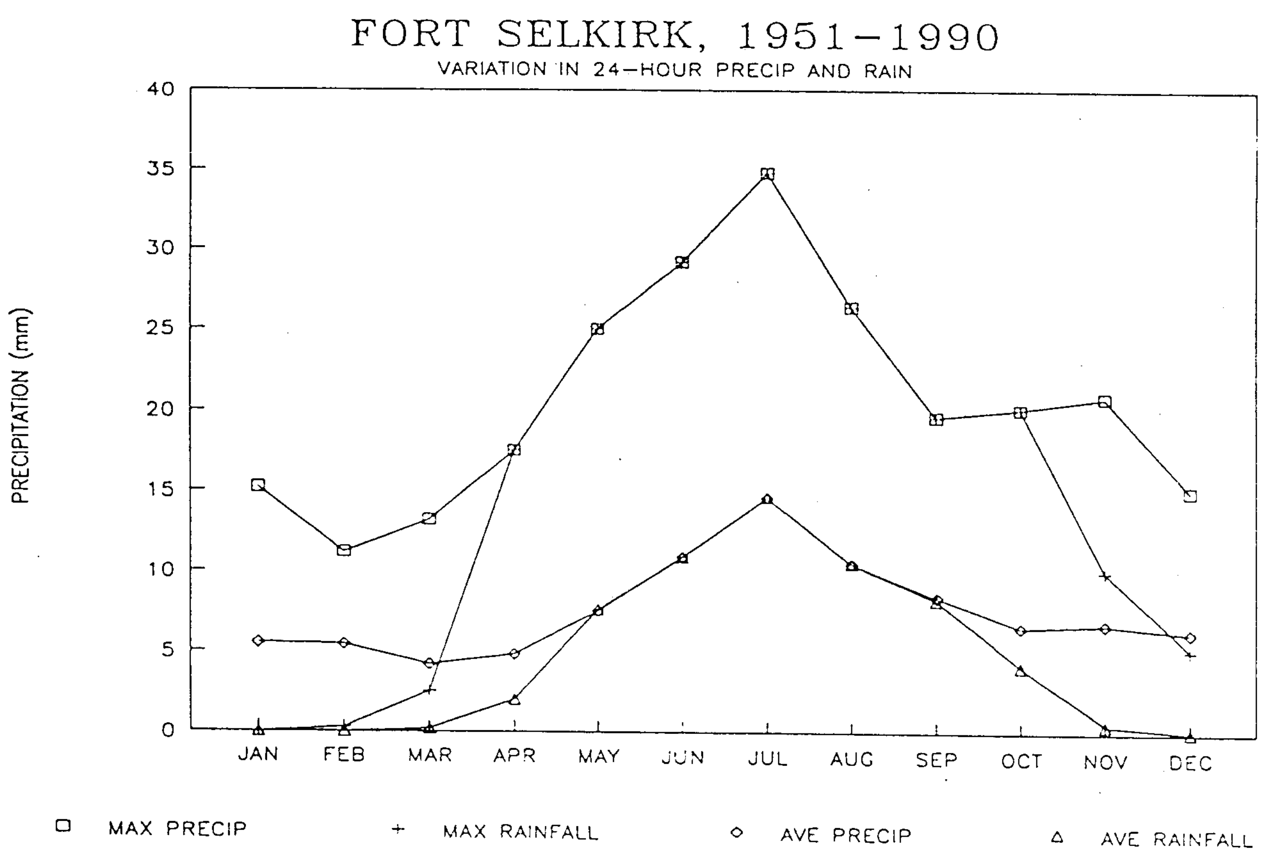


FIGURE 3.2.9 Seasonal variation in 24-hour rainfall and precipitation at Carmacks and Fort Selkirk.

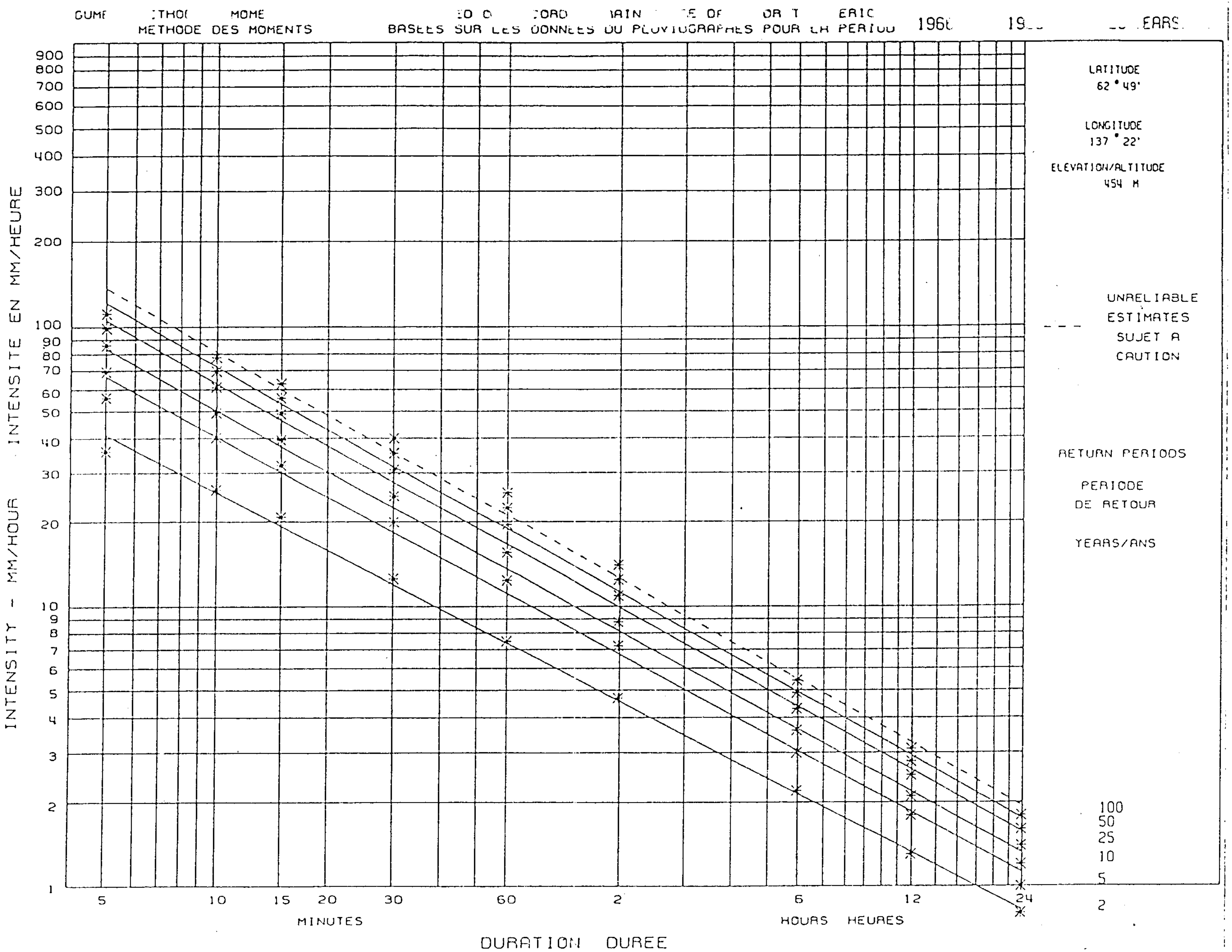


FIGURE 3.2.10 Short-duration rainfall-intensity-duration frequency analysis for Pelly Ranch (Fort Selkirk).

3.2.6 Snow Cover

Western Copper Holdings Ltd., operated three snow course sites in Williams Creek during the period between January 31 and May 16, 1992 (Figure 3.2.11). As described in the report by J. Gibson and Associates (1992), each site consisted of 5 stations located 20 m apart. Measurement techniques are described as being "identical to those used by Water Resources N.A.P. and the Surface Water Section of the British Columbia Ministry of Environment." [2] (J. Gibson and Associates Ltd. 1992 - page 4). The results of the snow survey measurements are summarized on Table 3.2.8, along with data from nearby snow survey sites operated by Indian and Northern Affairs, Canada. Statistical analyses (reported in Gibson, 1992) indicate that the Williams Creek data is best correlated to that from Mount Nansen. Graphs showing the best fit linear regression line (along with 95 % prediction confidence limits) between the 1992 Mount Nansen data and snow water equivalents observed at the three Williams Creek sites are presented on Figures 3.2.12 to 3.2.14. These analyses indicate that the three Williams Creek sites receive more snow than Mount Nansen. The potential annual variation in snow depths at the three Williams Creek snow course sites is summarized on Table 3.2.9 on the basis of the observed snow depths at Mount Nansen and the developed regression equations.

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[2] see B.C. Ministry of Environment, 1977.

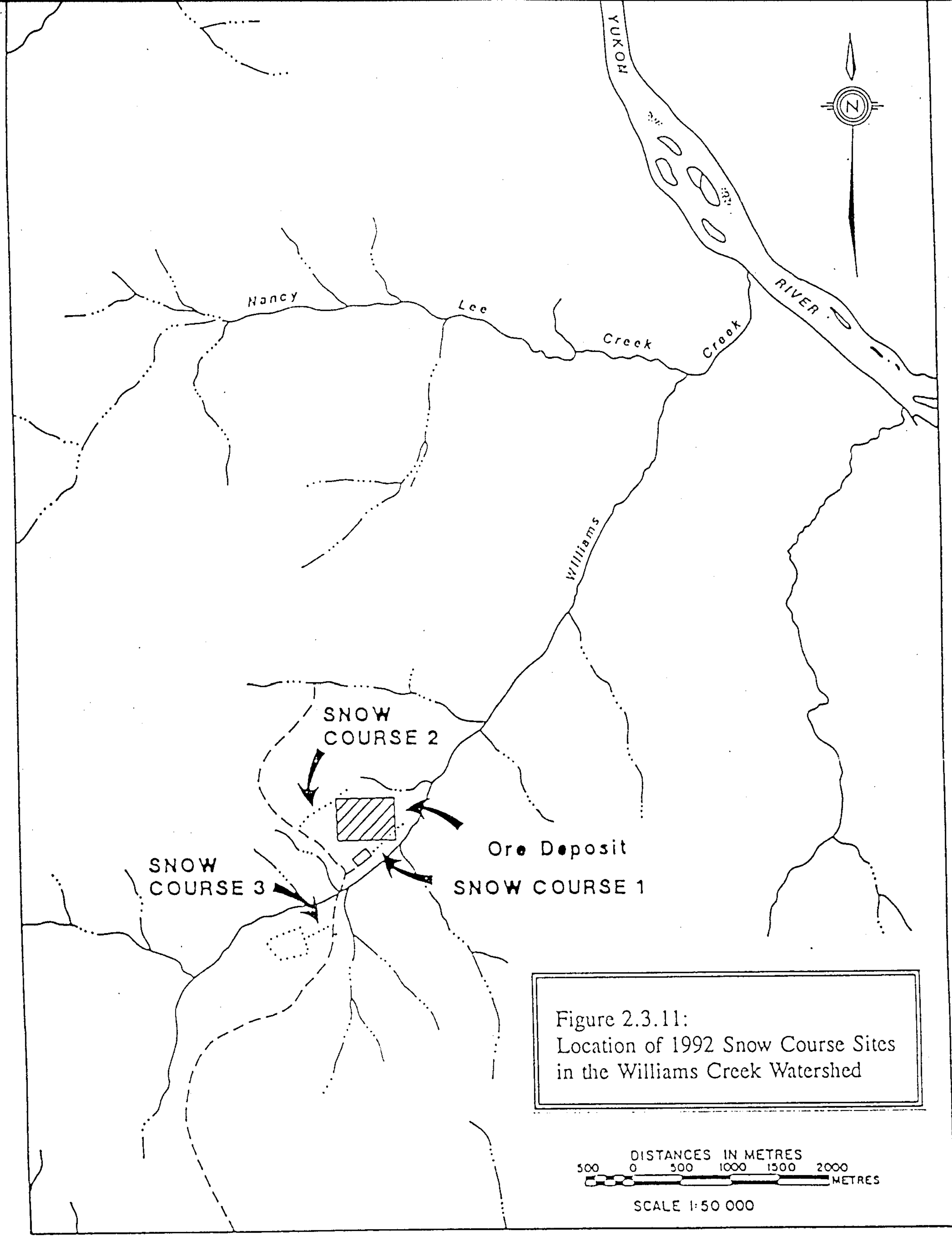

FIGURE 3.2.11 Location of 1992 snow course sites in the Williams Creek watershed.

DATE	SNOW COURSE	SNOW DEPTH (cm)	WATER EQUIV. (mm)	HISTORICAL AVERAGE WATER EQUIV. (mm)	YEARS OF RECORD
92-01-31	Williams #1	69.8	128	-	-
	Williams #2	73.6	164	-	-
	Williams #3	72.0	130	-	-
92-03-02	Mt. Nansen	54	92 E	68	16
	Mt. Berdoe	76	165	91	17
	Casino Cr.	67	124	98	17
	MacIntosh	69	138	79	16
	Williams #1	60	104	-	-
	Williams #2	69	110	-	-
	Williams #3	70	150	-	-
92-03-30	Mt. Nansen	60	102	74	16
	Mt. Berdoe	72	132	106	16
	Casino Cr.	70	135	121	15
	MacIntosh	73	111	97	16
	Williams #1	70	120	-	-
	Williams #2	73	130	-	-
	Williams #3	74	132	-	-
92-04-30	Mt. Nansen	25	68	13	15
	Mt. Berdoe	50	126 E	58	16
	Casino Cr.	83	207	118	15
	MacIntosh	53	121	56	16
	Williams #1	22	84	-	-
	Williams #2	36	129	-	-
	Williams #3	36	103	-	-
92-05-14	Mt. Nansen	0	68	0	16
	Mt. Berdoe	38	126	15	16
	Casino Cr.	83	207	69	11
	MacIntosh	39	121	12	16
	Williams #1	0	84	-	-
	Williams #2	11	129	-	-
	Williams #3	9	103	-	-

E = Estimated

TABLE 3.2.8 Snow survey data for Williams Creek and Carmacks Regional Snow Courses. Period March 1 to May 16, 1992 (after Gibson, 1992).

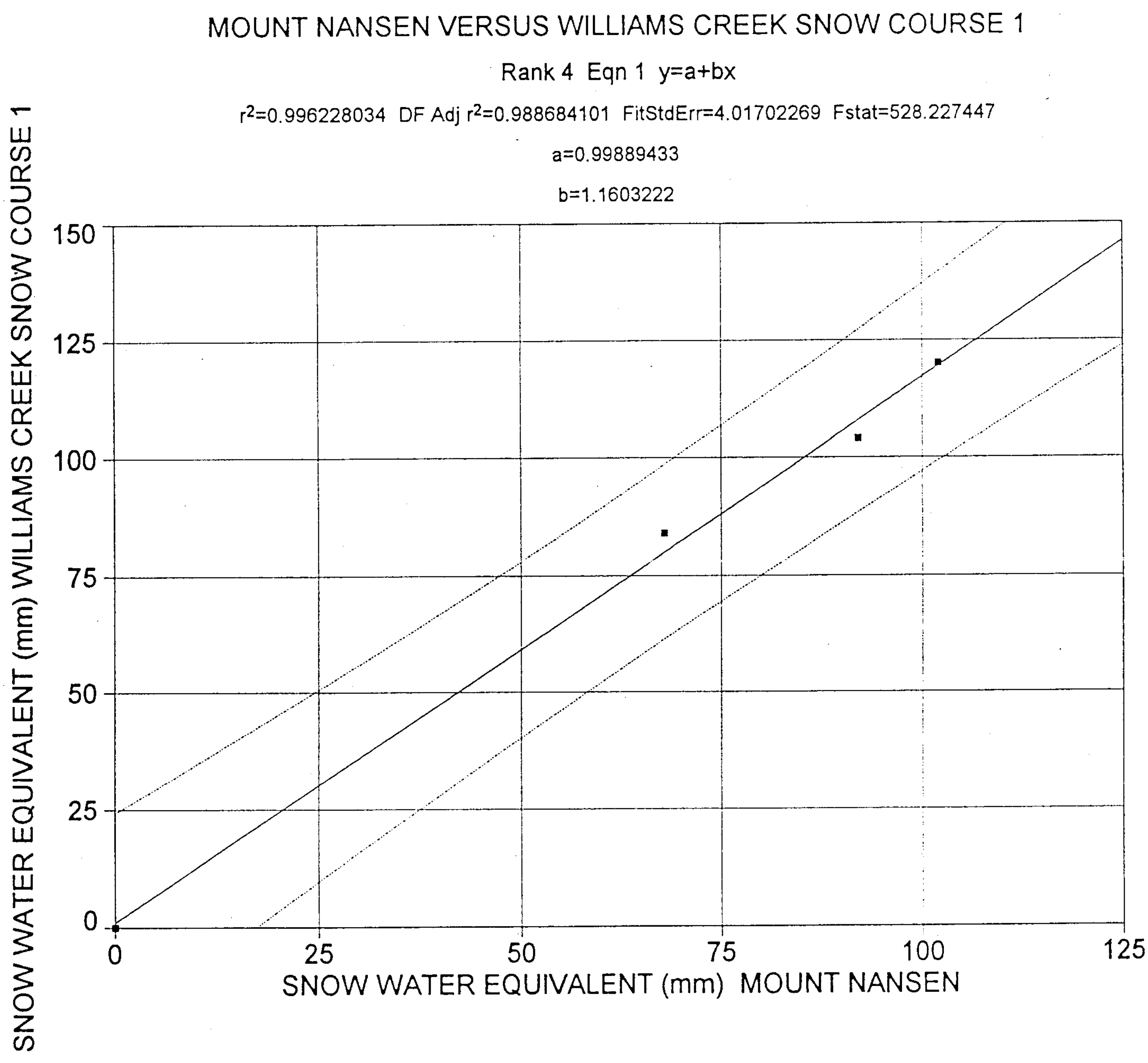

FIGURE 3.2.12 Relationship between snow cover at Williams Creek Snow Course 1 and Mount Nansen.

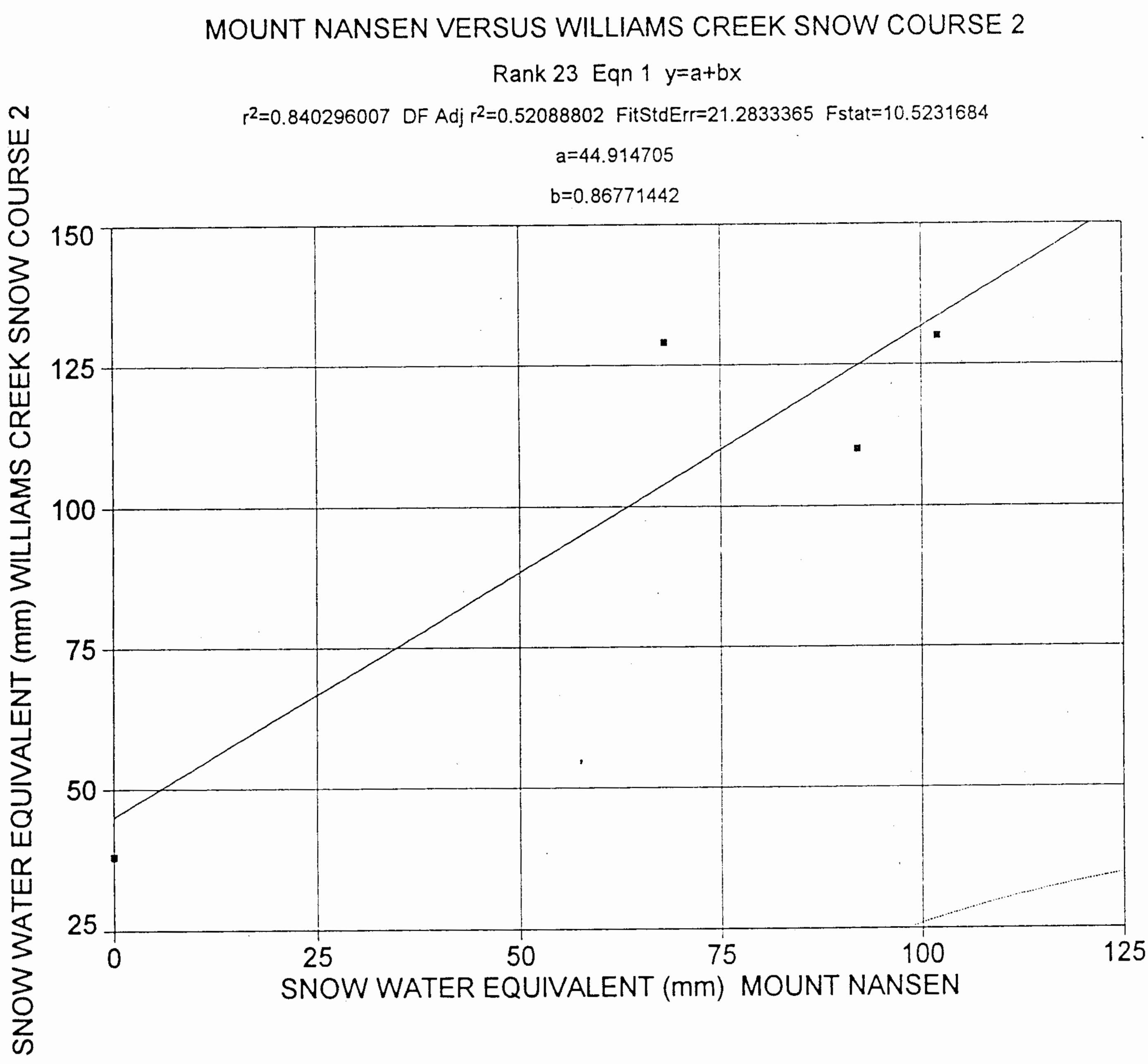

FIGURE 3.2.13 Relationship between snow cover at Williams Creek Snow Course 2 and Mount Nansen.

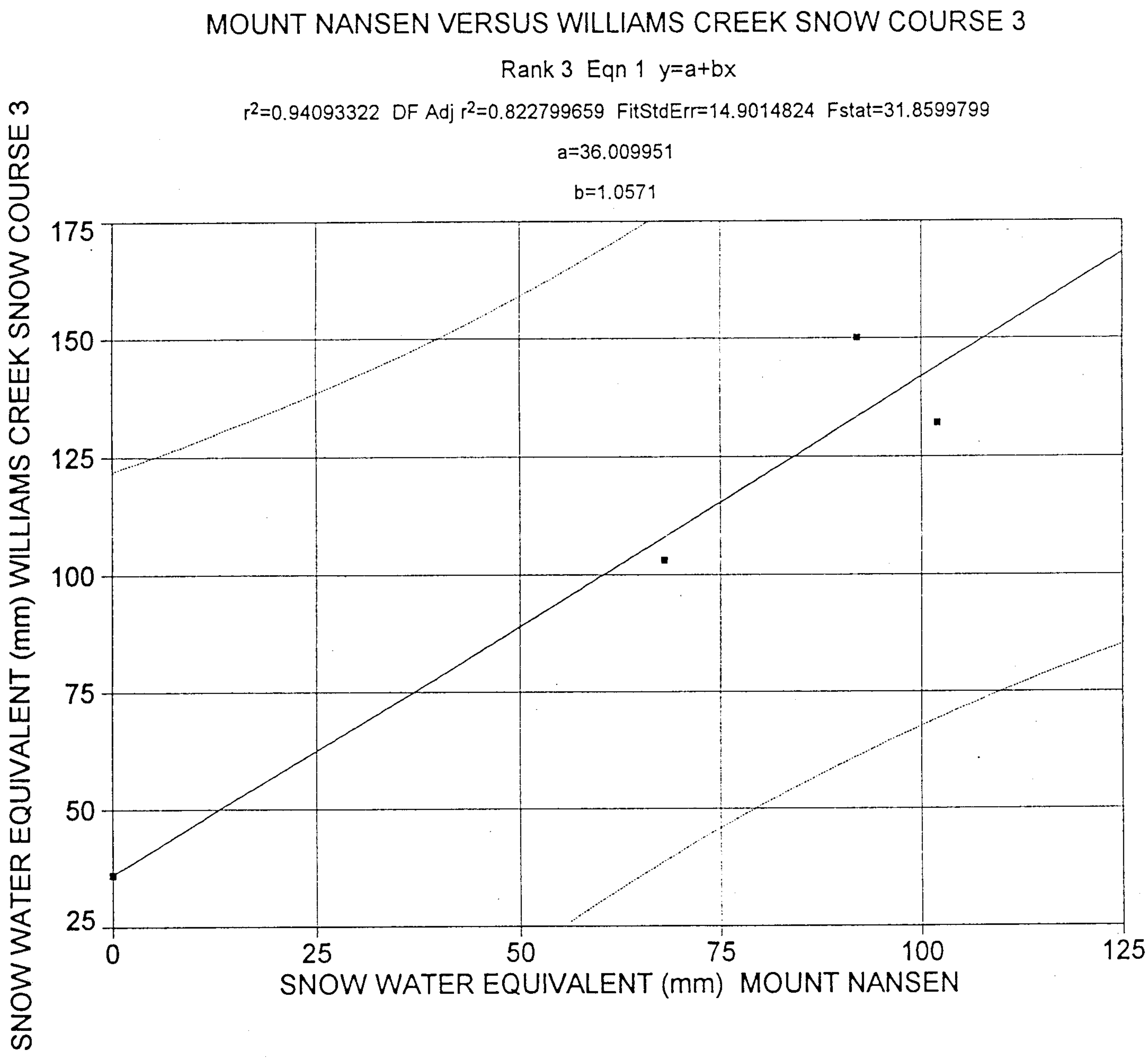

FIGURE 3.2.14 Relationship between snow cover at Williams Creek Snow Course 3 and Mount Nansen.

DATE	YEARS OF RECORD	SNOW WATER EQUIVALENT (mm)											
		MT. NANSEN			WILLIAMS CREEK								
					SITE 1			SITE 2			SITE 3		
		MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN
Feb 01	10	74	52	36	87	61	43	109	90	76	114	91	74
Mar 01	16	126	68	28	147	80	33	154	104	69	169	108	66
Apr 01	15	104	72	51	122	85	60	135	107	89	146	112	90
May 01	14	102	14	0	119	17	1	133	57	45	144	51	36
May 15	15	0	0	0	1	1	1	45	45	45	36	36	36

TABLE 3.2.9 Preliminary estimates of the seasonal variation in snow cover at the Williams Creek snow survey sites, predicted on the basis of data from Mt. Nansen.

3.2.7 Evapotranspiration and Water Balance

Potential lake evaporation and evapotranspiration has been estimated from climatological data using the Priestley and Taylor (1972) approach following the methodology of Davis (no date) The input parameters and results are summarized on Table 3.2.10. This analysis indicates that little or no evaporation or evapotranspiration will occur in the period between October and March. Potential evapotranspiration is calculated to exceed 95 mm/month in both June and July, however actual values will depend upon both water availability and vegetation characteristics. Potential lake evaporation values reach values of approximately 130 mm/month in June and July. Comparison of calculated potential lake evaporation and evapotranspiration values with observed precipitation values at Carmacks and Fort Selkirk suggest that a net water deficit could occur throughout the April to August period. Storage and melt of the winter snow cover will however reduce this potential deficit. Installation and operation of an evaporation pan is recommended if water balance consideration are an important component in the design of settling ponds or other mine infrastructure.

PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	DATA SOURCE
OBSERVED SUNSHINE (hrs)	7.0	90.0	171.7	230.4	270.4	278.2	270.2	239.4	142.4	77.8	15.9	7.7	1,801	AES 1982C. Normals for Pelly Ranch
DAYLIGHT HOURS	193.0	246.5	362.7	442.5	547.3	586.1	579.4	495.6	391.3	311.3	215.2	166.1	4,537	Russelo, Edey and Godfrey, 1974. Latitude 62°N
SOLAR RADIATION $MJ/m^2/month$	78.5	209.4	506.2	819.5	1,144.2	1,252.9	1,224.7	972.0	622.3	337.2	119.7	44.9	7,332	Russelo, Edey and Godfrey, 1974. Latitude 62°N
MEAN AIR TEMPERATURE (°C)	-28.0	-20.0	-11.0	0.0	7.5	13.0	15.0	12.5	5.0	-2.0	-15.5	-25.0	-49	Average Carmacks and Fort Selkirk. Table 2.3.2 this report
GROUND HEAT FLUX $MJ/m^2/month$	0	0	0	0	0	0	0	0	0	0	0	0	0	Assumed
ET mm/month	0	0	0	27.0	70.4	95.1	96.3	62.5	14.0	0	0	0	365	Calculated
LAKE EVAPORATION (mm/month)	0	0	4.2	42.9	98.3	129.4	131.1	89.1	25.9	0	0	0	521	Calculated
AVERAGE PRECIPITATION (mm/month)	18.9	13.6	8.8	8.3	21.5	35.1	53.2	37.0	28.0	21.1	21.1	18.4	285	Average Carmacks and Fort Selkirk. Table 2.3.3 this report
WATER BALANCE • ET (mm)	18.9	13.6	8.8	-18.8	-48.9	-60.0	-43.2	-25.5	14	21.1	21.1	18.4	-81	Calculated
• Lake (mm)	18.9	13.6	4.6	-34.6	-76.8	-94.3	-78.0	-52.1	2.1	21.1	21.1	18.4	-236	Calculated

TABLE 3.2.10 Preliminary estimates of potential lake evaporation, evapotranspiration and water balance.

3.3 Wildlife Resources

3.3.1. Habitat Description

The Williams Creek watershed is at the western edge of the Pelly River ecosection of Oswald and Senyk (1977). They characterize this ecosection as follows:

> "Pelly River: (36 336 km^2) White and black spruce/shrub-moss common; black spruce bog in moist, cool lowlands, aspen (white spruce) or sagewort-grassland on warm, dry sites, lodgepole pine common, alpine fir sparse; treeline at 1350-1500 m; pptn low, temp moderately cold."

The Study Area varies in elevation from 480 m at the Yukon River to 975 m on ridgetops at the headwaters of Williams Creek. No alpine or subalpine habitats are present. Most of the area is gently rolling, except where Williams Creek is fairly deeply incised near its confluence with the Yukon River.

Soil moisture, aspect, and fire history result in a patchwork of vegetation types, including grassy south-facing slopes, aspen woods, upland lodgepole pine and white spruce forest, and low, wet sites supporting black spruce, willows, and ericaceous shrubs.

Although the winter climate is cold, it is also relatively dry, and maximum snow depth seldom exceeds 60 cm (Farnell et al. 1991). Wildlife habitat types in the Williams Creek watershed, and the various terrain units included in each, are listed in Table 3.3.1. The habitat types delineated on the wildlife habitat capability map (Appendix 2) are described below.

TABLE 3.3.1 Wildlife habitat types and associated terrain units for Williams Creek Yukon.

WILDLIFE HABITAT TYPE[1]	HABITAT SYMBOL	TERRAIN UNITS INCLUDED[2]
1. Yukon River Valley		
- Floodplain/Low terraces	Yf	F1; F5
- Valley Slope	Ys	F7; M2B; BF4R
2. Williams Creek Watershed		
2.1 Mesic to wet valley bottoms:		
- Willow-dominant	Ww	F5; 55/W2; M3/W2
- Spruce-dominant	Ws	F2/W3;F3/W3; F2; F2/F3; F5; M4; M4/M2
2.2 Upland Forest:		
- Aspen-dominant	Ua	BF4*; M1; M1F6; M5; M5/M2
- Conifer-dominant	Uc	M1B; M2; M2B.; F6; CM5
2.3 Open Slopes and Cliffs:		
- Steep grassy slopes	Sh	Bf4*
- Cliffs	Sc	Bf4*

* This terrain type consists partly of grassy slopes and partly of aspen dominated forest. Cliffs are within the grassy slope habitat unit.

1. See text for further description.
2. See Section 3.1 of this report for description of terrain units.

3.3.1.1 Yukon River Valley

a) Floodplain/low terraces (Yf).
This unit is the richest and most productive in the Study Area. This is because of low elevation, deep fine-textured soils, good moisture conditions, and periodic fluvial events which set back succession. The following habitat types were noted within this unit, and illustrate the diversity which is found there:

1) White Spruce-Willow-Rose stands. Willow is tall and dense; some Viburnum also present. This is mostly near the banks of the Yukon River.
2) Spruce-horsetail community. This is in rich, wet sites.
3) Willow-sedge wetlands. These are old oxbow channels that are no longer active.

b) Valley Slopes (Ys).

These are generally steep, northeast-facing slopes along the Yukon River, which support spruce forest. In places there are steep cliffs and herbaceous openings. This unit was not inspected on the ground.

3.3.1.2 Williams Creek Watershed

a) Willow-dominant Wetlands (Ww).

Low, wet areas, usually along Williams Creek, where willows are the dominant vegetation. Scattered black spruce is often present, and other shrubs like Labrador tea also occur. Sedges, horsetail, coltsfoot, and mosses are common understory plants.

b) Spruce-dominant Wetlands (Ws).

Level to gently sloping valley bottom sites, including Williams Creek and minor tributaries. Typical sites have moderately open black spruce stands, with scattered willow, mountain alder, Labrador tea, and shrubby cinquefoil. The hummocky ground supports crowberry, red bearberry, and mosses. Production of herbaceous plants is fairly low, but variable.

c) Aspen-dominant Uplands (Ua).

South-facing slopes and well-drained ridges with good soil cover. Aspen cover varies from sparse on south-facing slopes to dense on east and west-facing slopes. On poor sites with shallow soils, lodgepole pine is a common subdominant tree, and occasional white spruce may occur. Bearberry and grades are the most common understory species. Some rose, highbush-cranberry, aster, pentstemon, white camas, and goldenrod also occurs. Browse production is low, except where juvenile aspens are common.

d) Conifer-dominant uplands (Uc).

Primarily well-drained slopes and ridges with shallow depth to bedrock. These areas are mostly dominated by lodgepole pine, but white spruce is also common, and minor amounts of black spruce aspen, and paper birch can also occur. The pine sites have very sparse understory growth and a thick layer of litter. Most pine-dominated sites have probably been burned by wildfire. Occasional Labrador tea, soapberry, lingonberry, cranberry, rose, bearberry, and fireweed noted in the sparse understory. Browse production may be good on some sites in early successional stages following fire.

e) Steep grassy slopes (Sh).

Steep, south-facing slopes which support largely grasses, forbs, low shrubs, and scattered aspen of small stature. These occur mostly along the north side of Williams Creek and the tributary that joins it about 1 km west of the Yukon River. Grasses such as purple reedgrass, and pasture sage, were dominant at one site: bearberry, juniper, rose, Gorman's penstemon, thorough-wort, and wild flax were also noted.

f) Cliffs (Sc).

Very localized eroded sites and vertical or near vertical cliffs along lower Williams Creek and the Yukon River.

3.3.2 Wildlife Occurrence

It should be noted that the wildlife field inspection was in mid-August in order to optimize logistics within the environmental program. This is a suitable time to describe habitat, but not the best time to encounter wildlife. Ungulates and large carnivores are best surveyed in winter, and birds in May or June.In addition, this inspection was done year after the crash in the 10-year cycle, further reducing the abundance of wildlife and sign.

Wildlife observations or sign recorded during the summer field reconnaissance and winter-spring observations made by staff of J. Gibson and Associates are listed in Appendix 2.

1. Ungulates

Moose: No moose were seen during the field visit, and moose sign was relatively scarce. Even the best willow stands had low levels of browse use. J. Gibson staff did not report any moose. Exploration camp personnel reported having seen only two moose in the past two summers. Aerial surveys in the Casino Trail area immediately west of Williams Creek gave an estimate of 0.04 moose/km^2 (maximum estimate 0.07/km^2) of habitable moose range, "... the lowest [density] found in the Yukon to date (Markel and Larsen, 1988). Those authors concluded that forage was not limiting, and speculated that the area "... could support a larger moose population than presently exists there." This also seems to apply to the Williams Creek area.

Snow depth is not believed to limit moose use of this area. In parts of the Yukon, moose populations are held below carrying capacity by grizzly predation on calves, wolf predation on any age classes, or human harvest. It is not known which if any of these factors apply to moose in the Casino Trail-Williams Creek area.

Caribou: I observed a single caribou track in two locations along an exploration road north of the Williams Creek camp. Staff at the camp have not seen caribou, and they must be considered rare in the area, even though some apparently suitable winter range is present. The animal which made the track would most likely be from the Klaza herd, which occurs to the west in the Dawson Range. The Klaza herd is known to range as far west as Victoria Mountain, about 30 km southwest of Williams Creek (Farnell et al. 1991) and individuals could presumably stray farther than that.

2. Large Carnivores

Wolf: I saw only one probable wolf scat, and it is likely that this species is presently of sporadic occurrence because of low moose numbers and the decline phase of the hare cycle. Exploration camp and J. Gibson staff reported having seen the occasional wolf, and they are reported to be taken by trappers. Markel and Larsen (1988) felt that wolf densities in the general area were likely to be low.

Grizzly bear: Grizzlies are probably more common in the Dawson Range west of Williams Creek, where alpine-subalpine habitats occur. However, they do descend to low elevations. Dr. M. Hoefs (personal communication) stated that grizzlies had recently frequented the village of Carmacks, and I saw a probable scat near the Yukon River. J. Gibson staff reported a probable track on the Williams Creek access road in spring. Grizzly densities may approximate 10 to 16 animals per 1000 km^2 in the general area (Markel and Larsen, 1988). Being wide-ranging, none are expected to reside entirely within the Williams Creek watershed.

Black bear: Some black bear sign was noted in August/92, including old scats (spring vegetation) and recent ones (berries). Habitat here is moderately good for this species, and several individuals are probably present, however population densities are not known.

3. <u>Furbearers</u>

Lynx: Lynx were probably common here at the peak of the hare cycle (winter 90/91) and the following year, when tracks were regularly seen by staff of J. Gibson Associates. The species is important in the regional trapline catch, and Yukon densities of up to 9 per 100 km^2 have been estimated in years of snowshoe hare abundance (Slough and Ward, 1990).

Coyote: Coyote sign was moderately common in the Williams Creek area in August/92. Most scats were old, but two fresh ones contained squirrel feet. Coyotes probably move to lower-elevation parts of the study area in winter. The species is of some importance in the trapline catch.

Red fox: I saw only one probable fox dropping. Foxes are a minor component of the regional trapline catch.

Wolverine: This wide-ranging species is never abundant, but does occur in the study area. I saw a track in mud at the exploration camp incinerator, and J. Gibson staff reported one track. Wolverines are a small component of the trapline catch, but are economically important because of the price they fetch.

Marten: Apparently uncommon in the immediate area of Williams Creek, although they are taken by local trappers. Population levels in this area aren't known.

Mink: Expected to occur primarily along the Yukon River and large streams and wetlands. One track was reported near the exploration camp, but this species is probably rare in the study area.

Ermine: Expected to occur based on occurrence in the trapline catch, but of little economic importance.

River otter: Probably occurs along Yukon River and possible in lower kilometre of Williams Creek, but not expected elsewhere in the watershed.

Beaver: As for otter.

4. <u>Other Mammals</u>

Snowshoe hare: No hares or fresh sign were seen in August/92, however old sign in the form of runways, carpets of droppings, and browsed shrubs were widespread and abundant. The population apparently crashed in this area in the spring of 1991. This species is an important food base for several predators.

Red squirrel: Very common throughout the area in August/92.

Ground squirrel: One or two apparent burrows were noted, but the species had not been seen by exploration camp personnel, and we did not see it. Suitable habitat appears to be present, and reasons for its' rarity here are not known.

Porcupine: Sign was noted in two locations.

5. <u>Birds</u>

Waterfowl: No standing water habitat is present and no waterfowl use the watershed.

Grouse: Occasional spruce grouse droppings were noted, but no birds were seen, and the species appears to be currently at a low ebb. Populations may be cyclic, and higher at other times. Suitable habitat occurs through most of the study area. Ruffed grouse may occur in rich aspen or willow sites along streams, but such habitats are not extensive. This species is also cyclic, and may currently be at its cyclic low.

Raptors: Golden eagle nests were seen on cliffs at two locations near the Yukon River. No eagles were seen, however they would have completed nesting by the date of our field inspection, if they did actually nest at all in this year of snowshoe hare scarcity. Several other species or raptors should also occur in the area, but only the American kestrel was observed.

3.3.3 Habitat Use and Importance

Habitat descriptions, observed wildlife sign, and known habitat needs of key species were used for a preliminary assessment of the importance or wildlife potential of each major habitat type. These are described for the Yukon River valley and the Williams Creek drainage in the following sections.

3.3.3.1 Yukon River Valley

A. FLOODPLAIN AND LOW TERRACES:

Wildlife Occurrence
Old moose pellets and browsing sign were noted, as well as much old snowshoe hare sign (pellets; browsing to 1.0m+ level). This is the only part of the study area where beaver sign was found. Beaver use deciduous shrubs along the riverbank and along the lower part of Williams Creek near the Yukon River. Two bear scats were observed during a short visit to this unit, a fresh dropping consisting entirely of Viburnum berries (probably black bear) and an older spring scat made up of graminoid material (very large, probably grizzly). Several squirrel middens were also observed.

Wildlife potential
This unit has high potential for moose, snowshoe hares, red squirrels, black bears, wolves, and lynx; moderate potential for marten, grizzly bears, beaver, ruffed grouse, and a variety of small mammals and forest birds.

Overall importance: High to Very High.

B. VALLEY SLOPE:

Wildlife occurrence
A golden eagle nest was seen on steep cliffs just down-stream from the mouth of Williams Creek.

Wildlife potential
Where cliffs and steep eroded slopes are present there are present there is a high potential for nesting by golden eagles. Such sites also have some potential for other raptors such as peregrine falcons. The forested slopes have low to moderate potential for moose, hares, lynx, marten, and black bears.

Overall importance: Moderate to High

3.3.3.2 Williams Creek Watershed

A. WILLOW-DOMINANT WETLANDS:

Wildlife occurrence
Occasional sign of moose browsing, but levels of use are low. Moderate to high levels of old hare sign, primarily around edges where conifers provide some cover. Snipe, spotted sandpiper, and solitary sandpiper seen in sedge openings or streamsides in this type, and Wilson's warbler in shrub stands.

Wildlife potential
High potential for moose and snowshoe hares (and therefore for wolves, lynx, and coyotes which prey on them). Moderate to high early summer importance for black bears (herbaceous forage). Expected to receive moderate use by nesting song-birds.

Overall importance: High

B. SPRUCE DOMINANT WETLANDS

Wildlife occurrence
Occasional sign of moose browsing on willows, but recent use has been low. Hare signs were old but abundant, including runways, pellets, and browsing sign. Some red squirrel sign. Occasional black bear and coyote scats.

Wildlife potential
Moderate potential for moose; moderate to high potential for the snowshoe hare and its predators. Moderate potential for black bears (berries), red squirrels, and spruce grouse.

Overall importance: Moderate

C. ASPEN-DOMINANT UPLANDS:

Wildlife occurrence
Hare sign abundant where juvenile aspens are common. Occasional moose pellet group noted, but not common. Occasional coyote and black bear scats. Flickers occasionally seen in this type; also some spruce grouse droppings.

Wildlife potential
Moderate potential for moose (but little sign), for snowshoe hares and their predators, and for black bears (spring foraging). Also expect some ruffed grouse use where rich aspen stands border streams.

Overall importance: Moderate

D. CONIFER DOMINANT UPLANDS

Wildlife occurrence
Red squirrels and their sign were very common. Some sign of black bears, coyotes, snowshoe hares, and spruce grouse. Moose sign not common at this time.

Wildlife potential
This type has high potential for red squirrels and spruce grouse, low to moderate potential for snowshoe hares and their predators, and very low to moderate potential for moose (depending on site conditions and successional stage).

Overall importance: Low

E. STEEP GRASSY SLOPES

Wildlife occurrence
Scrubby aspen-shrub stands around the edges of grassy slopes had abundant hare sign, and occasional coyote droppings. Little other wildlife sign was noted.

Wildlife potential
Shrub and juvenile aspen areas have high potential for hares and moderate potential for moose. These slopes appear to have good potential for moose. These slopes appear to have good potential for Arctic ground squirrels, but little sign could be found of this species. Grassy slopes are largely a vacant niche in this area because no large grazing animals are present.

Overall importance: Low to Moderate

F. CLIFFS

Wildlife occurrence
Golden eagle nest observed at two sites, one located in the grassy slope on the north side of lower Williams Creek, another facing the Yukon River just north of the mouth of Williams Creek.

Wildlife potential
High potential is mainly for golden eagles, however other raptors such as peregrines could occur, as well as ravens.

Overall importance: Very high

3.4 Surface Water Hydrology

3.4.1 Hydrological Setting

The Williams Creek watershed consists of two principal basins, Williams Creek and a left bank [3] tributary (Nancy Lee Creek), which flow into Yukon River (Figure 3.4.1). Basin morphometric parameters for 5 sites (Williams Creek above the Ore Body, Williams Creek at Confluence with Nancy Lee Creek, Nancy Lee Creek at Confluence with Williams Creek, Williams Creek at Confluence with Yukon River and Yukon River upstream of Confluence with Williams Creek) are summarized on Table 3.4.1.

Information presented in Burns and Gibson (1990) indicate that Williams Creek typically consists of a narrow deep channel of 1 to 2 m in width and 1 to 1.5 m in depth. The stream channel is described as "straight" with "few meanders or side channels".

3.4.2 On-site Hydrological Data

Western Copper Holdings Ltd., requested John Gibson and Associates to install a staff gauge on Williams Creek upstream of the Ore Body (Site W-9 on Figure 3.4.1) which was periodically read during the summer of 1991 and 1992. A water level recorder was also installed in lower Williams Creek (above the confluence with Yukon River) during the summer of 1992 (Site W-10 on Figure 3.4.1). A number of miscellaneous streamflow measurements were made at other sites established for water quality or other purposes during both 1991

[3] while looking downstream

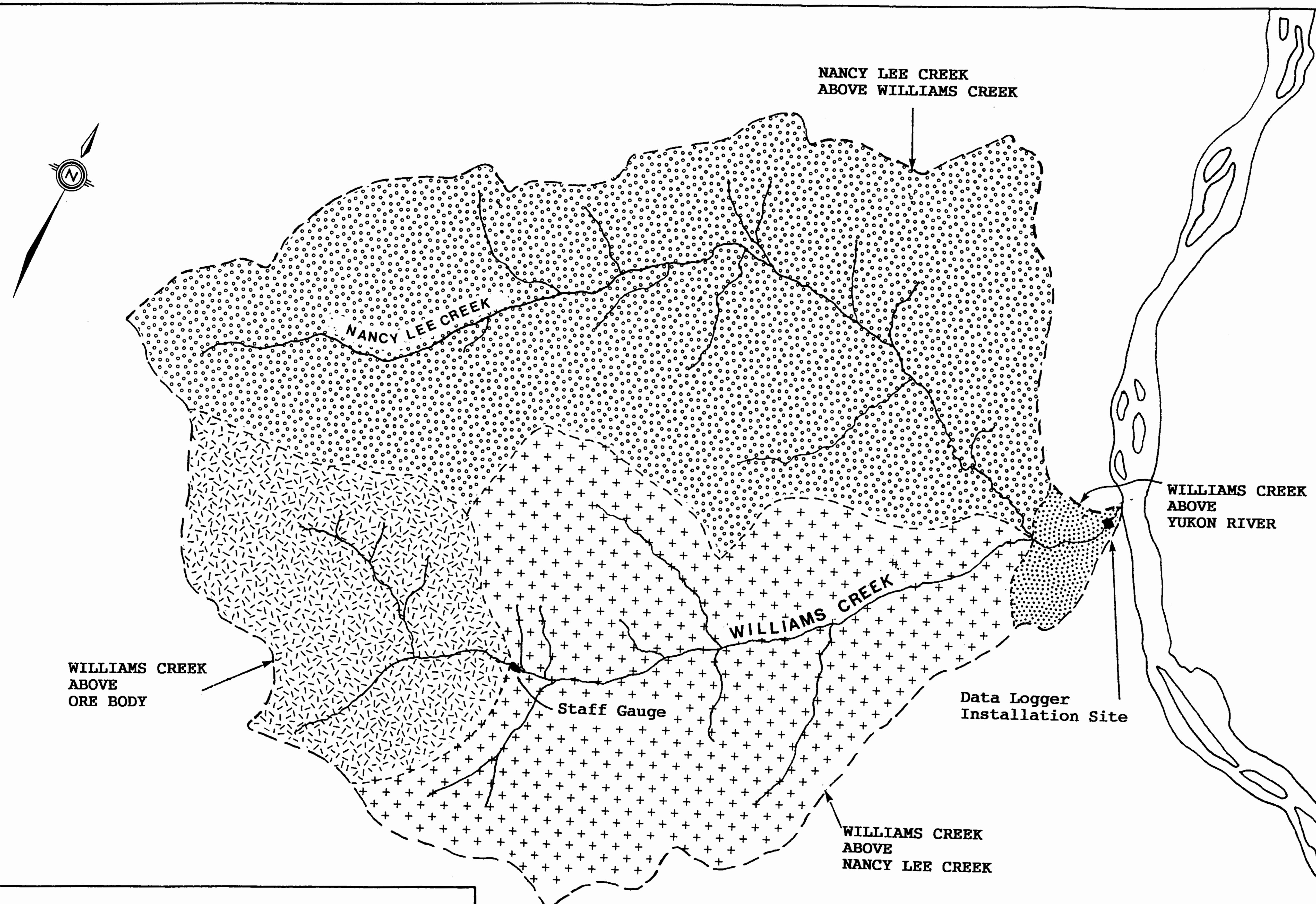

FIGURE 3.6.1 Location of reach boundaries and summary of physical habitat characteristics for the Williams Creek study area.

PARAMETER	LOCATION				
	WILLIAMS CR. ABOVE ORE BODY	WILLIAMS CR. ABOVE NANCY LEE CR.	NANCY LEE CR. ABOVE WILLIAMS CR.	WILLIAMS CR. ABOVE YUKON RIVER	YUKON RIVER ABOVE WILLIAMS CR.
Basin area (km^2)	13.0	42.4	44.3	88.0	90,600
Maximum Elevation (m asl)	823	823	960	960	--
Minimum Elevation (m asl)	680	511	511	488	--
Elevation Difference	137	312	449	472	--
Channel Length (m)	3,500	11,000	14,000	15,500	--
Average Channel Slope (m/m)	0.0395	0.0285	0.0321	0.0304	--

TABLE 3.4.1 Summary of basin characteristics.

and 1992. The available streamflow measurements are summarized on Table 3.4.2.

Sufficient discharge data is available from Williams Creek upstream of the Ore Body (Site W-9) to allow the establishment of a stage-discharge relationship for 1991 and 1992 (Figure 3.4.2). The 1991 data however is limited to gauge readings taken during discharge measurements. The 1992 observations are more numerous and the available discharge estimates are compiled on Table 3.4.3 and graphed on Figure 3.4.3. These data indicate that mid-summer discharges varied between 0.01 and 0.32 m^3/s in the period between June 10 and August 31.

The 1992 water level measurements on Williams Creek above the Yukon River (Figure 3.4.4) were observed to be affected by backwater flooding from Yukon River on July 10 and 11. Preliminary Water Survey of Canada (WSC) data indicate that the discharge on Yukon River at Carmacks was 2,720 m^3/s on July 11. This value was exceeded continuously in the period between June 17 and July 11 and thus the observed mid-June to mid-July water level measurements on Williams Creek are unreliable. Four discharge measurements were made at this site in 1992. However a water surface elevation was unavailable during the October 19 measurement as the river was ice covered. As a consequence there are only 3 reliable discharge observations, two of which were taken at nearly the same time. The resulting stage-discharge rating curve (Figure 3.4.5) is thus ill-

LOCATION	DATE	TIME	WATER LEVEL (m) STAFF GAUGE	WATER LEVEL (m) WATER LEVEL RECORDER	DISCHARGE (m^3/s)
W-3	May 17, 1992	10:40			0.109
W-4	Aug 07, 1991	16:50			0.044
	May 17, 1992	11:35			0.403
	Jul 05, 1992				0.080
W-5	Aug 07, 1991	-			0.023
Mainstem u/s W-5	Aug 07, 1992	-			0.023
W-9	Jul 06, 1991	09:25	0.117 *4		0.014
			0.117		0.011
		20:00	0.119		0.014
			0.119		0.012
	Aug 07, 1991	08:00	0.129		0.013
			0.129		0.015
			0.129		0.012
	Sep 17, 1991	13:00	0.250		0.029
			0.250		0.027
	May 16, 1992	20:00	0.585		0.291
	May 17, 1992	13:05	0.544		0.234
	Jul 08, 1992		0.381		0.069
W-10	Aug 07, 1991				0.202
	Sep 17, 1991				0.190
	Mar 31, 1992				0.005
	May 18, 1992 *1	14:10	0.391	0.391	0.894
	Jul 07, 1992 *2				0.271
	Jul 10, 1992 *3	14:20	0.434	0.455	0.376
	Jul 23, 1992	11:45	0.215	0.225	0.235
		12:15	0.215	0.225	0.211
	Oct 19, 1992	under complete ice cover/ float frozen			0.034
Mainstem u/s W-11	Jul 07, 1992				0.077
W-11	May 18, 1992	15:07			0.610
	Jul 07, 1992	-			0.141
	Oct 19, 1992	12:20			0.105 *5

NOTES:
*1 Data Logger installed May 18, 1992
*2 July 07, 1992 measurement by Burns/Harder
*3 July 10, 1992 measurement under backwater effect from Yukon River
*4 At lower gauge (W-9) heights, two or more flows were taken for better definition of lower end of curve
*5 under ice

TABLE 3.4.2 Summary of streamflow measurements.

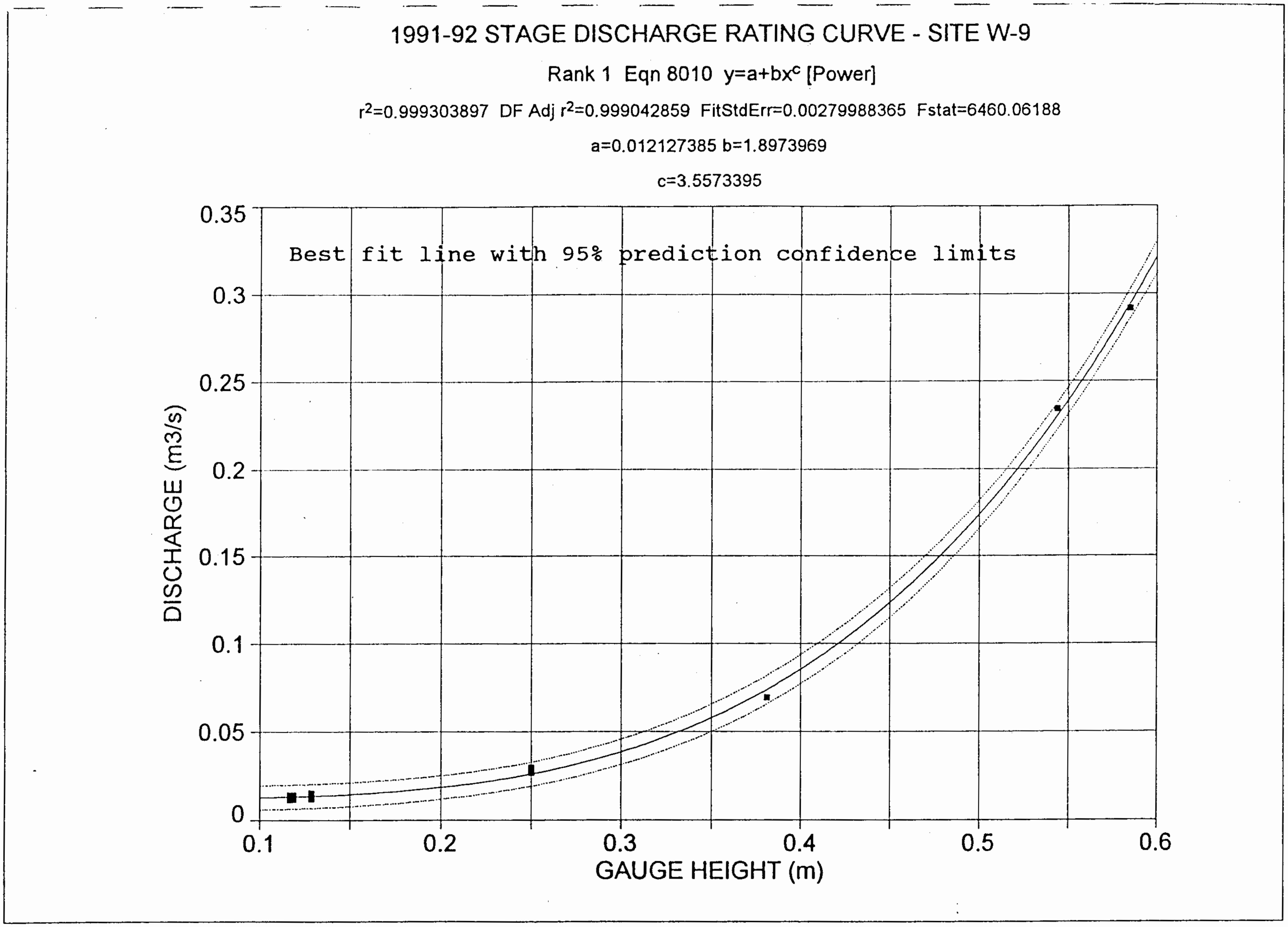

FIGURE 3.4.2 1991-1992 stage discharge rating curve, Williams Creek above the Ore Body (Site W-9)

DATE	MONTH					
	JUNE		JULY		AUGUST	
	GAUGE HEIGHT (m)	DISCHARGE (m3/s)	GAUGE HEIGHT (m)	DISCHARGE (m3/s)	GAUGE HEIGHT (m)	DISCHARGE (m3/s)
1			0.17	0.016	0.29	0.035
2			0.16	0.015	0.30	0.038
3			0.16	0.015	0.32	0.045
4			0.16	0.015	0.29	0.035
5			0.16	0.015	0.26	0.028
6			0.24	0.024	0.25	0.026
7			0.30	0.038	NA	NA
8			0.43	0.106	0.29	0.035
9			0.40	0.085	0.30	0.038
10	0.28	0.033	0.41	0.092	0.28	0.033
11	0.27	0.030	0.46	0.132	0.27	0.030
12	0.26	0.028	0.55	0.238	0.26	0.028
13	0.25	0.026	0.58	0.285	0.25	0.026
14	0.27	0.030	0.60	0.320	0.24	0.024
15	0.26	0.028	0.53	0.210	0.23	0.022
16	0.26	0.028	0.47	0.141	0.22	0.021
17	0.27	0.030	0.44	0.114	0.22	0.021
18	0.26	0.028	0.43	0.106	0.21	0.019
19	0.25	0.026	0.41	0.092	0.20	0.018
20	0.25	0.026	0.41	0.092	0.20	0.018
21	0.24	0.024	0.39	0.079	0.00	0.012
22	0.23	0.022	0.35	0.057	NA	NA
23	0.21	0.019	0.31	0.042	NA	NA
24	0.20	0.018	NA	NA	NA	NA
25	0.19	0.017	NA	NA	0.20	0.018
26	0.18	0.016	NA	NA	0.20	0.018
27	0.18	0.016	0.30	0.038	0.21	0.019
28	0.18	0.016	0.28	0.033	0.22	0.021
29	0.17	0.016	0.25	0.026	0.23	0.022
30	0.17	0.016	0.26	0.028	0.24	0.024
31			0.27	0.030	0.25	0.026

TABLE 3.4.3 Upper Williams Creek Streamflow data for the period June 10 - August 31, 1992 at Site W-9.

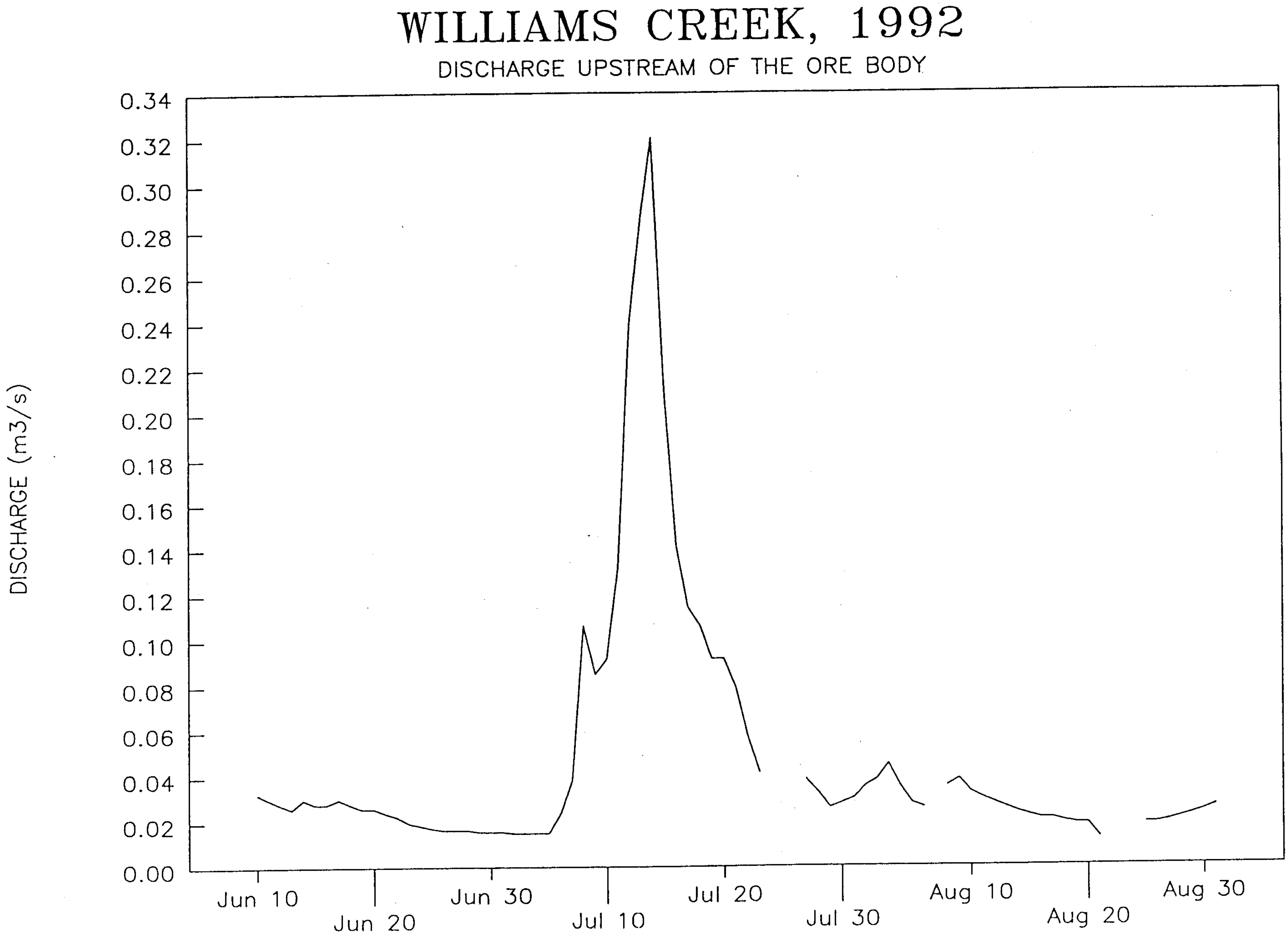

FIGURE 3.4.3 1992 discharge, Williams Creek above the Ore Body (Site W-9)

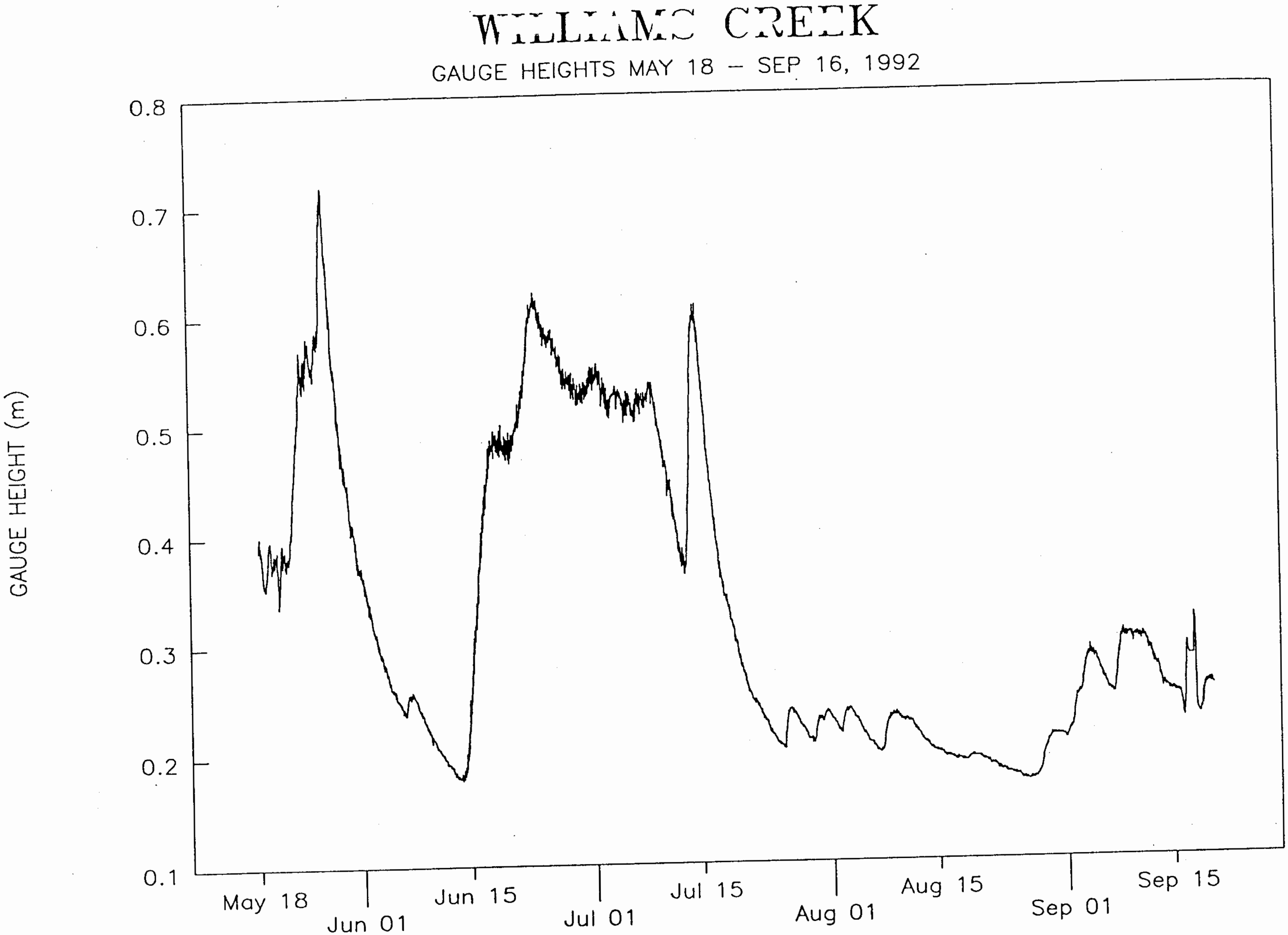

FIGURE 3.4.4 1992 water level measurements on Williams Creek above Yukon River (Site W-10)

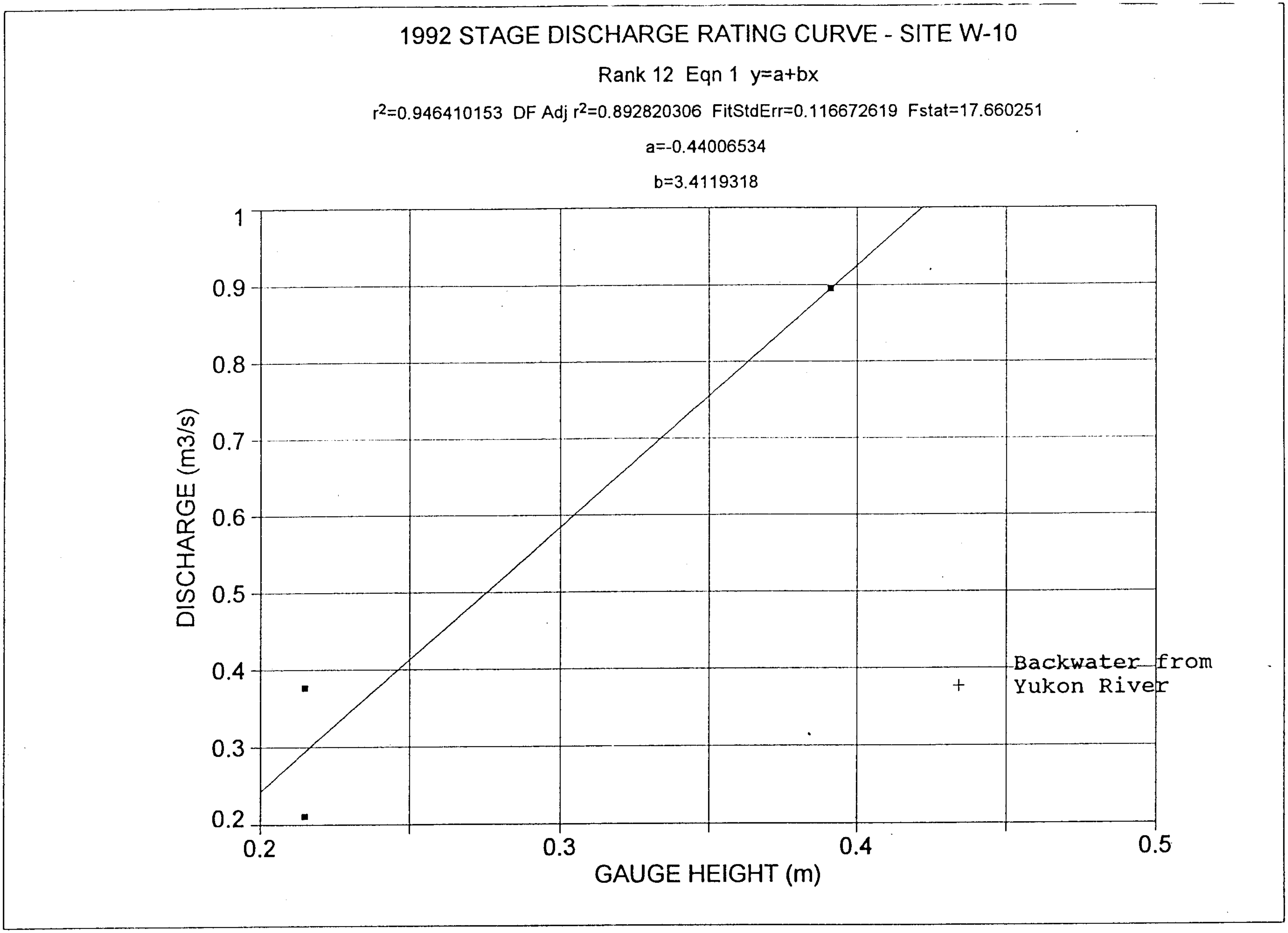

FIGURE 3.4.5 1992 stage-discharge rating curve, Williams Creek above Yukon River (Site W-10)

defined and cannot be used to reliably estimate discharges from measured water levels as the maximum gauged water level of 0.455 m is significantly smaller than the maximum observed water level of 0.719 m (Figure 3.4.4). In addition there are minor variations in the relationship between staff gauge and data logger readings (Figure 3.4.6) which likely result from inconsistent visual staff gauge readings, but may indicate inaccuracy in the data logger sensor. Despite these difficulties the data do indicate that streamflow in lower Williams Creek was on the order of 0.4 to 0.6 m^3/s during the period between August 1 and September 15, 1992.

3.4.3 Seasonal Variation in Discharge

Given the short duration and incomplete nature of the on-site data, discharge values from other stations must be used to describe the typical seasonal variation in discharge. Figure 3.4.7 shows the maximum, average and minimum daily flow observed on Yukon River at Carmacks. The basin area at Carmacks is 81,800 km^2 or approximately 90 per cent of that at the Williams Creek confluence. Maximum discharges typically occur during June and July. Flows then generally gradually decrease until mid winter when the smallest discharges of the year typically occur. Sizeable late-summer rainstorm floods can occur, however the largest flows in the year are associated with the spring freshet. On smaller streams, such as Vangorda Creek (basin area 91.2 km^2) which is located near Faro, the annual maximum flows typically occur as a result of snow melt or rain-on-snow events in May or June (Table 3.4.4, Figure

3.4.8). However in 1991 the annual maximum daily flow occurred on July 28, likely as a result of a mid-summer rainstorm. The available data however suggests that the largest floods have been associated with snow melt or rain-on-snow events.

3.4.4 Historical Variation in Peak Flows on Yukon River

The historical variation in annual maximum daily and instantaneous discharges on the Yukon River at Carmacks is shown on Figure 3.4.9. Flood frequency analyses (shown on Tables 3.4.5 and 3.4.6 [4]) indicate that the maximum 1992 discharge (2980 m^3/s on June 23) had an approximately 25-year return period. In comparison, the largest recorded flood (3,600 m^3/s) which occurred on June 24, 1962, had a return period of approximately 100 years. The 1992 freshet is therefore the second largest event on record and the extent of backwater flooding in lower Williams Creek was at least partially a result of these unusually severe conditions.

3.4.5 Peak Discharge Estimates

Janowicz (1989) has undertaken a regional flood frequency analysis of Yukon data from both the WSC and Indian and Northern Affairs Canada (INAC) stream gauging stations. This study allows various return period discharges to be estimated on the basis of watershed area and stream channel gradient. Potential instantaneous dis-

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[4] The predicted instantaneous peak flows are smaller than similar recurrence interval daily flows due to the differing periods of record used in the analysis. Additional work is therefore required prior to using these values for design purposes.

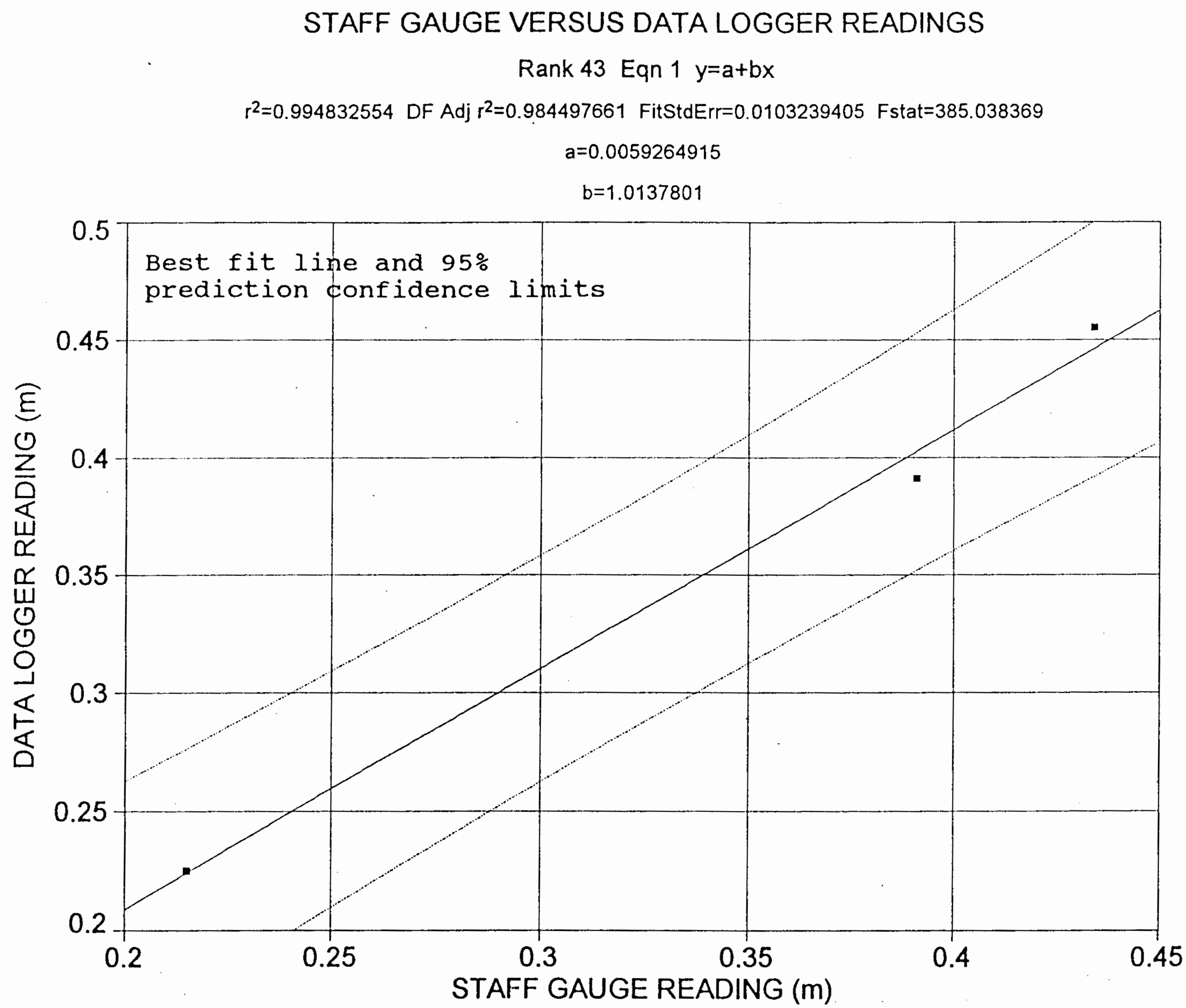


FIGURE 3.4.6 Relationship between staff gauge and data logger readings on Williams Creek above Yukon River (Site W-10)

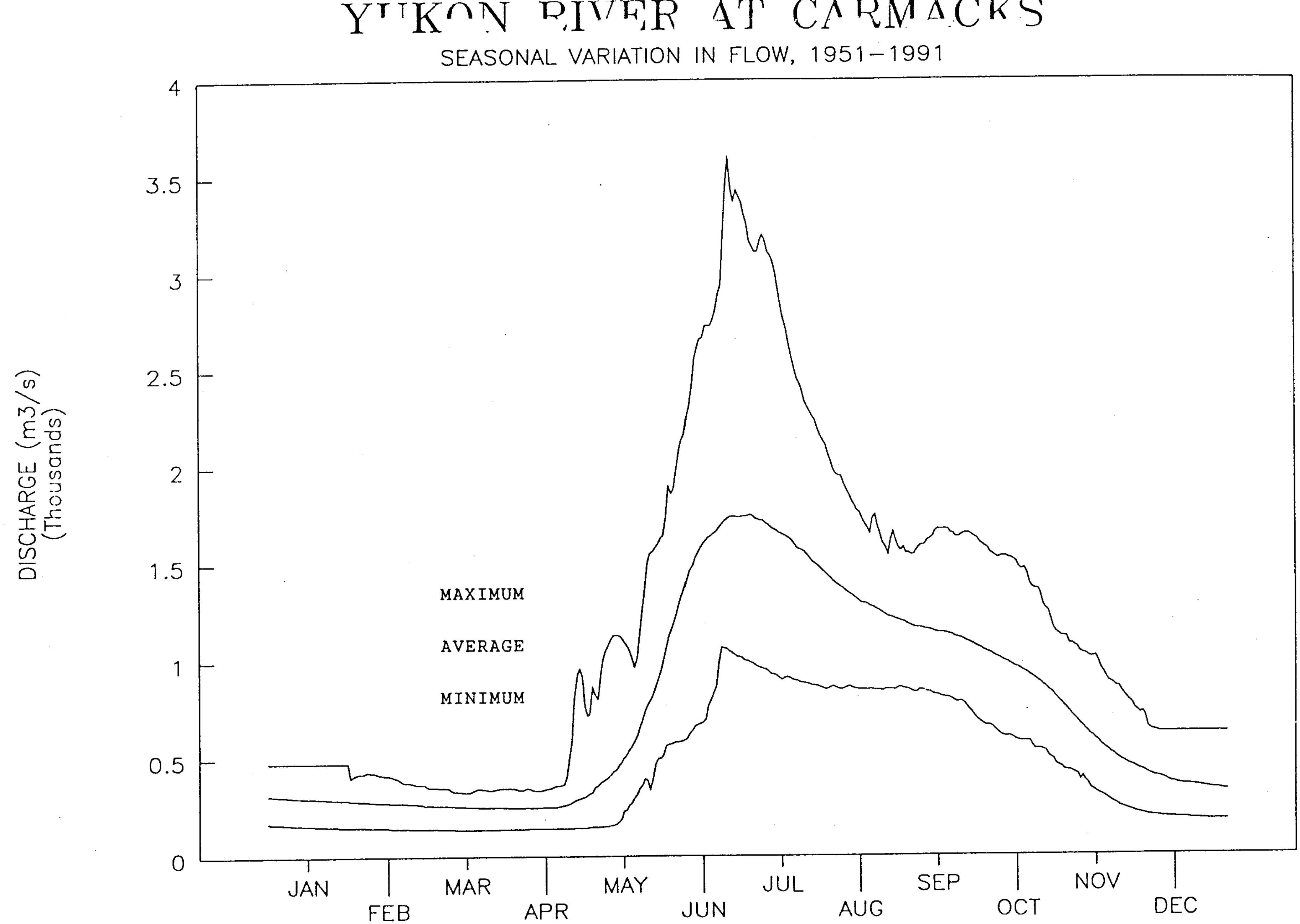


FIGURE 3.4.7 **Seasonal variation in discharge, Yukon River at Carmacks.**

YEAR	ANNUAL MAXIMUM DAILY DISCHARGE		ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE	
	DATE	VALUE (m3/s)	DATE	VALUE (m3/s)
1977	May 30	2.93	May 29	3.62
1978	Jun 08	1.59	Jun 15	2.00
1979	Jul 21	1.20	Jul 21	1.37
1980	Jul 17	3.32	Jul 17	4.72
1981	Jun 23	1.47	Jun 22	1.74
1982	Jun 09	5.54	Jun 08	6.90
1983	May 31	6.23	May 30	7.36
1984	Jun 06	5.62	Jun 06	6.11
1985	Jun 04	4.60	Jun 03	6.44
1986				
1987				
1988				
1989	May 09	2.43	Jun 14	3.78
1990	May 31	4.48	May 30	5.60
1991	Jul 28	4.61	Jul 28	5.16
1992	Jun 14	8.45	Jun 14	7.25

NOTE: Data supplied by Indian and Northern Affairs Canada

TABLE 3.4.4 Dates of Annual Maximum Daily and Instantaneous Discharge, Vangorda Creek at Faro Townsite Road.

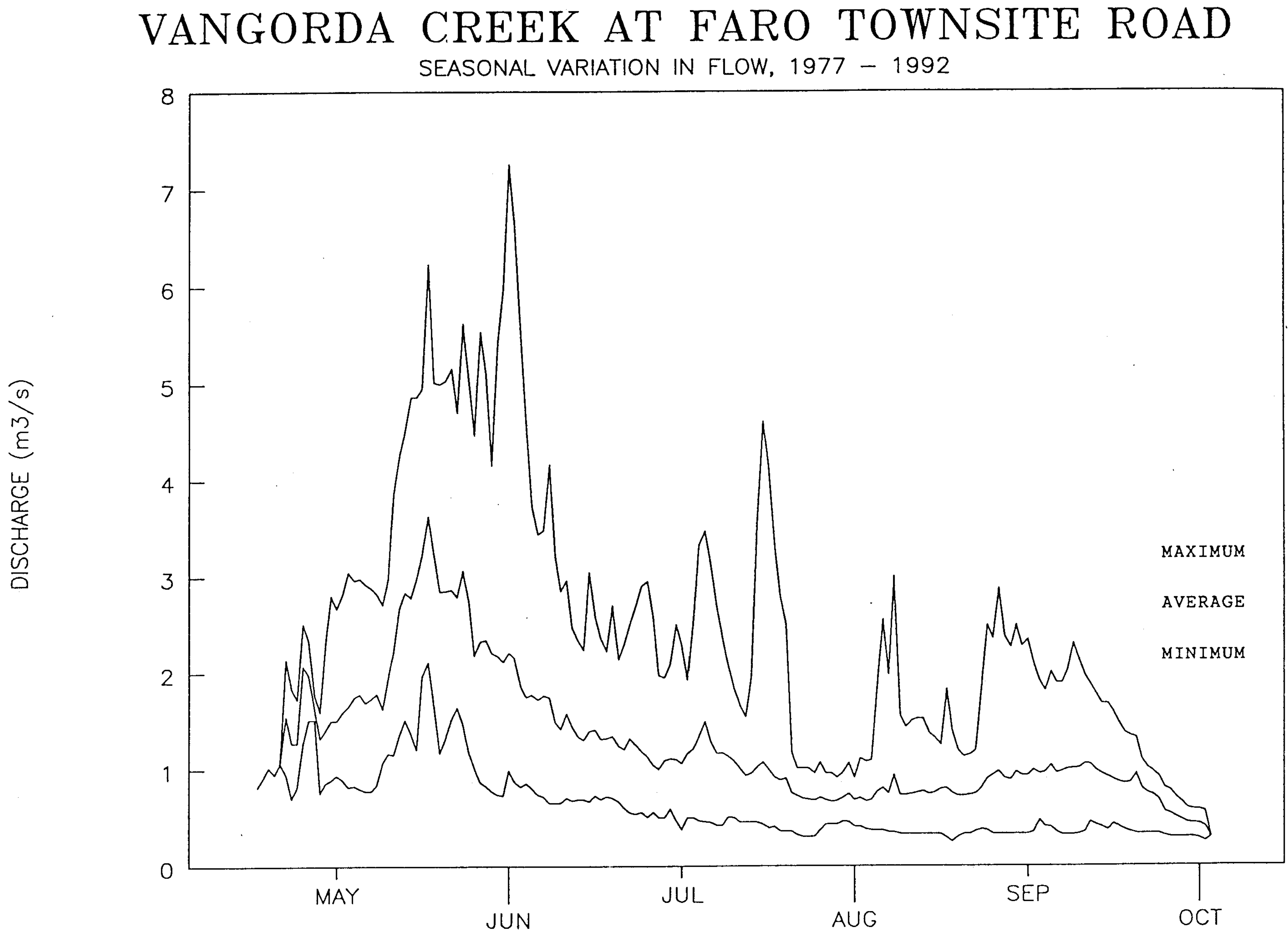
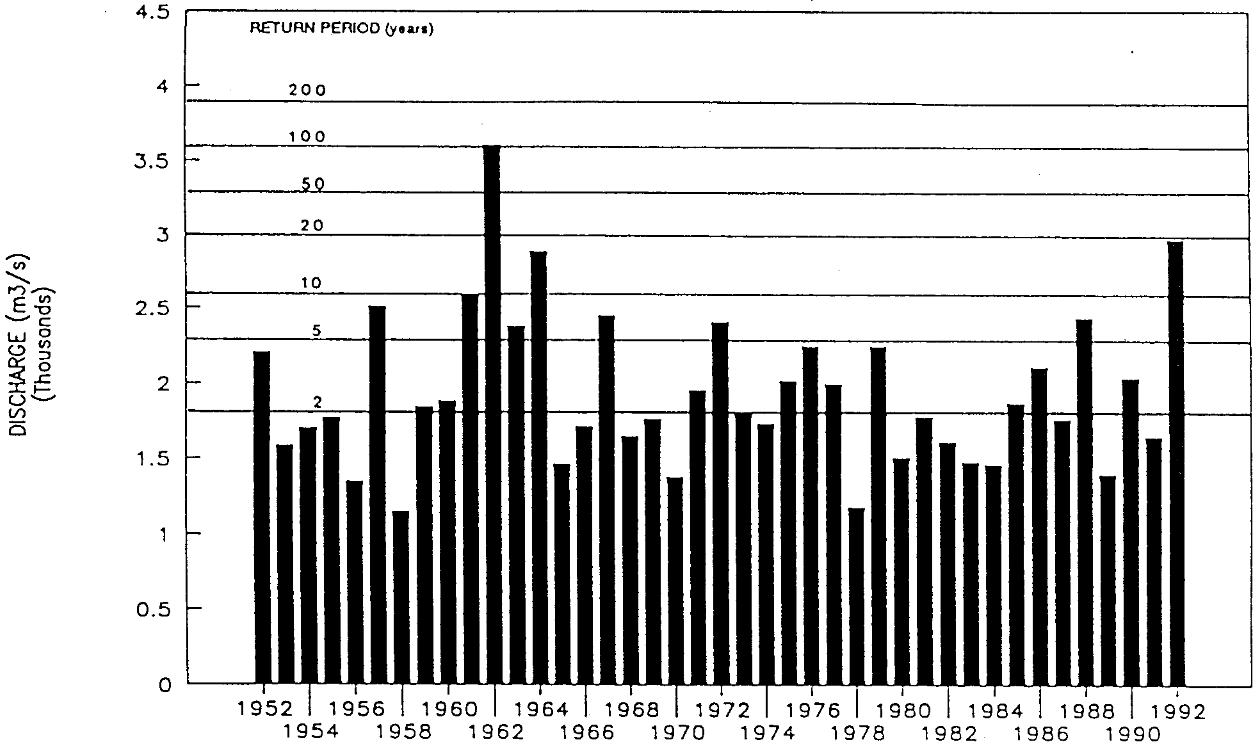


FIGURE 3.4.8 Seasonal variation in discharge, Vangorda Creek near Faro Townsite Road.

YUKON RIVER AT CARMACKS

ANNUAL MAXIMUM DAILY DISCHARGE, 1951–92



YUKON RIVER AT CARMACKS

MAXIMUM INSTANTANEOUS DISCHARGE 1951–92

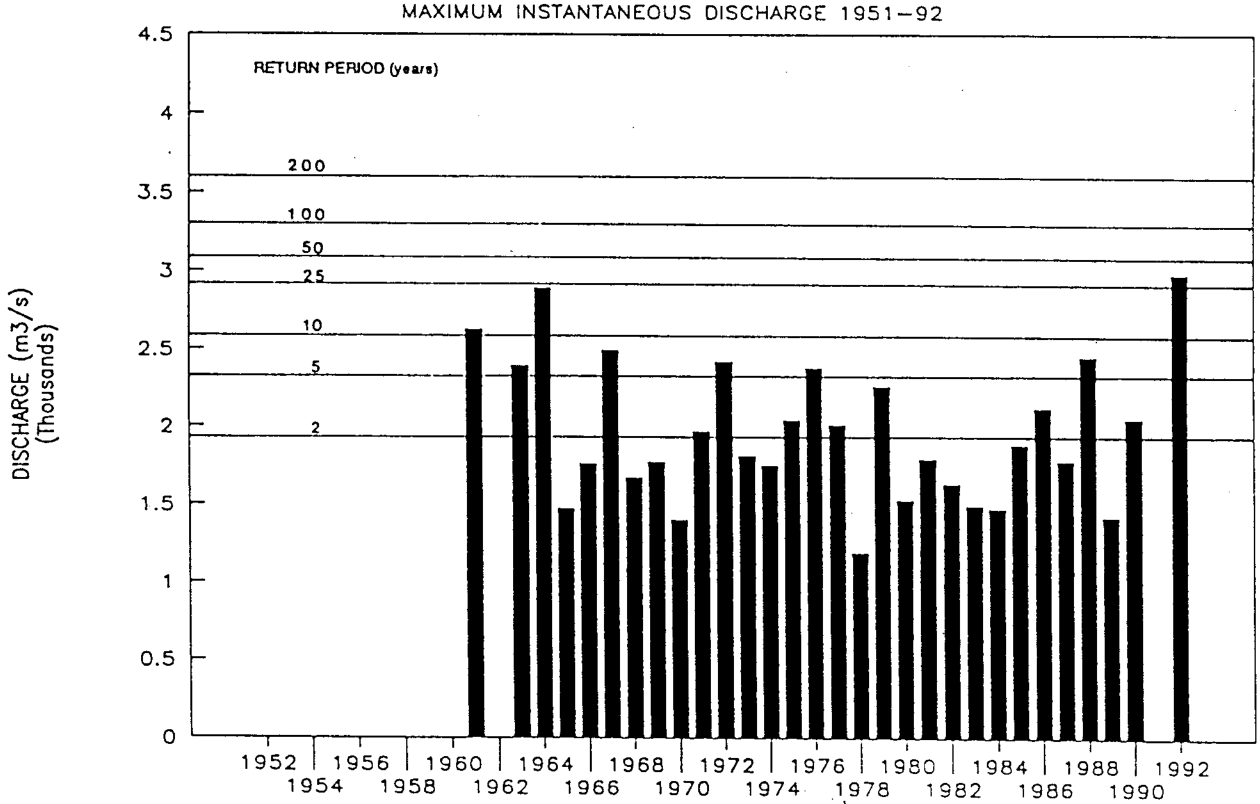


FIGURE 3.4.9 Historical variation in annual maximum daily and instantaneous discharges, Yukon River at Carmacks.

PERIOD OF RECORD: 19[illegible] 1992 BA[illegible]REA [illegible] km²

YEARS OF RECORD: 41 FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE COEFFICIENT OF SKEW: 1.080

FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m3/s) FOR A RETURN PERIOD OF:						
	2 Yrs	5 Yrs	10 Yrs	25 Yrs	50 Yrs	100 Yrs	200 Yrs
LOG NORMAL (Maximum Likelihood)	1,850	2,310	2,620	3,010	3,300	3,590	3,880
GUMBEL (Maximum Likelihood)	1,850	2,300	2,590	2,960	3,230	3,500	3,770
PEARSON TYPE III (By Moments)	1,850	2,320	2,620	2,990	3,260	3,510	3,760
LOG PEARSON TYPE III (By Moments)	1,850	2,310	2,610	2,990	3,280	3,580	3,880
ADOPTED VALUE	1,850	2,310	2,610	3,000	3,300	3,600	3,900

FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m3/s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)	1,710	2,010	2,090	2,560	2,320	2,970	2,590	3,510	2,790	3,930	2,980	4,360	3,160	4,810
GUMBEL (Maximum Likelihood)	1,710	2,000	2,070	2,520	2,300	2,870	2,590	3,320	2,800	3,660	3,000	4,000	3,210	4,330
PEARSON TYPE III (By Moments)	1,700	2,000	2,080	2,570	2,300	2,950	2,560	3,420	2,750	3,760	2,920	4,090	3,100	4,410
LOG PEARSON TYPE III (By Moments)	1,710	2,000	2,080	2,550	2,310	2,930	2,580	3,430	2,780	3,810	2,970	4,190	3,160	4,570
ADOPTED VALUE	1,700	2,010	2,070	2,570	2,320	2,970	2,560	3,510	2,750	3,930	2,920	4,360	3,100	4,810

NOTES:

Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowleged

TABLE 3.4.5 Flood Frequency Analysis, Annual Maximum Daily Discharge, Yukon River at Carmacks.

PERIOD OF RECORD: 1951 to 1992 BASIN AREA: 81,800 km2

YEARS OF RECORD: 30 COEFFICIENT OF SKEW: 0.522

FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE

FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m3/s) FOR A RETURN PERIOD OF:						
	2 Yrs	5 Yrs	10 Yrs	25 Yrs	50 Yrs	100 Yrs	200 Yrs
LOG NORMAL (Maximum Likelihood)	1,900	2,320	2,590	2,910	3,150	3,380	3,610
GUMBEL (Maximum Likelihood)	1,890	2,310	2,590	2,940	3,210	3,470	3,730
PEARSON TYPE III (By Moments)	1,920	2,330	2,570	2,840	3,020	3,200	3,360
LOG PEARSON TYPE III (By Moments)	1,910	2,320	2,580	2,880	3,100	3,320	3,520
ADOPTED VALUE	1,900	2,300	2,600	2,900	3,100	3,300	3,600

FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m3/s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)	1,740	2,070	2,090	2,580	2,280	2,940	2,510	3,600	2,660	3,740	2,810	4,090	2,950	4,450
GUMBEL (Maximum Likelihood)	1,720	2,050	2,060	2,560	2,270	2,910	2,530	3,360	2,720	3,700	2,900	4,030	3,090	4,360
PEARSON TYPE III (By Moments)	1,760	2,090	2,100	2,560	2,290	2,850	2,490	3,190	2,620	3,420	2,750	3,640	2,870	3,850
LOG PEARSON TYPE III (By Moments)	1,750	2,080	2,090	2,570	2,280	2,900	2,500	3,320	2,650	3,630	2,790	3,940	2,920	4,250
ADOPTED VALUE	1,720	2,090	2,060	2,580	2,270	2,940	2,490	3,600	2,620	3,740	2,750	4,090	2,870	4,450

NOTES:

Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowleged

TABLE 3.4.6 Flood Frequency Analysis, Annual Maximum Instananeous Discharge, Yukon River at Carmacks.

charges have been estimated using this procedure for various locations within the Williams Creek basin (Table 3.4.7). However, as discussed in Jacobsen et al. (1992), there is an impression that the flood values predicted by Janowicz's (1989) methodology may underestimate actual values.

> "The evidence of high flow events during the 1991 placer mining season and other hydraulic characteristics were surveyed at eight placer-mined streams. Flow rates, gradients, channel dimensions and other data were calculated. The results were compared to "White Book" [5] recommendations for flood flow designs. Wide variations were observed between the design flood estimates from the "White Book" and flood estimates calculated from field surveys. The conclusions suggest that a regional analysis method of design flood estimation for the design of stable channels may not be appropriate. Instead, it is recommended that stream-specific analysis is required. It is also suggested that field documentation of actual flood events be applied directly to channel design at that location."
>
> (Jacobsen et al., 1992, page 6)

Potential peak instantaneous discharges have therefore been estimated for comparative purposes on the basis of the Rational Method (Coulson, 1988) for sites with basin areas of <25 km^2. The rational method is based on the formula:

$$Qp = 0.28 \frac{C\,P\,A}{Tc}$$

---

[5] Hardy BBT (1991) which uses the procedures from Janowicz (1989)

LOCATION	UPSTREAM AREA (km^2)	STREAM CHANNEL LENGTH (m)	TIME OF CONC. (hrs)	PREDICTED INSTANTANEOUS DISCHARGE (m^3/s) FOR A RETURN PERIOD (years) OF:				
				2	5	20	50	100
Williams Creek above Ore Body	13.0	3,500	0.8	1.0	1.5	2.2	2.8	3.2
Williams Creek above Nancy Lee Creek	42.4	11,000	1.8	2.9	4.4	6.5	8.0	9.1
Nancy Lee Creek above Williams Creek	44.3	14,000	2.3	3.1	4.6	6.8	8.3	9.5
Williams Creek above Yukon River	88.0	15,500	2.4	5.9	8.7	12.7	15.4	17.4

TABLE 3.4.7 Predicted instantaneous flood discharges for various locations within the Williams Creek watershed.

where Qp is peak flow in m^3/s, C is the runoff coefficient, P is total precipitation in mm, A is drainage area in km^2 and Tc is the time of concentration in hours.

The short-duration rainfall intensities shown on Figure 3.2.10 have been used in this analysis. Time of concentration has been calculated assuming a 15 minute delay for overland flow to reach a stream channel and a subsequent water velocity of 2 m/s. The coefficient C (which represents the portion of the rainfall intensity that is available as peak runoff) has been estimated from surficial geology information (Section 3.2, Tempelman-Kluit, 1984 and Klassen et al., 1987) and procedures recommended in Coulson (1988). A value of 0.50 (representative for rolling forested terrain) has been increased by a value of 0.10 for return periods of 5 years or more to reflect snow melt during rain-on-snow events and by values of 0.02 and 0.05 for return periods of 10 to 25 and 50 to 100 years, respectively.

The results of the above analysis are shown on Table 3.4.8 and the calculated flows for Williams Creek above the Ore Body are an order of magnitude larger than those predicted on the basis of Janowicz (1989). The adopted time of concentration and coefficient C values may both be slightly high, but the results are still anomalous.

Flood frequency analysis of instantaneous discharges on Vangorda Creek (Table 3.4.9) provide a means of roughly verifying the

LOCATION	BASIN AREA (km2)	TIME OF CONCENTRATION (hrs)	RETURN PERIOD (yrs)	RUNOFF COEFFICIENT "C"	RAINFALL		PEAK DISCHARGE (m3/s)
					INTENSITY (mm/hr)	TOTAL (mm)	
WILLIAMS CREEK ABOVE ORE BODY	13.0	0.8	2	0.50	8.5	6.8	15.5
			5	0.60	13	10.4	28.4
			20	0.62	18	14.4	40.6
			50	0.65	22	17.6	52.1
			100	0.65	25	20	59.2

TABLE 3.4.8 Predicted discharges on Williams Creek above the Ore Body, based on the Rational Equation.

PERIOD OF RECORD: 1977 to 1992 BASIN AREA: 91.2 km2

YEARS OF RECORD: 13 FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE COEFFICIENT OF SKEW: -0.432

FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m3/s) FOR A RETURN PERIOD OF:						
	2 Yrs	5 Yrs	10 Yrs	25 Yrs	50 Yrs	100 Yrs	200 Yrs
LOG NORMAL (Maximum Likelihood)	5.37	6.66	7.10	7.44	7.61	7.74	7.84
GUMBEL (Maximum Likelihood)	4.45	6.70	8.18	10.0	11.0	13.0	14.0
PEARSON TYPE III (By Moments)	4.92	6.58	7.36	8.14	8.61	9.01	9.36
LOG PEARSON TYPE III (By Moments)	4.62	6.85	8.03	9.21	9.91	11.0	11.0
ADOPTED VALUE	4.6	6.9	8.0	9.2	9.9	10.5	11.0

FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m3/s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)	3.90	6.36	5.64	7.30	6.17	7.64	6.60	7.69	6.82	8.01	6.99	8.09	7.13	8.16
GUMBEL (Maximum Likelihood)	3.05	5.86	4.54	8.85	5.42	11.0	6.47	14.0	7.24	16.0	8.00	18.0	8.74	20.0
PEARSON TYPE III (By Moments)	3.63	6.22	4.87	8.29	5.39	9.34	5.88	10.0	6.17	11.0	6.41	12.0	6.61	12.0
LOG PEARSON TYPE III (By Moments)	3.17	6.73	3.97	12.0	4.31	15.0	4.61	18.0	4.78	21.0	4.81	22.0	5.02	24.0
ADOPTED VALUE	3.1	6.7	4.0	12.0	4.3	15.0	4.6	18.0	4.8	21.0	4.8	22.0	5.0	24.0

NOTES:

Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowleged

TABLE 3.4.9 Frequency analysis of annual maximum instantaneous discharges, Vangorda Creek at Faro Townsite Road.

predicted flows for Williams Creek above Yukon River as the basin areas are relatively similar (88.0 vs. 91.2 km^2). Comparison of Tables 3.4.7 and 3.4.9 indicate the Janowicz (1989) study over predicts the magnitude of peak flows on Vangorda Creek. [There is however no assurity that streamflow on Vangorda Creek is comparable to that on Williams Creek.]

Given the inability to calibrate the rational equation with on-site data, the results of the regional analysis conducted by Janowicz are more likely to be correct (and they compare reasonably well with the limited observed data). Nevertheless it would be desirable for additional rainfall and runoff data to be collected on Williams Creek such that the US Soil Conservation Service (McCuen, 1982, SCS, 1984) or other models could be calibrated. Until such time as this work can be undertaken, it is recommended that the discharge values shown on Table 3.4.7 be considered as minimum estimates and that additional analysis of relevant data be undertaken if streamflow is an important component for the design of mine site infrastructure.

3.4.6 Minimum Flows

Janowicz (1991) has undertaken a low flow frequency analysis of Yukon discharge data collected by the WSC and INAC. On the basis of this study "7-day low flow" values have been predicted for selected sites in the Williams Creek watershed (Table 3.4.10). This analysis indicates that commonly occurring mid-winter stream-

LOCATION	UPSTREAM AREA (km^2)	PREDICTED 7 DAY LOW FLOW (m^3/s) FOR A RETURN PERIOD (years) OF:						
		2	5	10	50	100	200	500
Williams Creek above Ore Body	13.0	0.008	0.004	0.003	0	0	0	0
Williams Creek above Nancy Lee Creek	42.4	0.030	0.017	0.012	0	0	0	0
Nancy Lee Creek above Williams Creek	44.3	0.031	0.018	0.012	0	0	0	0
Williams Creek above Yukon River	88.0	0.067	0.040	0.028	0	0	0	0

TABLE 3.4.10 Predicted 7-day low flow values for selected sites within the Williams Creek watershed.

flow values are very small (<0.001 to 0.07 m^3/s) and that no surface streamflow is expected for return periods of greater than 50 years.

3.5 Water and Stream Sediment Quality

3.5.1 Water Quality

Water quality data collected between October 1989 and October 1992 for the eleven stations on Williams Creek are presented in Appendix 3. These results are discussed in the following sections.

3.5.1.1 Physical Parameters, Nutrients and Major Ions

A summary of average values for physical parameters, nutrients and major ions is presented in Table 3.5.1.

<u>Alkalinity</u>

Average alkalinity for the Williams Creek mainstem sites over the entire sample period was between 107 and 149 mg/L as $CaCO_3$ (Table 3.5.1). Seasonal variation ranged between 38 and 255 mg/L with highest values measured during December (Figure 3.5.1).

Alkalinity values (average) for the tributary sites (W-1, W-2, W-3, W-5, W-6, W-7 and W-11) were between 84 and 130 mg/L as $CaCO_3$. Seasonal trends were generally similar to the mainstem sites (Figure 3.5.1).

Water Hardness

Average water hardness for the mainstem Williams Creek varied between 125 and 161 mg/L as $CaCO_3$ (Table 3.5.1). Highest values occurred during the low flow winter period when the relative contribution of ground water was highest. Water hardness Values were lowest during the spring freshet period. Seasonal variation for the mainstem sites is shown in Figure 3.5.2.

Water hardness values for the tributary sites (W-1, W-3, W-7 and W-5) were generally lower than mainstem sites. Seasonal trends were similar between the mainstem sites and tributary sites, with the exception of W-1 which had relatively high water hardness throughout the year (Figure 3.5.2).

pH

Mainstem pH values for Williams Creek ranged from 7.4 to 8.2 and there was relatively little variation between individual sample sites for each sample period (Figure 3.5.3). Values were generally lowest during the May sample period coinciding with high flows (Figure 3.5.3).

Tributary pH values ranged from 7.2 to 8.2 (Table 3.5.1) and exhibited a relatively high degree of variation between sites for the same sample period (Figure 3.5.3).

TABLE 3.5.1. Summary of physical water quality parameters for sampling stations in the Williams Creek drainage based on average values calculated for the October 1989 to October 1992 period.

					AVERAGE VALUES			
SAMPLE SITE	pH	ALKTY	H_2O hardness	SO_4	SUSP. SOLIDS	NO_4	NO_3	NH_4
MAINSTEM								
W10	7.9	113	125	15	13	0.01	BD	0.25
W4*	7.8	107	146	37	94	0.02	BD	0.05
W9	7.8	149	161	30	7	BD	BD	0.12
TRIBUTARY								
W11	7.8	109	128	27	6	BD	BD	BD
W1	7.8	116	206	103	31	0.5	BD	0.06
W2*	7.7	100	133	76	8	BD	BD	0.06
W3	7.7	130	138	12	BD	BD	BD	0.06
W5	7.5	84	102	4	462	BD	BD	0.07
W6*	7.9	140	169	51	BD	BD	0.003	0.05
W7	7.5	126	135	11	8	BD	BD	0.05
W8	NO DATA							

* data from only one sampling period.

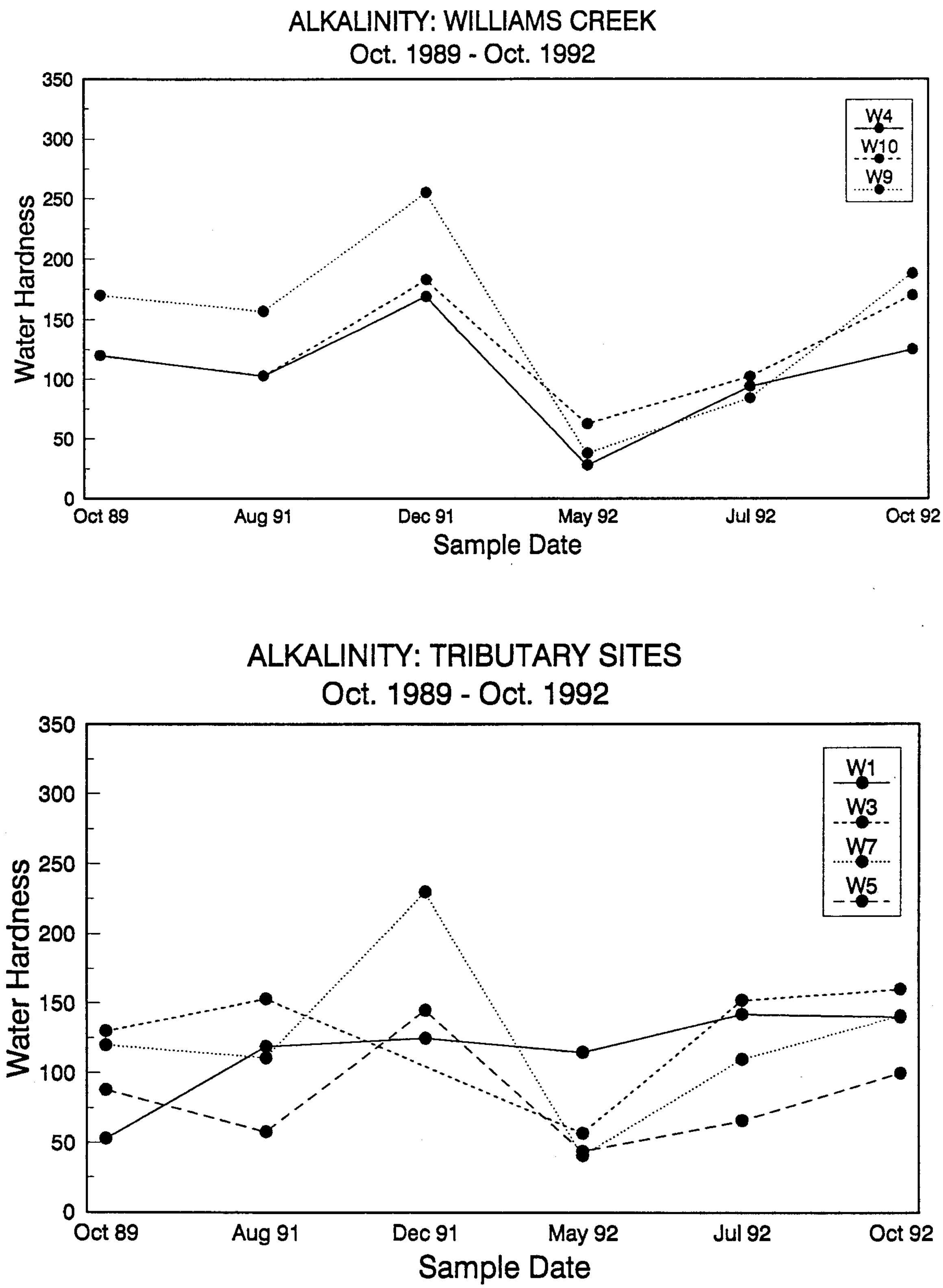
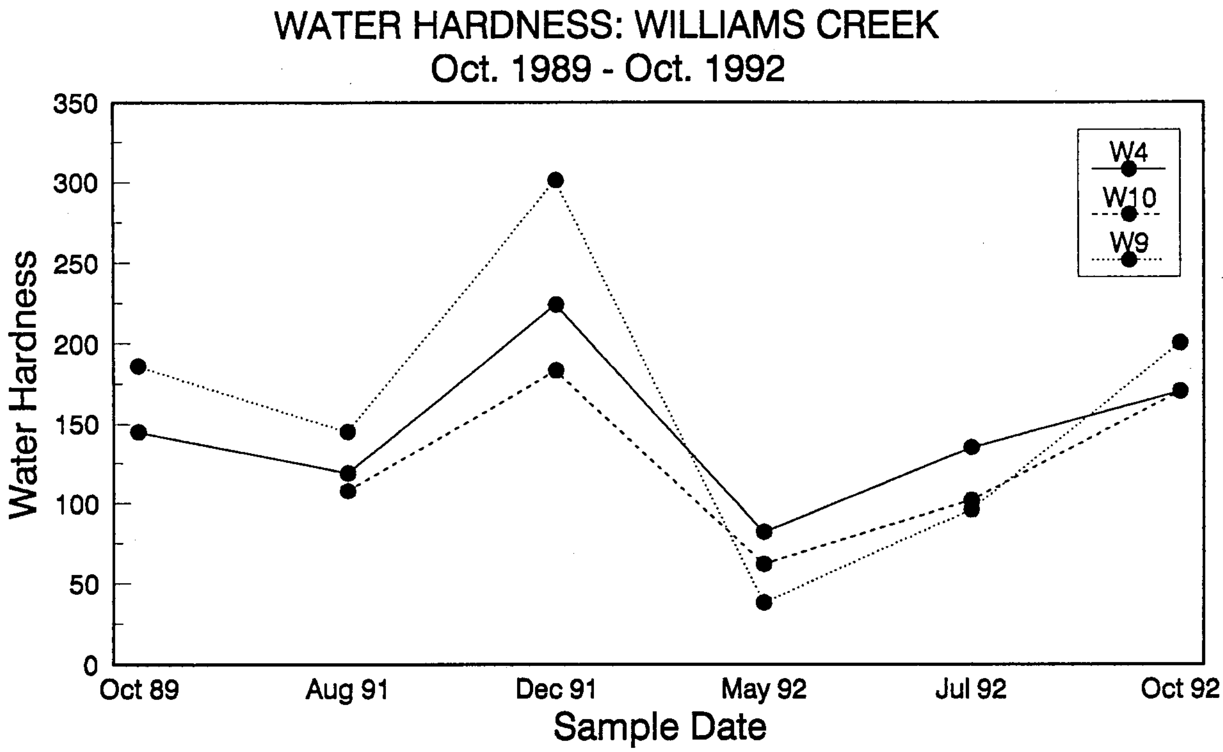


FIGURE 3.5.1 Alkalinity values for mainstem Williams Creek (Top) and tributary sites (Bottom) between October 1989 and October 1992.



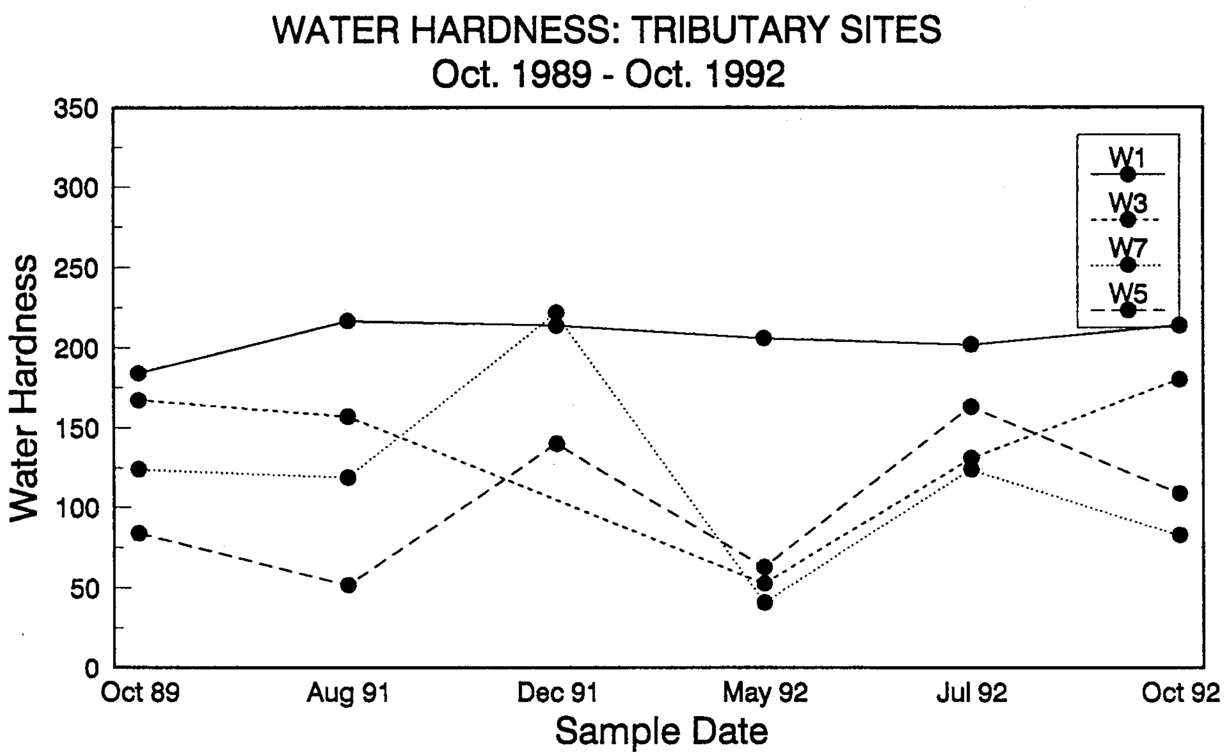
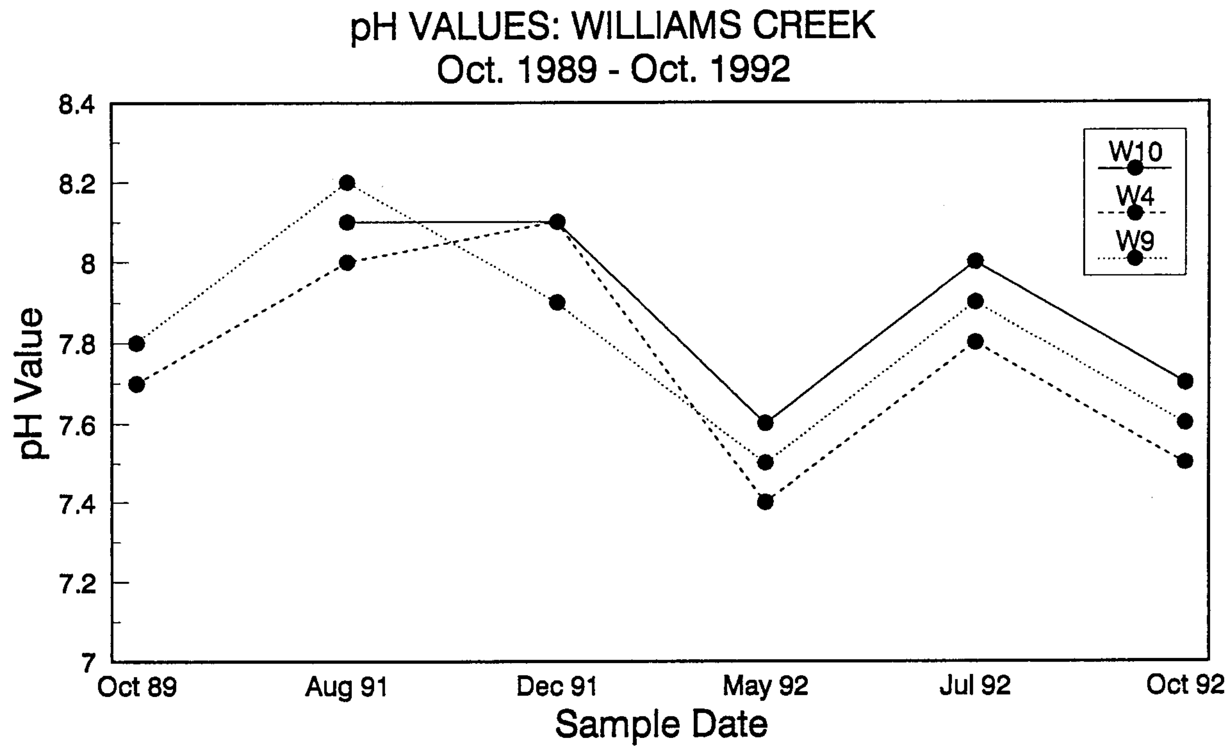


FIGURE 3.5.2 Water Hardness values for mainstem Williams Creek (Top) and tributary sites (Bottom) between October 1989 and October 1992.



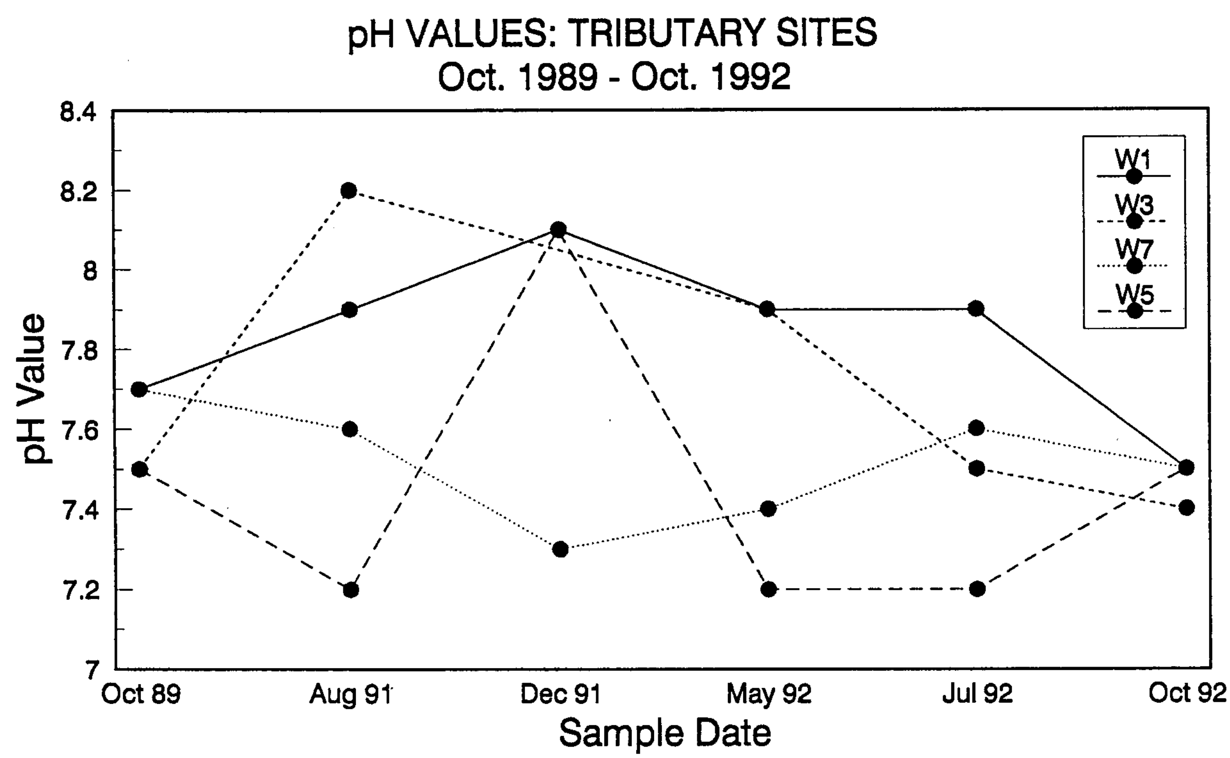


FIGURE 3.5.3 pH values for mainstem Williams Creek (Top) and tributary sites (Bottom) between October 1989 and October 1992.

Suspended Solids

Suspended solid concentrations were generally at low concentrations during all sample periods. Mainstem values ranged from below detection to 258 mg/L with average values of 7, 94 and 13 mg/L for sites W-10, W-4 and W-9 respectively (Table 3.5.1). The highest suspended sediment level (1,825 mg/L) occurred in August 1991 at Site W-5 located on a unnamed tributary flowing into Williams Creek from the south side of the valley downstream of the proposed mine site (Table 3.5.1 and Appendix 3).

Nitrates, Nitrites and Ammonia

Total ammonia concentrations were frequently below detection for mainstem and tributary sample sites (Appendix 3). Average values ranged from below detection in Nancy Lee Creek to 0.12 mg/L at the mainstem site W-9 in the upper watershed (Table 3.4.1). The maximum value observed was 0.44 mg/L during the December 1991 sample (Appendix 3).

Nitrates and nitrite concentrations were generally below or close to detection at the mainstem and tributary sites (Table 3.5.1 and Appendix 3).

3.5.1.2 Total and Dissolved Metals

Of the 32 elements included in the ICAP analysis, 12 elements were consistently below detection for total and dissolved components at the lower most site on Williams Creek (W-10; Appendix 3). These included antimony, beryllium, bismuth, cadmium, lead, lithium, molybdenum, selenium, silver, thorium, uranium and zirconium. These same elements were also not detectable in the Nancy Lee Creek samples (W-11) and the other tributary sites (Appendix 3). Elements which were frequently below detection included arsenic, chromium, cobalt, copper, phosphorous and vanadium (Appendix 5). Average total and dissolved values for selected elements commonly occurring in Williams Creek and tributary samples are summarized for the sample period in Tables 3.5.2 and 3.5.3 respectively. Selected elements are discussed below.

Aluminum

Aluminum was detectable in 10 of 17 samples collected from mainstem Williams Creek sites. Concentrations of detectable total aluminum ranged from 0.026 to 3.89 mg/L in the mainstem sites (Appendix 3 and Figure 3.5.4). The average total aluminum concentration for the lowermost Williams Creek mainstem site (W-10) was 0.18 mg/L (Table 3.5.2). Dissolved aluminum levels ranged from below detection (7 of 17 samples) to 0.043 mg/L (Appendix 3).

Aluminum was detectable in 13 of 33 samples collected from the tributary sites (Appendix 3). Average values for the sample period ranged from 0.02 to 3.23 mg/L mg/L (Table 3.5.2). The highest observed total concentration was 9.58 mg/L at Site W-5 with a corresponding dissolved level of 0.037 mg/L (Appendix 3; Tables 5.8

and 5.9). Total aluminum concentrations for selected tributary sites are presented in Figure 3.5.4.

Arsenic

Arsenic was detectable in 3 of 17 samples collected from mainstem Williams Creek sites and ranged from 0.08 to 0.16 mg/L (Figure 3.5.5). The average concentration of total arsenic at the lowermost Williams Creek mainstem site (W-10) was 0.05 mg/L (Table 3.5.2). Dissolved arsenic levels were below detection in all but one of the mainstem samples (0.06 mg/L; Appendix 3).

Arsenic was detectable in 7 of 33 samples collected from the tributary sites (Appendix 3). The highest observed total concentration was 0.016 mg/L at Sites W1 and W-7 (Figure 3.5.5). Dissolved values ranged from below detection (30 of 33 samples) to 0.012 mg/L.

Barium

Barium was detectable in all mainstem samples and ranged from 0.013 to 0.146 mg/L (Figure 3.5.6). The average concentration of total barium at the lower most Williams Creek mainstem site was 0.057 mg/L (Table 3.5.2). Dissolved barium levels ranged from 0.009 to 0.175 mg/L (Appendix 3).

Barium concentrations at the tributary sites ranged from 0.012 to 0.455 mg/L with the highest values occurring at Station W-1 and W-5

TABLE 3.5.2. Summary of total metal concentrations for sampling stations in the Williams Creek drainage based on average values calculated for the October 1989 to October 1992 period.

	AVERAGE VALUES									
SAMPLE SITE	Al	As	Cd	Ca	Cu	Fe	Pb	Mg	Na	Zn
W10	0.18	0.05	BD	37.0	0.003	0.35	BD	7.7	6.19	0.045
W4	1.14	0.05	BD	37.7	0.006	2.16	0.004	10.2	9.66	0.018
W2*	BD	BD	BD	44.2	BD	0.37	BD	12.8	12.8	0.033
W6*	BD	BD	BD	43.8	0.001	0.64	BD	13.9	14.3	0.108
W9	0.03	0.06	0.0003	41.1	0.002	0.66	BD	14.1	11.9	0.006
W11	0.06	0.07	BD	36.8	0.003	0.14	BD	8.7	8.7	0.006
W3	0.04	BD	BD	41.2	0.005	0.15	BD	7.9	6.5	0.014
W7	0.06	0.06	0.0003	40.9	0.005	2.10	0.004	8.3	6.2	0.010
W1	0.02	0.06	0.0003	60.6	0.002	0.14	BD	13.3	9.0	0.012
W5	3.23	0.06	0.0004	26.1	0.018	8.43	0.007	7.0	6.6	0.035
W8	NO	DATA	----	----	----	----	----	----	----	----

* data from only one sampling period.

TABLE 3.5.3. Summary of dissolved metal concentrations for sampling stations in the Williams Creek drainage based on average values calculated for the October 1989 to October 1992 period.

SAMPLE SITE	AVERAGE VALUES									
	Al	As	Cd	Ca	Cu	Fe	Pb	Mg	Na	Zn
W10	0.04	0.05	BD	35.4	0.002	0.11	BD	7.1	5.7	0.005
W4	0.02	0.06	BD	34.0	0.001	0.37	BD	9.1	8.7	0.004
W2	NO	DATA	----	----	----	----	----	----	----	----
W6	NO	DATA	----	----	----	----	----	----	----	----
W9	0.18	0.05	BD	39.5	BD	0.38	BD	12.9	10.2	0.004
W11	0.05	0.06	BD	34.9	0.002	0.10	BD	8.4	6.9	0.003
W3	0.03	BD	BD	35.0	0.001	0.14	BD	7.3	6.0	0.004
W7	0.02	0.06	BD	37.5	0.002	1.98	BD	7.3	6.2	0.005
W1	BD	0.06	BD	59.4	BD	0.05	BD	12.8	9.5	0.004
W5	0.04	0.005	BD	23.6	0.002	0.62	BD	5.9	5.6	0.005
W8	NO	DATA	----	----	----	----	----	----	----	----

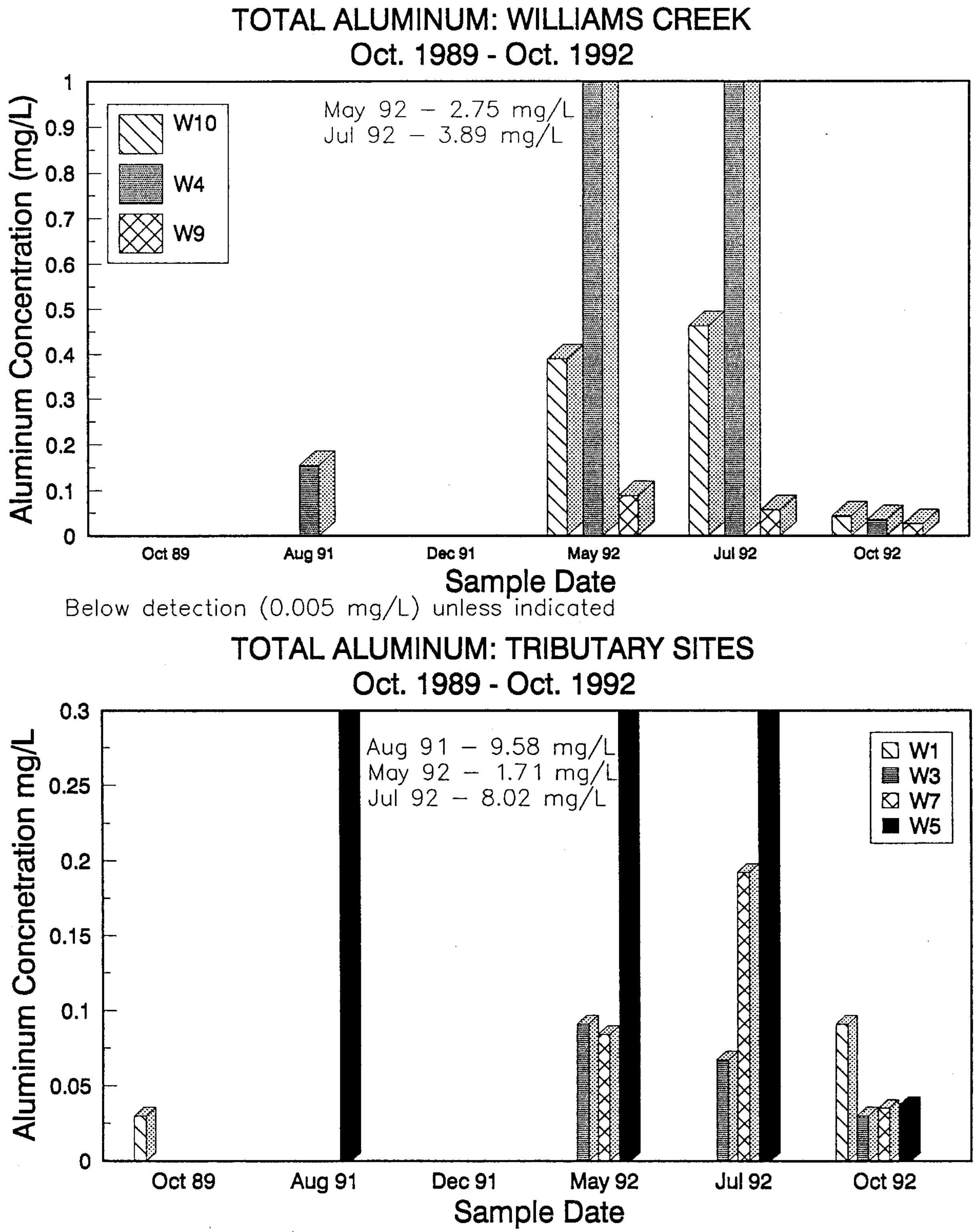
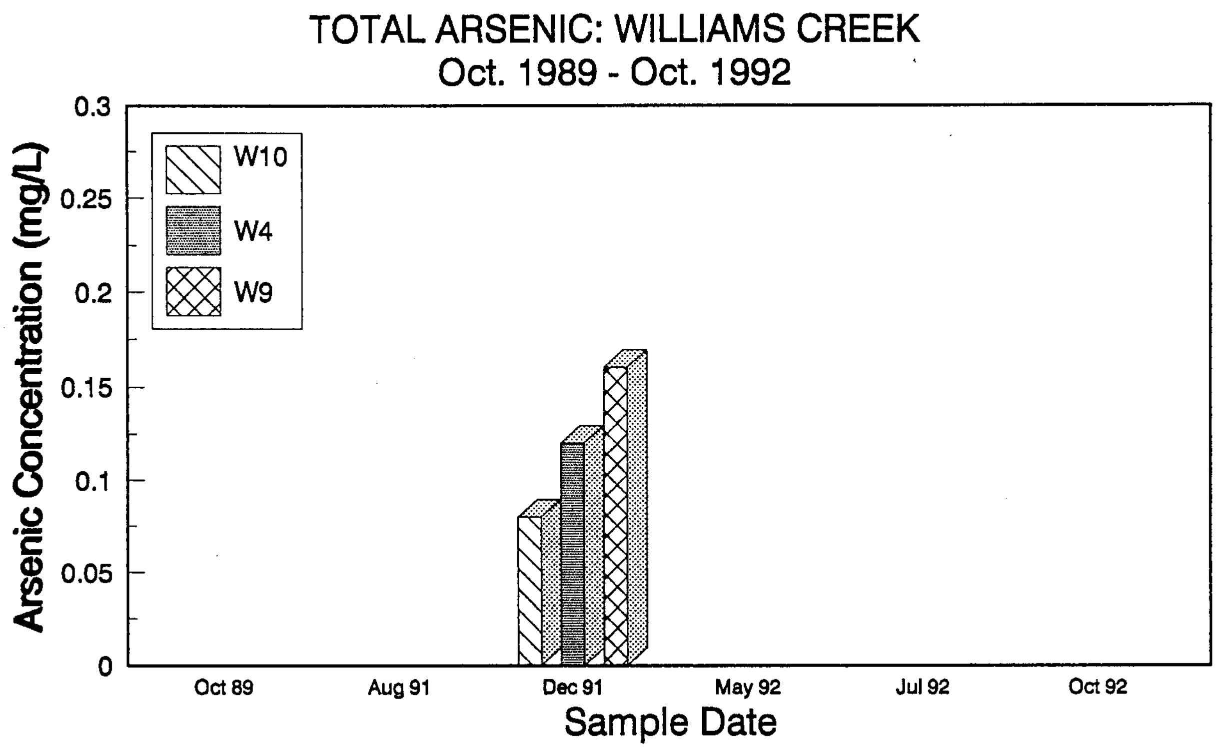


FIGURE 3.5.4 Concentration of total aluminum for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.



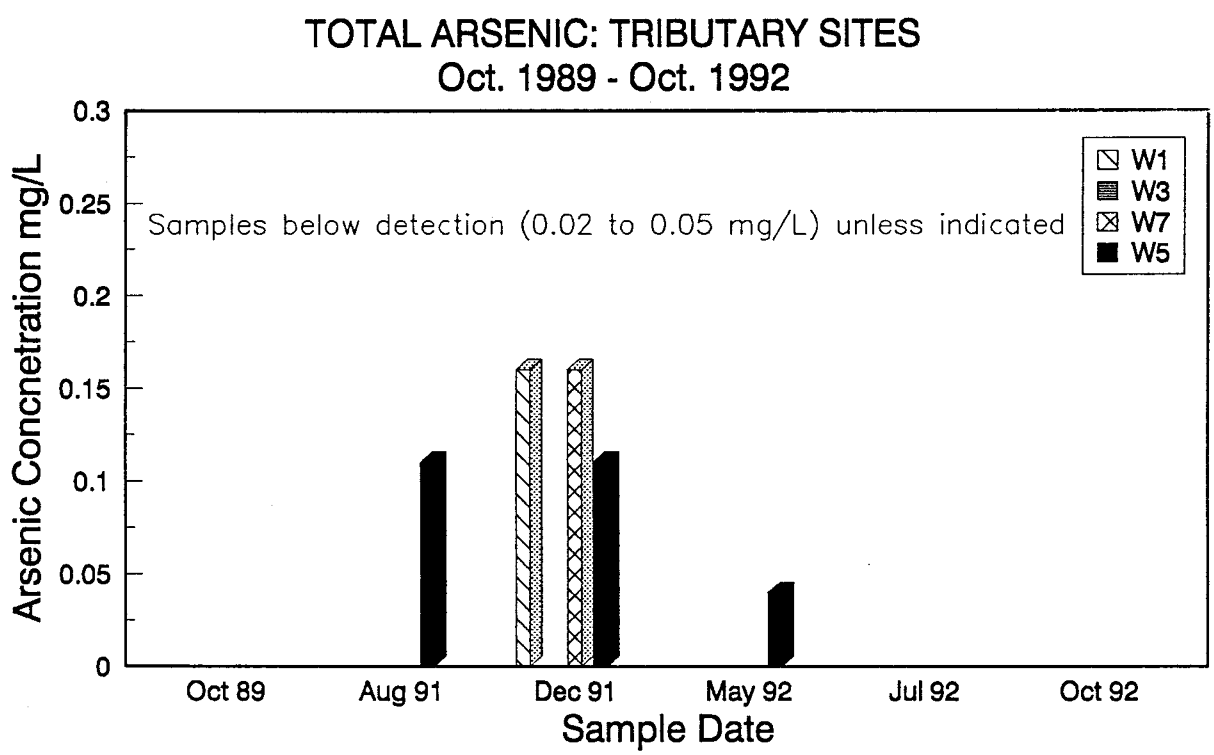


FIGURE 3.5.5 Concentration of total arsenic for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.

(Figure 3.5.6). Dissolved values ranged from 0.010 to 0.067 mg/L.

Cadmium

Cadmium was below detection for most samples. A total concentration of 0.0004 mg/L was observed at one mainstem site during May 1992 (Figure 3.5.7). Cadmium was present at Site W-5 on two occasions and once at W-1 (Figure 3.5.7) with a maximum value of 0.0006 mg/L.

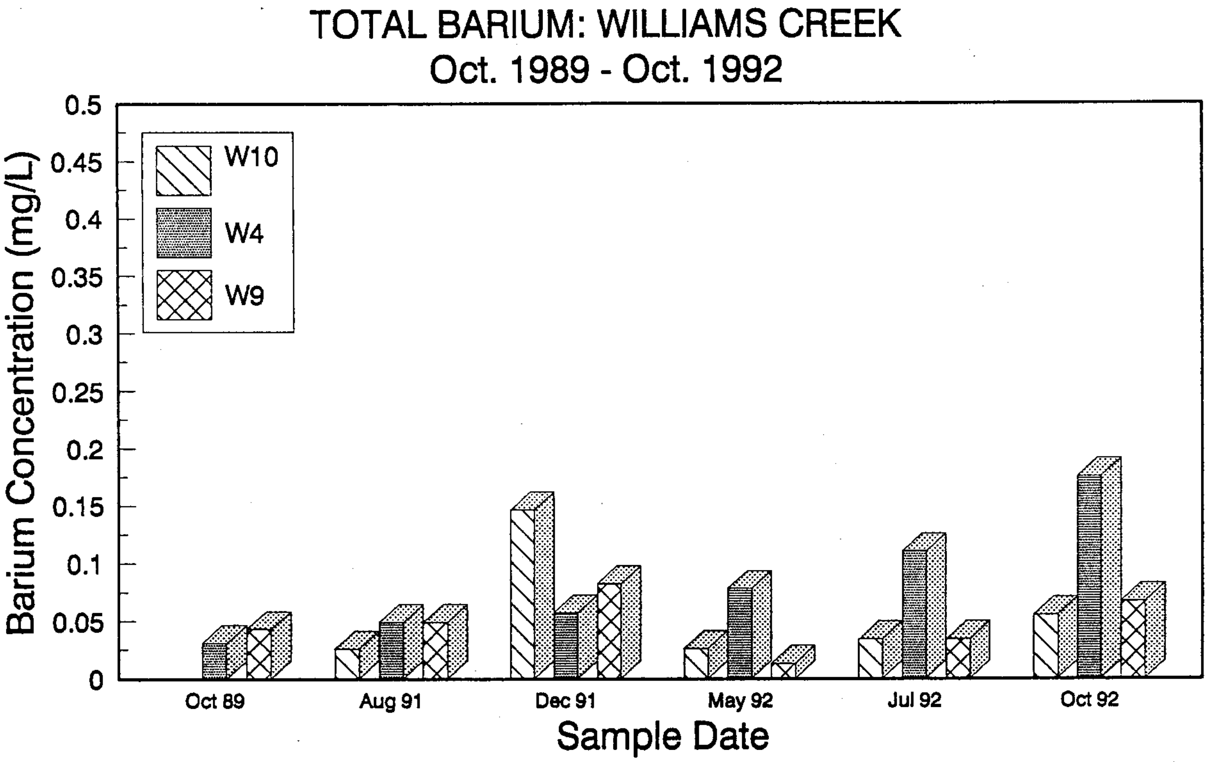
Chromium

Chromium was detectable in 11 of 17 samples collected from mainstem Williams Creek sites. Concentrations of total aluminum ranged from 0.002 to 0.012 mg/L in the mainstem sites (Figure 3.5.8). The average concentration for the lowermost site was 0.003 mg/L (Table 3.5.2) with a maximum value of 0.009 mg/L (Appendix 3; Table 3.15). Dissolved chromium levels ranged from below detection (12 of 17 samples) to 0.043 mg/L.

Chromium was detectable in 15 of 33 samples collected from the tributary sites (Figure 3.5.8). The highest observed total concentration was 0.05 mg/L at Site W-5. Dissolved values ranged from below detection (29 of 33 samples) to 0.007 mg/L.

Cobalt

Cobalt was detectable in 9 of 17 samples collected from mainstem Williams Creek sites. Concentrations of total cobalt ranged from 0.001 to 0.004 mg/L in the mainstem sites (Figure 3.5.9). The lower



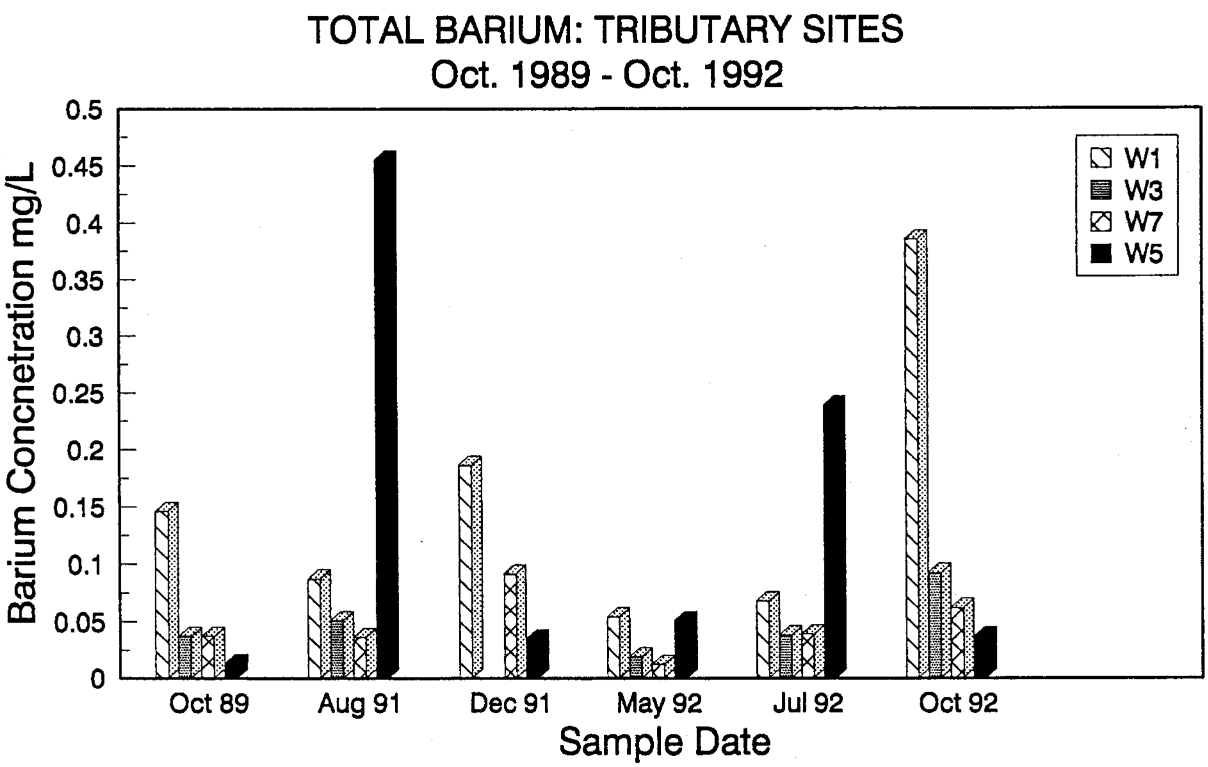
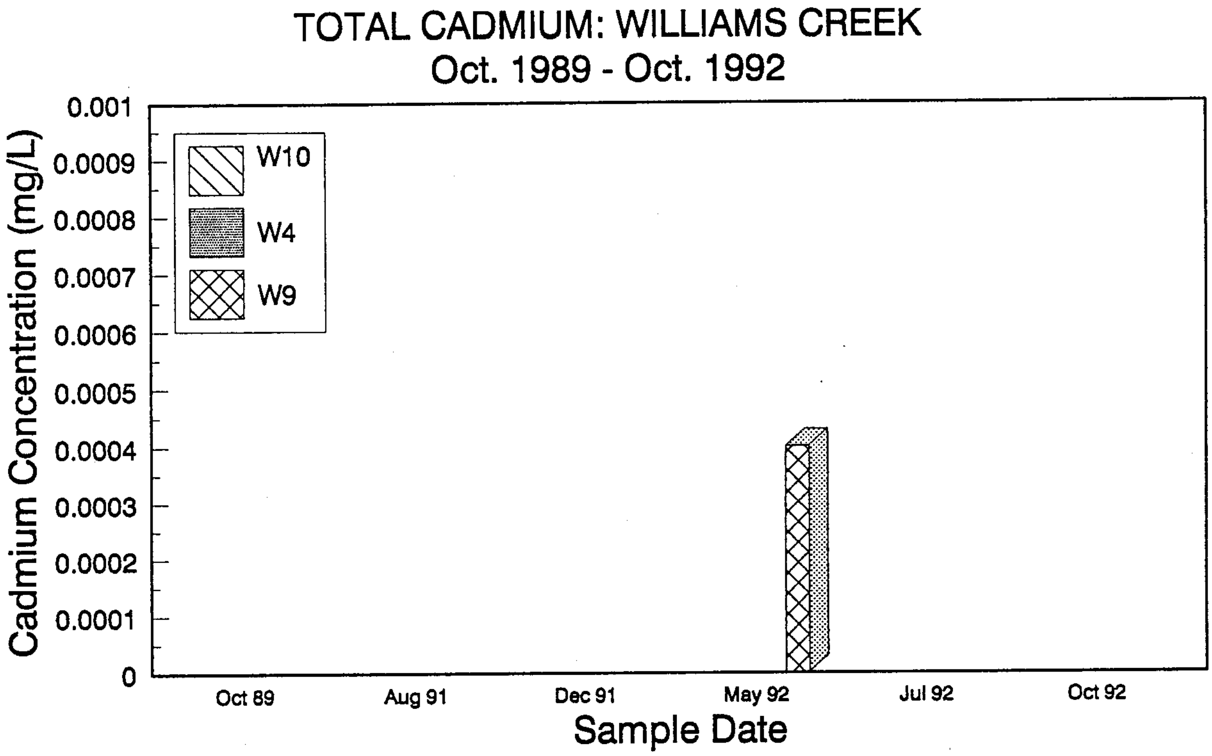


FIGURE 3.5.6 Concentration of total barium for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.



Samples below detetection (0.0002 to 0.0003 mg/L) unless indicated

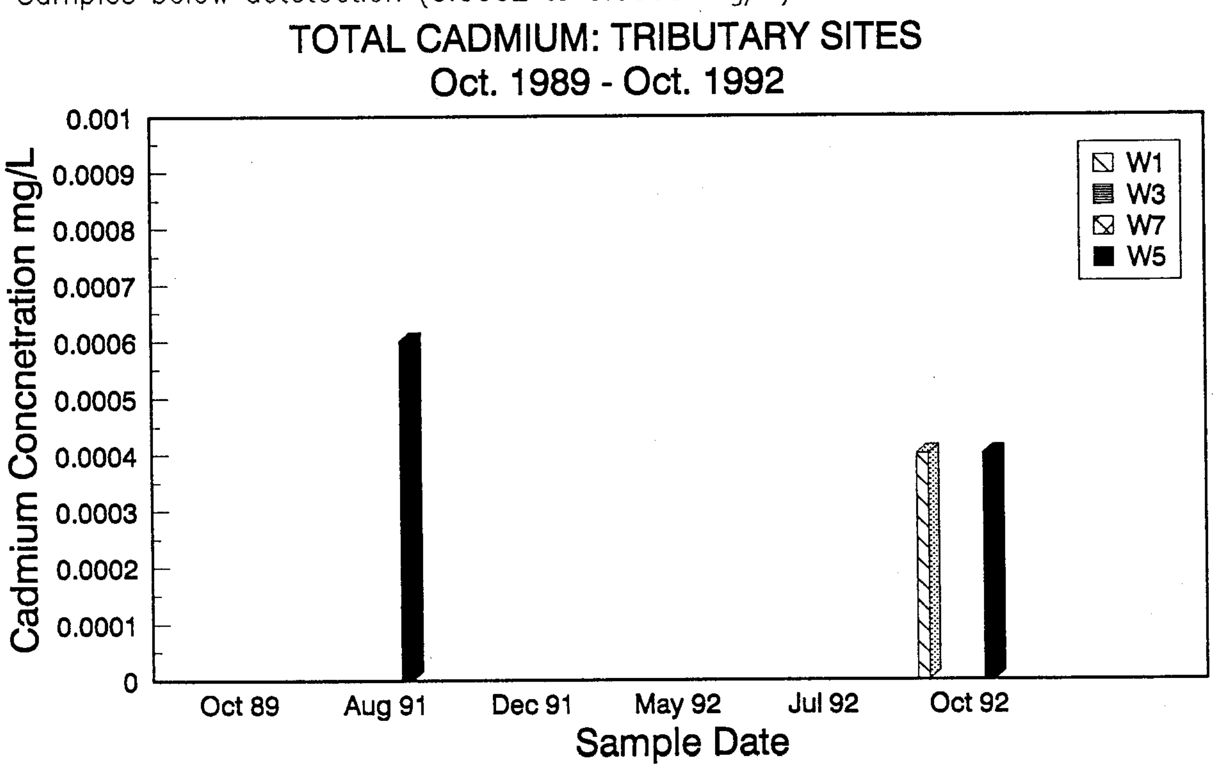


FIGURE 3.5.7 Concentration of total cadmium for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.

most mainstem site on Williams Creek had an average value of 0.001 mg/L and a maximum value of 0.002 mg/L (Table 3.5.2). Dissolved cobalt levels ranged from below detection (12 of 17 samples) to 0.004 mg/L (Appendix 3).

Cobalt was detectable in 10 of 33 samples collected from the tributary sites (Appendix 3). The highest observed total concentration was 0.016 mg/L at Site W-5 (Figure 3.5.9). Dissolved values ranged from below detection (27 of 33 samples) to 0.007 mg/L.

Copper

Copper was detectable in 9 of 17 samples collected from mainstem Williams Creek sites. Concentrations of total copper ranged from 0.001 to 0.014 mg/L in the mainstem sites (Figure 3.5.10). The lowermost Williams Creek mainstem site had an average value of 0.003 mg/L and a maximum value of 0.005 mg/L (Appendix 3; Table 3.15). Dissolved copper was generally below detection (13 of 15 samples) and had a high value of 0.005 mg/L at Site W-10 (Appendix 3; Table 3.15). Average values for total copper are presented in Table 3.5.2.

Copper was detectable in 14 of 28 tributary samples (Figure 3.5.10) with a range of 0.001 to 0.059 mg/L. The highest observed total copper concentration for the tributary sites was observed at Site W-5. Dissolved values ranged from below detection (16 of 23 samples) to 0.009 mg/L (Appendix 3).

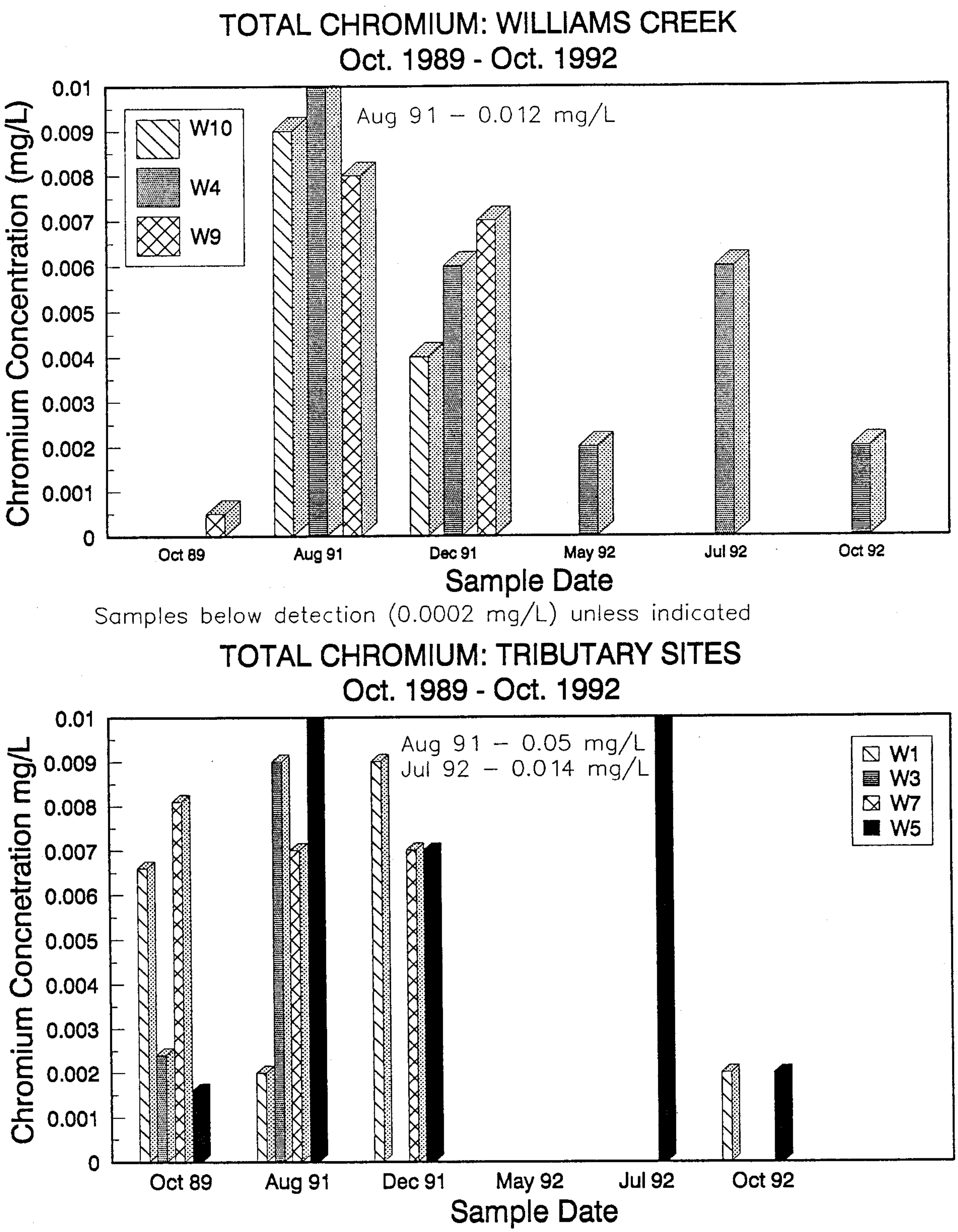
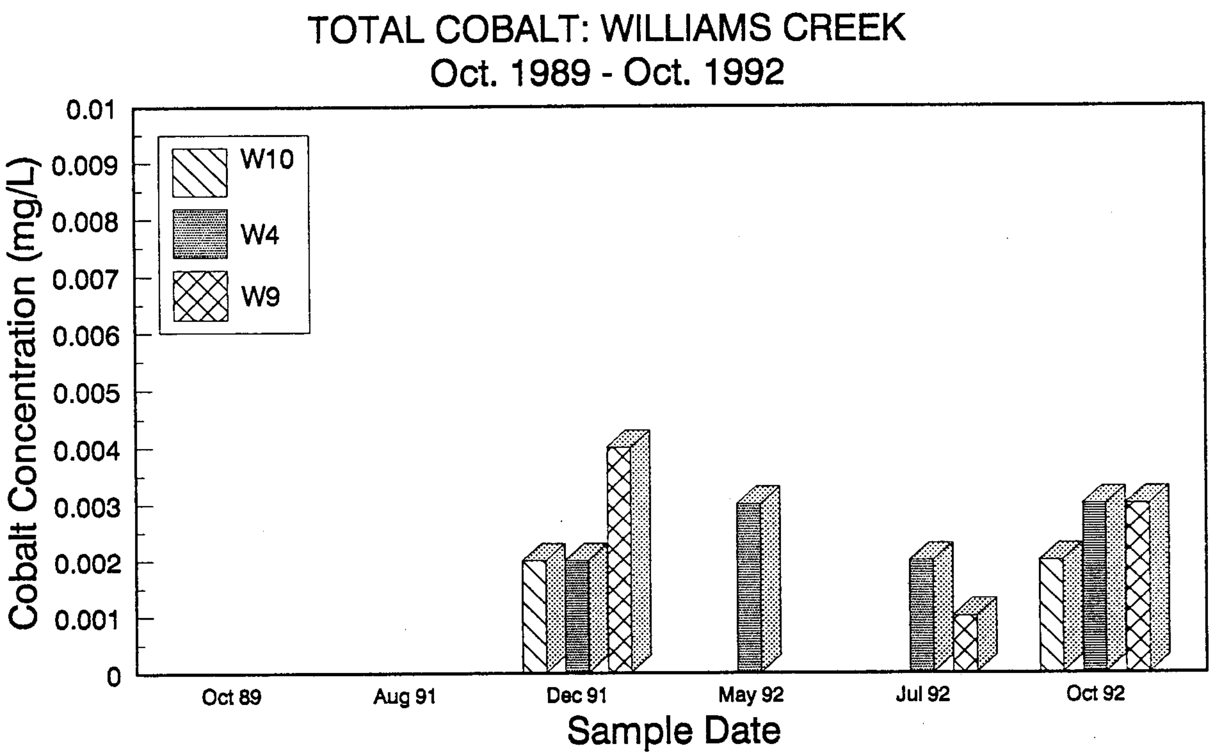


FIGURE 3.5.8 Concentration of total chromium for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.



Samples below detection (0.0005 mg/L) unless indicated

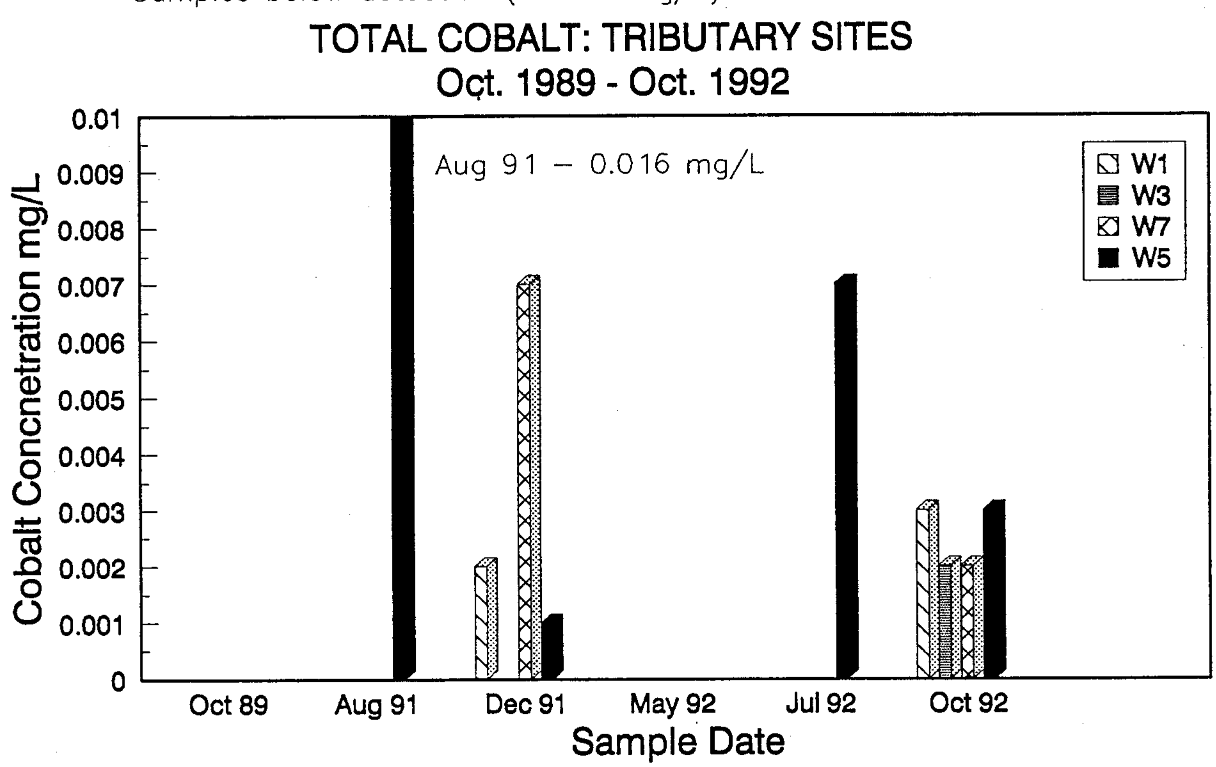


FIGURE 3.5.9 Concentration of total cobalt for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.

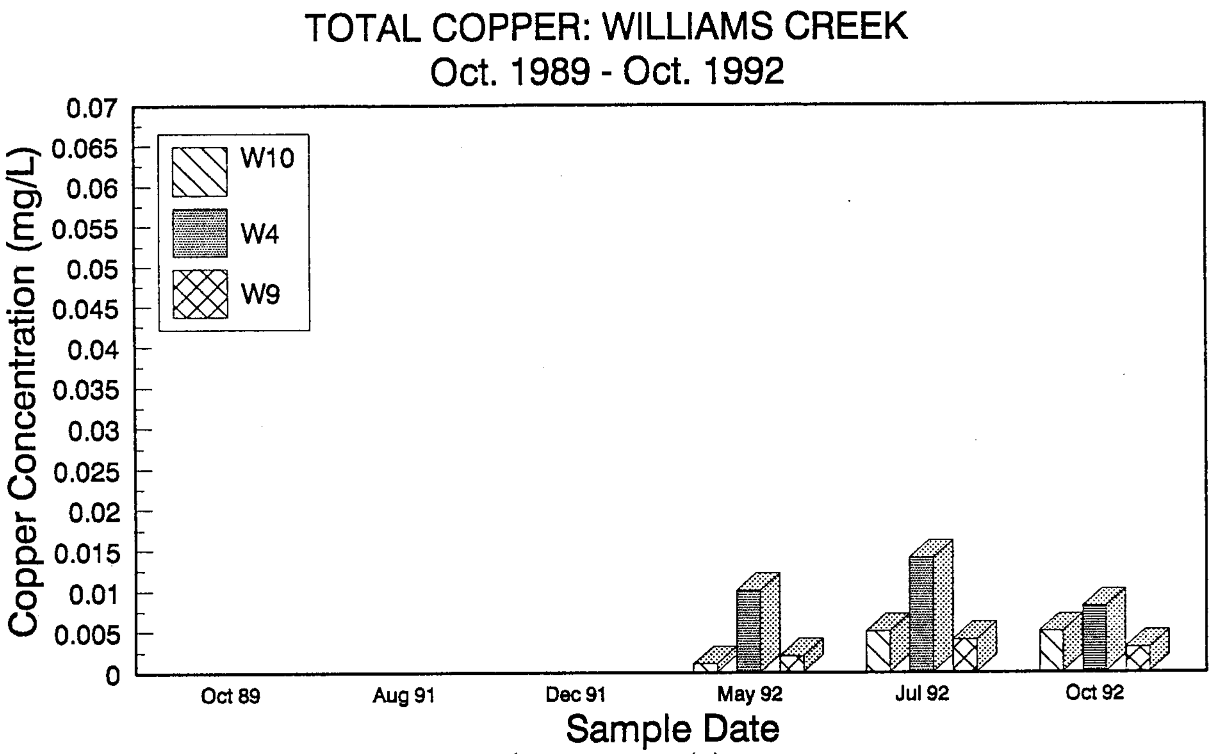
Iron

Iron was detectable in all samples with mainstem total values ranging from 0.07 to 3.68 mg/L (Figure 3.5.11). The average concentration of total iron in Lower Williams Creek (W-10) was 0.354 with a high value of 0.824 mg/L (Appendix 3; Table 3.15). Dissolved iron ranged from 0.022 to 0.628 mg/L and was detectable in all mainstem samples (Appendix 3).

Total iron concentrations for the tributary sites ranged from 0.037 to 31.4 mg/L with the highest values occurring at sites W-5 and W-7 (Figure 3.5.11).

Zinc

Zinc was detectable in 15 of 17 samples collected from mainstem Williams Creek sites. Concentrations of total zinc ranged from 0.003 to 0.195 mg/L in the mainstem sites (Figure 3.5.12). The average value at the lowermost mainstem site was 0.045 mg/L with a maximum value of 0.195 mg/L (Appendix 5; Table 5.15). Dissolved zinc levels ranged from below detection (3 of 15 samples) to 0.01 mg/L (Appendix 3). Zinc was detectable in most samples collected from the tributary sites (Figure 3.5.12). The highest observed total zinc concentration for the tributary sites was 0.0661 mg/L at Site W-5. Dissolved values ranged from below detection (3 of 22 samples) to 0.010 mg/L. Total and dissolved zinc values averaged over the sample period are compared for mainstem and tributary sites in Figure 3.5.13.



Samples below detection (0.0005 mg/L) unless indicated

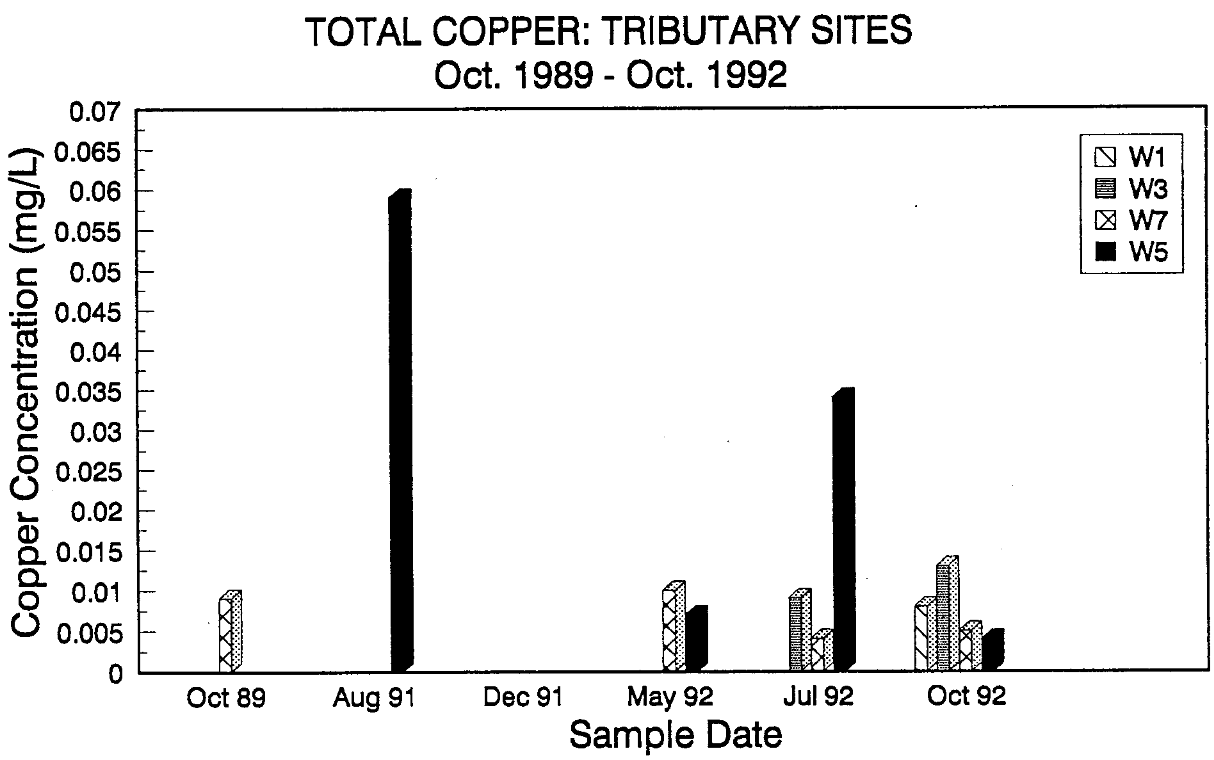


FIGURE 3.5.10 Concentration of total copper for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.

3.5.1.3 Summary of Background Water Quality

The water quality data collected in this study will provide a baseline from which potential impacts can be assessed once the mine is operational. These data will also be important to regulatory agencies setting the mine discharge limits for the project. The Canadian Council of Resource and Environment Ministers (CCREM) guidelines for water quality in Canada are generally considered to be a conservative limit set for the protection of fish and the aquatic ecosystem based on available data for acute and chronic toxicity responses of aquatic organisms. Although these guidelines are frequently used as water quality objectives for fish bearing streams, mine discharge limits set by the Yukon Territorial Water Board are more typically in line with Metal Mine Liquid Effluent Regulations.

Baseline data on total metal concentrations in Williams Creek have been compared to the recommended guideline values established by the CCREM for waters of similar and pH in Table 3.5.4. Two mainstem sites have been selected for this comparison, representing fish bearing waters of lower Williams Creek (Site W-10) and mainstem conditions in the upper watershed (W-4) below the proposed mine site.

Of the nine elements compared in Table 3.4.5, average background concentrations (October 1989 to October 1992) of total aluminum, arsenic, iron, and zinc in lower Williams Creek exceeded the

TABLE 3.5.4 Average concentrations of selected parameters for Site W-10 in lower Williams Creek and Site W-4 in the upper watershed compared to CCREM guideline values for waters of similar pH and hardness. (Values reported are totals).

PARAMETER	WILLIAMS W-10	WILLIAMS W-4	CCREM GUIDELINE
Hardness	75 to 225 mg/L as $CaCO_3$		
pH	7.9		6.5 to 9.0
Aluminum	0.181 mg/L	0.020 mg/L	0.1 mg/L
Arsenic	0.052 mg/L	0.058 mg/L	0.05 mg/L
Cadmium	<0.0004 mg/L	<0.0004 mg/L	0.0008 to 0.0013 mg/L
Chromium	0.003 mg/L	0.002 mg/L	0.02 mg/L * 0.002 mg/L **
Copper	0.003	0.001	0.002 to 0.003
Iron	0.354	0.374	0.3 mg/L
Lead	<0.005	<0.005	0.002 to 0.004 mg/L
Nickel	0.004	0.002	0.065 to 0.110 mg/L
Silver	<0.001	<0.001	0.0001 mg/L
Zinc	0.045	0.004	0.03 mg/L

recommended CCREM guideline. The average total concentration of copper was the same as the higher guideline value for a water hardness of 120 to 180 mg/L as $CaCO^3$. Total chromium concentrations exceeded the recommended CCREM guideline for protection of the aquatic ecosystem but were below the limit for fish protection. Cadmium was not detected in the mainstem site. The CCREM guideline for silver is 0.001 mg/L which is below the detection limit for the 1989 to 1992 samples. Detection limits for lead were also higher than the CCREM guideline value.

Similar to the lower site on Williams Creek, average total concentrations of arsenic, chromium iron and zinc at the upper site (W-4) also exceeded the CCREM guideline. The average total concentration of aluminum and copper was lower in upper Williams Creek and did not exceed the CCREM guidelines.

The CCREM guidelines are based on total metal concentrations. However, in many cases it is the dissolved component which is biologically available and of most concern with respect to chronic and acute toxicity in aquatic organisms. Data collected in this study indicated a high degree of variation in the ratio of the dissolved and total components throughout the sample period as well as between elements. A comparison of average dissolved and total values for lower Williams Creek is presented in Table 3.5.5.

TABLE 3.5.5 Comparison of average total and dissolved metal concentrations for Site W-10 in lower Williams Creek based on data collected between October 1989 and October 1992.

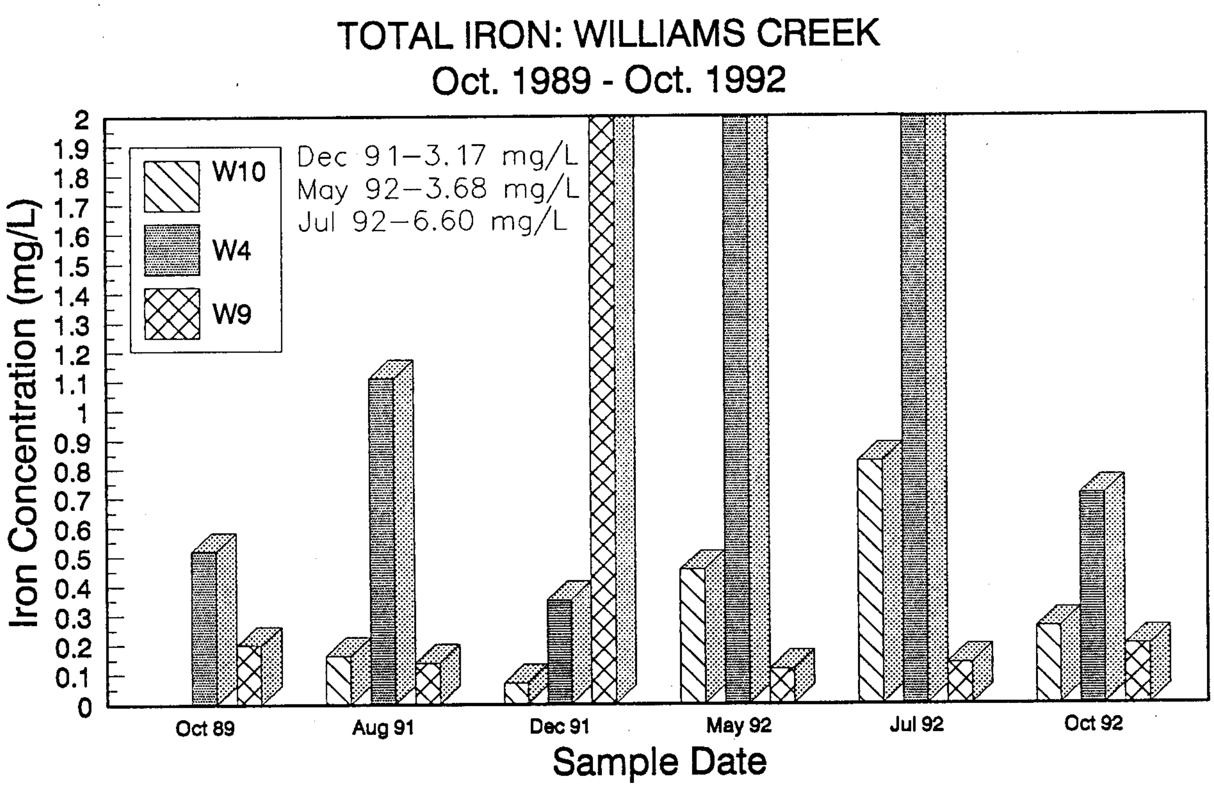
ELEMENT	TOTAL CONCENTRATION (mg/L)	DISSOLVED CONCENTRATION (mg/L)	PERCENT DISSOLVED
Al	0.180	0.035	20%
As	0.052	0.048	95%
Cd	BD	BD	
Cr	0.003	0.002	66%
Cu	0.003	0.002	66%
Fe	0.0354	0.113	32%
Ni	0.004	0.003	75%
Zn	0.045	0.005	11%

Water hardness values for Williams Creek indicate a moderate degree of buffering capacity with respect to potential metal toxicity. Natural buffering capacity would be lowest during periods of low water hardness. In lower Williams Creek, water hardness values are generally lowest during period of high stream discharge when the relative contribution of surface water is high compared to the ground water component (Gibson 1991a).

Further discussion of water quality in Williams Creek have been presented in earlier project reports (Burns and Gibson 1989; Gibson 1990a and b, 1991a and b).

3.5.2 Sediment Quality

The analysis of sediments collected from Williams and Nancy Lee creeks during July and August 1992 indicate that the major constituents are iron, aluminum, calcium, and magnesium. The minor constituents include, in decreasing order of relative concentration, zinc, chromium, copper, nickel, lead and cadmium. Of the 32 elements analyzed, seven were below detection in all samples; these included antimony, arsenic, bismuth, molybdenum, selenium and uranium. Samples collected from the mainstem of Williams Creek during July 1992 indicated relatively small variation in the concentration of all components between upstream and downstream sites (Figure 3.5.13). Particle size distributions for the July samples are presented in Figure 3.5.14. A second set off samples collected from Williams and Nancy Lee creeks during August 1992



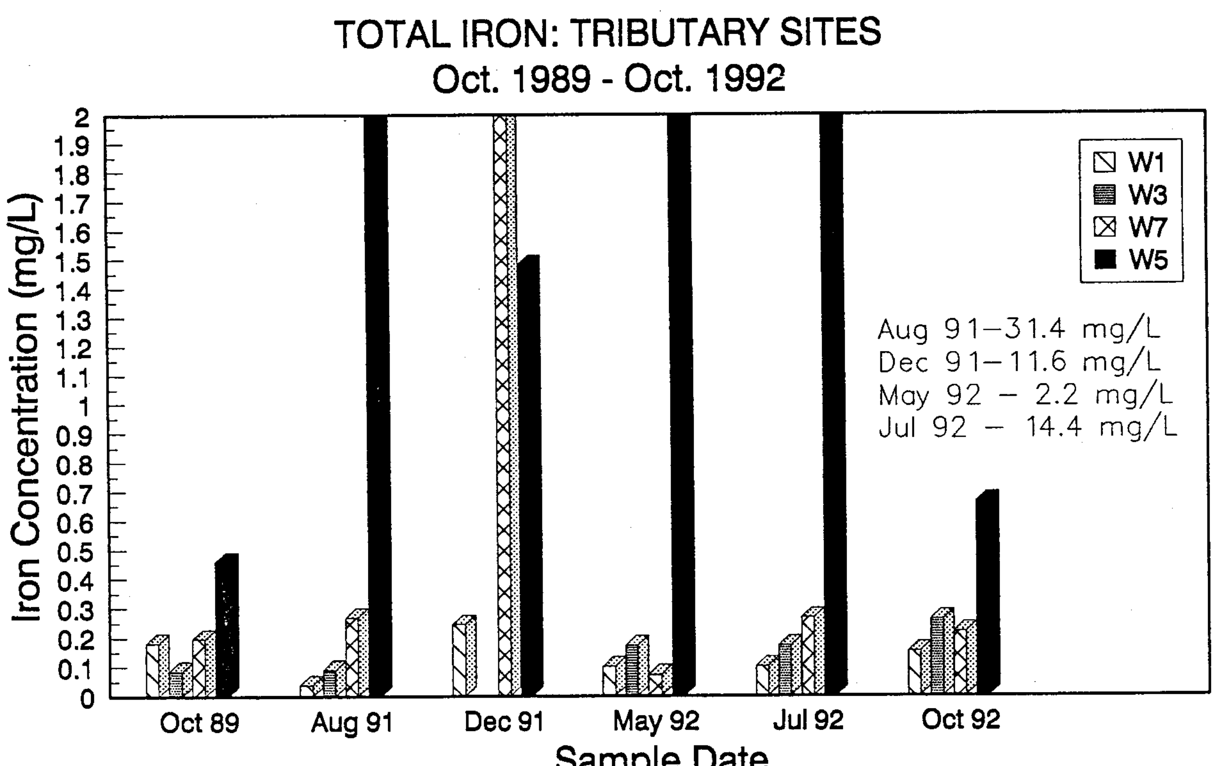


FIGURE 3.5.11 Concentration of total iron for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.

generally indicated the same sediment composition with respect to the relative concentration of major and minor constituents (Figure 3.5.15). A summary of the range of concentrations found for each element is presented in Table 3.5.5.

Results of the sediment analysis for the major constituents from the Williams and Nancy Lee creek samples are compared to results from Big Creek located 60 kilometres west of Williams Creek in Table 3.5.6). In all cases, the concentrations of aluminum, calcium, iron and magnesium are substantially lower in the Williams Creek sites than the Big Creek sites.

TABLE 3.5.5. Summary of metal concentrations in sediments collected from Williams and Nancy Lee Creeks - July and August 1992.

PARAMETER	CONCENTRATION RANGE (ug/g)	PARAMETER	CONCENTRATION RANGE (ug/L)
Aluminum	6750-9980	Potassium	
Barium	67-201	Lead	5.0-9.0
Beryllium	0.2-0.3	Lithium	BD-200
Calcium	6550-9770	Selenium	BD
Cadmium	BD-0.3	Silicon	270-760
Cobalt	5.2-7.4	Sodium	230-540
Chromium	16.4-22.4	Strontium	46.6-70.7
Copper	10.1-75.8	Thorium	BD-7.0
Iron	13300-21800	Titanium	539-704
Potassium	940-1400	Uranium	BD
Magnesium	3730-5370	Vanadium	30-52
Manganese	184-412	Zinc	30.8-48.0

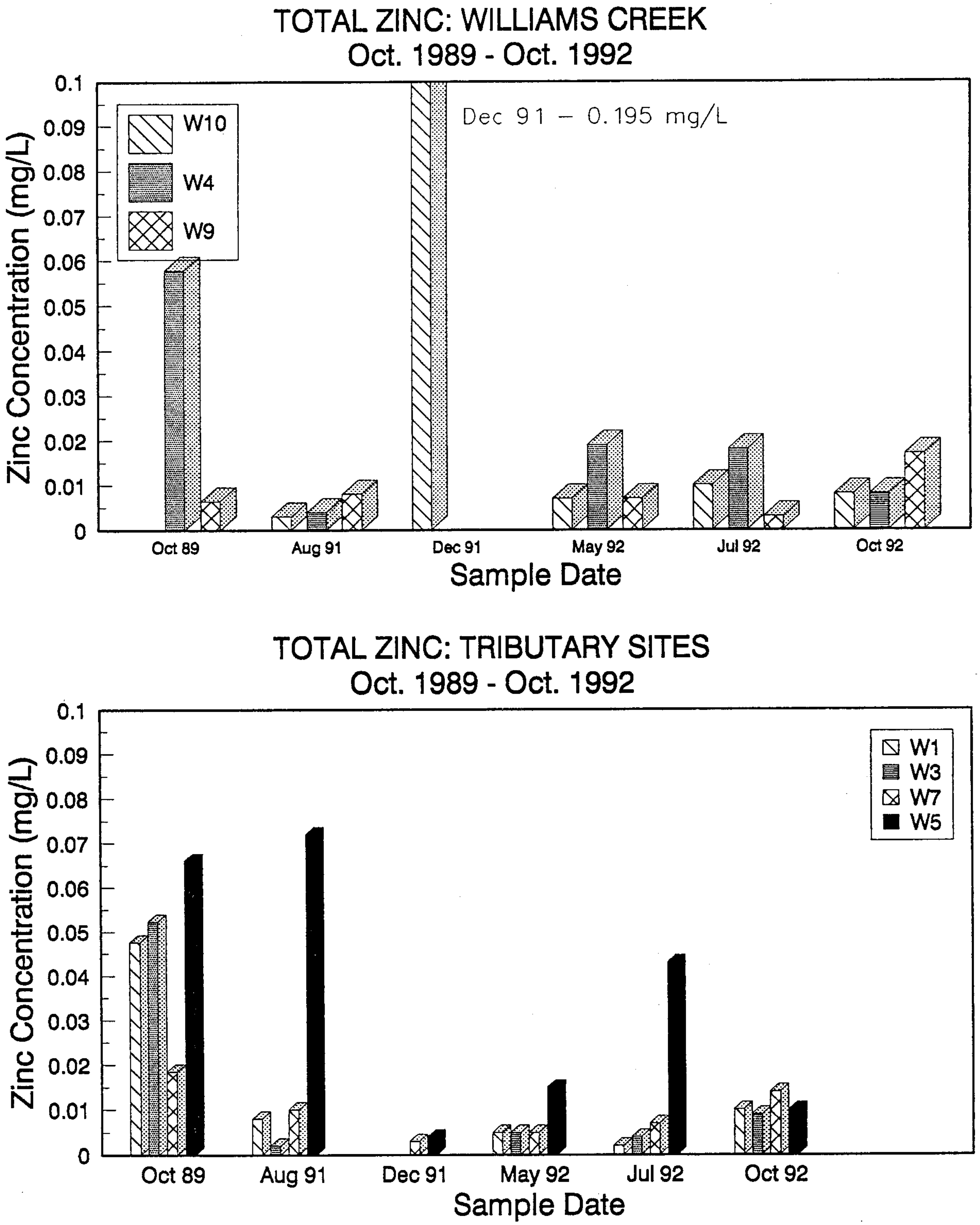
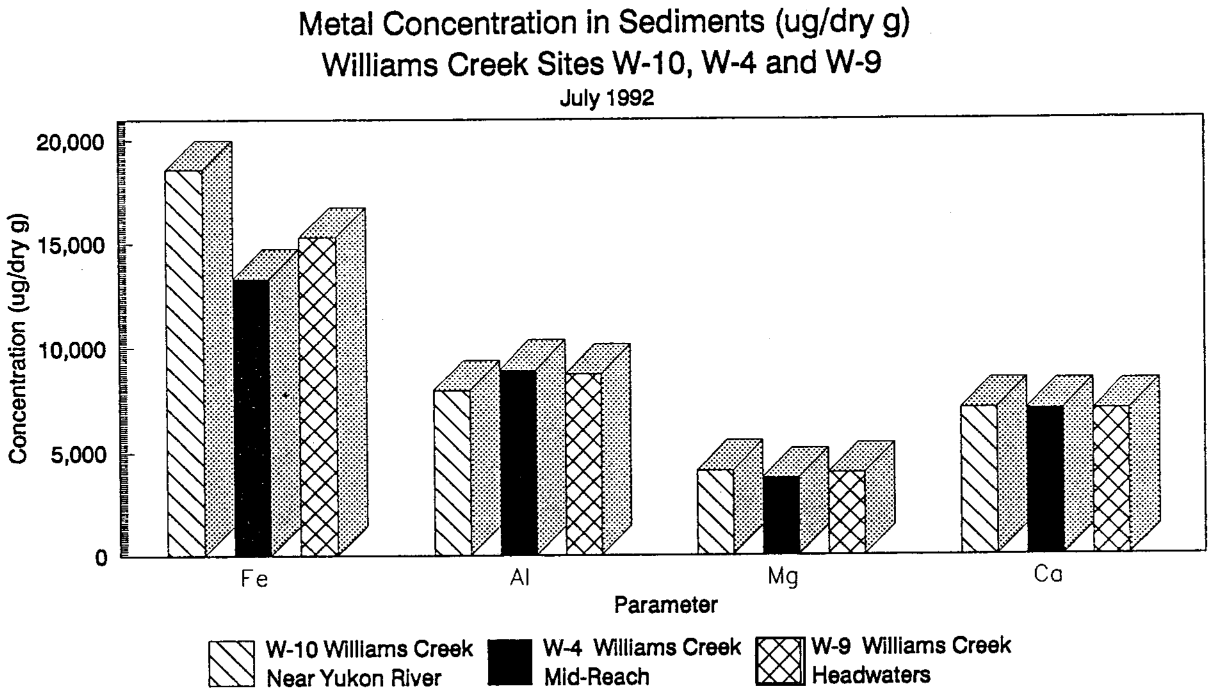


FIGURE 3.5.12 Concentration of total zinc for Williams Creek mainstem and selected tributary sites between October 1989 and October 1992.

TABLE 3.5.6 Guidelines for sediment contaminants in Ontario compared to the range in metal concentrations found at the Williams Creek Sites for July and August, 1992 samples.

ELEMENT	Ontario Guideline		WILLIAMS CREEK DRAINAGE	
	Lowest Effect Level ug/g	Severe Effect Level ug/g	Williams Creek Mains-tem	Nancy Lee Creek
Arsenic	6	33	BD	BD
Cadmium	0.6	10	BD - 0.3	0.3
Chromium	26	110	16.4 - 22.4	17.7
Copper	16	110	10.1 - 75.8	11.4
Iron	21,200	43,800	13300-21800	15,000
Manganese	460	1,100	184 - 412	190
Zinc	120	820	30.8 - 48.0	30.8
Lead	31	250	5.0 - 9.0	7.0

The Ontario Ministry of Environment has established sediment quality guidelines or arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel and zinc (Jaagumagi 1992). These guidelines have been developed using a Screening Level Concentration method developed by Persaud et al., (1992) which is based on observed sediment contaminant concentrations and the co-occurrence of benthic invertebrate species. Metal concentrations are plotted against species presence or absence and the 5th and 95th percentile values are taken as Lowest Effect Level (LEL) and Severe Effect Level (SEL) respectively. These guideline values are presented in comparison to the observed range in metal concentrations for the Williams Creek sites in Table 3.5.6.



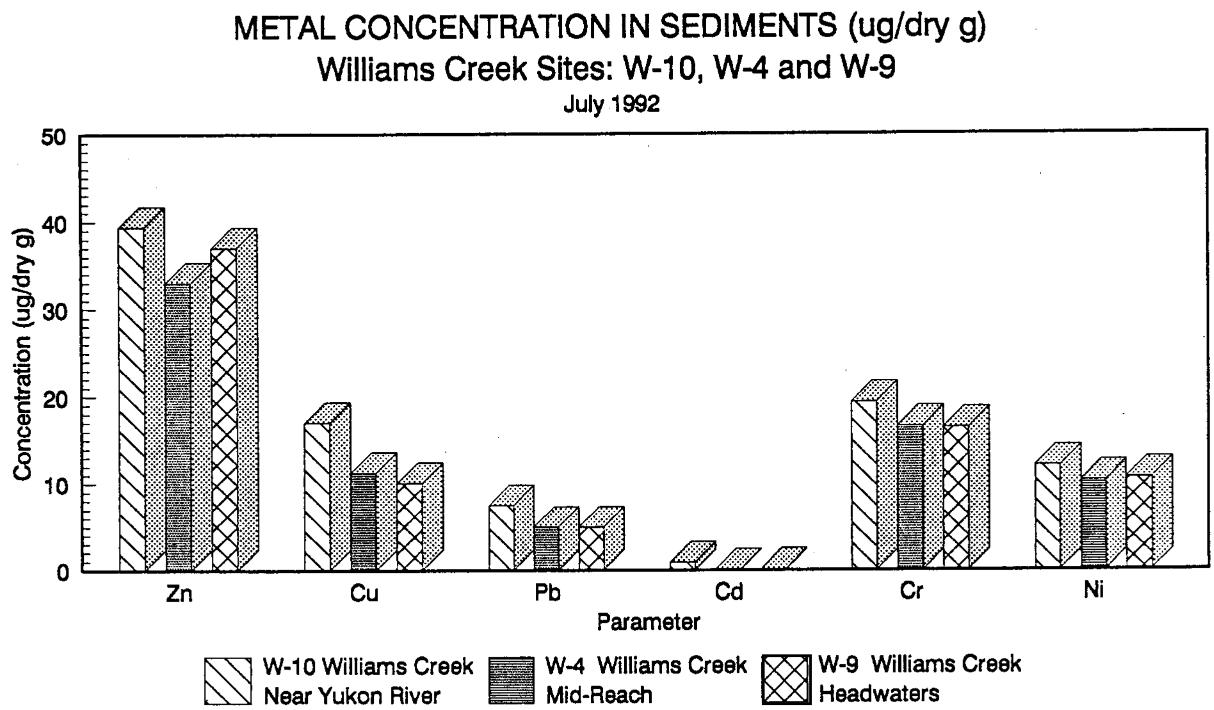


FIGURE 3.5.13 Analysis of sediment samples collected from Williams Creek mainstem sites during July 1992.

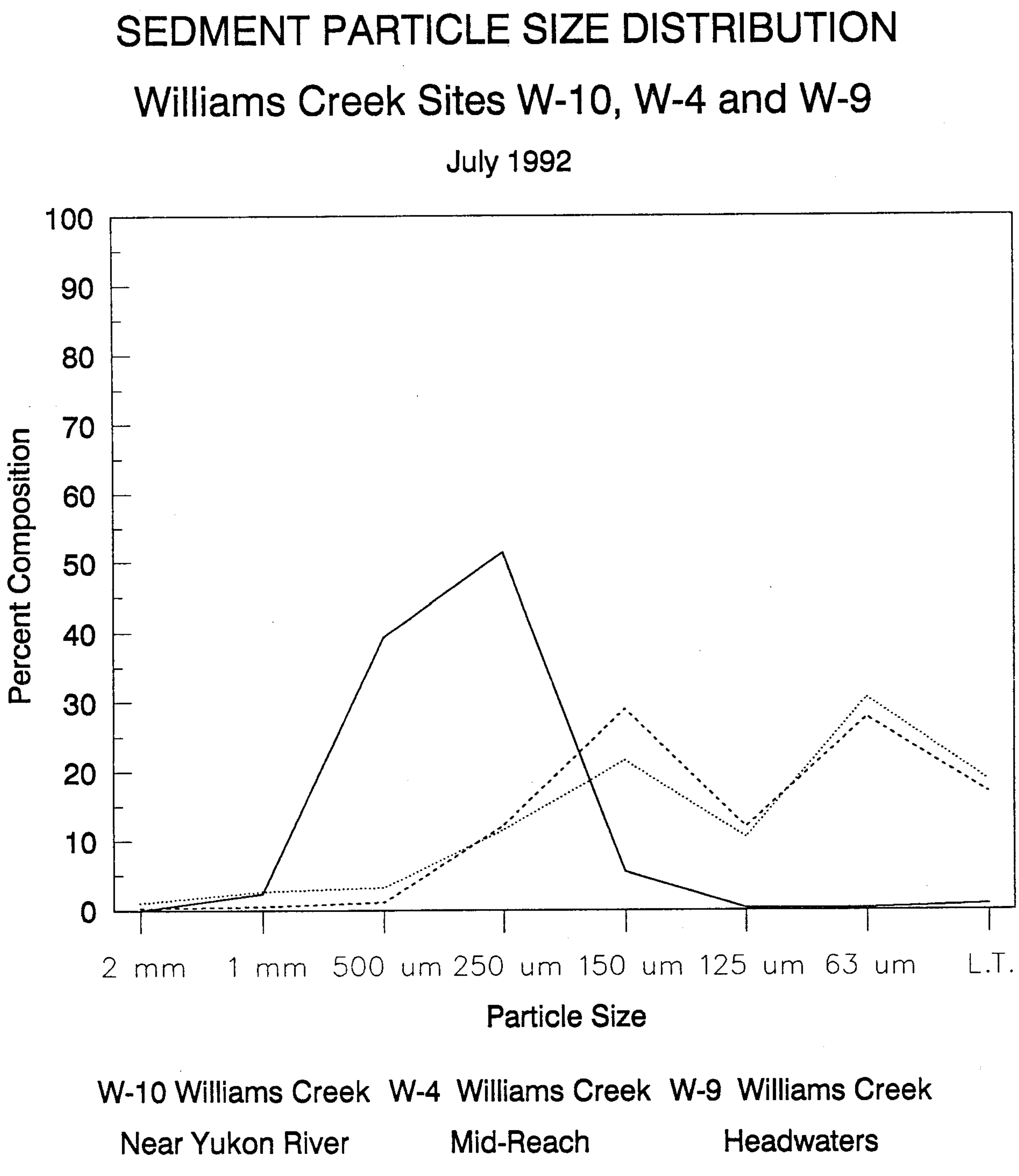
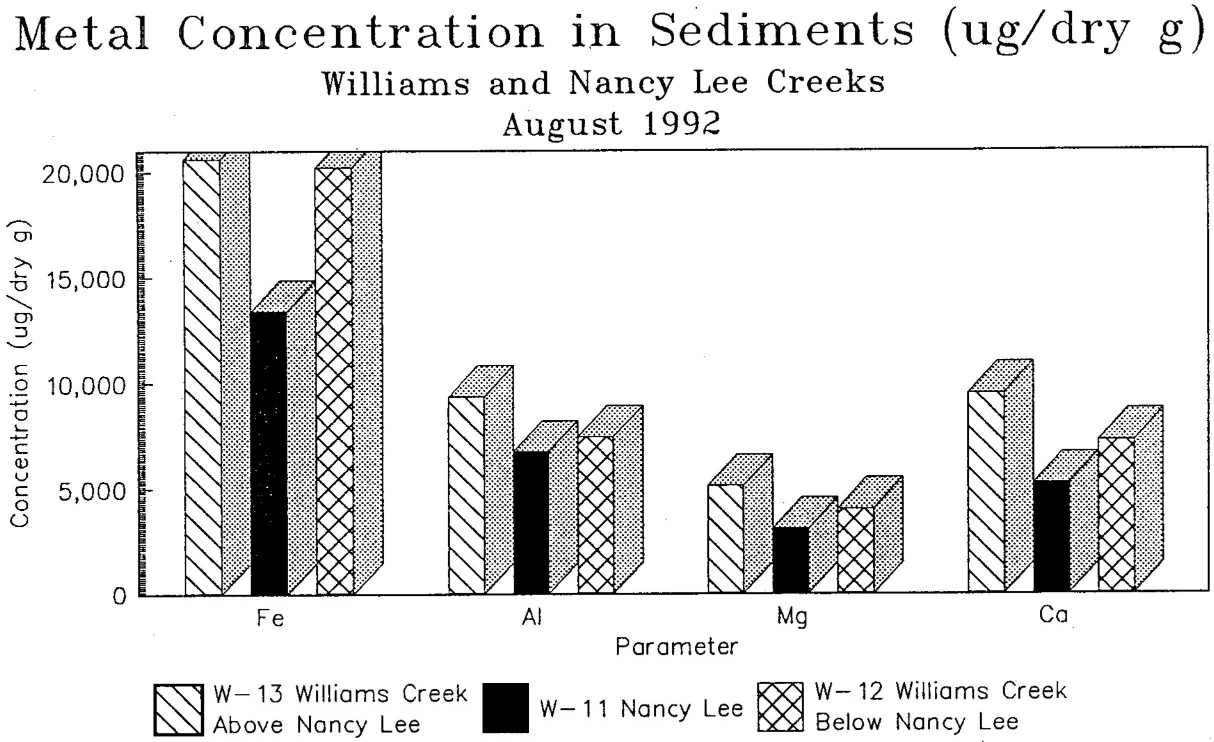


FIGURE 3.5.14 Particle size distribution for sediment samples collected from Williams Creek mainstem sites during July 1992.



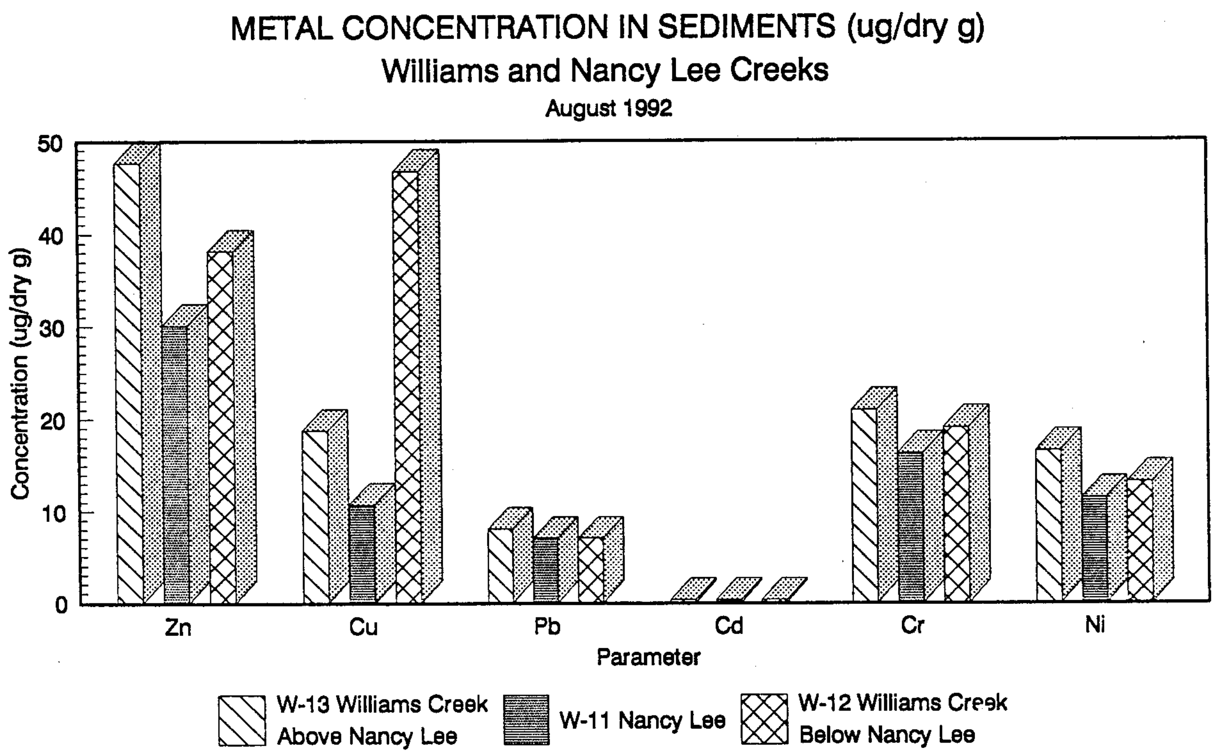


FIGURE 3.5.15 Analysis of sediment samples collected from Williams and Nancy Lee creeks during August 1992.

Concentrations of arsenic, cadmium, chromium, iron, manganese, zinc and lead at the Williams Creek mainstem and Nancy Lee sites were all below the lowest effect guideline level established by the Ontario Ministry of Environment. One of the mainstem Williams Creek samples collected from below Nancy Lee Creek during August 1992 had an unusually high copper value which was above the LEL guideline value (Table 3.5.6).

3.6 Aquatic Resources

This section of the report presents a description of habitat characteristics in the Williams Creek study area, describes the abundance and distribution of aquatic invertebrates and fish and provides an assessment of habitat use and importance within the study area. This report supersedes the earlier report titled "Initial Assessment of Aquatic Resources in Williams Creek" prepared in 1992.

3.6.1 Habitat Description

3.6.1.1 Williams Creek

Williams Creek originates at an elevation of approximately 890 m and flows north east into the Yukon River confluence at 482 m. Valley walls are generally stable through the watershed and the active channel is relatively stable throughout the watershed with no signs of recent lateral movement. There are some areas in the upper watershed where mass wasting in permafrost banks was evident during the summer of 1992. There is one major tributary (Nancy Lee

Creek) to Williams Creek located approximately 1.2 km upstream from the Yukon River (Figure 3.6.1).

Williams Creek has been designated into four reaches based on habitat characteristics. Reach habitat characteristics are presented in Figure 3.6.1. Physical characteristics are summarized in Tables 3.6.1 and 3.6.2 and are further described below.

Reach 1

Reach 1 extends approximately 1.2 km upstream from the Yukon River confluence. The channel has a gradient of 1.5 to 2.0%, is frequently confined by the valley walls and has an active channel width of 6 m. The lower 100 m of the stream flows through a moderately developed stable fan (Appendix 4; Plate 1). Wetted channel width in Reach 1 averaged 4 m during the August 1991 survey. Bed material is pre-dominantly gravels (40%) and larges (35%). Fine sediments are prevalent in the lower 300 m of the reach. Habitat diversity is moderate with a predominance of riffle (40%) and pool (30%) habitats and the occasional run area. There are no side channel habitats in this reach. Instream cover is moderately high due the high occurrence of undercut banks and over hanging vegetation and moderate amounts of small organic debris (Appendix 4; Plate 3).

Reach 2

Reach 2 of Williams Creek is approximately 3.3 km long. The single channel is more confined than Reach 1 with a higher gradient (2.0

TABLE 3.6.1 Summary of physical habitat parameters for Williams and Nancy Lee creeks based on August 1991 survey data.

PHYSICAL PARAMETER	Williams: Reach 1	Williams: Reach 2	Williams: Reach 3	Williams: Reach 4	Nancy Lee: Reach 1
Channel Width (m)	4.0	5.0	2.5	4.0	4.0
Riffle depth (m)	0.3	0.3	0.2	--	0.2
Max. pool depth (m)	1.0	0.7	0.6	--	0.9
Gradient (%)	1.5	2.0	2.0	1.0	2.0
% Pool	30	20	10	30	30
% Riffle	40	40	60	10	60
% Run	30	40	30	60	10
% Side channel	0	0	0	0	0
% Debris coverage	15	5	0	15	10
Crown closure (%)	30	70	70	60	80
BED MATERIAL					
% Fines	25	20	10	80	25
% Gravel	40	20	10	20	25
% Larges	35	60	70	0	50
% Bedrock	0	0	0	0	0
Bank height (m)	2.0	1.0	1.0	0.5	2.0
% Unstable banks	5	0	0	*10	0
% Bar occurrence	0	0	0	0	0

TABLE 3.6.2 Summary of physical habitat parameters for sample sites on the Yukon River and Merrice and Crossing Creeks based on August 1992 survey data.

PHYSICAL PARAMETER	Yukon River Site Y1	Yukon River Site Y2	Merrice Creek M1	Crossing Creek C1
Channel Width (m)	500	24	5.0	5.0
Riffle depth (m)	---	0.3	0.4	0.3
Max. pool depth (m)	---	1.2	1.3	1.0
Gradient (%)	1.0	0.5	1.0	1.5
% Pool	0	20	30	30
% Riffle	0	10	30	40
% Run	100	70	40	30
% Side channel	20	100	0	0
% Debris coverage	10	10	15	10
Crown closure (%)	0	10	30	30
BED MATERIAL				
% Fines	30	70	20	10
% Gravel	40	20	20	20
% Larges	30	10	60	70
% Bedrock	0	0	0	0
Bank height (m)	50	1.5	0.5	0.6
% Unstable banks	40	0	0	0
% Bar occurrence	20	20	0	0

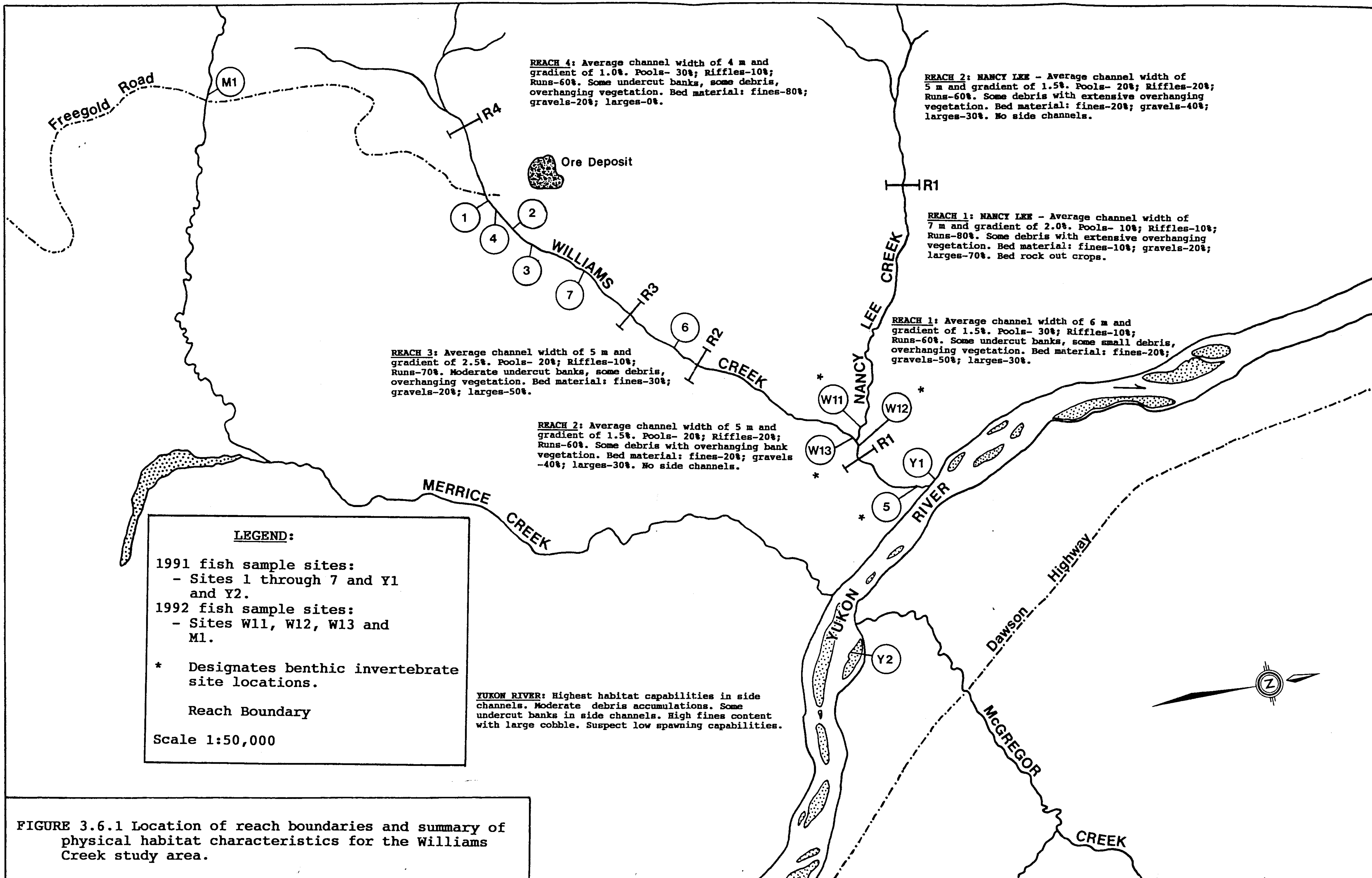


FIGURE 3.6.1 Location of reach boundaries and summary of physical habitat characteristics for the Williams Creek study area.

to 2.5%). The bed material is coarser with 60% larges and 20% gravels. Riffle habitats are more common than in Reach 1 and there is a lower incidence of pool and run habitat. The channel is characterized by abundant overhanging vegetation and moderate amounts of instream debris. The absence of gravels limits spawning potential in this reach. Rearing capabilities are moderately high based on the occurrence of pools, riffles and instream cover.

Reach 3

This reach is 1.0 km in length with a gradient of approximately 1.5 to 2.0%. The channel is less confined than in Reach 2; active channel width is 2.5 m with an average wetted width of 1 m during August. The predominant habitat type is run with little riffle habitat. Banks are generally stable with a moderate degree of under cutting. The bed material is predominantly larges (70%). Spawning potential is limited by the large bed material size. Extensive instream cover and large bed material size is suitable for rearing fish. However, channel width, low flow volumes and an absence of side channel habitats are probably major constraints to fish production in this reach (Appendix 4; Plate 3).

Reach 4

Reach 4 is 4.4 km in length and extends upstream to the headwater reach. This is a relatively low gradient reach (1.0%) characterized by a bed material of predominantly fines (80%) and small gravels. The channel is relatively unconfined with a wide valley flat.

Average width of the active channel is 4 m while wetted widths were less than 1 m during August. Water depths during August were typically between 30 and 50 cm. Habitat diversity was relatively low (Appendix 6; Plates 5, 6 and 7) with a predominance of runs (60%) and low incidence of riffle areas (10%).

__Nancy Lee Creek__

Two reaches were identified in Nancy Lee Creek. The lower reach is similar to Reach 2 of Williams Creek with a channel gradient of 1.5 to 2.5%. Bed material in Reach 1 is predominantly larges (50%) with a higher occurrence of gravels in Reach 2 (40%). Bed rock out crops are also evident in Reach 2 of Nancy Lee Creek. Active channel widths are between 5 and 7 m with wetted widths of 3 to 4 m during August, 1991. There is a 1 m chute located 1.1 km upstream of Williams Creek however this was not considered a potential obstructions to fish passage. Spawning potential in this creek is severely limited by the large size of the bed material.

3.6.1.2 Yukon River

The section of Yukon River near the Williams Creek confluence has a relatively low gradient with extensive bar and island development. There are numerous side channels ranging from 10 to 120 m in width. Bed material composition varies widely from fine sediments in many of the side channels to mixtures of large gravels and cobble larges along the mainstem margins.

The east bank of the river adjacent to the Williams Creek confluence is characterized by a moderately steep sloped gravel/cobble bank. This area was a gently flowing riffle during the August, 1991 sample. Water velocities and wetted bank slope were substantially higher during the October, 1991 and August 1992 surveys. The edge of the Williams Creek fan adjacent to the river bank is vegetated with sedges and grasses (Appendix 4; Plates 1 and 2). The Yukon River channel upstream and downstream Williams Creek is relatively straight. The lower 100 m of Williams Creek is subjected to back water effects from the Yukon River during high flow periods. This area was characterized by deep slow moving water with a small back eddy during the October, 1991 and August 1992 surveys. The west bank of the Yukon River across from Williams Creek is characterized by a steep unstable bank of fluvial materials. Highest fish habitat capabilities within this section of the Yukon River are likely associated with the side channel areas. These areas tend to be characterized by more diverse habitat types with areas of low water velocity and more abundant instream cover. Major side channel habitats are located approximately 0.5 km downstream of Williams Creek and 1.2 km upstream of the creek (Figure 3.6.1).

3.6.2 Fish Distribution and Abundance

Fish sampling results and observations collected during three survey periods between August 1991 and August 1992 are presented in the following section. Sampling results are summarized in Table 3.6.3.

August 1991 Survey

Total electrofishing area for the four mainstem Williams Creek sites sampled amounted to 627 m^2 (Table 3.6.3). Electrofishing samples were conducted in Reaches 1, 3 and 4 (Appendix 4; Plates 3, 4 and 7). Minnow traps (N=17) were also set at two additional sites in Reach 4 (Appendix 4; Plate 6). No fish were captured or observed in Williams Creek during the August survey. Sampling conditions were suitable for electrofishing and equipment was in good working order. Periodic investigations of stones from the bed material indicated low numbers of benthic invertebrates at all sites.

Electrofishing was also conducted along the margin of the mainstem Yukon River (Site Y1) immediately downstream of Williams Creek. Total sample area was 63 m^2 at this site (Appendix 4; Plate 2). A total of six chinook fry (*Onchorynchus tschawytscha*) ranging in size from 55 to 70 mm were captured at this time. Two slimy sculpins (*Cottus cognatus*) were also collected (Table 3.6.2). Moderate numbers of stoneflies were observed on the bed material of this site. Instream cover at this site was marginal; however, submerged vegetation did provide some cover along the edge of the bank. This site was in the influence of Williams Creek.

October 1991 Survey

1) Juvenile Fish Distribution

Electrofishing was conducted at Site #5 in Reach 1 and Site #6 in Reach 3 during the October survey. Total sample area was approx-

TABLE 3.6.3 Summary of fish sampling results for thrree sample periods between August 1991 and August 1992 in the Williams Creek study area.

SAMPLE PERIOD AND LOCATION	SAMPLE AREA (m^2)	SAMPLE DIFFICULTY	TOTAL FISH CATCH Chinook	Grayling	Sculpin	Burbot	Sucker	Pike
August 1991:								
Site Y1	102	Mod	6	0	2	0	0	0
Site W10	240	Low	0	0	0	0	0	0
Sites 4,6 &7	285	Low	0	0	0	0	0	0
Sites 1 & 2	17 Traps	Low	0	0	0	0	0	0
October 1991:								
Site Y2	110	Low	8	3	1	0	8	0
Site W10	154	Mod	10	1	1	0	0	0
August 1992:								
Site W10	81	High	55	1	16	0	2	1*
Site W12	72	Low	0	0	0	0	0	0
Site W13	51	Low	0	0	0	0	0	0
Site W11	92	Mod	0	0	0	0	0	0
Site 1	50	Low	0	0	0	0	0	0
Site M1	90	High	0	0	0	0	0	0
Site C1	Angled	Mod	0	3**	0	0	0	0

* This adult northern pike was angled near the Yukon River confluence.
** An additional seven other adult grayling were observed at this site.

imately 218 m^2. No fish were captured in the upper site (Reach 3). A total of eleven chinook salmon fry and one slimy sculpin were captured at the lower site. Eighty percent of the captured fish were collected with the first pass of the electrofisher indicating high rate of capture efficiency. The calculated density of chinook fry at this site was 7.1 fry per 100 m^2. All fry were very dark in colour and were taken from isolated areas of accumulated debris along the under cut bank of a deep pool. Chinook fry were not found in the bed material at this site. Chinook fry fork lengths ranged from 60 to 70 mm with a mean length of 68.1 mm. Sculpin density was calculated at 0.6 fish per 100 m^2 of stream habitat for Reach 1 of Williams Creek. One adult grayling (*Thymallus arcticus*) approximately 30 cm in length was also observed in the lower 100 m of the creek during the October survey. This fish had a dorsal lesion with fungal infection.

Sampling along the margin of the Yukon River (Site Y1) was not conducted due to high flow conditions at this time. A second Yukon River site (Y2) was established upstream of Williams Creek in a major side channel (Figure 3.6.1). A total sample area of 110 m^2 was enclosed with stop nets and electrofished. Four species were sampled with a total catch at this site of 20 fish. Sample results are summarized in Table 3.6.3. All but one of the fish collected from this side channel site were taken from a small debris clump located in shallow water. Fish were not found in open water areas or within the bed material. Captured chinook fry were dark in colour indicating they were probably inactive. Water temperature was 2°C at this time.

2) Adult Spawner Survey

Approximately 27 km of side channel and mainstem habitat of the Yukon River upstream and downstream of the Williams Creek confluence were surveyed by helicopter over a one hour period on October 9, 1991. Mainstem visibility was poor due to high flow conditions but visibility in many of the side channels and along the mainstem margin was adequate to observe the bed material. No spawning salmon or carcasses were observed. There was no indication of redd (spawning nest) construction either. Interviews with local members of the Carmacks Native Band indicated that chum salmon were present in the mainstem Yukon River during the last month as they migrated past Carmacks to upriver spawning areas. Local residents were not aware of any salmon spawning areas in the mainstem Yukon or tributary habitats within the Williams Creek study area. Fishing activity was not observed on the river at this time.

August 1992

1) Williams Creek Drainage

The total area sampled in lower Williams Creek (three sites) during the August 1992 survey was 204 m^2. An additional 92 m^2 was sampled in lower Nancy Lee Creek. A total of 72 fish were electrofished during this survey and four species identified (Table 3.6.3). Chinook fry were most abundant species comprising 76.3% of the catch (55 fish) followed by slimy sculpin (22%; 14 fish) and longnose suckers (*Catostomus catostomous* - 2.8%; 2 fish). One juvenile grayling 175 mm in length was also caught. All fish were collected from sample site W-10 located in the lower reach of Williams Creek approximately 250 m upstream of the Yukon River confluence (Figure 3.5.1). Fish recovery was hampered at this site by the high occurrence of debris and deep pool cover. Chinook fry captured from site W-10 had a mean fork length of 58.1 mm over a range of 49 to 76 mm. The mean fork length of the slimy sculpin was 51.7 mm with a range of 30 to 65 mm. The two longnose suckers captured were 100 and 130 mm in fork length. In addition to the electrofishing catch, a sub-adult northern pike (*Esox lucius*) was angled from lower Williams Creek near the confluence of the Yukon River by a member of the archaeologist survey team.

Fish were not captured or observed at either of the other two Williams Creek sample sites (W-12 and W-13) or in lower Nancy Lee Creek (W-11) during the August 1992 survey. Sampling difficulty was low at these sites during the 1992 survey and stop nets were used to increase catch probability and fish recovery. Physical habitat characteristics at these sites appeared to be suitable for juvenile rearing with an abundance of deep pool habitat, diverse instream cover and a cobble bed material.

Additional electrofishing in the upper mainstem of Williams Creek at the mine access road crossing indicated an absence of fish from the upper watershed. These results are consistent with sampling results from the 1991 studies.

2) Merrice Creek

Electrofishing was conducted at one site on Merrice Creek encompassing 90 m^2 of stream habitat above and below the Williams Creek access road crossing (Figure 3.6.1). This site is characterized by deep pools (30% of sample area) with undercut banks and overhanging bank vegetation. Shallow riffle habitat is also common in this section of the stream. The bed material is of gravels and large cobbles. Sample conditions were good during the August 1992 survey and the probability a fish capture and recovery was rated high. Upstream and downstream stop nets were used during the electrofishing sample and multiple passes of the sample area were made. No fish were caught or observed. A subsequent survey of the creek from a helicopter indicated there were no obstructions between Merrice Lake and the road crossing (Figure 3.6.1).

3) Crossing Creek

Crossing Creek was surveyed at three locations adjacent to the Freegold access road upstream of the road crossing. This creek is characterized by a stable channel, approximately 5 m wide (wetted and active width) with a bed material of gravels (20%) and large cobbles (60%) with some boulders. The stream has extensive riffle and pool habitats with abundant instream and bank cover. Habitat diversity is high and it appears that spawning and rearing capabilities for Arctic grayling would be high. Seven adult grayling (300 to 400 mm) were observed during the August 1992 survey. Three grayling in the same size range were also angled from one pool site adjacent to the road. The total angling sample effort was approximately 30 minutes. Electrofishing was not done at this site.

3.6.3 Fish Habitat Use and Capabilities

3.6.3.1 Habitat Use

Of the 13 fish species found in the upper Yukon River drainage (Table 3.6.4), six species were present in Williams Creek during the 1991 and 1992 studies. These were juvenile chinook salmon, Arctic grayling, slimy sculpins, longnose suckers, burbot (*Lota lota*) and northern pike. Experience in other Yukon River systems (Davies and Shepard 1981; Walker 1976; and Mathers, West and Burns 1981) indicate that species such as inconnu (*Stenodus leucicthys*), round whitefish (*Prosopium cylindraceum*) and broad whitefish (*Coregonus nasus*) may also be found in small tributary habitats of the Yukon River system at certain times of the year (Appendix 4). The following discussion is limited to fish species which have been observed in Williams Creek to date.

<u>**Chinook Salmon**</u>

1. Rearing

Fish sampling data indicate that juvenile chinook salmon rearing in Williams Creek is likely restricted to the lower one kilometre of

TABLE 3.6.4 List of fish species found in the Yukon River drainage and summary of general life history requirements (Adapted from: Montreal Engineering Co. Ltd.)

FAMILY	SPECIES	COMMON NAME	LIFE HISTORY/ REQUIREMENTS
Salmonidae	*Onchorhynchus tschawytscha***	Chinook salmon	anadromous; 1 year fresh water residence as juvenile; occasionally 2; mainstem and tributary spawners - August
	Onchorhynchus keta	Chum salmon	Anadromous; juvenile fish migrate seaward as fry; mainstem spawners - August
	Salvelinus namaycush	Lake trout	Non-anadromous; rear in lakes and large rivers; Fall spawners
	Coresonus clupeaformis	Lake whitefish	Generally lake dwelling; Fall spawning along shallow lake shores
	Coresonus nasus	Broad whitefish	Generally lake dwelling; Summer to Fall spawner; downriver migration of adults in mid-winter
	Coresonus sardinella	Least cisco	Migrating and non-migrating populations; Fall spawners - lake shore or river margins
	Prosopium cylindraceum	Round whitefish	Northern populations are found in rivers as well as lakes; Fall spawning - lake shores and river mouths
	Stenodus leucicthys	Inconnu	Anadromous and non-anadromous forms; juveniles rear in rivers up to 2 years; spawn in Summer to Fall
	*Thymallus arcticus***	Arctic grayling	Inhabit clear cold water - rivers, streams, lakes, and ponds; Spring spawning; complex seasonal migrations are common
Esocidae	*Esox lucius***	Northern pike	Spring spawner - in shallow vegetated areas of rivers and lakes; generally sedentary; predacious
Gadidae	*Lota lota***	Burbot	Spawns during mid-winter in rivers, streams, and lakes; migrates into rivers after spawning
Catostomidae	*Catostomus catostomus***	Longnose sucker	Spawns during Spring in streams and along lake shores
Cottidae	*Cottus cognatus***	Slimy sculpin*	Occupy a wide range of lake, stream, and river habitats; Spring spawning; nest builders; usually feed on aquatic invertebrates, other fish are also taken

* - indicates species has been recorded in Williams Creek drainage.

stream habitat. Although physical habitat capabilities in lower Nancy Lee Creek and Williams Creek downstream of this tributary appeared to be suitable for chinook rearing during the summer period, sampling indicated chinook did not use this section of the system. Juvenile chinook were not found in Williams Creek during the August 1991 survey but were found during the October 1991 and August 1992 surveys. These data indicate seasonal and annual variability in habitat use patterns by juvenile chinook salmon within the study area. Similar habitat use patterns have been noted in other Yukon River drainages. For instance, sampling conducted in a similar sized tributary (Grew Creek) in the upper Pelly River drainage resulted in no fish during the summer 1989 sample yet high numbers the following year (Harder and Bustard 1990). High flow levels preceding the August 1991 sample period in Williams Creek (refer to Section 3.4 of this report) may have displaced fish downstream into the Yukon River.

Results from other studies (Harder and Bustard 1990a and Beniston and Lister 1991) indicate relatively high chinook use of small tributary habitats in the Yukon drainage during the summer period. Sampling conducted in lower Williams Creek also indicated a relatively high level of habitat use during August 1992 with a chinook fry density of 67.9 fry per 100 m^2. By comparison, chinook fry densities in lower Vangorda Creek, which is a small tributary to the Pelly River near Faro, were 30.7 fry per 100 m2 during the August 1992 sample period (unpublished data from Curragh Inc.).

Chinook fry densities of up to 109 fry per 100 m^2 were observed in Vangorda Creek in other years (Harder and Bustard 1990a).

Fish sampling conducted in October 1991 indicated the lower section of Williams Creek is used by small numbers of juvenile chinook salmon. Chinook fry that were found in the creek during the October sample appeared to be in an inactive over-wintering state suggesting that juvenile chinook over-winter in the system. Juvenile chinook densities in lower Williams Creek were comparable to observed densities from a side channel habitat (Y2) of the Yukon River, upstream from Williams Creek. Fall chinook fry densities in lower Williams Creek were relatively low when compared to fry densities from Vangorda Creek. Harder and Bustard (1990) reported fall (October) chinook fry densities of 27.2 to 29.6 fry per 100 m^2 in Vangorda Creek. Chinook fry densities in Williams Creek during the fall were far lower at 6.0 fry per 100 m^2. However, the compared data sets are from different years and as such the differences may reflect variation in annual fry recruitment rather than habitat capability.

2) Spawning

Yukon River chinook salmon first arrive at Dawson, approximately 200 km downstream of Williams Creek, in late July enroute to upriver spawning grounds. The spawning period for chinook salmon in the Yukon River is generally between August and early September (Appendix 6). Chinook salmon generally spawn in major tributaries and along mainstem habitats of the Yukon River and tributary rivers. There are no reports of mainstem spawning in the vicinity of Williams Creek; spawning was not observed between Carmacks and Williams Creek during the August, 1991 and 1992 helicopter surveys. Furthermore there was no evidence of chinook spawning (redd construction) in Williams Creek during either survey. Chinook spawning capabilities in Williams Creek are limited by low flows and an absence of suitably sized bed material.

Arctic grayling

A single adult grayling was observed in the creek immediately upstream of the Yukon River during the October 1991 survey and a juvenile grayling was captured during the August 1992 survey. If spawning grayling had used the creek during the spring of 1991 or 1992, it would be expected that recently emerged fry would be present in the creek during the late July and August. The apparent absence of grayling fry during the 1991 and 1992 studies suggests low use of the system by spawning adult grayling. However, surveys have not been conducted during the grayling spawning period to confirm this.

3.6.3.2 Habitat Capabilities

Rearing

Fish rearing capabilities in Williams Creek are highest in the lower creek below the confluence of Nancy Lee Creek. Extensive undercut banks and overhanging vegetation contribute to the moderate rearing capabilities in this section of the creek. Higher capabilities are probably constrained by the relatively low incidence of large instream debris, small cobble size and absence of side channel habitat. Relatively low abundance of benthic invertebrates may also contribute to low overall summer rearing capabilities in the system (refer to Section 3.6.3 of this report).

Although obstructions to fish access were not present in Williams Creek, fish distribution was restricted to the lower end of the creek during the 1991 and 1992 studies. Rearing habitat capabilities in the upper system are probably limited by low flow volumes, small stream size and relatively low occurrence of riffle habitats upstream of Nancy Lee Creek.

Observed habitat selection by over-wintering chinook fry in lower Williams Creek indicate the presence of instream debris is an important habitat during this stage of the life history. Our assessment indicates this habitat type occurs relatively infrequently in Williams Creek. The absence of abundant large cobble material with interstitial areas probably also limits over-wintering capabilities in the system. It is suspected that low flow volumes and cold water temperatures are probably the most significant constraint to over-wintering capabilities in the system.

Lakes and ponds are important habitats for Arctic grayling. These areas provide flow stability and over-wintering habitats. In other studies (Harder and Bustard 1991a and 1991b), Arctic grayling were more prevalent in systems which are characterized by these habitat types. The absence of these habitats in the Williams Creek drainage probably limits grayling production in this system.

<u>Spawning</u>

There have been no reports of spawning salmon in Williams Creek and no indication that either chum or chinook salmon used the system in 1991. Spawning capabilities for salmon in Williams Creek are probably severely limited by the small stream size, low discharge and relatively high fines content in the bed material of Reach 1. Spawning capabilities for Arctic grayling are likely higher, however, it is suspected that the low occurrence of pool habitat in the lower reach probably also limits spawning capabilities for this species.

The lower 200 m of Williams Creek is influenced by the Yukon River during periods of high discharge. This area is characterized by low velocities and submerged vegetation along the banks and may be used by spawning northern pike during the spring period.

3.6.3 Benthic Invertebrates

3.6.3.1 Abundance and Distribution

A summary of the benthic invertebrate data collected in Williams Creek during 1991 and 1992 is presented in Table 3.6.5. Total and average number of insects collected at each of the three sample sites, including one site in lower Nancy Lee Creek, were similar with a range in total numbers from 751 to 910 insects. A total of 23 different taxonomic groups were identified in the drainage. Taxonomic richness of the 1992 samples varied between 14 and 19 taxa with the highest number found at the lowermost Williams Creek site (W-12) below Nancy Lee Creek. Plecopterans were the dominant order present in the William Creek sites (W-12 and W-13) representing between 50 and 79% of the community (Appendix 5). Plecopterans were co-dominant at the Nancy Lee Creek site during 1992 representing 34% of the total community. Dipterans were the sub-dominant order at all three sites during 1992 with chironomidae (*Orthocladiidae*) representing between 10 and 35% of the total insect community (Appendix 5).

Total number of insects sampled from the one site in lower Williams Creek (W-10) during 1991 was substantially lower than the 1992 results with a total of 266 insects from the three basket samplers. Community richness was similar between years with 15 taxa represented in the 1991 data set (Table 3.6.5). Dipterans were the dominant order in all three samples accounting for between 73 and 82% of total organisms. Chironomid (Orthocladiidae) were the most abundant taxa within this order for all of the replicate samples. Plecopterans were the next dominant order representing 18% of the total sample (Appendix 5).

3.6.3.2 Regional Comparisons

Benthic invertebrate data collected from lower Vangorda Creek during 1989 (Burns 1990) and lower Buttle Creek (Perrin 1991) in the upper Pelly River drainage are presented in Table 3.6.6 as a regional comparison for the Williams Creek data. Both creeks have

TABLE 3.6.5. Summary of total insect numbers and taxonomic richness for triplicate samples collected at sites in the Williams Creek drainage during 1991 and 1992.

SAMPLE SITE LOCATION AND DATE	TOTAL* INSECTS	TAXONOMIC RICHNESS	DOMINANT TAXA	SUB-DOMINANT TAXA
W-13 Williams - 1992	910	17	Plecoptera: Nemouridae	Chironomidae: Orthocladi-inae
W-11 Nancy Lee 1992	763	14	Plecoptera: Nemouridae	Chironomidae: Orthocladi-inae
W-12 Williams 1992	751	19	Plecoptera: Nemouridae	Chironomidae: Orthocladi-inae
W-10 Williams 1991	266	25	Chironomidae: Orthoclad-iidae	Plecoptera: Perlodidae

* Total insect numbers refers to number of insects collected in three basket samplers.

TABLE 3.6.6. Regional comparison of benthic invertebrate data between Williams Creek sites (1991 and 1992) and selected sites in the Pelly River drainage (1989 to 1990) expressed as the average number of insects per basket sampler.

DRAINAGE	YEAR	AVERAGE NUMBER	TAXONOMIC RICHNESS	DOMINANT ORDER	SUBDOMINANT ORDER
Williams W10	1991	89	11	Diptera	Plecoptera
Williams W12	1992	250	19	Plecoptera	Diptera
Williams W13	1992	303	17	Plecoptera	Diptera
Nancy Lee W11	1992	254	14	Plecoptera	Diptera
Vangorda	1989	1,055	19	Diptera	Plecoptera
Buttle	1990	430	12	Diptera	Ephemeroptera
Blind	1990	72	14	Diptera	Ephemeroptera

have a similar drainage area to Williams Creek. The total number of taxa represented for the 1991 and 1992 Williams Creek sites ranged from 11 to 19 which was similar to the variation observed at the reference sites (Table 3.6.6). Average numbers of organisms for the Williams Creek samples varied from 89 in 1991 to between 250 and 303 insects in the 1992 samples. These numbers are relatively low compared to average numbers obtained for Vangorda and Buttle creeks in 1989 and 1990 (Perrin 1991) respectively (Table 3.6.6). The average numbers of insects from the Williams Creek sites in 1992 was substantially higher than the Blind Creek averages for 1990 (Perrin 1991) while the 1991 Williams Creek data was similar (Table 3.6.6). However, Blind Creek is a major tributary to the Pelly River system and physical habitat characteristics and flow regimes are not comparable between the two systems.

3.7 Resource Use

3.7.1 Wildlife

Assessment of wildlife capabilities in the Williams Creek drainage indicate that hunting opportunity and activity would be minimal. Densities of moose and cariboo in the area are low (see Section 3.3.2 of this report). Discussions with members of the Carmacks First Nations indicated that there had been no moose or cariboo kills in the Williams Creek watershed in recent years, but that the area is part of the traditional hunting grounds.

Important furbearing animals in the Williams Creek watershed include lynx, coyote, wolverine and mink. There is one registered trapline encompassing the Williams Creek drainage. This is held by a member of the Carmacks First Nations. Although specific trapline records for the Williams Creek drainage are not kept, the area is trapped on more than one occasion during most years (Mr. J. Sam pers. comm.).

3.7.2 Fish

Chinook and chum salmon runs in the Yukon River support important commercial and native food fisheries. Escapement and catch data for the commercial and Native fisheries on these species is presented in Appendix 4. Adult chinook and chum salmon migrate up the Yukon River past Williams Creek between August and October. Salmon spawning does not occur in Williams Creek.

Members of the Carmacks First Nations harvest adult chinook and chum salmon from the Yukon River during the late summer and fall months. Catch records are not maintained specifically for the Carmacks area. Interviews with band members and village elders indicate that salmon fishing activities take place at many sites along the Yukon River between Carmacks and Fort Selkirk. Sites upstream of Carmacks are also used. Five seasonal fish camps were observed on the banks of the Yukon River between Carmacks and Williams Creek during the October 1991 survey. Three other fish camp sites were identified downstream of the Williams Creek confluence. Locations of the fish camps change annually depending on flow conditions in the river (Chief Fairclough, pers. comm.).

Other species which are also of importance with respect to Native and sport fisheries include Arctic grayling, inconnu, round and broad whitefish, burbot and Northern Pike. Small numbers of these species may be found at he confluence of Williams Creek and the Yukon River at certain times of the year. It is suspected that some sport fishing may occur at the mouth of Williams Creek during the summer months as recreational canoeists pass the creek enroute to Dawson City (refer to following section). The extent of the Native Fishery for these species in the Williams Creek area is not known. It is suspected that most fishing for these species would occur in the Yukon River. Historically there have been reports of some Native fishing in the backwaters of the Williams Creek confluence (Chief Fairclough pers. comm.).

3.7.3 Recreation

The most significant recreation activity within the study area is summer canoeing on the Yukon River. Canoeists generally use the river between late May and September with peak use in July and August. Dawson City is the usual destination with people typically starting their journey in the Whitehorse area or Carmacks. Visitor records collected at Fort Selkirk on the Yukon River downstream of Carmacks and Williams Creek indicate a total of 693 canoeists using this section of the river during 1992. This figure represents a 11%

increase over the 1991 visitor records. The usual length of time taken to canoe between Carmacks to Dawson trip is between 5 and 10 days depending on flow conditions and other factors. There is a designated campsite at Carmacks which is used by most canoeists as an overnight stop while restocking provisions. The length of river travelled on a daily basis can vary substantially but a range of between 35 and 50 kilometres would be typical. Using these estimates, and assuming the majority of canoeists have used Carmacks as the last stopping point, than it can be projected that the next logical camp location downstream from Carmacks would be between the Williams Creek area and Fort Selkirk. Preferred and designated camp sites along the Yukon River route are often associated with tributary confluences. Although the location of Williams Creek in relationship to Carmacks suggest it might be a logical stop-over point, examination of the fan area indicated low usage by campers. There was no evidence of regular campsites or fire pits.

The only other significant recreation activity in the area is the annual "Quest" Dog Sled race between Whitehorse and Dawson City. The Quest Trail parallels the west bank of the Yukon River and crosses lower Williams Creek approximately 150 m upstream of the Yukon River confluence.

The extent of other recreational activities such as hiking or skiing is not known. However, the Williams Creek area is not noted as a particularly popular or unique area for these activities. Access to the area is restricted by the seasonal road conditions.

3.7.4 Forestry and Native Plants

White and black spruce are the common conifer tree stands in the Williams Creek drainage, with some lodgepole pine occupying old burn areas. Commercial harvesting of these species in this region of the Yukon is not viable, therefore, commercial forestry values for the Williams Creek watershed are not significant.

Some of the indigenous plants of the region are used by members of the Carmacks First Nations for medicinal and traditional uses. Specific areas of collection within the region and individual species of concern have not been identified at this time.

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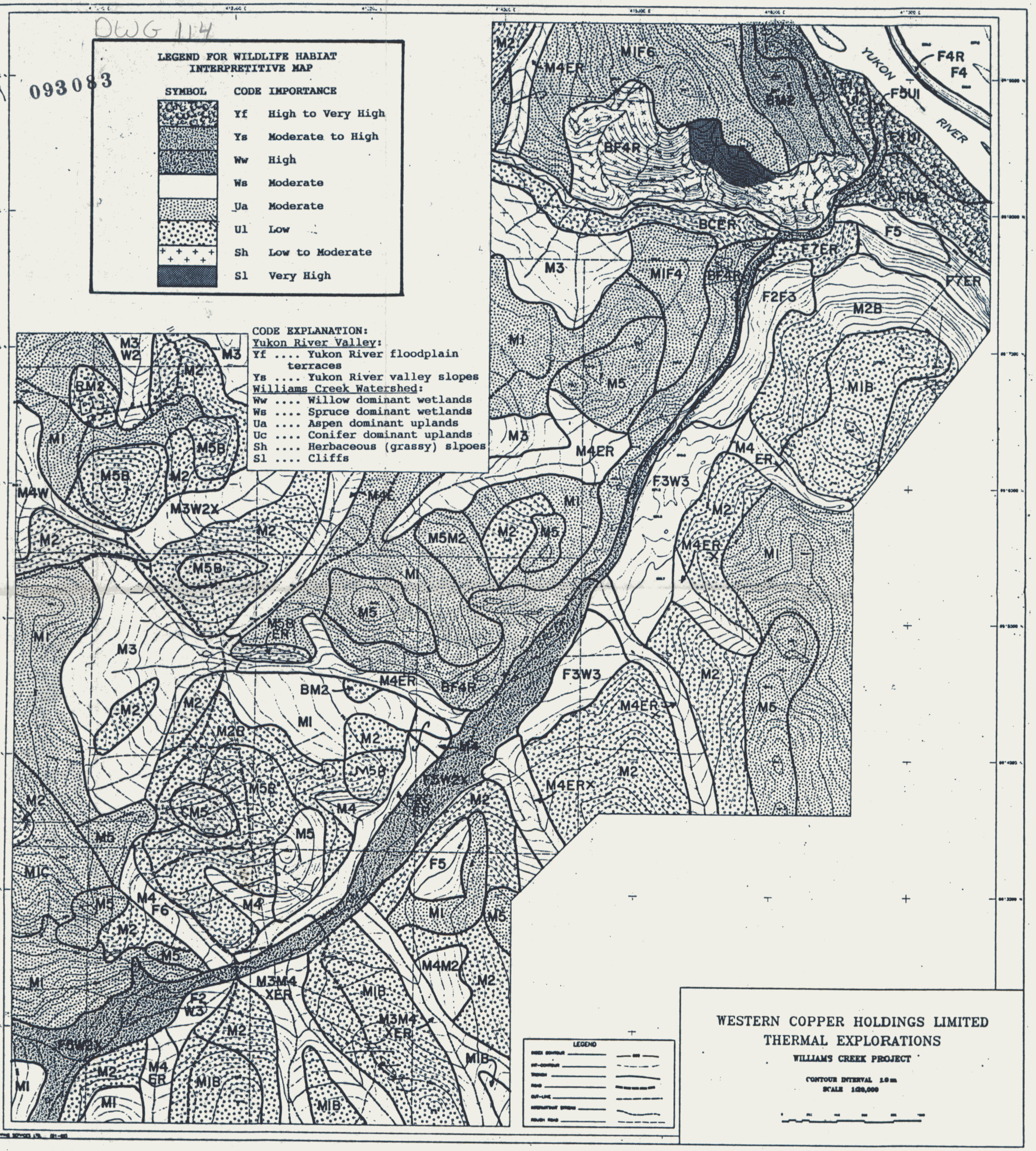
APPENDIX 1

Terrain and Vegetation Analysis: Terrain Analysis Maps for the Williams Creek drainage.



LEGEND
TERRAIN INTERPRETIVE MAP
Geotechnical and Environmental Considerations

LANDFORMS and MATERIALS	COMMON VEGETATION TYPE
Morainal Landforms - valley bottom and lower-slope glacial till; mainly a dense sandy silty matrix, but may be coarser and looser in upper valleys.	
M1 mainly thick subdued till landforms; average depths exceed 2m and slopes are usually less than 25%; in places there may be a thin veneer of silt or gravel.	Aspen, Kinnikinnick, minor Lodgepole Pine
M2 sloping till blanket overlying bedrock; depths range from 1-3m; slopes are mainly less an 40%.	Lodgepole Pine, Aspen, Black Spruce
M3 wet, subdued to moderately sloping till; features poor drainage, seepage, and/or shallow organic capping on slopes usually less than 30%.	Black Spruce, Willow, Labrador Tea
M4 Gullied till on valley sides; may contain fluvial and/or colluvial deposits; usually incised into bedrock.	Black Spruce, Willow, moss
M5 Shallow deposits of till overlying bedrock; dominantly south and east facing slopes; slopes greater than 40%.	Aspen, Lodgepole Pine, grass
Colluvial Landforms - lower slope, gravity-transported debris derived from bedrock.	
C accumulation of deep colluvial fans, cones and aprons (1-3m); blocky and rubbly debris may provide a source of coarse aggregate or ballast.	Black Spruce, Willow, moss
Bedrock Landforms	
B areas of bedrock outcrop and shallow colluvium	Open stands of Lodgepole Pine, Aspen and grasses
Fluvial-Glaciofluvial Landforms - valley-bottom and lower-slope granular material; texturally variable from clean, coarse sand and gravels to dirty, silty gravels with variable interlayers; in places, may be capped with thin veneer of silt or minor wet areas may occur; potential sources of aggregate depending on thickness of deposit and texture.	
F1 level to gently subdued surface, thick deposits	White and Black Spruce, Willow, moss
F2 subdued to moderately sloping (15-30%), thick deposits	White and Black Spruce, Willow, moss
F3 hummocky and ridged, moderately to moderately steeply sloping (30-65%), thick deposits	Aspen, Kinnikinnick, grass
F4 steeply sloping scarps (greater than 65%), thick deposits, south facing	Aspen and grasses
F5 subdued fluvial fans and low-lying terraces; high water table and occasional flooding may occur near channels and in depressions.	White Spruce, Birch, Willow, moss
F6 variable thickness (.5-2m) of sand and gravel overlying subdued to moderately sloping till surface; well-drained.	Lodgepole Pine, Willow, Labrador Tea
F7 steeply sloping scarps (greater than 65%)	Black Spruce, Willow, moss
Wetlands - valley-bottom and depressional areas which are wet for most of the year; inundation from high water table or flooding is the main constraint, but soft, compressible soils are also common.	
W1 dominantly organic materials greater than 1m thick	Black Spruce, Labrador Tea, Willow
W2 variable extent and thickness of organics (40-150cm) overlying wet floodplain sediments.	Willow, sedge, moss
W3 thin organics (less than 1m) and poorly drained mineral soil on floodplains and in large depressions; overbank silts and fine sands occur on floodplains; lacustrine silts and till usually underlie depressions.	Black Spruce, Labrador Tea, moss

GEOMORPHIC CONDITIONS AND PROCESSES

Permafrost - perennial frozen ground.
X areas of potential ground ice occur on poorly-drained till slopes and floodplain areas where organic soils predominate.

Terrain Hazard Units
R slopes which show evidence of active landsliding; mass movement and erosion hazard.
ER slopes which have the potential for mass movement and/or have high erosion potential.
E slopes which have moderate erosion potential.
D toe-slope areas actively receiving deposition from upslope landslides or on-going erosion.
U1 areas highly susceptible to flooding, channel shifting, or inundation by high water table.
U2 areas potentially susceptible to flooding, channel shifting, or inundation by high water table.

NOTE: Map units are defined by one or more symbols representing the occurrence of significant terrain features and conditions and/or geomorphic hazards which may have a beneficial or constraining effect on mine-facility and access-road development.

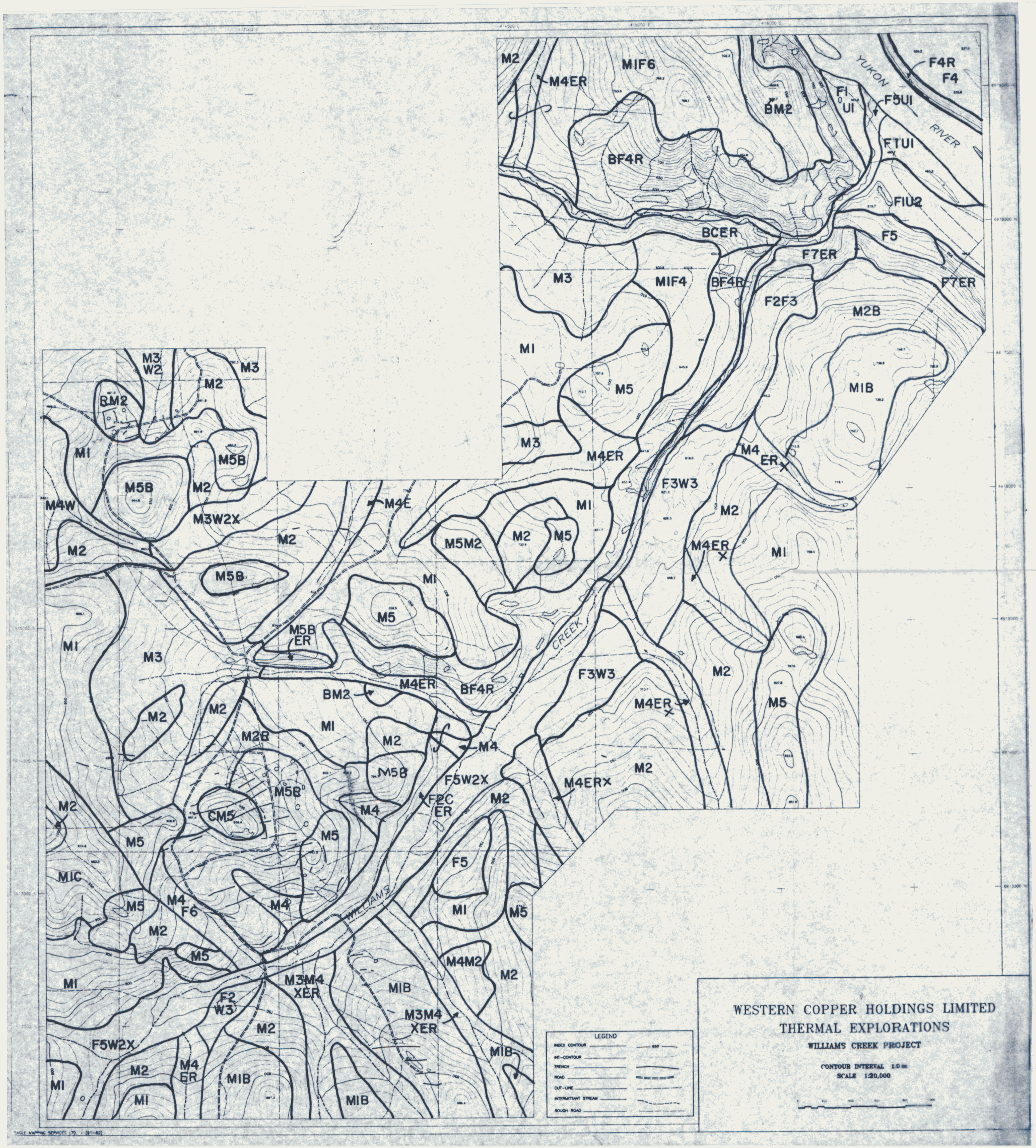
MAPPED BY: Mark Walmsley, P.Ag., P.Geo.
Westland Resource Group
Victoria, B.C.

MAPPED FOR: Western Copper Holdings Ltd.

WESTLAND RESOURCE GROUP

APPENDIX 2

Wildlife Habitat Assessment: Habitat Capability Map and Wildlife Observation Notes.



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LEGEND
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Geotechnical and Environmental Considerations

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MAPPED BY: Mark Walmsley, P.Ag., P.Geo.
Westland Resource Group
Victoria, B.C.

MAPPED FOR: Western Copper Holdings Ltd.

WESTLAND
RESOURCE GROUP

Appendix 1. - Winter-spring wildlife observations made by J. Gibson and Associates, Williams Creek area, October/89-May/91.

Species	Date	Observations
Snowshoe hare	Oct./90	Heavy browsing; many scats and sightings.
	Mar./91	Heavy sign (tracks and scats); roadside poplars barked.
	May/91	Numerous carcasses (fur and bones) throughout Williams Cr. Valley.
	Dec./91	Few tracks or scats noted.
	Jan./Mar./92	Few tracks.
	May/92	Few signs; no carcass remains.
Lynx	Mar./91	Tracks on Freegold Rd. & Williams Cr. Rd. to km 6.
	Dec./91	2 tracks at km 3, one at km 8.
	Jan./92	Tracks all along Freegold and Williams Cr. Roads.
Wolverine	Dec./91	Tracks in valley downstream from exploraton camp.
Marten	Dec./91	One set tracks at mouth of Williams Cr.
	Jan./92	One track at km 4, Williams Cr. Rd.
Mink	Jan./92	One track near exploration camp.
Wolf	Mar./91	Black wolf sighted, km 31 of Freegold Rd.
	May/91	" " " , km 3 of Williams Cr. Rd.
Black bear	May/91	Tracks and scats, Williams Cr. Rd., km 4-7.
	May/92	Tracks, km 7-8, Williams Cr. Rd. Sign of bears foraging on south-facing slopes. One bear seen at exploration camp.
Grizzly bear	May/92	Probable track, km 7-8, Williams Creek Rd.

Table 2. - Sightings and sign of wildlife, Williams Creek Yukon, August 10-12/92

Species	Number of occurrences (sightings or sign) recorded[1]							
	Visual	Vocal	Tracks/ Trails	Scats	Feeding sign	Nests/ burrows	Carcass remains	Total
MAMMALS								
Snowshoe hare			5	7	14		2	28
Red squirrel	2	4			8		2*	16
Ground squirrel						1		1
Porcupine				1	1			2
Beaver					1			1
Red fox				1				1
Coyote			1	9				10
Wolf				1				1
Black bear	1**		3	4				8
Grizzly bear				1				1
Wolverine			1					1
Moose			4	9	5			18
Caribou			1					1
BIRDS								
Spruce grouse				7				7
Golden eagle						2		2
Amer. kestrel	1							1
Snipe	1							1
Sp. sandpiper	1							1
Solit. sandpiper	1							1
Nighthawk		1						1
Raven	3	2						5
Gray jay	6							6
N. flicker	3							3
Wilson's warbler	1							1
Tree sparrow	1							1
AMPHIBIANS								
Northwestern toad	1**							1

Table 2. - Continued

1 multiple occurrences in the same locality (e.g. 3 moose pellet groups) were recorded as 1 occurrence.

* in coyote scats

** reported by P. Harder

APPENDIX 3

Water and Sediment Quality Data for Williams Creek: October 1989 to October 1992.

APPENDIX 3. Table 3.1. Analyses of total metals for Station W1 on an unnamed east flowing tributary of Williams Creek for the period October 1989 to October 1992.

PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
pH	7.7	7.9	8.1	7.9	7.9	7.5	7.833
Conductivity	462	410	450	389	350	475	422.667
Suspended Solids	20	17	100	<5	12	33	31.167
Turbidity	----	3	12	2	1	3	4.200
Aluminum	0.03	<0.005	<0.005	<0.005	<0.005	0.091	0.024
Antimony	<0.005	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	<0.02	<0.05	0.16	<0.04	<0.04	<0.05	0.060
Barium	0.146	0.087	0.186	0.054	0.068	0.385	0.154
Beryllium	<0.0001	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	0.004	----	----	----	----	----	0.004
Cadmium	<0.0002	<0.0003	<0.0003	<0.0003	<0.0003	0.0004	0.0003
Calcium	55.3	64.4	63.9	59	59	62	60.600
Chromium	0.0066	0.002	0.009	<0.001	<0.001	0.002	0.004
Cobalt	<0.0005	<0.001	0.002	<0.001	<0.001	0.003	0.001
Copper	<0.0005	<0.001	<0.001	<0.001	<0.001	0.008	0.002
Iron	0.181	0.038	0.244	0.1	0.099	0.152	0.136
Lead	<0.002	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	0.26	<0.05	<0.05	<0.05	<0.05	<0.05	0.085
Magnesium	11.2	13.7	13.2	14	13.4	14.2	13.283
Manganese	<0.001	0.003	0.01	<0.001	<0.001	0.005	0.004
Mercury	<0.005	----	----	----	----	----	<0.005
Molybdenum	0.015	0.021	0.025	0.022	0.015	0.023	0.020
Nickel	0.0009	<0.001	0.005	<0.001	0.003	0.002	0.002
Phosphorous	<0.05	0.02	0.06	0.03	<0.02	0.08	0.043
Potassium	1.1	1.27	1.18	1.22	1.1	1.51	1.230
Selenium	<0.005	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	4.42	7.5	2.7	6.43	8.72	9.52	6.548
Silver	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002
Sodium	4.42	10.9	8.8	9.34	8.91	11.4	8.962
Strontium	0.644	0.74	0.62	0.82	0.75	0.75	0.721
Thorium	<0.01	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	<0.001	<0.001	0.01	0.001	<0.001	<0.001	0.002
Uranium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	<0.0002	0.0059	<0.0005	<0.001	<0.001	0.015	0.004
Zinc	0.0476	0.008	<0.001	0.005	0.002	0.01	0.012
Zirconium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chloride	4.7	----	----	----	----	----	4.700
Fluoride	3.3	----	----	----	----	----	3.300
Nitrate	<0.1	<0.5	0.6	1.1	<0.2	0.6	0.517
Sulphate	129	112	102	95	93.9	83.9	102.633
Nitrite	<0.003	<0.003	<5.0	<0.03	<2.0	<2.0	<5.0
T. Phosphorous	----	----	0.05	0.005	0.011	0.049	0.029
Ammonia	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	0.058
Alkalinity as $CaCO_3$	53	119	125	115	142	140	115.667
Hardness as $CaCO_3$	184.2	217	213.9	206	202	214	206.183

APPENDIX 3. Table 3.2. Analyses of dissolved metals for Station W1 on an unnamed east flowing tributary of Williams Creek for the period October 1989 to October 1992.

PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
Aluminum	----	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Antimony	----	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	----	<0.05	0.12	<0.04	<0.04	<0.05	0.060
Barium	----	0.057	0.065	0.041	0.066	0.067	0.059
Beryllium	----	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	0.000
Boron	----	----	----	----	----	----	----
Cadmium	----	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	----	61.8	64.7	57.9	52.8	59.9	59.420
Chromium	----	<0.001	0.001	<0.001	<0.001	<0.001	0.001
Cobalt	----	<0.001	0.001	<0.001	<0.001	0.002	0.001
Copper	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	----	<0.005	0.08	0.08	0.09	<0.004	0.052
Lead	----	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	----	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	----	13.1	13	12.4	11.6	13.9	12.800
Manganese	----	0.003	0.003	<0.001	<0.001	0.002	0.002
Mercury	----	----	----	----	----	----	----
Molybdenum	----	0.024	0.023	0.019	0.014	0.021	0.020
Nickel	----	<0.001	0.002	<0.001	<0.001	<0.001	0.001
Phosphorous	----	<0.02	0.03	0.02	0.02	0.05	0.028
Potassium	----	1.19	1.04	0.99	1.1	1.45	1.154
Selenium	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	----	6.8	2.6	6.36	8.64	9.47	6.774
Silver	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	----	10	9.64	8.26	8.6	10.9	9.480
Strontium	----	0.69	0.61	0.73	0.68	0.7	0.682
Thorium	----	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	----	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	----	0.0044	<0.0005	<0.001	<0.001	0.015	0.021
Zinc	----	0.006	<0.001	0.002	0.002	0.01	0.004
Zirconium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hardness as $CaCO_3$	----	208	215.1	196	180	207	201.220

APPENDIX 3. Table 3.3. Analyses of total metals for Station W2 on Williams Creek 20 m downstream of the confluence with W1 for the period October 1989 to October 1992.

	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
pH	7.7	----	----	----	----	----	7.700
Conductivity	431	----	----	----	----	----	431.000
Suspended Solids	8	----	----	----	----	----	8.000
Turbidity	----	----	----	----	----	----	----
Aluminum	<0.02	----	----	----	----	----	<0.02
Antimony	<0.005	----	----	----	----	----	<0.005
Arsenic	<0.02	----	----	----	----	----	<0.02
Barium	0.035	----	----	----	----	----	0.035
Beryllium	<0.0001	----	----	----	----	----	<0.0001
Bismuth	----	----	----	----	----	----	----
Boron	<0.001	----	----	----	----	----	<0.001
Cadmium	<0.0002	----	----	----	----	----	<0.0002
Calcium	44.2	----	----	----	----	----	44.200
Chromium	<0.0002	----	----	----	----	----	<0.0002
Cobalt	<0.0005	----	----	----	----	----	<0.0005
Copper	<0.0005	----	----	----	----	----	<0.0005
Iron	0.371	----	----	----	----	----	0.371
Lead	<0.002	----	----	----	----	----	<0.002
Lithium	0.3	----	----	----	----	----	0.300
Magnesium	12.8	----	----	----	----	----	12.800
Manganese	0.068	----	----	----	----	----	0.068
Mercury	<0.005	----	----	----	----	----	<0.005
Molybdenum	0.003	----	----	----	----	----	0.003
Nickel	0.0015	----	----	----	----	----	0.002
Phosphorous	<0.05	----	----	----	----	----	<0.05
Potassium	0.9	----	----	----	----	----	0.900
Selenium	<0.005	----	----	----	----	----	<0.005
Silicon	3.99	----	----	----	----	----	3.990
Silver	<0.002	----	----	----	----	----	<0.002
Sodium	12.8	----	----	----	----	----	12.800
Strontium	0.444	----	----	----	----	----	0.444
Thorium	<0.01	----	----	----	----	----	<0.01
Titanium	<0.001	----	----	----	----	----	<0.001
Uranium	<0.02	----	----	----	----	----	<0.02
Vanadium	<0.0002	----	----	----	----	----	<0.0002
Zinc	0.033	----	----	----	----	----	0.033
Zirconium	----	----	----	----	----	----	----
Chloride	3.6	----	----	----	----	----	3.600
Fluoride	1.1	----	----	----	----	----	1.100
Nitrate	<0.1	----	----	----	----	----	<0.1
Sulphate	76	----	----	----	----	----	76.000
Nitrite	<0.003	----	----	----	----	----	<0.003
T. Phosphorous	----	----	----	----	----	----	----
Ammonia	0.06	----	----	----	----	----	0.060
Alkalinity as $CaCO_3$	100	----	----	----	----	----	100.000
Hardness as $CaCO_3$	133.1	----	----	----	----	----	133.100

APPENDIX 3. Table 3.4. Analyses of total metals for Station W3 on an unnamed east flowing tributary of Williams Creek for the period October 1989 to October 1992.

	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
pH	7.5	8.2	NO FLOW	7.9	7.5	7.4	7.700
Conductivity	380	263	----	114	210	340	261.400
Suspended Solids	<5	<5	----	<5	<5	<5	<5
Turbidity	----	<1	----	1	1	<1	1.000
Aluminum	<0.02	<0.005	----	0.091	0.067	0.03	0.036
Antimony	<0.005	<0.05	----	<0.02	<0.02	<0.02	<0.05
Arsenic	<0.02	<0.05	----	<0.04	<0.04	<0.05	<0.05
Barium	0.037	0.051	----	0.019	0.038	0.092	0.047
Beryllium	<0.0001	<0.0005	----	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	----	<0.02	<0.02	<0.02	<0.02
Boron	<0.001	----	----	----	----	----	<0.001
Cadmium	<0.0002	<0.0003	----	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	52.4	48.3	----	15	39.8	53.3	41.760
Chromium	0.0024	0.009	----	<0.001	<0.001	<0.001	0.003
Cobalt	<0.0005	<0.001	----	<0.001	<0.001	0.002	0.001
Copper	<0.0005	<0.001	----	<0.001	0.009	0.013	0.005
Iron	0.084	0.088	----	0.171	0.172	0.261	0.155
Lead	<0.002	<0.004	----	<0.004	<0.004	<0.005	<0.005
Lithium	0.34	<0.05	----	<0.05	<0.05	<0.05	0.108
Magnesium	8.89	8.74	----	3.56	7.3	11.1	7.918
Manganese	0.57	0.004	----	0.004	0.159	0.361	0.220
Mercury	<0.005	----	----	----	----	----	<0.005
Molybdenum	<0.001	<0.005	----	<0.003	<0.003	<0.004	<0.005
Nickel	0.0009	<0.001	----	<0.001	0.005	0.006	0.003
Phosphorous	<0.05	<0.02	----	0.03	0.03	0.03	0.032
Potassium	0.8	0.38	----	1.26	0.69	0.96	0.818
Selenium	<0.005	<0.01	----	<0.02	<0.02	<0.02	<0.02
Silicon	4.33	13	----	5.19	10.2	12.6	9.064
Silver	<0.002	<0.001	----	<0.001	<0.001	<0.001	<0.002
Sodium	7.32	8.06	----	2.36	6.44	8.51	6.538
Strontium	0.481	0.27	----	0.11	0.36	0.46	0.336
Thorium	<0.01	<0.02	----	<0.005	<0.005	<0.01	<0.02
Titanium	<0.001	<0.001	----	0.002	<0.001	<0.001	0.001
Uranium	<0.02	<0.02	----	<0.02	<0.02	<0.02	<0.02
Vanadium	<0.0002	0.0032	----	<0.001	<0.001	0.006	0.002
Zinc	0.0523	0.002	----	0.005	0.004	0.009	0.014
Zirconium	----	<0.001	----	<0.001	<0.001	<0.001	<0.001
Chloride	2.8	----	----	----	----	----	2.800
Fluoride	<1	----	----	----	----	----	<1
Nitrate	<0.1	<0.1	----	<0.05	<0.2	<0.2	<0.2
Sulphate	21	8.1	----	3.6	9.5	16.8	11.800
Nitrite	<0.003	<0.003	----	<0.03	<2.0	<2	<2
T. Phosphorous	----	----	----	0.02	0.013	0.01	0.014
Ammonia	0.08	<0.05	----	<0.05	<0.05	0.07	0.060
Alkalinity as $CaCO_3$	130	153	----	57	152	160	130.400
Hardness as $CaCO_3$	167.4	157	----	52.9	131	180	137.660

APPENDIX 3. Table 3.5. Analyses of dissolved metals for Station W3 on an unnamed east flowing tributary of Williams Creek for the period October 1989 to October 1992.

PARAMETER	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
Aluminum	----	<0.005	NO FLOW	0.046	0.066	<0.005	0.030
Antimony	----	<0.05	----	<0.02	<0.02	<0.02	<0.05
Arsenic	----	<0.05	----	<0.04	<0.04	<0.05	<0.05
Barium	----	0.05	----	0.017	0.036	0.046	0.037
Beryllium	----	<0.0005	----	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	----	<0.02	<0.02	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	<0.0003	----	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	----	45.8	----	14.4	33.6	46	34.950
Chromium	----	<0.001	----	<0.001	<0.001	<0.001	<0.001
Cobalt	----	<0.001	----	<0.001	<0.001	0.002	0.001
Copper	----	<0.001	----	<0.001	<0.001	0.002	0.001
Iron	----	0.064	----	0.11	0.11	0.26	0.136
Lead	----	<0.004	----	<0.004	<0.004	<0.005	<0.005
Lithium	----	<0.05	----	<0.05	<0.05	<0.05	<0.05
Magnesium	----	8.6	----	3.4	5.9	11.2	7.275
Manganese	----	0.004	----	0.002	0.154	0.36	0.130
Mercury	----	----	----	----	----	----	----
Molybdenum	----	<0.005	----	<0.003	<0.003	<0.004	<0.005
Nickel	----	<0.001	----	<0.001	0.003	0.003	0.002
Phosphorous	----	<0.02	----	0.02	<0.02	0.02	0.020
Potassium	----	0.34	----	1.1	0.7	0.91	0.763
Selenium	----	<0.01	----	<0.02	<0.02	<0.02	<0.02
Silicon	----	9	----	5.08	7.9	9	7.745
Silver	----	<0.001	----	<0.001	<0.001	<0.001	<0.001
Sodium	----	7.42	----	2.33	6.16	8.01	5.980
Strontium	----	0.26	----	0.1	0.31	0.4	0.268
Thorium	----	<0.02	----	<0.005	<0.005	<0.01	<0.02
Titanium	----	<0.001	----	<0.001	<0.001	<0.001	<0.001
Uranium	----	<0.02	----	<0.02	<0.02	<0.02	<0.02
Vanadium	----	0.0016	----	<0.001	<0.001	0.006	0.002
Zinc	----	0.002	----	0.003	0.002	0.008	0.004
Zirconium	----	<0.001	----	<0.001	<0.001	<0.001	<0.001
Hardness as $CaCO_3$	----	150	----	50.3	109	162	117.825

APPENDIX 3. Table 3.6. Analyses of total metals for Station W4 on Williams Creek 100m downstream of the confluence with W3 for the period October 1989 to October 1992.

PARAMETER	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
pH	7.7	8	8.1	7.4	7.8	7.5	7.750
Conductivity	395	210	465	98	210	370	291.333
Suspended Solids	<5	37	<5	253	258	<5	93.800
Turbidity	----	4	1	14	25	1	9.000
Aluminum	<0.02	0.154	<0.005	2.75	3.89	0.036	1.142
Antimony	<0.005	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	<0.02	<0.05	0.12	<0.04	<0.04	<0.05	0.053
Barium	0.031	0.049	0.057	0.078	0.11	0.175	0.083
Beryllium	<0.0001	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	<0.001	----	----	----	----	----	<0.001
Cadmium	<0.0002	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	<0.004
Calcium	40.5	32.7	63.4	15.6	27.7	46.4	37.717
Chromium	<0.0002	0.012	0.006	0.002	0.006	0.002	0.005
Cobalt	<0.0005	<0.001	0.002	0.003	0.002	0.003	0.002
Copper	<0.0005	<0.001	<0.001	0.01	0.014	0.008	0.006
Iron	0.519	1.11	0.349	3.68	6.6	0.709	2.161
Lead	<0.002	<0.004	<0.004	<0.004	0.005	<0.005	0.004
Lithium	0.35	<0.05	<0.05	<0.05	<0.05	<0.05	0.100
Magnesium	10.7	8.47	16.1	5.2	7.7	13	10.195
Manganese	0.077	0.058	0.1	0.136	0.191	0.166	0.121
Mercury	<0.005	----	----	----	----	----	<0.005
Molybdenum	<0.001	<0.005	0.01	<0.003	<0.003	<0.004	0.004
Nickel	0.0014	0.002	0.005	<0.001	0.014	0.005	0.005
Phosphorous	<0.05	0.05	0.04	0.03	0.2	0.03	0.067
Potassium	0.8	0.48	1.14	1.41	1	0.95	0.963
Selenium	<0.005	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	4.86	13.4	5.5	9.71	16.3	11	10.128
Silver	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002
Sodium	11.2	9.93	14.9	2.77	6.58	12.6	9.663
Strontium	0.372	0.26	0.42	0.142	0.24	0.4	0.306
Thorium	<0.01	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	<0.001	0.016	0.002	0.146	0.192	<0.001	0.060
Uranium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	<0.0002	0.0049	<0.0005	<0.001	0.016	0.01	0.005
Zinc	0.0578	0.004	<0.001	0.019	0.018	0.008	0.018
Zirconium	----	<0.001	<0.001	<0.001	0.002	<0.001	0.001
Chloride	3.6	----	----	----	----	----	3.600
Fluoride	<1	----	----	----	----	----	<1
Nitrate	<0.1	<0.1	<0.5	0.05	<0.1	<0.02	0.022
Sulphate	47	20.7	80.6	3.5	8.9	59.8	36.750
Nitrite	<0.0003	<0.003	<5	<0.03	<1	<2.0	<5
T. Phosphorous	----	----	0.032	0.018	0.173	0.017	0.060
Ammonia	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	0.052
Alkalinity as $CaCO_3$	120	103	169	28	94	125	106.500
Hardness as $CaCO_3$	145.1	119	224	82.5	135	170	145.933

APPENDIX 3. Table 3.7. Analyses of dissolved metals for Station W4 on Williams Creek 100 m downstream of the confluence with W3 for the period October 1989 to October 1992.

	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
Aluminum	----	0.007	<0.005	0.03	0.043	0.018	0.020
Antimony	----	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	----	<0.05	0.11	<0.04	<0.04	<0.05	0.058
Barium	----	0.04	0.053	0.01	0.041	0.054	0.040
Beryllium	----	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	----	30.7	61.3	7.49	27.3	43.4	34.038
Chromium	----	0.002	0.004	<0.001	<0.001	<0.001	0.002
Cobalt	----	<0.001	0.002	<0.001	<0.001	0.003	0.002
Copper	----	<0.001	<0.001	<0.001	<0.001	0.002	0.001
Iron	----	0.472	0.252	0.12	0.396	0.628	0.374
Lead	----	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	----	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	----	8.11	15.3	2.24	7.66	12	9.062
Manganese	----	0.037	0.098	0.014	0.033	0.165	0.069
Mercury	----	----	----	----	----	----	----
Molybdenum	----	<0.005	0.009	<0.003	<0.003	<0.004	0.005
Nickel	----	<0.001	0.004	<0.001	0.002	0.004	0.002
Phosphorous	----	0.03	0.02	0.02	0.03	0.02	0.024
Potassium	----	0.48	0.97	0.61	0.54	0.99	0.718
Selenium	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	----	10.5	4.8	2.73	14	10	8.406
Silver	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	----	9.2	13.8	1.74	6.37	12.5	8.722
Strontium	----	0.26	0.41	0.063	0.24	0.36	0.267
Thorium	----	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	----	0.002	<0.001	<0.001	0.002	<0.001	0.001
Uranium	----	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	----	0.003	<0.0005	<0.001	<0.001	0.014	0.004
Zinc	----	0.003	<0.001	0.004	0.007	0.008	0.004
Zirconium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hardness as $CaCO_3$	----	111	216	28.3	103	159	123.460

APPENDIX 3. Table 3.8. Analyses of total metals for Station W5 on an unnamed northwest flowing tributary of Williams Creek for the period October 1989 to October 1992.

PARAMETER	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
	OCT 89	AUG 91 *dupl.	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
pH	7.5	7.2	8.1	7.2	7.2	7.5	7.450
Conductivity	157	91	280	91	89	228	156.000
Suspended Solids	<5	1825	34	103	800	<5	462.000
Turbidity	----	120	17	11	27	3	35.600
Aluminum	<0.02	9.58	<0.005	1.71	8.02	0.037	3.229
Antimony	<0.005	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	<0.02	0.11	0.11	0.04	<0.04	<0.05	0.062
Barium	0.013	0.455	0.035	0.051	0.239	0.037	0.138
Beryllium	<0.0001	0.00065	<0.0005	<0.0002	<0.0002	<0.0002	0.0003
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	<0.001	----	----	----	----	----	<0.001
Cadmium	<0.0002	0.0006	<0.0003	<0.0003	<0.0003	0.0004	0.0004
Calcium	18.8	29.5	39.6	13.1	25.3	30.3	26.100
Chromium	0.0016	0.05	0.007	<0.001	0.014	0.002	0.013
Cobalt	<0.0005	0.016	0.001	<0.001	0.007	0.003	0.005
Copper	<0.0005	0.059	<0.001	0.007	0.034	0.004	0.018
Iron	0.458	31.4	1.48	2.2	14.4	0.664	8.434
Lead	<0.002	0.015	<0.004	<0.004	0.009	<0.005	0.007
Lithium	0.36	<0.05	<0.05	<0.05	<0.05	<0.05	0.102
Magnesium	4.16	8.95	10.1	4.09	6.9	7.62	6.970
Manganese	0.046	0.62	0.191	0.098	0.419	0.304	0.280
Mercury	<0.005	----	----	----	----	----	<0.005
Molybdenum	<0.001	<0.005	<0.005	<0.003	<0.003	<0.004	<0.005
Nickel	0.0029	0.04	0.007	<0.001	0.025	0.004	0.013
Phosphorous	<0.05	1.64	0.16	0.08	0.82	0.03	0.463
Potassium	<0.2	3.28	1.65	1.61	1.21	0.52	1.410
Selenium	<0.005	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	5.53	19.8	5.9	7.84	22.2	13	12.378
Silver	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002
Sodium	5.57	6.56	9.7	2.85	6.28	8.65	6.602
Strontium	0.089	0.22	0.159	0.083	0.15	0.157	0.143
Thorium	<0.01	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	<0.001	1.07	0.005	0.084	0.364	<0.001	0.262
Uranium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	<0.0002	0.126	<0.0005	0.008	0.043	0.007	0.031
Zinc	0.0661	0.072	0.004	0.015	0.043	0.01	0.035
Zirconium	----	0.005	<0.001	<0.001	0.003	<0.001	0.002
Chloride	1.01	----	----	----	----	----	1.010
Fluoride	<1	----	----	----	----	----	<1
Nitrate	<0.1	<0.05	<0.2	<0.05	<0.03	<0.2	<0.2
Sulphate	3.29	3.2	3.8	2	2.7	9.4	4.065
Nitrite	<0.003	0.003	<2.0	<0.03	<0.05	<2.0	0.001
T. Phosphorous	----	----	0.132	0.022	0.24	0.027	0.070
Ammonia	<0.05	0.08	<0.05	<0.05	0.11	0.2	0.065
Alkalinity as $CaCO_3$	88	58	145	44	66	100	83.500
Hardness as $CaCO_3$	84	51.8	140	63.3	163	109	101.850

APPENDIX 3. Table 3.9. Analyses of dissolved metals for Station W5 on an unnamed northwest flowing tributary of Williams Creek for the period October 1989 to October 1992.

	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
		*dupl.					
Aluminum	----	0.037	<0.005	0.058	0.06	0.034	0.039
Antimony	----	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	----	<0.05	0.09	<0.04	<0.04	<0.05	0.005
Barium	----	0.037	0.032	0.017	0.041	0.031	0.032
Beryllium	----	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	----	23.7	39.4	10	19	26.1	23.640
Chromium	----	0.007	0.006	<0.001	<0.001	<0.001	0.003
Cobalt	----	0.001	0.001	<0.001	<0.001	0.003	0.001
Copper	----	0.001	<0.001	0.006	<0.001	0.001	0.002
Iron	----	0.987	0.748	0.392	0.63	0.322	0.616
Lead	----	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	----	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	----	5.82	9.83	2.88	4.37	6.6	5.900
Manganese	----	0.142	0.224	0.053	0.194	0.271	0.177
Mercury	----	----	----	----	----	----	----
Molybdenum	----	<0.005	<0.005	<0.003	<0.003	<0.004	<0.005
Nickel	----	0.0045	0.005	<0.001	0.002	0.003	0.003
Phosphorous	----	<0.02	0.11	0.03	0.03	0.03	0.044
Potassium	----	0.23	1.25	1.12	0.28	0.5	0.676
Selenium	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	----	10.6	5.5	4.3	14.3	11.4	9.220
Silver	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	----	5.38	7.95	2.47	5.44	6.96	5.640
Strontium	----	0.074	0.156	0.06	0.11	0.136	0.107
Thorium	----	<0.02	<0.02	<0.005	<0.005	<0.01	<0.01
Titanium	----	0.003	0.003	<0.001	0.002	<0.001	0.002
Uranium	----	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	----	0.004	<0.0005	0.001	<0.001	0.006	0.003
Zinc	----	0.004	<0.001	0.008	0.005	0.008	0.005
Zirconium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hardness as $CaCO_3$	----	51.8	139	38	135	93.7	91.500

APPENDIX 3. Table 3.10. Analyses of total metals for Station W6 on Williams Creek 50 m downstream of the confluence with W5 for the period October 1989 to October 1992.

	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
pH	7.9	----	----	----	----	----	7.900
Conductivity	415	----	----	----	----	----	415.000
Suspended Solids	<5	----	----	----	----	----	<5
Turbidity	----	----	----	----	----	----	----
Aluminum	<0.02	----	----	----	----	----	<0.02
Antimony	<0.005	----	----	----	----	----	<0.005
Arsenic	<0.02	----	----	----	----	----	<0.02
Barium	0.034	----	----	----	----	----	0.034
Beryllium	<0.0001	----	----	----	----	----	<0.0001
Bismuth	----	----	----	----	----	----	----
Boron	0.002	----	----	----	----	----	0.002
Cadmium	<0.0002	----	----	----	----	----	<0.0002
Calcium	43.8	----	----	----	----	----	43.800
Chromium	0.0012	----	----	----	----	----	0.001
Cobalt	<0.0005	----	----	----	----	----	<0.0005
Copper	0.001	----	----	----	----	----	0.001
Iron	0.637	----	----	----	----	----	0.637
Lead	<0.002	----	----	----	----	----	<0.002
Lithium	0.3	----	----	----	----	----	0.300
Magnesium	13.9	----	----	----	----	----	13.900
Manganese	0.101	----	----	----	----	----	0.101
Mercury	<0.005	----	----	----	----	----	<0.005
Molybdenum	<0.001	----	----	----	----	----	<0.001
Nickel	0.0018	----	----	----	----	----	0.002
Phosphorous	<0.05	----	----	----	----	----	<0.05
Potassium	0.9	----	----	----	----	----	0.900
Selenium	<0.005	----	----	----	----	----	<0.005
Silicon	5.08	----	----	----	----	----	5.080
Silver	<0.002	----	----	----	----	----	<0.002
Sodium	14.3	----	----	----	----	----	14.300
Strontium	0.426	----	----	----	----	----	0.426
Thorium	<0.01	----	----	----	----	----	<0.01
Titanium	<0.001	----	----	----	----	----	<0.001
Uranium	<0.02	----	----	----	----	----	<0.02
Vanadium	<0.0002	----	----	----	----	----	<0.0002
Zinc	0.108	----	----	----	----	----	0.108
Zirconium	----	----	----	----	----	----	----
Chloride	1.3	----	----	----	----	----	1.300
Fluoride	<1	----	----	----	----	----	<1
Nitrate	<0.1	----	----	----	----	----	<0.1
Sulphate	51	----	----	----	----	----	51.000
Nitrite	0.003	----	----	----	----	----	0.003
T. Phosphorous	----	----	----	----	----	----	----
Ammonia	0.05	----	----	----	----	----	0.050
Alkalinity as $CaCO_3$	140	----	----	----	----	----	140.000
Hardness as $CaCO_3$	168.6	----	----	----	----	----	168.600

APPENDIX 3. Table 3.11. Analyses of total metals for Station W7 on an unnamed east flowing tributary of Williams Creek for the period October 1989 to October 1992.

PARAMETER	CONCENTRATION (mg/L) BY SAMPLE PERIOD OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
pH	7.7	7.6	7.3	7.4	7.6	7.5	7.517
Conductivity	325	192	435	81	166	345	257.333
Suspended Solids	<5	<5	23	<5	<5	<5	8.000
Turbidity	----	1	6	2	4	<1	2.800
Aluminum	<0.02	<0.005	<0.005	0.084	0.192	0.035	0.057
Antimony	<0.005	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	<0.02	<0.05	0.16	<0.04	<0.04	<0.05	0.060
Barium	0.037	0.036	0.091	0.012	0.039	0.062	0.046
Beryllium	<0.0001	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	0.016
Boron	0.007	----	----	----	----	----	0.007
Cadmium	<0.0002	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	0.0003
Calcium	38.2	36.2	68.3	11.5	37	54.4	40.933
Chromium	0.0081	0.007	0.007	<0.001	<0.001	<0.001	0.004
Cobalt	<0.0005	<0.001	0.007	<0.001	<0.001	0.002	0.002
Copper	0.009	<0.001	<0.001	0.01	0.004	0.005	0.005
Iron	0.195	0.267	11.6	0.072	0.266	0.219	2.103
Lead	0.003	<0.004	<0.004	<0.004	<0.004	<0.005	0.004
Lithium	0.36	<0.06	<0.05	<0.05	<0.05	<0.05	0.103
Magnesium	8.84	6.83	12.6	2.83	7.2	11.3	8.267
Manganese	0.026	0.03	3.62	0.004	0.007	0.073	0.627
Mercury	<0.005	----	----	----	----	----	<0.005
Molybdenum	<0.001	<0.005	0.008	<0.003	<0.003	<0.004	0.004
Nickel	0.002	0.002	0.009	<0.001	0.007	0.002	0.004
Phosphorous	<0.05	<0.02	0.34	0.03	0.03	0.03	0.083
Potassium	0.3	0.25	0.5	1.54	0.35	0.44	0.563
Selenium	<0.005	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	4.69	13.9	5.8	4.14	13.9	14.8	9.538
Silver	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002
Sodium	7.21	5.56	6.45	1.74	6.09	9.93	6.163
Strontium	0.161	0.14	0.23	0.053	0.18	0.26	0.171
Thorium	<0.01	<0.02	<0.02	<0.005	<0.005	<0.01	<0.01
Titanium	<0.001	<0.001	0.005	0.002	0.008	<0.001	0.003
Uranium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	<0.0002	0.0008	<0.0005	<0.001	<0.001	0.006	0.007
Zinc	0.0185	0.01	0.003	0.005	0.007	0.014	0.010
Zirconium	----	0.001	<0.001	<0.001	0.002	<0.001	0.001
Chloride	2.6	----	----	----	----	----	0.433
Fluoride	<1	----	----	----	----	----	<1
Nitrate	<0.1	<0.1	<0.05	<0.05	<0.1	<0.2	<0.2
Sulphate	15.1	10.9	0.83	1.1	11	29.6	11.422
Nitrite	<0.003	<0.003	<0.5	<0.03	<1	<2.0	<2.0
T. Phosphorous	----	----	0.3	0.016	0.015	<0.005	0.084
Ammonia	0.05	<0.05	0.05	<0.05	<0.05	0.06	0.052
Alkalinity as $CaCO_3$	120	111	230	41	110	141	125.500
Hardness as $CaCO_3$	123.6	119	222	41	124	183	135.433

APPENDIX 3. Table 3.12. Analyses of dissolved metals for Station W7 on an unnamed east flowing tributary of Williams Creek for the period October 1989 to October 1992.

	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
Aluminum	----	<0.005	<0.005	0.059	0.017	0.035	0.024
Antimony	----	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	----	<0.05	0.12	<0.04	<0.04	<0.05	0.060
Barium	----	0.036	0.09	0.01	0.039	0.061	0.047
Beryllium	----	<0.0005	0.003	<0.0002	<0.0002	<0.0002	0.0008
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	----	34.5	60.3	11.1	37	44.6	37.500
Chromium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	----	<0.001	0.007	<0.001	<0.001	<0.001	0.002
Copper	----	<0.001	<0.001	0.009	<0.001	0.002	0.002
Iron	----	0.199	9.4	0.07	0.054	0.161	1.977
Lead	----	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	----	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	----	6.63	9	2.73	7.24	11.1	7.340
Manganese	----	0.024	2.59	0.002	0.004	0.066	0.537
Mercury	----	----	----	----	----	----	----
Molybdenum	----	<0.005	<0.005	<0.003	<0.003	<0.004	<0.005
Nickel	----	0.004	0.005	<0.001	0.002	0.001	0.003
Phosphorous	----	<0.02	0.2	0.02	<0.02	<0.02	0.056
Potassium	----	0.19	0.45	1.46	0.23	0.4	0.546
Selenium	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.001
Silicon	----	11	5.3	3.9	13.5	9.9	8.720
Silver	----	<0.001	<0.001	<0.001	<0.001	<0.001	0.000
Sodium	----	6.86	6.35	1.69	6.06	9.92	6.176
Strontium	----	0.138	0.16	0.051	0.176	0.2	0.145
Thorium	----	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	----	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	----	0.0007	<0.0005	<0.001	<0.001	0.003	0.001
Zinc	----	0.003	0.002	0.004	0.006	0.009	0.005
Zirconium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hardness as $CaCO_3$	----	114	188	39.4	122	158	124.280

APPENDIX 3. Table 3.13. Analyses of total metals for Station W9 on Williams Creek for the period October 1989 to October 1992.

PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
pH	7.8	8.2	7.9	7.5	7.9	7.6	7.815
Conductivity	505	275	635	85	130	475	350.833
Suspended Solids	<5	<5	15	<5	<5	<5	6.667
Turbidity	----	<1	7	2	<1	<1	2.400
Aluminum	<0.02	<0.005	<0.005	0.088	0.057	0.026	0.034
Antimony	<0.005	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	<0.02	<0.05	0.16	<0.04	<0.04	<0.05	0.060
Barium	0.043	0.049	0.082	0.013	0.034	0.067	0.288
Beryllium	<0.0001	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	0.004	----	----	----	----	----	0.004
Cadmium	<0.0002	<0.0003	<0.0003	0.0004	<0.0003	<0.0004	0.0003
Calcium	44.2	35.6	83	9.8	25.7	48.5	41.133
Chromium	0.0005	0.008	0.007	<0.001	<0.001	<0.001	0.003
Cobalt	<0.0005	<0.001	0.004	<0.001	0.001	0.003	0.002
Copper	<0.0005	<0.001	<0.001	0.002	0.004	0.003	0.002
Iron	0.199	0.138	3.17	0.117	0.137	0.197	0.660
Lead	<0.002	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	0.29	<0.06	<0.05	<0.05	<0.05	<0.05	<0.06
Magnesium	18.2	13.8	22.7	3.1	7.5	19.2	14.083
Manganese	0.015	0.016	1.3	0.003	<0.001	0.044	1.379
Mercury	<0.005	----	----	----	----	----	<0.005
Molybdenum	<0.001	<0.005	0.007	<0.003	<0.003	<0.004	0.004
Nickel	0.0012	0.005	0.007	<0.001	0.006	0.003	0.004
Phosphorous	<0.05	<0.02	0.37	0.03	<0.02	0.02	0.085
Potassium	1.3	0.82	1.91	0.85	0.45	1.64	1.162
Selenium	<0.005	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	4.92	9.9	4.3	3.66	13	12	7.963
Silver	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002
Sodium	19.1	14.2	7	2.13	5.98	22.9	11.885
Strontium	0.583	0.4	0.56	0.078	0.28	0.54	0.407
Thorium	<0.01	<0.02	<0.02	<0.005	0.01	<0.01	0.013
Titanium	<0.001	<0.001	0.007	0.004	0.002	<0.001	0.003
Uranium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	<0.0002	0.0038	<0.0005	0.001	<0.001	0.016	0.004
Zinc	0.0064	0.008	<0.001	0.007	0.003	0.017	0.006
Zirconium	----	<0.001	<0.001	<0.001	0.002	<0.001	0.001
Chloride	2	----	----	----	----	----	2.000
Fluoride	<1	----	----	----	----	----	<1
Nitrate	<0.1	<0.1	<0.05	<0.05	<0.1	<0.2	<0.2
Sulphate	54	17	50.8	1.8	6.2	47.8	29.600
Nitrite	<0.003	<0.003	<5.0	<0.03	<1	<2.0	<5
T. Phosphorous	----	----	0.29	0.012	0.009	0.009	0.080
Ammonia	0.08	<0.05	0.44	<0.05	<0.05	0.06	0.122
Alkalinity as $CaCO_3$	170	157	255	38	84	188	148.667
Hardness as $CaCO_3$	185.3	145	301	38	96.4	200	160.950

APPENDIX 3. Table 3.14. **Analyses of dissolved metals for Station W9 on Williams Creek for the period October 1989 to October 1992.**

PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
Aluminum	----	<0.005	<0.005	0.035	0.022	0.022	0.178
Antimony	----	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	----	<0.05	0.16	<0.04	<0.04	<0.05	0.050
Barium	----	0.049	0.066	0.009	0.029	0.064	0.043
Beryllium	----	<0.0005	<0.0005	<0.0002	<0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	----	35.5	81.9	8.15	25.5	46.3	39.470
Chromium	----	<0.001	0.005	<0.001	<0.001	<0.001	0.002
Cobalt	----	<0.001	0.004	<0.001	<0.001	0.003	0.002
Copper	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	----	0.094	1.24	0.043	0.379	0.161	0.383
Lead	----	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	----	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	----	13	22.5	2.58	7.54	18.9	12.904
Manganese	----	0.016	1.26	0.001	<0.001	0.042	0.264
Mercury	----	----	----	----	----	----	----
Molybdenum	----	<0.005	0.006	<0.003	<0.003	<0.004	0.004
Nickel	----	0.005	0.004	<0.001	0.004	0.003	0.003
Phosphorous	----	<0.02	0.23	0.02	<0.02	<0.02	0.062
Potassium	----	0.81	1.83	0.62	0.38	1.41	1.010
Selenium	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	----	9.9	4	2.95	12.6	11.6	8.210
Silver	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	----	13.9	6.7	1.84	5.91	22.7	10.210
Strontium	----	0.4	0.55	0.065	0.232	0.53	0.355
Thorium	----	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	----	<0.001	0.002	<0.001	<0.001	<0.001	0.001
Uranium	----	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	----	0.0037	<0.0005	<0.001	<0.001	0.011	0.003
Zinc	----	0.004	<0.001	0.003	0.002	0.008	0.004
Zirconium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hardness as $CaCO_3$	----	142	297	31.2	95.6	194	151.960

APPENDIX 3. Table 3.15. Analyses of total metals for Station W10 on Williams Creek upstream of the Yukon River confluence for the period October 1989 to October 1992.

PARAMETER	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
pH	----	8.1	8.1	7.6	8	7.7	7.900
Conductivity	----	188	204	97	140	355	196.800
Suspended Solids	----	<5	<5	25	20	<5	13.000
Turbidity	----	2	1	7	6	<1	3.400
Aluminum	----	<0.005	<0.005	0.389	0.463	0.043	0.181
Antimony	----	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	----	<0.05	0.08	<0.04	<0.04	<0.05	0.052
Barium	----	0.026	0.146	0.026	0.034	0.055	0.057
Beryllium	----	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	----	32.1	59	16.3	29.9	47.9	37.040
Chromium	----	0.009	0.004	<0.001	<0.001	<0.001	0.003
Cobalt	----	<0.001	0.002	<0.001	<0.001	0.002	0.001
Copper	----	<0.001	<0.001	0.001	0.005	0.005	0.003
Iron	----	0.163	0.07	0.454	0.824	0.257	0.354
Lead	----	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	----	<0.06	<0.05	<0.05	<0.05	<0.05	<0.06
Magnesium	----	6.79	8.61	4.53	6.71	12	7.728
Manganese	----	0.004	0.034	0.024	0.027	0.018	0.021
Mercury	----	----	----	----	----	----	----
Molybdenum	----	<0.005	<0.003	<0.003	<0.003	<0.004	<0.005
Nickel	----	0.006	0.004	<0.001	0.006	0.003	0.004
Phosphorous	----	<0.02	<0.02	0.02	0.04	0.03	0.026
Potassium	----	0.41	1.24	1.4	0.62	1.3	0.994
Selenium	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	----	13.2	1.4	6.18	12.2	10	8.596
Silver	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	----	7.77	2.57	3.49	6.02	11.1	6.190
Strontium	----	0.24	0.166	0.132	0.29	0.47	0.260
Thorium	----	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	----	0.002	0.001	0.017	0.02	<0.001	0.008
Uranium	----	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	----	0.0021	<0.0005	<0.001	<0.001	0.01	0.003
Zinc	----	0.003	0.195	0.007	0.01	0.008	0.045
Zirconium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chloride	----	----	----	----	----	----	----
Fluoride	----	----	----	----	----	----	----
Nitrate	----	<0.1	0.08	<0.05	<0.1	<0.20	0.106
Sulphate	----	15.5	12.2	4.9	9.5	34.8	15.380
Nitrite	----	<0.003	<0.5	<0.03	<1	<2.0	<2.0
T. Phosphorous	----	----	0.015	0.014	0.04	0.025	0.019
Ammonia	----	<0.05	0.05	<0.05	<0.05	<0.05	0.050
Alkalinity as $CaCO_3$	----	103	166	59	94	144	113.200
Hardness as $CaCO_3$	----	108	183	62.5	102.2	170	125.140

APPENDIX 3. Table 3.16. Analyses of dissolved metals for Station W10 on Williams Creek upstream of the Yukon River confluence for the period October 1989 to October 1992.

	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
PARAMETER	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
Aluminum	----	<0.005	<0.005	0.08	0.042	0.043	0.035
Antimony	----	<0.05	<0.05	<0.02	<0.02	<0.02	<0.05
Arsenic	----	<0.05	0.06	<0.04	<0.04	<0.05	0.048
Barium	----	0.026	0.038	0.017	0.03	0.054	0.033
Beryllium	----	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	<0.0005
Bismuth	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	<0.0003	<0.0003	<0.0003	<0.0003	<0.0004	<0.0004
Calcium	----	31	57.1	15.8	29.5	43.5	35.380
Chromium	----	<0.001	0.004	<0.001	<0.001	<0.001	0.002
Cobalt	----	<0.001	<0.001	<0.001	<0.001	0.001	0.001
Copper	----	<0.001	<0.001	<0.001	<0.001	0.005	0.002
Iron	----	0.08	0.022	0.171	0.164	0.129	0.113
Lead	----	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
Lithium	----	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	----	6.63	6.92	4.38	6.65	11	7.116
Manganese	----	0.001	0.002	<0.001	<0.001	0.016	0.004
Mercury	----	----	----	----	----	----	----
Molybdenum	----	<0.005	<0.005	<0.003	<0.003	<0.004	<0.005
Nickel	----	0.004	<0.001	<0.001	0.004	0.003	0.003
Phosphorous	----	<0.02	<0.02	0.02	0.04	0.02	0.016
Potassium	----	0.59	0.64	1.25	0.5	1.32	0.860
Selenium	----	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02
Silicon	----	10.4	1.2	5.21	11.5	8.9	7.442
Silver	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	----	7.35	0.89	3.48	5.92	11.1	5.748
Strontium	----	0.24	0.11	0.131	0.234	0.43	0.229
Thorium	----	<0.02	<0.02	<0.005	<0.005	<0.01	<0.02
Titanium	----	0.001	0.001	0.001	<0.001	<0.001	0.005
Uranium	----	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	----	0.0011	<0.0005	<0.001	<0.001	0.004	0.004
Zinc	----	0.002	<0.001	0.005	0.01	0.008	0.005
Zirconium	----	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hardness as $CaCO_3$	----	105	171	58.1	102	156	118.420

APPENDIX 3. Table 3.17. Analyses of total metals for Station W11 on Nancy Lee Creek upstream of the Williams Creek confluence for the period October 1989 to October 1992.

PARAMETER	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
pH	----	----	8.1	7.4	----	7.8	7.767
Conductivity	----	----	350	84	----	320	251.333
Suspended Solids	----	----	<5	8	----	<5	6.000
Turbidity	----	----	1	5	----	<1	2.333
Aluminum	----	----	<0.005	0.13	----	0.055	0.063
Antimony	----	----	<0.05	<0.02	----	<0.02	<0.05
Arsenic	----	----	0.12	<0.04	----	<0.05	0.070
Barium	----	----	0.04	0.016	----	0.046	0.034
Beryllium	----	----	<0.0005	<0.0002	----	<0.0002	<0.0005
Bismuth	----	----	<0.01	<0.02	----	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	----	<0.0003	<0.0003	----	<0.0004	<0.0004
Calcium	----	----	53.9	13.8	----	42.6	36.767
Chromium	----	----	0.004	<0.001	----	<0.001	0.002
Cobalt	----	----	<0.001	<0.001	----	0.002	0.001
Copper	----	----	<0.001	0.003	----	0.005	0.003
Iron	----	----	<0.005	0.161	----	0.268	0.143
Lead	----	----	<0.004	<0.004	----	<0.005	<0.005
Lithium	----	----	<0.05	<0.05	----	<0.05	<0.05
Magnesium	----	----	11.3	3.4	----	11.5	8.733
Manganese	----	----	0.003	0.007	----	0.083	0.031
Mercury	----	----	----	----	----	----	----
Molybdenum	----	----	<0.05	<0.003	----	<0.004	<0.05
Nickel	----	----	0.002	<0.001	----	<0.02	0.007
Phosphorous	----	----	<0.02	<0.02	----	<0.02	<0.02
Potassium	----	----	1.13	1.3	----	1	1.143
Selenium	----	----	<0.01	<0.02	----	<0.02	<0.02
Silicon	----	----	3.6	4.92	----	10	6.173
Silver	----	----	<0.001	<0.001	----	<0.001	<0.001
Sodium	----	----	9.29	2.78	----	9.69	7.253
Strontium	----	----	0.39	0.088	----	0.33	0.269
Thorium	----	----	<0.02	<0.005	----	<0.01	<0.02
Titanium	----	----	0.002	0.003	----	<0.001	0.002
Uranium	----	----	<0.02	<0.02	----	<0.02	<0.02
Vanadium	----	----	<0.0005	<0.001	----	0.008	0.003
Zinc	----	----	0.004	0.007	----	0.007	0.006
Zirconium	----	----	<0.001	<0.001	----	<0.001	<0.001
Chloride	----	----	----	----	----	----	----
Fluoride	----	----	----	----	----	----	----
Nitrate	----	----	<0.2	<0.05	----	<0.2	<0.2
Sulphate	----	----	49.2	2.6	----	29.2	27.000
Nitrite	----	----	<2	<0.03	----	<2.0	<2.0
T. Phosphorous	----	----	0.01	0.012	----	0.006	0.009
Ammonia	----	----	<0.05	<0.05	----	<0.05	<0.05
Alkalinity as $CaCO_3$	----	----	135	50	----	143	109.333
Hardness as $CaCO_3$	----	----	181	49.5	----	155	128.500

APPENDIX 3. Table 3.18. Analyses of dissolved metals for Station W11 on Nancy Lee Creek upstream of the Williams Creek confluence for the period October 1989 to October 1992.

PARAMETER	CONCENTRATION (mg/L) BY SAMPLE PERIOD						
	OCT 89	AUG 91	DEC 91	MAY 92	JUL 92	OCT 92	AVERAGE
Aluminum	----	----	<0.005	0.084	----	0.05	0.046
Antimony	----	----	<0.05	<0.02	----	<0.02	<0.05
Arsenic	----	----	0.1	<0.04	----	<0.05	0.063
Barium	----	----	0.035	0.014	----	0.045	0.031
Beryllium	----	----	<0.0005	<0.0002	----	<0.0002	<0.0005
Bismuth	----	----	<0.01	<0.02	----	<0.02	<0.02
Boron	----	----	----	----	----	----	----
Cadmium	----	----	<0.0003	<0.0003	----	<0.0004	<0.0004
Calcium	----	----	50.1	13.2	----	41.4	34.900
Chromium	----	----	0.003	<0.001	----	<0.001	0.002
Cobalt	----	----	<0.001	<0.001	----	0.001	0.001
Copper	----	----	<0.001	<0.001	----	0.004	0.002
Iron	----	----		0.115	----	0.2	0.105
Lead	----	----	<0.004	<0.004	----	<0.005	<0.005
Lithium	----	----	<0.05	<0.05	----	<0.05	<0.05
Magnesium	----	----	10.7	3.24	----	11.4	8.447
Manganese	----	----	<0.001	<0.001	----	0.08	0.027
Mercury	----	----	----	----	----	----	----
Molybdenum	----	----	<0.005	<0.003	----	<0.004	<0.005
Nickel	----	----	0.002	<0.001	----	0.003	0.002
Phosphorous	----	----	<0.02	<0.02	----	<0.02	<0.02
Potassium	----	----	0.92	1.19	----	0.99	1.033
Selenium	----	----	<0.01	<0.02	----	<0.02	<0.02
Silicon	----	----	3.3	4.47	----	9.6	5.790
Silver	----	----	<0.001	<0.001	----	<0.001	<0.001
Sodium	----	----	8.24	2.74	----	9.6	6.860
Strontium	----	----	0.37	0.084	----	0.33	0.261
Thorium	----	----	<0.02	<0.005	----	<0.01	<0.02
Titanium	----	----	<0.001	0.001	----	<0.001	0.001
Uranium	----	----	<0.02	<0.02	----	<0.02	<0.02
Vanadium	----	----	<0.0005	<0.001	----	0.006	0.003
Zinc	----	----	<0.001	0.003	----	0.006	0.003
Zirconium	----	----	<0.001	<0.001	----	<0.001	<0.001
Hardness as $CaCO_3$	----	----	169	47	----	151	122.333

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: P.A. HARDER & ASSOCIATES LTD.
#201 - 560 Johnson Street
Victoria, B.C.
V8W 3C6

Workorder: 19080
Received : 22-Jul-92
Completed: 04-Aug-92

Attn: P.A. Harder

Re: Sediment Samples

PREPARATION:

Samples were dried at 55C then seived using a 100 mesh screen. The percent by weight that was +100 mesh and -100 mesh is reported.

DIGESTION:

A portion of the -100 mesh fraction was microwave digested with reverse aqua regia in a sealed teflon vessel. All results are on a dry weight basis on the -100 mesh fraction.

QA/QC:

One of the samples was digested and analyzed in duplicate - results reported. A Standard Reference Material (SRM) was digested and analyzed concurrently with the samples - also reported. The SRM is from the National Bureau of Standards and is freeze dried Buffalo River sediment.

/2...

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: J. GIBSON & ASSOCIATES
Site 15, Comp 111, RR2
Whitehorse, Yukon
Y1A 5A5

Workorder: 19039
Received : 13-Jul-92
Completed: 27-Jul-92

Re: Sediment Samples Williams Ck

Sample type		sediment	sediment	sediment	sediment
Identification		W4	W9	W10	W10
Lab Reference #		19039-001	19039-002	19039-003A	19039-003B
ICP - Ultrasonic Nebulization					
Method used		microwave RAR soluble	microwave RAR soluble	microwave RAR soluble	microwave RAR soluble
Amount analysed		0.529 g	0.507 g	0.540 g	0.520 g
Aluminum	Al	8920	8710	8240	7670
Antimony	Sb	< 4.	< 4.	< 4.	< 4.
Arsenic	As	< 9.	< 10.	< 9.	< 10.
Barium	Ba	112.	111.	130.	132.
Beryllium	Be	0.2	0.2	0.2	0.2
Bismuth	Bi	< 7.	< 7.	< 6.	< 7.
Cadmium	Cd	< 0.09	< 0.10	< 0.09	< 0.10
Calcium	Ca	7040	6990	7080	7040
Chromium	Cr	16.6	16.4	20.0	18.5
Cobalt	Co	5.2	5.8	6.4	6.5
Copper	Cu	11.3	10.1	17.0	16.9
Iron	Fe	13300	15300	18900	18200
Lead	Pb	5.	5.	6.	9.
Lithium	Li	200	70	100	100
Magnesium	Mg	3730	3990	4160	4020
Manganese	Mn	184.	228.	359.	352.
Molybdenum	Mo	< 0.5	< 0.5	< 0.5	< 0.5
Nickel	Ni	10.3	10.6	11.9	12.0
Phosphorus	P	630	650	850	860
Potassium	K	1300	1000	1200	1100
Selenium	Se	< 0.9	< 1.0	< 0.9	< 1.0
Silicon	Si	300	270	450	410
Sodium	Na	540	390	370	340
Strontium	Sr	56.9	65.3	61.4	56.1
Thorium	Th	< 2.	< 2.	< 2.	< 2.
Titanium	Ti	690.	674.	682.	685.
Uranium	U	< 9.	< 10.	< 9.	< 10.
Vanadium	V	30.	31.	45.	46.
Zinc	Zn	33.0	37.0	39.2	39.6
Zirconium	Zr	7.1	5.4	5.0	5.3
Results in		ug/g	ug/g	ug/g	ug/g

/2...

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

Sample type	sediment	sediment	sediment
Identification	W4	W9	W10
Lab Reference #	19039-001	19039-002	19039-003
Particle Size			
% Retained on mesh #			
10 (2 mm)	0.3	1.0	0.0
18 (1 mm)	0.5	2.7	2.4
35 (500 um)	1.1	3.2	39.3
60 (250 um)	12.2	11.5	51.5
100 (150 um)	29.0	21.6	5.5
120 (125 um)	12.0	10.5	0.3
230 (63 um)	27.8	30.6	0.2
< 230	17.1	18.8	0.8

Test results are for internal use only. Quanta Trace liability is limited to the testing fee paid.

Analyst: [signature]

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: P.A. HARDER & ASSOCIATES LTD. W/O: 19080

Sample type		SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
Identification		WC-3 W-12	WC-3 W-12	WC-4 W-13	WC-4 W-13	NL-1 W-11
		WILLIAMS CK	WILLIAMS CK	WILLIAMS CK	WILLIAMS CK	07-JUL-92
		07-JUL-92	07-JUL-92	07-JUL-92	07-JUL-92	
Lab Reference #		19080-001	19080-002	19080-003	19080-004	19080-005
Gravimetric						
+100 Mesh	%	88.73	68.24	57.67	42.72	86.79
-100 Mesh	%	11.27	31.76	42.33	57.28	13.21
ICP - Ultrasonic Nebulization						
Method used		microwave RAR soluble	microwave RAR soluble	microwave RAR soluble	microwave RAR soluble	microwave RAR soluble
Amount analysed		0.512 g	0.539 g	0.526 g	0.528 g	0.536 g
Aluminum	Al	8620	7280	9980	8710	6750
Antimony	Sb	< 4.	< 4.	< 4.	< 4.	< 4.
Arsenic	As	< 10	< 10	< 10	< 10	< 10
Barium	Ba	158.	120.	201.	168.	66.9
Beryllium	Be	0.2	0.2	0.3	0.2	0.2
Bismuth	Bi	< 8.	< 7.	< 7.	< 7.	< 7.
Cadmium	Cd	0.3	0.3	0.3	0.3	0.3
Calcium	Ca	8010	6550	9770	9260	5600
Chromium	Cr	20.1	17.8	22.4	19.3	17.7
Cobalt	Co	6.7	6.0	7.2	7.4	5.5
Copper	Cu	75.8	17.6	20.1	17.3	11.4
Iron	Fe	21800	18600	23100	18100	15000
Lead	Pb	8.	6.	7.	9.	7.
Lithium	Li	< 40	< 40	< 40	< 40	< 40
Magnesium	Mg	4260	3770	5370	4860	3120
Manganese	Mn	357.	328.	412.	351.	190.
Molybdenum	Mo	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Nickel	Ni	13.3	12.8	16.6	16.3	11.3
Phosphorus	P	940	820	1100	900	810
Potassium	K	940	910	1400	1200	600
Selenium	Se	< 1.	< 1.	< 1.	< 1.	< 1.
Silicon	Si	670	600	690	760	490
Sodium	Na	260	230	290	280	270
Strontium	Sr	62.8	46.6	70.7	57.1	37.5
Thorium	Th	4.	4.	3.	7.	7.
Titanium	Ti	704.	539.	691.	558.	594.
Uranium	U	< 10	< 10	< 10	< 10	< 10
Vanadium	V	53.	46.	52.	42.	44.
Zinc	Zn	40.1	36.0	48.0	47.4	30.8
Zirconium	Zr	5.1	5.0	4.9	5.1	3.2
Results in		ug/dry g	ug/dry g	ug/dry g	ug/dry g	ug/dry g

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-056

To: P.A. HARDER & ASSOCIATES LTD.

W/O: 19080 Page

Sample type	SEDIMENT
Identification	NL-1 w-11
	07-JUL-92
Lab Reference #	19080-006

Gravimetric		
+100 Mesh	%	78.74
-100 Mesh	%	21.26

ICP - Ultrasonic Nebulization		
Method used		microwave RAR soluble
Amount analysed		0.513 g
Aluminum	Al	6730
Antimony	Sb	< 4.
Arsenic	As	< 10
Barium	Ba	70.0
Beryllium	Be	0.2
Bismuth	Bi	< 8.
Cadmium	Cd	0.3
Calcium	Ca	4890
Chromium	Cr	14.7
Cobalt	Co	5.5
Copper	Cu	10.
Iron	Fe	11800
Lead	Pb	6.
Lithium	Li	< 40
Magnesium	Mg	3030
Manganese	Mn	189.
Molybdenum	Mo	< 0.5
Nickel	Ni	11.5
Phosphorus	P	540
Potassium	K	750
Selenium	Se	< 1.
Silicon	Si	500
Sodium	Na	310
Strontium	Sr	37.2
Thorium	Th	5.
Titanium	Ti	487.
Uranium	U	< 10
Vanadium	V	34.
Zinc	Zn	29.3
Zirconium	Zr	3.5
Results in		ug/dry g

APPENDIX 4

Aquatic Resources of Williams Creek: Photographic Plates of Stream Habitat Types, Life History Information and Salmon Escapement Data for the Yukon River.

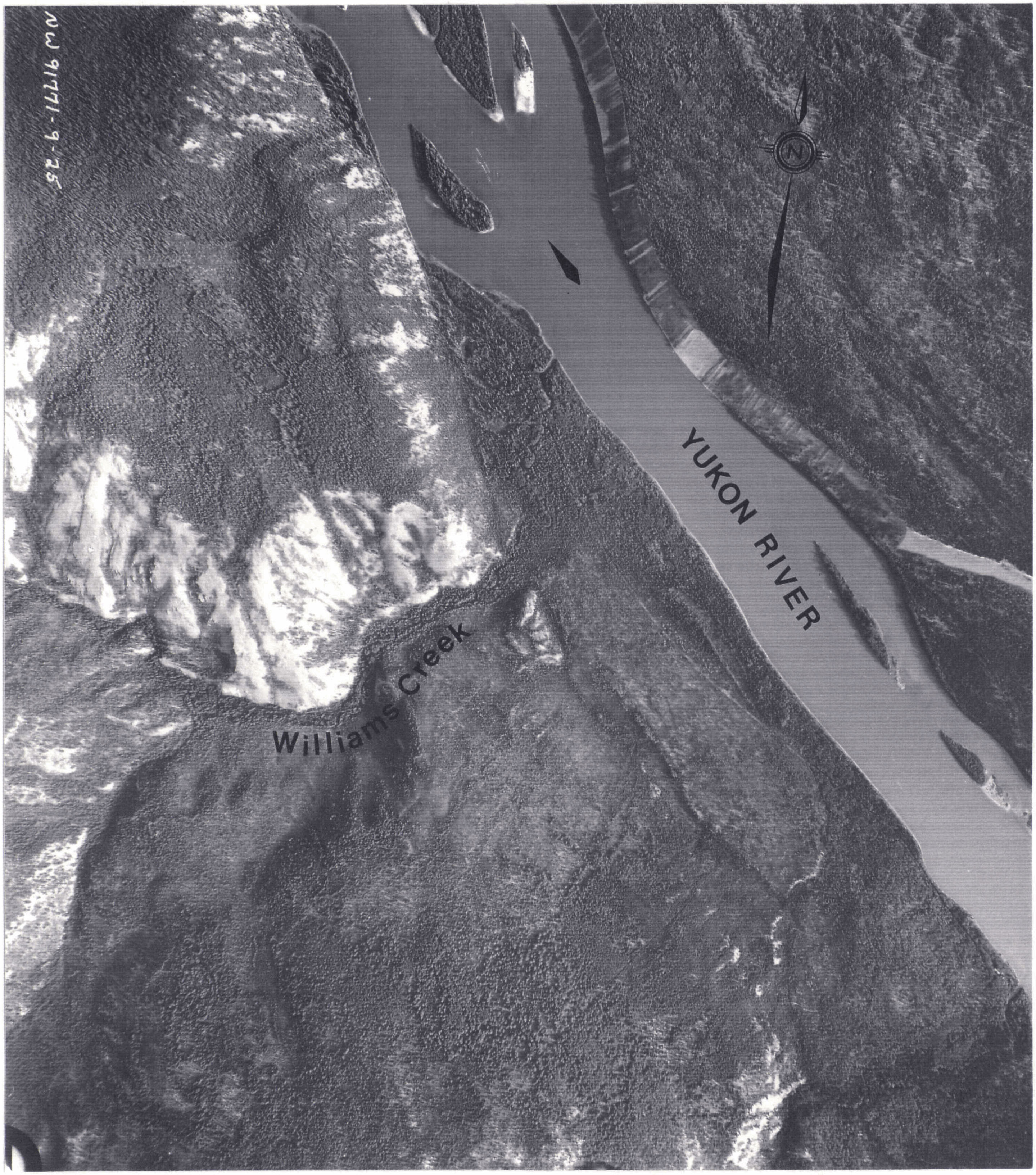


PLATE 1. Aerial photograph of lower Williams Creek from the Yukon River confluence upstream to Nancy Lee Creek. Northwest Survey Corporation Ltd. NW 91771-9-25.

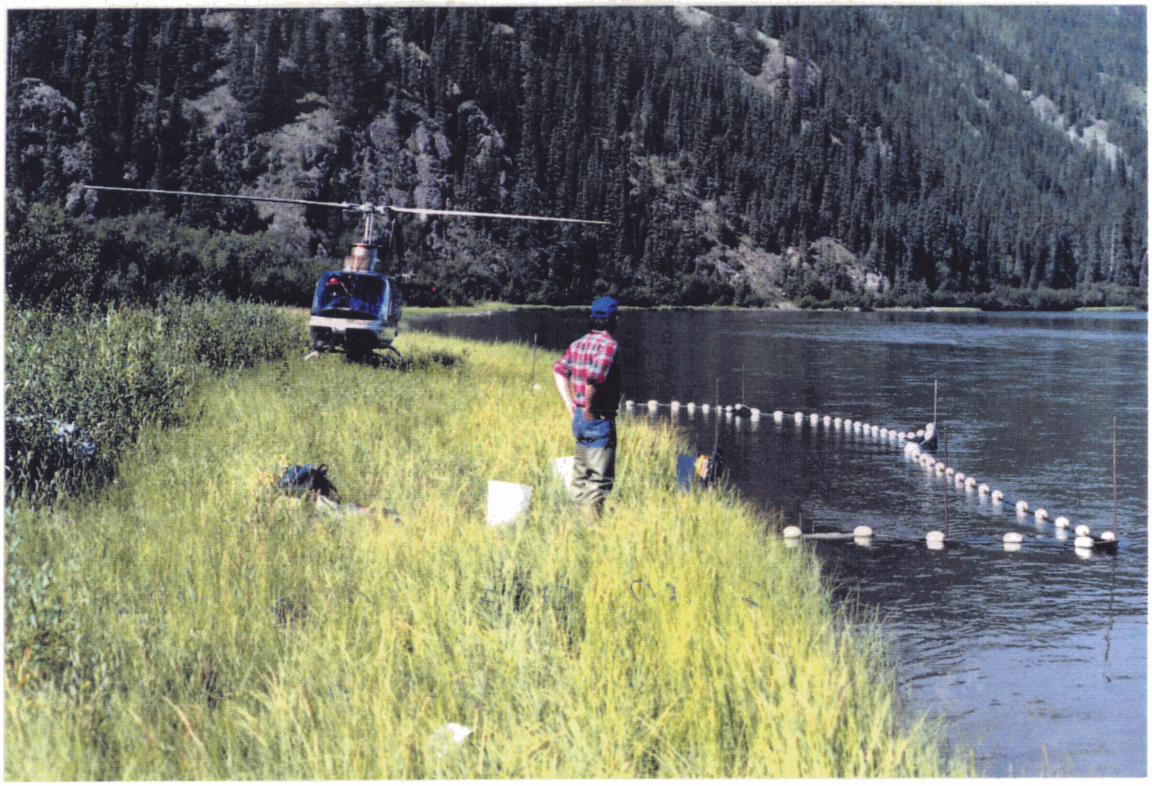


PLATE 2. Fish sample Station Y1 on the west bank of the Yukon River approximately 80 m downstream of the Williams Creek confluence. Electrofisher enclosure nets in place during August, 1991 fish sample.

PLATE 3. Fish sample Station W1 in Williams Creek approximately 300 m upstream of the Yukon River confluence during August, 1991. Cobble riffle habitat with undercut banks and over hanging vegetation.

PLATE 4. Reach 3 of Williams Creek approximately 5.5 km upstream of the Yukon River confluence. Electrofishing Site #6 during August, 1991. Note undercut banks, instream cover and overhanging vegetation.

PLATE 5. Physical Sample Site #3 in Reach 4 of Williams Creek approximately 8 km upstream of the Yukon River confluence during August, 1991.

PLATE 6. Minnow trap Site #1 in Reach 4 of Williams Creek approximately 8.5 km upstream of the Yukon River confluence during August, 1991.

PLATE 7. Electrofishing Site #4 in Reach 4 of Williams Creek approximately 8.5 km upstream of the Yukon River confluence during August, 1991. Note stability of undercut banks.

APPENDIX 4: Summary of Life History Information for Fish Species found in the Upper Yukon River Drainage.

The following section provides a brief summary of the major life history stages for fish species which are found in the Yukon river drainage. This information is summarized in Table A1. General information on biology, habitat use and distribution has been taken from Scott and Crossman (1972).

Chinook Salmon *(Onchorhynchus tshawytscha)*

Chinook salmon spawn in the late summer and fall. In the Yukon River system, spawning can occur in mainstem river habitats and moderate sized tributaries. Juvenile chinook fry rear in small stream and river habitats for between one and two years before migrating seaward as smolts.

Tagging studies (Brock, 1976 and Milligan et al 1985) indicate that adult chinook salmon reach Dawson City on the Yukon River in the first week of July with peak migration occurring between July 20 and August 6. These fish travel an average of 30.9 km/day (Brock 1976) and can be expected to the Williams Creek area approximately one to two weeks after their arrival at Dawson. Observations made at Ross River indicate peak spawning for chinook salmon between mid and late August (DFO data files, Whitehorse).

Scale analysis of spawning chinook salmon captured at the White-horse hatchery indicate that the majority of male spawners are five and six year old fish while females were predominantly (82.4%) six year fish (Brock 1976). Similar analyses at the Dawson fish wheel indicated a predominance of younger fish (four year), however, this is likely a reflection of the sampling bias attributable to the fish wheel. Data collected at the Whitehorse hatchery shows that the average fecundity of a returning female chinook salmon in the upper Yukon system is between 3500 and 5000 eggs.

Chum Salmon (*Onchorhynchus keta*)

Chum salmon are a fall spawning species. In the Yukon River there are two runs of chum salmon; an early run which spawns during late summer and a late run which spawns in the late fall (A. von Finster, pers. comm). Chum salmon usually spawn along the margins of mainstem rivers or in the lower reaches of tributary habitats. Eggs deposited in gravel redds incubate through the fall and winter months and hatch some time in late winter or early spring depending on water temperatures. Fry emerge from the gravel during the spring and migrate seaward shortly thereafter. Freshwater rearing is generally limited to weeks during the downstream migration period.

Slimy Sculpin (*Cottus cognatus*)

The slimy sculpin has a widespread distribution throughout the Yukon. The biology of the slimy sculpin is not well documented. Spawning occurs in the spring and a nest is built. Eggs are small (2.3 to 2.6 mm) and adhesive. Age 3 females (100 mm fork length) can produce approximately 1,400 eggs. Eggs hatch about four weeks after spawning.

A wide variety of stream and lake habitats are used by the slimy sculpin. This sculpin appears to be an opportunistic feeder with diets varying depending on prey availability. Aquatic invertebrates tend to be the main diet component but small fish are also consumed.

Round Whitefish (*Prosopium cylindraceum*)

The round whitefish is a common northern species distributed throughout the Yukon. This species spawns during the fall using shallow, gravelly habitats along lake margins, at the mouths of rivers and occasionally in mainstem river habitats; river and stream habitats are more commonly used by northern populations. In Northern Canada, spawning has been observed in late October. Spawning females (305 to 432 mm fork length) can produce between 2,461 and 10,459 eggs.

The round whitefish is a bottom feeder consuming a wide variety of benthic invertebrates. Young fish have also been reported in the diets of some northern populations. Eggs of other fish may also be eaten by the round whitefish.

Burbot (*Lota lota*)

The burbot is a mid-winter spawner spawning in shallow waters of lakes and rivers with a bed material of sands or gravels. Spawning usually occurs under ice cover. Spawning has been noted from November to May but usually occurs between January and March in Canada. It has been estimated that a 343 mm female produces about

46,000 eggs while a 643 mm fish may produce over 1.3 million eggs. The eggs are laid on the bed material and fertilized. Eggs hatch in about 30 days at water temperatures of 43°F.

Young burbot feed on aquatic invertebrates while older fish tend to prey on other fish species. Burbot are generally night feeders.

<u>Longnose Suckers (*Catastomus*)</u>

Longnose suckers is a common northern species with a wide distribution throughout Northern canada. The longnose sucker spawns in the spring using stream areas and shallow lake margins. Upstream migrations usually occur between mid-April and mid-May with movement during the late afternoon and evening hours. In streams, spawning usually occurs in shallow, fast moving waters over a gravel bed material. The eggs are adhesive and small (2.8 to 3.0 mm). Females may produce between 17,000 and 60,000 eggs. Eggs hatch approximately two weeks after spawning depending on water temperatures and young fish remain in the gravel for another one to two weeks before emerging in June.

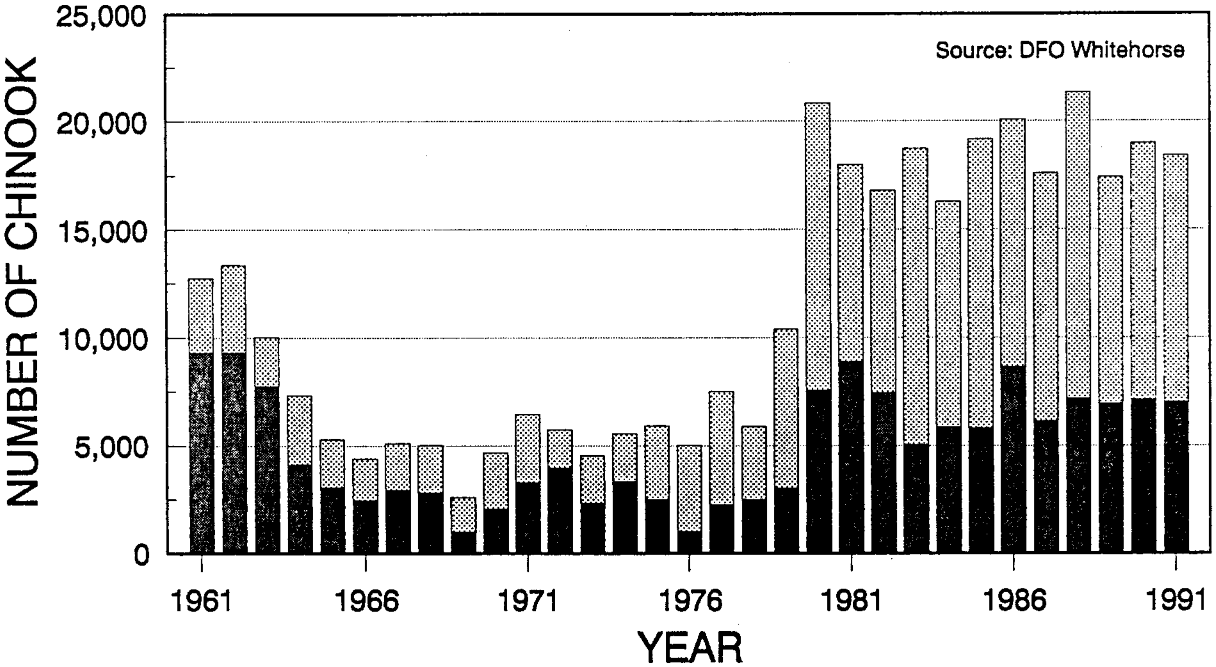
High variation in growth has been reported for different regions of Canada. In British Columbia spawning adults have ranged from 130 to 400 mm. Longnose suckers live to spawn more than once.

<u>Northern Pike (*Esox lucius*)</u>

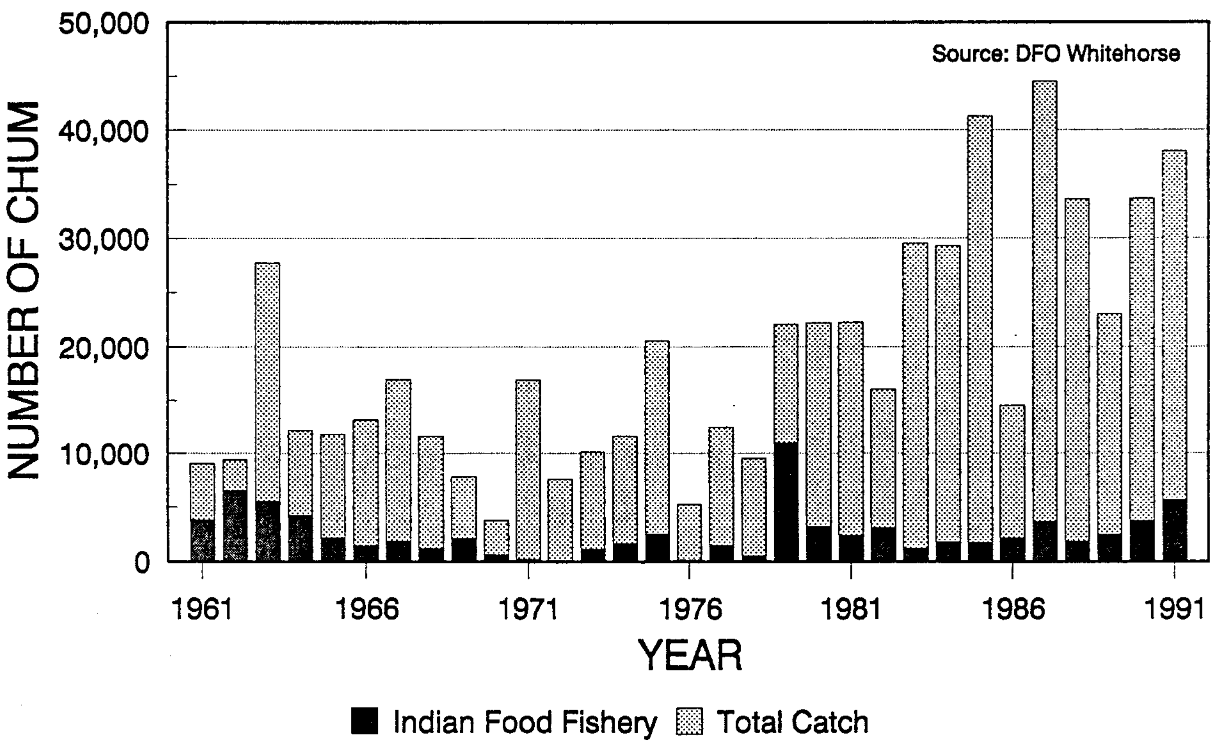
The Northern Pike is widely distributed throughout the Yukon. This species spawns during the spring (April to May) following ice break-up. Spawning areas are typically characterized by shallow waters with low velocity and extensive aquatic vegetation. Flood plains of larger rivers and bays in lakes are commonly used by spawning fish. Eggs are small (2.5 to 3.0 mm) and adhesive; they are deposited in small groups over the spawning area. Females have an average of 32,000 eggs; egg to fry mortality rates are extremely high. Eggs hatch one to two weeks, after spawning, with the young fish (6 to 8 mm) remaining attached to aquatic vegetation for a further one to two weeks. Growth can be rapid with a size of 152 mm often being obtained during the first growing season. Growth rates in northern areas are less with increased longetivity for individual fish.

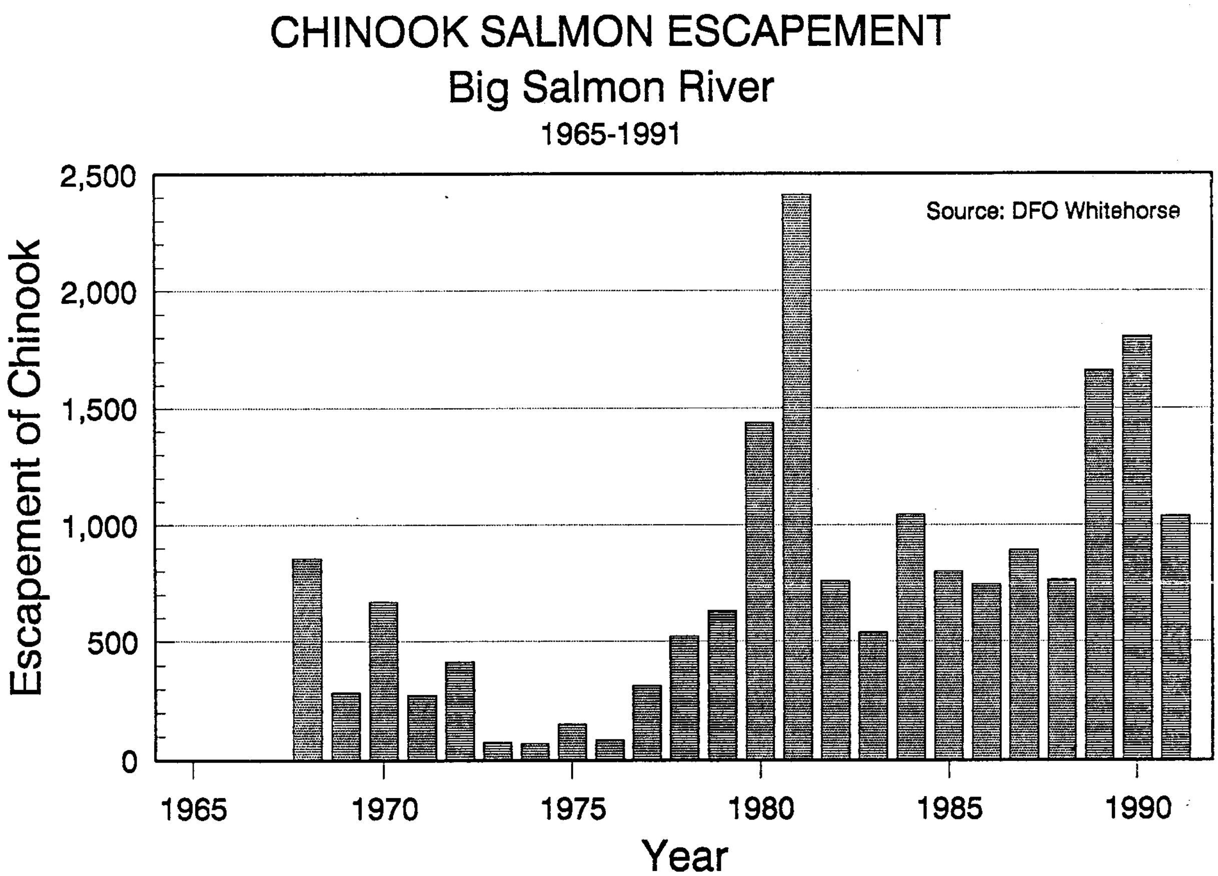
After the yolk sac has been absorbed young northern pike feed on larger zooplankton and aquatic invertebrates. Older fish eat a wide variety of vertebrate food items with fish often representing over 90% of the diet.

CHINOOK CATCH
Yukon River Drainage
1961-1991

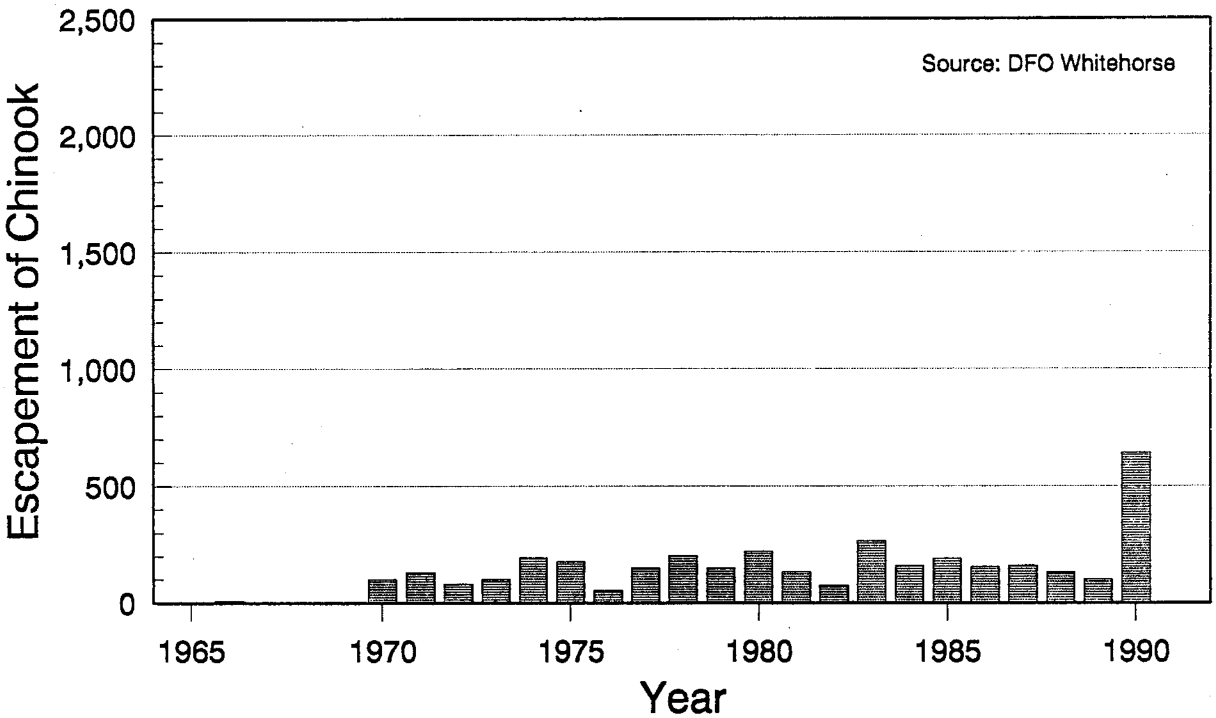


CHUM CATCH
Yukon River Drainage
1961-1991

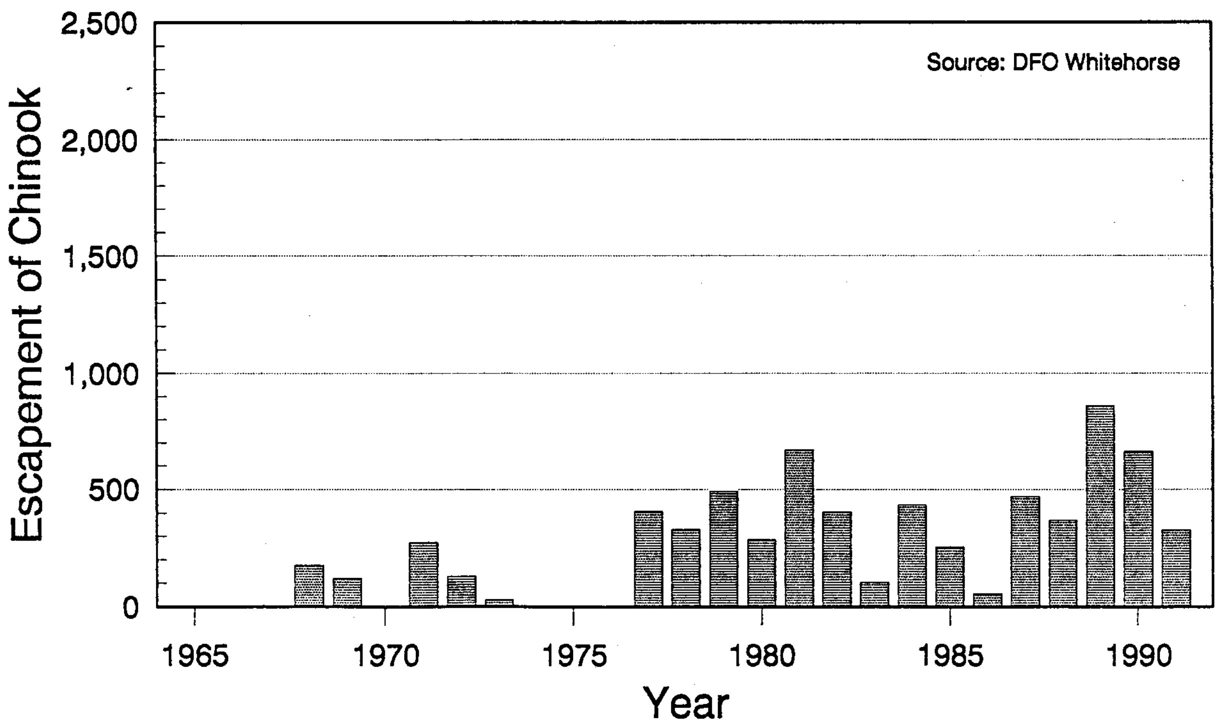



CHINOOK SALMON ESCAPEMENT
Big Salmon River
1965-1991
Source: DFO Whitehorse
Escapement of Chinook
0
500
1,000
1,500
2,000
2,500
1965
1970
1975
1980
1985
1990
Year

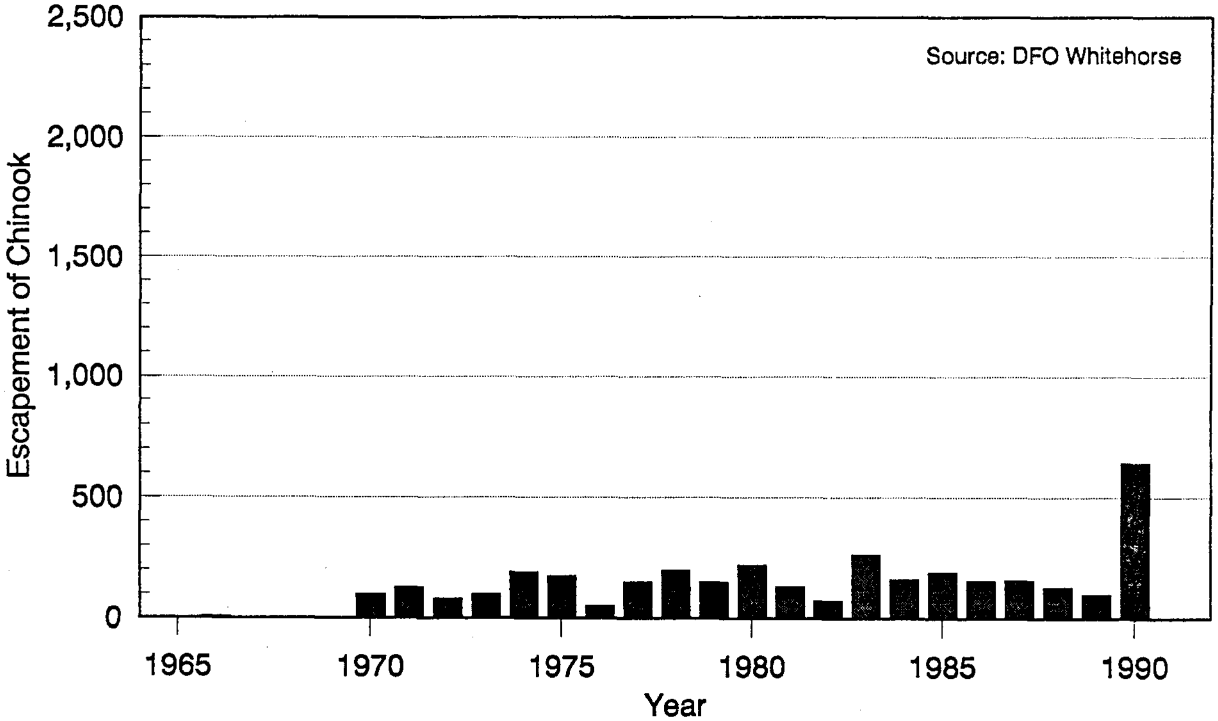
CHINOOK SALMON ESCAPEMENT
Tatchun River
1965-1991



CHINOOK SALMON ESCAPEMENT
Little Salmon River
1965-1991



CHINOOK SALMON ESCAPEMENT
Tatchun River
1965-1991



APPENDIX 5

Benthic Invertebrate Results for Triplicate Basket Samples Collected from four sites in the Williams Creek drainage during 1991 and 1992.

APPENDIX 5: TABLE 5.1. Benthic invertebrate data for triplicate samples collected from Lower Nancy Lee Creek (W-11) between July 7 and August 12, 1992.

CLASSIFICATION	INSECT NUMBERS			TOTAL	% of TOTAL
	REPL 1	REPL 2	REPL 3		
PHYLUM ARTHROPODA - CLASS INSECTA					
Order Collembola					
Order Ephemeroptera					
Family Baetidae					
Baetis	8		7	15	2
Family Heptageniidae					
Cinygmula	10		13	23	3
Epeorus					
Order Plecoptera					
Family Nemouridae					
Nemoura	80	106	77	263	34
Zapada					
Family Perlodidae					
Isoperla					
Family Chloroperlidae					
Sweltza/Triznaka					
Order Thysanoptera					
Order Hemiptera					
Family Cicadellidae					
Order Trichoptera					
Family Limnephilidae					
Clostoeca					
Dicosmoecus	1			1	<1
Family Lepidostomatidae					
Lepidostoma	19	3	7	29	4

APPENDIX 5: TABLE 5.1 (Cont). Benthic invertebrate data for triplicate samples collected from Lower Nancy Lee Creek (W-11) between July 7 and August 12, 1992.

CLASSIFICATION	INSECT NUMBERS			TOTAL	% of TOTAL
	REPL 1	REPL 2	REPL 3		
Order Diptera					
Family Tipulidae	4	3		7	1
Family Psychodidae		9	11	20	3
Family Culicidae					
adults					
Family Simuliidae					
Metacnephia	3	38	1	42	6
Simulium	29	16	13	58	8
Simulium pupae		6	5	11	1
Simulium adults					
Family Ceratopogonidae					
Family Chironomidae					
Orthocladiinae	81	134	46	261	34
Tanytarsini	4		5	9	1
pupae	1	3	2	6	<1
Family Empididae	9	5	4	18	2
Family Phoridae					
adults					
CLASS ARACHNIDA					
Order Acarina					
Hydracarina					
PHYLUM NEMATODA					
PHYLUM ANNELIDA					
TOTAL	249	323	191	763	

APPENDIX 5: TABLE 5.2. Benthic invertebrate data for triplicate samples collected from Lower Williams Creek (W-12) below Nancy Lee Creek between July 7 and August 12, 1992.

CLASSIFICATION	INSECT NUMBERS			TOTAL	% of TOTAL
	REPL 1	REPL 2	REPL 3		
PHYLUM ARTHROPODA - CLASS INSECTA					
Order Collembola					
Order Ephemeroptera					
Family Baetidae					
Baetis	18	13	18	49	7
Family Heptageniidae					
Cinygmula	20	18	13	51	7
Epeorus					
Order Plecoptera					
Family Nemouridae					
Nemoura					
Zapada	169	45	100	314	42
Family Perlodidae					
Isoperla	1	1	3	5	1
Family Chloroperlidae					
Sweltza/Triznaka	19	13	22	54	7
Order Thysanoptera					
Order Hemiptera					
Family Cicadellidae		1		1	<1
Order Trichoptera	1	1	1	3	<1
Family Limnephilidae					
Clostoeca					
Dicosmoecus					
Family Lepidostomatidae					
Lepidostoma		1		1	<1

APPENDIX 5: TABLE 5.2. (Cont). Benthic invertebrate data for triplicate samples collected from Lower Williams Creek (W-12) below Nancy Lee Creek between July 7 and August 12, 1992.

CLASSIFICATION	INSECT NUMBER			TOTAL	% of TOTAL
	REPL 1	REPL 2	REPL 3		
Order Diptera					
Family Tipulidae	4		2	6	1
Family Psychodidae			3	3	<1
Family Culicidae					
adults		1		1	<1
Family Simuliidae					
Metacnephia					
Simulium	8		2	10	1
Simulium pupae	6		2	8	1
Simulium adults		2		2	<1
Family Ceratopogonidae					
Family Chironomidae					
Orthocladiinae	68	47	33	148	20
Tanytarsini	3	3		6	1
pupae	5	5	2	12	2
Family Empididae	5			5	1
Family Phoridae					
adults					
CLASS ARACHNIDA					
Order Acarina					
Hydracarina	47	9	16	72	10
PHYLUM NEMATODA					
PHYLUM ANNELIDA					
TOTAL	374	160	217	751	

APPENDIX 5: TABLE 5.3. Benthic invertebrate data for triplicate samples collected from Lower Williams Creek (W-13) above Nancy Lee Creek between July 7 and August 12, 1992.

CLASSIFICATION	INSECT NUMBERS			TOTAL	% of TOTAL
	REPL 1	REPL 2	REPL 3		
PHYLUM ARTHROPODA - CLASS INSECTA					
Order Collembola					
Order Ephemeroptera					
Family Baetidae					
Baetis	2	7	16	25	3
Family Heptageniidae					
Cinygmula	3	16	5	24	3
Epeorus			3	3	<1
Order Plecoptera					
Family Nemouridae					
Nemoura					
Zapada	20	350	272	642	71
Family Perlodidae					
Isoperla	2	13		15	2
Family Chloroperlidae					
Sweltza/Triznaka		35	24	59	6
Order Thysanoptera					
Order Hemiptera					
Family Cicadellidae					
Order Trichoptera					
Family Limnephilidae					
Clostoeca					
Dicosmoecus	1	3		4	<1
Family Lepidostomatidae					
Lepidostoma		3	2	5	<1

APPENDIX 5: TABLE 5.3 (Cont). Benthic invertebrate data for triplicate samples collected from Lower Williams Creek (W-13) above Nancy Lee Creek between July 7 and August 12, 1992.

CLASSIFICATION	INSECT NUMBERS			TOTAL	% of TOTAL
	REPL 1	REPL 2	REPL 3		
Order Diptera					
Family Tipulidae	5	7	6	18	2
Family Psychodidae		6	2	8	1
Family Culicidae					
adults		1		1	<1
Family Simuliidae					
Metacnephia					
Simulium			2	2	<1
Simulium pupae					
Simulium adults					
Family Ceratopogonidae					
Family Chironomidae					
Orthocladiinae		56	27	83	9
Tanytarsini		2		2	<1
pupae		1		1	<1
Family Empididae	1		2	3	<1
Family Phoridae					
adults					
CLASS ARACHNIDA					
Order Acarina					
Hydracarina		10	5	15	2
PHYLUM NEMATODA					
PHYLUM ANNELIDA					
TOTAL	34	510	366	910	

APPENDIX 5: TABLE 5.4. Benthic invertebrate data for triplicate samples collected from Lower Williams Creek (W-10) above the Yukon River confluence between July 7 and August 12, 1991.

CLASSIFICATION	INSECT NUMBERS			TOTAL	% of TOTAL
	REPL 1	REPL 2	REPL 3		
PHYLUM ARTHROPODA - CLASS INSECTA				0	
Order Collembola	2	3		5	
Order Ephemeroptera					
Family Baetidae					
Baetis	1			1	
Family Heptageniidae					
Cinygmula					
Epeorus					
Order Plecoptera					
Family Nemouridae					
Nemoura					
Zapada	1			1	
Family Perlodidae					
Isoperla	19	12	7	38	
Family Chloroperlidae					
Sweltza/Triznaka	4	2	1	7	
Order Thysanoptera	1			1	
Order Hemiptera					
Family Cicadellidae		1	1	2	
Order Trichoptera					
Family Limnephilidae					
Clostoeca	1		1	2	
Dicosmoecus					
Family Lepidostomatidae					
Lepidostoma					

APPENDIX 5: TABLE 5.4 (Cont). Benthic invertebrate data for triplicate samples collected from Lower Williams Creek (W-10) above the Yukon River confluence between July 7 and August 12, 1991.

CLASSIFICATION	INSECT NUMBERS			TOTAL	% of TOTAL
	REPL 1	REPL 2	REPL 3		
Order Diptera					
Family Tipulidae					
Family Psychodidae					
Family Culicidae					
adults					
Family Simuliidae					
Metacnephia					
Simulium					
Simulium pupae					
Simulium adults	2	1	1	4	
Family Ceratopogonidae					
Family Chironomidae					
Orthocladiinae	65	33	57	145	
Tanytarsini	10	18	9	37	
pupae	3	1	2	6	
Family Empididae					
Family Phoridae					
adults		1		1	
CLASS ARACHNIDA					
Order Acarina					
Hydracarina			3	3	
PHYLUM NEMATODA			2	2	
PHYLUM ANNELIDA					
TOTAL	109	72	85	266	

Y, W, WC, ARCHAEOLOGY

AN ARCHAEOLOGICAL IMPACT ASSESSMENT FOR THE PROPOSED WILLIAMS CREEK COPPER OXIDE PROJECT, WILLIAMS CREEK VALLEY, NEAR CARMACKS, YUKON TERRITORY

093083

Prepared for:

WESTERN COPPER HOLDINGS LTD.,
400-1199 West Hastings Street,
Vancouver, B.C.
V6E 3T5

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FEB 17 1993
MINING RECORDERS OFFICE
WHITEHORSE, Y.T.

Prepared by:

Peter S. Merchant, B.A., **Robert J. Muir,** M.A.
and
Diana Alexander, M.A.

Antiquus Archaeological Consultants Ltd.,
23021-132 Ave, Maple Ridge B.C.

January 31, 1993

In fulfillment of Yukon Tourism, Heritage Branch Permit No. 92-15ASR.

ACKNOWLEDGEMENTS

Foremost, we would like to thank Western Copper Holdings Ltd., for retaining us to conduct this study and for making other necessary arrangements relating to the fieldwork component of this study. We would also like to thank Mr. Wilfred Charlie, Ms. Viola Mullet, Mr. Johnny Sam (Little Salmon and Carmacks First Nations Band) and Chief Eric Fairclough and the Council of the Little Salmon and Carmacks First Nations Band for their valuable assistance during this study.

Ms. Ruth Gotthardt and Mr. Jeff Hunston of the Yukon Tourism, Heritage Branch deserve thanks for their prompt processing of our permit application, site forms and for providing information regarding previous archaeology and local contacts.

We alone are responsible for any errors and/or short-comings in this report. We would also like to stress that the opinions and recommendations presented herein are ours, and they may, or may not, reflect those held by Western Copper Holdings Limited, Yukon Tourism, Heritage Branch, or the Little Salmon and Carmacks First Nations Band.

SYNOPSIS

In August, 1992, Western Copper Holdings Ltd., retained Antiquus Archaeological Consultants Ltd., to conduct an Archaeological Impact Assessment of the Williams Creek Valley, Yukon Territory. Fieldwork was conducted between August 11 and 14, 1992, by Mr. Mike Rousseau and Mr. Peter Merchant.

Two historic archaeological sites were identified and recorded in the lower portion of the Williams Creek system.

Site 115-I/07/001 is located about 1.25 km southwest of the confluence of Williams Creek and the Yukon River at the confluence of Williams Creek and one of its major tributaries. It consists of a partially collapsed log cabin, a partially collapsed log barn, and a substantial quantity of associated domestic and mining-related refuse and artifacts. The nature of the cabin and barn construction and the associated refuse suggests that it was occupied primarily during the 1930s and 1940s. A mine adit was identified on the north side of the creek about 400 m west of this historic area along a well-defined trail.

Site 115-I/07/005 is located along the bank of the Yukon River about 1.25 km southeast of its confluence with Williams Creek. It lies along what Wilfred Charlie called the old "Dawson Trail". It consists of the collapsed remains of a large historic log cabin. It is connected to 115-I/07/001 by a horse trail which strongly suggests that the two sites are related. It seems that this site represents a supply and ore transfer station for the mine which was facilitated by river transport.

Both of these sites are in danger of adverse impacts due to land altering activities associated with the proposed construction of a water pipeline and possible access roads. Although these sites are considered to be of only minimal significance we believe that impacts to them can be avoided without extensive cost or inconvenience. We recommend that both sites be avoided by all land-altering activity, particularly access road construction. If this is not possible then a systematic data recovery program should be carried out for these sites. Such a study should include detailed architectural sketching, mapping and artifact collection within portions of the site(s) likely to be impacted. This idealy should be conducted by a qualified archaeologist with experience in recording historical sites.

CONTENTS

AN ARCHAEOLOGICAL IMPACT ASSESSMENT FOR THE PROPOSED WILLIAMS CREEK COPPER OXIDE PROJECT, WILLIAMS CREEK VALLEY, NEAR CARMACKS, YUKON TERRITORY

1.0 INTRODUCTION AND BACKGROUND

Between August 11 and 14, 1992, Antiquus Archaeological Consultants Ltd., conducted an archaeological impact assessment of The Williams Creek Copper Oxide Project, Yukon Territory. This investigation was carried out on behalf of Western Copper Holdings Ltd., 900-850 West Hastings Street, Vancouver, V6C 1E1. Ms. Ruth Gotthardt of the Heritage Branch, Yukon Tourism, oversaw this study on behalf of the Yukon Government. The investigations were conducted by archaeologists Mike K. Rousseau (M.A.) and Peter S. Merchant (B.A.) under Yukon Tourism, Heritage Branch Permit No. 92-15ASR.

The primary objectives of this study were to identify all archaeological (historic and prehistoric) concerns located within the proposed project impact area, to assess the relative signficicance of these sites, and to determine the nature and assess the intensity, magnitude, and severity of potential adverse impacts which may occur as a result of the proposed land-altering development.

1.1 Natural Setting

The Williams Creek drainage area is located about 38 km north-west of Carmacks, on the west side of the Yukon River (Figures 1 to 4). The valley runs east-west terminating in the Yukon river. The main valley is U-shaped with steeper relief on the south face. Few floor-side junctures and suitable habitable glacial terraces occur. The lower portion of the Williams Creek Valley is a low delta, with extensive marshy areas and numerous low rock outcrops.

The drainage area is located on the northeast flank of the unglaciated Dawson Range which is part of the Klondike Plateau -- an uplifted erosion surface dissected by narrow valleys. The topography is low with local relief of approximately 300 metres and a maximum elevation of 915 metres above sea level. The area is unglaciated with the exception of weak valley glaciation resulting in small lateral morraines and kame terraces. Overburden is generally less than 1 metre in thickness and consists of moss and organic material overlying 5 to 20 centimetres of white felsic volcanic ash with 10 centimetres of organics.

Dominant flora consists of dwarf willow and alder on south-facing slopes and in the moist valley bottom. White spruce and poplar occupy the dryer well drained soils of the hillside. Water and timber suitable for historic mining activities are available locally (Archer Cathro 1991).

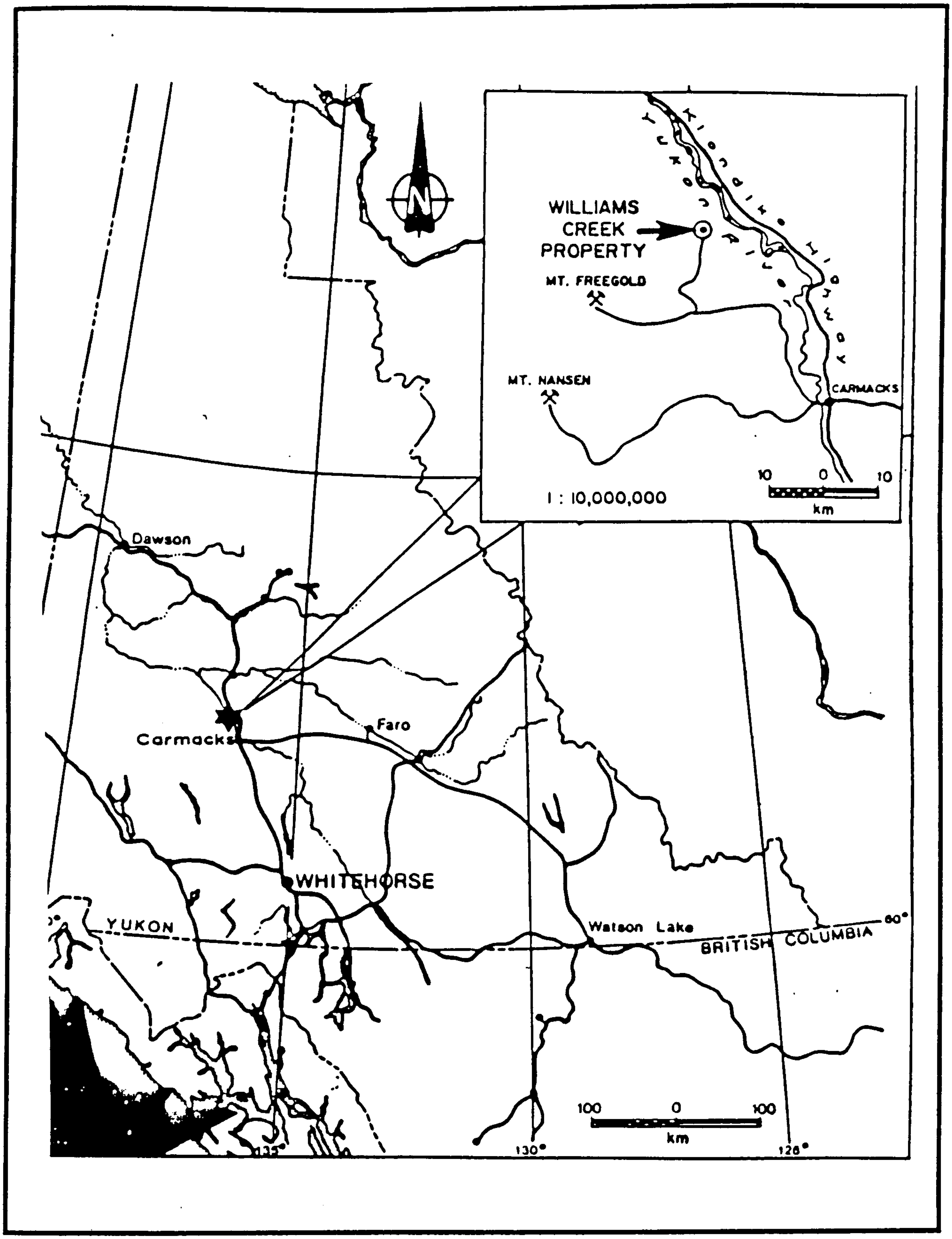

FIGURE 1. Location of the Williams Creek Copper Oxide Project, Northwest of Carmacks.

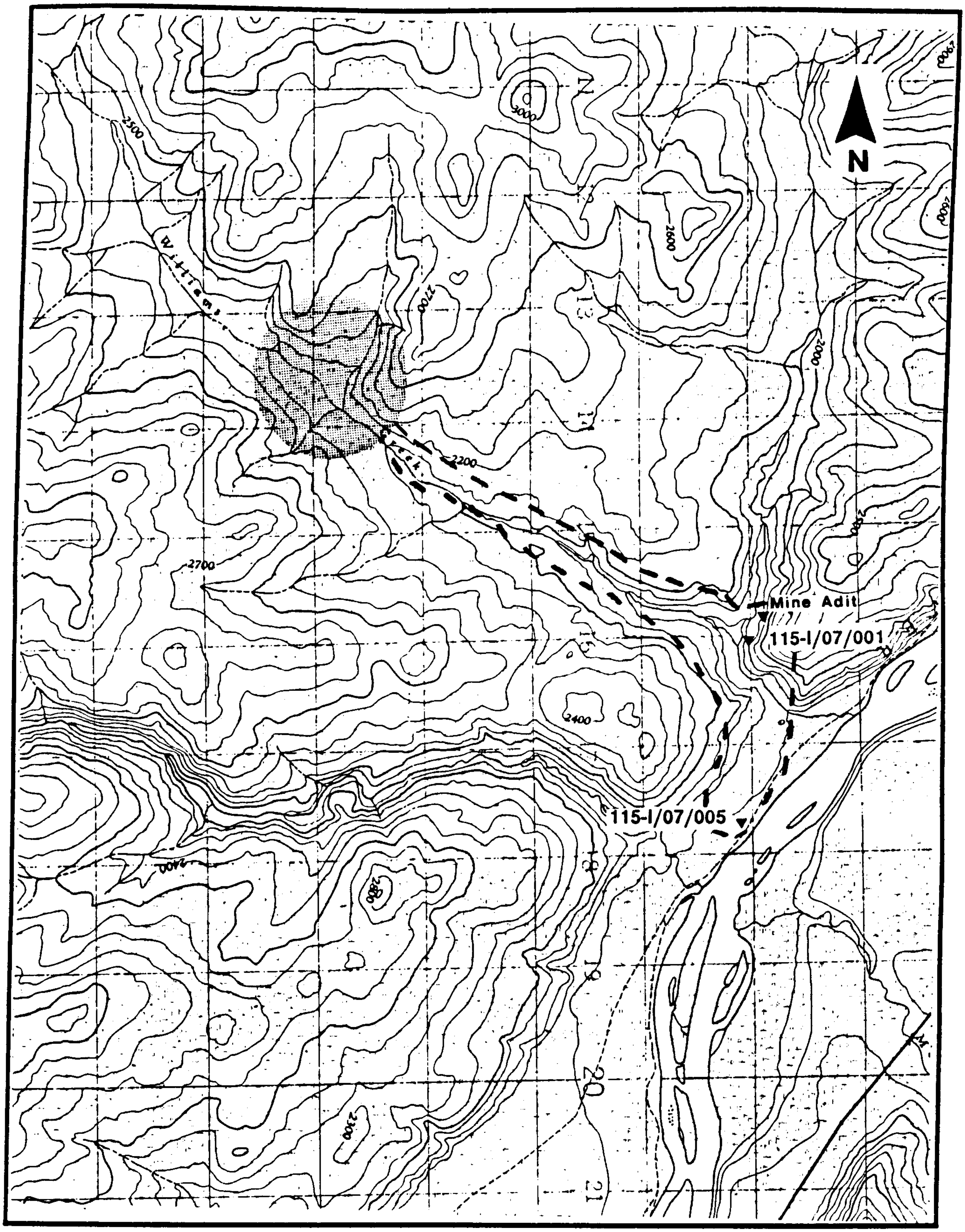

FIGURE 2. 1:50,000 scale Map of the Williams Creek Copper Oxide Project area. The proposed mine development area (shading) and water pipeline route (area within dotted lines) were examined during this study.

FIGURE 3. A view of the Williams Creek Valley, looking southwest from Williams Creek delta.

FIGURE 4. A view of the Williams Creek delta and Yukon River, looking east.

1.2 Cultural Setting

1.2.1 Traditional Native Land Use Practices

This section of the report attempts to reconstruct traditional Native land use practices in the Williams Creek Valley, that is, subsistence and settlement patterns as they existed before Euro-Canadians arrived in the Yukon in the early 19th century. Discussion focusses on those aspects of the ethnographic record that can most effectively predict the location of prehistoric Native sites. Criteria commonly used by Natives to select a good place for a camp or village were: (1) the presence of a dry, level camping ground, (2) the availability of trees for fuel, shelter, and construction, (3) proximity to fresh drinking water, (4) the abundance, variety, and accessibility of local food resources, and (5) access to trade and transportation routes.

Information contained in this section is primarily based on previously documented historic, ethnohistoric and ethnolinguistic research. Unstructured interviews were also conducted with Johnny Sam and Wilfred Charlie from the Carmacks Band to acquire some information about Native use of the Williams Creek Valley. This section is not intended to provide a comprehensive ethnohistory of the area. Little information is provided here on Native mythology, art, music, ritual, or religion. No attempt is made to predict the location of places with social, religious, or other cultural significance to living communities, but that have left no physical evidence of their use and are therefore, not classified as archaeological sites.

The Williams Creek Valley is within the traditional territory of the Northern Tutchone. Natives from this ethnolinguistic group spoke a dialect of Tutchone, one of many Athapaskan languages (McClellan 1981a:493). This group was composed of neighbouring bands linked to each other by marriage, kinship, and frequent association, but although they shared the same language, culture, and history, they did not function as a social or political unit. Each band was comprised of closely related families who usually wintered with, or near, each other. The bands were social communities with common interests, but they were not political units. Land was recognized as part of a band's territory as long as members of the band were using the resources on that land. Since band membership was very fluid, the band's territorial boundaries were flexible. (McClellan 1981a:493).

The Williams Creek Valley is currently being used by the Carmacks Band, the closest living community of Northern Tutchone. Since Carmacks was an important Native community as early as 1850, the Williams Creek Valley was probably used by Natives from Carmacks even before Euro-Canadian contact. The Northern Tutchone are part of the Subarctic Cordillera cultural division (McClellan and Denniston 1981) a classification that includes most of the Native groups in the Yukon, eastern Alaska, and northern B.C. Most groups in this division speak Athapaskan, live in similar environments, and have similar subsistence and settlement patterns.

Early historic accounts of the Tutchone are rare. Exceptions include Campbell's (1958) journal entries on Natives near Fort Selkirk in the mid-1800's, Schwatka's (1885:82-4) plotting of camps and villages in 1883, and Glave's (1892) brief account of the Southern Tutchone. Moreover, few ethnographic accounts of the Northern Tutchone are available. McClellan (1981a) has provided the best general ethnographic summary of the common cultural practices of the Northern and Southern Tutchone and has expanded on some aspects of these cultures in her numerous other reports (1948-75, 1950, 1964, 1970, 1975a, 1975b, 1981b, 1985).

Other general ethnographic accounts of the Tutchone are provided by Cruikshank (1974, 1975a, 1975b), Denniston (1966), Tanner (1966), and Johnson and Raup (1964). Linguistic studies were carried out by Ritter (1976) and Ritter, McGinty, and Edwards (1977). Unpublished theses and dissertations, including Arcand's (1966) work around Carmacks, have focussed primarily on socioeconomic practices in the 20th century (Le Gros 1981; McDonnell 1975).

1.2.1.1 Seasonal Round of Subsistence Activities

Northern Tutchone families spent much of the winter indoors subsisting on dried foods. During the warmer weather, families travelled throughout their band's territory dispersing and regrouping to make the most efficient use of the available resources. The following discussion outlines the general pattern of aggregation and dispersal that these families followed throughout the year.

The minimal family group had at least two adults of each sex and commonly consisted of adult siblings or parents, daughter and son-in-law (McClellan 1981a:500). These small mobile families exploited hundreds of square miles each year and were prepared to make major adjustments to their movement in response to changes in the distribution of key resources (McClellan 1981a:493). Each family group spend much of the year travelling and camping on their own, but would join with other families in their band on a regular basis at important hunting and fishing camps. The Tutchone were divided into two clans or moieties, were exogamous (i.e.chose marriage partners from outside their moieties) and practiced matrilineal descent (i.e. inherited possessions and rights through the mother). No formal political organization existed and leaders were chosen on the basis of their personality and skills as a hunter and trader (McClellan 1981a:500).

Summer travel was generally overland on foot, but log rafts, canoes, dug-outs, and skin boats were occasionally used for short trips and to cross waterbodies. Winter travel was facilitated by snowshoes. Goods were also packed and dragged on skins or transported by dogs with packs and possibly, sleds (McClellan 1981a:498).

At the beginning of November, families began to gather at their wintering places, usually a sheltered fishing site on lake or on a tributary of a major river (McClellan 1981a:497). Fish caught near the camp were used to augment a winter diet consisting of mostly dried foods (primarily salmon, moose and caribou). Upland meat caches were periodically visited to supplement the food supplies.

Shelters were conical or rectangular with a tied pole frame. Rectangular structures took the form of a single or double lean-to with brush walls and a moss, bark or skin roof. The more temporary, conical forms were also typically brush covered, though some Northern Tutchone constructed a skin covered domed winter tent. Two or more families lived in each structure, each cooking their own meals but sharing a central fire. Other structures constructed at the camps included: meat or fish drying racks, racks for storing boats and toboggans, food storage caches, hide tanning and smoking frames, sweathouses, and menstrual huts (McClellan 1981a:498).

March and April were a critical period of the year when stored food may have become low or exhausted and hunting was poor. Families usually dispersed at this time to find enough food to stay alive. Some gathered where the whitefish were spawning, while others trapped muskrat and beaver (McClellan 1981a:493) .

Birds were probably never a large part of the Native diet, but they provided a welcome alternative to fish and ungulates. Waterfowl (swans, geese and ducks) were sought in the spring and fall during their migrations through the area (J.Sam) and provided a key resource in late May when game was scarce and lean and stored foods exhausted. Ptarmigan and grouse were also abundant (McClellan 1981a:493) and could be caught at any time of the year when other resources were low.

As the weather warmed in May, 5 to 10 small family units would gather at locations in the valleys where whitefish, grayling, pike, and sucker were spawning (McClellan 1981a:496). For example, the Selkirk Band gathered at the mouth of Mica Creek every year to catch whitefish and grayling with nets and fish traps. These summer camps were typically located in open grassy places where breezes kept the mosquitoes down (McClellan 1981a:498). The women focussed on fishing, but the men also hunted and trapped nearby (especially for moose and beaver). Food plants were also gathered as they became available. Berries were the most important plant food, but roots, shoots and bark were also eaten, and certain barks and roots were collected as raw materials for nets, fish traps, fish lines, mats and baskets.

The dominant salmon run occurred every year between mid-July and early August when the King salmon (Oncorhynchus tshawytscha) spawned. Fish were caught in traps, weirs, dip and gill nets, and with spears, gaffs and hook and line. Good fishing spots were returned to year after year (McClellan 1981a:497). The salmon were split lengthwise and dried in the open on racks set over small fires (J. Sam) and stored in underground caches or on platform caches. Pike (1967) notes that fish drying racks could be seen at every likely spot along the Pelly River and that these sites commonly had rafts tied to the banks.

In mid-August following the salmon fishing, families dispersed into the uplands to hunt, fish, and gather plants. Much of this food was dried and stored in scattered caches for the winter. Since the Northern Tutchone salmon runs did not equal those seen on the Alsek drainage, they were as dependant on dried meat as fish. Moose and caribou were the main source of meat for the Native populations in the area. Mountain sheep and mountain goats were also important in the diet but only available in the uplands. Marmots, ground squirrels, and varying hare were the most important small game, while foxes, wolverines, marten, beaver and mink were also hunted for their furs, but rarely eaten (McClellan 1981a:493). The ungulates also provided other subsistence needs such as shelter, clothing, babiche, and bone and antler for tools. Ungulates were caught in both communal and individual hunts, though the techniques varied according to the intended game and group size (Cruikshank 1974). Hunting technology included the use of snares set singly along trails or in openings in brush fences, corrals, surrounds, deadfalls and pitfalls. Game were killed with spears, harpoons, and bow and arrow. Arrowheads, harpoons, and spears were made of stone, antler, bone or Native copper (McClellan 1981:476).

In late September, mostly families returned to the major river valleys to catch spawning dog salmon. Dog salmon (Oncorhynchus keta) were smaller and less abundant than the King salmon and the abundance rose and fell in four year cycles. After fishing, families would again scattered to hunt and trap before winter returned.

Commonly used fish and caribou hunting camps also served as trade centers and/or as locations for potlatching (Cruikshank 1974). Before Euro-Canadians moved into the area, the Tutchone typically received coastal and Euro-Canadian trade goods from the Tlingit, who travelled into Tutchone territory on trails located southwest of the study area (Cruikshank 1974). Consequently, most of the early Native trade and trails tended to be oriented at right angles to the Yukon, Pelly, and Ross Rivers, unlike the later Euro-Canadian trade that followed the major waterways. Trade to the north was controlled by the Han. These groups also tried to monopolize local sources of Native copper (McClellan 1981a:494). Carmacks was an important trade center as early as 1850 and was located on a Tlingit trade route (later called the Dalton Trail) (McClellan 1975a:503, 509)

1.2.1.2 Traditional Native Use of the Williams Creek Valley

Moose is the most common ungulate now hunted in the Williams Creek Valley, but caribou are also present on occasion and were probably more common in the past before the large migratory herds of caribou in the region were reduced to the current small scattered populations (J. Sam). In the summer (May to October) these animals could have been hunted from fishing basecamps on the Yukon River, while in the winter they may have been hunted, as they are now, while trapping in the valley (J.Sam). Given current estimates of ungulate populations, individual hunts rather than communal hunts were probably the norm for the valley. Other wildlife that may have been hunted or trapped in the valley include: grizzly bear, black bear, marten, weasel, mink, otter, red fox, coyote, woodchuck, ground squirrel, wolf, beaver, muskrat, rabbit, pika ,and porcupine (Rand 1945). Lynx and wolverine are two other important species trapped in the valley (J.Sam). A few waterfowl may also have been caught in the spring and fall at the small ponds. These traditional activities would have produced small scattered kill and/or butchering sites throughout the drainage, and a few small basecamps in the creek valley.

Salmon, whitefish, pike and graylings spawn in the Yukon River and summer fish camps were probably constructed along the shore of the river to catch these fish. Unfortunately archaeological remains from these sites may have been buried or destroyed by flooding and ice flows on the river. Any raised beachlines may afford better site preservation. Early trade and travel routes (predecessors to the historic routes) probably followed the Yukon River and crossed the mouth of Williams Creek. As a result, small transit camps may be expected in this area. All sites in the study area are expected to be small and on flat, well-drained locations.

1.2.2 History of Euro-Canadian Settlement

The first Euro-Canadian to visit Tutchone territory was Robert Campbell. An employee of the Hudson's Bay Company, he was assigned the task of developing the fur trade and establishing posts in Northern Tutchone territory. In 1843 he travelled to the Pelly River from his newly established post on Frances Lake to establish Fort Pelly Banks. He continued down the Pelly River to its confluence with the Yukon River, but was turned back by tales of hostile Natives downstream (Campbell 1958). He returned however in 1848 to build Fort Selkirk at the confluence of the Pelly and Yukon River. Numerous Natives visited the fort during its construction including a groups of Chilkat Tlingit from Lynn Canal. These Tlingit commonly used this location for trading with the Tutchone and in 1852, Fort Selkirk was raided by Tlingit who resented the loss of their trade monopoly. The residents were permitted to leave unharmed but the following year the Fort was burned

(Campbell 1958). By 1886, another post was established in Northern Tutchone territory at the mouth of the Stewart River. Fort Selkirk was then reopened in 1893 (McClellan 1981a:503).

Gold was first discovered in the Yukon River watershed in 1863 (Hamilton 1964), but the first official miner to enter the area arrived in 1875. Relatively little mining activity occurred in Tutchone territory over the next 20 years, partly because the Tlingit prevented most miners from entering the area before the late 1890's. The first publish account of Euro-Canadian travel along the Yukon River was made by Schwatka (1885, 1894) who made a reconnaissance for the U.S. Army in 1883. George Dawson and William Ogilvie, Canadian geologists, also explored the Pelly and Upper Yukon Rivers in the late 1880's, while men from the 1890 Frank Leslie's Illustrated Newspaper Alaska expedition went down the Yukon River from Chilkat Pass. Members of this expedition later returned to set up trading posts in Southern Tutchone territory (at Neskatahin in 1896 and Champagne in 1902). An old Tlingit route to Fort Selkirk was also developed into the "Dalton Trail" during the gold rush (McClellan 1981a:503).

The gold rush followed reports in August, 1896, of discoveries in Bonanza Creek (by George Carmacks), a tributary of the Klondike near Dawson City. In the next few years miners poured in, mainly by ship up the Lynn Canal to Dyea or Skagway and thence through the Chilkoot and White Passes and down 500 miles of the Yukon River to Dawson. Dawson rapidly acquired a population of 25,000. A brief spurt of development occurred at Fort Selkirk when the North West Mounted Police and Yukon Field Force were stationed there in response to the Klondike Gold Rush. By 1899 a telegraph line linked the Klondike to Yukon.

Most miners soon left the area but a second phase of mining occurred in the early 1900's with the introduction of larger dredges and flumes. Gold, copper, lead and silver were found and mined in Tutchone territory. The construction of the Alaska Highway in 1942 increased mining activity and brought a second large influx of Whites into the area (34,000 people, mostly men). Many soon left but others settled in Whitehorse and in other small settlements in Tutchone territory. Until the steamers ceased operation on the Yukon, Fort Selkirk was a service community with various trading stores, church services, and a restricted resident population. The original Whitehorse to Dawson City road and subsequent revisions by passed this community which was essentially abandoned in the 1950's in favour of Pelly Crossing.

1.2.3 Historic Change to the Native Economy

The arrival of Euro-Canadians in the Yukon resulted in changes to the traditional Native subsistence and settlement pattern. Since the mid-1800's, the Tutchone "have repeatedly moved their "headquarters", realigning their bands in response to the activities of the" Euro-Canadians (McClellan 1981a:493). McClellan describes these changes in terms of three phases (1981b). During the first phase, few Euro-Canadians actually visited the area and their trade goods reached the Tutchone primarily through trade with other intermediary Native groups, such as the Tlingit and Han. The trapping of furbearers gained more importance after the establishment of a Hudson's Bay Company fur trading post at Fort Selkirk in 1848. To acquire the furs demanded by this new trade the Native population became more dispersed and new camps were created to facilitate the trade and maximize the returns from trapping. Technological changes included the use of guns, steel traps, wire snares, twine fish nets, iron knives, and dog sleds. Alcohol and new diseases were also introduced into the area reducing Native populations. Intermarriage with Euro-Canadians led to further acculturation.

In the second phase (beginning in the 1990's), Euro-Canadian gold miners, missionaries, administrators and settlers moved into the area in large numbers. The Tlingit lost their position as middlemen in the trade with the Euro-Canadians and transportation now focussed on the rivers. Natives were hired for these new activities forcing them to adopt a more sedentary lifestyle. Intermarriage with Euro-Canadians and other Native groups increased. Missionaries became the new dictators of social and moral behaviour and Native children were forced to attend schools that went against traditional forms of childrearing and left the youth alienated from older family members. All Natives began to depend more heavily on moose hunting as these animals increased and the caribou herds dwindled (McClellan 1981a:496).

The third phase begins in 1942 with the construction of the Alaska Highway. The roads and airfields opened up the area to non-Native settlers who soon outnumbered the Native population. Many Natives lost jobs as older transportation systems were abandoned. Acculturation increased with the changing economy and technology. In 1950 the federal and territorial governments began to take over health, education, and welfare from the missionaries. Improved communication resulted in the Natives becoming more politically aware and active and strengthened their determination to maintain a culture rooted in traditional values.

1.2.3.1 Historic Use of the Williams Creek Valley

In the 20th century, the Williams Creek Valley was used by Natives for winter trapping (J. Sam). Snowmobiles permitted the entire trap line to be checked in one day (12 hours) from a basecamp on the opposite shore of the Yukon River (J. Sam). Dogsleds would have allowed similar practices at an earlier date. The valley continued to be used as a hunting area for moose and caribou, but most hunting was done by single Native hunters in the winter while in the area for trapping (J. Sam). These activities would have produced small, scattered kill and/or butchering sites in the valley.

Fishing sites used to catch salmon, as well as, pike, sucker, whitefish, and graylings were constructed along the bank of the Yukon River where deep water with currents and eddies forced the fish close to shore (J.Sam). The river bank was also used as a travel corridor. The "Old Dawson Trail" from Whitehorse to Dawson City followed either the eastern or western bank of the river, while the "Old Telegraph Trail" built in 1899 between Whitehorse and Klondike crossed the mouth of Williams Creek (J. Sam; W. Charlie). Other trails constructed before and since (such as the Toboggan-Dog Race Trail) probably followed the same routes. Small transit and camp sites should be expected at the mouth of Williams Creek where these trails were located.

Euro-Canadian mining and prospecting activities at the lower end of the creek in the 1930's and 1940's should be represented by log structures and mine deposits. These cabins were also used by Natives while hunting and trapping in the area (W. Charlie).

2.0 PROPOSED DEVELOPMENT PROJECT

The Williams Creek property is a large mining development located 38 km northwest of the town of Carmacks near the head waters of the Williams Creek within the Dawson Range (Figure 1). In the late 1960's, exploration for porphyry copper deposits in the Dawson Range lead to the discovery of the Casino porphyry deposit located 104 km northwest of Williams Creek. The Williams Creek property was staked at this time by G. Wing of Whitehorse to cover copper occurences he found while prospecting prior to the Casino discovery. The Dawson Range Joint Venture optioned the property and conducted reconnaissance prospecting and geochemical sampling. Archer, Cathro & Associetes Limited acted as Manager and earned the right to acquire abandoned properties. Thirteen mineralized zones have been located and explored by bulldozer trenching, 8 have been drill tested (Archer Cathro 1991).

Exploration of the area designated No. 1 Zone by bulldozer and diamond drill began in 1970. In 1971 further drilling, bulldozer trenching and road construction continued. In 1972 further drilling continued. In 1989 3 tonnes of surface oxide was collected by Western Copper Holdings and Thermal Exploration Co (Archer Cathro 1991). Development continues today

Specific land-altering activities relating directly to the development include:

(1) construction of an open pit mine, leach pads and waste rock dumps at the southwestern end of Williams Creek Valley;

(2) grading and levelling for the construction of access roads and accomodation throughout the project area;

(3) development of a water pipeline from the Yukon River through Williams Creek Valley to the mine development;

3.0 IMPACT ASSESSMENT OBJECTIVES AND METHODS

3.1 Objectives

The main objectives of this archaeological impact assessment study were:

(1) to review and present a summary account of documented archaeological, ethnographic and historical information pertaining to the proposed development area, and to obtain additional oral information from local informants;

(2) to locate and record all archaeological sites within the proposed project area by conducting intensive systematic surface reconnaissance survey and judgemental shovel testing within areas displaying medium to high archaeological site potential (i.e., relatively flat terrain; banks of lakes, ponds, and streams; tops and edges of prominent ridges, knolls, and terraces; etc.); these areas were selected based on examination of detailed topographic maps, areal photographs as well as observation made during a helicopter "fly over" of the study area;

(3) to record each identified site in detail, evaluate its overall heritage significance, and to conduct limited additional subsurface testing employing judgementally placed

shovel tests and evaluative tests in order to determine the nature, horizontal and vertical extent, and relative integrity of buried cultural deposits;

(4) to identify the nature, magnitude, extent, intensity, and duration of any adverse impacts which will potentially be imposed on identified heritage resources as a direct or indirect result of the proposed developments; and

(5) to present recommendations that will outline an effective management plan strategy for sites threatened by potential direct adverse impacts arising from the proposed developments.

All five of these objectives were met. The study was carried out in accordance with permit conditions defined by the Yukon Tourism, Heritage Branch.

3.2 Field Methods

Fieldwork for this impact assessment study was conducted between August 11 and 14, 1992, by Mike Rousseau and Peter Merchant. An initial meeting on Tuesday morning (Aug 11) took place between Mr. Mike Rousseau, Mr. Peter Merchant and the chief and council of the Northern Tutchone First Nations Band in Carmacks and discussed the objectives of the impact assessment project.

A helicopter overview flight of the study area was conducted prior to ground survey to determine which areas had medium and high archaeological site potential so that we could examine them during the following judgemental ground reconnaissance survey (Figure 2). The areas contained within the proposed open pit mine, leach pads, waste rock dumps, and other minor related facilities were assessed to have either nil or low archaeological site potential. Nevertheless, we examined several of the more easily accessible locations deemed to have low site potential within the proposed mine facility impact areas, but no sites were identified.

The lower portions of the valley were deemend to have a greater site potential (Figures 3 and 4). This area is only accessible by foot and for the two days of this reconn- aissance survey the guiding services and assistance/ expertise of Wilfred Charlie were retained. A judgemental shovel testing program was employed as a site discovery/ investigation technique in those areas lacking surficially evident cultural remains but suggesting high to moderate archaeological site potential (e.g., relatively flat or raised terraces or areas adjacent to extant and extinct river and stream channels). Shovel tests averaged 45 cm in diameter and were dug to sterile glacial deposits. All removed matrices were passed through 1/8" (3mm) mesh screen to ensure the recovery of relatively small artifacts and cultural debris.

Two historic archaeological sites were identified, 115-I/07/001 and 115-I/07/005, they were recorded and described on a Yukon Territory Archaeological Site Form according to guideline criteria. Detailed site maps were drawn using pace-and-compass method, and its exact location was plotted on a general plan map (Figures 5,6 and 7). All surficially evident cultural depressions features were described and measured. Photographs of all structures were taken using colour print film. The location of all identified features were clearly indicated in the field by fluorescent survey flagging tape tied to immediately associated vegetation.

3.3 Site Significance Evaluation Methodology

Each site was evaluated based on criteria outlined by the B.C. Ministry of Tourism, Archaeology Branch (1991). The purpose of a heritage resource significance evaluation is to provide an assessment of the importance of sites located during an inventory. The B.C. Archaeology Branch (1991:13,42,44) defines seven heritage significance evaluation categories for historic sites. These heritage significance categories include:

(1) Scientific Significance:

(a) Does the site contain evidence which may substantively enhance understanding of historic patterns of settlement and land use in a particular locality, region or larger area?

(b) Does the site contain evidence which can make important contributions to other scientific disciplines or industry?

(2) Historic Significance:

(a) Is the site associated with the early exploration, settlement, land use, or other aspect of the Yukon Territories cultural development?

(b) Is the site associated with the life or activities of a particular historic figure, group, organization, or institution that has made a significant contribution to, or impact on, the community,territory or nation?

(c) Is the site associated with a particular historic event whether cultural, economic, military, religous, social or political that has made a significant contribution to, or impact on, the community, territory or nation?

(d) Is the site associated with a traditional recurring event in the history of the community, territory or nation such as an annual celebration?

(3) Public Significance:

(a) Does the site have potential for public use in an interpretive, educational or recreational capacity?

- -visibility and accessibility to the public
- -ability of the site to be easily interpreted
- -opportunities for protection against vandalism
- -economic and engineering feasibility of reconstruction, restoration and maintenance
- -representativeness and uniqueness of the site
- -proximity to established recreation areas
- -compatibility with surrounding zoning regulations or land use
- -land ownership and administration
- -local community attitude toward site preservation, development or destruction
- -present use of the site

(b) Does the site receive visitation or use by tourists, local residents or school groups?

(4) Ethnic Significance:

(a) Does the site presently have traditional, social or religous importance to a particular ethnic group or community?
(b) Is the site representative of a particular ethnic group or community?

(5) Economic Significance

(a) What value of user-benefits may be placed on the site?
-visitors' willingness-to-pay
-visitors' travel costs

(6) Integrity and Condition

(a) Does the site occupy its original location?
(b) Has the site undergone structural alterations? If so, to what degree has the site maintained its original structure?
(c) Does the original site retain most of its origin
al materials?
(d) Has the site been disturbed by either natural or artificial means?

(7) Other

(a) Is the site a commonly acknowledged landmark?
(b) Does, or could, the site contribute to a sense of community or identity either alone or in conjunction with similar sites in the vicinity?
(c) Is the site a good typical example of an early structure or device commonly used for a specific purpose throughout an area or period of time?
(d) Is the site representative of a particular architectural style or pattern?

Values for each heritage significance evaluation category were measured and assigned using a simple five-part (low, medium-low, medium-high, and high) relative scale ranking scheme. An "overall" heritage significance value rating for a site was then judgementally determined by collectively considering, weighing, and then "averaging" the values previously assigned to each significance criteria category. Scientific significance and public significance categories are often relegated greater decisive "weight" compared to other significance evaluation categories when evaluating the "overall" heritage value of a site. This is because these two categories encompass a number of important considerations that are usually of greater ineterest and concern to both the public and academic community.

Sites (or portions thereof) determined to have "low-medium" overall heritage significance value rating often do not require further management attention or mitigation. However, sites with greater than "medium" overall significance value ratings are usually considered worthy of some sort of suitable protective and/or mitigative actions if they are in direct or indirect conflict with a proposed land-altering project.

3.4 Impact Identification and Assessment

The purpose of the impact identification and assessment component of a heritage study is to determine, "...the net change between the integrity of an archaeological site with and without the proposed development" (Archaeology Branch 1991:14). Impacts are often described and assessed according to "level-of-effect" indicators, which entail a consideration of their magnitude, severity, duration, range, frequency, diversity, cumulative effect, and rate of change (Archaeology Branch 1991:14,46). These indicators are often reported in an objective manner, and are intended to provide a qualitative and quantitative assessment of specific land-altering activities associated with a development project.

Following the site significance evaluations, sites located within the project area have been examined in light of potential impacts to them as a consequence of proposed land-altering development within the project area. Anticipated land-altering activities associated with the proposed development varies considerably from location to location, however, many areas will be effected by removal of vegetation, grading, levelling, excavation and surface disturbance due to heavy machinery traffic. All of these activities may impose extensive, permanent, adverse impacts to archaeological sites within the project area.

4.0 INVENTORY RESULTS AND SITE DESCRIPTIONS

Despite extensive shovel testing, foot traverse and surface inspection of potential impact areas associated with the proposed project no prehistoric archaeological sites were encountered during this study. Two historic archaeological sites were however identified in the lower Williams Creek drainage area (Figures 5 and 8 to 12). We have recorded and mapped these sites in detail. General descriptions and planimetric maps for each of the sites are provided below (Figures 6 and 7).

4.1 Site 115-I/07/001

This is a medium-sized historic mining/habiation site consisting of a partially collapsed log cabin, partially collapsed log barn, and a substantial quantity of associated domestic and mining-related refuse and artifacts (Figures 8 to 10). The nature of the cabin and the associated refuse suggest that it was occupied primarily during the 1930s-1940s. A mine adit was identified on the north side of the creek about 400 m west of this historic site area along a well-defined trail. Wilfred Charlie recalled that Bill Lahan, Bill Tear, Fred Gouder, Frank Zimmer, and George Fairclough all had a hand at prospecting in this area, and they occupied this cabin site at various times.

The site occupies an area on the north side of Williams Creek at its junction with a major unnamed tributary (Figure 6). The area has numerous extinct shoreline terraces extending back 5-10 m towards the site. The majority of the site is intact. A total of two log structures, three depressions and three refuse piles were observed at the site. Refuse remains consisted of cans, bottles, dynamite boxes, a wheelbarrow, and a brandy barrel.

4.2 Site 115-I/07/005

This site consists of the collapsed remains of another large historic log cabin located along the bank of the Yukon River about 1.25 km southeast of the confluence with Williams Creek (Figures 11 to 12).

The main log structure occupies an area approximately 17 m back from the river bank on the south side of what Wilfred Charlie called the old "Dawson Trail" (Figure 7). The remains of a collapsed outhouse lie 5 m south of the log cabin. The remains of a light wooden structure lie 15 m north of the log cabin on the bank of the river. This structure is probably associated with river transport due to its proximity to the river. Eight depressions were observed at the site, one of these lay inside the log cabin and was probably used as a cellar. Associated refuse consisted of large tin cans, fuel cans and Hudson Bay Company tobbacco tins.

There is a horse trail leading from the above mentioned log cabin site (**115-I/07/005**) to the log cabin site/mine (**115-I/07/001**) which strongly suggests that the two sites are related. It seems that 005 represents a supply and ore transfer station for the mine which was facilitated by river transport.

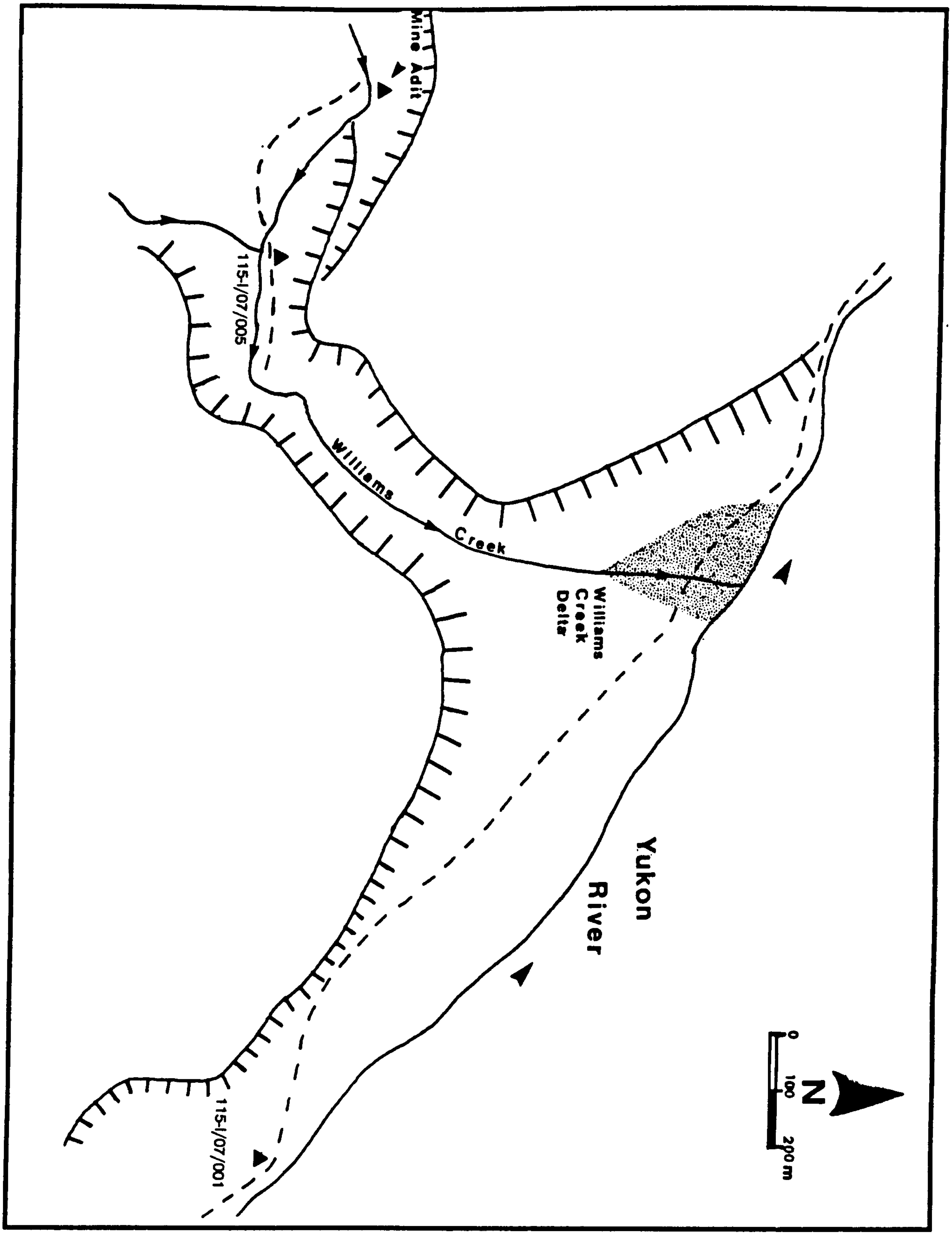

FIGURE 5. Map of the Williams Creek delta indicating the location of sites identified during this study.

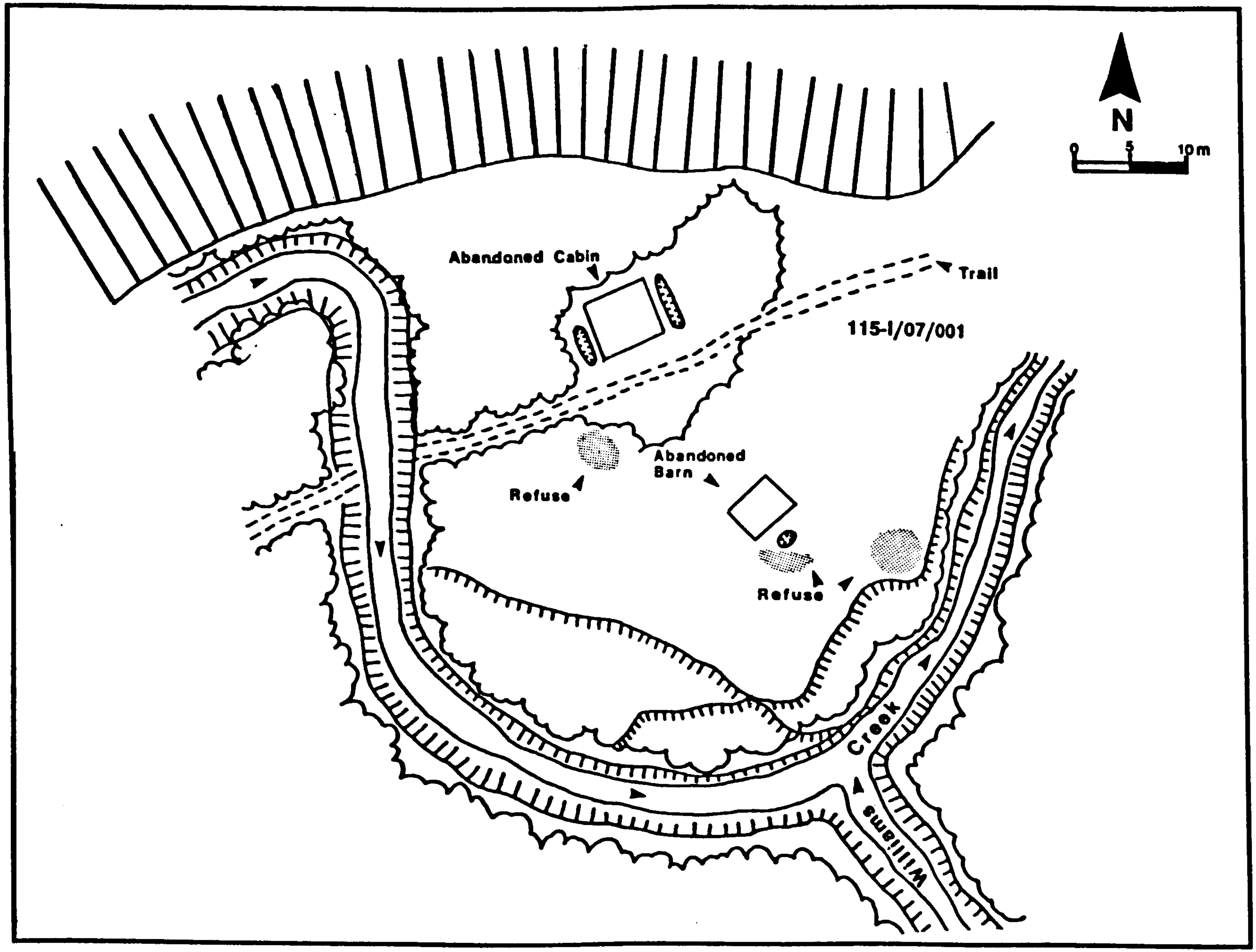

FIGURE 6. Map of site 115-I/07/001.

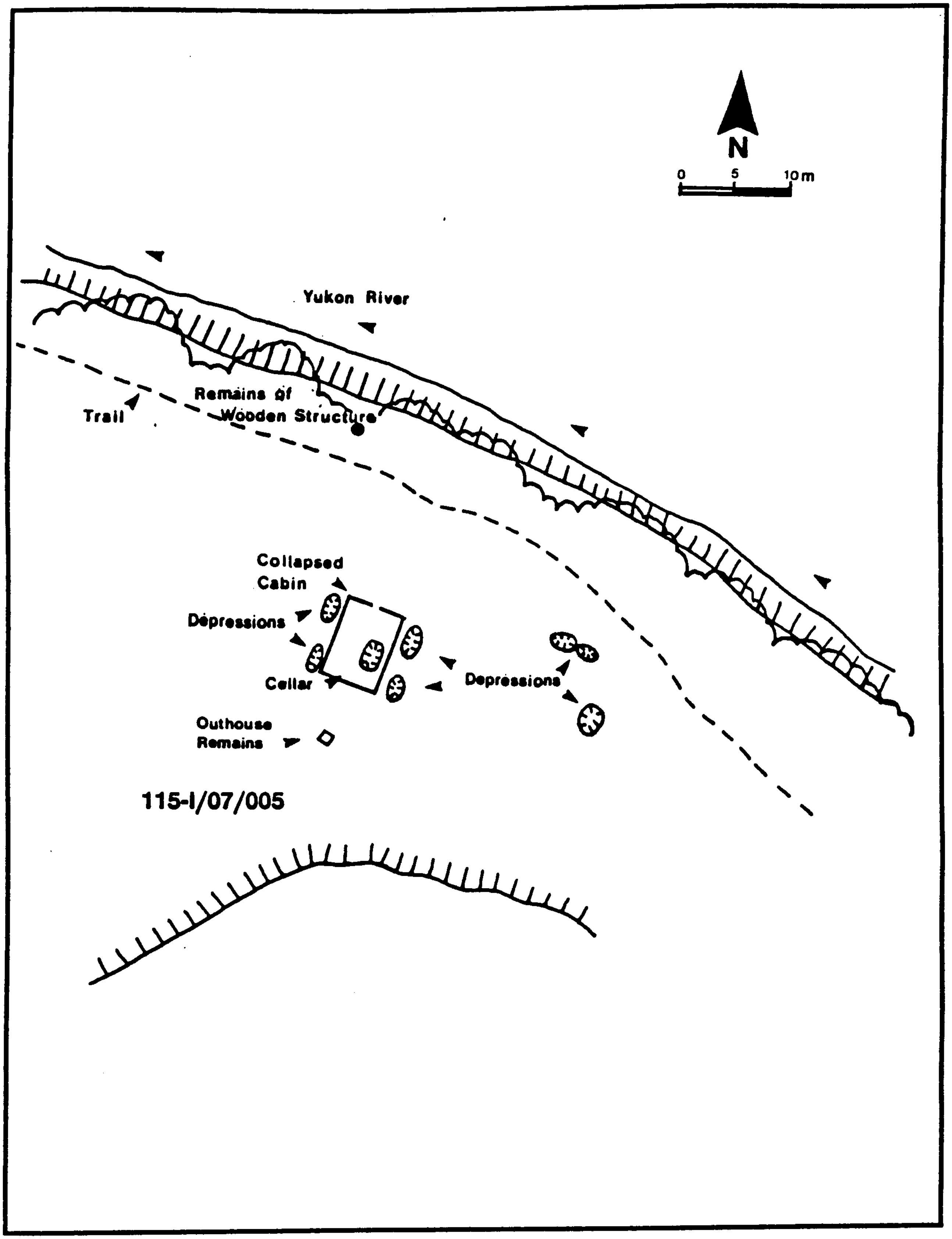

FIGURE 7. Map of site 115-I/07/005.

FIGURE 8. A view of log cabin structure at site 115-I/07/001, looking north.

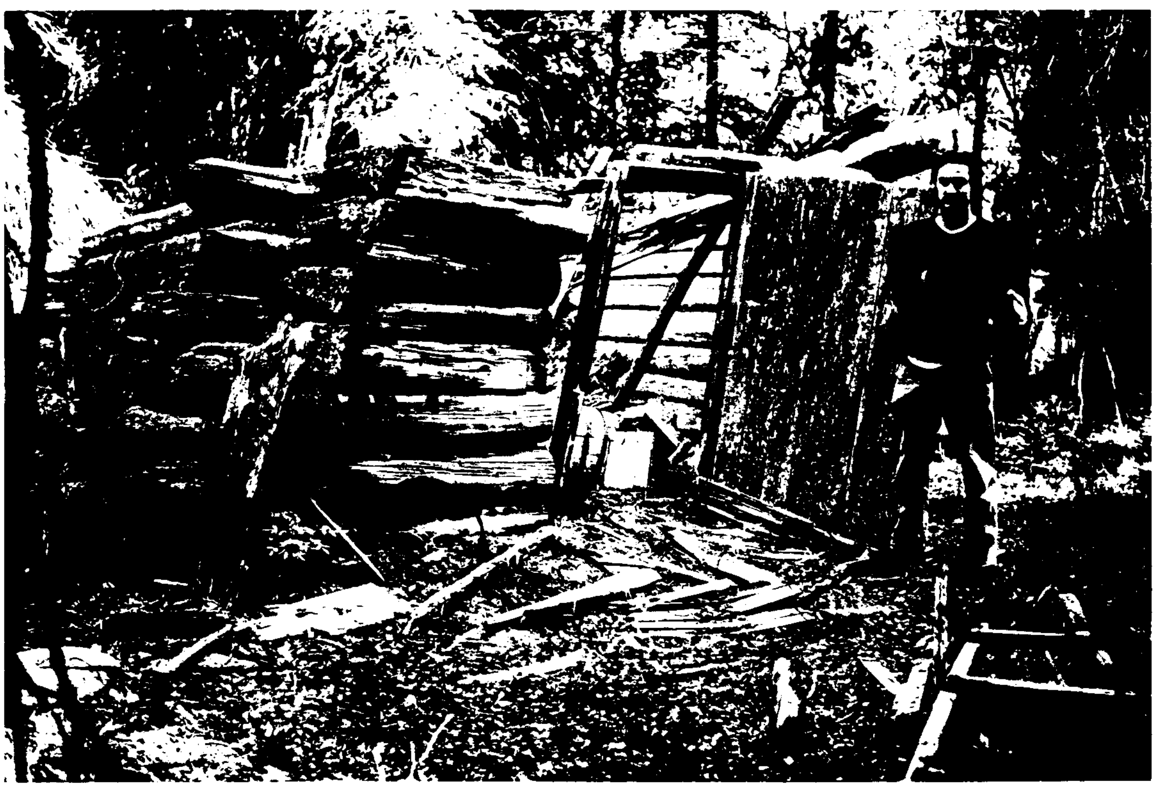

FIGURE 9. A view of log "barn" at site 115-I/07/001, looking east.

FIGURE 10. A view of mine adit associated with site 115-I/07/001.

FIGURE 11. A view of log cabin at site 115-I/07/005, looking west.

FIGURE 12. A view of log cabin at site 115-I/07/005, looking north.

5.0 SITE SIGNIFICANCE EVALUATIONS

The methodology used for assessing the "overall" heritage resource significance value of a site is discussed in Section 3.3 The results of the assessments are presented below.

5.1 Site 115-I/07/001

This large historic dwelling (Section 4.1; Figures 8-10) site is considered to have a **"medium-low"** heritage significance value rating. Its scientific significance value is assessed to be of medium value as it consists of two relatively intact dwellings that provide understanding of historic patterns of settlement and land use in the Williams Creek Valley, but makes little contribution to other scientific disciplines or industry.

The historic significance of the site is considered to be **low** since it isn't associated with early exploration, settlement, or land use. Neither is it associated with a particular historic figure, group, organization, or institution. It is also not associated with a particular historic event or recurring event.

Its public significance is rated **low**, since it is not readily accessible as an interpretive, educational or recreational capacity, it also receives no visitations by tourists, local residents or school groups.

Ethnic significance is also rated **low**, since it has no evident traditional, social or religous importance, nor is it representative of a particular ethnic group or community. Its economic significance is rated low, since no monetary benefits could be directly derived from the site.

The integrity and condition of the site is rated **medium**, since the site occupies its original location, has undergone no obvious structural alterations, but some original materials have been removed or have decayed and the site has been disturbed by natural means.

5.2 Site 115-I/07/005

This site is assessed to have an overall "**medium-low**" heritage significance value rating (Section 4.2; Figures 11-12). Its scientific value is deemed to be medium because it contains evidence that enhances understanding of historic patterns of settlement and land use particularly in relation to the "Dawson Trail".

Historic significance is assessed to be **low** since it isnt associated with early exploration, settlement, or land use. Neither is it associated with a historic figure, group, organization, or institution. It uis also not associated with a historic event or recurring event.

Its public significance is rated **low**, since it is not readily accessible as an interpretive , educational or recreational capacity. it also receives no visitations by tourists, local residents or school groups.

Ethnic significance is also rated **low**, since it has no evident traditional, social or religous importance, nor is it representative of a particular ethnic group or community.

Its economic significance is rated **low**, since no monetary benefits could be directly derived from the site.

The integrity of the site is rated as **medium**, since the site occupies its original location, has undergone no obvious structural alterations, but some original materials have been removed or have decayed and the site has been disturbed by natural means.

6.0 IMPACT IDENTIFICATION AND ASSESSMENT

The methodology used to identify and define impacts is discussed in Section 3.4. This section presents the impact assessment results.

6.1 Site 115-I/07/001

The remaining undisturbed portion of site **115-I/07/001** is in potential conflict with the proposed construction of a water pipeline from the Yukon River up Williams Creek Valley to the proposed minning development. Proposed land altering-activities associated with the construction of the proposed pipeline such as the removal of vegetation, removal of trees, construction of access roads, associated grading, and heavy equipment traffic as well construction of a pipeline R-O-W could result in direct and permanent adverse impacts to the southern portion of **115-I/07/001**.

6.2 Site 115-I/07/005

The remaining undisturbed portions of **115-I/07/005**, and associated trails are in potential conflict with the proposed development of the above mentioned pipeline. Though direct impact is improbable, the construction of the necessary access roads, and associated removal of vegetation, removal of trees, grading and heavy equipment traffic could adversely impact directly upon this site.

7.0 MANAGEMENT RECOMMENDATIONS

No archaeological sites (historic or prehistoric) were identified within the areas proposed for the open pit mine, leach pads and waste rock dumps. Consequently, we recommend that these developments be allowed to proceed as planned without further concern for archaeological resources.

Two historic archaeological sites were identified near the base of Williams Creek Valley. Both of these sites are in danger of adverse impacts due to land altering activities associated with the proposed construction of a water pipeline and possible access roads. Although these sites are considered to be of only minimal significance we believe that impacts to them can be avoided without extensive cost or inconvenience. We recommend that both sites be avoided by all land-altering activity, particularly access road construction. If this is not possible then a systematic data recovery program should be carried out for these sites. Such a study should include detailed architectural sketching, mapping and artifact collection within portions of the site(s) likely to be impacted. This idealy should be conducted by a qualified archaeologist with experience in recording historical sites.

Finally, the lower portion of the Williams Creek system, notably the Williams Creek delta and its confluence with the Yukon River, displays moderate prehistoric site potential. This area is very large and could not be adequately examined in its entirety during our August inspection. Consequently, we recommend that once a R.O.W has been decided upon for the proposed water pipeline and any associated access roads, these specific areas should be examined in detail by implementing an intensive systematic foot traverse and shovel testing program.

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Environmental Services for
Industry and Government

Vancouver, Canada
Seattle, U.S.A.

EVS ENVIRONMENT CONSULTANTS

Our File: 9/576-01

July 2, 1992

Mr. Ken McNaughton
Exploration Manager
Silver Standard Resources Inc.
Suite 900 - 850 West Hastings
Vancouver, B.C.
V6C 1E1

RECEIVED
FEB 17 1993
MINING RECORDERS OFFICE
WHITEHORSE, Y.T.

Dear Sir:

Re: Microbial Toxicity Test of Treated Mine Effluent

Please find attached the results of the above toxicity test.

Neutralized raffinate was tested at concentrations ranging from 8% - 82% for effects on respiration of sewage microbes. The rate of respiration was unaffected by this solution, even at the highest concentration tested. The treated mine effluent is not expected to be toxic to sewage microbes under the test conditions in the above concentration range.

I trust the results of this test are satisfactory. Please do not hesitate to contact me, should you require further details.

Yours truly,

EVS CONSULTANTS

André Sobolewski, Ph.D.
Microbiologist

093083

ABS/abs

195 Pemberton Avenue
North Vancouver, B.C.
Canada V7P 2R4
Tel: (604) 986-4331
Fax: (604) 662-8548

2517 Eastlake Ave. East
Suite 200
Seattle, WA
USA 98102
Tel: (206) 328-4188
Fax: (206) 328-4291

PRINCIPLE OF THE TEST

The test determines the effect of an effluent on the respiration of sewage microbes under standardized conditions. The rate of CO_2 production, a direct measure of overall microbial respiration, is measured for increasing levels of effluent and is compared with control levels (no effluent) to calculate toxicity. The presence of a toxicant should reduce microbial respiration in a dose-dependent manner. Any toxic effect should be detectable within one hour, but the test is run for 6 hours to accurately assess respiration rates.

MATERIALS AND METHODS

Neutralized raffinate (1.2 Litre) was received from PRA on June 29th, 1992. The solution was kept at room temperature until used for the toxicity test on the following day. Sewage sludge was obtained from the Lion's Gate Wastewater Treatment Plant. It was used in the test within 2 hours of sampling.

A sterile glucose solution was prepared to provide sewage microbes with a source of nutrient (carbon source). Glucose was added to a final concentration of 3 g/L in the test. A sterile solution (HCM media) providing additional macronutrients was also added to all test solutions. This solution had the following composition:

Monopotassium Phosphate	1.36 g
Dipotassium Phosphate	1.42 g
Ammonium Nitrate	1.1 g
Magnesium Sulfate	0.05 g
Calcium Chloride	0.01 g
Distilled water	800 mL

The method used for assessing microbial activity was originally described by Bartha and Pramer (1965)[1], and it has since been incorporated in other officially-recognized methods, such as U.S. EPA protocol § 796.3100 - Aerobic aquatic biodegradation. The raffinate, sewage sludge and nutrients were all added to "Biometer flasks", which consist of 250 Enlermeyer flasks modified with a side-arm addition which serves as an alkali (0.2 N KOH) reservoir to trap CO_2 produced by sewage microbes (Shown in Appendix A). A septum in the side-arm allows for the removal of the alkali solution, and the flask has a septum with an Ascarite column that maintains CO_2-free aerobic conditions within the flask. The CO_2 trapped in the KOH solution was measured by titrating a $BaCl_2$ precipitate of this solution with HCl to the phenolphthalein end-point. All standard reagents used in this test were prepared in CO_2-free water.

Each flask received a total volume of 50 mL solution, composed of the standard solutions, sewage sludge, and 41 mL of a dilution series of the effluent made up distilled water, as indicated below. Their proportions follow a logarithmic dilution series.

Dilution	Water	Effluent	Sewage	Glucose	HCMM
0% (Control)	41 mL	0 mL	2.5 mL	2.5 mL	4 mL
8%	37 mL	4 mL	2.5 mL	2.5 mL	4 ml
13%	34.3 mL	6.7 mL	2.5 mL	2.5 mL	4 mL
25%	28.4 mL	12.6 mL	2.5 mL	2.5 mL	4 mL
45%	18.5 mL	22.5 mL	2.5 mL	2.5 mL	4 mL
82%	0 mL	41 mL	2.5 mL	2.5 mL	4 mL

[1]Bartha, R. and D. Pramer. 1965. Features of a flask and method for measuring the persistence and biological effects of pesticides in soil. Soil Science 100: 68-70.

The flasks containing the test solutions were sealed and incubated at room temperature. They were agitated sufficiently to ensure that respiration was not limited by lack of oxygen in solution.

At intervals of 1.5 hours — over a 6 hour period — the KOH solution was withdrawn from each flask and titrated for CO_2. Fresh KOH was then replenished to trap CO_2 for the next sampling. The volume of HCl required for the titration was subtracted from a reagent blank, and the resulting value was multiplied by 25 to convert mL HCl into μmoles CO_2, as indicated below. The rate of CO_2 production was determined from a plot of CO_2 produced vs time.

RESULTS

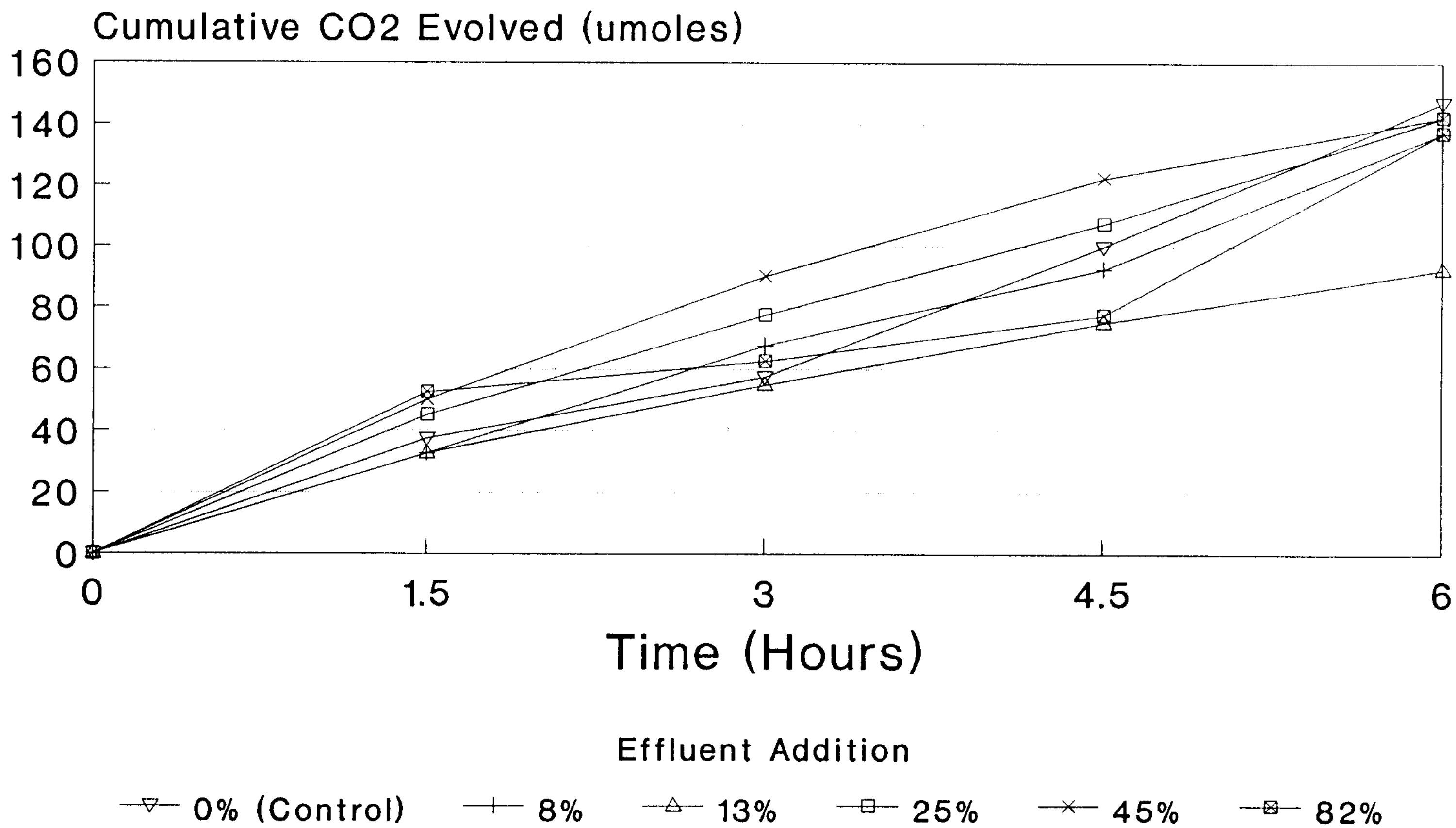
The rates of respiration measured in this test are plotted on the following graph. There are no significant differences in the respiration rate for different effluent dilutions compared with the control incubation, and no consistent dose-response curve can be calculated from these data. The raw data for the titration of CO_2 produced in the flasks are appended to this report.

The 15% dilution flask evidently had a lower respiration rate than the other flasks. The lack of any dose-response relationship in this test indicates that this result was not due to substances present in the raffinate. The result was probably caused by the heterogeneity of the sewage sludge used in this test: this sample likely received a clump of material which did not contain a lot of microbes, thus resulting in an overall reduced respiration rate.

In conclusion, the raffinate tested showed no sign of toxicity to sewage microbes in the concentration range of 8-82% under the test conditions.

EFFLUENT TOXICITY TEST

Inhibition of Microbial Respiration



1:30 hr
4:00 PM

2:30 PM

Date	Sample	m/s HC1 added	
	Blank		
	Control	34.3 - 16 =	18.3
	9%	52.8 - 34.3 =	18.5
	15%	71.3 - 52.8 =	18.5
	28%	91.0 - 73.0 =	18.0
	50%	0 - 17.8 =	17.8
	90%	35.5 - 17.8 =	17.7

3 hrs
5:30PM

Date	Sample	m/s HC1 added	
	Blank		
	Control	0 - 19.0 =	19
	9%	37.4 - 19.0 =	18.4
	15%	56.4 - 37.5 =	18.9
	28%	74.9 - 56.4 =	18.5
	50%	22.0 - 3.8 =	18.2
	90%	41.4 - 22.0 =	19.4

4:30 hr
7:00 PM

Date	Sample	m/s HCl added	
	Blank	56.3 – 36.5 =	19.8
	Control	0 – 18.1 =	18.1
	9%	36.9 – 18.1 =	18.8
	15%	56.0 – 37.0 =	19.0
	28%	74.8 – 56.2 =	18.6
	50%	36.5 – 18.0 =	18.5
	90%	77.2 – 58.0 =	19.2

6 hrs
8:30 PM

Date	Sample	m/s HCl added	
	Blank		
	Control	0 – 17.9 =	17.9
	9%	35.9 – 17.9 =	18.0
	15%	55.0 – 35.9 =	19.1
	28%	52.1 – 33.7 =	18.4
	50%	71.4 – 52.4 =	19.0
	90%	88.8 – 71.4 =	17.4

APPENDIX A

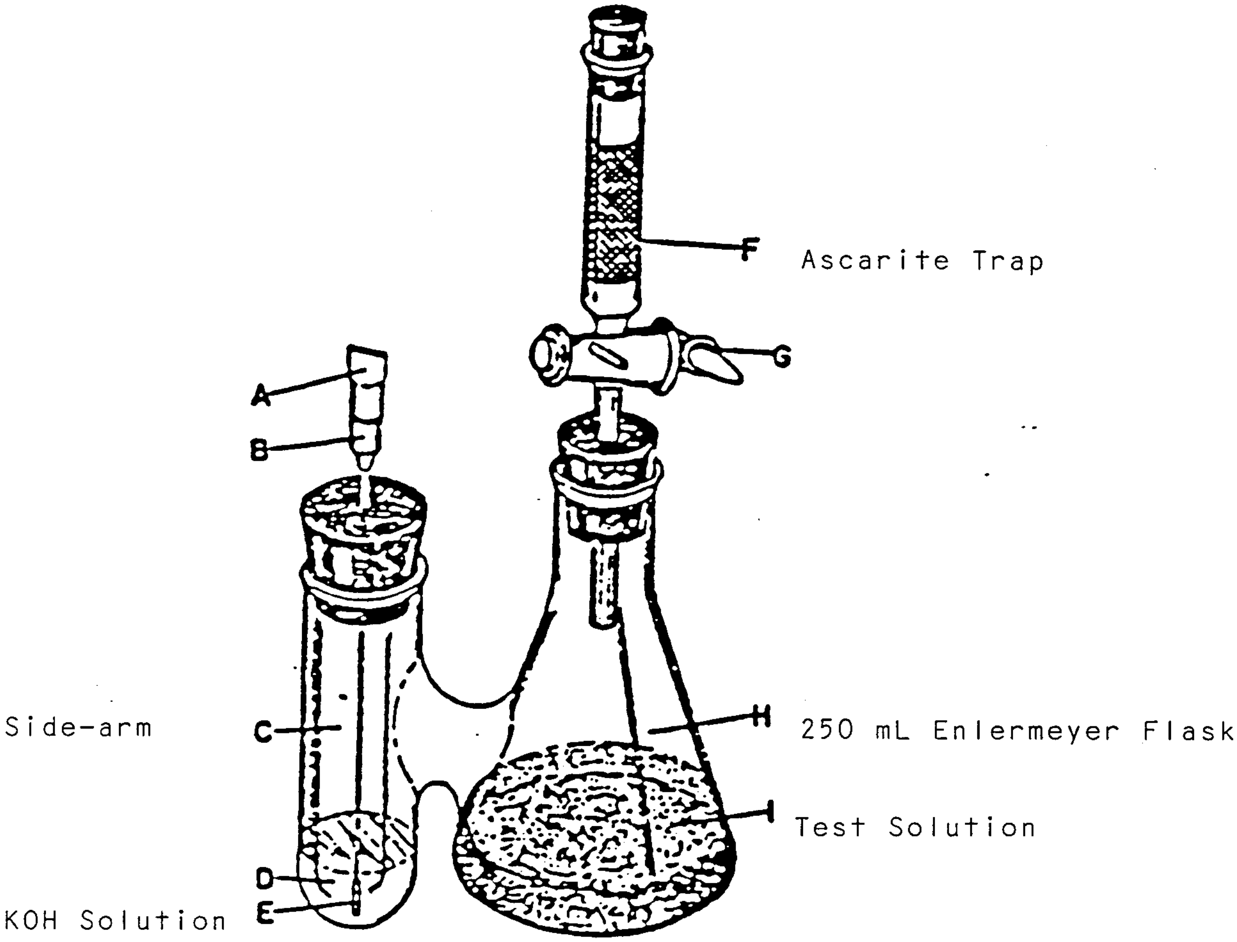


Diagram of a Biometer Flask

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WATER QUALITY AND HYDROLOGY SURVEYS

OF

WILLIAMS CREEK MINERAL PROPERTY

093083

Prepared for

Western Copper Holdings Ltd.

Prepared by

J. Gibson & Associates

Whitehorse, Yukon

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1.0 Introduction

J. Gibson & Associates were contracted by Western Copper Holdings Ltd. of Vancouver B.C. to conduct environmental baseline surveys of the surface waters draining the Williams Creek mineral property.

The preliminary survey was done in October 1989 with additional survey events in May, August and December 1991 and May 1992.

This report details the water quality, stream sediment and hydrology (preliminary) data collected during the July and October 1992 surveys. A complete hydrology data report will be issued under separate cover by a hydrologist on contract to P. Harder & Associates.

2.0 Study Area

Williams Creek a north easterly flowing tributary to the Yukon River approximately 25 kilometers downstream of the Village of Carmacks (Figure 1.)

Williams Creek consists of a right fork mainstem channel and a tributary left fork channel commonly called Nancy Lee Creek (Figure 2). Exploration work up to the end of 1991 was confined to the north side of the mainstem channel around the main mineralized area. In 1992 exploration work (trenching) was extended to the valley slopes on the south side of the mainstem channel. All exploration work is confined to the upper stream reaches with the exception of access road construction (August 1992) from the camp area downstream to approximately Station W-4. The access road was constructed along the slope toe on the north side of the valley well out of active stream channel.

2.1 Sample Stations

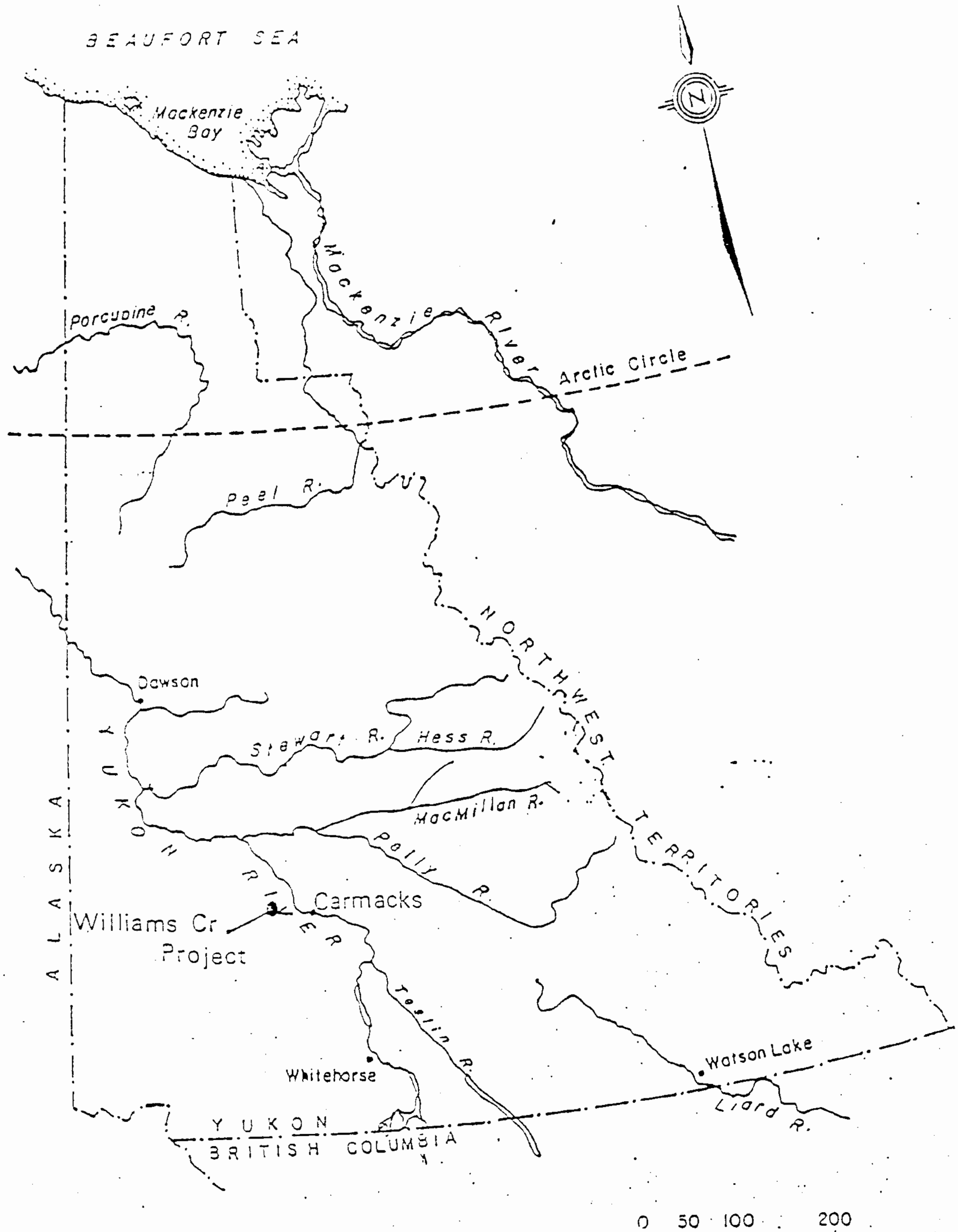

FIGURE I LOCATION OF WILLIAMS CREEK PROJECT

Sample stations within the Williams Creek watershed remain unchanged from the two previous surveys. Locations and descriptions are:

W-1. East flowing tributary to Williams Creek draining the south east hillside of the deposit. Sample station is located 50 meters downstream of the slope toe, 30 meters downslope of the new access road. Surface flow is intermittent.

W-3. East flowing tributary to Williams Creek draining the north facing hillside of the deposit. Station is 20 meters upstream of access road stream crossing. Station W-7 is located two kilometers upstream on this tributary.

W-4. Williams Creek mainstem 100 meters downstream of the confluence with W-3.

W-5. Northeast flowing tributary to Williams Creek draining the hillside across the valley from the deposit. 1992 exploration trenching located approximately 750 meters to the west of the channel.

W-7. East flowing tributary draining the north face of the mineral deposit. Upstream station for W-3.

W-8. Southeast flowing tributary to Williams Creek draining the south hillside adjacent to the deposit. Surface flow occurs only during peak of snowmelt runoff.

W-9. Williams Creek approximately 500 meters upstream of mine access road crossing. This is the upstream water quality station.

W-10. Williams Creek at the mouth. Station is located 150 meters upstream from confluence with the Yukon River.

W-11. Nancy Lee tributary above the confluence with mainstem Williams Creek.

There was no surface flow at station W-8 during either survey event and was therefore not sampled. Station W-5 was found to be of spring

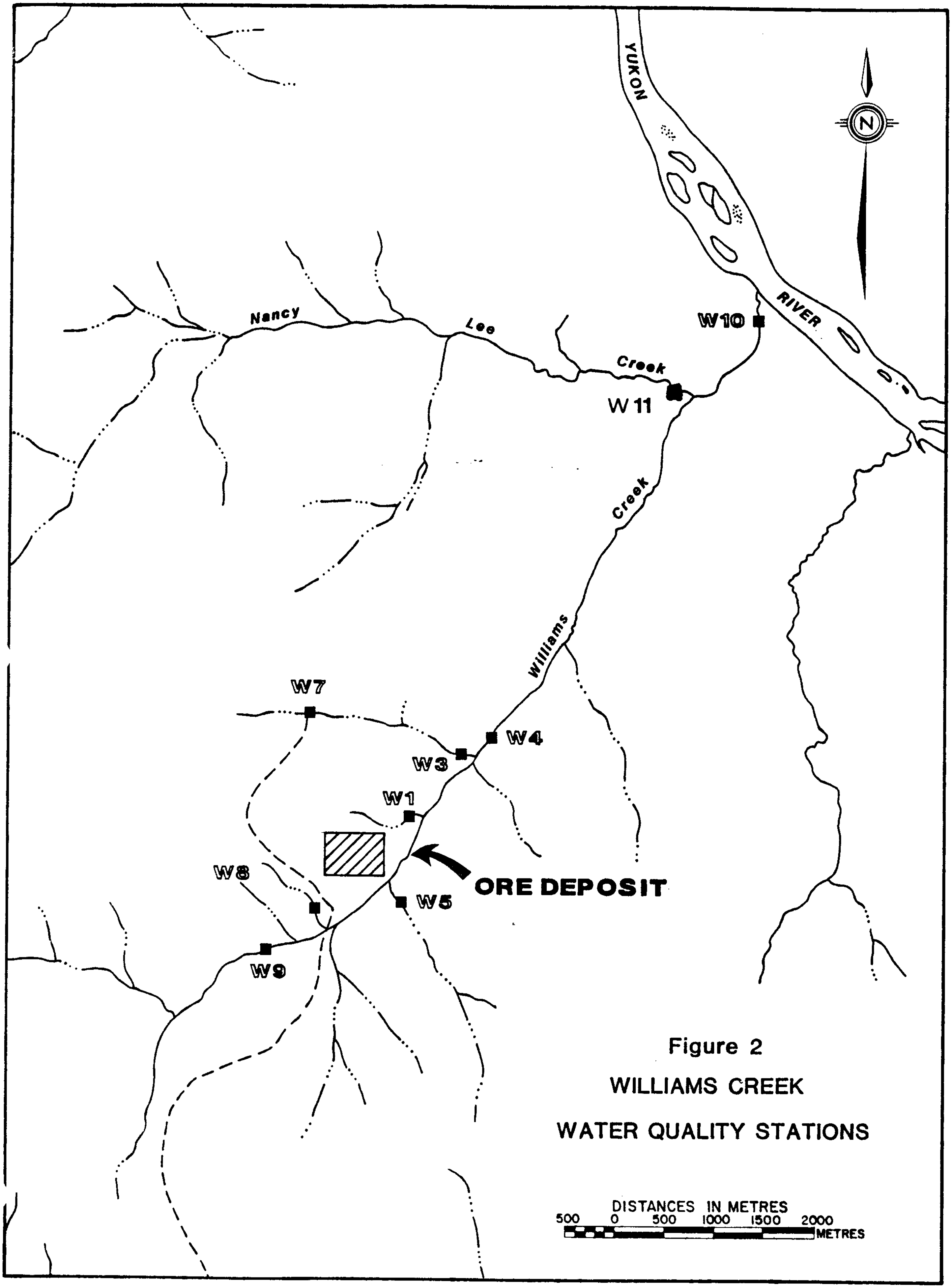

Figure 2
WILLIAMS CREEK
WATER QUALITY STATIONS

origin 50 meters upstream of existing station during the July survey. The channel appears to be fed by a series of springs and surface runoff at varying times as surface flow was located under ice cover in December 1991 upstream of the main spring.

3.0 Hydrology Data Collection

Hydrometric data was collected at each sample station in conjunction with water quality sampling. Data was collected using methods outlined in Water Measurement Manual (U.S. Department of the Interior 2nd edition) and Hydrometric Field Manual (Inland Water Directorate, Environment Canada 1981). For open water streamflow measurements and when ice cover could be removed throughout the cross section, flows were measured using a Price 22A velocity meter and area calculations. For flow volumes below the Price meter's capabilities, volumes were measured using a bucket and stopwatch or simply estimated if below 2 liters per second. During the October 1992 survey, all stations with the exception of W-1 had complete ice cover. Similiar to December 1991, stations in the upper stream reach had extremely low flow volumes (< 1 l/s) moving between successive layers of overflow glaciation.

The staff gauge installed in August 1991 at the mine access road crossing of the mainstem channel (approximately Station W-9) was again monitored daily by camp staff for the duration they were onsite. A number of streamflow measurements were again taken at varying gauge heights to further define the stage discharge relationship developed from 1991 data.

In May 1992 a basic climate data station consisting of a precipitation gauge and a maximum / minimum thermometer was installed near the camp site. The instruments were monitored on a near daily basis by camp staff. Precipitation and temperature data from the Yukon Government highway maintenance camp in Carmacks to establish a correlation between sites was obtained from Environment Canada in Whitehorse. The water level recorder instrumentation at station W-10 was removed during the October survey. The installation's culvert and staff gauge were left intact for future use. Preliminary data review indicates hourly water level readings were obtained from the time of installation (May 18) to September 16 at which time the channel became ice covered and the recorder's float froze in. The installation was under backwater effect from the Yukon River for a short period in July due to the near historic high water levels in the river the past summer. Data from the recorder was downloaded to a Lotus 123 file for workup and together with all other hydrology data was sent to P. Harder & Associates hydrologist for final workup and reporting under separate cover.

4.0 Water Quality Data Collection

4.1 Sample Methods

Water quality samples were taken at each station using new bottles supplied by Quanta Trace Laboratories of Burnaby. All laboratory analysis was done by Quanta Trace. A 2 liter sample was taken at all stations for routine chemical analysis (suspended solids, turbidity, pH, conductivity, alkalinity, nitrate, nitrite, sulphate, ammonia and total phosphorus). A 100 ml sample was taken for each of total and dissolved metals analysis.

The 2 liter and the 100 ml total metal samples were each rinsed three times with sample water prior to filling. The 100 ml dissolved metal sample was rinsed three times with filtered sample water. The water was filtered onsite using a 60 ml disposable syringe with an inline 45 micron filter. This filtering system was used to avoid sample contamination problems encountered in previous survey events where a

Nalgene vacuum filter flask was used. A new syringe and filter were used for each sample site.

All sample bottles were labeled with station number (on lid, neck and label), location, date and general analysis category (routine, dissolved or total metals). This information along with field measurement results for pH, conductivity, water temperature and general observations were recorded in a field note book.

All metal samples (dissolved and total) were then preserved with 0.5 ml nitric acid / 100 ml of sample.

During open water, all water samples were collected in mid channel at mid depth where possible. For sampling under ice cover, a hole to water level was first chopped or augured, bailed out three times and then the sample taken from the recharge. This method was used to reduce the effect of stream bed material disturbance during auguring. Samples on tributary channel were taken far enough upstream to avoid any influence from mainstem flows. Mainstem stations were sampled far enough downstream of the confluence with tributary channels to ensure adequate mixing and a representative sample.

4.2 Field Measurements

Field measurements for pH, conductivity and water temperature were taken at each station in conjunction with water quality sampling. A Hanna Instruments EP portable meter was used to measure pH. The meter was calibrated to a 7.0 standard prior to the field survey. A Hanna Instruments DiSt 3 portable meter was used for measuring conductivity. The meter was calibrated to a known standard prior to use. Water temperature was measured using a standard water thermometer registering in Celsius.

4.3 Quality Control

Field quality control measures for both surveys involved duplicate samples for all measured parameters at station W-10. Quanta Trace Laboratories conducted additional duplicate analysis on one sample from the survey on each event. A "filter train" for dissolved metals was not used as the chance of contamination during filtering were removed by using disposable syringes with inline filters.

5.0 Sediment Data Collection

5.1 Sample Methods

Stream channel sediment samples were collected at three sites during the July 1992 survey:

W-9. The upper water quality station above the mine access road crossing.

W-4. The lower mainstem water quality station for the upper stream reach.

W-10. Williams Creek at the mouth.

Due to channel profile at the two upper stations (narrow and deep) and the lack of sediment within the wetted channel, sediment samples were taken at three locations along each stream bank within a 10 meter section. At each location a 250 ml poly sample bottle converted into a scoop with a pin hole at the bottom to allow any captured water to drain was used to obtain a 200 ml sediment sample from below water line. A 1 liter glass bottle supplied by Quanta Trace Labs was filled with the sediment to make a composite sample.

The lower station (W-10) sample was taken at three points across the stream cross section.

A new poly scoop was used for each site to reduce chances of cross contamination.

A total volume of greater than half a liter was obtained for each station.

Sediment samples (no preservative added) were kept cool along with water quality samples and shipped to the laboratory for metals analysis and particle size distribution.

5.2 Quality Control

Duplicate metals analysis was done on the composite sediment sample from Williams Creek at the mouth (W-10).

6.0 Water Quality Analysis

6.1 Water Quality Results

Field measurement results for all stations sampled in July and October, 1992 are contained in Table 1. Field results are consistent with results measured during previous surveys.

Water quality analysis results for the July 1992 survey are presented in Table 2a, for the October 1992 surveyin Table 2b.

The July, 1992 survey was done in the post-freshet period as water levels were decreasing in Williams Creek and it's tributaries.

Station W-5, draining the north facing slope across the watershed from the mineral deposit had a number of anomalous physical and metal parameters during the August 1991 survey due to erosion during and after the freshet period. This anomaly was also noted for the August 1992 post freshet period. Suspended solids (800 mg/l) and turbidity (27 FTU) values are well above background and other tributary station levels. The increase in suspended sediment has again resulted in elevated levels of sediment related parameters at W-5 and at the mainstem downstream station W-4.

At station W-5, total aluminum values were measured at 8.02 mg/l with a level of 3.89 mg/l at W-4 and 0.463 mg/l at the lower downstream station W-10. The previously measured high for total aluminum was 10.3 mg/l at station W-5 in August 1991.

Total titanium values at W-5 were 0.364 mg/l with the increase again

Table 1. Field Measurement Results for pH, Conductivity, Water Temperature and Streamflow Volumes, Williams Creek Stations, July and October, 1992.

Station	pH (ru)		Cond. (us/cm)		Temp(c)		Flow(cms)	
	July	Oct.	July	Oct.	July	Oct.	July	Oct.
W-1	8.2	7.4	370	430	1	0.5	0.002e	ice
W-3	7.6	7.1	280	220	6	0	0.004e	ice
W-4	7.9	7.1	170	330	9	0	0.080	ice
W-5	7.4	7.7	120	210	9	-0.5	0.010	ice
W-7	7.6	7.8	120	310	10	-0.5	0.004e	ice
W-8	No Surface Flow							
W-9	7.9	7.7	150	430	7	0	0.069	ice
W-10	6.2	6.5	160	220	9	-0.5	0.376	0.034
W-11	-	6.6	-	190	-	-0.5	-	0.105

e = estimated

ice means under ice cover. W-10 and W-11 were also under ice cover in October but had sufficient volume for a measurement once ice cover was removed.

Table 2a. Water Quality Data for Williams Creek. July, 1992.

Parameter	W-1 Diss.	W-1 Total	W-3 Diss.	W-3 Total	W-4 Diss.	W-4 Total
Cond. us/cm		350		210		210
Turb. FTU		1		1		25
pH (r.u.)		7.9		7.5		7.3
Alkal. CaC03		142		152		94
Susp. Solids		12		<5		258
Nitrate		<0.2		-		<0.1
Sulphate		93.9		9.5		8.9
Ammonia		<0.05		-		-
Nitrite		<2.0		-		<1
T. Phosphorus		0.011		0.013		0.173
T. Hard CaC03	180	202	109	131	103	125
Aluminum	<0.005	-	0.066	0.067	0.043	3.89
Antimony	<0.02	-	-	-	-	-
Arsenic	<0.04	-	-	-	-	-
Barium	0.066	0.068	0.036	0.038	0.041	0.11
Beryllium	<0.0002	-	-	-	-	-
Bismuth	<0.02	-	-	-	-	-
Cadmium	<0.0003	-	-	-	-	-
Calcium	52.8	59.0	33.6	39.8	27.3	27.7
Chromium	<0.001	-	-	-	-	0.006
Cobalt	<0.001	-	-	-	-	0.002
Copper	<0.001	-	-	0.009	-	0.014
Iron	0.09	0.099	0.11	0.172	0.396	6.60
Lead	<0.004	-	-	-	-	0.005
Lithium	<0.05	-	-	-	-	-
Magnesium	11.6	13.4	5.9	7.3	7.66	7.7
Manganese	<0.001	-	0.154	0.159	0.033	0.191
Molybdenum	0.014	0.015	<0.003	-	-	-
Nickel	<0.001	0.003	0.003	0.005	0.002	0.014
Phosphorus	0.02	-	-	0.03	0.03	0.20
Potassium	1.1	1.1	0.70	0.69	0.54	1.0
Selenium	<0.02	-	-	-	-	-
Silicon	8.64	8.72	7.9	10.2	14.0	16.3
Silver	<0.001	-	-	-	-	-
Sodium	8.60	8.91	6.16	6.44	6.37	6.58
Strontium	0.68	0.75	0.31	0.36	0.240	0.24
Thorium	<0.005	-	-	-	-	-
Titanium	<0.001	-	-	-	0.002	0.192
Uranium	<0.02	-	-	-	-	-
Vanadium	<0.001	-	-	-	-	0.016
Zinc	0.002	0.002	0.002	0.004	0.007	0.018
Zirconium	<0.001	-	-	-	-	0.002
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

(-) indicates not detected

Parameter	W-9 Diss.	W-9 Total	W-10 Diss.	W-10 Total	W-11 Diss.	W-11 Total
Cond. us/cm		130		140	no	sample
Turb. FTU		<1		6		
pH (r.u.)		7.9		8.0		
Alkal. CaC03		84		94		
Susp. Solids		<5		20		
Nitrate		<0.1		<0.1		
Sulphate		6.2		9.5		
Ammonia		<0.05		<0.05		
Nitrite		<1		<1		
T. Phosphorus		0.009		0.040		
T. Hard CaC03	95.6	96.4	102	102.2		
Aluminum	0.022	0.057	0.042	0.463		
Antimony	<0.02	-	-	-		
Arsenic	<0.04	-	-	-		
Barium	0.029	0.034	0.030	0.034		
Beryllium	<0.0002	-	-	-		
Bismuth	<0.02	-	-	-		
Cadmium	<0.0003	-	-	-		
Calcium	25.5	25.7	29.5	29.9		
Chromium	<0.001	-	-	-		
Cobalt	<0.001	0.001	-	-		
Copper	<0.001	0.004	-	0.005		
Iron	0.379	0.137	0.164	0.824		
Lead	<0.004	-	-	-		
Lithium	<0.05	-	-	-		
Magnesium	7.54	7.5	6.65	6.71		
Manganese	<0.001	-	-	0.027		
Molybdenum	<0.003	-	-	-		
Nickel	0.004	0.006	0.004	0.006		
Phosphorus	<0.02	-	0.04	0.04		
Potassium	0.38	0.45	0.50	0.62		
Selenium	<0.02	-	-	-		
Silicon	12.6	13.0	11.5	12.2		
Silver	<0.001	-	-	-		
Sodium	5.91	5.98	5.92	6.02		
Strontium	0.232	0.28	0.234	0.29		
Thorium	<0.005	0.01	-	-		
Titanium	<0.001	0.002	-	0.02		
Uranium	<0.02	-	-	-		
Vanadium	<0.001	-	-	-		
Zinc	0.002	0.003	0.01	0.01		
Zirconium	<0.001	0.002	-	-		
	mg/l	mg/l	mg/l	mg/l		

Parameter	W-5 Diss.	W-5 Total	W-7 Diss.	W-7 Total	W-8 Diss.	W-8 total
Cond. us/cm		89		166	no	flow
Turb. FTU		27		4		
pH (r.u.)		7.2		7.6		
Alkal. CaCO3		66		110		
Susp. Solids		800		<5		
Nitrate		<0.03		<0.1		
Sulphate		2.7		11.0		
Ammonia		0.11		<0.05		
Nitrite		<0.5		<1.0		
T. Phosphorus		0.240		0.015		
T. Hard CaCO3	135	163	122	124		
Aluminum	0.060	8.02	0.017	0.192		
Antimony	<0.02	-	-	-		
Arsenic	<0.04	-	-	-		
Barium	0.041	0.239	0.039	0.039		
Beryllium	<0.0002	-	-	-		
Bismuth	<0.02	-	-	-		
Cadmium	<0.0003	-	-	-		
Calcium	19.0	25.3	37.0	37.0		
Chromium	<0.001	0.014	-	-		
Cobalt	<0.001	0.007	-	-		
Copper	<0.001	0.034	-	0.004		
Iron	0.630	14.4	0.054	0.266		
Lead	<0.004	0.009	-	-		
Lithium	<0.05	-	-	-		
Magnesium	4.37	6.9	7.24	7.2		
Manganese	0.194	0.419	0.004	0.007		
Molybdenum	<0.003	-	-	-		
Nickel	0.002	0.025	0.002	0.007		
Phosphorus	0.03	0.82	<0.02	0.03		
Potassium	0.28	1.21	0.23	0.35		
Selenium	<0.02	-	-	-		
Silicon	14.3	22.2	13.5	13.9		
Silver	<0.001	-	-	-		
Sodium	5.44	6.28	6.06	6.09		
Strontium	0.11	0.15	0.176	0.18		
Thorium	<0.005	-	-	-		
Titanium	0.002	0.364	<0.001	0.008		
Uranium	<0.02	-	-	-		
Vanadium	<0.001	0.043	-	-		
Zinc	0.005	0.043	0.006	0.007		
Zirconium	<0.001	0.003	-	0.002		
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

Table 2b. Water Quality Data for Williams Creek. October 1992.

Parameter	W-1		W-3		W-4	
	Diss.	Total	Diss.	Total	Diss.	Total
Cond. us/cm		475		340		370
Turb. FTU		3		<1		1
pH (r.u.)		7.5		7.4		7.5
Alkal. CaC03		140		160		125
Susp. Solids		33		<5		<5
Nitrate		0.6		<0.2		<0.02
Sulphate		83.9		16.8		59.8
Ammonia		<0.05		0.07		0.06
Nitrite		<2.0		<2		<2.0
T. Phosphorus		0.049		0.010		0.017
T. Hard CaC03	207	214	162	180	159	170
Aluminum	<0.005	0.091	-	0.030	0.018	0.036
Antimony	<0.02	-	-	-	-	-
Arsenic	<0.05	-	-	-	-	-
Barium	0.067	0.385	0.046	0.092	0.054	0.175
Beryllium	<0.0002	-	-	-	-	-
Bismuth	<0.02	-	-	-	-	-
Cadmium	<0.0004	0.0004	-	-	-	-
Calcium	59.9	62.0	46.0	53.3	43.4	46.4
Chromium	<0.001	0.002	-	-	-	0.002
Cobalt	0.002	0.003	0.002	0.002	0.003	0.003
Copper	<0.001	0.008	0.002	0.013	0.002	0.008
Iron	<0.004	0.152	0.260	0.261	0.628	0.709
Lead	<0.005	-	-	-	-	-
Lithium	<0.05	-	-	-	-	-
Magnesium	13.9	14.2	11.2	11.1	12.0	13.0
Manganese	0.002	0.005	0.360	0.361	0.165	0.166
Molybdenum	0.021	0.023	-	-	-	-
Nickel	<0.001	0.002	0.003	0.006	0.004	0.005
Phosphorus	0.05	0.08	0.02	0.03	0.02	0.03
Potassium	1.45	1.51	0.91	0.96	0.99	0.95
Selenium	<0.02	-	-	-	-	-
Silicon	9.47	9.52	9.0	12.6	10.0	11.0
Silver	<0.001	-	-	-	-	-
Sodium	10.9	11.4	8.01	8.51	12.5	12.6
Strontium	0.70	0.75	0.40	0.46	0.36	0.40
Thorium	<0.01	-	-	-	-	-
Titanium	<0.001	-	-	-	-	-
Uranium	<0.02	-	-	-	-	-
Vanadium	0.015	0.015	0.006	0.006	0.014	0.01
Zinc	0.010	0.010	0.008	0.009	0.008	0.008
Zirconium	<0.001	-	-	-	-	-
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

(-) indicates non detectable

Parameter	W-5 Diss.	W-5 Total	W-7 Diss.	W-7 Total	W-8 Diss.	W-8 Total
Cond. us/cm		228		345	no	flow
Turb. FTU		3		<1		
pH (r.u.)		7.5		7.5		
Alkal. CaCO3		100		141		
Susp. Solids		<5		<5		
Nitrate		<0.2		<0.2		
Sulphate		9.4		29.6		
Ammonia		0.20		0.06		
Nitrite		<2.0		<2.0		
T. Phosphorus		0.027		<0.005		
T. Hard CaCO3	93.7	109	158	183		
Aluminum	0.034	0.037	0.035	0.035		
Antimony	<0.02	-	-	-		
Arsenic	<0.05	-	-	-		
Barium	0.031	0.037	0.061	0.062		
Beryllium	<0.0002	-	-	-		
Bismuth	<0.02	-	-	-		
Cadmium	<0.0004	-	-	-		
Calcium	26.1	30.3	44.6	54.4		
Chromium	<0.001	0.002	-	-		
Cobalt	0.003	0.003	-	0.002		
Copper	0.001	0.004	0.002	0.005		
Iron	0.322	0.664	0.161	0.219		
Lead	<0.005	-	-	-		
Lithium	<0.05	-	-	-		
Magnesium	6.60	7.62	11.1	11.3		
Manganese	0.271	0.304	0.066	0.073		
Molybdenum	<0.004	-	-	-		
Nickel	0.003	0.004	0.001	0.002		
Phosphorus	0.03	0.03	-	-		
Potassium	0.50	0.52	0.40	0.44		
Selenium	<0.02	-	-	-		
Silicon	11.4	13.0	9.9	14.8		
Silver	<0.001	-	-	-		
Sodium	6.96	8.65	9.92	9.93		
Strontium	0.136	0.157	0.20	0.26		
Thorium	<0.01	-	-	-		
Titanium	<0.001	-	-	-		
Uranium	<0.02	-	-	-		
Vanadium	0.006	0.007	0.003	0.006		
Zinc	0.008	0.010	0.009	0.014		
Zirconium	<0.001	-	-	-		
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

Parameter	W-9 Diss.	W-9 Total	W-10 Diss.	W-10 Total	W-11 Diss.	W-11 Total
Cond. us/cm		475		355		320
Turb. FTU		<1		<1		<1
pH (r.u.)		7.6		7.7		7.8
Alkal. CaC03		188		144		143
Susp. Solids		<5		<5		<5
Nitrate		<0.2		<0.20		<0.20
Sulphate		47.8		34.8		29.2
Ammonia		0.06		<0.05		<0.05
Nitrite		<2.0		<2.0		<2.0
T. Phosphorus		0.009		0.025		0.006
T. Hard CaC03	194	200	156	170	151	155
Aluminum	0.022	0.026	0.043	0.043	0.050	0.055
Antimony	<0.02	-	-	-	-	-
Arsenic	<0.05	-	-	-	-	-
Barium	0.064	0.067	0.054	0.055	0.045	0.046
Beryllium	<0.0002	-	-	-	-	-
Bismuth	<0.02	-	-	-	-	-
Cadmium	<0.0004	-	-	-	-	-
Calcium	46.3	48.5	43.5	47.9	41.4	42.6
Chromium	<0.001	-	-	-	-	-
Cobalt	0.003	0.002	0.001	0.002	0.001	0.002
Copper	<0.001	0.003	0.005	0.005	0.004	0.005
Iron	0.161	0.197	0.129	0.257	0.200	0.268
Lead	<0.005	-	-	-	-	-
Lithium	<0.05	-	-	-	-	-
Magnesium	18.9	19.2	11.0	12.0	11.4	11.5
Manganese	0.042	0.044	0.016	0.018	0.080	0.083
Molybdenum	<0.004	-	-	-	-	-
Nickel	0.003	0.003	0.003	0.003	0.003	0.004
Phosphorus	<0.02	0.02	0.02	0.03	-	-
Potassium	1.41	1.64	1.32	1.30	0.99	1.0
Selenium	<0.02	-	-	-	-	-
Silicon	11.6	12.0	8.9	10.0	9.6	10.0
Silver	<0.001	-	-	-	-	-
Sodium	22.7	22.9	11.1	11.1	9.60	9.69
Strontium	0.53	0.54	0.43	0.47	0.33	0.33
Thorium	<0.01	-	-	-	-	-
Titanium	<0.001	-	-	-	-	-
Uranium	<0.02	-	-	-	-	-
Vanadium	0.011	0.016	0.004	0.010	0.006	0.008
Zinc	0.008	0.017	0.008	0.008	0.006	0.007
Zirconium	<0.001	-	-	-	-	-
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

detected at W-4 (0.192 mg/l). Titanium was also detected at station W-7 in concentrations of 0.008 mg/l. The highest level of titanium was detected in August 1991 at station W-5 (1.12 mg/l).

Total chromium levels at W-5 were 0.014 mg/l and 0.006 mg/l at the downstream station W-4. Chromium was not detected at any other stations during 1992 surveys.

Elevated zinc (0.043 mg/l), iron (14.4 mg/l), nickel (0.025 mg/l) and vanadium (0.043 mg/l) levels were also detected at station W-5 with corresponding increases measured in the downstream station W-4. With the exception of vanadium, elevated levels of the above parameters were also detected at station W-10.

In contrast to the post freshet period in August 1991, a number of parameters at station W-5 did not have elevated concentrations in the July 1992 survey (arsenic, beryllium, cadmium), and parameters that were elevated did not have concentrations as high as in August 1991. This is likely due to lower flow volumes in the July 1992 survey (0.010 cms) versus 0.021 in August 1991 and resulting lower suspended solids and turbidity levels.

Water quality results for the October 1992 survey show significant decreases in concentrations of all elevated parameters at station W-5 and the mainstem downstream stations of W-4 and W-10. At station W-5 suspended solids and turbidity values decreased to < 5 mg/l and 3 FTU respectively with corresponding decreases in sediment related parameters. Aluminum values decreased to 0.036 mg/l, titanium values to below detection limits of 0.001 mg/l, chromium to 0.002 mg/l, iron to 0.709 mg/l, vanadium to 0.016 mg/l, nickel to 0.004 mg/l and zinc to 0.010 mg/l.

The relationship of surface water volumes to the concentrations of a number of parameters are detailed in Figures 3, 4 and 5. Typically, parameters related to groundwater influence (calcium, magnesium ,

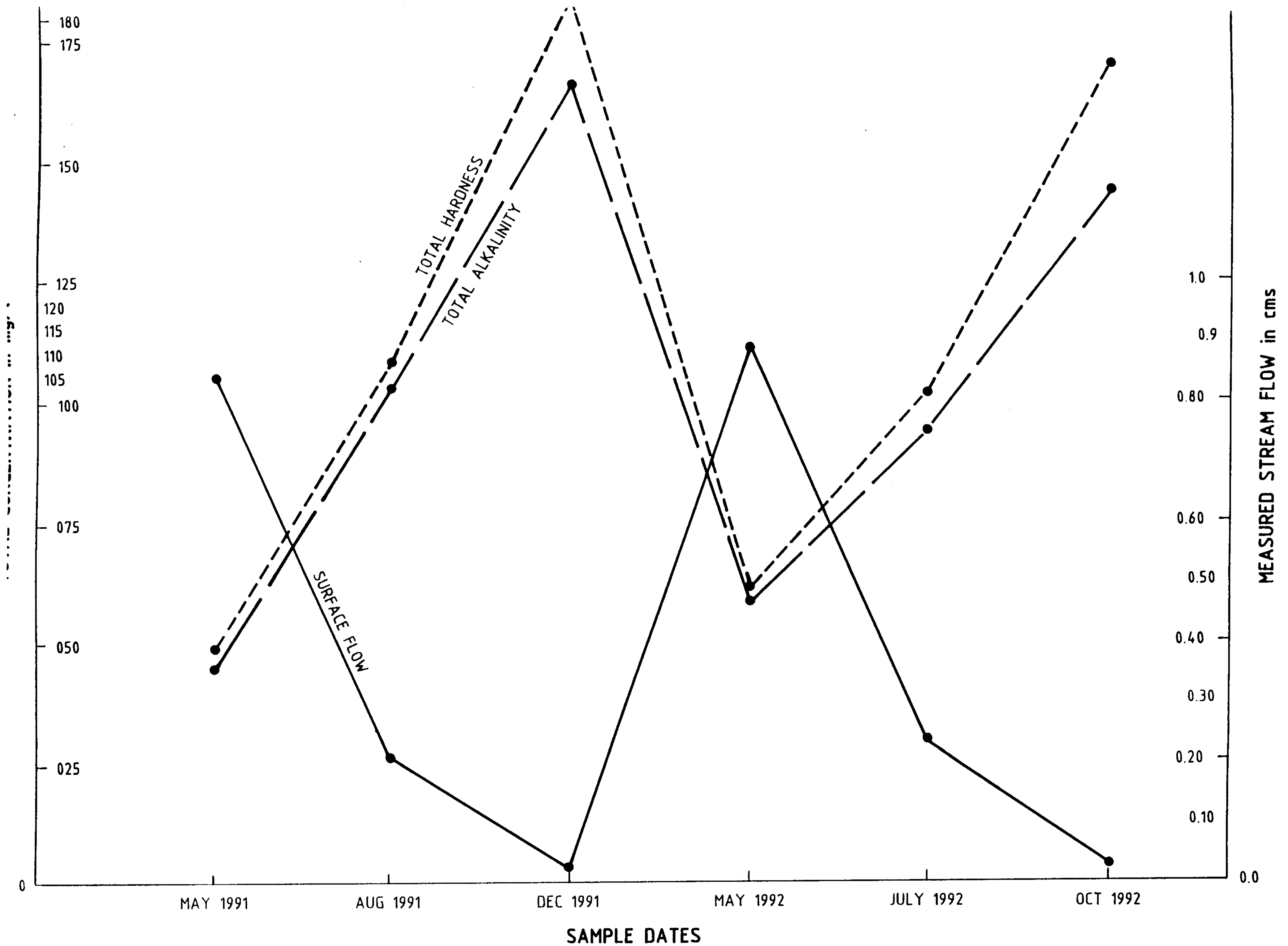

FIGURE 3. Relationship of total hardness, alkalinity concentrations to surface flow. Station W-10 Williams Creek, Yukon.

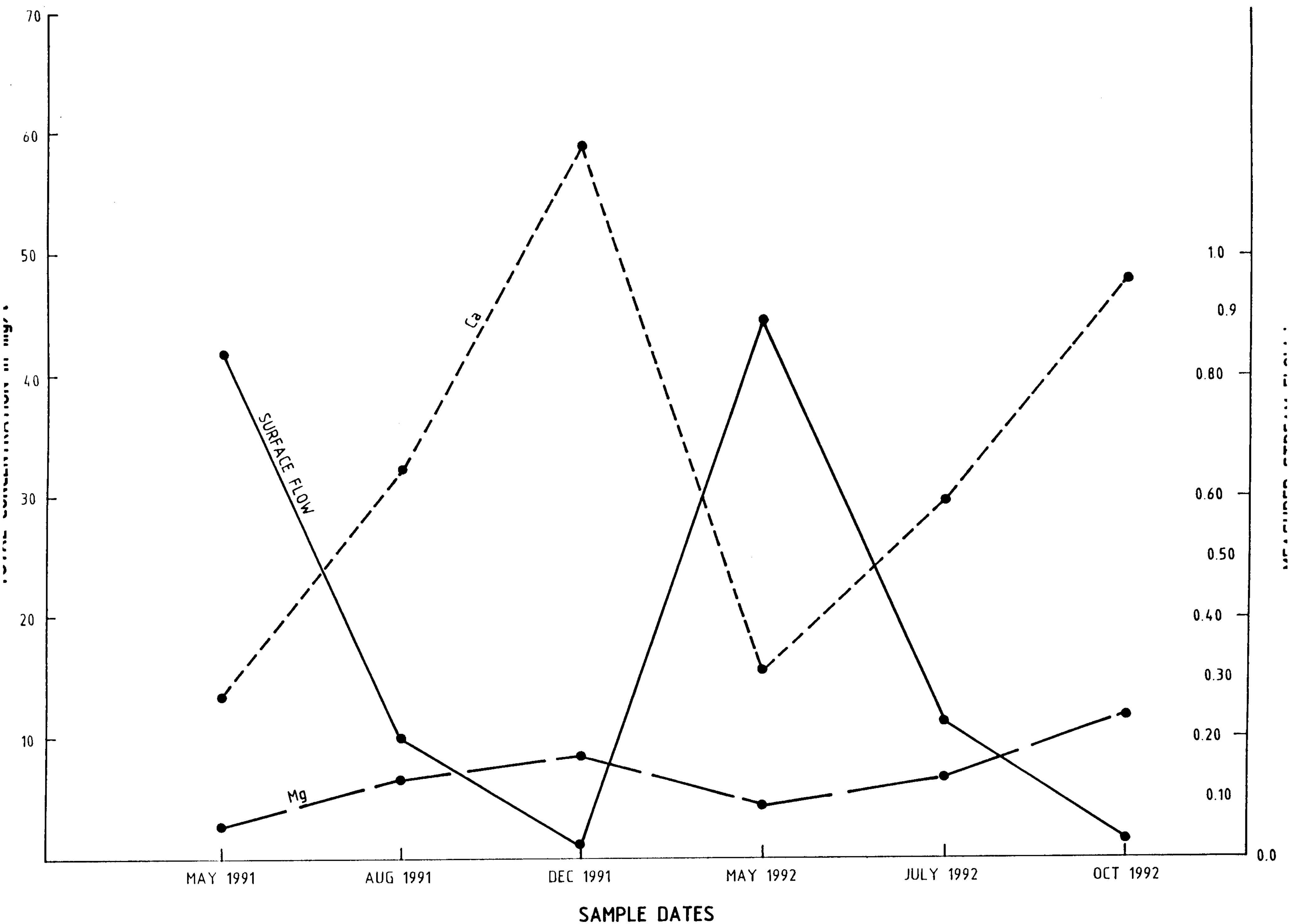

FIGURE 4. Relationship of dissolved calcium and magnesium concentrations to surface flow. Station W-10 Williams Creek, Yukon.

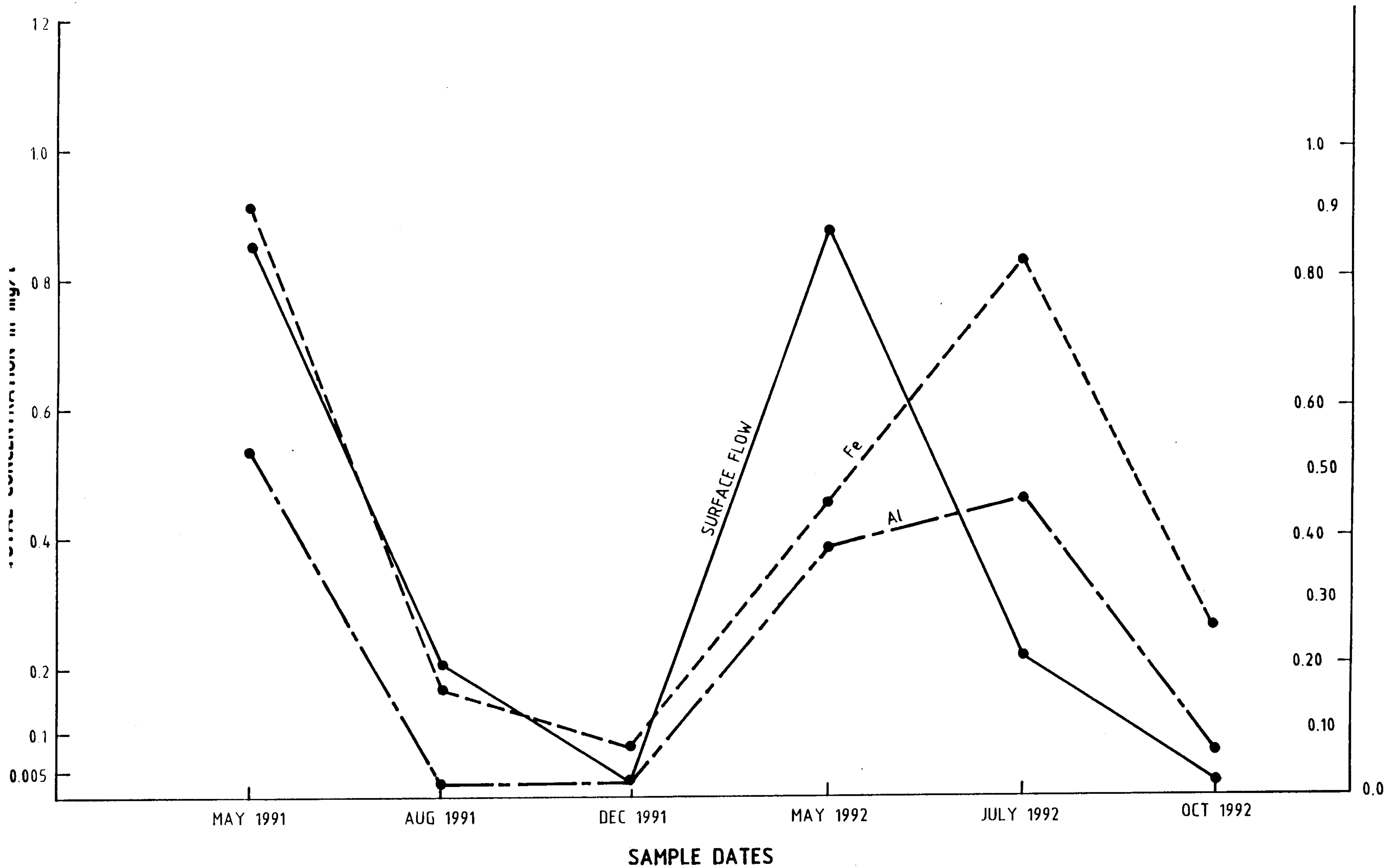

FIGURE 5. Relationship of total iron and aluminum concentrations to surface flow. Station W-10 Williams Creek, Yukon.

total alkalinity, total hardness, barium, strontium, sulphate and conductivity) increase in concentration during winter and early spring as groundwater flows increase in relation to total flow volumes. Sediment related parameters (cadmium, aluminum, copper, iron, titanium, zinc and nickel) tend to show increased levels during periods of higher surface flow as the erosional process increases the volumes of sediment in the surface water.

Figure 3 details the relationship of groundwater related parameters total alkalinity and hardness to volumes of surface flow over the study period. Similiarly, Figure 4 shows the relationship of dissolved calcium and magnesium concentrations to surface flow volumes.

Figure 5 details the relationship of sediment related parameters aluminum and iron to surface flow volumes over the study period.

6.2 Yukon River Background Water Quality

Yukon River background water quality is detailed by data from the federal NAQUADAT system. The NAQUADAT station "Yukon River at Carmacks" is the closest data station to the Williams Creek watershed, located approximately 25 kilometers upstream of the mouth of Williams Creek. There are few tributaries to the Yukon River between Carmacks and Williams Creek that would have any significant impact on water quality over the intervening distance (pers. conv. G.W.Whitely, Administrator Pollution Control N.A.P.).

Yukon River at Carmacks NAQUADAT data to coincide with survey dates for Williams Creek is not available as yet, so data for the period 1980 to 1987 has been used. The Yukon River at Carmacks and Williams Creek at the mouth (W-10) data is compared on the range of parameter results only (Table 3). As a number of NAQUADAT parameters were analyzed for "extractable" concentrations only, the data could not be compared to the Williams Creek "total" concentrations.

Table 3. Yukon River at Carmacks (Naquadat) and Williams Creek at the Mouth. Analysis Results Range for Various Parameters.

Parameter	Yukon River @ Carmacks		Williams Creek @ Mouth	
	Total	Diss.	Total	Diss.
Susp.Solids			<5 - 32	
Cond. (us/cm)	105 - 238		75 - 355	
Turb. (FTU)	0.1 - 42.0		<1 - 8	
pH (ru)	7.0 - 8.3		7.4 - 8.1	
T.AlkalCaCO3	46.7 - 101		46 - 166	
Nitrite			<2.0	
Nitrate			<0.2 - 0.08	
Sulphate		4.0 - 13.4	2.7 - 34.8	
Ammonia			<0.05 - 0.05	
T.Phosphorus			0.009 - 0.043	
T.Hard.CaCO3	51.8 - 123		49.9 - 183	35.5 - 105
Aluminum			<0.005-0.54	<0.005-0.082
Antimony			<0.02	<0.02
Arsenic			<0.04-0.08	<0.04-0.06
Barium			0.026-0.146	0.017-0.054
Beryllium			<0.0002	<0.0002
Bismuth			<0.02	<0.02
Cadmium			<0.0004-0.0004	<0.0003
Calcium		1.5 - 34.1	13.5 - 59.0	13.5 - 57.1
Cobalt			<0.001-0.002	<0.001-0.001
Copper	0.001-0.06		<0.001-0.006	<0.001-0.005
Iron	0.001-5.1		0.07 - 0.92	0.022 - 0.16
Lead			<0.004	<0.004
Lithium			<0.05	<0.05
Magnesium		3.0 - 10.5	2.78 - 12.0	2.70 - 11.0
Manganese	0.01-0.12		0.004-0.034	<0.001-0.016
Molybdenum			<0.003	<0.003
Nickel			0.003-0.006	<0.001-0.004
Phosphorus			<0.02 - 0.04	<0.02 - 0.04
Potassium		0.5 - 2.7	0.41 - 1.46	0.50 - 1.32
Silicon			1.4 - 13.2	<0.02 - 11.5
Silver			<0.001	<0.001
Sodium		1.0 - 3.0	2.51 - 11.1	0.89 - 11.1
Zinc	0.001-0.04		0.002- 0.145	<0.001-0.01
	mg/l	mg/l	mg/l	mg/l

Yukon River @ Carmacks. Naquadat Station 00YT09AH0001
Data for period 1980 to 1987.

6.3 Quality Control

Duplicate samples for both surveys at station W-10 show little significant variation in analysis results. The largest variation (% variance) occurs in concentrations near the parameters respective detection limits (example 0.003 to 0.004 mg/l) where the difference has little significance. Samples are felt to be representative of surface water for that survey.

Similiarly, duplicate analysis by Quanta Trace Laboratories of one sample of each survey set (W-5) show consistent results.

All laboratory results for duplicate analysis and "in house" quality control are contained in the report appendix.

7.0 Stream Sediment Analysis

7.1 Sediment Analysis Results

The laboratory analysis results for sediment sample collected at stations W-4, W-9 and W-10 are presented in Table 4.

Particle size distribution for the above stations is presented in Table 5.

The analysis results indicate the sediment is comprised mainly of aluminum, calcium, iron and magnesium particulate matter. In lesser concentrations, barium, chromium, copper, lithium, manganese, nickel, phosphorus, potassium, silicon, sodium, titanium and zinc also occur. Analysis results for the major constituents are compared with analysis results for sediments from a 1984 study of the Big Creek watershed **"An Environmental Overview of Big Creek, Yukon"** (Table 6). Big Creek is located approximately 60 kilometers to the west of Williams Creek within the Dawson Range. The Big Creek study sampled sediments at six stations on three survey events. The mean concentration values for each element for each station were used to establish a "range" of

Table 4. Stream Channel Sediment Analysis Results for Williams Creek Stations. July, 1992.

Parameter	Station # W-4	Station # W-9	Station # W-10
Aluminum	8920	8710	8240
Antimony	<4	<4	<4
Arsenic	<9	<10	<9
Barium	112	111	130
Beryllium	0.2	0.2	0.2
Bismuth	<7	<7	<6
Cadmium	<0.09	<0.10	<0.09
Calcium	7040	6990	7080
Chromium	16.6	16.4	20.0
Cobalt	5.2	5.8	6.4
Copper	11.3	10.1	17.0
Iron	13300	15300	18900
Lead	5	5	6
Lithium	200	70	100
Magnesium	3730	3990	4160
Manganese	184	228	359
Molybdenum	<0.5	<0.5	<0.5
Nickel	10.3	10.6	11.9
Phosphorus	630	650	850
Potassium	1200	1000	1200
Selenium	<0.9	<1.0	<0.9
Silicon	300	270	450
Sodium	540	390	370
Strontium	56.9	65.5	61.4
Thorium	<2	<2	<2
Titanium	690	674	682
Uranium	<9	<10	<9
Vanadium	30	31	45
Zinc	33.0	37.0	39.2
Zirconium	7.1	5.4	5.0
	ug/g	ug/g	ug/g

Table 5. Stream Chammel Sediment Particle Size Distribution.
Williams Creek Stations. July 1992.

Particle Size Mesh #	W-4	W-9	W-10
10 (2 mm)	0.3	1.0	0.0
18 (1 mm)	0.5	2.7	2.4
35 (500 um)	1.1	3.2	39.3
60 (250 um)	12.2	11.5	51.5
100 (150 um)	29.0	21.6	5.5
120 (125 um)	12.0	10.5	0.3
230 (63 um)	27.8	30.6	0.2
< 230	17.1	18.8	0.8

Mesh # = % retained on mesh #

concentrations. The range is compared to that established by the three stations single survey results from Williams Creek.

Table 6. Comparison of Sediment Parameter Concentration Ranges for Williams Creek and Big Creek.

Parameter	Big Creek	Williams Creek
Aluminum	9,930 - 16,900	7,670 - 8,920
Calcium	5,980 - 9,470	6,990 - 7,080
Iron	29,000 - 81,100	13,300 - 18,900
Magnesium	5,010 - 9,370	3,730 - 4,160

all results in ug/g

No comparison of sediment particle size distribution was done.

8.0 Summary

Within the period October 1989 to October 1992, seven water quality survey events have been completed for the Williams Creek watershed. Water quality analysis results and streamflow measurements detail the seasonal changes in water quality. The most significant change in water quality occurs yearly during and after freshet with an increase in sediment and sediment related metal parameter concentrations at Station W-5. The increased sediment deposition and parameter levels can be detected in the downstream mainstem station (W-4) to the lower station at the creek's confluence with the Yukon River (W-10).
No other tributary channel to the mainstem appears to have an impact on water quality comparable to W-5.
Exploration work and access road construction thus far do not appear to have had any significant impact on the hydrology or water quality of Williams Creek.

In addition to water quality and streamflow surveys, additional hydrology and climate studies have been implemented to assist in the understanding of the Williams Creek watershed. Analysis of the additional studies data will be covered under separate report.

A P P E N D I X

Analysis of Environmental Samples

Laboratory Results and Quality Control Report

July and October 1992

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-056

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: J. GIBSON & ASSOCIATES
Site 15, Comp 111, RR2
Whitehorse, Yukon
Y1A 5A5

Workorder: 19024
Received : 13-Jul-9
Completed: 20-Jul-9

Re: W WATERS

Sample type	water	water	water	water	water
Identification	W-1	W-1	W-3	W-3	W-4
Lab Reference #	19024-001	19024-001	19024-002	19024-002	19024-003
Gravimetric - Solids					
Suspended	12.	-	< 5.	-	258.
Results in	mg/l		mg/l		mg/l
Physical Tests					
Conduct. uS/cm	350.	-	210.	-	137.
Turbidity FTU	1.	-	1.	-	25.
pH	7.9	-	7.5	-	7.8
Alkalinity as mg/l CaCO3					
Hydroxide	< 5.	-	< 5.	-	< 5.
Carbonate	< 5.	-	< 5.	-	< 5.
Bicarbonate	142.	-	152.	-	94.
Total	142.	-	152.	-	94.
Results in	mg/l		mg/l		mg/l
IEC - Water Soluble Anions					
Nitrite NO2-N	< 2.	-	< 2.	-	< 1.
Nitrate NO3-N	< 0.2	-	< 0.2	-	< 0.1
Sulfate SO4	93.9	-	9.5	-	8.9
Results in	mg/l		mg/l		mg/l
SIE - Water Soluble Ions					
Ammonia NH3-N	< 0.05	-	< 0.05	-	< 0.05
Results in	mg/l		mg/l		mg/l
Colorimetric					
Total PO4-P	0.011	-	0.013	-	0.173
Results in	mg/l		mg/l		mg/l

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-056

To: J. GIBSON & ASSOCIATES W/O: 19024 Page 2

Sample type		water	water	water	water	water
Identification		W-1	W-1	W-3	W-3	W-4
Lab Reference #		19024-001	19024-001	19024-002	19024-002	19024-003
ICP - Ultrasonic Nebulization						
Method used		filt. 0.45u RAR soluble DISSOLVED	microwave RAR soluble TOTAL	filt. 0.45u RAR soluble DISSOLVED	microwave RAR soluble TOTAL	filt. 0.45u RAR soluble DISSOLVED
Aluminum	Al	< 0.005	< 0.005	0.066	0.067	0.043
Antimony	Sb	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Arsenic	As	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Barium	Ba	0.066	0.068	0.036	0.038	0.041
Beryllium	Be	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bismuth	Bi	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium	Cd	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003
Calcium	Ca	52.8	59.0	33.6	39.8	27.3
Chromium	Cr	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	Co	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Copper	Cu	< 0.001	< 0.001	< 0.001	0.009	< 0.001
Iron	Fe	0.09	0.099	0.11	0.172	0.396
Lead	Pb	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Lithium	Li	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Magnesium	Mg	11.6	13.4	5.9	7.3	7.66
Manganese	Mn	< 0.001	< 0.001	0.154	0.159	0.033
Molybdenum	Mo	0.014	0.015	< 0.003	< 0.003	< 0.003
Nickel	Ni	< 0.001	0.003	0.003	0.005	0.002
Phosphorus	P	0.02	< 0.02	< 0.02	0.03	0.03
Potassium	K	1.1	1.1	0.70	0.69	0.54
Selenium	Se	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Silicon	Si	8.64	8.72	7.9	10.2	14.0
Silver	Ag	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sodium	Na	8.60	8.91	6.16	6.44	6.37
Strontium	Sr	0.68	0.75	0.31	0.36	0.240
Thorium	Th	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Titanium	Ti	< 0.001	< 0.001	< 0.001	< 0.001	0.002
Uranium	U	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Vanadium	V	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Zinc	Zn	0.002	0.002	0.002	0.004	0.007
Zirconium	Zr	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Results in		mg/l	mg/l	mg/l	mg/l	mg/l
Total Hardness as CaCO3	mg/l	180.	202.	109.	131.	103.

/3..

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-056?

To: J. GIBSON & ASSOCIATES

Sample type	water	water	water	water	water
Identification	W-4	W-5	W-5	W-5	W-5
Lab Reference #	19024-003	19024-004A	19024-004A	19024-004B	19024-004B
Gravimetric - Solids					
Suspended	-	800.	-	800.	-
Results in		mg/l		mg/l	
Physical Tests					
Conduct. uS/cm	-	89.	-	90.	-
Turbidity FTU	-	27.	-	26.	-
pH	-	7.2	-	7.2	-
Alkalinity as mg/l CaCO3					
Hydroxide	-	< 5.	-	< 5.	-
Carbonate	-	< 5.	-	< 5.	-
Bicarbonate	-	66.	-	66.	-
Total	-	66.	-	66.	-
Results in		mg/l		mg/l	
IEC - Water Soluble Anions					
Nitrite NO2-N	-	< 0.5	-	< 0.5	-
Nitrate NO3-N	-	< 0.3	-	< 0.3	-
Sulfate SO4	-	2.7	-	2.9	-
Results in		mg/l		mg/l	
SIE - Water Soluble Ions					
Ammonia NH3-N	-	0.11	-	0.11	-
Results in		mg/l		mg/l	
Colorimetric					
Total PO4-P	-	0.240	-	0.220	-
Results in		mg/l		mg/l	

/4..

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

W/O: 19024 Page 4

Sample type	water	water	water	water	water
Identification	W-4	W-5	W-5	W-5	W-5
Lab Reference #	19024-003	19024-004A	19024-004A	19024-004B	19024-004B
ICP - Ultrasonic Nebulization					
Method used	microwave RAR soluble TOTAL	filt. 0.45u RAR soluble DISSOLVED	microwave RAR soluble TOTAL	filt. 0.45u RAR soluble DISSOLVED	microwave RAR soluble TOTAL
Aluminum Al	3.89	0.060	8.02	0.059	7.97
Antimony Sb	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Arsenic As	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Barium Ba	0.11	0.041	0.239	0.041	0.230
Beryllium Be	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bismuth Bi	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium Cd	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003
Calcium Ca	27.7	19.0	25.3	18.7	25.9
Chromium Cr	0.006	< 0.001	0.014	< 0.001	0.013
Cobalt Co	0.002	< 0.001	0.007	< 0.001	0.008
Copper Cu	0.014	< 0.001	0.034	0.001	0.034
Iron Fe	6.60	0.630	14.4	0.636	14.0
Lead Pb	0.005	< 0.004	0.009	< 0.004	0.013
Lithium Li	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Magnesium Mg	7.7	4.37	6.9	4.31	7.0
Manganese Mn	0.191	0.194	0.419	0.189	0.413
Molybdenum Mo	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Nickel Ni	0.014	0.002	0.025	0.004	0.024
Phosphorus P	0.20	0.03	0.82	0.03	0.77
Potassium K	1.0	0.28	1.21	0.25	1.1
Selenium Se	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Silicon Si	16.3	14.3	22.2	14.0	22.0
Silver Ag	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sodium Na	6.58	5.44	6.28	5.42	6.18
Strontium Sr	0.24	0.11	0.15	0.10	0.16
Thorium Th	< 0.005	< 0.005	< 0.005	< 0.005	0.005
Titanium Ti	0.192	0.002	0.364	0.002	0.312
Uranium U	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Vanadium V	0.016	< 0.001	0.043	0.002	0.042
Zinc Zn	0.018	0.005	0.043	0.006	0.043
Zirconium Zr	0.002	< 0.001	0.003	< 0.001	0.003
Results in	mg/l	mg/l	mg/l	mg/l	mg/l
Total Hardness as CaCO3 mg/l	135.	67.2	163.	66.5	161.

/5..

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

W/O: 19024

Sample type	water	water	water	water	water
Identification	W-7	W-7	W-9	W-9	W-10-1
Lab Reference #	19024-005	19024-005	19024-006	19024-006	19024-007
Gravimetric - Solids					
Suspended	< 5.	-	< 5.	-	20.
Results in	mg/l		mg/l		mg/l
Physical Tests					
Conduct. uS/cm	166.	-	130.	-	140.
Turbidity FTU	4.	-	< 1.	-	6.
pH	7.6	-	7.9	-	8.0
Alkalinity as mg/l CaCO3					
Hydroxide	< 5.	-	< 5.	-	< 5.
Carbonate	< 5.	-	< 5.	-	< 5.
Bicarbonate	110.	-	84.	-	94.
Total	110.	-	84.	-	94.
Results in	mg/l		mg/l		mg/l
IEC - Water Soluble Anions					
Nitrite NO2-N	< 1.	-	< 1.	-	< 1.
Nitrate NO3-N	< 0.1	-	< 0.1	-	< 0.1
Sulfate SO4	11	-	6.2	-	9.5
Results in	mg/l		mg/l		mg/l
SIE - Water Soluble Ions					
Ammonia NH3-N	< 0.05	-	< 0.05	-	< 0.05
Results in	mg/l		mg/l		mg/l
Colorimetric					
Total PO4-P	0.015	-	0.009	-	0.040
Results in	mg/l		mg/l		mg/l

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quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-056

To: J. GIBSON & ASSOCIATES

W/O: 19024 Page

Sample type		water	water	water	water	water
Identification		W-7	W-7	W-9	W-9	W-10-1
Lab Reference #		19024-005	19024-005	19024-006	19024-006	19024-007
ICP - Ultrasonic Nebulization						
Method used		filt. 0.45u RAR soluble DISSOLVED	microwave RAR soluble TOTAL	filt. 0.45u RAR soluble DISSOLVED	microwave RAR soluble TOTAL	filt. 0.45u RAR soluble DISSOLVED
Aluminum	Al	0.017	0.172	0.022	0.057	0.042
Antimony	Sb	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Arsenic	As	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Barium	Ba	0.039	0.044	0.029	0.034	0.030
Beryllium	Be	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bismuth	Bi	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium	Cd	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003
Calcium	Ca	37.0	37.0	25.5	25.7	29.5
Chromium	Cr	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	Co	< 0.001	< 0.001	< 0.001	0.001	< 0.001
Copper	Cu	< 0.001	0.004	< 0.001	0.004	< 0.001
Iron	Fe	0.054	0.266	0.379	0.137	0.164
Lead	Pb	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Lithium	Li	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Magnesium	Mg	7.24	7.2	7.54	7.5	6.65
Manganese	Mn	0.004	0.007	< 0.001	< 0.001	< 0.001
Molybdenum	Mo	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Nickel	Ni	0.002	0.007	0.004	0.006	0.004
Phosphorus	P	< 0.02	0.03	< 0.02	< 0.02	0.04
Potassium	K	0.23	0.35	0.38	0.45	0.50
Selenium	Se	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Silicon	Si	13.5	13.9	12.6	13.0	11.5
Silver	Ag	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sodium	Na	6.06	6.09	5.91	5.98	5.92
Strontium	Sr	0.176	0.18	0.232	0.28	0.234
Thallium	Tl	< 0.005	< 0.005	< 0.005	0.01	< 0.005
Titanium	Ti	< 0.001	0.008	< 0.001	0.002	< 0.001
Uranium	U	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Vanadium	V	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Zinc	Zn	0.006	0.007	0.002	0.003	0.01
Zirconium	Zr	< 0.001	0.002	< 0.001	0.002	< 0.001
Results in		mg/l	mg/l	mg/l	mg/l	mg/l
Total Hardness as CaCO3	mg/l	122.	124.	95.6	96.4	102.

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quanta trace laboratories inc.
#101-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

Sample type	water	water	water
Identification	W-10-1	W-10-2	W-10-2
Lab Reference #	19024-007	19024-008	19024-008
Gravimetric - Solids			
Suspended	-	21.	-
Results in		mg/l	
Physical Tests			
Conduct. uS/cm	-	145.	-
Turbidity FTU	-	6.	-
pH	-	8.0	-
Alkalinity as mg/l CaCO3			
Hydroxide	-	< 5.	-
Carbonate	-	< 5.	-
Bicarbonate	-	88.	-
Total	-	88.	-
Results in		mg/l	
IEC - Water Soluble Anions			
Nitrite NO2-N	-	< 1.	-
Nitrate NO3-N	-	< 0.1	-
Sulfate SO4	-	9.4	-
Results in		mg/l	
SIE - Water Soluble Ions			
Ammonia NH3-N	-	< 0.05	-
Results in		mg/l	
Colorimetric			
Total PO4-P	-	0.042	-
Results in		mg/l	

quanta trace laboratories inc.
#101 3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-056[illegible]

To: J. GIBSON & ASSOCIATES

W/O: 19024 Page [illegible]

Sample type		water	water	water
Identification		W-10-1	W-10-2	W-10-2
Lab Reference #		19024-007	19024-008	19024-008
ICP - Ultrasonic Nebulization				
Method used		microwave RAR soluble TOTAL	filt. 0.45u RAR soluble DISSOLVED	microwave RAR soluble TOTAL
Aluminum	Al	0.463	0.042	0.481
Antimony	Sb	< 0.02	< 0.02	< 0.02
Arsenic	As	< 0.04	< 0.04	< 0.04
Barium	Ba	0.034	0.031	0.035
Beryllium	Be	< 0.0002	< 0.0002	< 0.0002
Bismuth	Bi	< 0.02	< 0.02	< 0.02
Cadmium	Cd	< 0.0003	< 0.0003	< 0.0003
Calcium	Ca	29.9	29.7	30.6
Chromium	Cr	< 0.001	< 0.001	< 0.001
Cobalt	Co	< 0.001	< 0.001	< 0.001
Copper	Cu	0.005	0.002	0.006
Iron	Fe	0.824	0.153	0.848
Lead	Pb	< 0.004	< 0.004	< 0.004
Lithium	Li	< 0.05	< 0.05	< 0.05
Magnesium	Mg	6.71	6.72	6.9
Manganese	Mn	0.027	< 0.001	0.025
Molybdenum	Mo	< 0.003	< 0.003	< 0.003
Nickel	Ni	0.006	0.002	0.003
Phosphorus	P	[illegible]	[illegible]	0.04
Potassium	K	[illegible]	[illegible]	[illegible]
Selenium	Se	< [illegible]	< [illegible]	< [illegible]
Silicon	Si	12.2	11.7	11.7
Silver	Ag	< [illegible]	< [illegible]	< 0.001
Sodium	Na	6.02	5.93	6.40
Strontium	Sr	[illegible]	[illegible]	[illegible]
Thallium	Tl	< 0.005	< 0.005	< 0.005
Titanium	Ti	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	< [illegible]	< [illegible]
[illegible]	[illegible]	< [illegible]	< [illegible]	[illegible]
Zinc	Zn	[illegible]	[illegible]	[illegible]
Zirconium	Zr	< [illegible]	< [illegible]	< [illegible]
Results in		mg/l	mg/l	mg/l
Total Hardness				
as CaCO3	mg/l	102.2	102.	102.9

[illegible] results are for internal use only. Quanta Trace liability is limited to the testing fee paid.

Analyst: [signature]

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: J. GIBSON & ASSOCIATES
Site 15, Comp 111, RR2
Whitehorse, Yukon
Y1A 5A5

Workorder: 19039
Received : 13-Jul-92
Completed: 27-Jul-92

Re: Sediment Samples Williams Ck

Sample type		sediment	sediment	sediment	sediment
Identification		W4	W9	W10	W10
Lab Reference #		19039-001	19039-002	19039-003A	19039-003B
ICP - Ultrasonic Nebulization					
Method used		microwave RAR soluble	microwave RAR soluble	microwave RAR soluble	microwave RAR soluble
Amount analysed		0.529 g	0.507 g	0.540 g	0.520 g
Aluminum	Al	8920	8710	8240	7670
Antimony	Sb	< 4.	< 4.	< 4.	< 4.
Arsenic	As	< 9.	< 10.	< 9.	< 10.
Barium	Ba	112.	111.	130.	132.
Beryllium	Be	0.2	0.2	0.2	0.2
Bismuth	Bi	< 7.	< 7.	< 6.	< 7.
Cadmium	Cd	< 0.09	< 0.10	< 0.09	< 0.10
Calcium	Ca	7040	6990	7080	7040
Chromium	Cr	16.6	16.4	20.0	18.5
Cobalt	Co	5.2	5.8	6.4	6.5
Copper	Cu	11.3	10.1	17.0	16.9
Iron	Fe	13300	15300	18900	18200
Lead	Pb	5.	5.	6.	9.
Lithium	Li	200	70	100	100
Magnesium	Mg	3730	3990	4160	4020
Manganese	Mn	184.	228.	359.	352.
Molybdenum	Mo	< 0.5	< 0.5	< 0.5	< 0.5
Nickel	Ni	10.3	10.6	11.9	12.0
Phosphorus	P	630	650	850	860
Potassium	K	1300	1000	1200	1100
Selenium	Se	< 0.9	< 1.0	< 0.9	< 1.0
Silicon	Si	300	270	450	410
Sodium	Na	540	390	370	340
Strontium	Sr	56.9	65.3	61.4	56.1
Thorium	Th	< 2.	< 2.	< 2.	< 2.
Titanium	Ti	690.	674.	682.	685.
Uranium	U	< 9.	< 10.	< 9.	< 10.
Vanadium	V	30.	31.	45.	46.
Zinc	Zn	33.0	37.0	39.2	39.6
Zirconium	Zr	7.1	5.4	5.0	5.3
Results in		ug/g	ug/g	ug/g	ug/g

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quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

Sample type	sediment	sediment	sediment
Identification	W4	W9	W10
Lab Reference #	19039-001	19039-002	19039-003
Particle Size			
% Retained on mesh #			
10 (2 mm)	0.3	1.0	0.0
18 (1 mm)	0.5	2.7	2.4
35 (500 um)	1.1	3.2	39.3
60 (250 um)	12.2	11.5	51.5
100 (150 um)	29.0	21.6	5.5
120 (125 um)	12.0	10.5	0.3
230 (63 um)	27.8	30.6	0.2
< 230	17.1	18.8	0.8

Test results are for internal use only. Quanta Trace liability is limited to the testing fee paid. Analyst: ______

quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF ENVIRONMENTAL SAMPLES

To: J. GIBSON & ASSOCIATES
Site 15, Comp 111, RR2
Whitehorse, Yukon
Y1A 5A5

Workorder: 19601
Received : 22-Oct-92
Completed: 03-Nov-92

Attn: John Gibson

Re: William's Creek Surface Waters

Sample type	WATER	WATER	WATER	WATER	WATER
Identification	W-1	W-1	W-3	W-3	W-4
Lab Reference #	19601-001	19601-001	19601-002	19601-002	19601-003
Gravimetric - Solids					
Suspended	33.	-	< 5.	-	< 5.
Results in	mg/l		mg/l		mg/l
Physical Tests					
Conduct. uS/cm	475.	-	340.	-	370.
Turbidity FTU	3.	-	< 1.	-	1.
pH	7.5	-	7.4	-	7.5
Alkalinity as mg/l CaCO3					
Hydroxide	< 5.	-	< 5.	-	< 5.
Carbonate	< 5.	-	< 5.	-	< 5.
Bicarbonate	140.	-	160.	-	125.
Total	140.	-	160.	-	125.
Results in	mg/l		mg/l		mg/l
IEC - Water Soluble Anions					
Nitrite NO2-N	< 2.	-	< 2.	-	< 2.
Nitrate NO3-N	0.6	-	< 0.2	-	< 0.2
Sulfate SO4	83.9	-	16.8	-	59.8
Results in	mg/l		mg/l		mg/l
SIE - Water Soluble Ions					
Ammonia NH3-N	< 0.05	-	0.07	-	0.06
Results in	mg/l		mg/l		mg/l
Colorimetric					
Total PO4-P	0.049	-	0.010	-	0.017
Results in	mg/l		mg/l		mg/l

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quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

W/O: 19601

Sample type		WATER	WATER	WATER	WATER	WATER
Identification		W-1	W-1	W-3	W-3	W-4
Lab Reference #		19601-001	19601-001	19601-002	19601-002	19601-003
ICP - Ultrasonic Nebulization						
Method used		field filt. RAR soluble DISSOLVED	microwave RAR soluble TOTAL	field filt. RAR soluble DISSOLVED	microwave RAR soluble TOTAL	field filt. RAR soluble DISSOLVED
Aluminum	Al	< 0.005	0.071	< 0.005	0.030	0.018
Antimony	Sb	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Arsenic	As	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Barium	Ba	0.067	0.385	0.046	0.092	0.054
Beryllium	Be	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bismuth	Bi	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium	Cd	< 0.0004	0.0004	< 0.0004	< 0.0004	< 0.0004
Calcium	Ca	59.9	62.0	46.0	53.3	43.4
Chromium	Cr	< 0.001	0.002	< 0.001	< 0.001	< 0.001
Cobalt	Co	0.002	0.003	0.002	0.002	0.003
Copper	Cu	< 0.001	0.008	0.002	0.013	0.002
Iron	Fe	< 0.004	0.152	0.260	0.261	0.620
Lead	Pb	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Lithium	Li	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Magnesium	Mg	13.9	14.2	11.2	11.1	12.0
Manganese	Mn	0.002	0.005	0.360	0.360	0.165
Molybdenum	Mo	0.021	0.023	< 0.004	< 0.004	< 0.004
Nickel	Ni	0.001	0.002	0.003	0.006	0.004
Phosphorus	P	0.05	0.08	0.02	0.03	0.02
Potassium	K	1.45	1.51	0.91	0.96	0.99
Selenium	Se	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Silicon	Si	9.47	9.52	9.0	12.6	10.
Silver	Ag	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sodium	Na	10.9	11.4	8.01	8.51	12.5
Strontium	Sr	0.70	0.75	0.40	0.46	0.36
Thorium	Th	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Titanium	Ti	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Uranium	U	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Vanadium	V	0.015	0.015	0.006	0.006	0.014
Zinc	Zn	0.010	0.010	0.008	0.009	0.008
Zirconium	Zr	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Results in		mg/l	mg/l	mg/l	mg/l	mg/l
Total Hardness						
	mg/l	[illegible]	[illegible]	162	159	159

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quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

Sample type	WATER	WATER	WATER	WATER	WATER
Identification	W-4	W-5	W-5	W-5	W-5
Lab Reference #	19601-003	19601-004A	19601-004A	19601-004B	19601-004B
Gravimetric - Solids					
Suspended	-	< 5.	-	< 5.	-
Results in		mg/l		mg/l	
Physical Tests					
Conduct. uS/cm	-	228.	-	228.	-
Turbidity FTU	-	3.	-	3.	-
pH	-	7.5	-	7.2	-
Alkalinity as mg/l CaCO3					
Hydroxide	-	< 5.	-	< 5.	-
Carbonate	-	< 5.	-	< 5.	-
Bicarbonate	-	100.	-	100.	-
Total	-	100.	-	100.	-
Results in		mg/l		mg/l	
IC - Water Soluble Anions					
Nitrite NO2-N	-	< 2.	-	< 2.	-
Nitrate NO3-N	-	< 0.2	-	< 0.2	-
Sulfate SO4	-	9.4	-	9.4	-
Results in		mg/l		mg/l	
SIE - Water Soluble Ions					
Ammonia NH3-N	-	0.20	-	0.20	-
Results in		mg/l		mg/l	
Colorimetric					
Total PO4-P	-	0.027	-	0.034	-
Results in		mg/l		mg/l	

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quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

Sample type		WATER	WATER	WATER	WATER	WATER
Identification		W-4	W-5	W-5	W-5	W-5
Lab Reference #		19601-003	19601-004A	19601-004A	19601-004B	19601-004B
ICP - Ultrasonic Nebulization						
Method used		microwave RAR soluble TOTAL	field filt. RAR soluble DISSOLVED	microwave RAR soluble TOTAL	field filt. RAR soluble DISSOLVED	microwave RAR soluble TOTAL
Aluminum	Al	0.036	0.034	0.037	0.024	0.037
Antimony	Sb	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Arsenic	As	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Barium	Ba	0.175	0.031	0.037	0.032	0.036
Beryllium	Be	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bismuth	Bi	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium	Cd	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004
Calcium	Ca	46.4	26.1	30.3	26.4	30.0
Chromium	Cr	0.002	< 0.001	0.002	< 0.001	0.002
Cobalt	Co	0.003	0.003	0.003	0.002	0.002
Copper	Cu	0.008	0.001	0.004	0.002	0.003
Iron	Fe	0.709	0.322	0.664	0.376	0.618
Lead	Pb	< 0.005	< 0.005	< 0.005	< 0.005	0.005
Lithium	Li	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Magnesium	Mg	13.0	6.60	7.62	6.73	7.65
Manganese	Mn	0.166	0.271	0.304	0.272	0.304
Molybdenum	Mo	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Nickel	Ni	0.005	0.003	0.004	0.003	0.004
Phosphorus	P	0.03	0.03	0.03	0.03	0.03
Potassium	K	0.95	0.50	0.52	0.44	0.48
Selenium	Se	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Silicon	Si	11.	11.4	13.0	11.4	13.1
Silver	Ag	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sodium	Na	12.6	6.96	8.65	7.17	8.54
Strontium	Sr	0.40	0.136	0.157	0.139	0.157
Thorium	Th	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Titanium	Ti	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Uranium	U	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Vanadium	V	0.01	0.006	0.007	0.009	0.007
Zinc	Zn	0.008	0.008	0.010	0.010	0.010
Zirconium	Zr	< 0.001	< 0.001	< 0.001	< 0.0010	< 0.001
Results in		mg/l	mg/l	mg/l	mg/l	mg/l
Total Hardness						
as CaCO3	mg/l	17[illegible]	95.[illegible]	109	95	108

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quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

Sample type	WATER	WATER	WATER	WATER	WATER
Identification	W-7	W-7	W-9	W-9	W-10-1
Lab Reference #	19601-005	19601-005	19601-006	19601-006	19601-007
Gravimetric - Solids					
Suspended	< 5.	-	< 5.	-	< 5.
Results in	mg/l		mg/l		mg/l
Physical Tests					
Conduct. uS/cm	345.	-	475.	-	355.
Turbidity FTU	< 1.	-	< 1.	-	< 1.
pH	7.5	-	7.6	-	7.7
Alkalinity as mg/l CaCO3					
Hydroxide	< 5.	-	< 5.	-	< 5.
Carbonate	< 5.	-	< 5.	-	< 5.
Bicarbonate	141.	-	188.	-	144.
Total	141.		188.	-	144.
Results in	mg/l		mg/l		mg/l
C - Water Soluble Anions					
Nitrite NO2-N	< 2.		< 2.	-	< 2.
Nitrate NO3-N	< 0.2	-	< 0.2	-	< 0.2
Sulfate SO4	29.6		47.0		34.0
Results in	mg/l		mg/l		mg/l
SIE - Water Soluble Ions					
Ammonia NH3-N	0.06		0.06		< 0.05
Results in	mg/l		mg/l		mg/l
Colorimetric					
Total PO4-P	< 0.005	-	0.009	-	0.025
Results in	mg/l		mg/l		mg/l

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quanta trace laboratories inc.
#401-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

Sample type		WATER	WATER	WATER	WATER	WATER
Identification		W-7	W-7	W-9	W-9	W-10-1
Lab Reference #		19601-005	19601-005	19601-006	19601-006	19601-007
ICP - Ultrasonic Nebulization						
Method used		field filt. RAR soluble DISSOLVED	microwave RAR soluble TOTAL	field filt. RAR soluble DISSOLVED	microwave RAR soluble TOTAL	field filt. RAR soluble DISSOLVED
Aluminum	Al	0.035	0.035	0.022	0.026	0.043
Antimony	Sb	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Arsenic	As	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Barium	Ba	0.061	0.062	0.064	0.067	0.054
Beryllium	Be	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bismuth	Bi	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium	Cd	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004
Calcium	Ca	44.6	54.4	46.3	48.5	43.5
Chromium	Cr	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	Co	< 0.001	0.002	0.003	0.003	0.001
Copper	Cu	0.002	0.005	< 0.001	0.003	0.005
Iron	Fe	0.161	0.219	0.161	0.197	0.129
Lead	Pb	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Lithium	Li	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Magnesium	Mg	11.1	11.3	18.9	19.2	11.
Manganese	Mn	0.066	0.073	0.042	0.044	0.016
Molybdenum	Mo	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Nickel	Ni	0.001	0.002	0.003	0.003	0.003
Phosphorus	P	< 0.02	< 0.02	< 0.02	0.02	0.02
Potassium	K	0.40	0.44	1.41	1.64	1.32
Selenium	Se	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Silicon	Si	9.9	14.8	11.6	12.0	8.9
Silver	Ag	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sodium	Na	9.92	9.93	22.7	22.9	11.1
Strontium	Sr	0.20	0.26	0.53	0.54	0.43
Thorium	Th	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Titanium	Ti	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Uranium	U	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Vanadium	V	0.003	0.006	0.011	0.016	0.004
Zinc	Zn	0.009	0.014	0.008	0.017	0.008
Zirconium	Zr	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Results in		mg/l	mg/l	mg/l	mg/l	mg/l
Tot'l Hardness	mg/l	[illegible]	[illegible]	[illegible]	200.	156.

quanta trace laboratories inc.
#401 3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

To: J. GIBSON & ASSOCIATES

W/O: 19601

Sample type	WATER	WATER	WATER	WATER	WATER
Identification	W-10-1	W-10-2	W-10-2	W-11	W-11
Lab Reference #	19601-007	19601-008	19601-008	19601-009	19601-009
Gravimetric - Solids					
Suspended		< 5.	-	< 5.	-
Results in		mg/l		mg/l	
Physical Tests					
Conduct. uS/cm		355.	-	320.	-
Turbidity FTU	-	< 1.	-	< 1.	-
pH		7.9	-	7.8	-
Alkalinity as mg/l CaCO3					
Hydroxide	-	< 5.	-	< 5.	-
Carbonate	-	< 5.	-	< 5.	-
Bicarbonate	-	141.	-	143.	-
Total	-	141.	-	143.	-
Results in		mg/l		mg/l	
D - Water Soluble Anions					
Nitrite NO2-N	-	< 2.	-	< 2.	-
Nitrate NO3-N	-	< 0.2	-	< 0.2	-
Sulfate SO4		34.6	-	29.2	-
Results in		mg/l		mg/l	
DIE Water Soluble Ions					
Ammonia NH3-N		< 0.05		< 0.05	-
Results in		mg/l		mg/l	
Colorimetric					
Total PO4-P		0.025		0.006	-
Results in		mg/l		mg/l	

/8...

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To: J. GIDDON & ASSOCIATES

Sample type / Identification / Lab Reference #		WATER W-10-1 19601-007	WATER W-10-2 19601-008	WATER W-10-2 19601-008	WATER W-11 19601-009	WATER W-11 19601-009
ICP - Ultrasonic Nebulization -- Method used		microwave RAR soluble TOTAL	field filt. RAR soluble DISSOLVED	microwave RAR soluble TOTAL	field filt. RAR soluble DISSOLVED	microwave RAR soluble TOTAL
Aluminum	Al	0.043	0.023	0.027	0.050	0.055
Antimony	Sb	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Arsenic	As	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Barium	Ba	0.055	0.053	0.053	0.045	0.046
Beryllium	Be	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Bismuth	Bi	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium	Cd	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004
Calcium	Ca	47.9	43.2	46.7	41.4	42.6
Chromium	Cr	0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	Co	0.002	0.001	0.002	0.001	0.002
Copper	Cu	0.005	0.004	0.005	0.004	0.005
Iron	Fe	0.257	0.135	0.147	0.200	0.268
Lead	Pb	0.005	< 0.005	< 0.005	< 0.005	< 0.005
Lithium	Li	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Magnesium	Mg	12	11.	12.	11.4	11.5
Manganese	Mn	0.018	0.015	0.015	0.080	0.083
Molybdenum	Mo	0.004	< 0.004	< 0.004	< 0.004	< 0.004
Nickel	Ni	0.003	0.001	0.002	0.003	0.004
Phosphorus	P	[illegible]3	0.02	0.03	< 0.02	< 0.02
Potassium	K	1.3[illegible]	1.26	1.27	0.99	1.0
Selenium	Se	[illegible]2	0.02	< 0.02	< 0.02	< 0.02
Silicon	Si	10.[illegible]	8.9	9.7	9.6	10.
Silver	Ag	[illegible]01	< 0.001	< 0.001	< 0.001	< 0.001
Sodium	Na	11.1	10.3	10.5	9.60	9.69
Strontium	Sr	[illegible]47	0.33	0.35	0.33	0.33
Thallium	Tl	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Titanium	Ti	[illegible]01	< 0.001	< 0.001	< 0.001	< 0.001
[illegible]	[illegible]	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Vanadium	V	0.010	0.010	0.012	0.006	0.008
Zinc	Zn	0.008	0.007	0.008	0.006	0.007
Zirconium	Zr	0.001	< 0.001	< 0.001	< 0.001	< 0.001
Results in		mg/l	mg/l	mg/l	mg/l	mg/l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	155

Test results are for internal use only. Quanta Trace liability is limited to the testing fee paid. Analyst: [signature]

Quanta Trace Laboratories

03-Nov-92

QUALITY CONTROL REPORT
SAMPLE # 19601-001 W-1

C ions

Calcium	59.9	Magnesium	13.9
Sodium	10.9	Potassium	1.45

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	140
Sulphate(SO4)	83.9	Chloride(Cl)	2.5
Fluoride(F)	0	Nitrate Nitrogen(NO3)	.6

Results For Sample #19601-001 W-1

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 4.64365		
Anion Sum	= 4.6582		
Difference	= .145454E-01		<= .178702

Quanta Trace Laboratories 03-Nov-92

QUALITY CONTROL REPORT
SAMPLE # 19601-002 W-3

Cations

Calcium	46.07	Magnesium	11.2
Sodium	8.01	Potassium	.91

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	160
Sulphate(SO4)	16.8	Chloride(Cl)	1.3
Fluoride(F)	0	Nitrate Nitrogen(NO3)	0

Results For Sample #19601-002 W-3

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 3.59191		
Anion Sum	= 3.58342		
Difference	= .849152E-02		<= .162043

Quanta Trace Laboratories 03-Nov-92

Q U A L I T Y   C O N T R O L   R E P O R T
S A M P L E # 1 9 6 0 1 - 0 0 3 W - 4

Cations

Calcium	43.46	Magnesium	12
Sodium	12.5	Potassium	.99

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	125
Sulphate(SO4)	59.8	Chloride(Cl)	1.4
Fluoride(F)	0	Nitrate Nitrogen(NO3)	0

Results For Sample #19601-003 W-4

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 3.72484		
Anion Sum	= 3.78263		
Difference	= .577898E-01		<= .165131

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03-Nov-92

QUALITY CONTROL REPORT
SAMPLE # 19601-004A W-5

Cations

Calcium	26.3	Magnesium	6.6
Sodium	6.96	Potassium	.5

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	100
Sulphate(SO4)	9.4	Chloride(Cl)	1.2
Fluoride(F)	0	Nitrate Nitrogen(NO3)	0

Results For Sample #19601-004A W-5

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 2.17083		
Anion Sum	= 2.22765		
Difference	= .568233E-01		<= .141029

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QUALITY CONTROL REPORT
SAMPLE # 19601-004B W-5 DUPLICATE

Cations

Calcium	26.6	Magnesium	6.73
Sodium	7.17	Potassium	.44

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	100
Sulphate(SO4)	9.4	Chloride(Cl)	1.1
Fluoride(F)	0	Nitrate Nitrogen(NO3)	0

Results For Sample #19601-004B W-5 DUPLICATE

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 2.2041		
Anion Sum	= 2.22483		
Difference	= .207374E-01		<= .140985

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QUALITY CONTROL REPORT
SAMPLE # 19601-005 W-7

Cations

Calcium	44.66	Magnesium	11.1
Sodium	7.9	Potassium	.4

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	141
Sulphate(SO4)	27.6	Chloride(Cl)	1.1
Fluoride(F)	0	Nitrate Nitrogen(NO3)	0

Results For Sample #19601-005 W-7

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 3.5825		
Anion Sum	= 3.46478		
Difference	= .117719		<= .160204

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03-Nov-92

QUALITY CONTROL REPORT
SAMPLE # 19601-007 W-10-1

Cations

Calcium	43.5	Magnesium	11
Sodium	11.1	Potassium	1.32

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	144
Sulphate(SO4)	34.8	Chloride(Cl)	1.5
Fluoride(F)	0	Nitrate Nitrogen(NO3)	0

Results For Sample #19601-007 W-10-1

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 3.59211		
Anion Sum	= 3.64432		
Difference	= .522065E-01		<= .162987

Quanta Trace Laboratories 03-Nov-92

QUALITY CONTROL REPORT
SAMPLE # 19601-008 W-10-2

Cations

Calcium	43.2	Magnesium	11
Sodium	10.5	Potassium	1.26

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	141
Sulphate(SO4)	34.6	Chloride(Cl)	1.6
Fluoride(F)	0	Nitrate Nitrogen(NO3)	0

Results For Sample #19601-008 W-10-2

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 3.54951		
Anion Sum	= 3.58303		
Difference	= .335259E-01		<= .162037

Quanta Trace Laboratories 03-Nov-92

Q U A L I T Y   C O N T R O L   R E P O R T
S A M P L E   #   1 9 6 0 1 - 0 0 9   W - 1 1

Cations

Calcium	41.4	Magnesium	11.4
Sodium	9.6	Potassium	.99

Anions

Phenolthalein Alkalinity	0	Total Alkalinity	143
Sulphate(SO4)	29.2	Chloride(Cl)	1.3
Fluoride(F)	0	Nitrate Nitrogen(NO3)	0

Results For Sample #19601-009 W-11

		STATUS	LIMITS:
Cation-Anion Bal.:		PASSED	
Cation Sum	= 3.44654		
Anion Sum	= 3.50205		
Difference	= .055511		<= .160782

quanta trace laboratories inc.
#407-3700 Gilmore Way, Burnaby, B.C., V5G 4M1 Tel:(604)438-5226 Fax:436-0565

ANALYSIS OF QA/QC SAMPLES

To: Quality Assurance Report

Workorder: S0055
Completed: 03-Nov-92

The Certified Reference Material below was analyzed by ICP concurrently with the following QTL workorder numbers:

19540, 19602, 19606, 19634, 19656, 19659, 19601, 19637, 19638, 19639, 19640, 19643, 19647, 19648, 19655.

Sample type		water	water
Identification		NIST 1643c	NIST 1643c
Lab Reference #		S0055-000	S0055-002
ICP - Ultrasonic Nebulization--			
Method used		TOTAL NIST MEAN	microwave RAR soluble TOTAL
Aluminum	Al	0.115	0.11
Antimony	Sb	-	< 0.02
Arsenic	As	0.0821	0.09
Barium	Ba	0.0496	0.049
Beryllium	Be	0.0232	0.0233
Bismuth	Bi	0.0120	< 0.02
Cadmium	Cd	0.0122	0.012
Calcium	Ca	36.8	36.0
Chromium	Cr	0.0190	0.018
Cobalt	Co	0.0235	0.024
Copper	Cu	0.0223	0.019
Iron	Fe	0.107	0.094
Lead	Pb	0.0353	0.035
Lithium	Li	0.0165	< 0.05
Magnesium	Mg	9.45	10.1
Manganese	Mn	0.0351	0.036
Molybdenum	Mo	0.104	0.10
Nickel	Ni	0.0606	0.052
Phosphorus	P	-	< 0.02
Potassium	K	2.30	2.72
Selenium	Se	0.0127	< 0.02
Silicon	Si	-	< 0.05
Silver	Ag	0.00221	< 0.001
Sodium	Na	12.2	13.1
Strontium	Sr	0.264	0.253
Thorium	Th	-	< 0.01
Titanium	Ti	-	0.003
[illegible]	[illegible]	[illegible]	[illegible]
Vanadium	V	0.0314	0.035
Zinc	Zn	0.0739	0.067
Zirconium	Zr	-	< 0.001
Results in		mg/l	mg/l

Test results are for internal use only. Quanta Trace liability is limited to the testing fee paid. Analyst: ______