ARIS SUMMARY SHEET

District Geologist, Kamloops
Off Confidential: 94.11.26

ASSESSMENT REPORT 23348
MINING DIVISION: Nicola

PROPERTY: Craigmont
LOCATION: LAT 50 12 30 LONG 120 55 30
UTM 10 5563636 648064
NTS 092I02W

CAMP: 012 Nicola Belt

CLAIM(S): Bird 1-4
OPERATOR(S): Craigmont Holdings
AUTHOR(S): Trenholme, B.S.
REPORT YEAR: 1993, 99 Pages
COMMODITIES SEARCHED FOR: Magnetite
KEYWORDS: Triassic,Nicola Group,Volcanics,Sediments,Intrusives,Skarn
Magnetite,Hematite,Pyrite,Chalcocite,Chalcopyrite

WORK DONE: Geochemical,Drilling
HYDG
ROTD 45.7 m 2 hole(s)
MINFILE: 092ISE035

CRAIGMONT MINES
A DIVISION OF M.SEVEN INDUSTRIES INC.

GROUNDWATER MONITORING AND SUPPLY

AR 23348

PB 5395 0501

AUGUST 1993

KLOHN LEONOFF

AR 23348

Province of
British Columbia

Ministry of
Energy, Mines and
Petroleum Resources
GEOLOGICAL SURVEY BRANCH

ASSESSMENT REPORT TITLE PAGE AND SUMMARY

TITLE OF REPORT [type of survey(s)]	TOTAL COST
Ground Water Monitoring and Supply	$21 517.55

AUTHOR(S) Blair S. Trenholme P.Eng SIGNATURE(S)

NOTICE OF WORK PERMIT NUMBER(S)/DATE(S) NA YEAR OF WORK 1993

STATEMENT OF WORK - CASH PAYMENT EVENT NUMBER(S)/DATE(S) 3044861, Nov. 26, 1993

PROPERTY NAME Craigmont

CLAIM NAME(S) (on which work was done) Bird 1-4, Merrell 1-4, Edith 1-2, Al 2, Al 6

COMMODITIES SOUGHT MA

MINERAL INVENTORY MINFILE NUMBER(S), IF KNOWN 092ISE-035

MINING DIVISION Nicola NTS 092I02W

LATITUDE 50 ° 12 ' 30 " LONGITUDE 120 ° 55 ' 30 " (at centre of work)

OWNER(S)

1) Craigmont Holdings Ltd 2)

MAILING ADDRESS

320-1639 W. 2nd Ave.
Vancouver B.C.
V6J 1H3

OPERATOR(S) [who paid for the work]

1) Same 2)

MAILING ADDRESS

Same

PROPERTY GEOLOGY KEYWORDS (lithology, age, stratigraphy, structure, alteration, mineralization, size and attitude):

Triassic	Magnetite, hematite, pyrite
Nicola Group	Chalcocite
Volcanics	Chalcopyrite
Sediments	
Skarn	

REFERENCES TO PREVIOUS ASSESSMENT WORK AND ASSESSMENT REPORT NUMBERS

G.S.B.
DEC 2 0 1993

KLOHN-CRIPPEN
A Merger of:
Klohn-Crippen, Klohn Leonoff, Crippen Division of Simons, Toronto Division of Simons

Our File: PB 5395 0801
MIN 94

November 26, 1993

GEOLOGICAL BRANCH
ASSESSMENT REPORT

23,348

Craigmont Mines
320 - 1639 West 2nd Ave.
Vancouver, B.C.
V6J 1H3

Mr. W.F. Moore, P.Eng.
Director

Assessemt Report

Dear Sir:

This letter outlines work done for Craigmont Mines by Klohn-Crippen Consultants Ltd. (formerly Klohn Leonoff Ltd.) on the Craigmont Mine site near Merritt. The information contained herein is intended to assist with reporting of assessment work in accordance with the Province of British Columbia, Ministry of Energy, Mines and Petroleum Resources, Mineral Tenure Act, Sections 25, 26 & 27.

1. BACKGROUND

Location

The Craigmont Mine is located in the Interior Plateau Region of south-central British Columbia approximately 13 km northwest of Merritt (see Drawing A-5001). The mine site is located on the lower slopes of the Promontory Hills which rise to the west of the Stumbles Creek Valley. The tailings impoundment is situated in the Stumbles Creek Valley. A narrow ridge separates the Stumbles Creek Valley from the Guichon Creek Valley to the east.

History

The Craigmont Mine was in operation from 1962 to 1982. The Craigmont orebody was originally mined for its copper values. However, the ore also contained significant grades of magnetite and hematite. For approximately the first eight years of mine operation, the magnetite was deposited with the tailings until a magnetite recovery circuit was installed in the mill. Recovery of magnetite from the ore started in about 1970.

The recovered raw magnetite was stockpiled at the minesite. Following closure of the mine, the magnetite was processed in the mill to produce media-grade magnetite for sale to the coal mining industry for use in the flotation process. The processed media-grade magnetite was stored in stockpiles at the minesite. Since closure, the stockpiled magnetite has been sold, recently at a rate of about 60 000 tonnes per year, and is now nearly depleted.

New Magnetite Recovery Operation
As the magnetite stockpiles are virtually depleted, Craigmont is planning to supplement this magnetite supply by recovering magnetite from tailings deposited during the operational life of the Craigmont Mine. Klohn Leonoff Ltd. was retained by Craigmont to prepare a mine development plan. This was presented in the report entitled "Mine Plan", dated September 12, 1991. Based on that and other studies, Craigmont has developed the site and built new tailings storage dykes and a processing plant which began preliminary operation in 1993.

2. WORK DONE IN 1993

The 1993 work includes groundwater quality monitoring on the Craigmont Mine site. The work included:

- development of wells on the property to collect information about the state of groundwater quality;
- determination of background levels of groundwater quality prior to commencement of the new tailings mining and processing project;
- ongoing monitoring to determine any changes in groundwater quality; and
- preparation of an engineering report (Klohn Leonoff, 1993), drawings and letters to document the above.

Well locations are shown on the attached Drawing B5002. One of the wells will also serve as a water supply well for the plant. The wells have been sampled several times since development and the samples tested for a standard suite of water quality parameters. More extensive descriptions of the work carried out are included in the referenced reports.

The total amounts billed by Klohn-Crippen on various aspects of the project to October 1, 1993 are summarized in Table 1.

Table 1 - Summary of Expenditures

Sub-Project Description	Total Billed
Groundwater Sampling Well Installations	$14,683.75
Groundwater Monitoring	$6,833.80
Total	$21,517.55

We note that other costs, including those incurred by the well drilling and well developement contractors, were paid directly by Craigmont Mines, and were not billed through Klohn-Crippen. Consequently, those costs are not reflected in the above totals.

We trust that the information included herein is sufficient. If you have any further questions, please do not hesitate to call.

Yours very truly,

KLOHN-CRIPPEN CONSULTANTS LTD.

Blair Trenholme

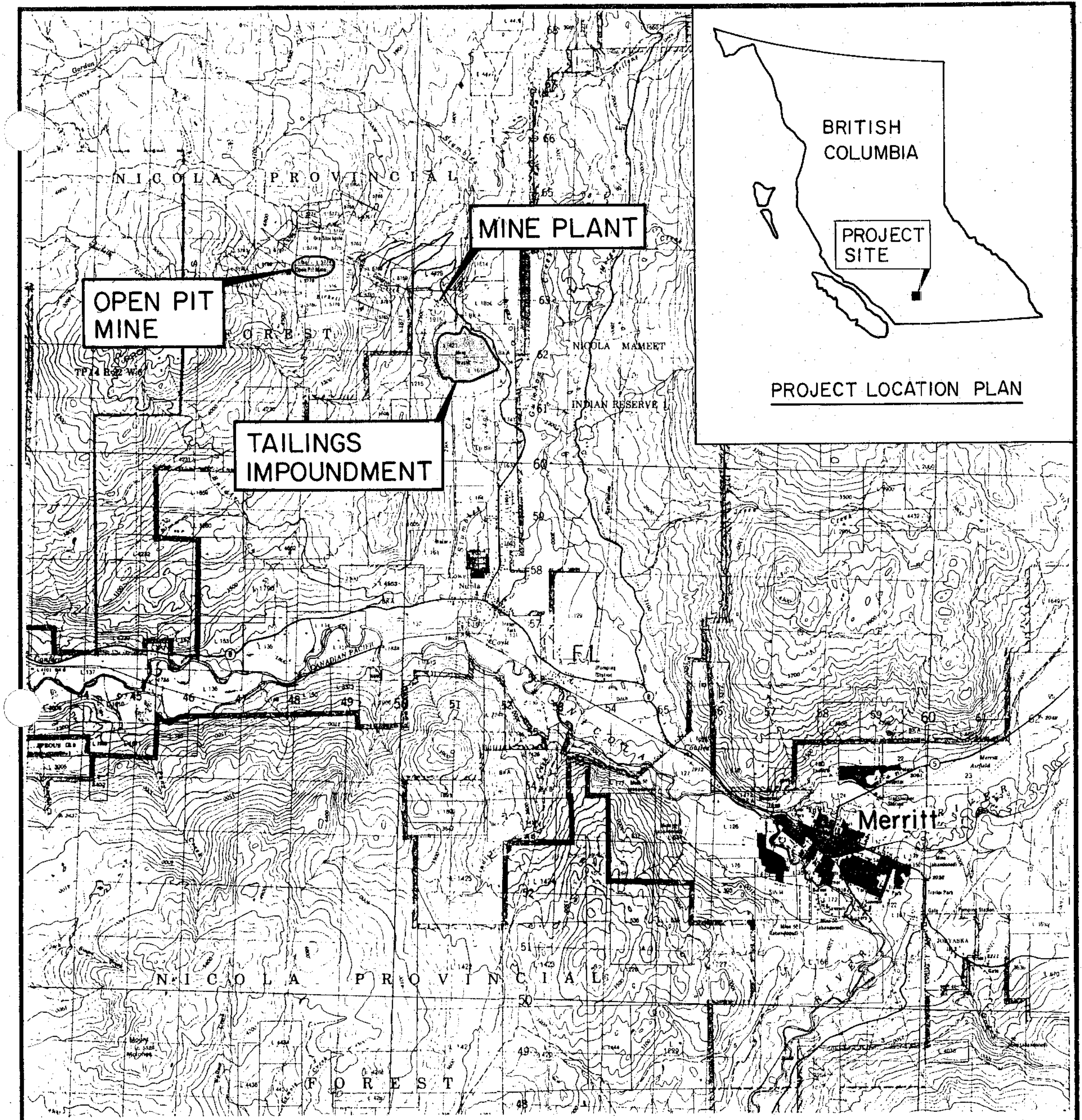
Blair S. Trenholme, P.Eng.
Project Engineer

BST/SR:lp
Attach.

LIST OF REFERENCES

Klohn Leonoff, 1992, "Mine Plan", September. Consultant's report to Craigmont Mines.

Klohn Leonoff, 1993, "Groundwater Monitoring and Supply", August 3. Consultant's report to Craigmont Mines.



PROJECT LOCATION PLAN

SCALE 1 : 100 000

KLOHN-CRIPPEN

PROJECT
GROUNDWATER SUPPLY AND MONITORING

TITLE
LOCATION PLAN

CLIENT:
CRAIGMONT MINES

DATE OF ISSUE
JULY 29, 1993

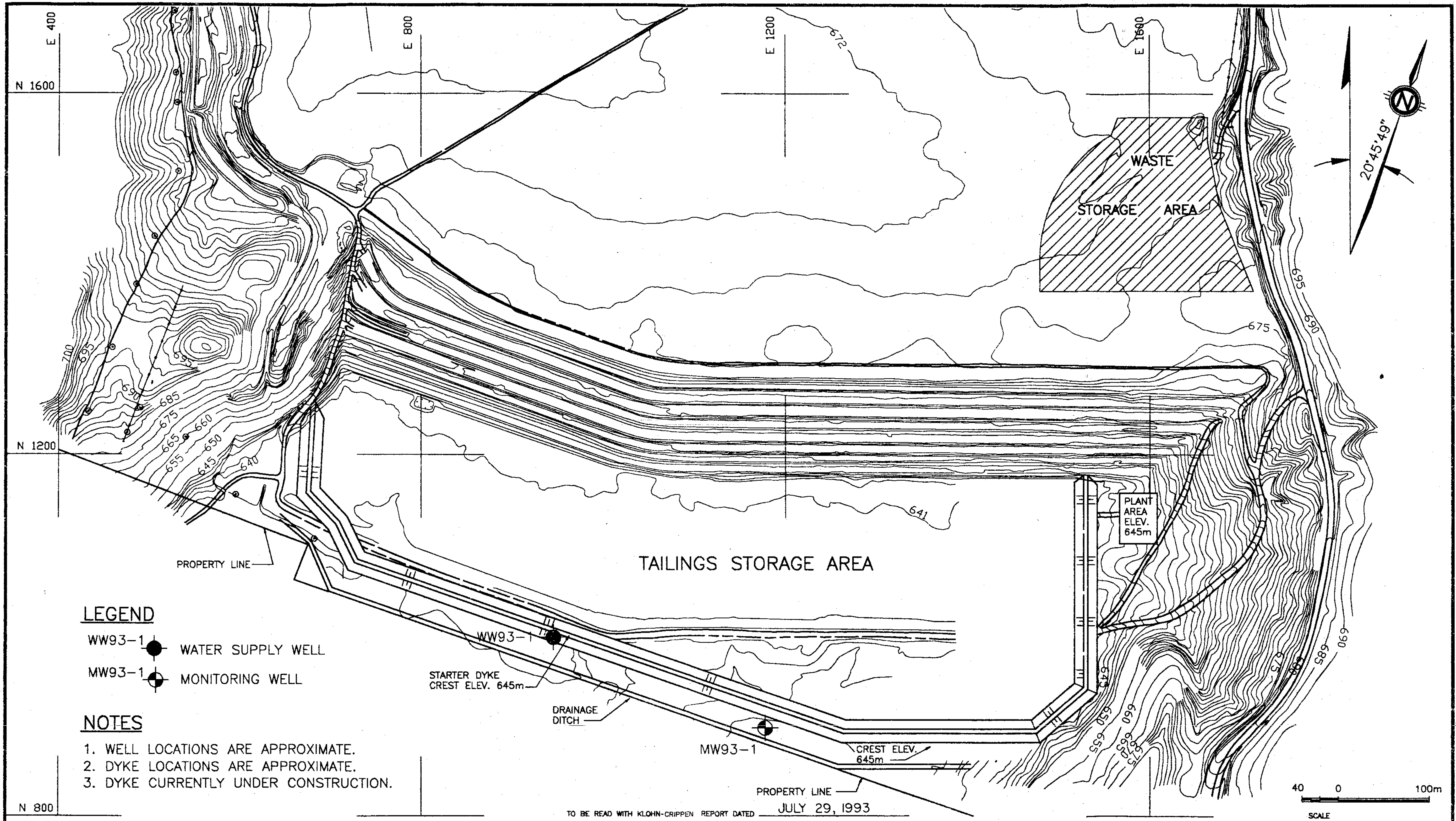
APPROVED

PROJECT No.
PB 5395 05

DWG. No.
A-5001

REV.

NCI-760



LEGEND

WW93-1 ●	WATER SUPPLY WELL
MW93-1 ⊕	MONITORING WELL

NOTES

1. WELL LOCATIONS ARE APPROXIMATE.
2. DYKE LOCATIONS ARE APPROXIMATE.
3. DYKE CURRENTLY UNDER CONSTRUCTION.

TO BE READ WITH KLOHN-CRIPPEN REPORT DATED JULY 29, 1993

KLOHN-CRIPPEN		DATE
DESIGNED	H.McC	4/93
DRAWN	K.NG	4/93
CHECKED	HWL	7/93
RECOMMENDED		
APPROVED		

KLOHN-CRIPPEN

CLIENT
CRAIGMONT MINES

PROJECT
GROUNDWATER SUPPLY AND MONITORING

TITLE
SITE PLAN

DATE OF ISSUE	PROJECT No.	DWG. No.	REV
JUL 29, 1993	PB5395 05	B-5002	

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APPENDICES

DRAWINGS

1. INTRODUCTION

Craigmont Mine, located near Merritt, British Columbia (Drawing A-5001), was in operation from 1962 to 1982. The orebody was originally mined for copper but the ore also contained significant grades of magnetite and hematite. The magnetite was discarded with the tailings until a magnetite recovery circuit was installed in about 1970. Craigmont is currently mining an existing media-grade magnetite stockpile and also plans to recover magnetite from the existing tailings impoundment.

Klohn Leonoff Ltd. was retained by Craigmont in 1991 to prepare a development plan for its magnetite recovery project, which is detailed in Klohn Leonoff's report titled "Mine Plan" (1991). After the development plan was submitted, Klohn Leonoff was retained to install a groundwater supply well and a groundwater monitoring well. The groundwater supply well, which will be used as part of the mill water supply, will intercept some of the seepage from the new tailings impoundment. Water samples will be collected from the monitoring well. These water samples will be analyzed at a commercial laboratory to monitor the water quality downstream of the new tailings impoundment.

This report documents the installation of one groundwater supply well and one groundwater monitoring well in March 1993. The scope of work comprised:

- installation, development and test pumping of a water supply well;
- installation, development and response testing of a monitoring well; and
- collection and analysis of one water quality sample from each of the wells.

2. PROJECT DESCRIPTION

Exploration programs commissioned by Craigmont Mines have identified the lower portion of the south end of the impoundment as being rich in magnetite (Klohn Leonoff, 1991). This recent exploration has revealed that the magnetite-rich tailings, covered by up to 12 m of magnetite-poor tailings, extend upstream from the toe of the embankment for a distance of at least 250 m.

Craigmont plans to recover the magnetite from the tailings with a wet extraction process. The wet process tailings will be stored in the area south of the existing impoundment toe and north of the southern property boundary (Drawing B-5002). Only water will be added to the mined tailings during the recovery process. The waste material (tailings low in magnetite) will be disposed of on top of the existing impoundment in areas not intended for mining.

3. SITE CONDITIONS

3.1 General

The Craigmont Mine is located in the Interior Plateau Region of south-central British Columbia approximately 13 km northwest of Merritt. Access to the minesite is via Highway 8 west from Merritt to the community of Lower Nicola and north via a paved access road (Drawing A-5001).

The minesite is located on the lower slopes of the Promontory Hills which rise to the west of the Stumbles Creek Valley. The tailings impoundment is situated in the Stumbles Creek Valley. A narrow ridge separates the Stumbles Creek Valley from the Guichon Creek Valley to the east.

3.2 Surficial Geology

The topography of the site is generally controlled by bedrock but has been modified by glaciation and subsequent erosion and deposition by post-glacial streams. The floor of the Stumbles Creek Valley is flat and sparsely vegetated. The valley slopes are largely covered with a thin veneer of glacial till and colluvium. The valley is infilled primarily with glacio-fluvial outwash, which is overlain with small quantities of recent alluvium.

The geotechnical drill hole logs for holes in the vicinity of the tailings impoundment (Golder Brawner, 1971) indicate that the soils underlying the tailings impoundment and overlying the bedrock consist of compact to dense sand and gravel with occasional traces of silt. The drill holes penetrated natural ground to a maximum depth of about 15 m. Some pockets of firm silt and clay were encountered at depths greater than about 12 m below ground surface. Recent drilling for the monitoring well and water supply well confirms these conditions to a depth of 30 m.

3.3 Climate and Hydrology

The climate at the site is typical of the semi-arid Interior Plateau Region. A review of the hydrology of the Craigmont minesite was carried out by studying published hydrologic and meteorologic information for the area.

Three Atmospheric Environment Services (AES) Climate Stations are operated near the minesite as summarized in Table 3.1.

Table 3.1 - Atmospheric Environment Services Climate Stations

NO.	NAME	ELEV. (m)	PERIOD OF RECORD
1125075	Merritt Craigmont Mines	732	1962-1972, 1972-1976
1125070	Merritt	591	1918-1952, 1962-1966
1125079	Merritt STP	588	1968-present

Climate normals calculated by AES for the Merritt Craigmont Mines gauge show average daily temperatures between -7.5°C in January and 17.5°C in July, with an annual mean of 6°C. Total precipitation at the site averages 330 mm per year of which approximately 60% falls as rain and 40% as snow. Measurable precipitation occurs on an average of 89 days per year.

The minesite area drains into Stumbles Creek, which in turn flows into the Nicola River. The catchment area for Stumbles Creek upstream of the mine is about 44 km^2. Stumbles Creek originates as the confluence of several small streams which have their headwaters in the Promontory Hills to the west of the mine. The area contains several swampy areas but no significant lake.

A preliminary estimate of streamflow at the minesite was obtained from a regional flood frequency study prepared in 1985 for the Ministry of Transportation and Highways for the Clapperton Creek to Kamloops area. The area is north of the minesite, and the focus of the study was to determine peak streamflows for highway crossings, but the results were extrapolated to provide a preliminary estimate of flows at the site. Table 3.2 summarizes the estimated peak daily discharges for the 44-km^2 basin for four return periods.

Table 3.2 - Stream Flow Estimates - Stumbles Creek

RETURN PERIOD (Years)	PEAK DAILY DISCHARGE(1) (m^3/s)
Mean Annual	1.3
10	2.8
50	3.5
100	4.0
200	4.4

(1) Estimates based on 1985 MOTH study.

4. MARCH 1993 FIELD PROGRAM

4.1 Monitoring Well

A two-inch (50 mm) diameter monitoring well was installed close to the downstream toe of the starter dyke alignment (see Drawing B-5002). A six-inch (150 mm) hole was drilled and cased to 15.2 m with a Cyclone air rotary drill rig. Samples were collected from the drill return every 5 ft. The casing was pulled back to 9.1 m, and 3.0 m of 10-slot PVC well screen were installed from 9.1 m to 6.1 m. This depth was selected so that exfiltration from the new tailings impoundment would be intercepted. The monitoring well was installed to intercept the seepage from the new tailings impoundment and may not be deep enough to intercept the most concentrated seepage from the existing tailings area, particularly when the new impoundment is holding water.

The annular space around the screen was backfilled with silica sand to form a filter and stabilize the formation. Bentonite chips and cement were placed above the silica sand to seal the monitoring zone. The casing was pulled back concurrently with backfilling to a depth of 3.3 m. The drill hole log, backfill record and completion detail are included in Appendix I.

After the monitoring well was installed, the filter pack was developed with surging, jetting and pumping tools to remove the fines and stabilize the filter pack. The well was also response tested. The results of the well development and response test are included in Appendix I.

One water sample was collected from the well in March 1993 and another in May 1993. An equipment blank was also analyzed. The quality control forms for the water samples and the water sample results are included in Appendix II. The water sample from the monitoring well was analyzed for:

- physical parameters;

- dissolved anions;
- nutrients;
- total metals; and
- dissolved metals.

Temperature, conductivity and pH were measured in the field at the time of sampling and the results are included in Appendix II. An equipment blank and a sample of the distilled water that was used for decontaminating the equipment were also analyzed. The water sample testing results are discussed in Section 5.

4.2 Water Supply Well

An 8-inch (200 mm) diameter hole was drilled and cased to 29.9 m with a Cyclone air rotary drill rig. A 3.0 m length of 120-slot (0.120 inch/3.0 mm slot width), telescoping, stainless steel screen was installed with a K-packer from 29.9 m to 26.8 m. The casing was pulled back to a depth of 26.2 m. The drill hole log and well completion details are included in Appendix I.

The well was developed by air-lifting water out of the well with the drill rig's air compressor. The well was developed for a total of six hours, part of the time with the air outlet below the top of the screen and part of the time with the air outlet at a depth of 18.3 m. Most of the sand flushed from the well was collected in a 45-gallon (200 ℓ) drum during development and sand volumes were monitored. The sand return at the end of development was about one cup per 200 US gallons.

A three-step pumping test was conducted at rates of about 100 USgpm (23 m^3/h), 400 USgpm (91 m^3/h) and 550 USgpm (125 m^3/h). The test duration for each step ranged from about one hour to two hours. The well was allowed to recover between each step. Water levels were recorded in the water supply well during drawdown and recovery with a water level meter. Flows were monitored with a flow meter at the well head and an orifice meter at the end of the discharge hose.

One water sample was collected from the well after the pumping test was complete. The water sample results are included in Appendix II and discussed in Section 5. As with the monitoring well, the water sample from the pumping well was analyzed for:

- physical parameters;
- dissolved anions;
- nutrients;
- total metals; and
- dissolved metals.

Temperature, conductivity and pH were measured in the field at the time of sampling and the results are included in Appendix II.

5. RESULTS

5.1 Water Chemistry

As discussed in Section 4, water samples were collected shortly after well installation in March 1993 and analyzed for physical parameters, major ions, nutrients and heavy metals. The monitoring well only was sampled in May 1993. Both wells were sampled in July 1993 but the results are not available for this report. The heavy metals analysis for the first round was by the relatively inexpensive inductively coupled plasma (ICP) method, which is appropriate for a first analysis. The advantage of the ICP method is that a complete suite of metals can be analyzed quickly and inexpensively. However, the ICP detection limits for a few of the heavy metals are higher than the Canadian Drinking Water Quality Guidelines. These heavy metals were analyzed by more sensitive methods for the second sampling round.

Results of the analyses are included in Appendix II. The water analysis results show that none of the individual constituents exceeds the Canadian Drinking Water Guidelines. However, the total dissolved solids (about 900 mg/ℓ) are significantly over the drinking water guideline of 500 mg/ℓ, which is based primarily on palatability. The high dissolved solids may cause corrosion and the manganese may cause pipe encrustation. The results from subsequent sampling rounds will be useful for further evaluation of water quality.

Sulphate concentrations for the March 1993 sample from both the monitoring well and water supply well are close to 300 mg/ℓ. These sulphate concentrations are significantly above expected background concentrations and are, therefore, indicative of tailings water. However, the metal concentrations are all low indicating that significant heavy metal concentrations have not reached the southern property boundary, except in the unlikely event that the metals are following a flowpath deeper in the aquifer.

Although heavy metals have not been detected in the March 1993 groundwater samples at the southern property boundary, periodic sampling of water from wells downstream of the mine is advisable to document the water quality. An additional four monitoring wells are recommended for monitoring the groundwater quality across the width of the valley, as first recommended in Klohn Leonoff's proposal dated November 28, 1991.

Klohn Leonoff personnel will sample the water supply well and monitoring well in accordance with Klohn Leonoff's groundwater sampling and handling guidelines, which are included as Appendix IV. The samples will be collected monthly for one year unless the data indicate that the sampling frequency can be decreased. A quarterly sampling schedule will probably be established after one year. Frequent sampling prior to impounding the tailings storage area will help to establish the pre-pond groundwater chemistry with reasonable confidence.

5.2 Water Supply

The drawdown and recovery plots are included in Appendix III. These plots indicate that the aquifer transmissivity is about 3×10^{-3} m^2/s. All of the time-drawdown plots flattened within 20 minutes, which could indicate either a recharge boundary or delayed yield from the aquifer. A one-day to three-day constant rate pumping test is required to determine the cause of the flattening with more confidence. Such a pumping test can be conducted after the water supply pump is installed, and could be carried out concurrently with other field work.

Preliminary calculations indicate that the current (no tailings pond) transmission capacity of the aquifer is about 400 USgpm (91 m^3/h) or 1 million m^3 per year. This transmission capacity is based on:

760

- a calculated transmissivity of 3×10^{-3} m^2/s;
- a regional hydraulic gradient equal to the topographic gradient (about 0.02); and

- an aquifer width that is about equal to the valley width (800 m).

The preliminary estimate is based on very little data and could be in error by as much as plus or minus a factor of ten. A constant rate pumping test will increase the confidence in the transmissivity estimate. The confidence in the groundwater gradient estimate could be increased by recording water levels at three locations along the length of the aquifer.

Preliminary calculations also indicate that the natural recharge to the aquifer is in the same order as the transmission capacity. These calculations are based on:

- average annual precipitation of 330 mm/yr;
- catchment of 44 km^2; and
- infiltration of 10%.

760

Given the high permeability of the surficial sands and gravels, the infiltration rate could be as high as 30%. However, the calculated recharge is approximately in balance with the calculated aquifer transmission capacity. Therefore, 400 USgpm (91 m^3/h) is the approximate safe yield for all groundwater users in the valley. Extended pumping in excess of 400 USgpm (91 m^3/h) under natural recharge conditions could lower the water table and reduce the aquifer yield.

During operation of the magnetite recovery project, much of the recharge to the water supply well will likely come from seepage losses from the new tailings impoundment. Therefore, high pumping rates will probably be more sustainable after a pond has been established in the new storage area. Monitoring of pre-pond and pre-pumping groundwater levels are required for evaluation of safe yields after the tailings pond is established.

Periodic water level monitoring in the water supply well during operation will be required to guard against aquifer over-extraction, particularly if the aquifer safe yield is not evaluated. Klohn Leonoff will monitor the groundwater levels concurrently with the monthly groundwater sampling. Periodic monitoring of water levels in wells downstream of the mine may also be advisable to detect any possible impacts of the water supply well operation. Monitoring of water levels in the tailings pond and pumping volumes to the tailings is also recommended to provide correlative data.

A 20 hp to 25 hp pump (requiring 575 V) could provide flows of up to 400 USgpm (91 m^3/h) against 55 m total dynamic head, which would be the approximate total head to the water storage tanks. Even though the aquifer may not be able to sustain this flow rate over an extended period, this size of pump would facilitate a proper constant rate pump test and could be useful for obtaining large volumes of water in a relatively short time. A heated pump shack that allows the pump to be removed for maintenance is required around the well head. High and low limit switches in the well will help prevent aquifer over-extraction, re-start the pump at high water and prevent pump damage. A 1.5-inch (38 mm) diameter PVC drop tube in the water supply well will allow monitoring of the water level in the pumping well. The final details of the pump installation will be determined in consultation with a pump supplier. Two quotes, one from North Central Pump of Prince George and one from Lingo Pumps of Vernon, are included in Appendix III.

Because the weekly pumping volumes will be limited by the available aquifer recharge and the impacts on downstream groundwater users, a constant rate pumping test is warranted. This pumping test can be conducted after the pump is installed, which will minimize the testing costs. An observation well that is installed to a depth of 30 m within 15 m of the well is required for a proper estimate of long term safe yield. The pumping test would last for one day to three days. If more monitoring wells are installed, the pumping test could be conducted concurrently with the well installations.

6. CONCLUSIONS

1. A 29.9 m deep, 8-inch (200 mm) diameter water well was installed with 3.0 m of 120-slot screen at the bottom. The well was sited close to the toe of the new dyke in the centre of the valley.

2. A 9.1 m deep, 2-inch (50 mm) diameter monitoring well was installed close to the downstream toe of the new dyke. Water samples from the monitoring well can be analyzed for potential contamination. The monitoring well will intercept exfiltration from the new tailings impoundment. The monitoring well may not be deep enough to intercept the most concentrated seepage from the existing tailings area, particularly when the new impoundment is holding water.

3. The water well was developed by the air lift method until the sand return in the water totalled less than one cup in about 200 gallons. The water was sand-free during test pumping and will likely remain sand-free during production pumping.

4. The water quality from the water supply well is within the specifications of the Canadian Drinking Water Guidelines except for total dissolved solids. The water quality guideline for total dissolved solids is based on palatability. The manganese in the water, although within the drinking water guideline, may cause pipe encrustation.

5. The pumping test data indicate that the aquifer is very permeable. However, the weekly pumping volume will likely be limited by recharge and consideration of downstream groundwater users. The safe yield from the well will likely be controlled by the quantity of seepage from the new tailings impoundment.

6. The safe yield of the aquifer under natural recharge conditions can be estimated with data from a one day to three day constant rate pumping test. A new observation well would be required to record water levels away from the pumping well.

7. RECOMMENDATIONS

1. Sample the monitoring well according to Klohn Leonoff's Sampling and Handling Guidelines in Appendix IV. The Sampling and Handling Guidelines are designed to make the data quality sufficient for meaningful interpretation.

2. Sample the monitoring well monthly for the next year, unless the data indicate that less frequent sampling is appropriate. These samples will help to establish the groundwater chemistry prior to impoundment of new tailings. A quarterly sampling schedule will probably be established after one year.

3. Monitor the water levels in the monitoring well and the pumping well. Also monitor the water levels in the new tailings pond and record the volumes of water transferred to and removed from the tailings pond.

4. Install a 20 hp requires (575 V) pump in the water supply well, which will produce about 400 USgpm (91 m^3/h). Construct a heated pump house that will allow the pump to be removed from the well for maintenance. Install a 1.5-inch (38 mm) diameter, Schedule 80, flush-threaded PVC drop tube in the water supply well for monitoring water levels.

5. Survey the elevations of wells and the pond staff gauge.

6. Install an additional four monitoring wells, as outlined in Klohn Leonoff's proposal dated November 28, 1991.

KLOHN LEONOFF LTD.

Hugh McCreadie, P.Eng.
Project Hydrogeologist

Steve Ki.

fr Blair Trenholme, P.Eng.
Project Engineer

REFERENCES

Klohn Leonoff Ltd. (September 1991). "Mine Plan".

Golder Brawner Associates (July 1971). "Evaluation of Stability of Tailings Dam", Craigmont Copper Mine.

Task Force on Water Quality Guidelines of the Canadian Council of Ministers of the Environment (April, 1992). "Canadian Drinking Water Quality Guidelines".

APPENDIX I

DRILL HOLE LOGS AND COMPLETION DETAILS

TEST HOLE LOG

STARTED: 21/03/93 **FINISHED:** 21/03/93

DRILLING METHOD: AIR ROTARY w/CASING

GROUND ELEV(m):

COORDINATES(m):

Su - kPa

20 60 100 140 180

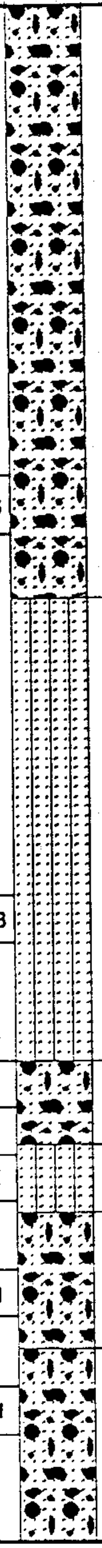
VANE	FIELD	LAB	
PEAK	◆	■	▲ UC/2
REMOLD	◇	□	△ P.PEN/2

● SPT N

Wp% W% WL%

× - - - - ○ - - - - ×

10 30 50 70 90



DEPTH (m)	SPT BLOWS PER 0.15m	OTHER TESTS	SAMPLE TYPE AND NUMBER	SYMBOL	DESCRIPTION OF MATERIALS	PIEZOMETER DETAILS
			GRAB		SAND and GRAVEL - fine to coarse sand - fine gravel - trace to some silt - moist - brown	
7.7			GRAB		SILT and SAND - fine sand - wet - grey	
13.7			RTN		SAND and GRAVEL - coarse sand - fine to coarse gravel - rounded to sub-rounded - trace silt - moist - grey	
14.8			RTN		SILT and SAND - fine sand - wet - grey	
15.7			RTN		SAND and GRAVEL - fine to coarse - trace silt - rounded to sub-angular - moist - grey	
17.5			RTN		SAND and GRAVEL Continued	

PROJECT NO.: PB 5395 05 01

PROJECT: CRAIGMONT GROUNDWATER

LOCATION: MERRITT B.C.

LOGGED BY: HMCC **CHECKED BY:**

SHEET 1 **OF** 2 **HOLE NO.:** WW93-1

FORM: SI01 93/04/12

TEST HOLE LOG

Su - kPa
20 60 100 140 180

	FIELD	LAB	
VANE PEAK	◆	■	▲ UC/2
REMOLD	◇	□	△ P.PEN/2
	● SPT N		

Wp% W% WL%
× - - - - - ○ - - - - - ×
10 30 50 70 90

STARTED: 21/03/93 **FINISHED:** 21/03/93

DRILLING METHOD: AIR ROTARY w/CASING

GROUND ELEV(m):

COORDINATES(m):

DEPTH (m)	SPT BLOWS PER 0.15m	OTHER TESTS	SAMPLE TYPE AND NUMBER	SYMBOL	DESCRIPTION OF MATERIALS	PIEZOMETER DETAILS
					- fine to coarse sand - fine to coarse gravel - rounded to sub-angular - wet - grey	
21						
			RTN			
22						
23						
			RTN			
24						
25						
26						
27						
28						
29						
			RTN			
30						
					30.5	
					END OF TESTHOLE = 30.5 metres	
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						

NOTES:
1. Well completion detail shown separately.
2. Sample type "RTN" is a sample from the drill return.

PROJECT NO.: PB 5395 05 01

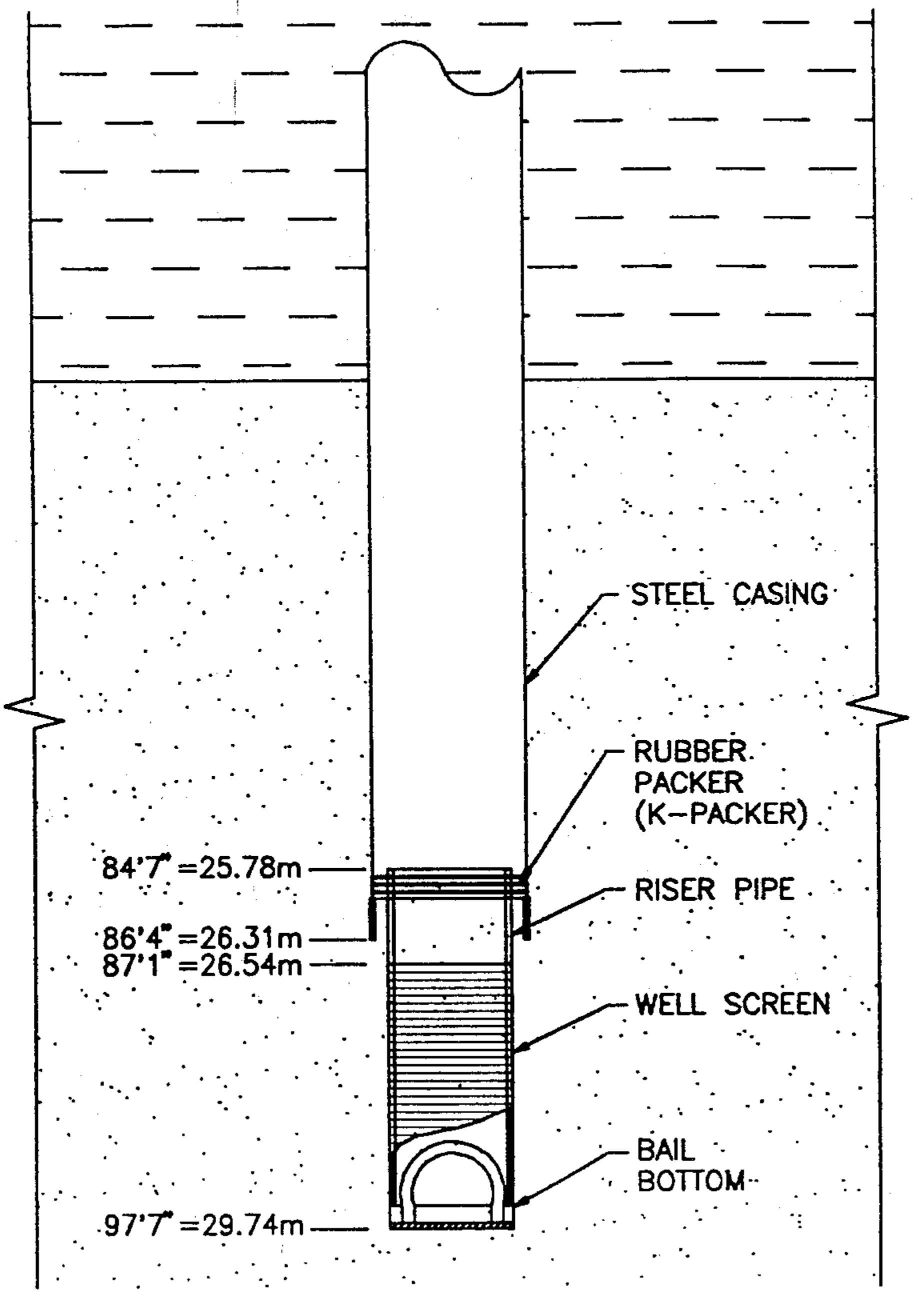
PROJECT: CRAIGMONT GROUNDWATER

LOCATION: MERRITT B.C.

LOGGED BY: HMCC **CHECKED BY:**

SHEET 2 **OF** 2 **HOLE NO.:** WW93-1

FORM: SI01 93/04/12



NOTES:

1. SCREEN I.D. AND K–PACKER RISER I.D. = 6 1/2" = 165mm
2. TOTAL SCREEN LENGTH = 10'6" = 3.20m
3. K–PACKER AND RISER LENGTH = 2'6" = 0.76m

SCALE N.T.S.

KLOHN-CRIPPEN

PROJECT GROUNDWATER SUPPLY AND MONITORING

TITLE WATER SUPPLY WELL DETAIL (WW93–1)

CLIENT: CRAIGMONT MINES

DATE OF ISSUE July 30/93

APPROVED HMcC

PROJECT No. PB5395 05

DWG. No. FIG. 1

REV.

DRILLING NOTES

Mar 21/93

Drillers set up and advanced casing to 20'. They reported that they just got into the water table, formation was fine

Mar 22/93

20-40 Driller reported that "clay stringers" were plugging his bit from time to time. Only had to hammer the casing a bit to get it to 30 ft, then it fell under its own weight. The Driller hooked up a choker

1st pipe 22'11" (incl. shoe)
2nd pipe 19'8" 42'7"
3rd pipe 18'9" 61'4"

40-60 Some water and grey "slop" came out when air turned on @ 40' (after welding). Had to work the hammer more from 40 to 50, especially 45 to 50. Had to work casing hammer 50 to 55. Bit was grinding, chattering. Started to get some water return from 55 to 60, samples cleaned up

4th pipe 19'0" 80'4"

60-80 Paused at 66' and blew water, driller figures ~100 gpm, I figured ~10 gpm. Lots of "gravel" (coarse) laying in the pile of drill cuttings. After 75', the return water was sometimes brown, sometimes grey. Driller said "There's fine layers." Sat at 80 ft & blew for about 5 minutes... driller estimated about 200-300 gpm. The water cleared up quickly

5th pipe 18'8" 99'0"

Nor-West 534-4108 Dave

80-100 Impressive burst of water when he restarted. Casing only moving millimetres per blow now. Water cleaned up quickly, as usual at 100'

→ 1:30 left drillers to do sieves.

KLOHN LEONOFF

PROJ. NO. 93 5315 0501 ENG. [illegible]
PROJECT CRAIGMONT GROUNDWATER
LOCATION MERRITT, BC
DRILL HOLE NW93-1
DATE MAR 21/93 SHEET 1 OF 3

DRILLING NOTES

Start developing 11:00 → water clear within 5 min.

"Eyeball" flow rate ~ [illegible]00 gpm

Rods only, positioned at 6" off the bottom

air compressor 600 cfm/250 psi

11:20 - 11:40 3 handfuls of sand (water directed into sawed-off barrel → 30 gal).

11:40 - 12:00 1½ handfuls of sand

12:10 Yield suddenly decreased to ~100 gpm and turned dirty brown. The water turned clean again in ~20 minutes but yield only ~150 ~ 200 gpm now ... no longer coming out of the head

1:15 <½ handful of sand, although not quite as much water was going into the barrel

1:15 - 4:00 surged the well a few times, both in the lower screen and upper screen. The water would turn muddy brown (2 gallons was opaque in a 5 gallon pail) ... but would clean up fairly quickly. The last surge cleared up within 5 minutes.

4:05 Drillers pulled rods & discovered that they had come unthreaded at 60' ∴ rethreaded the rods and blew the well for another hour

5:30 → WL @ 6.0 m below top of casing
stickup = 32" = 2'8"

LEONOFF

PROJ. NO. PB 5395 05 ENG. HMcC
PROJECT CRAIGMONT
LOCATION
DRILL HOLE WW93-1
DATE MAR 23/93 SHEET 2 OF 3

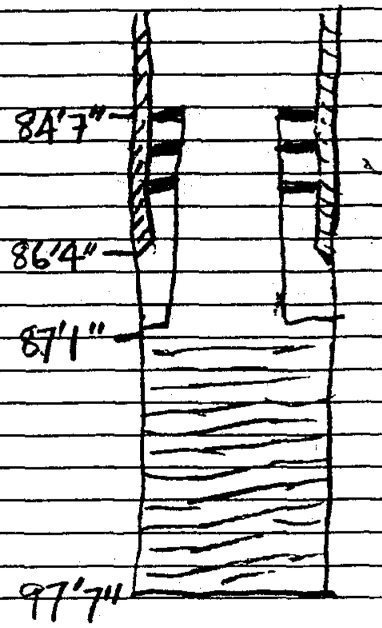
DRILLING NOTES

Screen Installation

checked total depth inside casing → within 1" of total casing length

Total screen length 10'6"
K-packer and riser 2'6"
13'0"

Pulled casing 11'0"



Screen ID and K-packer riser I.D. = 6 1/2"

KLOHN LEONOFF

PROJ. NO. PB5395 05 ENG. HMcC
PROJECT CRAIGMONT GROUNDWATER
LOCATION MERRITT, BC
DRILL HOLE WW93-1
DATE MAR 23/93 SHEET 3 OF 3

GRAIN SIZE ANALYSIS

SIEVE NO.	OPENING SIZE (inches)	TOTAL WT. RETAINED INCLUDING PAN	PAN	SAMPLE ONLY	% RETAINED	% PASSING
	3					
	1½					
	3/4					100
	3/8 .375	152	100	52	13	87
4	0.187	214	↓	114	28	72
10	0.0787	287		187	46	54
16	0.0469	338		238	59	41
30	0.0234	413		313	77	23
35	0.0197					
40	0.0165					
60	0.0098					
100	0.0059					
200						
PAN		505		405	100	0

SAMPLE DEPTH 91 ft
MASS: BEFORE SPLIT ~ 3 kg
AFTER SPLIT 405 gm

KLOHN LEONOFF

PROJECT	CRAIGMONT	NO.	
DETAILS	GROUNDWATER INVESTIGATION		
ENG.	HMcC	CHK.	
DATE	MAR 22/93	SHEET	1 OF 1

GRAIN SIZE ANALYSIS

SIEVE NO.	OPENING SIZE (inches)	TOTAL WT. RETAINED g			% RETAINED	% PASSING
		INCLUDING PAN	PAN	SAMPLE ONLY		
	3					
	1½					
	3/4 (.75)			0		100
	3/8 (.375)	177	100	77	24	76
4	0.187	219	100	119	36	64
10	0.0787	286	100	186	57	43
16	0.0469	394	100	294	90	10
30	0.0234	427	100	327	100	0
35	0.0197					
40	0.0165					
60	0.0098					
100	0.0059					
200						

SAMPLE DEPTH 95 ft

MASS: BEFORE SPLIT ~3 kg

AFTER SPLIT

KLOHN LEONOFF

PROJECT CRAIGMONT	NO.
DETAILS GROUNDWATER INVESTIGATION	
ENG. HMcL	CHK.
DATE MAR 22/93	SHEET 1 OF 1

KL-METRIC

G25 - REV SEPT. '92

GRAIN SIZE ANALYSIS

SIEVE NO.	OPENING SIZE (inches)	TOTAL WT. RETAINED (g) INCLUDING PAN	PAN	SAMPLE ONLY	% RETAINED	% PASSING
	3					
	1½					
	¾	0	170			100
	⅜ (.375	178	170	8	2	98
4	0.187	343		173	49	51
10	0.0787	511		341	96	4
16	0.0469	524		354	100	0
30	0.0234					
35	0.0197					
40	0.0165					
60	0.0098					
100	0.0059					
200						
TOTAL						

SAMPLE DEPTH 97 ft
MASS: BEFORE SPLIT ~ 3 kg
AFTER SPLIT 354 g

KLOHN LEONOFF

PROJECT	CRAIGMONT	NO.	PB 5395 0501
DETAILS	GROUNDWATER INVESTIGATION		
ENG.	LMcL	CHK.	
DATE	MAR 22/93	SHEET	1 OF

NOR-WEST WATER WELL DRILLING LTD.

P.O. Box 3446
Langley 534-4108

23191 Fraser Highway, Langley
Evenings: Langley 534-4222

WELL LOG

OWNER CRAIGMONT MINES LTD. C/O KLOHN LEONOFF LTD.

ADDRESS 10200 SHELLBRIDGE WAY
RICHMOND, B. C. V6X 2W7

LOCATION CRAIGMONT MINES LTD
LOWER NICOLA, B.C.

MARCH 24th, 19 93

Date Begun	MARCH 21/93	Completed	MARCH 23/93
Yield	(estimated) 100 +	Gallons per minute	
Static Water Level	20	feet from surface	
Pumping Water Level	85	feet from surface	
Casing Used	98FT 10 INCHES OF 8 INCH		
Bottom of Casing	96FT 4 INCHES	feet from surface	
Stick-up above ground	2FT 5 INCHES	feet	
Screen Used	2 - #120 SLOT STAINLESS STEEL SCREENS C/W 2FT RISER PIPE		
Top of Screen	97FT 1 IN	feet from surface	
Bottom of Screen	97FT 7 IN	feet from surface	
Sources of Water	g.p.m. at	feet	
Sources of Water	g.p.m. at	feet	
Sources of Water	g.p.m. at	feet	
Sources of Water	g.p.m. at	feet	
Rig No.	A/R #1		
Driller	C.V. WALSH & T. OSTER		

RECOMMENDED PUMP SET AT .... FT. RATE .... G.P.M.

NOTE: "THIS WELL SHOULD BE PUMP TESTED TO ESTABLISH AN ACCURATE YIELD."

Depth	Material
0	SAND AND GRAVEL
18	WET SILT AND FINE SAND
24	
	WET SILTY SAND AND GRAVE
	WET SILTY SAND AND GRAV
48	WATER BEARING SILTY SAN (GRAVEL LAYERS)
60	TIGHT WATER BEARING SAN AND GRAVEL
66	WATER BEARING GRAVEL
	WATER BEARING GRAVEL
98	

TEST HOLE LOG

STARTED: 22/03/93	FINISHED: 22/03/93
DRILLING METHOD: AIR ROTARY w/CASING	
GROUND ELEV(m):	
COORDINATES(m):	

Su - kPa: 20 60 100 140 180

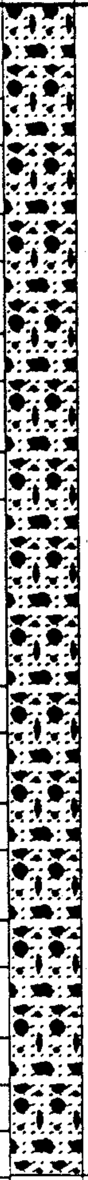
VANE	FIELD	LAB	
PEAK	◆	■	▲ UC/2
REMOLD	◇	□	△ P.PEN/2

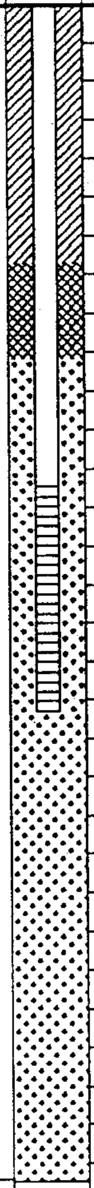
● SPT N

W_P% ×- - - - - - ○ - - - - - -× W_L%
W%

10 30 50 70 90

DEPTH (m)	SPT BLOWS PER 0.15m	OTHER TESTS	SAMPLE TYPE AND NUMBER	SYMBOL	DESCRIPTION OF MATERIALS	PIEZOMETER DETAILS
0 – 15.2			RTN RTN RTN RTN RTN RTN RTN RTN RTN		SAND and GRAVEL - fine to coarse sand - trace fine gravel - rounded to sub-angular - brown to 9 m, increasingly grey to 15 m - moist from 4.5 m on	
15.2					END OF TEST HOLE = 15.2 m	





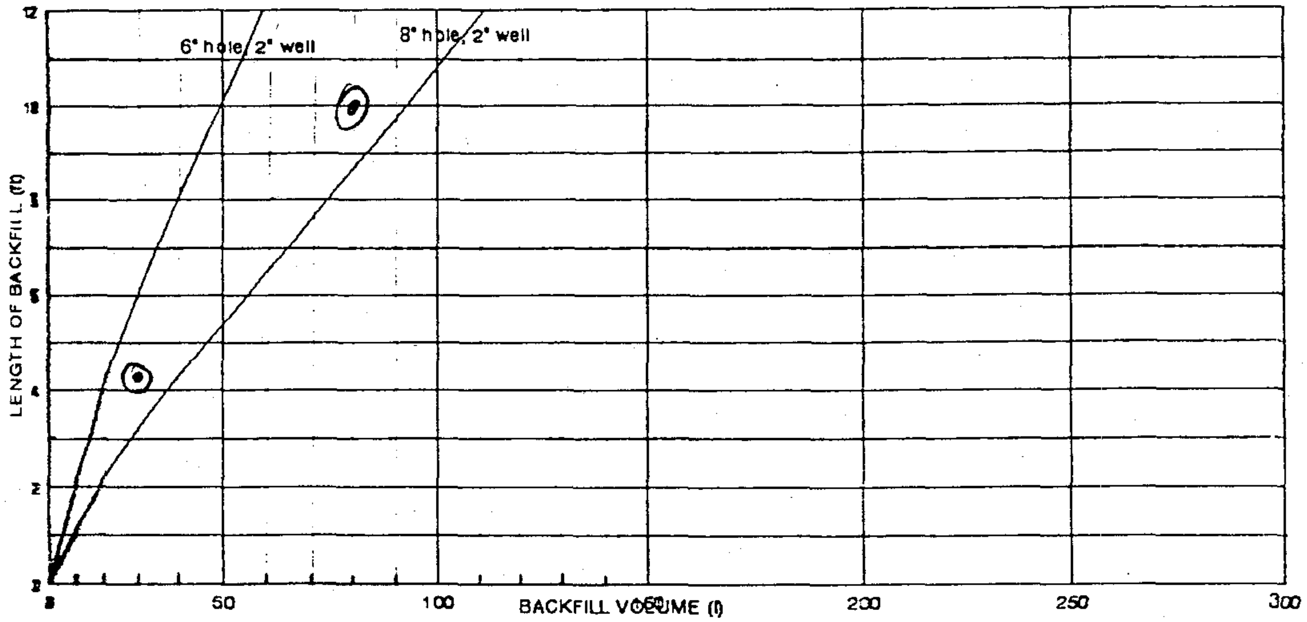
Depth scale: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FORM: SI01 93/04/12

PROJECT NO.: PB 5395 05 01	
PROJECT: CRAIGMONT GROUNDWATER	
LOCATION: MERRITT B.C.	
LOGGED BY: HMCC	CHECKED BY:
SHEET 1 OF 1	HOLE NO.: MW93-1

MONITORING WELL BACKFILL RECORD

BACKFILL MATERIAL AND COMMENTS	VOLUME	LENGTH OF CASING (ft)	DEPTH TO CASING (ft)	DEPTH TO BACKFILL (ft)	LENGTH OF BACKFILL (ft)
SAND - pouring into casing and pull casing)		31'4"	30'	30'	0
PVC stickup = 2'5") at start					
30 l/bag sand (meas'd) ←	100 lb				
0.69 ft³/bag 3/8" chips (stated) ←	50 lb				
SAND	30 l		26'4"	~~25~~ 25'0"	4'2"
"	80 l				10'0"
"	105 l		15		
BENTONITE CHIPS (3/8")					
20 l/bag 3/8" chips (meas'd) ←	50 lb				
BENTONITE	30 l		"	"	4'0"
PVC stickup = 2'5" at end					
BENTONITE → 100 ml →	181	- 103 gm	= 78 gm/100 ml		
GROUT MIX					
In hole: - 3 × 2½ gal water					
- 4 × 50 lb bags Concrete Mix (sand)					
- 3 double handfuls of Quik-Gel					
In pad: - 3 × 50 lb bags Concrete Mix					
- 3 double handfuls Quik Gel					

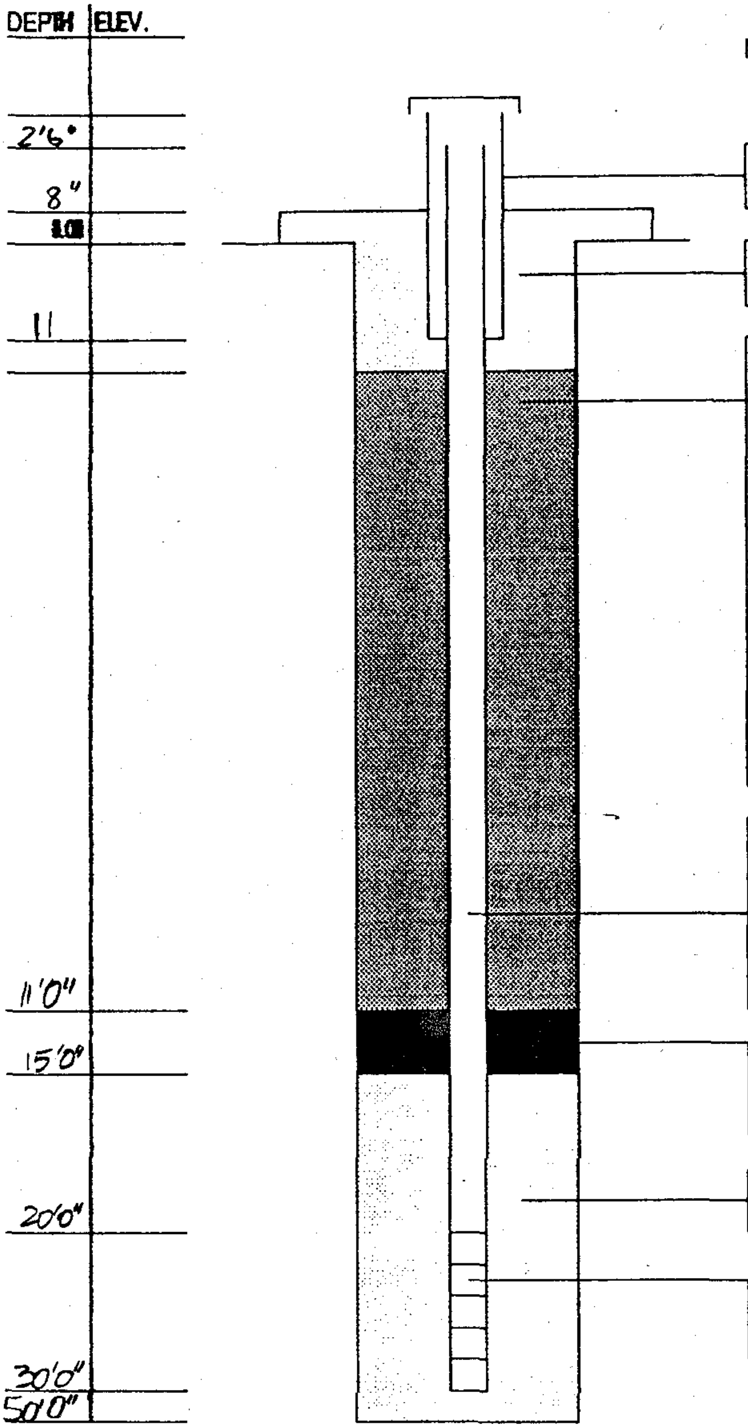


KLOHN LEONOFF

PROJECT NUMBER: PB 5395 05
ENG: HMcC
PROJECT: CRAIGMONT GROUNDWATER
LOCATION: MERRITT, BC
DETAILS: MW 93-1
DATE: MAR 22/93
PAGE 1 OF 1

MONITORING WELL CONSTRUCTION DETAIL

NOT TO SCALE



Protective Casing with Locking Cap and Drain Hole 6" casing

Redi–Mix Cement Pad
2' diamder pad

Cement–Bentonite Grout
~~Placed through tremie~~

Water (UK gal)	Cement (bags)	Bentonite (50 lb bags)	Grout (UK gal)

Comments: Poured into hole (above water table). Ready Mix used instead of pure Type 10.

Schedule 80, Flush–threaded, 2" diameter, PVC Riser Pipe
Total Length: 9'10" + 3×(9'7")
= 38'7" = 37'19"
Cutoff: 6'11"
Length in Ground incl. stickup: 31'8"

Bentonite Chips (gravel–size) (3/8") (35 l)

Silica Sand Backfill
#2/12 LONE STAR (105 l)

20 –slot PVC screen Sched. 80
Machine–Cut Slots, 5' length, cap on the bottom

COMMENTS: 3×9'7" = 27' 21" = 28'9" + 9'10" = 37'19" = 38'7"
Stickup when all pipe in the ground = 8'7"

KLOHN LEONOFF

PROJ. NO. PB 5395 05 ENG. HMcC
PROJECT CRAIGMONT GROUNDWATER
LOCATION MERRITT, BC
DRILL HOLE MW93-1
DATE MAR 22/93 SHEET 1 OF 1

MONITORING WELL DEVELOPMENT RECORD

DEVELOPMENT METHOD;*DEVELOPING TOOL*(see detailed description)
WATER TANK MATERIAL; *NONE USED*
WELL DEVELOPMENT PARAMETERS

	START	FINISH	COMMENTS
TIME	10.16	15.16	
pH	8.5	7.8	
TDS	460	440	
TEMP	10	10	
DEPTH TO WATER	3.7475	3.7475	
FILTRATION TIME	2MINS		START-2 MINS to 100 ML
WATER COLOUR	BROWN	CLEAR	
DEPTH OF WELL	9.60	9.64	

WATER AND SEDIMENT VOLUME RECORD

TIME	VOLUME		DESCRIPTION		COMMENTS
(h:m)	WATER	SED.	COLOUR	GRAIN SIZE	
1 HR	NONE	400ml	BROWN	8000	WELL MAKING 2 GPM
2 HR	USED	150ml	BROWN	8000	SAND & PYRITE
3 HR		150ml	BROWN	5000	SAND & PYRITE
4 HR		0	CLEAR	NIL	WELL MAKING 4 GPM
5 HR		0	CLEAR	NIL	

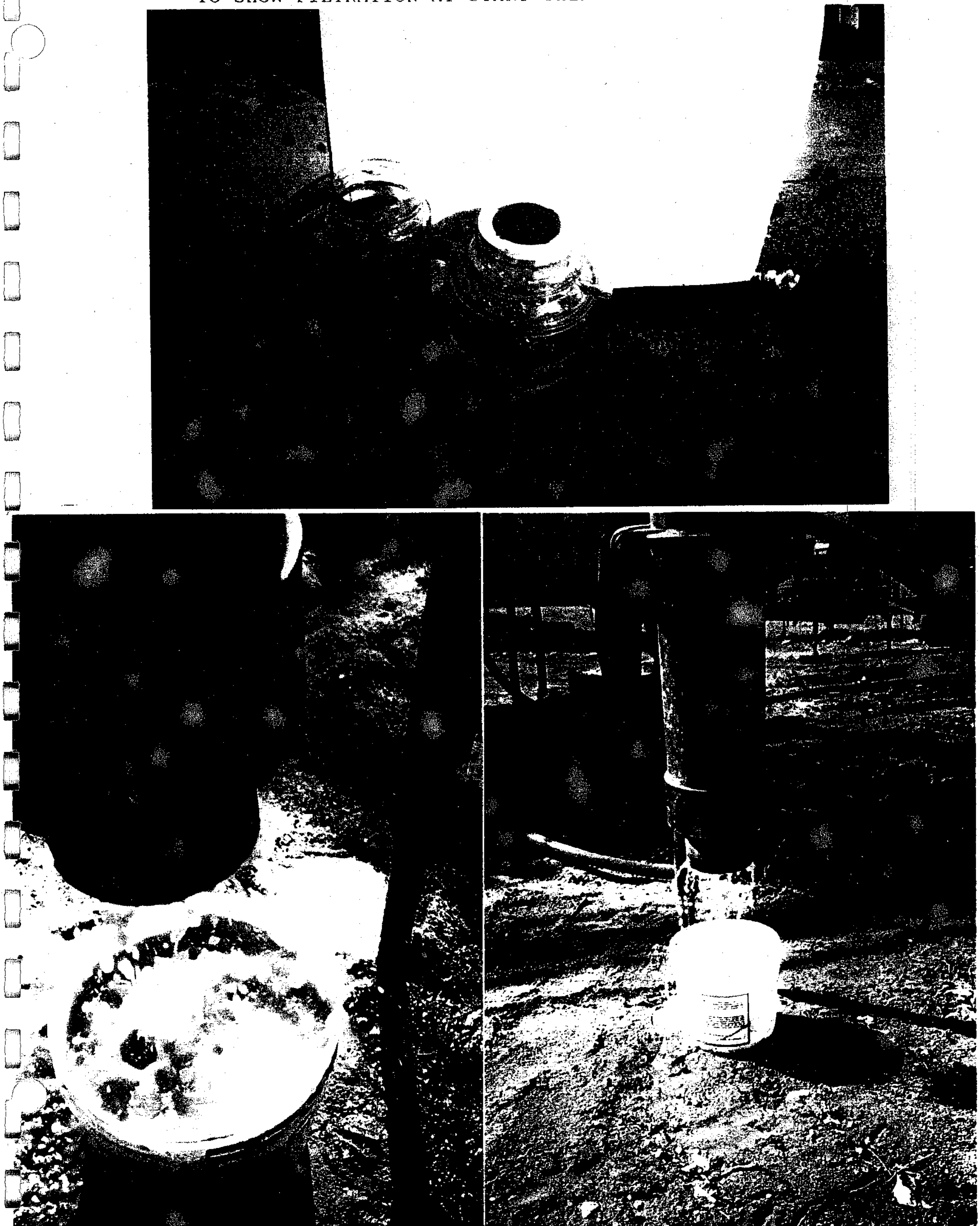
COMMENTS:

PHOTOGRAPHS:See photos of water, sediment and filter residue

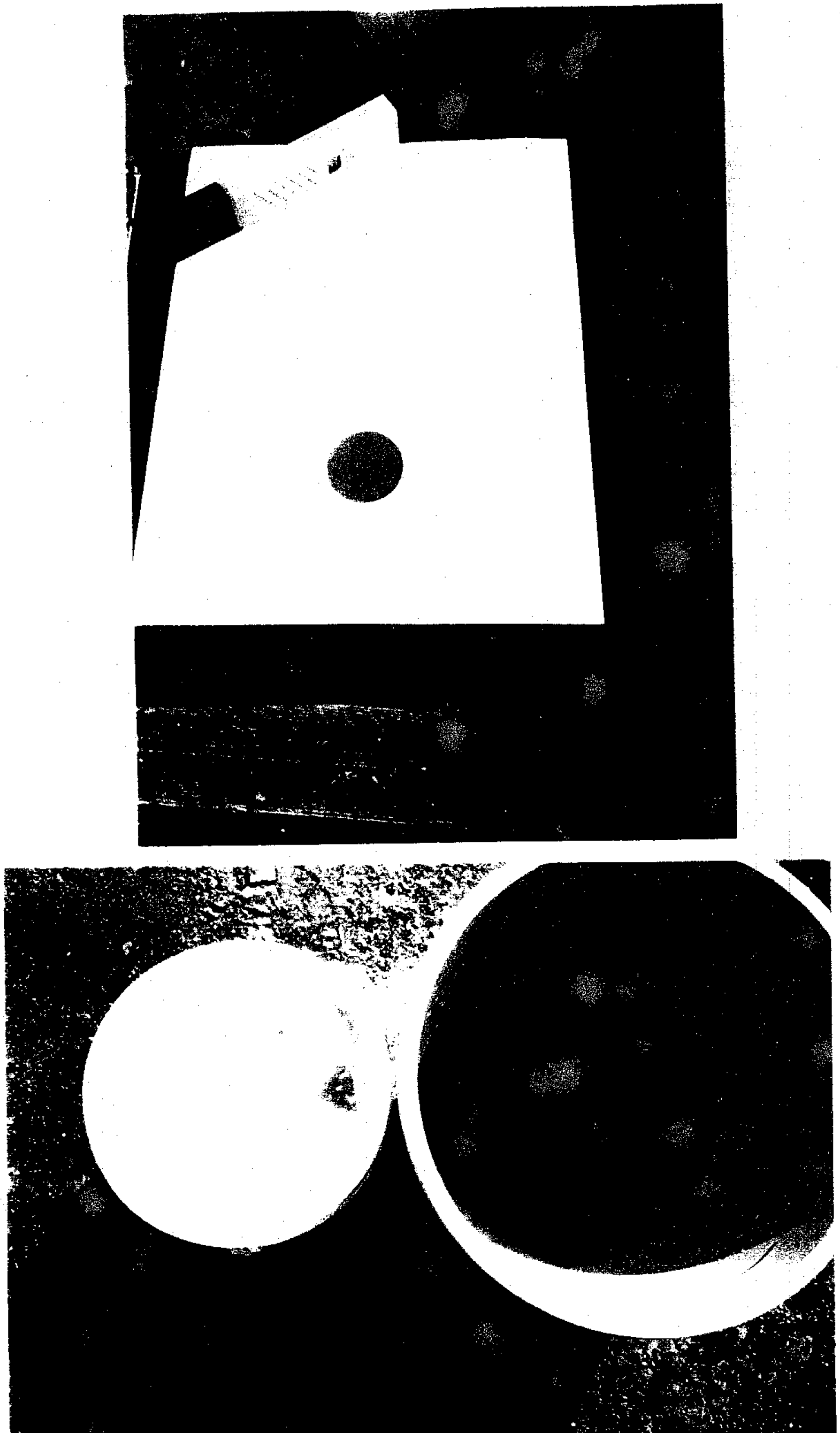
NORTH CENTRAL PUMP LTD.	PROJ.NO.__________ENG.H.McC
	PROJECT: CRAIGMONT MINE
	LOCATION MERRIT
	DRILL HOLE:MONITOR WELL MW93-1
	DATE 26/03/93 SHEET 1 OF 1

CRAIGMONT MINE-26.03.93
TO SHOW RESIDUE WHEN DEVELOPING COMMENCED

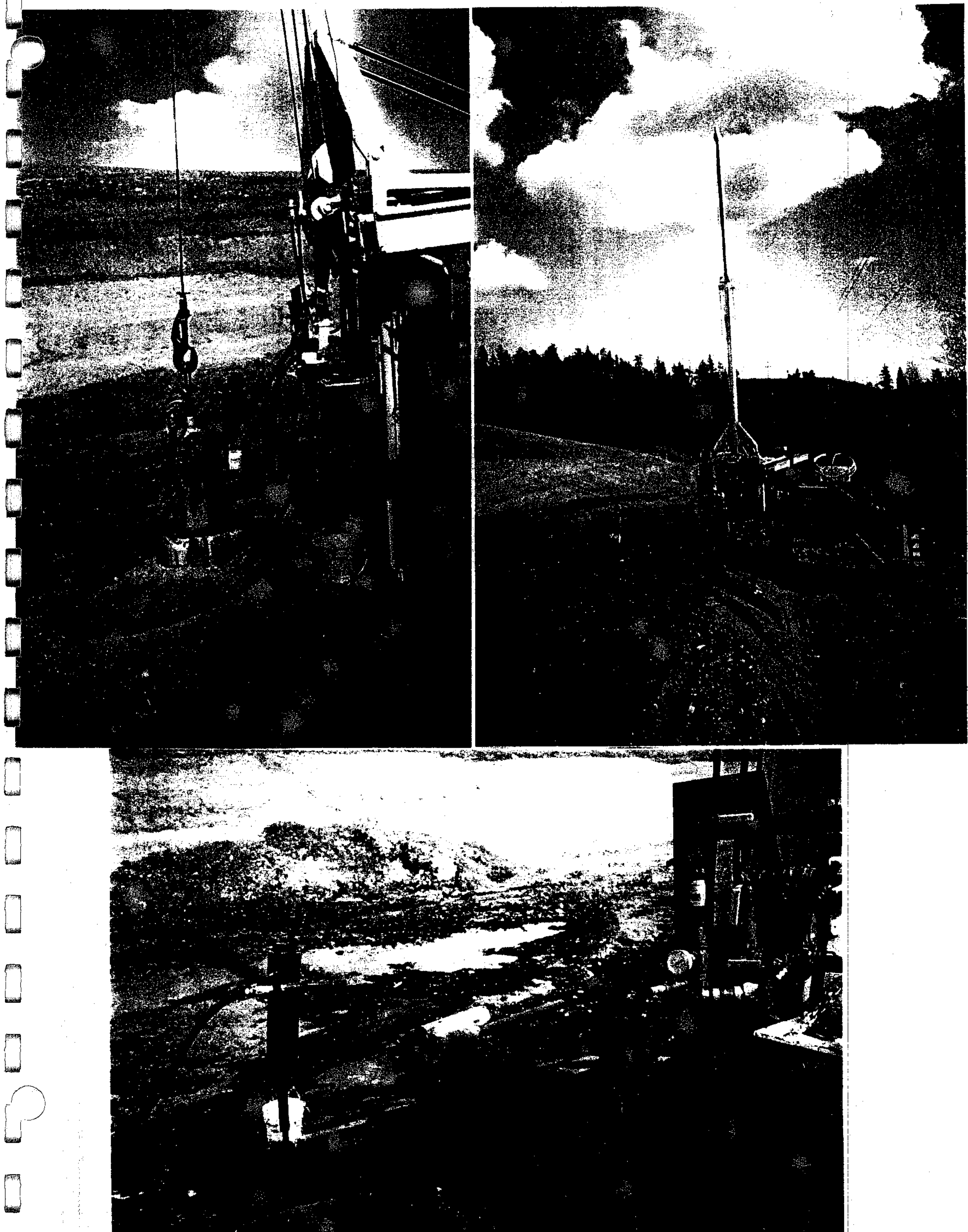
CRAIGMONT MINE-26/03/93
TO SHOW FILTRATION AT START THEN WATER CLEARING



CRAIGMONT MINE-26 03 93
TO SHOW FILTRATION AT END OF DEVELOPING
CLEAR WATER AT END OF DEVELOPING &
DEVELOPED RESIDUE



DEVELOPING METHOD-CRAIGMOUNT MINE
26/03/93 USING "AARDVARK" DEVELOPING TOOL



RESPONSE TEST

[redacted]
[redacted] Distilled water
[redacted]mm)
[redacted] (mm)
[redacted]
[redacted]t Head in 2" well

[redacted]G CONDITION: Good (new)
[redacted]ITION: Good (new)
[redacted]CONDITION: Good (new)

WELL NO.: MW93-1
PROJ. NO.: PB539505
LOCATION: CRAIGMONT
DATE: MAR 26/93
PAGE 1 OF
WELL INNER DIA. (mm): 1 7/8"
PVC STICKUP (mm): 24"
TOTAL DEPTH (m): 9.55+.09=9.64
AIR TEMP.: ~14°C
PROBE SERIAL NO.: Orange
TESTED BY: HMcL

[redacted]AND COMMENTS

[redacted]	TIME OF DAY (h:m:s)	EL. TIME (______)	DEPTH * TO WATER (m)	HEAD DIFF. (m)	% HEAD DIFF.	COMMENTS
Mar26	3:23 PM		3.750			
	3:30					Transducer at bottom
						of well.
	3:40		3.28 mV			
	3:41		3.7475 m			
	3:52		30.51 mV			
	3:53		3.7475 m			
	3:55					Start pouring water
						@ 4l (took ~30s)
	3:57		30.53 mV			
	3:57:30		3.7475 m			
	4:15					Start pouring water
						@ 3l (took 15s)
	4:17		3.7475			

KLOHN LEONOFF

* All depths measured from top of PVC monitoring well riser

APPENDIX II

WATER CHEMISTRY

1988 Triumph Street, Vancouver, B.C., Canada V5L 1K5

analytical
service
laboratories
ltd.

FAX: (604) 253-6700 TEL: (604) 253-4188

CHEMICAL ANALYSIS REPORT

Date:	April 21, 1993
ASL File No.	9664C
Report On:	Water Analysis (PB53950501)
Report To:	**Klohn Leonoff Ltd.** 10200 Shellbridge Way Richmond, BC V6X 2W7
Attention:	**Mr. Hugh McCreadie**
Received:	April 5, 1993

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Barbara Szczachor, B.Sc.
Manager, Water Quality Lab

Brent A. Makelki, B.Sc.
Project Chemist

RESULTS OF ANALYSIS **File No. 9664C**

		8" Well	MW93-1	Equip. Blank	Distilld Water
		93 03 26	93 03 26	93 03 26	93 03 26
Physical Tests					
Colour CU		<5	<5	-	-
Conductivity umhos/cm		963	1000	-	-
Total Dissolved Solids		857	892	-	-
Hardness CaCO3		456	446	-	-
pH		7.75	7.48	-	-
Total Suspended Solids		3	87	-	-
Turbidity NTU		0.31	42.8	-	-
Dissolved Anions					
Alkalinity - Total	CaCO3	269	239	-	-
Chloride Cl		8.4	11.4	-	-
Fluoride F		0.13	0.11	-	-
Sulphate SO4		291	287	<1.0	<1.0
Nutrients					
Ammonia Nitrogen	N	<0.005	0.009	-	-
Nitrate Nitrogen	N	0.565	1.38	-	-
Nitrite Nitrogen	N	<0.001	0.003	-	-

< = Less than the detection limit indicated.
Results are expressed as milligrams per litre except for pH,
Conductivity (umhos/cm), Turbidity (NTU), and Colour (CU).

RESULTS OF ANALYSIS

File No. 9664C

		8" Well 93 03 26	MW93-1 93 03 26	Equip. Blank 93 03 26	Distilld Water 93 03 26
Total Metals					
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.084	0.087	<0.010	<0.010
Beryllium	T-Be	<0.005	<0.005	<0.005	<0.005
Bismuth	T-Bi	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	130	131	0.122	<0.050
Chromium	T-Cr	<0.015	<0.015	<0.015	<0.015
Cobalt	T-Co	<0.015	<0.015	<0.015	<0.015
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	<0.030	0.183	<0.030	<0.030
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.015	<0.015	<0.015	<0.015
Magnesium	T-Mg	32.3	29.1	<0.010	<0.010
Manganese	T-Mn	0.037	0.061	<0.005	<0.005
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.020	<0.020	<0.020	<0.020
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	4.0	4.9	<2.0	<2.0
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20
Silver	T-Ag	<0.015	<0.015	<0.015	<0.015
Sodium	T-Na	46.5	61.0	<2.0	<2.0
Strontium	T-Sr	0.430	0.430	<0.001	<0.001
Thallium	T-Tl	<0.10	<0.10	<0.10	<0.10
Tin	T-Sn	<0.30	<0.30	<0.30	<0.30
Titanium	T-Ti	<0.010	0.012	<0.010	<0.010
Tungsten	T-W	<0.10	<0.10	<0.10	<0.10
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.046	0.061	<0.005	<0.005

< = Less than the detection limit indicated.
Results are expressed as milligrams per litre except for pH,
Conductivity (umhos/cm), Turbidity (NTU), and Colour (CU).

RESULTS OF ANALYSIS **File No. 9664C**

		8" Well	MW93-1	Equip. Blank
		93 03 26	93 03 26	93 03 26
Dissolved Metals				
Aluminum	D-Al	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20
Arsenic	D-As	<0.20	<0.20	<0.20
Barium	D-Ba	0.084	0.087	<0.010
Beryllium	D-Be	<0.005	<0.005	<0.005
Bismuth	D-Bi	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010	<0.010
Calcium	D-Ca	130	131	0.122
Chromium	D-Cr	<0.015	<0.015	<0.015
Cobalt	D-Co	<0.015	<0.015	<0.015
Copper	D-Cu	<0.010	<0.010	<0.010
Iron	D-Fe	<0.030	<0.030	<0.030
Lead	D-Pb	<0.050	<0.050	<0.050
Lithium	D-Li	<0.015	<0.015	<0.015
Magnesium	D-Mg	32.2	29.0	<0.010
Manganese	D-Mn	0.037	0.061	<0.005
Molybdenum	D-Mo	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.020	<0.020	<0.020
Phosphorus	D-P	<0.30	<0.30	<0.30
Potassium	D-K	4.0	4.5	<2.0
Selenium	D-Se	<0.20	<0.20	<0.20
Silver	D-Ag	<0.015	<0.015	<0.015
Sodium	D-Na	45.7	60.0	<2.0
Strontium	D-Sr	0.430	0.430	<0.001
Thallium	D-Tl	<0.10	<0.10	<0.10
Tin	D-Sn	<0.30	<0.30	<0.30
Titanium	D-Ti	<0.010	<0.010	<0.010
Tungsten	D-W	<0.10	<0.10	<0.10
Vanadium	D-V	<0.030	<0.030	<0.030
Zinc	D-Zn	0.030	0.061	<0.005

< = Less than the detection limit indicated.
Results are expressed as milligrams per litre except for pH, Conductivity (umhos/cm), Turbidity (NTU), and Colour (CU).

METHODOLOGY File No. 9664C

Samples were analyzed by methods acceptable to the appropriate regulatory agency. Outlines of the methodologies utilized are as follows:

Conventional Parameters in Water

These analyses are carried out in accordance with procedures described in "Standard Methods for the Examination of Water and Wastewater" 18th Ed. published by the American Public Health Association, 1992. Further details are available on request.

Metals in Water

These analyses are carried out in accordance with procedures described in "Standard Methods for the Examination of Water and Wastewater" 18th Edition published by the American Public Health Association, 1992. The procedures involve a variety of instrumental analyses including atomic emission spectrophotometry (ICP) and atomic absorption spectrophotometry (AA) to obtain the required detection limit for each element. Specific details are available on request.

End of Report

988 Triumph Street, Vancouver, B.C., Canada V5L 1K5

analytical
service
laboratories
ltd.

ASL

FAX: 604-253-6700 TEL: 604-253-4188

CHEMICAL ANALYSIS REPORT

Date:	May 18, 1993
ASL File No.	D1234
Report On:	Water Analysis (PB53950701)
Report To:	**Klohn Leonoff Ltd.** 10200 Shellbridge Way Richmond, BC V6X 2W7
Attention:	**Mr. Hugh McCreadie**
Received:	May 5, 1993

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Frederick Chen, B.Sc.
Project Chemist

Susan Kessler
Susan Kessler
Project Chemist

RESULTS OF ANALYSIS - Water File No. D1234

		MW93-1	Maury Grant	Luke Grant	BK Blank
		93 05 03	93 05 03	93 05 03	93 05 03
Physical Tests					
Colour	CU	<5	6	<5	<5
Conductivity	umhos/cm	1050	970	894	-
Total Dissolved Solids		840	760	701	-
Hardness	CaCO3	456	453	406	-
pH		7.05	7.36	7.07	-
Total Suspended Solids		3	<1	<1	-
Turbidity	NTU	0.15	<0.10	0.47	-
Dissolved Anions					
Alkalinity - Total	CaCO3	288	256	273	-
Chloride	Cl	11.5	9.8	12.3	-
Fluoride	F	0.13	0.12	0.13	-
Sulphate	SO4	271	259	189	<1.0
Nutrients					
Ammonia Nitrogen	N	<0.005	0.007	<0.005	-
Nitrate Nitrogen	N	1.49	0.267	0.044	-
Nitrite Nitrogen	N	0.005	0.009	0.001	-
ortho-Phosphate	P	0.030	0.042	0.067	-
Total Dissolved Phosphate	P	0.030	0.042	0.067	-
Total Phosphorus	P	0.033	0.042	0.070	-

Results are expressed as milligrams per litre except where noted.
< = *Less than the detection limit indicated.*

RESULTS OF ANALYSIS - Water

File No. D1234

		MW93-1	Maury Grant	Luke Grant	Vacuum Blank
		93 05 03	93 05 03	93 05 03	93 05 03
Total Metals					
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	0.0004	0.0005	0.0010	<0.20
Barium	T-Ba	0.104	0.087	0.037	<0.010
Beryllium	T-Be	<0.005	<0.005	<0.005	<0.005
Bismuth	T-Bi	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	0.0003	<0.0002	<0.0002	<0.010
Calcium	T-Ca	136	132	114	0.085
Chromium	T-Cr	<0.015	<0.015	<0.015	<0.015
Cobalt	T-Co	<0.015	<0.015	<0.015	<0.015
Copper	T-Cu	<0.010	<0.010	0.073	<0.010
Iron	T-Fe	<0.030	<0.030	0.067	<0.030
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.015	<0.015	<0.015	<0.015
Magnesium	T-Mg	30.7	30.9	29.8	0.017
Manganese	T-Mn	0.029	<0.005	0.085	<0.005
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.020	<0.020	<0.020	<0.020
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	5.0	5.4	4.9	<2.0
Selenium	T-Se	<0.0005	<0.0005	<0.0005	<0.20
Silver	T-Ag	<0.015	<0.015	<0.015	<0.015
Sodium	T-Na	64.2	46.5	38.8	<2.0
Strontium	T-Sr	0.466	0.440	0.437	<0.001
Thallium	T-Tl	<0.10	<0.10	<0.10	<0.10
Tin	T-Sn	<0.30	<0.30	<0.30	<0.30
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010
Tungsten	T-W	<0.10	<0.10	<0.10	<0.10
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	<0.005	<0.005	0.211	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water **File No. D1234**

		MW93-1 93 05 03	Maury Grant 93 05 03	Luke Grant 93 05 03
Dissolved Metals				
Aluminum	D-Al	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20
Arsenic	D-As	0.0004	0.0005	0.0010
Barium	D-Ba	0.100	0.087	0.037
Beryllium	D-Be	<0.005	<0.005	<0.005
Bismuth	D-Bi	<0.10	<0.10	<0.10
Cadmium	D-Cd	0.0003	<0.0002	<0.0002
Calcium	D-Ca	133	131	114
Chromium	D-Cr	<0.015	<0.015	<0.015
Cobalt	D-Co	<0.015	<0.015	<0.015
Copper	D-Cu	<0.010	<0.010	0.059
Iron	D-Fe	<0.030	<0.030	0.038
Lead	D-Pb	<0.050	<0.050	<0.050
Lithium	D-Li	<0.015	<0.015	<0.015
Magnesium	D-Mg	30.1	30.7	29.8
Manganese	D-Mn	0.025	<0.005	0.078
Molybdenum	D-Mo	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.020	<0.020	<0.020
Phosphorus	D-P	<0.30	<0.30	<0.30
Potassium	D-K	5.0	5.0	4.9
Selenium	D-Se	<0.0005	<0.0005	<0.0005
Silver	D-Ag	<0.015	<0.015	<0.015
Sodium	D-Na	62.7	46.2	38.8
Strontium	D-Sr	0.455	0.433	0.437
Thallium	D-Tl	<0.10	<0.10	<0.10
Tin	D-Sn	<0.30	<0.30	<0.30
Titanium	D-Ti	<0.010	<0.010	<0.010
Tungsten	D-W	<0.10	<0.10	<0.10
Vanadium	D-V	<0.030	<0.030	<0.030
Zinc	D-Zn	<0.005	<0.005	0.208

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water **File No. D1234**

		Distil. Water
Physical Tests		
Colour	CU	<5
Conductivity	umhos/cm	-
Total Dissolved Solids		-
Hardness	CaCO3	-
pH		-
Total Suspended Solids		-
Turbidity	NTU	-
Dissolved Anions		
Alkalinity - Total	CaCO3	-
Chloride	Cl	-
Fluoride	F	-
Sulphate	SO4	<1.0

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water **File No. D1234**

		Distil. Water
<u>Total Metals</u>		
Aluminum	T-Al	<0.20
Antimony	T-Sb	<0.20
Arsenic	T-As	<0.20
Barium	T-Ba	<0.010
Beryllium	T-Be	<0.005
Bismuth	T-Bi	<0.10
Cadmium	T-Cd	<0.010
Calcium	T-Ca	<0.050
Chromium	T-Cr	<0.015
Cobalt	T-Co	<0.015
Copper	T-Cu	<0.010
Iron	T-Fe	<0.030
Lead	T-Pb	<0.050
Lithium	T-Li	<0.015
Magnesium	T-Mg	<0.010
Manganese	T-Mn	<0.005
Molybdenum	T-Mo	<0.030
Nickel	T-Ni	<0.020
Phosphorus	T-P	<0.30
Potassium	T-K	<2.0
Selenium	T-Se	<0.20
Silver	T-Ag	<0.015
Sodium	T-Na	<2.0
Strontium	T-Sr	<0.001
Thallium	T-Tl	<0.10
Tin	T-Sn	<0.30
Titanium	T-Ti	<0.010
Tungsten	T-W	<0.10
Vanadium	T-V	<0.030
Zinc	T-Zn	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

METHODOLOGY File No. D1234

Samples were analyzed by methods acceptable to the appropriate regulatory agency. Outlines of the methodologies utilized are as follows:

Conventional Parameters in Water

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These analyses are carried out in accordance with procedures described in "Standard Methods for the Examination of Water and Wastewater" 18th Edition published by the American Public Health Association, 1992. The procedures involve a variety of instrumental analyses including atomic emission spectrophotometry (ICP) and atomic absorption spectrophotometry (AA) to obtain the required detection limit for each element. Specific details are available on request.

End of Report

WATER SAMPLE QUALITY CONTROL

8" WELL
WELL No.: WW93-1
DATE: MAR 26/93

PURGE RATE: ~550 USgpm
PURGE VOLUME: ~ 8000 gal
PURGE TIME: Start 9:01 AM Finish 9:16 AM
SAMPLING DEVICE: submersible pump
INTAKE DEPTH: 79 ft BGS

DEPTH TO WATER: 6.01 m @ 9:00 AM

DECONTAMINATION PROCEDURES:
The pump and discharge line was disinfected before coming on site. The well was pumped for about 6 hours on Mar 25/93.

FIELD PARAMETERS:

	Time	Value	Meter	Calibration
pH	12:47	7.0	CORNING PS15	7.00±0.01@25°C
T (°C)	12:42	50°F	POCKET THERM.	None
EC (μS)	12:40	970	CORNING PS17	300 μS

Comments
Field parameters measured after sampling (~3½ hrs). The pump will be re-started & field parameters re-measured at the well head later this afternoon.

SAMPLES:

Analysis	Volume	Bottle Type	Preservation	Time of Sample
Diss. Metals	500 ml	Plastic	0.5 ml HNO_3	9:15
Major Ions	1000 ml	"	None	9:13

Comments:
Sampled from port at well directly into bottle wearing latex gloves. Metals filtered & preserved ~ 9:45

KLOHN LEONOFF

PROJECT	CRAIGMONT	NO.	[illegible]
DETAILS	GROUNDWATER SUPPLY AND MONITORING		
ENG.	HM, C	CHK.	
DATE	[illegible]	SHEET	OF

WATER SAMPLE QUALITY CONTROL

WELL No.: MW93-1
DATE: MAR 26/93

PURGE RATE: ~3 l/min
PURGE VOLUME: 28l
PURGE TIME: Start 2:15PM Finish 2:30 PM
SAMPLING DEVICE: Bailer 4 ft long
INTAKE DEPTH:

DEPTH TO WATER: 2.750

DECONTAMINATION PROCEDURES:
Rinsed inside & outside of bailer w/ distilled water.

FIELD PARAMETERS:

	Time	Value	Meter	Calibration
pH	2:51PM	7.3	CORNING PS15	7.00±0.01 @25°C
T (°C)	2:49PM	46°F	Pocket	None
EC (μS)	2:47PM	1030	CORNING PS17	300μS

Comments
North Central Pumps TDS meter → 440

SAMPLES:

Analysis	Volume	Bottle Type	Preservation	Time of Sample
Diss. Metals	500ml	Plastic	.25ml HNO_3	2:40PM
Major Ions	2×500ml		—	3:00PM

Comments:
Filtration in vacuum filtration canister
Equipment Blank taken w/ distilled water.

KLOHN LEONOFF

PROJECT	CRAIGMONT	NO.	PB 5395 05
DETAILS	GROUNDWATER SUPPLY AND MONITORING		
ENG.	HMcC	CHK.	
DATE	MAR 26/93	SHEET	OF

CHAIN OF CUSTODY RECORD

WELL No.: MW93-1
SAMPLE DATE: MAR 26/93

FROM		TO		LOCATION	INITIALS
DATE	TIME	DATE	TIME		
MAR 26/93	3:15			Klohn Leonoff cooler on ice	

KLOHN LEONOFF

PROJECT	CRAIGMONT	NO.	PB 5395 05
DETAILS	GROUNDWATER SUPPLY AND MONITORING		
ENG.	HMcC	CHK.	
DATE	MAR 26/93	SHEET	OF

KL-METRIC

G25 - REV SEPT. '92

CHAIN OF CUSTODY RECORD

WELL No.: WW93-1
SAMPLE DATE: MAR 26/93

FROM		TO		LOCATION	INITIALS
DATE	TIME	DATE	TIME		
Mar 26	9:15	Mar 26	11:15	In North Central Pump's cooler, no ice.	
Mar 26	11:15	Mar 27	~4:00	In Klohn Leonoff's cooler on ice.	
Mar 27	~4:00	Apr 5	8:00AM	In Klohn Leonoff's fridge @ 10200 Shellbridge Way	
Apr 5	8:00AM			In KL's cooler on ice → courier to ASL labs.	

KLOHN LEONOFF

PROJECT CRAIGMONT NO. PB 5395 0501
DETAILS GROUNDWATER SUPPLY + MONITORING
ENG.
CHK.
DATE MAR 26/93
SHEET 1 OF

KL-METRIC

G25 - REV. SEPT. '92

GROUNDWATER SAMPLING RECORD

COMMENTS: 3.805 m = depth
to water before removing
Waterra tubing that was installed in March.
3.805 m = depth to water after removing Waterra

WELL NO.: MW93-1
DATE OF SAMPLING: May 3/93

WEATHER: Overcast, no rain, ~ 5°C

EQUIPMENT DECONTAMINATED AND CHECKED (Y/N):
Sampling Apparatus: Y Water Level Probe: Y Field Parameter Meters: ___

DEPTH TO WATER

Probe:

Item	Time	Reading	Comments
Depth* to Water (m)	3:40PM	3.915	Inside BK pump*
Depth* to Bottom (m)	3:10 PM	9.55	before installing BK pump
Depth to Water	5:15 PM	3.930	Inside BK pump

WELL PURGING

Volume of Standing Water Column $(960-390)\times\pi\times\frac{4.8^2}{4}=10.3\ell$ Purge Volume = 30 ℓ
Pumping Method BK pump
Measuring Device 10 ℓ bucket Well yield (High, Low): High
Purging Record

Intake Depth (m)	Time From	Time To	Volume (ℓ)	Description of Water/Comments
4.53 BTP	4:00	4:02	10	clear, pH=6.7, EC=1000 @ 4:20
"	4:21	4:24	+10 = 20	" , pH=7.6, EC=1050 @ 4:27
"	4:28	4:30		" , pH=7.5, EC=1070 @ 4:31

FIELD PARAMETERS

Parameter	Time	Calibration Standard Stated	Calibration Standard Measured	Groundwater Sample	Comments
Temperature °C	~~3:0~~ 4:34			3.0	all meas'd in
pH	4:31	7.0	6.9	7.5	250 ml beaker
Conductivity μS	4:31	1400	1420	1070	

SAMPLING

Method BK pump

Sample Type	Time	Filtration (Y/N)	Filtration Method	Preservation (Y/N)	Preservation Type	Container Type
Total Metals (T.M.)	4:49	Y	–	Y	HNO_3	plastic
Total Mercury (T.Hg)	–	–	–	–	–	–
Dissolved Metals (D.M.)	4:44	Y	~~HNO_3~~ direct	Y	HNO_3	plastic
Major Anions (M.A.)	4:54	N	–	–	–	plastic

SIGNATURE McCreadie

KLOHN LEONOFF

* All depths measured from top of monitoring well PVC

* Additional stickup from BK = 0.086 m (discharge nozzle removed).
Check: 3.915 − 0.086 = 3.829 ≈ 3.805 m

GROUNDWATER SAMPLING RECORD

COMMENTS: dug well, sampled from garden hose; concrete lining; suction pump

WELL NO.: LUKE GRANT

DATE OF SAMPLING: MAY 3/93

WEATHER: cool, overcast no rain

EQUIPMENT DECONTAMINATED AND CHECKED (Y/N):

Sampling Apparatus: — Water Level Probe: — Field Parameter Meters: Y

DEPTH TO WATER

Probe:

Item	Time	Reading	Comments
Depth* to Water (m)	—	—	—
Depth* to Bottom (m)	—	—	—

WELL PURGING

Volume of Standing Water Column =

Purge Volume =

Pumping Method

Measuring Device 10 l bucket

Well yield (High, Low): High

Purging Record

Intake Depth	Time From	Time To	Volume	Description of Water/Comments
	7:00	7:35	210 gal	10 l or 2 gal/ 20 s = 6 gpm
				EC = 840 pH = 6.9 @ 7:07
				EC = 880 pH = 7.1 @ 7:28

FIELD PARAMETERS

Parameter	Time	Calibration Standard		Groundwater Sample	Comments
		Stated	Measured		
Temperature	7:29	—	—	6.0	—
pH	7:28	7.0	7.0	7.1	buffer 7.1 @ 7:31
Conductivity	7:28	1400	1410	880	standard 1420 @ 7:35

SAMPLING

Method Garden hose

Sample Type	Time	Filtration		Preservation		Container
		(Y/N)	Method	(Y/N)	Type	Type
Total Metals (T.M.)	7:20-7:25	N	—	Y	HNO_3	plastic
Total Mercury (T.Hg)	↓	—	—	—	—	—
Dissolved Metals (D.M.)	↓	Y	vacuum	Y	HNO_3	plastic
Major Anions (M.A.)	↓	N	—	N	—	plastic

SIGNATURE HMcCreadie

KLOHN LEONOFF

* All depths measured from top of monitoring well PVC

GROUNDWATER SAMPLING RECORD

COMMENTS: Dug well, culvert
Suction pump
No sampling port at pump. Sampled at barn.
"Supplies two houses + feed water (cattle)"

WELL NO.: Maury Grant
DATE OF SAMPLING: May 3/93

WEATHER: Overcast, cool, no rain.

EQUIPMENT DECONTAMINATED AND CHECKED (Y/N):
Sampling Apparatus: ____ Water Level Probe: ____ Field Parameter Meters: Y

DEPTH TO WATER

Probe:

Item	Time	Reading	Comments
Depth* to Water (m)	8:20PM	2.0	
Depth* to Bottom (m)			

WELL PURGING

Volume of Standing Water Column = NA **Purge Volume =** NA
Pumping Method suction
Measuring Device 10 l bucket Well yield (High, Low): High
Purging Record

Intake Depth	Time From	Time To	Volume	Description of Water/Comments
	6:10	6:25	90 gal	⑥ ② gal/20s = 6 gpm ≈ 10 l

FIELD PARAMETERS

Parameter	Time	Calibration Standard		Groundwater	Comments
		Stated	Measured	Sample	
Temperature °C	6:40	X	X	5.0	
pH	↓	7.0	7.0	7.2	
Conductivity µS	↓	1400	1410	900	

SAMPLING

Method hose by barn

Sample Type	Time	Filtration		Preservation		Container
		(Y/N)	Method	(Y/N)	Type	Type
Total Metals (T.M.)	625-630	N	—	Y	HNO_3	plastic
Total Mercury (T.Hg)	X	X	X	X	X	X
Dissolved Metals (D.M.)	625-630	Y	vacuum	Y	HNO_3	plastic
Major Anions (M.A.)	625-630	N	—	N	—	plastic

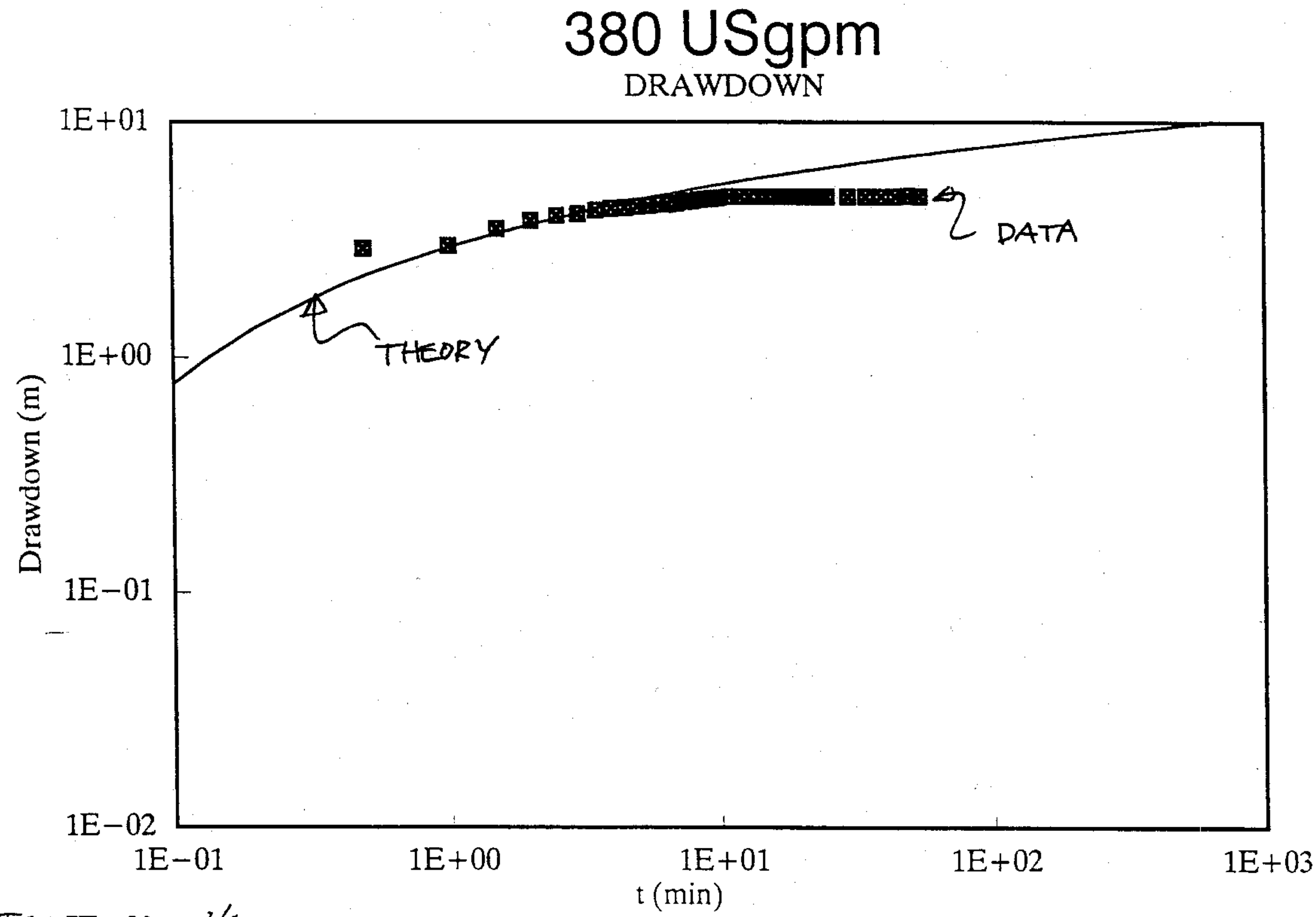
SIGNATURE HMCready.

KLOHN LEONOFF

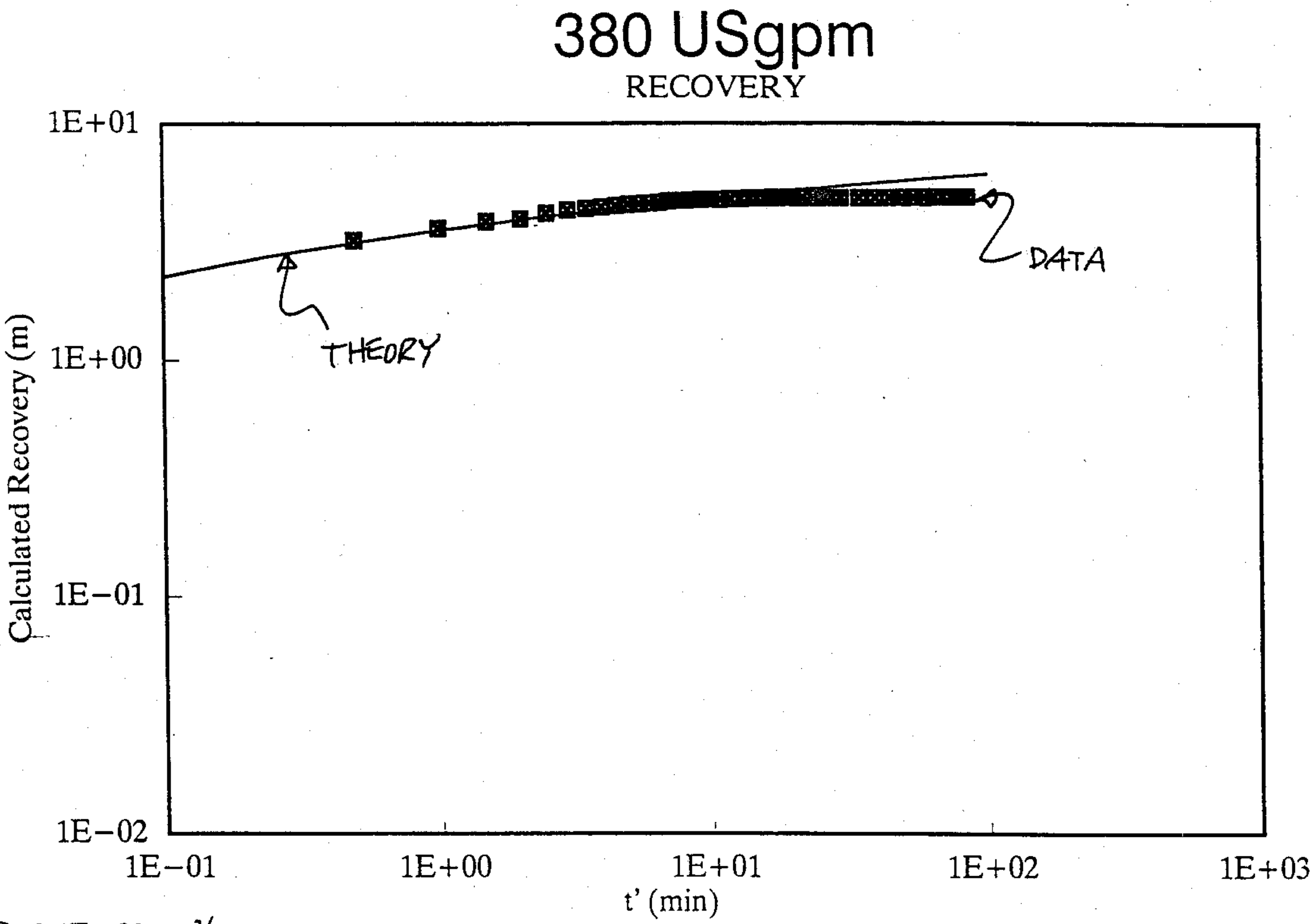
• All depths measured from top of monitoring well PVC

APPENDIX III

PUMPING TEST DATA



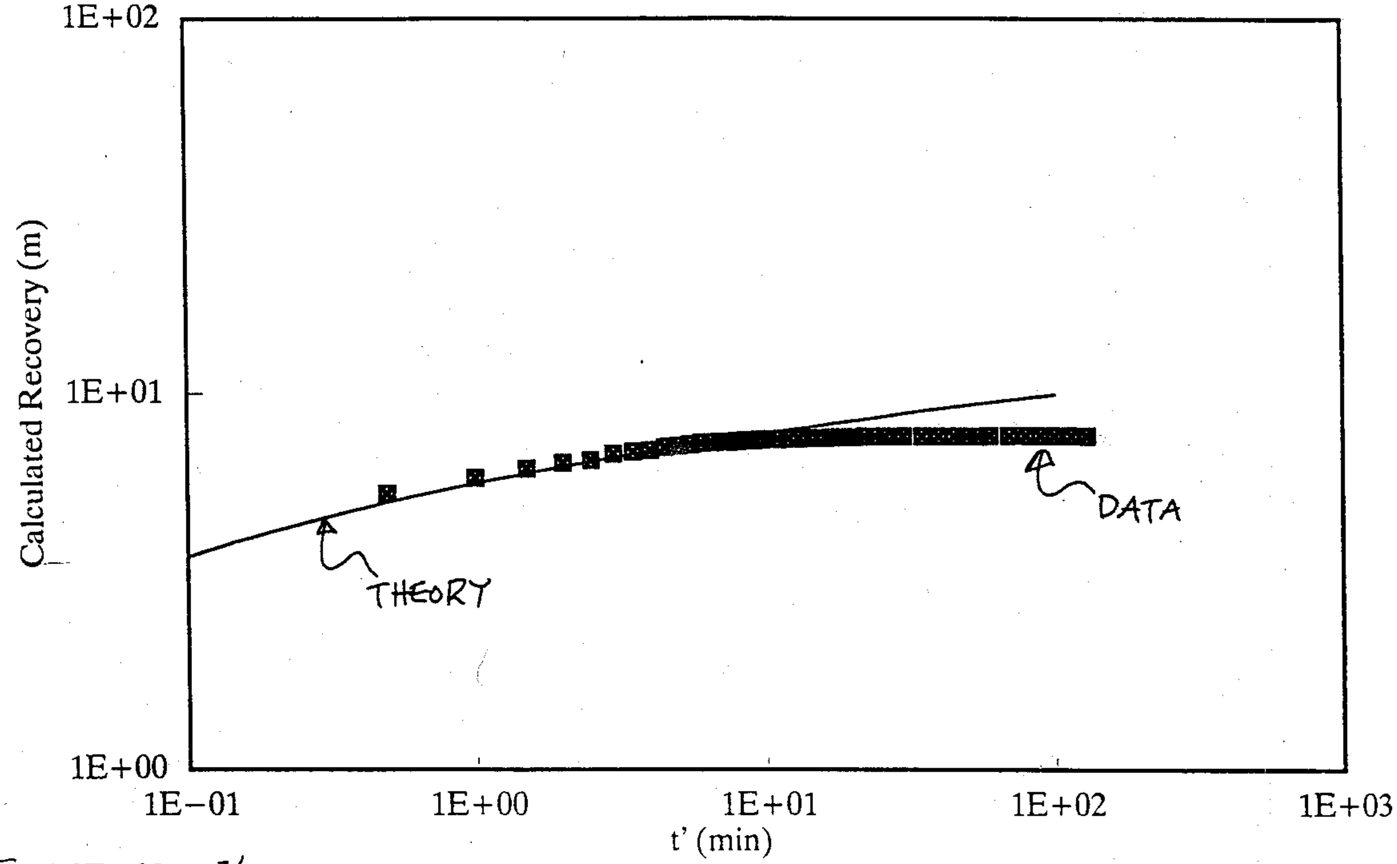
T= 1.7E−03 m^2/s
1.6E+00



T= 3.4E−03 m²/s
7.9E−02

550 USgpm

RECOVERY

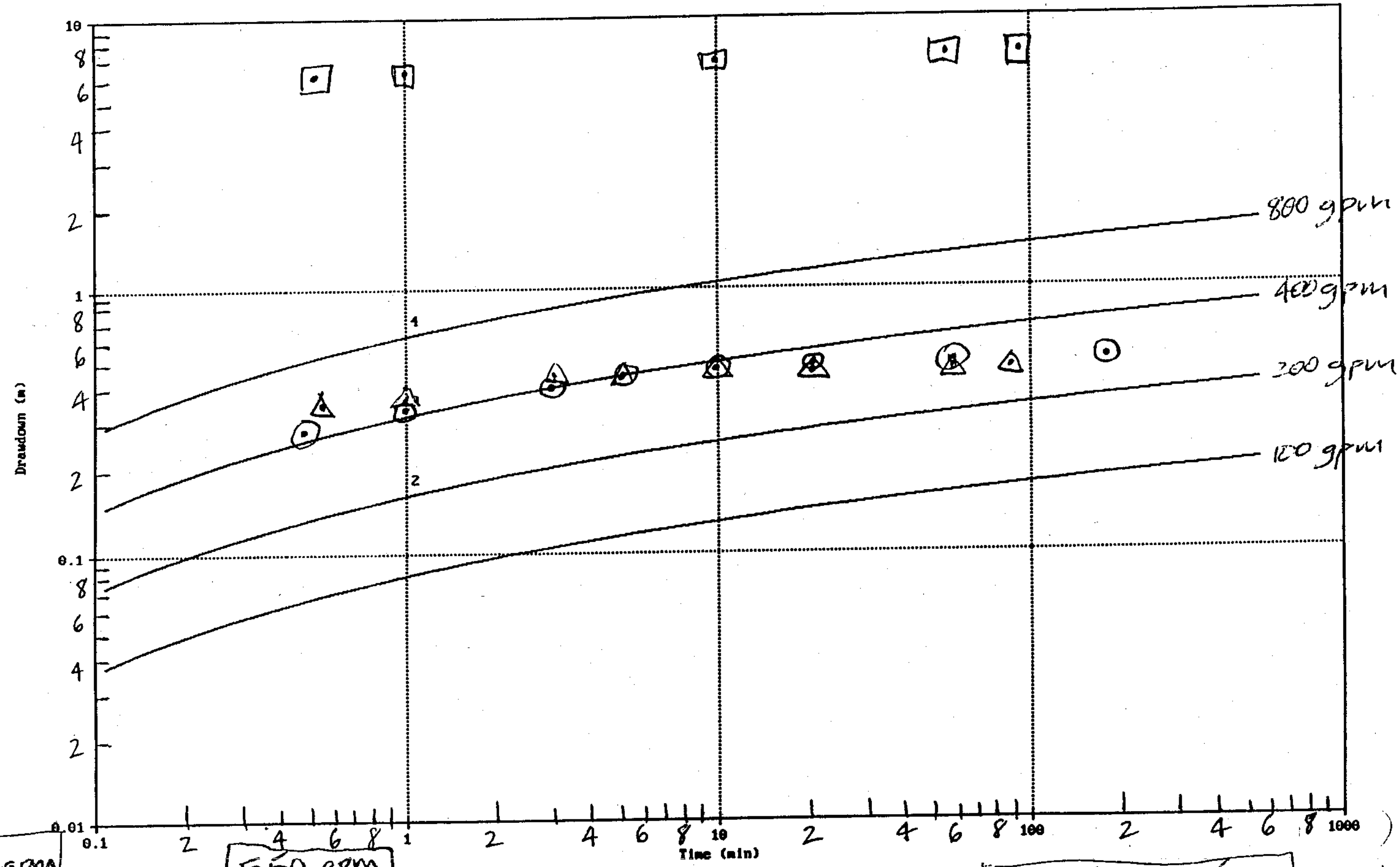


T= 3.0E−03 m²/s
S= 7.1E−02

'RF' NO. ''VE

PUMP TEST

THEIS CURVES



400 gpm
⊙ DRAWDOWN
△ RECOVERY

550 gpm
⊡ DRAWDOWN

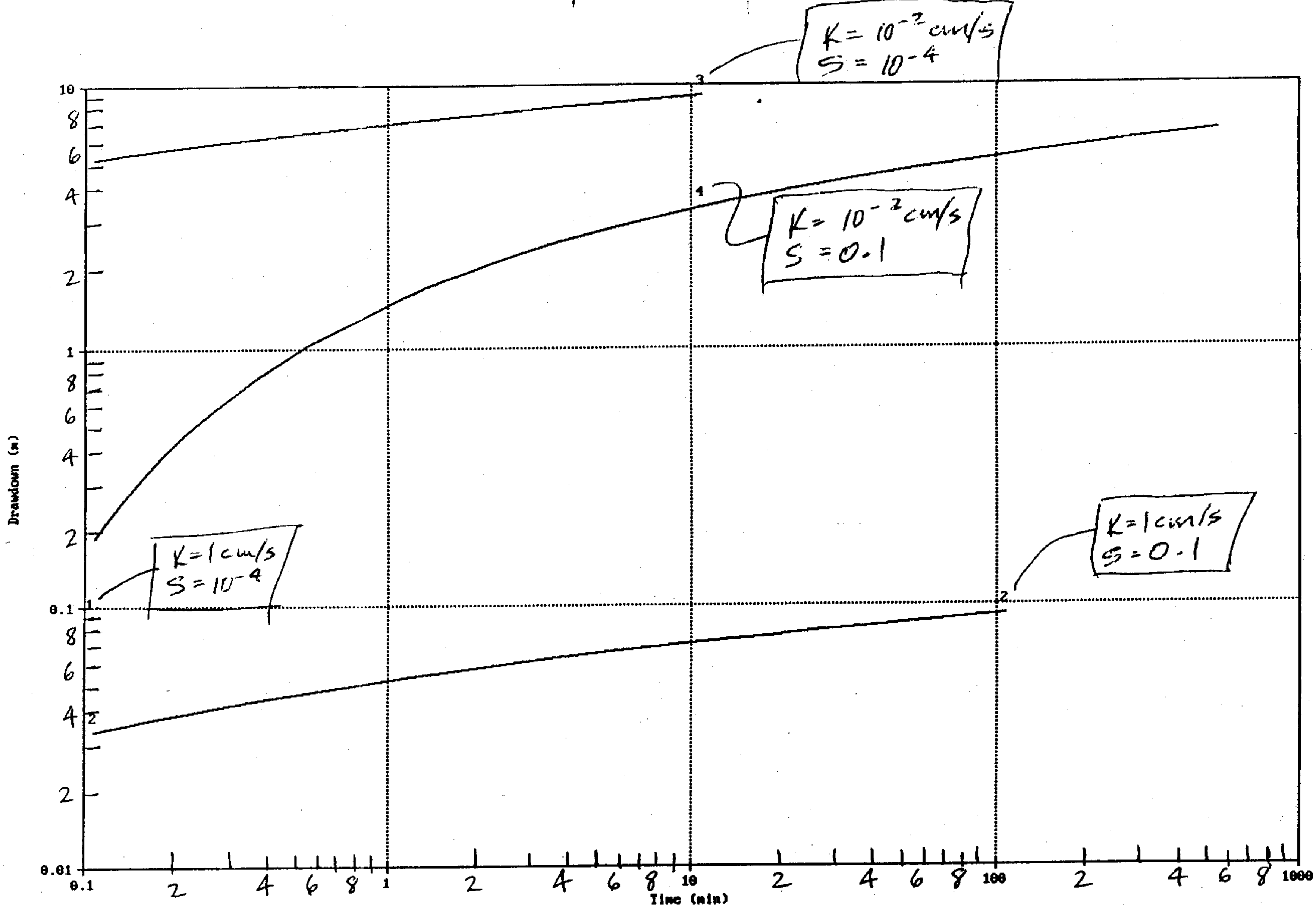
K = 0.1 cm/s
thickness = 24m
r = 4"
S = 0.1

0.001 m/s

0.102 m

THEIS CURVES

[illegible]
PUMP TEST

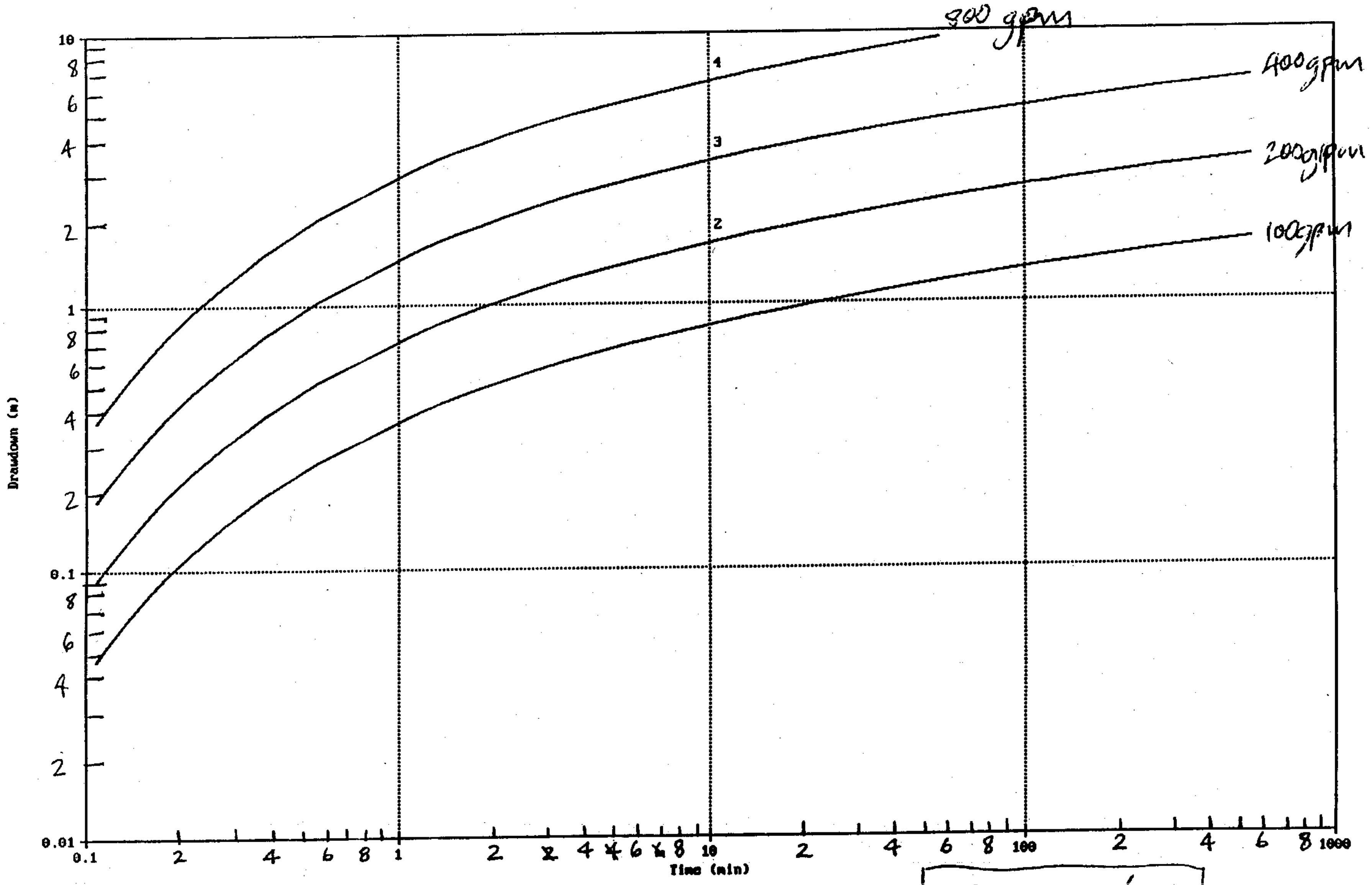


Q = 400 USgpm
r = 4"
thickness = 24 m

[illegible]

THEIS CURVES

PUMP TEST.



K = 0.01 cm/s
thickness = 24 m
S = 0.1
r = 4"

APPENDIX IV

GROUNDWATER SAMPLING AND HANDLING GUIDELINES

TABLE OF CONTENTS

July 28, 1993

1. INTRODUCTION

This document constitutes the groundwater sampling procedures recommended by Klohn Leonoff Ltd. for sampling monitoring wells at the Placer Dome Inc. Campbell Mine for the parameters presently chosen for analysis. The plan presents only general procedures and techniques for sample collection, sample preservation and shipment, field analytical procedures, and chain-of-custody control. In addition, specific procedures, data sheets and management techniques should be developed by the staff members responsible for sampling.

Some common problems noted by U.S. EPA for groundwater sampling are:

- Owners/operators have not prepared sampling and analysis (S&A) plans or do not keep plans on site.
- Plans contain very little information or do not adequately describe the S&A program that the owner/operator is employing at his facility.
- Field sampling personnel are not following the written plan or are not aware that it exists.
- Improper well evacuation techniques are used.
- Sampling equipment is used that may alter chemical constituents in groundwater.
- Sampling techniques are used that may alter chemical composition of samples.
- Facility personnel are not using field blanks, chemical standards, and chemically spiked samples to identify changes in sample quality after collection.
- Field personnel do not properly clean non-dedicated sampling equipment after use.
- Field personnel place sampling equipment (rope, bailer, tubing) on the ground where it can become contaminated prior to use.
- Field personnel do not document their field activities adequately (e.g. keep sampling logs).
- Field personnel are not following proper chain-of-custody procedures.

- Little attention is paid to reporting data errors or anomalies.
- Quality Assurance/Quality Control (QA/QC) protocol is inadequate (field and/or laboratory).

The purpose of these guidelines is to avoid these problems.

2. EQUIPMENT

2.1 Maintenance and Storage

Procedures for handling and storing sampling equipment should be consistent with those for analytical laboratory equipment, since the sampling equipment will be included in the process of analyzing parameters at very low concentrations. For example:

- equipment should be stored in sealed containers in a clean room dedicated to water sampling;
- equipment should be repaired or replaced if it is malfunctioning;
- equipment should be transported to the sampling site in sealed containers; and
- equipment should be cleaned with deionized water between each sample.

2.2 List

Equipment for sampling includes:

- plastic-coated water level probe with incremental depth markings of 0.01 m;
- wash bath of about 10 L size for decontaminating the water level probe;
- disposable surgical latex gloves;
- deionized water;
- well log and monitoring well completion diagram with surveyed reference elevation;
- data forms for documenting the sampling details;
- discharge line to volumetric measurement device;
- in-line filter holder (Milli-pore or equivalent);

- 0.45 micron filter papers;
- appropriate sample bottles;
- pH meter, conductivity meter, and thermometer;
- Brainard-Kilman pump;
- commercially purchased bailer for 2-inch monitoring wells, which can be disassembled for decontamination and is fitted for in-line pressure filtering;
- non-contaminating bailer line (e.g. fishing line, teflon-coated stainless steel) of sufficient strength to prevent breakage;
- volumetric measurement devices (e.g. 10-L pail and 1-L graduated cylinder);
- tweezers (for filter paper);
- indelible marker;
- wash bottle(s);
- large bottle-type brush for cleaning bailer and/or sampling pump if necessary;
- large bottle-type brush and threaded 19-mm (3/4-inch) diameter PVC pipe for cleaning the monitoring well if necessary;
- hangman and pulley/reel assembly for lowering and raising the bailer;
- clean rags;
- paper towels;
- tape for sealing sample bottles;
- small screwdriver for calibrating field pH and conductivity meters;
- container(s) for field parameter measurements;
- clipboard or binder for sampling forms; and
- sampling van.

3. SAMPLE COLLECTION

3.1 Step 1 - Prepare for Sampling

Wear a fresh pair of disposable latex gloves throughout the sampling process.

Prior to taking any measurements or samples, prepare and test:

- sample bottles;
- sampling pump;
- in-line filtration apparatus;
- field parameter standard solutions;
- field parameter sample container;
- field parameter meters; and
- water level probe.

Also start the field sampling form, which documents:

- well number;
- well depth;
- water level depth;
- well yield - high, medium or low;
- purge volume and pumping rate;
- time well purged;
- collection method;

- field analysis data and method(s);
- field observations of sampling event;
- name of sample collector; and
- climatic conditions including air temperature.

An example of a sampling record is included.

3.2 Step 2 - Measure Static Water Level and Total Depth

a) Dip the water level probe in water to confirm that it is operating.

b) Check that the tape length is correct.

c) Decontaminate the water level probe by rinsing it in a deionized water bath.

d) Measure the depth to water from the top of the PVC to within at least 0.01 m.

e) Measure the total depth of the well from the top of the PVC to within at least 0.01 m.

f) Calculate the volume of the water column in the well.

3.3 Step 3 - Purge Well

The water standing in a well prior to sampling is not representative of in situ groundwater quality and must be removed so that formation water can replace the stagnant water. Table 3.1 summarizes the recommended pumping methods.

Table 3.1 - Recommended Pumping Method

High Water Level (<15 m)*	Brainard-Kilman
Low Water Level (>15 m)	Bailer

* Can be extended to 30 m

a) Rinse all tubes, pump parts, bailer line and anything else to be lowered into the well with deionized water to prevent cross contamination.

b) If a pump is used, lower the pump intake to a point just below the standing water level in the well; ensure that the well water is not agitated. The intake should be maintained near the water surface to maximize the purging action. Deeper submergence will result in ineffective purging because the flow into the pump will come from the screen.

c) Gently pump or bail three well volumes from the well. Lower the intake during pumping, if necessary.

e) Dispose of the purged water in an environmentally acceptable manner.

3.4 Step 4 - Measure Field Parameters

Near the end of well purging, the field parameters (temperature, conductivity, and pH) should be measured because they are subject to change once the groundwater is removed from the well. To measure:

a) Rinse the meters with deionized water and blot dry with clean paper towels.

b) Rinse the field parameter sample container and blot dry with clean paper towels.

c) Calibrate the field parameter meters in the standard solutions (the standard solutions should be comparable to the values expected in the field).

d) Rinse the meters with deionized water and blot dry with clean paper towels.

e) Fill the field sample container immediately after the water has been extracted from the well.

f) Immediately measure the parameters in order:

- temperature;
- conductivity; and
- pH.

3.5 Step 5 - Withdraw Sample

The sample withdrawal method is dependent on the well characteristics, and the method used for purging. Since the purging will assist in "pre-cleaning", this same equipment, where possible, should be utilized for sampling. The sampling should be carried out in order:

- total metals (T.M.);
- dissolved metals (D.M.); and,
- major anions (M.A.).

To sample:

a) Take precautions to prevent dirt and dust from contaminating the samples.

b) Filter the dissolved metals sample as a pressure filtering operation in the discharge line. Samples transferred directly from the sampling equipment through the filter to the sample bottle have less opportunity to become contaminated. If a bailer is used for sampling, it should have fittings appropriate for in-line pressure filtering.

c) Before filling, rinse the sample bottles out twice with the water being collected (unless the preservative is already in the container).

d) Fill the containers almost full but leave room to add the preservative and allow shaking.

e) Add preservative according to Step 6. Shake the container to dissolve and/or mix the preservative.

f) Cap the sample containers tightly.

g) Complete the sample label before moving to the next sampling site. Ensure that the dissolved metals and total metals samples are not mixed up.

h) Store the sample in its shipping container (typically a cooler). Tape for keeping dust out of the cooler and ice-packs for keeping the samples cool will probably be necessary during the summer months.

3.6 Step 6 - Preserve Samples

Many of the chemical constituents and physicochemical parameters that are to be measured or evaluated in groundwater monitoring programs are not chemically stable. Sample preservation mitigates the effects of sample degradation.

Preservation methods are generally limited to pH control, chemical addition, refrigeration, and protection from light, and are intended to:

1) retard biological action;
2) retard hydrolysis; and
3) reduce sorption effects.

Table 3.2 summarizes the appropriate sample bottle types and sample preservation measures.

Table 3.2 - Sampling and Preservation Procedures for Groundwater Monitoring(1)

PARAMETER GROUP	SPECIFIC ANALYSIS	BOTTLE TYPE	PRESERVATIVE	MAXIMUM HOLDING TIME
Physical Parameters	Suspended Solids, Turbidity, Conductivity, pH, Colour, Dissolved Solids, Hardness	1-L plastic(2)	4°C	Conductivity and pH are field-determined but samples should be shipped ASAP to minimize pH shift
Major Anions	Bicarbonate, Sulphate, Chloride, Fluoride			28 days
Nutrients	O-Phosphate, D-Phosphorous, T-Phosphorous, Nitrate, Nitrite, Ammonia.			48 hours
Total Metals	Al, Sb, As, Ba, Be, Bi, Bo, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, Se, Si, Ag, Sr, U, V, Zn	250-mL plastic	2 mL HNO_3, 4°C	6 months
Dissolved Metals	Al, Sb, As, Ba, Be, Bi, Bo, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, K, Se, Si, Ag, Na, Sr, U, V, Zn	250-mL plastic	Field filtration (0.45 micron), 2 mL HNO_3, 4°C	6 months

1. References: Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, U.S. EPA SW-846 (2nd edition, 1982).
Methods for Chemical Analysis of Water and Wastes, U.S. EPA-600/4-79-020.
Standard Methods for the Examination of Water and Wastewater, 16th Edition (1985).
Collection and Preservation of Environmental Samples, Analytical Service Laboratories, December 1986.

2. Plastic = Polyethylene

The nitric acid and sodium hydroxide used for preserving the samples can cause severe burns and should be handled with care.

Metallic ions that migrate through the unsaturated (vadose) and saturated zones and arrive at a groundwater monitoring well may be present in the well. Particles (e.g. silt, clay), which may be present in the well even after well evacuation procedures, may absorb or adsorb various ionic species which would lower the dissolved metal content in the well water. Groundwater samples on which metals analysis will be conducted should be split into two portions. One portion should be filtered through a 0.45-micron membrane filter, transferred to the sample bottle, preserved with nitric acid, and analyzed for dissolved metals. The remaining portion should be transferred to a bottle, preserved with nitric acid, and analyzed for total metals. Any difference in concentration between the total and dissolved fractions may be attributed to the original metallic ion content of the particles and any sorption of ions to the particles.

3.7 Step 7 - Ship Samples to Laboratory

3.7.1 Sample Labels

The labels should be sufficiently durable to remain legible even when wet and should include:

- sample identification number;
- name of collector;
- date and time of collection;
- place of collection;
- parameter(s) requested i.e. Total Metals, Total Mercury, Dissolved Metals, Total Cyanide or Major Anions.

3.7.2 Packing

- Seal and carefully pack the sample bottles in an upright position to ensure that they are not disturbed during shipping.
- Pack ice in properly sealed, water-tight plastic bags around the sample bottles.
- Position the shipping thermometer so that it is not against the ice.
- Use newspaper or equivalent as a packing material. The analytical laboratory requests that styrofoam chips not be used since the styrofoam is messy and can possibly contaminate the samples.
- Seal the shipping container.

3.7.3 Chain-of-Custody Record

A chain-of-custody record should be filled out and should accompany every shipping container sent to the laboratory. The record should include:

- sample number;
- signature of collector;
- date and time of collection;
- sample type;

- identification of well;
- number of sample bottles;
- signature of person(s) involved in the chain of possession;
- inclusive dates of possession;
- internal temperature of shipping container when samples were sealed into the shipping container;
- maximum temperature recorded during shipment;
- minimum temperature recorded during shipment; and
- internal temperature of shipping (refrigerated) container upon opening in the laboratory.

An example of a chain-of-custody record is included.

4. FIELD QUALITY CONTROL (QC)

4.1 Introduction

The field quality control program should document the condition of the monitoring well and verify the adequacy of the sampling and handling program. If the QC program identifies a source of error, the QC should not be used to correct the groundwater data. Instead, the source of the error should be identified and documented, and corrective action, including resampling, should be initiated.

The QC steps can be divided into four categories:

- field parameters;
- blanks and spikes;
- preliminary data review; and
- annual well tests.

4.2 Field Parameters

All field measurement equipment must be calibrated prior to field use and recalibrated in the field before measuring each sample. This includes temperature, pH, and EC measurement systems.

4.3 Blanks and Spikes

4.3.1 Trip Blank

Have the laboratory fill one of each type of sample bottle with deionized water, transport it to the site, handle it like a sample (except for running it through the sampling equipment), and return it to the laboratory for analysis for dissolved metals. A sampling record with a dummy sample number should be completed. One trip blank per sampling round is recommended.

4.3.2 Equipment Blank

To ensure that non-dedicated sampling devices have been effectively cleaned (in the laboratory and field), have the laboratory provide one equipment blank (deionized water) for each piece of equipment (e.g. Brainard Kilman pump, bailer). All sampling and handling steps must be followed to ensure that procedures and equipment are tested by this blank. A sampling record with a dummy sample number should be completed. One equipment blank for each sampling round is recommended for each set of equipment. The blank should be analyzed for dissolved metals.

4.3.3 Field Spike

To ensure that the field and transportation procedures are not creating changes in water chemistry, have the laboratory provide two unacidified samples with known concentrations of metals comparable to the expected field conditions (field spike). Two spikes are recommended so that the difference between natural sample degradation and sample degradation due to the sampling and handling procedures can be documented. Follow all sampling and handling steps with one of the spikes to ensure that procedures and equipment are tested. With the other spike, simply transfer the contents to another bottle and acidify. Sampling records with dummy sample numbers should be completed. The analytical chemist should retain a sample of the spike in the laboratory and analyze for dissolved metals at the same time as the field sample for comparison.

4.4 Preliminary Data Review

On receipt of the laboratory data, all results should be compared with previous data from the well and with data from adjacent wells to identify anomalous data. Possible reasons for identified anomalies should be assessed and resampling initiated to verify any anomalies.

4.5 Annual Well Tests

4.5.1 General

Annual well tests provide documentation of the well condition and, therefore, the quality of the data. Complete records of the tests should be filed.

4.5.2 Sedimentation

The quantity of sediment in each well should be documented by measuring the total depth of the monitoring well. Any sediment should be bailed or educted out of the well, described (sand, silt, organic matter, etc.), and documented.

4.5.3 Hydraulic Integrity

The hydraulic integrity of the well should be checked by establishing a packer immediately above the well screen and filling the well with clean water. On completion, the test water must be removed from the system. This test should follow sampling.

4.5.4 Rising Head Test

An annual rising head test is required to verify the performance of each well. Following a similar procedure every year, data should be collected from 5% recovery to 95% recovery. The rising head test data collection form included in these guidelines should be completed in full. The time data should be measured to the second for wells which recover 95% in less than an hour. The data should be analyzed by qualified personnel and compared to earlier results to determine whether or not the well response has changed.

The steps to complete the test are:

1. The day before the test, record:
    - well no.;
    - date;
    - time;
    - water level in the standpipe.

2. The day of the test, record:
    - date;
    - page number;
    - well inner diameter (nearest mm);
    - PVC stickup;
    - total depth;
    - air temperature;
    - probe serial number;
    - initials.

3. Just prior to inserting the Waterra pump on the day of the test, record:
    - date;
    - time;
    - water level in the standpipe

4. Insert the Waterra pump into the standpipe and position the intake about 3 m below the water surface.

5. Just before pumping is started, record:
    - date;
    - time;
    - water level in the standpipe.

6. Record the pumping method, decide the time pumping is to start and record that time to the nearest second.

7. Starting at the pre-determined time, pump 4.0 L (for a 2-in standpipe) out of the standpipe into a bucket with volume markings on the side. Adjust the volume for different sizes of standpipe pipe to give about 2 m of drawdown in the standpipe.

8. Leave the Waterra in the well (perhaps clamp with vice-grips) and immediately start to record the recovery readings. Readings should be taken for 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 17, 14, 12, 10, 9, 8, 7, 6, 5 percent difference. Percent difference is the current difference in water level divided by the original difference in water level.

Example:
depth to water before pumping: 1.00 m
depth to water immediately after pumping: 3.00 m
original difference = 3.00-1.00 = 2.00 m
one of the recovery readings: 1.80 m
current difference = 1.80-1.00 = 0.80 m

percent difference = 0.80/2.00 = 0.40 or 40%

The time for successive readings can be approximately predicted by plotting percent difference vs. time on semi-logarithmic graph paper with percent difference plotted vertically on the logarithmic scale. A straight line drawn through the first few data points will approximate the trend. As successive points are plotted, adjustments can be made. If the well recovers very quickly, two people may be required to collect enough data.

9. Record the time that pumping stopped as soon as time permits.

10. Document the quantity of water lost out of the Waterra by measuring how far the water level inside the Waterra tubing has fallen since pumping stopped.

11. Document the time when the Waterra was removed from the standpipe. The Waterra should remain in the standpipe until the percent difference has decreased to at least 20%. If the test is less than, say, two hours, the Waterra should remain in the standpipe for the whole test.

12. Pour the pumped water into a graduated cylinder or equivalent to determine the quantity of water pumped to the nearest tenth of a litre.

13. Comment on the well condition (e.g. PVC riser broken, cap missing, water ponded around standpipe collar, everything fine) and on noteworthy occurrences during the test.

14. Comment on the colour and sediment content of the water pumped from the well.

15. If readings are not being taken at least every two weeks in the standpipes, return within a few days to record the water level. Continue to return until the water has returned to static or until the data indicates that the water level will not reach the original static reading.

16. Include all barometric data from the site meteorlogical station for the duration of the test.

KLOHN LEONOFF

Our File: PB 5395 0701
WR 47

May 25, 1993

Craigmont Mines Ltd.
320-1639 West Second Avenue
Vancouver, British Columbia
V6J 1H3

Mr. R.C. Hermann, P.Eng.
Director

Magnetite Recovery Project
Groundwater Monitoring and Supply

Dear Sir:

As requested by Bryan Quinlan on May 21, 1993, this letter summarizes the groundwater sample water results for the samples that have been collected so far from the monitoring well and water supply well that have been installed at Craigmont Mine.

As discussed in our draft report dated April 29, 1993, the water samples that were collected shortly after well installation in March 1993 were analyzed for physical parameters, major ions, nutrients and heavy metals. The heavy metals analysis was by the relatively inexpensive inductively coupled plasma (ICP) method, which is appropriate for a first analysis. The advantage of the ICP method is that the majority of the metals are analyzed quickly and inexpensively as a group. However, the ICP detection limits for a few of the heavy metals are higher than the Canadian Drinking Water Quality Guidelines. The second sampling round in May used more sensitive methods for these parameters. Cyanide was not analyzed because we understand that cyanide has not been used in the milling process at this site. Uranium was judged as unnecessary and was therefore not analyzed. The need for a mercury analysis will be reviewed prior to the next sampling round.

The water analysis results (attached) show that none of the individual constituents exceeds the Canadian Drinking Water Guidelines (also attached). However, the total dissolved solids (900 mg/ℓ) are significantly over the drinking water guideline of 500 mg/ℓ, which is based primarily on palatability. The high dissolved solids may cause corrosion and the manganese may lead to pipe encrustation.

Sulphate concentrations from both the monitoring well and water supply well are close to 300 mg/ℓ, which are significantly above expected background concentrations and therefore are indicative of tailings water. However, the metal concentrations are all low and indicate that no significant heavy metal concentrations have reached the southern property boundary, except in the unlikely event that the metals are following a flowpath deeper in the aquifer.

Although heavy metals have not been detected in the groundwater samples, periodic sampling of water from wells downstream of the mine is advisable to document the water quality. An additional four monitoring wells are recommended for monitoring the groundwater quality across the width of the valley, as first recommended in Klohn Leonoff's proposal dated November 28, 1991.

Klohn Leonoff personnel will sample the monitoring well in accordance with Klohn Leonoff's groundwater sampling and handling guidelines. The water supply well will be sampled after the pump has been installed. The samples will be collected monthly for one year unless the data indicate that the sampling frequency can be decreased. A quarterly sampling schedule will probably be established after one year of data have been collected. Frequent sampling prior to start-up of the tailings facility will help to establish the pre-pond groundwater chemistry with reasonable confidence. The analysis of the next round of water samples will include total and faecal coliform bacteria.

We trust that this letter meets your current needs. Please call if you have any questions or require further information.

Yours very truly,

KLOHN LEONOFF LTD.

HMcCreadie

for Steve Rice, P.Eng.
Project Manager

HMcC/SR/hmcc
Encl.

ports total exposure from all sources to be only 0.1 mg·d^{-1} (NAS 1982). Drinking water is considered to be a negligible source of antimony intake compared with other foods (Health and Welfare Canada 1980).

Data on antimony concentrations in Canadian drinking water are not readily available. Antimony concentrations in Canadian surface water range from 0.001 to 9.1 mg·L^{-1} (NAQUADAT 1980). Under certain soft-water conditions, antimony may be leached from plumbing materials (Health and Welfare Canada 1980).

1.3.1.1.3 Water Treatment

Little documented information is available on antimony removal by water treatment processes. Because antimony has chemical and biological characteristics similar to those of arsenic (NAS 1980a), treatment processes suitable for arsenic may be applicable. It is anticipated that alum or ferric sulphate coagulation-flocculation in the presence of turbidity and activated carbon adsorption may have some potential for decreasing the concentration of antimony in raw waters.

1.3.1.2 Arsenic

1.3.1.2.1 Existing Drinking Water Guideline

The Guidelines for Canadian Drinking Water Quality 1978 list the maximum acceptable concentration of arsenic in drinking water as 0.05 mg·L^{-1} (Health and Welfare Canada 1979a).

1.3.1.2.2 Canadian Exposure

In general, Canadian surface waters contain less than 0.05 mg·L^{-1} of total dissolved arsenic. Concentrations greater than 0.05 mg·L^{-1} have been found in groundwater in some parts of Canada (Health and Welfare Canada 1980).

1.3.1.2.3 Water Treatment

The effectiveness of water treatment for arsenic removal is dependent on the valence state of the arsenic in the raw water supply. Conventional coagulation or softening processes have been investigated. It has been generally indicated that the conversion from As(III) to As(V) is desirable and can be accomplished by oxidation using either chlorine or potassium permanganate (Shen 1973; Sorg and Logsdon 1978; U.S. EPA 1978a). Of the common metal coagulants, ferric sulphate was found to be superior to alum for removal. However, both coagulants could reduce concentrations of As(V) in raw waters from fairly high levels to less than 0.05 mg·L^{-1}. Lime softening is quite effective for arsenic removal from hard waters. This removal is dependent on the pH and the arsenic valence. At high pH obtained through the lime treatment process, raw waters containing up to 0.35 mg·L^{-1} As could be effectively treated (Sorg and Logsdon 1978).

In terms of special treatment, it has been found that activated alumina could be effective for arsenic removal (Sorg and ogsdon 1978). This is not a common treatment for surface waters.

For private groundwater supplies, a special process has been developed in Nova Scotia, using chlorination followed by

Table 1-1. Summary – Guidelines for Canadian Drinking Water Quality 1978

Parameter	Maximum acceptable concentration[1] in drinking water (mg·L^{-1})[2,3]
Inorganic Parameters	
Antimony	—
Arsenic	0.05
Asbestos	—
Barium	1.0
Boron	5.0
Cadmium	5 $\mu g \cdot L^{-1}$
Chloride	250
Chromium	0.05
Copper	1.0
Cyanide	0.2
Fluoride	1.5
Hardness[4]	—
Iron	0.3
Lead	0.05
Manganese	0.05
Mercury	1 $\mu g \cdot L^{-1}$
Nitrate (as N)[5]	10.0
Nitrite (as N)	1.0
pH	6.5-8.5[6]
Selenium	0.01
Silver	0.05
Sulphate	500
Sulphide (as H_2S)	0.05
Total dissolved solids	500
Uranium	0.02
Zinc	5.0
Organic Parameters	
Aldrin + dieldrin	0.7 $\mu g \cdot L^{-1}$
Carbaryl[4]	70 $\mu g \cdot L^{-1}$
Chlordane (total isomers)	7 $\mu g \cdot L^{-1}$
2,4-D	0.1
DDT (total isomers)	0.03
Diazinon	14 $\mu g \cdot L^{-1}$
Dieldrin + aldrin	0.7 $\mu g \cdot L^{-1}$
Endrin	0.2 $\mu g \cdot L^{-1}$
Heptachlor + heptachlor epoxide	3 $\mu g \cdot L^{-1}$
Lindane	4 $\mu g \cdot L^{-1}$
Methoxychlor	0.1
Methyl parathion	7 $\mu g \cdot L^{-1}$
Nitrilotriacetic acid (NTA)	0.05
Parathion	35 $\mu g \cdot L^{-1}$
Pesticides (total)[7]	0.1
Phenols	2 $\mu g \cdot L^{-1}$
2,4,5-TP	0.01
Toxaphene	5 $\mu g \cdot L^{-1}$
Trihalomethanes	0.35
Physical Parameters	
Colour	15 TCU[8]
Odour	—
Taste[4]	—
Temperature[4]	15°C
Turbidity	5 NTU[9]
Radiological Parameters[10]	
^{137}Cs (Cesium)	50 $Bq \cdot L^{-1}$
^{131}I (Iodine)	10 $Bq \cdot L^{-1}$
^{226}Ra (Radium)	1 $Bq \cdot L^{-1}$
^{90}Sr (Strontium)	10 $Bq \cdot L^{-1}$
^{3}H (Tritium)	40 000 $Bq \cdot L^{-1}$

Table 1-1. (Cont'd)

Parameter		Maximum acceptable concentration[1] in drinking water $(mg \cdot L^{-1})$[2,3]
Microbiological Parameters		
Microorganisms	a. No sample should contain more than 10 total coliform organisms per 100 mL; b. not more than 10% of the samples taken in a 30-d period should show the presence of coliform organisms; c. not more than two consecutive samples from the same site should show the presence of coliform organisms: and d. none of the coliform organisms detected should be fecal coliforms.	

[1] Maximum Acceptable Concentration (MAC):
Drinking water that contains substances in concentrations greater than these limits is either capable of producing deleterious health effects or is aesthetically objectionable (Health and Welfare Canada 1979a).

[2] Unless otherwise indicated.

[3] Total unless otherwise indicated.

[4] Not discussed in Chapter 1.

[5] Where both nitrate and nitrite are present the total nitrate- plus nitrite-nitrogen should not exceed 10 $mg \cdot L^{-1}$.

[6] Logarithmic scale, no units.

[7] The "total pesticide" limit applies to water in which more than one of the pesticides mentioned in Chapter 1 are present. The sum of their concentrations should not exceed 0.1 $mg \cdot L^{-1}$.

[8] True colour units.

[9] Nephelometric turbidity units.

[10] Becquerel.

Source: Health and Welfare Canada 1979a.

Table 1-2. Water Treatment Processes

Process	Purposes
Aeration	Removal of volatile taste and odour compoun and other dissolved gases (e.g. H_2S, CH_4) Oxygenation and deoxygenation Oxidation (iron)
Presedimentation	Removal of readily settleable particulate matter
Chemical oxidation	Disinfection, biological control Taste and odour control Oxidation of dissolved metals (iron, manganese) Oxidation of some organic chemicals; colour removal enhancement
Coagulation-flocculation	Destabilization of colloidal material and macromolecules and agglomeration of settleable or filterable particulates for the removal of turbidity and colour
Sedimentation	Removal of settleable flocculated particulates prior to filtration
Filtration	Removal of particulates, polishing of water through physical and chemical/biological processes Dual chemical-physical filters (iron and manganese removal)
Softening	Reduction in hardness through the removal of calcium and magnesium by precipitation or ion exchange
Carbon adsorption	Taste and odour control Colour reduction assistance Removal of some organic chemicals including trihalomethane precursors

an exchange medium containing ferric hydroxide. This process can attain high removals at low water flows (Lutwick 1980).

1.3.1.3 Asbestos

1.3.1.3.1 Existing Drinking Water Guideline

No maximum acceptable concentration of asbestos in drinking water was established in the Guidelines for Canadian Drinking Water Quality 1978 as it is believed that the ingestion of asbestos at the concentrations found in drinking water do not constitute a health hazard (Health and Welfare Canada 1979a; NRCC 1982).

1.3.1.3.2 Canadian Exposure

Based on assumed asbestos concentrations and respiratory volumes, the daily intake of asbestos from air has been suggested to be less than 0.6 μg. Because of the paucity of data on asbestos in food and water, dietary intakes can only be approximated. An asbestos intake from water has been calculated at 1.88 ng (2 $L \cdot d^{-1}$ of water containing approximately 1.9 × 10^6 fibres per litre), considerably less than that from air (Health and Welfare Canada 1980).

A study of selected Canadian drinking water supplies indicated concentrations of asbestos ranging from less than 10^5 to 2 x 10^9 (chrysotile) fibres per litre in raw water and maximum concentrations of 9.5 × 10^6 fibres per litre in water treated by filtration (Health and Welfare Canada 1979b; Toft *et al.* 1981).

1.3.1.3.3 Water Treatment

Of the two primary asbestos groups, the amphibole forms are more amenable to treatment than is chrysotile asbestos, which is more prevalent in Canada (NAS 1977; Health and Welfare Canada 1979b). Both conventional and special coagulation-flocculation-filtration treatment process trains are reasonably effective for removal of chrysotile fibres from raw water. Data from existing Canadian facilities have indicated 18- to 300-fold reductions, whereas other pilot and full-scale studies have suggested removals by factors of 10-50 000 (Watkins *et al.* 1978; Toft *et al.* 1981; Hayward 1984).

Because of the measurement technique used, electron microscopy fibre counting, the large numbers generated are not precise, and removal rates should be viewed with some caution. However, with good process control, it is anticipated that target fibre counts in finished water in the (0.1-1) × 10^6 fibres per litre range could be obtained (Logsdon *et al.* 1983).

Under certain water quality conditions, release of fibres from the erosion of asbestos-cement pipes used in water distribution systems may occur. Water-conditioning measures to make the distributed water less corrosive is a potential mitigation option where problems have been identified (NAS 1982).

Table 2-2. ***Summary – Guidelines for Recreational Water Quality***

Parameter	Guideline	Parameter	Guideline
cteriological		Aesthetics	All water should be free from: – materials that will settle to form objectionable deposits; – floating debris, oil, scum and other matter; – substances producing objectionable colour, odour, taste or turbidity; and – substances and conditions or combinations thereof in concentrations which produce undesirable aquatic life.
ecal coliforms	The geometric mean of not less than 5 samples taken over a 30-d period should be less than 200 fecal coliforms per 100 mL. Resampling should be performed when any sample exceeds 400 fecal coliforms per 100 mL.		
Pathogens Coliphages Enterococci *E. coli* *P. aeruginosa* *G. lamblia*	) see text		
Clarity	The water should be sufficiently clear that a Secchi disc is visible at a minimum of 1.2 m.	Oil and grease	Oil or petrochemicals should not be present in concentrations that: – can be detected as a visible film, sheen or discolouration on the surface; – can be detected by odour; or – can form deposits on shorelines and bottom deposits that are detectable by sight and odour.
pH	5.0-9.0, provided that when the pH is near the extremes of this range, the buffering capacity of the water is very low.		
Turbidity[1]	The turbidity of water should not be increased more than 5.0 NTU over natural turbidity when this is low. (<50 NTU)	Aquatic plants	Rooted or floating plants which could entangle bathers should be absent; very dense growths could affect other activities such as boating and fishing.

[1] Singleton 1986.

Source: Health and Welfare Canada 1983.

sed as a fecal pollution indicator for many years because of ease of measurement, but counts do not correlate well with the incidence of gastrointestinal (GI) illness and use of this group is being phased out. Recent improvements in detection and measurement techniques enable the use of organisms which give a more reliable indication of health risk. These organisms include enterococci, the fecal coliform *Escherichia coli* and the pathogen *Pseudomonas aeruginosa*, which causes ear infections (otitis externa). *Pseudomonas aeruginosa*, as an opportunistic pathogen, strictly should not be classified as an indicator organism; however, it is utilized in this manner.

Some Canadian provinces, the International Joint Commission, the U.S. Environmental Protection Agency and some U.S. states have recommended or are in the process of recommending the use of one or more of the following microorganisms – *E. coli*, enterococci and *P. aeruginosa* – as indicator organisms for health risk assessment at swimming beaches. Recent studies using these organisms allow a more accurate assessment to be made of the risk of becoming ill from exposure to pathogens at bathing beaches. Dufour (1984) showed that there was a direct linear relationship between the rate of swimming-associated gastrointestinal illness and the densities of both *E. coli* and enterococci. Either organism could be used as a reliable indicator of fecal contamination. The current Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada 1983) have the flexibility to take these developments into account and the phasing in of measurements of these organisms will be considered when their assessment as indicators is completed.

The following text discusses the guidelines for microbiological characteristics of bathing beaches, found in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada 1983). These recognize that some provinces have more restrictive requirements which relate directly to local conditions. Brief discussions on the more recent guidelines from other agencies can also be found below.

A number of procedures for use in assessing recreational water quality have been reviewed by a committee responsible for watershed management in the Toronto area: (1) development of a methodology to evaluate the effect of wet-weather bacterial densities in interpreting water quality objectives; (2) selection of sampling stations by considering the water source and water-use locations and factors affecting bacterial transport in streams and rivers; (3) sediment phase monitoring to permit detailed mass balance computations; (4) estimation of bacterial growth and die-off rates; and (5) bacterial inputs from other sources such as waterfowl, mammals, etc. (Toronto Area Watershed Management Strategy Steering Committee 1985).

2.3.1.1 Fecal Coliforms

2.3.1.1.1 Guideline

Until the Federal-Provincial Advisory Committee on Environmental and Occupational Health revises the guideline, the following recommendation is made.

The geometric mean of not less than five samples taken over a 30-d period should be less than 200 fecal coliforms per