DATA BOOK

Lower Chase River Dam

Prepared for

CITY OF NANAIMO

Prepared by:

EBA ENGINEERING LTD.

#1 - 4376 Boban Drive

Nanaimo, B.C.

September 1992

SUMMARY

This Data Book has been prepared to present guidelines such that the Lower Chase River Dam can be operated and maintained in a safe condition in accordance with sound procedures.

The Lower Chase River Dam is located on the Chase River in the southwest part of the City of Nanaimo. The dam is accessible via Nanaimo Lakes Road, refer Figure 1. The structure is comprised of a central, vertical concrete cut off wall with end dumped soil and rock including slag and cinders, forming the upstream and downstream shoulders. The dam is about 23m high and has a crest length of about 77m. A photograph of the dam is included as Figure 2.

The Data Book has been divided into three sections:

Section 1: Operational Data
Section 2: Emergency Procedures
Section 3: Technical Data

A table of contents for each section is included in this summary.

It is the responsibility of the City of Nanaimo Manager of Public Works to maintain and update all copies of the Data Book. An amendment sheet has been included for this purpose. The distribution of this data book follows:

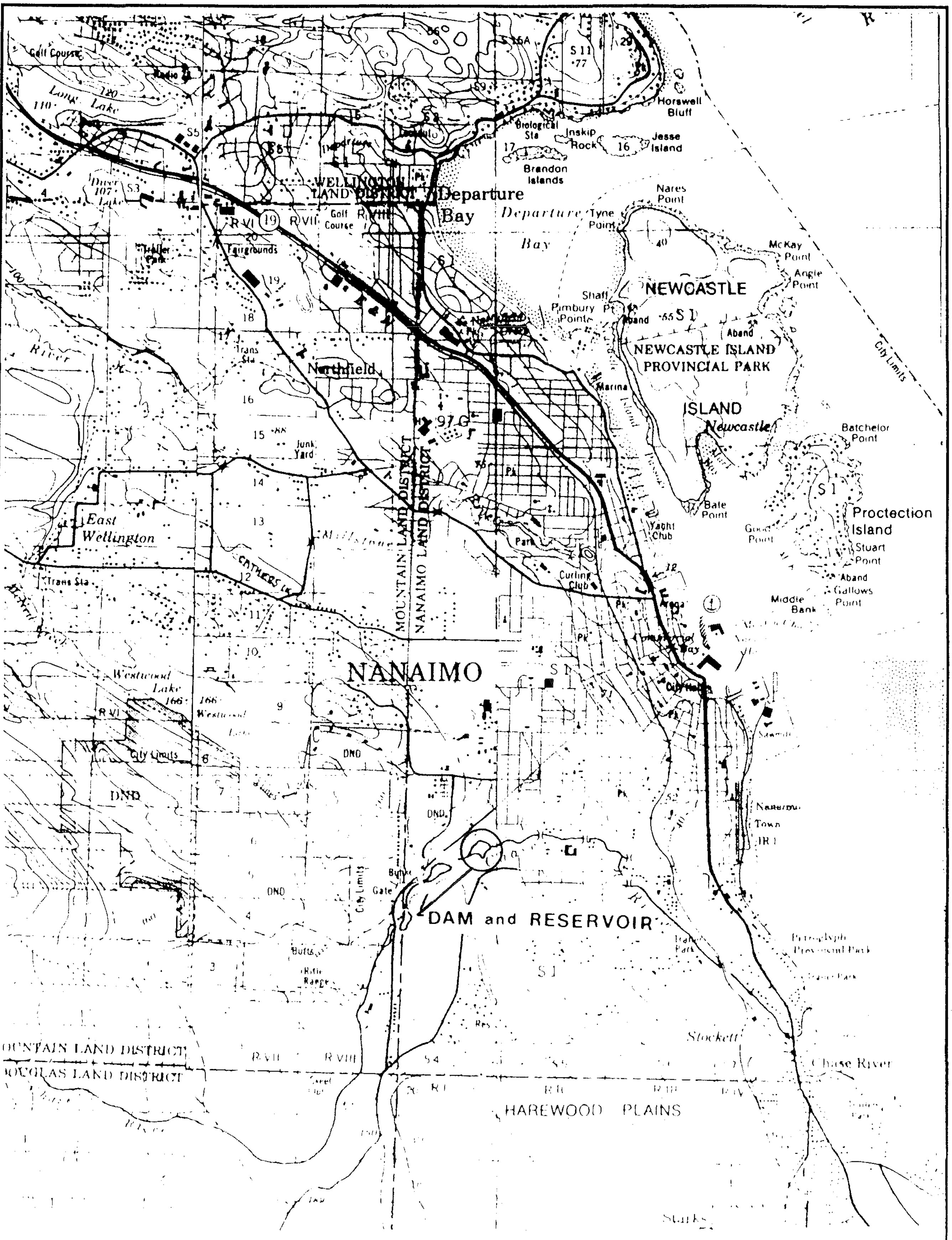
1 copy: City of Nanaimo Public Works Library
1 copy: City of Nanaimo Engineering Library
1 copy: City of Nanaimo Field Manual

AMENDMENT SHEET

Authority: The Manager of Utilities for the City of Nanaimo is responsible for maintaining and updating all copies of the Data Book.

Amendment Date	Description of Amendment	Initial of Person Inserting Amendment
2003-May-14	Updated 2.0 Emergency situations, 3.0 Notification Information and 4.0 Emergency Procedures.	DP
2003-Jun-03	Updated Appendix 4 Emergency Response Plan Contact List	DP

FIGURE 1
LOCATION PLAN



LOWER CHASE RIVER DAM Figure 1

FIGURE 2
PHOTOGRAPH OF DAM

CONCRETE FOOTBRIDGE OVER CONCRETE SPILLWAY

RESERVOIR

OPERATIONAL DATA

Section 1

TABLE OF CONTENTS

EMERGENCY PROCEDURES

Section 2

TABLE OF CONTENTS

TECHNICAL DATA

Section 3

TABLE OF CONTENTS

SECTION 1
OPERATIONAL DATA

OPERATIONAL DATA

Section 1

TABLE OF CONTENTS

1.0 STATIC DATA

1.1 Table of Static Data

The relevant static data for the Lower Chase River Dam is contained in Table 1-1.

TABLE 1-1

Item	Data	Comments
Name:	**Lower Chase River Dam**	Also referred to as: Lower Colliery Dam, Lower Harewood Colliery Dam Howard No. 4 Dam and Harewood No. 2 Dam
Hazard Classification:	**B**	M of E criteria, dam is considered to be "major". "Disaster Potential Classification" estimated to be "B"
Co-Ordinates:	**N 5446292 E 430138**	As determined by Wright, Parry, Taylor & Fuller in February 1992
Structure Type:	**Earth fill, rock fill and mine waste dam with 1.2m thick vertical, concrete cut-off wall**	
Height of Dam at Crest:	**23.3m**	As determined by Wright, Parry, Taylor & Fuller in February 1992
Width of Dam at Crest:	**77m**	As determined by Wright, Parry, Taylor & Fuller in February 1992
Storage Capacity for Reservoir:	**17.3 Ha-m**	Quantity of water stored is 17.3 Ha-m (140 acre-feet), as per water license. Note: this should be confirmed.
Water License Data:		See application for Water License in Appendix 1A. Licensed on November 23, 1984.
Owner Information:	**The City of Nanaimo**	
Year of Construction:	**1910 to 1920**	Believed to have been completed in about 1910 by Wakesiah Colliery.

1.2 Documentation by Others

A number of documents and other correspondence relating to the dam are in existence in the City of Nanaimo files. These are listed in Table 1-2.

TABLE 1-2

Item	Location
Letters and memos by the City of Nanaimo	City of Nanaimo Public Works Files
Golder Associates' Site Inspection Report V77241	City of Nanaimo Public Works Files
Golder Associates' Site Investigation Report V78040	City of Nanaimo Library No. 092 Appendix 1B - Section 1 - Operational Data
Willis, Cunliffe, Tait Dam Rehabilitation Program Contract Documents NA7157-1	City of Nanaimo Library No. 189
1978 Storm Drainage Study	City of Nanaimo Library No. 475 Appendix 3A - Section 3 - Technical Data
Dayton and Knight Ltd. Lower Harewood Colliery Dam Data File	City of Nanaimo Public Works Files

2.0 INSPECTION REQUIREMENTS

The inspection requirements for the Lower Chase River Dam are summarized in Table 1-3.

TABLE 1-3
RECOMMENDED INSPECTION AND MONITORING

TYPE	NATURE OF INSPECTION/MONITORING	FREQUENCY
1. Monitoring	- seepage flow - reservoir level - precipitation	weekly (at least daily during storms)
2. Monitoring	- suspended soils in seepage flows	monthly
3. Detailed Inspections	- settlement or cracking of dam crest and associated concrete structure - debris impeding flow through spillway	monthly
4. Special Inspections	- as above with special attention to new disturbances, for example cracking and erosion, or slope movements	during and after major storms and seismic events
5. Major Inspections	- including dam, abutments, spillway, reservoir, etc.	every 2 years

Notes:

1. It has been noted that minor seepage has occurred and is continuing to occur immediately downstream of the dam. The seepage appears to be clear. Such seepage is generally a concern for dams. It is recommended that a V-notch weir be constructed and that the seepage flows be monitored on a weekly basis, along with reservoir elevation and precipitation, in order to determine whether or not the seepage is a hazard to the stability of the structure. A staff gauge should be installed in a readily accessible location to allow the reservoir level to be measured. The frequency of monitoring should be at least daily during major storms, i.e. (10 year

events or greater). The origin of this seepage is not currently known, but it is recommended that it should be investigated.

2. In addition, samples of the seepage water should be collected near the toe of the dam and tested for suspended solids on a monthly basis to determine if internal erosion is occurring.

3. Monthly inspections should be made of the dam crest and associated concrete structures to detect settlements or cracking, and of the spillway entrance to detect build up of debris which could impede flow through the spillway. A sample inspection form is included in Appendix 1C.

   The monitoring and monthly inspections could be carried out by City of Nanaimo staff and the resulting data provided as reference material for the field inspections.

4. Special inspections should be undertaken during and after major storms (10 year event or greater) and after significant seismic activity (50 year event or greater) of the Dam, reservoir and related facilities. Evidence of ground movement should be recorded any time it is observed.

5. This is an unattended, operational dam. On the basis of its Disaster Potential Classification it should have a major inspection carried out at least once every 2 years. The major inspections should include not only the dam proper but also the abutments, spillway, reservoir, downstream slopes and so on. A sample inspection form is provided in Appendix 1C.

   Major inspections including summary reports should be carried out by Professional Engineers with Dam Safety and Geotechnical experience.

Copies of the inspection and monitoring reports should be filed in Appendix 1D of the Operational Data section of the Data Book, in chronological order.

3.0 SITE DESCRIPTION AND GENERAL RECENT HISTORY

The Lower Chase River Dam is located on the Chase River which is in the southwest part of the City of Nanaimo, as shown on Figure 1, and is accessible via Nanaimo Lakes Road. The co-ordinates of the dam are N 5446292 and E 430138.

Lower Chase River Dam reservoir is used largely for recreational purposes. The reservoir also has some flood control capabilities with the temporary storage to the spillway invert elevation. The watershed area contributory to the reservoir has been estimated to be approximately 2625 hectares. This should be confirmed as part of a hydrologic study of the reservoir.

Lower Chase River Dam is situated about 0.3 km downstream from Middle Chase River Dam and discharges into the Chase River. The Greater Nanaimo Water District offices are about 1.3 km upstream on Nanaimo Lakes Road.

Lower Chase River Dam is also known as Lower Harewood Colliery Dam and the Lower Colliery Dam. The dam may have been at the end of an old railroad spur from the Harewood Mine. The structure consists of a thick vertical concrete core wall which is 0.3m thick from the top to 0.6m below the crest and then increases in thickness to 1.2m. End dumped soil and rock fill including mine waste form both the upstream and downstream shoulders of the dam. A dam site plan and cross-section are included in Appendix 1B.

The dam is situated in a steep sided ravine with both abutments believed to be comprised of silty overburden. The dam foundation material is believed to be dense sandy silt with some gravel. Some weathered siltstone is exposed on the lower portions of the right abutment.

The uncontrolled 2 bay spillway is located in the right abutment. The 2 bays join approximately 15m from the intake. At this point an open channel extends approximately 25m to a steep chute formed by the bedrock surface. A log jam has formed in the pool at the base of the chute.

Concrete walls line both sides of the spillway down to the open rock chute.

There is some erosion of the overburden evident on both sides of the chute, however, due to the limited thickness of overburden this poses no threat to the performance of the spillway.

When this dam was in service as a water supply reservoir there were two pipe conduits passing through the embankment. The outlet of the pipes, which projected out of the downstream face of the dam at about mid-height, have been removed and the pipes blocked upstream. The control valves for the pipes were located on the upstream side of the dam.

Improvement and remedial construction of the Lower Chase River Dam was carried out in 1980. Tree and brush cover over the downstream face of the dam was removed and the lower half of the slope was regraded to 2 horizontal to 1 vertical. A berm drain was constructed about half way up to the dam face, at the top of the regraded portion. A seepage trench was also constructed at the contact with the right abutment.

In addition, the pipe conduits through the dam were filled with concrete to within 5m of the outlet end. The last 5m of downstream pipe section was filled with granular filter material. The spillway wall and floor was repaired and the south spillway wall was raised. Grouted rock rip rap was provided at the spillway discharge. There is minor continued seepage downstream of the dam, however visually noticeable suspended solids and evidence of piping has not been noted during periodic observation over several years.

1-18 Operational Data

Periodic observations have been made of the dam and related facilities since 1980.

The most significant note with respect to past observations of the dam was the appearance of a crack in the berm material added in 1980. This was monitored for at least 2 years after initial observation without any indication of change.

4.0 OPERATIONAL INFORMATION

4.1 Recommended Maintenance

A summary of the recommended maintenance is given in Table 1-4

TABLE 1-4
RECOMMENDED MAINTENANCE

TYPE	NATURE OF MAINTENANCE	FREQUENCY
Routine	includes removal of debris from reservoir and spillway, and vegetation growth from dam face	Monthly
Preventative	concrete repairs, embankment surface repairs and protection, bridge railings	as necessary, but at least annually
Capital	See Technical Data Book (Section 3)	-

4.2 General

No moving operational devices are believed to exist at this dam. A controllable low level outlet that once existed within the dam structure has been decommissioned and infilled with concrete. The reservoir level is presently determined by the open spillway, and is not directly controllable.

The hydrological aspects of the Chase River system were assessed and reported in the 1978 Storm Drainage Study. The inflow to the Lower Chase River reservoir was estimated to be 57.8 m^3/sec for a 100 year storm. The spillway capacity with a 0.9m discharge depth (determined by the top of the concrete wall) was estimated to be is 53.8 m^3/sec, therefore the spillway may not to be adequate to transmit the flow resulting from a 100 year storm.

Maintenance of the dam should be carried out on a monthly basis or as found necessary to perform clean up, removal of debris from the reservoir or spillway and growth from the dam area. Preventative measures such as minor repair of concrete and embankment surfaces should be made as found necessary and under the direction of the City of Nanaimo Engineering Department. However, major maintenance to repair seepage, erosion, or other damage to the dam or appurtenant structures must be made with prior consultation and direction by a professional engineer with dam safety and geotechnical experience. Maintenance activities should be documented using a standard form as attached in Appendix 1C, and a copy should be retained in Appendix 1D in chronological order. The maintenance record should be reviewed as part of the regular inspections.

4.3 Flood Operating Criteria

The most critical operating requirement during a flood event is that the spillway be kept clear and that overtopping of the dam be prevented.

Extreme floods and high water levels, increased seepage or evidence of seepage, settlement or damage to the dam or appurtenant structures constitute an emergency situation. In such circumstances, the procedures outlined in the "Emergencies Procedures Data" section of this book should be followed and observations should be made on an ongoing basis over the duration of the emergency event. The vicinity of outlet structures should be inspected for possible signs of erosion and scour at low reservoir levels following extreme flooding and high water levels.

4.4 Seepage Conditions

Seepage along the toe of the dam should be collected and monitored with a weir. The depth of water through the weir should be recorded along with the reservoir level and precipitation during each weekly inspection. Any evidence of erosion suggested by increased amounts of suspended solids or sediment, or unexplained increase in flow constitutes an emergency event and should be brought to the immediate attention of the Manager of Public Works.

5.0 SITE PHOTOGRAPHS

LOWER COLLIERY SADDLE DAM

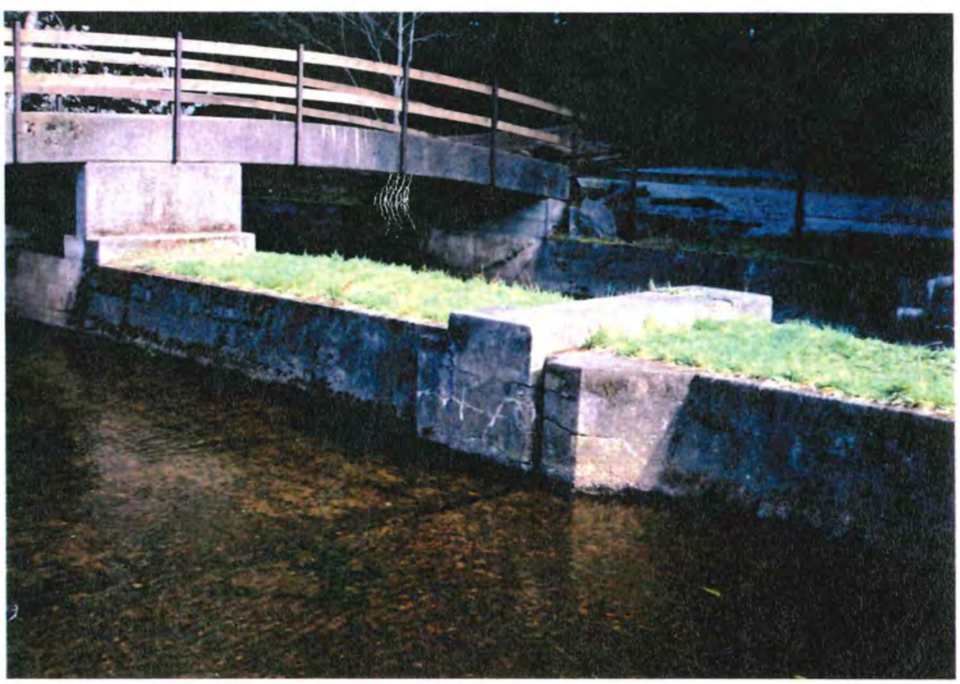
OLD CONCRETE ABUTMENT UPSTREAM OF FOOTBRIDGE AT SPILLWAY

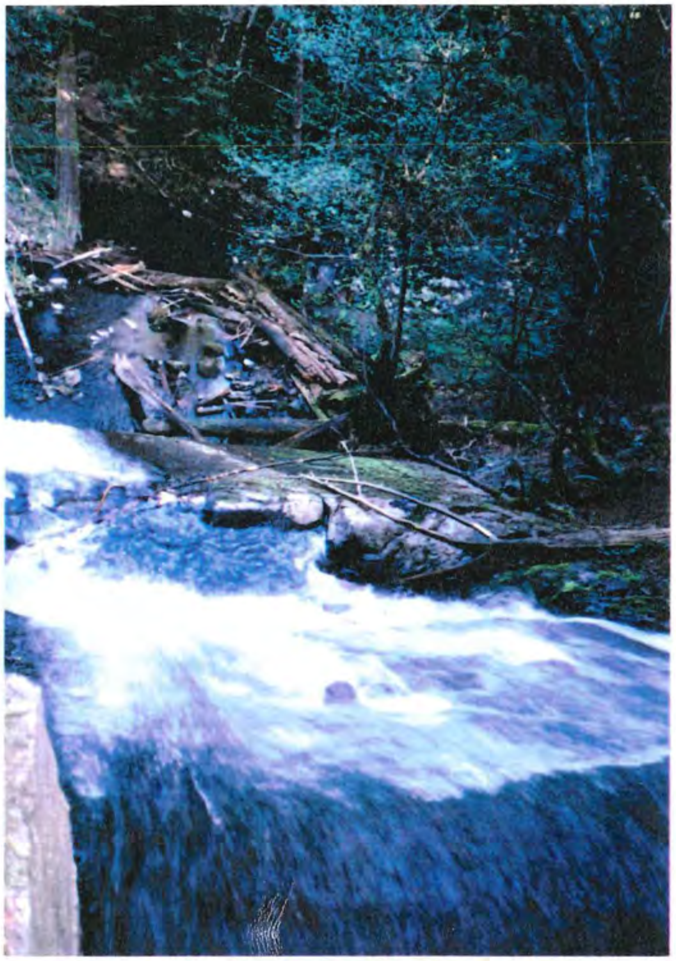
OLD CONCRETE SPALLING AND SEGREGATED BENEATH
FOOTBRIDGE AT SPILLWAY

VIEW DOWNSTREAM ON CONCRETE SPILLWAY

VIEW UPSTREAM ON CONCRETE SPILLWAY

UPSTREAM VIEW OF SPILLWAY CONCRETE CHANNELS





END OF CONCRETE SPILLWAY

APPENDIX 1A
APPLICATION FOR WATER LICENCE

FOR WATER RECORDER STAMP

Application for a Water Licence

WATER ACT

(Section 8)

I/we City of Nanaimo
(Full name or names, if land owned jointly.)

of 455 Wallace Street, Nanaimo, B. C. V9R 5J6
(Mailing address)

hereby apply to the Comptroller of Water Rights for a licence to { ~~divert and use~~ / store } water out of

Chase River which flows eastward
(Name of creek, lake, or spring.) (Direction of flow.)

and discharges into S.W. corner of Nanaimo Harbour and give notice of my application to all persons affected.

{ ~~The point of diversion~~ / The storage dam } will be located at on a bearing of South 7°00' West, a distance of 1090 feet from the intersection of Wakesiah Ave. and Harewood Road (Old Nanaimo Lakes Road)
(Give distance and direction from some surveyed or known point.)

The quantity of water to be ~~diverted or~~ stored is 140 acre-feet, constant.
(Cubic feet per second, gallons per day, or acre-feet per annum.)

The purpose for which the water will be ~~used~~ stored is Park recreation, swimming. Fisheries management activities of Fish and Wildlife Branch, Ministry of R.&C.

The land or mine on which the water will be ~~used~~ stored is Lot "A" Section One, Nanaimo Land District, Plan 15450 (C16008.001)
(Full and correct legal description)

A copy of this application was posted on the 2 (Day.) August (Month.), 1979

at the proposed point of diversion or site of the dam and on the land or mine where the water is to be used

and two copies will be filed in the office of the Water Recorder at Nanaimo British Columbia.

Objections to this application may be filed with the said Water Recorder or with the Comptroller of Water Rights, Parliament Buildings, Victoria, B.C. V8V 1X5, within thirty days of the serving of a signed copy of the application.

City of Nanaimo
Applicant.

By [signature] A. Leynard, P.Eng.
Agent.

455 Wallace Street, Nanaimo, B. C.
Agent's address.

IMPORTANT

Every applicant must do the following:

(1) *Post the application on the ground;* that is, in conspicuous places at or near the proposed point of diversion, site of the dam (if any), and place of use.

(2) *File two copies with the Water Recorder* in whose district the point of diversion will be, within twenty days of the posting on the ground.

(3) Within ninety days of the posting of the application on the ground, serve signed copies on all owners of land or mining property that will be affected physically by the proposed works or by the operation or utilization thereof, and on all licensees or prior applicants whose points of diversion are at or below the applicant's proposed point of diversion.

All copies must be signed and completed by filling in the blanks in the above form; and, in addition, the two copies filed with the Water Recorder must contain a sketch showing the applicant's land, the location of the point of diversion and the dam (if any), and all land touched or crossed by the works, and the additional information indicated on the other side of this form.

Both sides of the two copies filed with the Water Recorder must be fully and correctly completed or the application may have to be returned.

It is advisable to file the application with the Water Recorder as soon as possible after posting it on the ground because the date of filing will, in most cases, determine the priority of the licence that may be issued.

NOTE.—This sheet need only be completed on the two copies of the application filed with the Water Recorder.

To the Comptroller of Water Rights:

In support of my application for a water licence I submit the following information:—

(1) My title to the place of use is Reg. Owner: City of Nanaimo (Harewood Improvement Distri
(Whether registered owner, agreement holder, pre-emptor, etc.)

(2) The proposed works will be an earthfill dam with protected spillway and upper face,
(Give general description—pump, pipe, ditch, etc.)
about 82 feet in overall height on lower face, assumed depth of water in reservoir taken as 46 feet from Golder Associates report. Dam is existing colliery dam. Improvements are to be made. Construction plans will follow.

(3) The dam ~~to be~~ as constructed will be a earthfill with protected upper face dam, and
(Type.)
will be 82 feet in height, and 197 feet in length.

(4) The maximum area of the reservoir will be 6.15 acres.

(5) The depth of storage at the dam, from bottom of sluice-pipe to crest of the spillway, will be 46 feet.

(6) The head of water to be used will be — feet.
(For power and hydraulic mining only.)

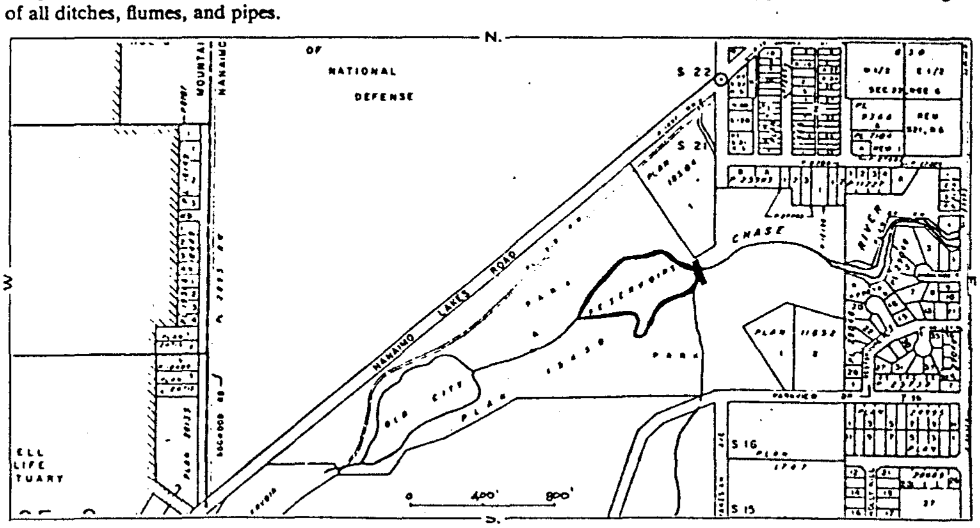
(7) The area of land to be irrigated will be storage only acres.

(8) (*a*) The works will be entirely on my own property, or

(*b*) The works will affect physically the property of the following owners:— City of Nanaimo propert

Name of Owner, Including the Crown	Legal Description of Land	Area Required for Works	
		Length	Breadth
N/A	N/A		

Sketch, showing applicant's land and all other land touched by the works or flooded, also the location of the point of diversion and other works, including buildings to be served with water, if applicable, and the lengths of all ditches, flumes, and pipes.



Lower Harewood Dam
(Lower Colliery Dam)
(Lower Chase River Dam)

City of Nanaimo
Applicant.

A. Laynard, P.Eng
Agent.

W.R.B. 4— 0

APPENDIX 1B
GOLDER ASSOCIATES REPORT
V 78040

Golder Associates
CONSULTING GEOTECHNICAL ENGINEERS

REPORT TO
WILLIS CUNLIFFE & TAIT LIMITED
ON
SITE INVESTIGATION
NANAIMO DAMS
NANAIMO, BRITISH COLUMBIA

Distribution:

4 copies - Willis Cunliffe & Tait Ltd.
Victoria, British Columbia

2 copies - Golder Geotechnical Consultants Ltd.
Vancouver, British Columbia

May, 1978

V78040

TABLE OF CONTENTS

<u>TABLE OF CONTENTS</u> (Cont'd)

1.0 INTRODUCTION

Golder Associates were retained by Willis, Cunliffe, Tait and Company Ltd. to carry out a geotechnical investigation of five existing dams within the municipal boundaries of the City of Nanaimo. The dams are designated as the: Westwood Lake, Upper, Middle, Lower Chase River and Powerline Dams. The dams are located east and south of the center of the City of Nanaimo as shown in Figure 1.

A preliminary examination of the existing dams was carried out on January 26 and 27, 1978. Based on observations at that time, and in the absence of constructions records, a field investigation program was instigated to determine as much as possible about the foundation geology, the embankment conditions, zoning, materials used as fill and the quality of construction procedure. In addition to determining the composition of the dam embankments it was intended to determine, the seepage conditions within and beneath the dams. This information was required to permit an assessment of the stability of the dams and to form the basis of recommendations to the City of Nanaimo regarding the treatment and required upgrading of the dams.

2.0 CONCLUSIONS

The general conclusions we have drawn from our study of the five dams may be summarized as follows: -

1) The Upper Chase River dam is safe and requires no further work.

2) The Westwood Lake and Middle Chase River dams appear to be in satisfactory condition at present, but we have

recommended minor improvements to the dams including construction of a seepage control ditch.

3) The Lower Chase River dam is reasonably safe but requires some additional fill placement to improve the overall downstream slope stability.

4) The Power Line dam is not considered safe and it is strongly recommended that the reservoir should not be impounded to normal pool level but should be maintained at a lower level. In order to ensure this it is recommended that the dam be breached.

3.0 SCOPE OF GEOTECHNICAL INVESTIGATION

The site investigation work for the project was performed between March 7 and March 29, 1978. Within this period, boreholes and testpits were used to determine the soil and hydrology ground water condition at the Westwood Lake Dam, Middle and Lower Chase River Dams and at Power Line dam sites. No investigation work was considered necessary at the Upper Chase River dam.

In general the drilling work did not prove to be entirely satisfactory as the earthfill used in some of the dams was too coarse to permit sampling. As a result of the difficult drilling encountered it was not possible to install all of the piezometers we had intended, which would have provided a better definition of the phreatic surface within the embankments. However, the limited data which was obtained has provided a basis on which to assess the overall stability of the structures.

Because of access difficulties it was necessary to rely on manual boring (hand auger) at the Power Line dam. At the other sites a truck mounted rotary rig was used but where the embankment fill proved too difficult to advance a standard borehole, an airtrack machine was employed to provide an indication of the material types used in construction.

Testpits were excavated using a backhoe and in areas where access was not possible, hand excavation was used to put down the testpits.

3.1 Westwood Lake Dam

Two boreholes (BH1 & BH2) and five test pits were put down at the dam site at the locations shown on Figure 2. Two piezometers were installed in BH1 to monitor the phreatic surface within the dam. Two pits (TP1 & TP3) were excavated to investigate the fill placement at the abutments and the other three pits (TP2, TP4, & TP5) were positioned to examine points of seepage discharge observed on the downstream slope.

3.2 Upper Chase River Dam

No investigation was undertaken.

3.3 Middle Chase River Dam

Three boreholes (BH3, BH4, BH5) and four testpits were put down at the dam site at the locations shown in Figure 3. The first two holes were drilled with the rotary drill rig. The drilling did not reach foundation strata. The airtrack employed for the third borehole (BH5) was successful in advancing through the dam fills. Two pits (TP1 & TP2) were excavated at the abutments while, TP3 was located at a source of seepage and TP4 was excavated immediately adjacent to the upstream concrete wall at the dam.

3.4 Lower Chase River Dam

Four boreholes (BH6, BH7, BH8 & BH9) and four pits were put down at the dam site. The locations are shown in Figure 4. Only BH9 which was drilled with airtrack equipment was able to penetrate the dam fill material with any degrees of success. Three of the testpits were put down at sources of seepage while TP4 was excavated immediately adjacent to the upstream concrete wall.

3.5 Power Line Dam

Three hand auger holes and five test pits were put down at the dam site at the locations shown in Figure 5.

4.0 DESCRIPTION OF DAMS

4.1 Westwood Lake Dam

This dam is located on the eastshore of Westwood Lake, at the south end of Westwood Road.

The dam is an earthfill embankment about 11.0 m high with a crest width of 5.0 m, and a total crest length of about 97.0 m. The dam alignment is V-shaped, as shown in Figure 2. The downstream face slopes at 2.5 horizontal to 1 vertical while the upstream face is standing at 1.6 horizontal to 1 vertical. At the time of the investigation the lake level was 1.5 m below the crest.

The dam is situated in a steep sided ravine with valley side slopes varying between 1.25 and 1.75 horizontal to 1 vertical. The right abutment of the dam when looking downstream appears to be founded on bedrock while the left abutment is founded on overburden. The exposed bedrock is massive and competent and the joints and fractures appear to be tight. Borehole 1 indicates that the right side of the dam is founded directly on bedrock and Borehole 2 indicates that the left side of the dam is founded on very dense sand with some silt and gravel.

The hydraulic control facilities are not well defined at the dam site but appear to consist of a conduit passing through the embankment. The inlet to the discharge system is not visible on the upstream side of the dam, however a conduit and control valves are located at the downstream toe of the dam near the north or left abutment. The exposed part of the conduit is a wood stave pipe. Water was flowing through the pipe under the dam at the time of the investigation and it appears that the valves could not be successfully opened or closed. The reservoir water levels are controlled by a spillway structure at the north end of the lake. The spillway was not inspected for this study.

The downstream slope was covered with grass and traces of miscellaneous garbage debris. It appears that recently the underbrush which was growing on the slope has been cut. It is understood that within the past few years, the dam was raised about 1.5 m above the original section and the concrete facing which extends from the crest to a depth of 0.9 m to 1.2 m below lake level was constructed to protect the upstream face from erosion due to wave action.

Based on information obtained from the field work it appears that the dam has a narrow impervious core zone of clayey silt with an upstream and downstream shell consisting of sandy silt with some gravel. An inferred section through the dam is shown in Figure 6. Atterberg Limits were performed on the clayey silt and gradation analysis of the sandy silt was carried out. The results of the testing are shown in Figure 10 and 11.

The field investigation indicates from the relative looseness of the materials penetrated that there was little or no effort made to compact the fill materials as they were being placed. There appears to have been some site preparation prior to placement of the fill materials as the boreholes indicated the foundation base area directly beneath the crest has been stripped of topsoil and organics. Test pits excavated at the abutments, downstream of the crest of the dam indicate, however, that not all of the topsoil and organics were stripped from the dam foundation base area prior to fill placement.

Seven sources of seepage were encountered at this dam site. Four seepage zones were noted at the downstream toe of the dam. Three of these areas were not investigated as two of them were considered to be the result of natural ground water seepage and the third was from surficial runoff. The four seepage zones at the downstream toe were investigated by test pits located as shown on Figure 2.

Seepage zone S1 was located at the toe of the dam and had an estimated discharge of about 0.5 gpm. Seepage zone S2 was located about 1.5 m above the control valve structure and minor seepage appeared to flow from the contact of the embankment fill to overburden. Gradation curves for material obtained from the above two areas are shown in Figure 12.

The third seepage zone S3 was located about 18.2 m from the left abutment and 1.8 m below the crest. Some minor seepage was flowing from a silty sand and gravel which was part of the embankment fill. It is significant to note that this seepage stopped when the level of the lake was lowered.

Seepage zone S4 was located adjacent to the wood stave pipe near the downstream toe of the dam. As mentioned in our report of February 3, 1978, the flow could be attributed to piping along the outside of the pipe, to uncontrolled seepage through the embankment or simply to a leak from the wood stave pipe close to that point. The investigation was unable to clarify this point further.

4.2 Upper Chase River Dam

The Upper Chase River Dam is located across the road from the Greater Nanaimo Water District offices. The structural composition of the Upper Chase River dam is not well defined. It is difficult to determine from visual observations the extend of the fill at this dam. The upstream face of the dam however consists of a 0.9 m thick vertical concrete buttressed wall. There is a wide granular fill berm downstream of the concrete wall. The pool level is controlled by a concrete spillway which discharges into two large diameter culverts which pass beneath Nanaimo Lakes Road. Following the preliminary inspection, this dam was considered safe and no further work was recommended for this site.

4.3 Middle Chase River Dam

This dam is situated about 1 km downstream of the Greater Nanaimo Water District offices on Nanaimo Lakes Road. It is understood that this dam was formerly the site of an old railroad crossing.

This structure appears to be an earth and rock fill dam with a 0.6 m thick vertical concrete wall upstream. Backfill material was placed upstream of the wall in the reservoir area. The dam is approximately 10.0 m high with a crest width of about 8.0 m and a crest length of about 38.0 m. The downstream face stands at about 2 horizontal to 1 vertical.

The dam is situated in a steepsided ravine with both abutments founded on bedrock. Bedrock exposures on either abutment indicate a massive rock formation with tight joints and fractures and some weathering. Borehole 5 (BH5) indicates that the underlying foundation is a sandy silt.

Adjacent to the left abutment is a 14.0 m wide unregulated spillway which is founded on bedrock. A concrete wall, runs along the right side of the spillway channel and separates the embankment fill from the spillway. The dense sandy silt forming the left side of the spillway was being eroded in several areas. At the time of the investigation a log blocked the west part of the spillway intake.

Based on local information it is understood that there is a conduit under the dam. The intake and outlet to the pipe are not visible at present. The remains of what is thought to be the control valve structure is situated a few meters upstream of the concrete wall. There is the possibility that the conduit and control valve are still in place and that the outlet to the pipe was covered during additional fill dumping some 30 years ago.

The dam appears to be constructed with a vertical concrete core with fill and rockfill end dumped on either side of the wall. The fill apparently consists of sand and gravel with some silt. At the right abutment the contact between the bedrock and concrete wall shows signs of deterioriation. An inferred section through the dam based on the results of the field work is shown in Figure 7.

At approximately chainage 0+30 m there is an opening in the concrete wall at or just below the reservoir level. This hole is covered by a wooden panel. It is understood that the opening in the wall was made about 1950 to increase the discharge capacity of the reservoir during a period of heavy rainfall which caused concern that the dam might be overtopped. At that time additional fill was end-dumped on the downstream side of the wall.

Three seepage zones were noted at the locations shown in Figure 3. Seepage zone S1 located at the downstream toe, flows at a moderate to heavy rate from a relatively clean gravel. The water was clear. The second seepage zone S2 located closer to the right abutment showed heavy flows. Significantly, this flow stopped when the level of the reservoir dropped by less than 0.5 m. Seepage zone S3, located in the valley bottom, appeared as a boil with some sand in suspension. It is considered that this seepage is related to the flows observed at S1. Gradation curves of the material taken from seepage zones S1 and S3 are shown in Figure 13.

4.4 Lower Chase River Dam

This dam is located approximately 450 m downstream of the Middle Chase River Dam. It is understood that this dam was formerly the site of an old railroad crossing.

The structure appears to be an earth and rock fill dam with an upstream concrete core wall. The dam is 24.0 m high with a crest width of 10.0 m and a crest length of about 50.0 m. The downstream face slopes at 1.6 horizontal to 1 vertical. The vertical concrete wall which forms part of the upstream face is 0.3 m thick to a level 0.6 m below the crest and then increased in thickness to 1.2 m.

The dam is situated in a steep-sided ravine which has been cut by the Chase River at this location. Both abutments are founded on the silty overburden material. Test pit 3 and borehole 9 indicate that the underlying foundation material is a dense sandy silt with some gravel. The spillway is founded on dense silt to sandy silt.

The hydraulic control facilities at the dam consist of an unregulated spillway on the right bank, and a conduit passing through the embankment fill. The outlet of the pipe projects out of the downstream face of the dam at about midheight. Water was flowing through the pipe at the time of the investigation. Three control valves are located on the upstream side of the dam. Two of the control valves are adjacent to the concrete wall and the third situated a few meters upstream of the dam face in the reservoir. It is unkown if the control valves are operating.

An inferred section through the dam is shown in Figure 8. Based on the results of the field work the dam appears to have been constructed with a concrete core wall with rockfill end dumped on either side of the wall to provide structural support. Fill consisting of slag, cinders, sand and gravel has been end dumped on the downstream side of the original dam cross-section to form the existing downstream slope of the dam. The results of the field investigation indicate the fill is very loose to loose. The results of the drilling through the rockfill indicates that some voids exist in the rockfill. These voids are up to 0.3 m size.

Seepage was noted at two points, at the locations shown on Figure 4. One seepage zone S1 was located approximately 50 m downstream of the toe on the left bank where a minor flow was observed flowing from a sand

and gravel stratum. This seepage was attributed to normal ground water discharging from the valley wall. The second seepage zone S2 was located a few meters to the left of the spillways channel on the top of the left abutment. Seepage was observed at several locations and was collected at a central low point. This water is associated with seepage flowing from under the spillway channel.

4.5 Power Line Dam

This site is located about one kilometer south east of Westwood Lake.

The embankment is 6.0 m high with a crest width of about 1.5 m and a crest length of about 60 m. Both the upstream and downstream faces slope at about 1.3 horizontal to 1 vertical with local areas as steep as 1 horizontal to 1 vertical.

The hydraulic control for this dam is apparently provided by a conduit passing under the embankment. The conduit was observed at the downstream toe at Station 0+20. The pipe outlet and control value could not be located. The system is operational as it is being used to maintain the pool level at about 3 m below the crest level.

The structural composition of this dam is difficult to define, but based on the shallow testpits and auger holes put down during the investigation, the dam is considered to be an earthfill structure with a timber crib maintaining the earthfill.

Trees of up to 0.6 m diameter were growing on the crest and downstream slope. On the upstream face at station 0+32 a beaver hole was observed at pool level. It was not possible to determine how far this hole extended into the face of the dam. A beaver's lodge was observed adjacent to this hole on the east abutment.

Both abutments are founded on overburden at the site. The general embankment fill consists of sandy silt with some gravel, roots and organics. The investigation holes indicated the fill is underlain by 0.3 to 0.6 m of burnt topsoil and organic matter. The topsoil layer is underlain by a soft to firm clayey silt. On the left abutment bedrock was encountered at a depth of 0.2 to 0.9 m.

An inferred section through the dam is shown in Figure 9. The results of the investigation indicate that a minimum of site preparation was carried out prior to placing the fill material for the dam.

A small amount of water was observed discharging at seepage zone S1. This flow was apparently flowing through the conduit under the dam. No undefined sources of seepage were observed along the downstream toe of the dam. The area immediately downstream of the dam was swampy due to poor general site drainage.

5.0 ASSESSMENT OF DAM SAFETY

5.1 General

The case histories of unsatisfactory earth and rockfill dam performances show that the major number of failues are associated with overtopping of the embankments, erosion along conduits or conrete structures passing through the fill, uncontrolled under-seepage; or to instability of the slopes during certain loading conditions.

5.2 Types of Problems Considered

The work we have done in order to assess the safety of these five dams consisted of:-

a) A detailed inspection of the embankments in the field to determine if there were any obvious external cause for concern such as cracks, slumping, unclean seepage etc.

b) A subsurface investigation program at four of the sites to determine the composition of the embankments and to examine areas of seepage.

c) A series of stability analyses of the embankment downstream slopes to evaluate the stability of the face.

An important consideration in each case however was the fact that the dams have been in existance for a long time, probably about 50 years. This indicates that if there is no change in the stresses imposed on the dam, and if the embankments do not deteriorate for other reasons, the structures are safe. The effects of earthquake loading or large flooding would be examples of new loads; erosion of the toe of the dam or settlement of the crest would be examples of deterioration.

The drilling investigation was intended to provide data so that an understanding of the embankment zoning, and the type of materials and quality control used in the construction could be evaluated. This phase of the work was only partially successful due to the nature of the embankment fills encountered. However, we consider that the data we have been able to obtain at this time is sufficient to form the basis for an opinion regarding the structural integrity of the dams.

5.3 Stability Analyses

Stability analyses were performed for the Westwood Lake, Middle and Lower Chase River dams. The analyses are based on the soil conditions as encountered from the drilling program and the cross-sections as shown in Figures 6, 7 and 8.

The slope stability of an embankment is usually considered at four critical times in the life of the dam: immediately after construction, during rapid reservoir drawdown, during earthquakes, and finally under the seepage pressures which exist on the downstream slope with the reservoir full. Because all of these dams have been operating successfully for many years we consider it reasonable to discount the first two possibilities. In addition available records show that tremors up to 7.3 on the Richter scale have occurred within a 120 Kilometer radius of the site. We have therefore not considered earthquake loading as a new stress condition, provided the other cases are not marginal. Consequently we have narrowed our examination of stability to the case normally referred to as "steady state seepage".

The Janbu and Bishop stability methods were used for calculating the factors of safety. The Bishop analysis was used to assess the stability of the rockfill section of the Lower Chase River dam. The soil properties and parameters used in the analyses and the resulting factors of safety are summarized in Table V.

Our analyses indicate that the downstream slope of the Westwood Lake and Middle Chase River Dams generally have a factor of safety above 1.5 but range from 1.4 to 1.7 against a deep seated overall failure. The downstream slope of the Lower Chase River dam has the lowest computed factor of safety against a deep seated failure since the failure surface examined was mainly through the loose slag fill. A factor of safety of 1.2

was calculated for the rockfill, assuming that the loose slag fill did not exist. This is a very conservative assumption as the overall stability does include the effect of the slag fill. The factor of safety, considering the total dam section, is 1.4.

To define the factor of safety for each dam to a greater degree of accuracy would require more field work and monitoring of the phreatic surfaces in the dams for an extended time period. This is not considered necessary at this time as the resulting refinement to the analyses would not alter the overall results significantly.

6.0 RECOMMENDATIONS

6.1 General Maintenance

We believe that the following precautions and maintenance be undertaken on a routine basis in order that any deterioration in the present conditions of the dams does not go undetected and that the dams will not be subjected to unusually high loading.

1) The vegetation on the downstream slope, toe, and abutments be cleared so that any erosion, excess seepage or other deterioration does not go unnoticed.

2) The seepage be collected and measured wherever possible at one point, to determine if there is an abnormal (with reference to reservoir level) increase in underseepage.

3) The crest be inspected to detect localized settlements or cracking.

4) The spillways be kept clear to prevent build up in pond level above the normal storage level.

5) Inspection be made at the outlet end of conduits passing through the embankments to ensure that retrogressive erosion of the fill in contact with the pipe is not occurring.

6.2 Westwood Lake Dam

We recommend that the seepage water leaking from the downstream slope of the embankment be collected by an interceptor ditch cut parallel to the downstream toe. The flow in the interceptor ditch should be carried to the creek through a simple flow measurement device such as a V-notch weir. Construction details are shown in Figure 14. The backfill filter material should be a 40 mm minus pit run sand and gravel with less than 8 per cent passing the No. 200 sieve. The proposed gradation of the material is shown in Figure 15.

The conduits and control valve system at the dam site should be fully defined and repaired. The reservoir level is controlled by a spillway at the north end of the lake. This spillway should be checked on a regular basis to ensure it is operating so the dam will not be overtopped.

The piezometers which were installed during the drilling program should be read on a monthly basis for the next year to provide information on the phreatic surface within the dam with respect to reservoir level.

6.3 Upper Chase River Dam

This structure appears quite safe and we have no specific recommendation regarding methods to enhance its security. However, this dam also should be subject to routine inspections to ensure a deterioration in the facility does not go undetected.

6.4 Middle Chase River Dam

We recommend that a downstream seepage interceptor ditch similar to that described in section 6.2 be used to collect water passing through the embankment. Details of the ditch are shown in Figure 14. The backfill filter material should be a 40 mm minus gravel with less than 10 per cent passing No. 10 sieve. The proposed gradation of the material is shown in Figure 16.

The conduit and control valve system should be properly defined and made functional. The spillway concrete should be repaired to prevent further deterioration and possible leakage along the embankment - concrete contacts. It is recommended that the spillway chute right wall should be extended further downstream to prevent discharge water from the spillway flowing into the valley near the toe of the dam. The exposed soil on the left wall of the spillway should be faced with concrete or protected to prevent possible erosion of the exposed soil at high discharge flows.

The hole which was cut in the upstream concrete wall should be plugged with concrete or otherwise permanently sealed.

6.5 Lower Chase River Dam

We recommend that the seepage water from beneath the spillway should be located and the source covered with a designed granular filter. The discharge should then be channelled to the spillway chute or some other point which is remote from the dam.

The conduit and control valve system should be examined and made functional.

The safety against shear failure of the steep downstream face is considered to be adequate for normal operation. It is recommended that due to the location and presence of a residential development downstream, the factor of safety should be upgraded to a minimum of 1.5 against rotational failure. In order to achieve this, fill should be placed against the downstream slope. It is considered desirable to decrease the overall slope of the downstream face from its present inclination of 1.6 horizontal to 1 vertical to a slope of 2 horizontal to 1 vertical. Alternatively, a weight berm may be used to achieve the same end. The dimensions of the berm have not been determined at this time as further study would be required. A preliminary estimate indicates a berm 11 m high, from the valley bottom up the existing downstream slope, with a top width of 5 m, would be sufficient to provide the desired increase in stability. The downstream slope of the berm would be constructed at 2 horizontal to 1 vertical. This berm would be constructed with a clean pit run sand and gravel with a designed toe drain along the valley bottom to collect any seepage which may enter the berm.

6.6 Power Line Dam

We consider that this structure is unsafe for the following reasons:

1) Unsatisfactory site preparation prior to construction.
2) Poor embankment construction containing degradable materials
3) Inadequate crest width.
4) Sideslopes which are overly steep.
5) Large trees growing on dam face and crest.
6) Beaver holes in the upstream slope fill.
7) Discharge facilities which are ill-defined and could lead to overtopping.

8) Difficulty of access to site if maintenace required.

We recommend that positive measure be taken to prevent the Power Line dam from being reimpounded to normal reservoir level. The pool level should be maintained at about 3 m to 5 m below present crest level by whatever means are considered most economic. The discharge conduit should not be relied upon in this regard as it might become plugged by debris or inoperative. Breaching the dam is probably the most direct means of dealing with the problem.

It is not considered practical to attempt to improve the safety of the existing embankment as the foundation conditions are poor. It is recommended that if it is decided to maintain a dam at this location a new structure should be built. Based on field observations a suitable site appears to be immediately downstream of the present dam. It is recommended however that a more detailed appraisal for a new site and an investigation of sub-surface conditions be carried out before a decision is made on construction of a new dam to impound the reservoir at this location. In addition the two saddle dams at the other end of this reservoir would have to be investigated and probably rebuilt.

We trust this provides the information you require at this time. We would be pleased to assist you if additional work for this project is required.

Yours very truly,

GOLDER GEOTECHNICAL CONSULTANTS LTD.

R.M. Wilson, P. Eng.

J.A. Hull, P. Eng.

RMW/JAH/ld

V78040

TABLE III
RECORD OF TEST PITS

C. Lower Chase River Dam

Testpit No.	Depth (meters)	Strata Description
1	0 - .3	Loose SLAG, CINDERS, COAL (Fill)
	.3 - .6	TOPSOIL & ORGANICS
	.6 - 1.2	Firm, brown sandy, gravelly SILT roots, occ. cobble
2	0 - 1.2	Loose slag, some SAND & GRAVEL (FILL)
3	0 - .9	Loose SLAG, CINDERS & ROOTS (Fill)
	.9 - 1.2	Dense, grey brown, silty gravelly SAND, some cobbles (Till-like).
4	0 - 1.5	Loose CINDERS, SLAG, sand roots. (Fill)
	1.5	ROCKFILL

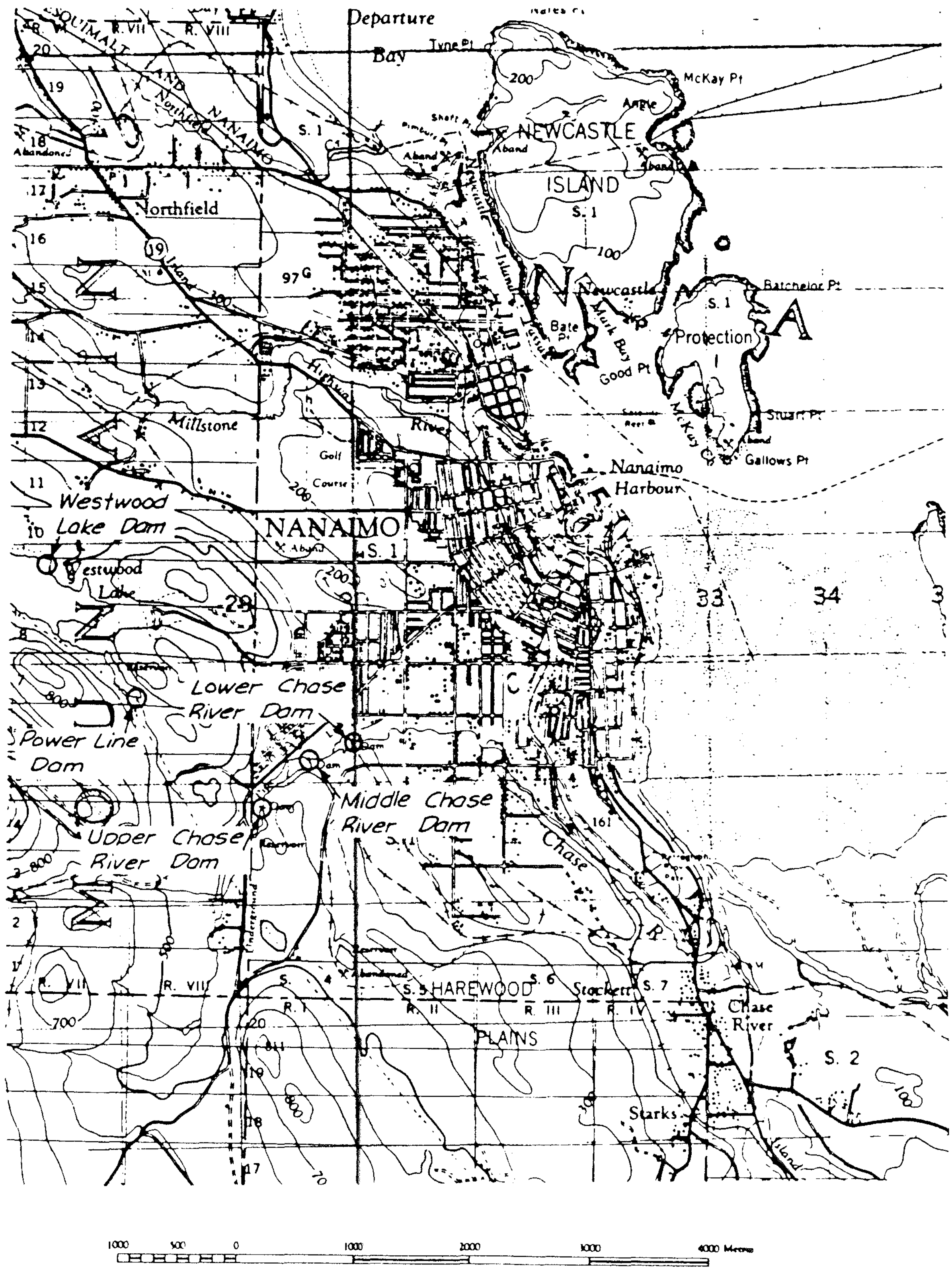
TABLE V
Summary of Stability Analysis

Dam	Friction Angle Ø	Cohesion	Unit Weight Kg/m^3	Calculated Factor of safety	Depth of Selected Failure Surface
A. Westwood Lake	27°	0	2002	1.9	Shallow
	27°	0	2002	1.4	Deep
B. Middle Chase River	35°	0	2002	2.5	Shallow
	35°	0	2002	1.9	Deep
	32°	0	2002	1.7	Deep
C. Lower Chase River	30°	0	1282	1.9	Shallow in slag, etc.
	33°	0	1282	1.7	Shallow in slag etc.
	38°	0	2243	1.2	Deep rockfill
	30° 38°	0 0	1282 2243	1.4	Deep through slag and rock fill.

Note: Factors of safety are calculated for static loading conditions.

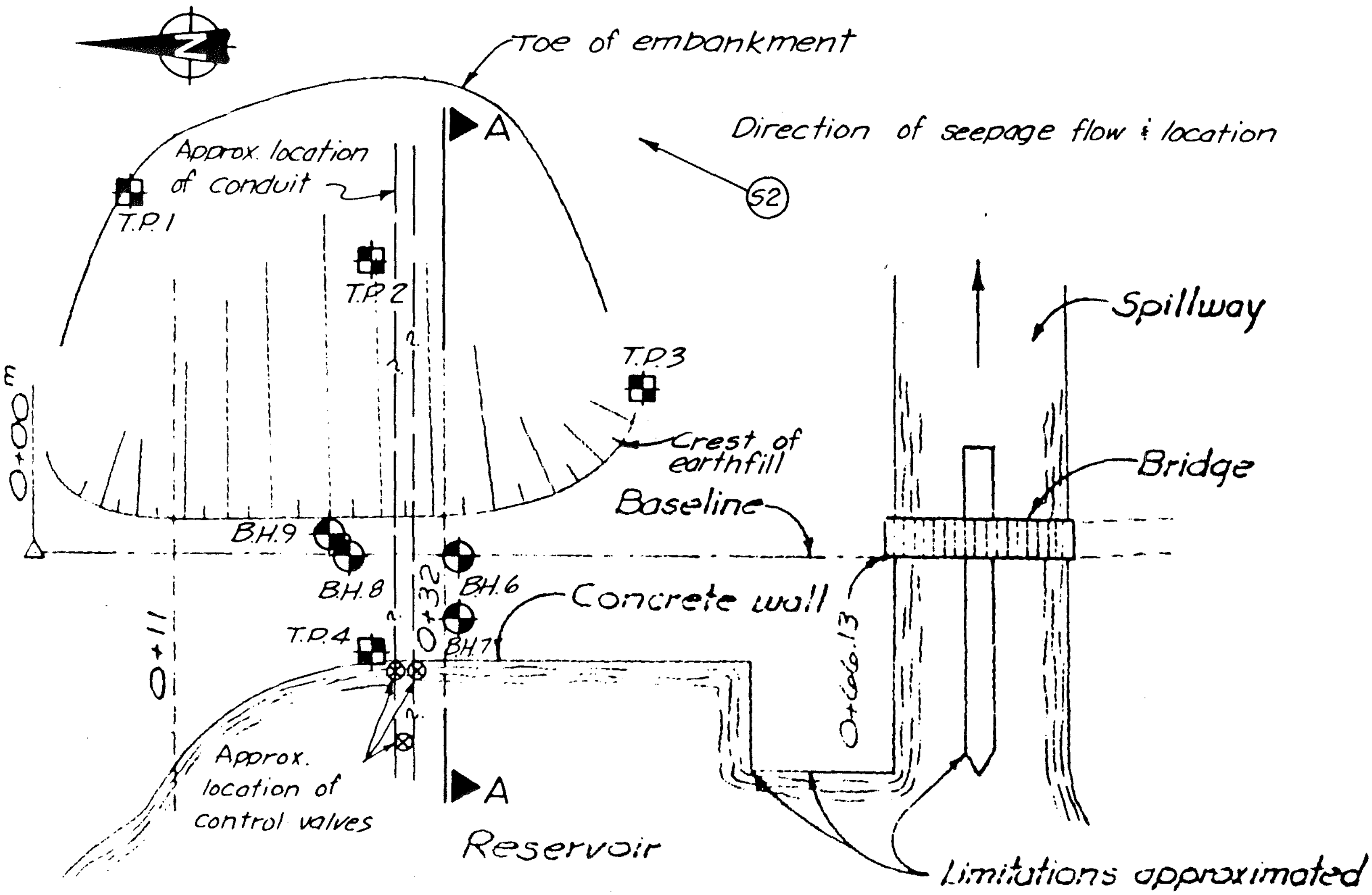
KEY PLAN

Figure 1



V78040 R.D APR.78

V78040 R.D Apr. '78



Scale : 1 : 500

LEGEND

Hand Dug Test Pits

Test Pits Excavated by Backhoe

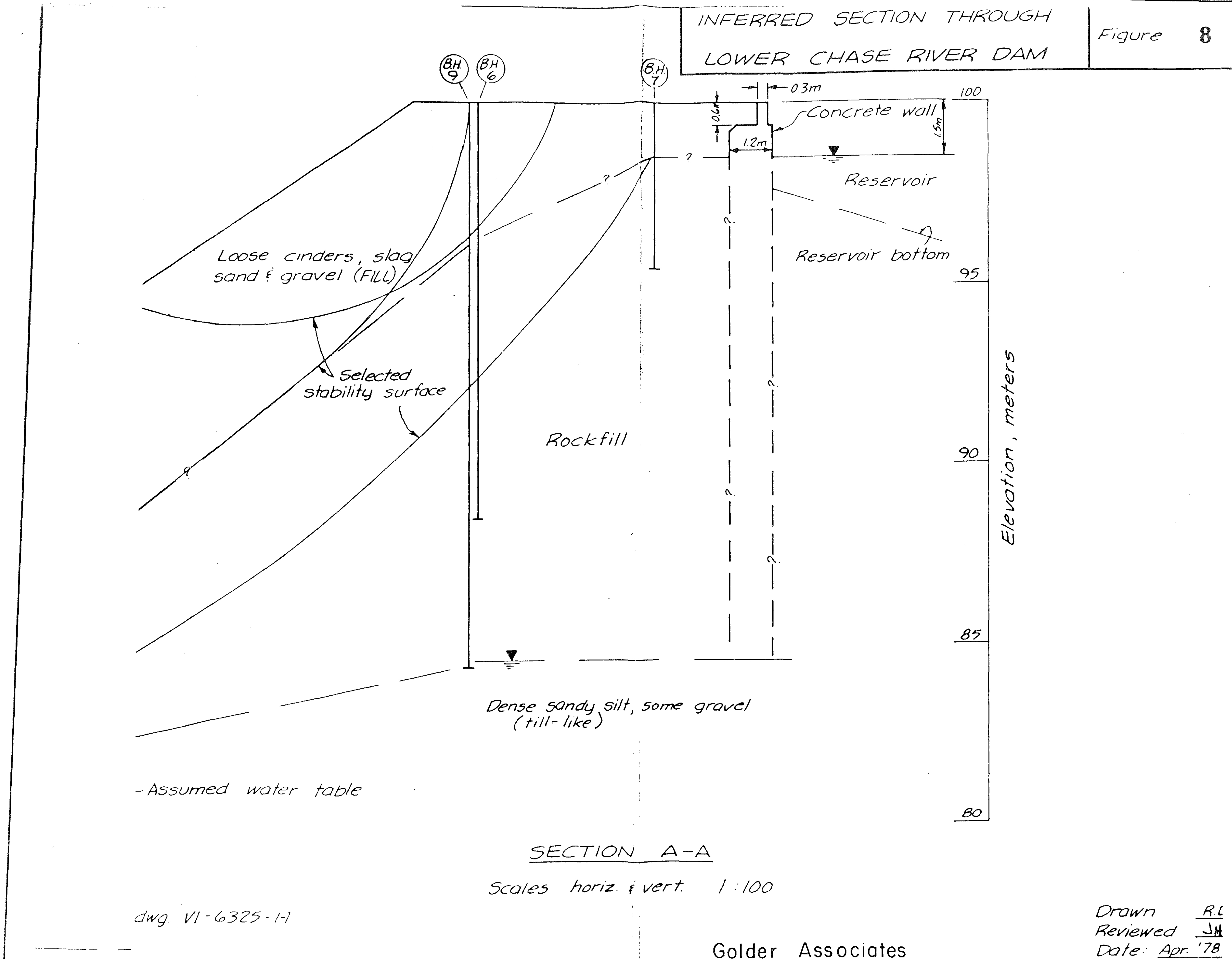
Borehole

REFERENCE

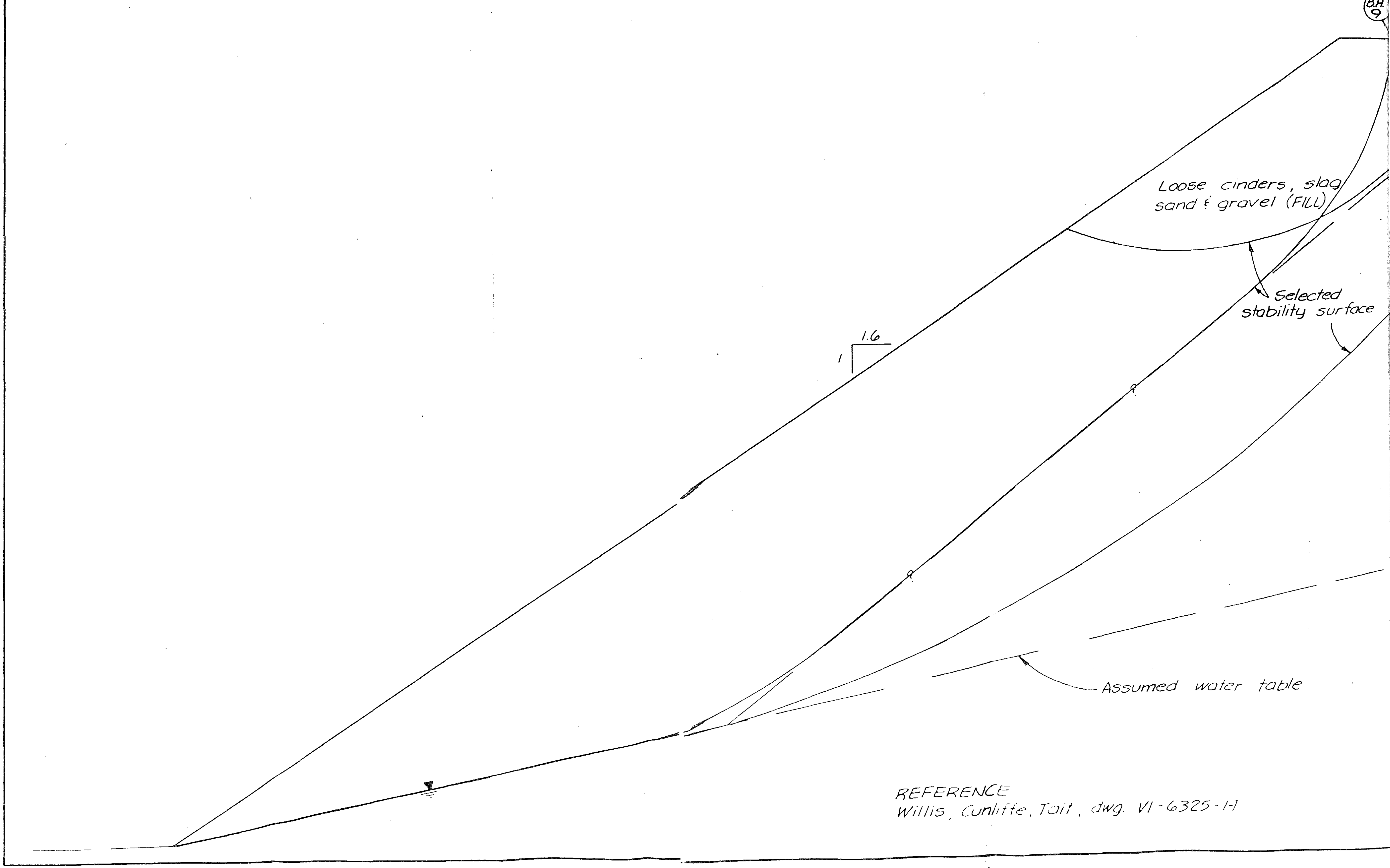
Taken from Willis Cunliffe Tait dwg. VI 6325-1-1

SITE PLAN
LOWER CHASE RIVER DAM

Figure 4



INFERRED SECTION THROUGH
LOWER CHASE RIVER DAM
Figure 8
B.H. 9
B.H. 6
B.H. 7
0.3m
0.6m
1.2m
1.5m
Concrete wall
Reservoir
Reservoir bottom
Loose cinders, slag
sand & gravel (FILL)
Selected
stability surface
Rockfill
Dense sandy silt, some gravel
(till-like)
100
95
90
85
80
Elevation, meters
– Assumed water table
SECTION A-A
Scales horiz. & vert. 1:100
dwg. V1-6325-1-1
Golder Associates
Drawn R.L
Reviewed JH
Date: Apr. '78
V78040



REFERENCE
Willis, Cunliffe, Tait, dwg. VI-6325-1-1

Project No. 178042 -

RECORD OF BOREHOLE 6

LOWER CHASE RIVER DAM

LOCATION (See Figure 2)

BORING DATE March 14, 1978

BOREHOLE TYPE Rotary

BOREHOLE DIAMETER 114 mm

SAMPLER HAMMER WEIGHT 63.6 kg. DROP 762 mm

DATUM W,C,T, Dwg. VI 6325-1-1

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.3	Ground Surface							
0.0	Very loose cinders, slag, etc. (FILL)		1	D.O.	4			
			2	"	1/18"			
97.8 / 2.5	Loose to compact SANDS GRAVELS, COBBLES (FILL)		3	"	9	Lost		
96.6 / 3.7	Loose gravels cobbles & boulders (ROCKFILL)							Lost mud circulation
			4	"	17			
			5	"	22	Lost		
			6	"	>100	Lost		Hole cased to 10.3 lost mud circ at 10.3m, no return 10.3m - 11.6 m
88.7 / 11.6	End of Borehole							Stopped because possibility of jamming rods in hole, also casing damaged from driving into rockfill

VERTICAL SCALE 1 : 100

Golder Associates

DRAWN R.D.

CHECKED G.

Project No. V78042

RECORD OF BOREHOLE 7

LOWER CHASE RIVER DAM

LOCATION (See Figure 2) BORING DATE March 15, 1978

BOREHOLE TYPE Rotary BOREHOLE DIAMETER 114mm

SAMPLER HAMMER WEIGHT 63.6 kg DROP 762 mm DATUM WCT Dwg. VI 6325-1-1

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.3	Ground Surface							
0.0 98.8	Loose, rust brown fine to coarse SAND, some gravel trace silt & cinders (FILL)		1	DO	17			
1.5 95.7	Very coarse gravels with cobbles & boulders (ROCKFILL)		2	"	16	lost		- Lost mud circ. at 1.5m - drill with air to 4.6m - no return - stopped because of possibility of jamming rods in hole.
4.6	End of Borehole							

VERTICAL SCALE 1 : 100

Golder Associates

DRAWN B.D.
CHECKED [illegible]

Project No. V78042

RECORD OF BOREHOLE 8
LOWER CHASE RIVER DAM

LOCATION (See Figure 2) BORING DATE March 16, 1978

BOREHOLE TYPE Rotary BOREHOLE DIAMETER 114 mm

SAMPLER HAMMER WEIGHT 63.6 kg. DROP 762 mm DATUM W, C, T Dwg. VI 6325-1-1

SOIL PROFILE								
ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.3	Ground Surface							Drill with air
	Loose black SAND GRAVEL, SLAG, CINDERS (FILL)							
96.9 / 3.4	Loose coarse GRAVELS COBBLES & BOULDERS (ROCKFILL)							- hole cased to 6.7 m. No return from 6.7 - 8.1 m
92.2 / 8.1	End of Borehole							- driving shoe for casing damaged

VERTICAL SCALE 1 : 100

Golder Associates

DRAWN B.D.
CHECKED G

Project No. V78040

RECORD OF BOREHOLE 9
LOWER CHASE RIVER DAM

LOCATION (See Figure 2)

BOREHOLE TYPE Air Track

BORING DATE March 28, 1978

BOREHOLE DIAMETER 50 mm

DATUM WCT Dwg. VI 6325-1-1

SOIL PROFILE								
ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.3	Ground Surface							
0.0	Loose cinders, sand, gravels							
95.7 / 4.6	Cobbles & boulders (ROCKFILL)							- lost air circ. at 4.6m - no return
85.4 / 14.9	TILL-LIKE MATERIAL							
84.8 / 15.5	End of Borehole							

VERTICAL SCALE 1 : 100

Golder Associates

DRAWN B.D.
CHECKED

APPENDIX 1C
INSPECTION FORM
MAINTENANCE REPORTS

DAM INSPECTION REPORT

DAM: ______________________________

DATE OF INSPECTION: ______________ INSPECTOR: ______________

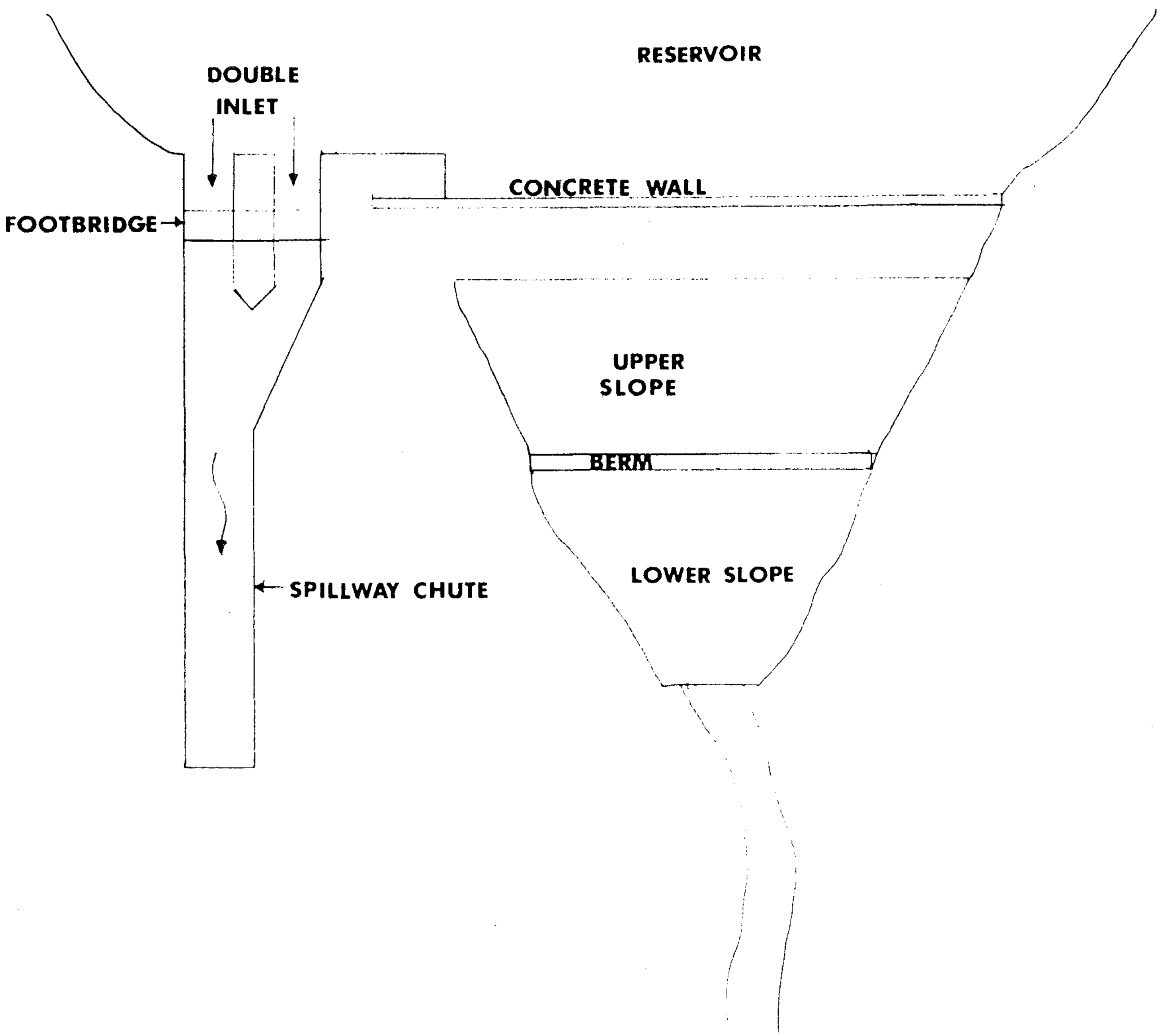
TYPE OF INSPECTION: Weekly Monitoring ☐
Monthly Monitoring ☐
Detailed Inspection ☐
Special Inspection ☐ Reason: ______________

WEATHER: ______________ RESERVOIR LEVEL: ______________

	None	Comments
Reservoir Water Quality		
Bank Stability		
Trees Toppling		
Erosion		
Debris in Reservoir		
Log Booms and Anchors		
Embankment Crest: cracking		
settlement		
Roadworks		
Downstream Slope: grass cover		
erosion		
trees		
cracking		
settlement		
wet areas		
seepage through weir		
Upstream Face: spalling		
cracking		
erosion		
scaling		
exposed reinforcing steel		
Spillway Inlet Debris		
Concrete spalling		
cracking		
erosion		
scaling		
exposed reinforcing steel		
movement		

DAM INSPECTION REPORT

		None	Comments
Slope Erosion			
Invert	spalling		
	erosion		
Stilling Basin	debris		
	water quality		
	erosion		



MAINTENANCE RECORD

DAM: ____

DATE: ____________________

REASON FOR WORKS: ____________________________

____

____

____

DESCRIPTION OF MAINTENANCE WORKS:

____

____

____

____

____

____

RELEVANT INFORMATION: ____________________________

____

____

____

NAME: ____________________

APPENDIX 1D
COMPLETED INSPECTION FORMS AND MAINTENANCE RECORDS

SECTION 2
EMERGENCY PROCEDURES

EMERGENCY PROCEDURES

Section 2

TABLE OF CONTENTS

1.0 STATIC DATA

The static data for the Lower Chase River Dam is summarized in Table 2-1.

TABLE 2-1

Item	Data	Comments
Name:	**Lower Chase River Dam**	Also referred to as: Lower Colliery Dam, Lower Harewood Colliery Dam, Howard No. 4 Dam and Harewood No. 2 Dam
Hazard Classification:	**B**	M of E criteria, dam is considered to be "major". "Disaster Potential Classification" estimated to be "B"
Co-Ordinates:	**N 5446292 E 430138**	As determined by Wright, Parry, Taylor & Fuller in February 1992
Structure Type:	**Earth fill, rock fill and mine waste dam with 1.2m thick vertical, concrete cut off wall**	
Height of Dam at Crest:	**23.3m**	As measured by Wright, Parry, Taylor & Fuller, February 1992
Width of Dam at Crest:	**77m**	As measured by Wright, Parry, Taylor & Fuller in February 1992
Storage Capacity for Reservoir:	**17.3 Ha-m**	Quantity of water stored is 17.3 Ha-m (140 acre-feet), as per water license. Note: This should be confirmed.
Water License Data:		See application for Water License in Appendix 1A. Licensed on November 23, 1984.
Owner Information:	**The City of Nanaimo**	
Year of Construction:	**1910 to 1920**	Believed to have been completed in about 1910 by Wakesiah Colliery.

2.0 EMERGENCY SITUATIONS

A list of occurrences which are considered Emergency Situations are included as Table 2.2. Also in this table is a list of authorities to be contacted in each case.

Refer to the **Emergency Response Plan Contact List (Appendix 4)** for phone numbers of each contact.

TABLE 2.2
EMERGENCY SITUATIONS

Description of Occurrence	Contact
1. Failure or incipient failure of the dam.	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies
2. Overtopping or incipient overtopping of dam (water level at top of upstream concrete wall).	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies
3. Occurrence of damaging earthquakes or severe storms.	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies
4. Slumping, cracking or bulging of the dam, abutments or reservoir slopes.	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies
5. Damage to or movement of the spillway walls or invert.	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies
6. Occurrence of new springs, seeps or boggy areas.	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies

7. Fire (forest or structural)	Fire Department And Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies
8. Drownings or other accidents to persons.	Ambulance and Police
9. Criminal activity such as damage to property	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla
10. Significant fish or wildlife losses in the reservoir.	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies Province of BC – Fish & Wildlife Branch
11. Oil and hazardous substance spills.	Director of Eng. & Public Works, Mac Mackenzie Manager of Utilities, Scott Crane Water Supply Foreman, Ritchie Fulla And Ministry, WLAP, Environmental Emergencies

3.0 NOTIFICATION INFORMATION

3.1 Telephone

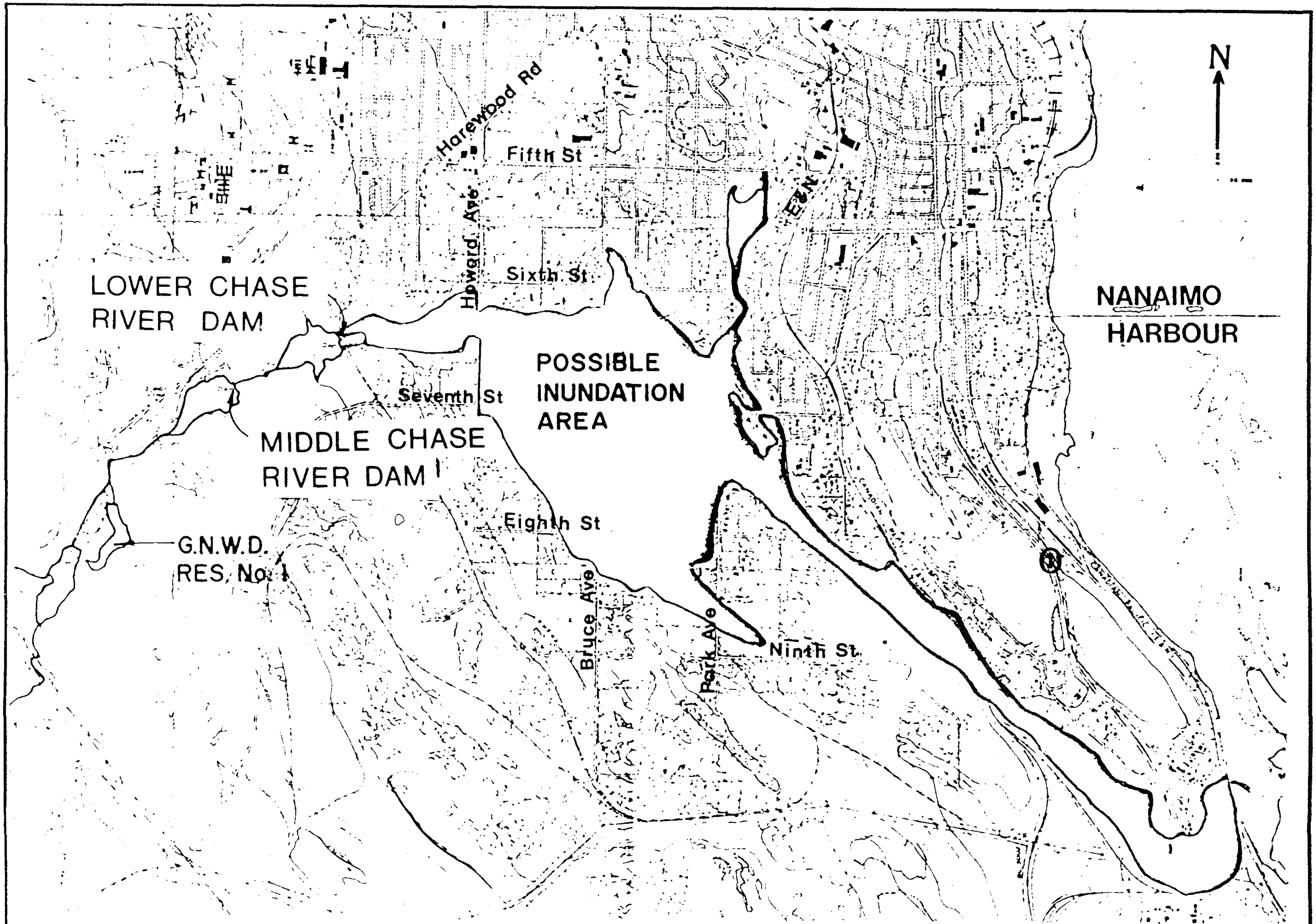
The nearest telephone is located at the Greater Nanaimo Water District office which is approximately 1.3 km upstream (south) of the Lower Chase River Dam.

3.2 Directory

When an emergency situation has been identified, the Manager of Utilities or Water Supply Foreman must be notified. Refer to red divider near the back of this book which contains the **Emergency Response Plan Contact List (Appendix 4)** and phone numbers of each contact.

3.3 Inundation

A map of the southern part of the City of Nanaimo showing the area inundated by a release of the Chase River reservoirs follows:



LOWER CHASE RIVER DAM

Figure 2

4.0 EMERGENCY PROCEDURES

The City of Nanaimo employee responsible for the day-to-day maintenance and the inspections of the dam is referred to as the tender. The dam tender works under the supervision of the Water Supply Foreman, Ritchie Fulla.

4.1 Uncontrolled Release of Reservoir

If the dam is failing, it is unlikely that there is any site action which can be taken to delay or prevent the occurrence. Therefore, the highest priority for the tender is to alert the Emergency Response Authorities of the situation. When a failure is discovered, the tender should:

a) Contact the Manager of Utilities, Scott Crane or Water Supply Foreman, Ritchie Fulla.
b) Establish with the supervisor who is to contact the various authorities. Refer to the **Emergency Response Plan Contact List** to notify the appropriate authorities.
c) Contact those authorities assigned to the tender.
d) Rope off the dam access.
e) Contact the City of Nanaimo's Manager of Utilities to verify the above action has been taken.
f) Attend the dam such that the public is discouraged from entering the area.

4.2 Overtopping

In the event of high reservoir level, (i.e. at or above the top of the upstream concrete wall) the tender should:

a) Contact the City of Nanaimo's Manager of Utilities, Scott Crane.
b) Begin placing sandbags on the crest of the dam. Sandbags are available from the Public Works Yard.
c) The high outflow from the reservoir may cause distress to the footbridge and the weight of the sandbags will help to keep it in place.
d) Take a reading of the reservoir level every 30 minutes and report these to the City of Nanaimo's Manager of Utilities.
e) Maintain regular contact with the City of Nanaimo's Manager of Utilities such that person is aware of any changes in the situation. A schedule of times for telephone calls should be arranged, for example every hour on the hour.

4.3 Earthquake or Severe Storm

In the event of an occurrence such as an earthquake or severe storm, the tender should:

a) Do an inspection of the dam, spillway and reservoir to assess the conditions and identify any changes or potential problems.
b) Contact the City of Nanaimo's Manager of Utilities and agree on what action should be taken.

4.4 Other Damage

When other damage to the dam, reservoir or spillway is noticed, or an increase or change in the seepage, the City of Nanaimo's Manager of Utilities should be notified immediately. Subsequently, the affected area should be closely monitored and any changes noted. If the area poses a threat to the public, it should be roped off and attended for the protection of park users.

4.5 Fire

In the case of a fire the tender should:

a) Contact the Fire Department.
b) Contact the City of Nanaimo's Manager of Utilities.
c) Attempt to keep the public well clear of the area.

4.6 Drownings or Other Accidents

The tender, being the City officer on the scene, should ensure that the ambulance and police are immediately summoned and that first aid is made available to those in need.

Once these measures have been taken, the City of Nanaimo's Manager of Utilities should be advised of the occurrence.

4.7 Criminal Activity

Once the RCMP and City of Nanaimo's Manager of Utilities have been notified, the affected area should be roped off and the public kept clear such that no further disturbance to the site occurs.

4.8 Hazardous Spills or Significant Fish or Wildlife Losses

Should the tender become aware of one of these conditions he should:

a) Have the reservoir area cleared of people fishing or swimming.
b) Contact the City of Nanaimo's Manager of Utilities and agree which agencies should be telephoned and by whom.
c) Contact those agencies assigned to the tender.
d) Install stoplogs at the spillway and at the Middle and Upper Chase River Dams spillways to delay the spread of the harmful effects.
e) Attend the dam such that the public is discouraged from entering the area.

APPENDIX 4

EMERGENCY RESPONSE PLAN CONTACT LIST

EMERGENCY RESPONSE PLAN CONTACT LIST

First Prepared: ***January 1997***
Updated: ***June 2003***

DEPARTMENT & TITLE	NAME	BUSINESS PHONE	RESIDENCE PHONE	CELL PHONE	OTHER CONTACT	
WATER WORKS PERSONNEL						
Chief Commissioner GNWD	Mac MacKenzie	756-5301	741-8197	755-9788		
GNWD Superintendent	Wayne Hansen	755-4409	758-1319	755-6098		
Manager of Utilities	Scott Crane	756-5305	1-250-468-5825	755-5930		
Water Supply Foreman	Ritchie Fulla	756-5324	756-4534	755-5731		
EMERGENCY COORDINATION CENTRE						
Nanaimo Emergency Program Coordinator	Jim Kipp	753-5212	753-9309	714-9519	Fax	753-5100
EOC Fax No.					Fax	753-5480
Director EOC, Gen. Mgr. Comm. Serv.	Andy Laidlaw	756-5346	758-4578	755-5636	EOC	
Alternate	Dave Nichols	755-4474	754-1841	714-4019		
WEYERHAEUSER CANADA LTD.						
Division Manager	Jim Sears	245-6360	390-9078	741-6842		
Superintendent, Forestry	Brad Rodway	245-6330	1-250-752-8097	714-8339		
Superintendent, Cowichan Operations	Jon Slater	1-250-246-5481	390-0662	1-250-246-5724		
Weekend Duty (Safety Net Security)	Brian Guzda Joe Plant			755-9623 701-1782		
FIRE DEPARTMENT						
Emergency		**911**				
Fire Chief	Ron Lambert	755-7550	245-3976	714-9924	EOC	
Deputy Chief	Keith MacDonald	755-7551	758-2138	755-5708	EOC	
Deputy Chief	Doug Angrove	755-7552	758-4474	755-9858		
Assistant Chief	Wade Smith	755-7553	722-2836	741-4722		

DEPARTMENT & TITLE	NAME	BUSINESS PHONE	RESIDENCE PHONE	CELL PHONE	OTHER CONTACT	
POLICE						
Emergency		**911**				
RCMP	Watch Commander	754-2345				
A/O.I.C.	Inspector Jeff Lott	755-3230	753-6775	714-8101 Pgr1-800-456-6771	EOC	753-5417
Second I/C	S/Sgt. Randy Munroe	754-2345	390-0805	729-5188	EOC	753-5417
AMBULANCE						
Emergency		**911**				
Administration		741-5500		616-9623	EOC	753-5608
PROVINCE OF BRITISH COLUMBIA						
Provincial Emergency Program (PEP) Victoria	1-800-663-3456 24 hrs. Switchboard Jim Whyte, VI Regional Mgr	 1-250-952-5848 1-250-952-4544				1-800-663-3456 24 hrs.
Acting Head Dam Safety (Victoria)	Will Jolley	1-250-387-3263	1-250-477-5541	812-1603	Fax	952-6792
Senior Dam Safety Officer (Victoria)	Scott Morgan	1-250-387-3265				
Regional Dam Safety Officer (Nanaimo)	John Baldwin	741-5685	756-4977	616-3340	Fax	741-5686
Engineer Under the Water Act	George Bryden	741-5680			Fax	741-5686
Fish and Wildlife Branch	Margaret Hennigman	751-3214				
CENTRAL VANCOUVER ISLAND HEALTH REGION						
Vancouver Island Medical Health Officer on Call		1-250-361-8887				
Medical Health Officer	Dr. Fred Rockwell	740-6988		616-6711		
Chief Public Health Inspector	David Coombe	755-6215	756-9625	616-6708		
Regional Public Health Engineer	Murray Sexton	755-6215				
Regional Water Specialist	Ed Walsh	755-6215	1-250-248-0345			
TESTING LABS						
B.C. Research	Susan Ewing	1-604-224-4331 Ext. 231	After Hours: 1-604-228-8967			

DEPARTMENT & TITLE	NAME	BUSINESS PHONE	RESIDENCE PHONE	CELL PHONE	OTHER CONTACT	
Cantest Ltd.	Walter Brandl	1-604-734-7276	After Hours: 1-604-680-2049 Pgr.			
UTILITIES						
B.C. Hydro	24 Hour	1-888-769-3766				
Telus		611				
Centra Gas- Operations Supervisor	Chris Hyland	751-8300		740-7770		
TRANSPORTATION & HIGHWAYS						
Area Manager, Nanaimo South	Dave Dick	390-6269		720-7344		
District Manager	Mike Proudfoot	390-6116		1-250-334-6813		
Mainroad Mid-Island Contracting Ltd.	Barry Dales Chris McColl	722-9494 722-9494	752-9093 758-4856	714-8181 755-5117		
Helicopter	West Coast Helicopters – Jim Vallance	754-5448 24 hrs.	758-8801			
	SunWest Helicopters – Brian Salos	1-250-752-0707 24 hrs.		954-9401		
Airplane	Baxter Air	754-1066 daylight 7 days/wk.				
	North Vancouver Air – Anthony Kuun (fixed wing for night flying)	1-800-228-6608 1-604-278-1608 24 hours		1-604-340-5078		
Snowcats:	Cercomm Electronics – Sulo Poystila	758-2652	758-4392	741-6151		
	BC Hydro – Bob Bell Martin McMinn	 755-4775 755-4707	 1-250-338-4086 714-7031	 741-4116 714-6460		
Canadian Transport Emergency Centre	24 hours call collect cell phone call *666	1-613-996-6666				
CONTRACTORS- EXCAVATION						
Fournier Excavating Ltd		754-7390			Fax	754-1082
Hazelwood Construction Services Inc.		716-1940			Fax	751-1941
Heathcote Contracting Ltd.		758-7652			Fax	758-7642

DEPARTMENT & TITLE	NAME	BUSINESS PHONE	RESIDENCE PHONE	CELL PHONE	OTHER CONTACT	
Hub Excavating Ltd.		1-250-954-3700				
Knappett Industries Ltd.		751-2151			Fax	751-2155
Sound Contracting Ltd		1-250-248-8155				
Town & Country Construction Parksville Ltd.		1-250-248-5761			Fax	248-8757
Copcan Contracting/Gregson Holdings	Brian Gregson Dave Gregson	754-7260 754-7260	756-4388 754-4483	755-9325 755-6523		
CONTRACTORS - GENERAL						
Carlson G W Construction Ltd		753-6481				
Knappett Construction Ltd		1-250-475-6333			Fax	1-250-475-6444
Robinson D Contracting Ltd		758-1151				
ELECTRIC GENERATOR RENTAL						
Simpson-Maxwell	Bob Robinson	756-7700	729-0191			
BOTTLED WATER						
Canadian Springs Water Company – Victoria	Carol Sabiston Terry Griff	1-800-665-3285	1-250-383-0614	1-250-881-6120 24 hrs. 1-250-217-1666		
Old Victoria Water Company	Bill Caldwell	1-800-661-4900				
TANKER TRUCKS						
Island Farms Dairy Association	Steve Wainwright	1-250-360-5200				
Mainroad Mid-Island Contractors Ltd.	Barry Dales Chris McColl	722-9494 722-9494	752-9093 758-4856	714-8181 755-5117		
Stan Woods	Stan Woods	758-2678	758-2678	755-5174 or 741-4309 24 hrs		
Island H_2O	Dan Cutting	754-4721				
B.C. Water Service	Michael Hilker	1-250-954-3628		1-250-248-0710		
Canadian Springs – Victoria (no tanker truck in Victoria, but she will make arrangements for one)	Carol Sabiston	1-800-665-3285	1-250-383-0614	1-250-881-6120 24 hrs.		

DEPARTMENT & TITLE	NAME	BUSINESS PHONE	RESIDENCE PHONE	CELL PHONE	OTHER CONTACT	
Pure Water Transport – Vancouver	Wayne Kemp Ted Campbell	1-888-530-6225 24 hrs.				
ALTERNATE WATER SOURCES						
Lantzville Improvement District	Scott Churko	390-4006		751-9989		
Nanaimo Golf Club	Jim Moffit	758-5221				
Emergency Coordinator, RDN	Maureen Pearse	390-4111				
Parksville	Brian Hackwood, Mgr. Op. Keith Dumond/Operations	1-250-954-4667 1-250-954-4665		 1-250-951-8237		
Ladysmith	City Hall Emergency After Hours	245-6400 741-3373				
North Cowichan	 Tom Todd/Asst. Op.Mgr.	1-250-746-3100 1-250-746-3106 1-250-746-5112 24 hrs.				
OTHER AGENCIES & SERVICES						
Radiation Protection Services		1-604-660-6633				
Environmental Protection Service (Canada)		1-604-666-6100 24 hrs.				
Chlorine Emergency Plan (CHLOREP)	Nexen Chemicals Terry Jevne, Plant Mgr.	722-2212 then hit 8 for chemical emergency 722-2212 then hit 1400 for his line				
Nanaimo Regional General Hospital	Dave Roberts- Plant	754-2141		740-7927		
School District No. 68 (Nanaimo)		754-5521			Night	754-9511
Pacific Biological Station	Terry Brack Stu Fraser Bob Williams	756-7051 756-7080 756-7085	245-1360 754-8167 754-1556	 714-5485		
Fisheries & Oceans	Margaret Wright	756-7269	753-8774			
	Radio room	1-604-666-3500				
Tourism Nanaimo (Hotels, Motels)		756-0106				

SECTION 3
TECHNICAL DATA

TECHNICAL DATA

Section 3

TABLE OF CONTENTS

1.0 STATIC DATA

A summary of the Static Data for the Lower Chase River Dam is given in Table 3-1.

TABLE 3-1

Item	Data	Comment
Name:	**Lower Chase River Dam**	Also referred to as: Lower Colliery Dam, Lower Harewood Colliery Dam, Howard No. 4, and Harewood No. 2 Dam
Hazard Classification:	**B**	M of E criteria, dam is considered to be "major". "Disaster Potential Classification" estimated to be "B"
Co-Ordinates:	**N 5446292 E 430138**	As determined by Wright, Parry, Taylor & Fuller in February 1992
Structure Type:	**Earth fill, rock fill and mine waste dam with 1.2m thick vertical, concrete cutoff wall**	
Height of Dam at Crest:	**23.3m**	As measured by Wright, Parry, Taylor & Fuller, February 1992
Width of Dam at Crest:	**77m**	As measured by Wright, Parry, Taylor & Fuller in February 1992
Storage Capacity for Reservoir:	**17.3Ha-m**	Quantity of water stored is 17.3 Ha-m (140 acre-feet),as per water license. Note: This should be confirmed.
Water License Data:		See application for Water License in Appendix 1A. Licensed on November 23, 1984.
Owner Information:	**The City of Nanaimo**	
Year of Construction:	**1910 to 1920**	Believed to have been completed in about 1910 by Wakesiah Colliery.

2.0 ACTION PLAN

The remedial works recommended at the Lower Chase River Dam are listed in Table 3-2

TABLE 3-2

Item	Recommended Completion Date	Estimated Cost	Aug. 2003
A weir should be constructed at the toe of the dam and fitted with a stilling basin to collect any fines being carried in the seepage water	June 1992	$2,500.00	Not done
A staff gauge should be installed to measure the reservoir level along with a precipitation gauge	June 1992	$500.00	Done.
Installation of a log boom across the spillway inlet for the safety of swimmers and boaters. This boom will also catch debris floating toward the spillway and this material will require periodic removal	June 1992	$2,500.00	Not done.
The trees leaning over the reservoir must be removed prior to toppling	Ongoing	-----	Done as required.
Erosion due to path on upper portion of downstream slope of dam should be repaired	September 1992	$500.00	Done.
Upper slope should be cleared of existing vegetation, regraded and hydroseeded.	September 1992	$2,500.00	Regrading & hydroseeding still required clearing done yearly.

TABLE 3-2

Item	Recommended Completion Date	Estimated Cost	
Surface water which flows down left abutment should be collected at top of slope and channelled away	September 1992	$500.00	Not done.
The source of the existing seepage must be determined. This may include: review of historic information, underwater inspection, dye testing and boreholes.	September 1993	$5,000.00	Regular inspections note amount of seepage.
Once the source of the seepage has been established, remedial measures to stop the flow may be necessary.	N/A	-----	
A seismic assessment of the embankment and spillway should be carried out	September 1993	$20,000.00 Cost will include 3 dams on Chase River	Not done.
The hydrological data for the Chase River system should be updated	September 1993	$40,000.00 Cost will include 3 dams on Chase River	Done in 2002 by Water Management Consultants.
Dead trees should be removed from the reservoir.	September 1997 (or as funding permits prior to this)	$10,000.00	not done.

3.0 TECHNICAL DATA

3.1 Hydrological Aspects

The hydrological aspects of the Chase River system were assessed and reported in the 1978 Storm Drainage Study (see Appendix 3A). The inflow to the Lower Chase River reservoir was estimated to be 57.8 m^3/s, for a 100 year storm in the 1978 study. The spillway capacity with a 0.9 m discharge depth (determined by the top of the concrete wall) was estimated to be 53.8 m^3/sec, therefore the spillway may not be adequate to transmit the flow resulting from a 100 year storm.

3.2 Seismic and Geological Concerns

Geology

The bedrock underlying the Lower Chase River dam is sedimentary rock of Cretaceous aged Nanaimo Group. Bedrock consisting of conglomerates of the Millstream Member, is exposed downstream of the Lower Chase River Dam. the bedrock, where exposed, dips 35 degrees downstream, suggestive of proximity to a fault. Drilling by Golder Associates in 1978 suggests that the Lower Chase River Dam is founded upon overburden. Their borehole No. 9 through the dam encountered dense but unlithified sandy silt with some gravel, which may represent alluvium or till. It appears that some weathered siltstone is exposed in places along the lower portion of the right abutment.

Seismic Concern

There is a fault associated with the Chase River valley, which runs west of the dam location, refer to Westwater Mining Ltd report in Appendix 3B. It should be determined if this fault is active and the impact of it on the safety of the dam should be assessed.

3.3 Upstream Concerns

There are 4 other dams (No. 1 Reservoir Dam, Upper Chase River Dam, Middle Chase River Dam, which are City owned, and Powerline Dam in the Morrell Bird Sanctuary) upstream of the Lower Chase River Dam. Uncontrolled release of any of these reservoirs would likely cause the Lower Chase River Dam to be overtopped.

Nanaimo Lakes Road crosses the Chase River approximately 1.3km upstream of the reservoir. Should a chemical or oil spill occur near this crossing, the reservoir could be affected.

3.4 Downstream Concerns

The Chase River flows through many residential areas downstream of the Chase Dams. The Inundation map included in Appendix 3C indicates the extent of possible flooding of these areas. A large number of residences in the area bordered by Sixth Street, Ninth Street, Wakesiah Avenue and the E & N tracks would be affected as well as the utility, railway and Island Highway Chase River crossings.

3.5 Background Information

The Lower Chase River Dam is located on the Chase River which is southwest of the City of Nanaimo, as shown on Figure 1, and is accessible via the Nanaimo Lakes Road.

Lower Chase River Dam reservoir is used largely for recreational purposes and is annually stocked by the Provincial Fish and Wildlife department. The reservoir also has some flood control capabilities with the temporary storage to the spillway invert elevation. The watershed area contributory to the reservoir has been estimated to be approximately 2625 hectares. This should be checked during the upgrading of the hydrological data.

Lower Chase River Dam is situated about 0.7 km downstream from Nanaimo City No. 1 reservoir. The dam is also situated 0.3 km downstream from Middle Chase River Dam and discharges into the Chase River. The Greater Nanaimo Water District offices are about 1.3 km upstream on Nanaimo Lakes Road.

Lower Chase River Dam is also known as Lower Harewood Dam Colliery and as Lower Colliery Dam. The dam may have been at the end of an old railroad spur. The structure consists of a vertical concrete core wall which is 0.3m thick from the top to 0.6m below the crest and then increases in thickness to 1.2m. End dumped soil and rock fill, including mine waste form both the upstream and downstream shoulders of the dam. A dam site plan and cross-section are included in Appendix 3C.

The dam is situated in a steep sided ravine with both abutments believed to be comprised of silty overburden. The dam foundation material is believed to be dense sandy silt with some gravel. Some weathered siltstone is exposed on the lower portions of the right abutment.

The uncontrolled 2 bay spillway is located on the right abutment.

The 2 bays join approximately 15m from the intake. At this point, an open channel extends approximately 25m to a steep chute formed by a bedrock surface.

Concrete walls line both sides of the spillway down to the open rock chute.

There is some erosion of the overburden evident on both sides of the chute, however, due to the limited thickness of overburden this poses no threat to the performance of the spillway. A log jam has formed in the pool at the base of the chute.

When this dam was in service as a water supply reservoir there were two pipe conduits passing through the embankment. The outlet of the pipes, which projected out of the downstream face of the dam at about mid-height, have been removed and the pipes blocked upstream. The control valves for the pipes were located on the upstream side of the dam.

Improvement and remediation reconstruction of the Lower Chase River Dam was carried out in 1980. Tree and brush cover over the downstream face of the dam was removed and the lower half of the slope was regraded to 2 horizontal to 1 vertical. A berm drain was constructed about halfway up the dam face, at the top of the regraded portion. A seepage trench was also constructed at the contact with the right abutment.

In addition, the pipe conduits through the dam were filled with concrete to within 5m of the outlet end. The last 5m of downstream pipe section was filled with granular filter material. The spillway wall and floor was repaired and the south spillway wall was raised. Grouted rock rip rap was provided at the spillway discharge. There is minor continued seepage downstream of the dam, however, visually noticeable suspended solids and evidence of piping has not been noted during periodic observation over several years.

Periodic observations have been made of the dam and related facilities since 1980. The most significant note with respect to past observations of the dam was the appearance of a crack in the berm material added in 1980. This was monitored for at least 2 years after initial observation without an indication of change.

APPENDIX 3A
HYDROLOGIC ASSESSMENT

HYDROLOGICAL ASPECTS OF THE CHASE RIVER RESERVOIRS

1. General

The investigation of the Chase River Dams at Nanaimo includes a look at anticipated maximum runoff flows in relation to the capability of each dam discharge works to handle these flows. Accordingly, estimates of the capacity of each spillway are undertaken and these compared to the estimated maximum runoff for selected frequency periods, in this case, 10 years, 50 years and 100 years.

2. History of Flooding

It is a point of some interest to note that in the 50± year life span of these structures, only one flood has been recorded which created some concern. The year of this flood cannot be pinpointed exactly, but its magnitude was sufficient to cause concern at the Middle Chase River dam where a hole was cut in the concrete wall which forms the top portion of the dam with the apparent intent of using this as an overflow for the spillway. This emergency operation was obviously never completed and the partial opening in the dam was subsequently covered with heavy wood sheathing. Investigations made during the course of this study indicate that this spillway is lacking the capacity to handle a flood of major proportions.

3. Runoff Estimates

a) Lower Chase River Dam

The total catchment area contributing to Chase River runoff at the lower dam is about 6.227 acres or 9.73 square miles. The terrain within this basin can be classified as rolling to mountainous. The higher areas are timbered and the lower slopes mainly cleared and surfaced with grass.

The time of concentration at the lower dam can be calculated using Kirpich's formula:

$$tc \text{ (hours)} = 0.00013 \frac{L^{0.770}}{S^{0.385}} \text{ where:}$$

L = Distance in feet from point of discharge to most remote point in the basin along the watercourse.

S = Average slope between these points in feet per foot =

$$\frac{3{,}030}{5.9 \times 5{,}280} = 0.097 \quad \text{therefore:}$$

$$tc = 0.00013 \times \frac{(5.9 \times 5{,}280)^{0.770}}{(0.097)^{0.385}}$$

$$= 0.920 \text{ hours}$$

$$tc = 55 \text{ minutes}$$

From the proposed new Nanaimo rainfall-intensity-duration curves (see Figure 1) for a 10 year return period, an average intensity of 1.1 inches/hour was selected opposite the 55 minute duration storm.

The coefficient of runoff for this type of terrain was taken from the Handbook of Concrete Pipe Hydraulics (see Appendix 1). Using the lower portion of Band 3 for an average intensity of 1 inch/hour, a coefficient of 0.20 was selected. This corresponds to the value stated in Appendix 2 taken from Culvert Hydraulics, Design and Installation (published by the Ministry of Highways in 1963) where a value of 0.21 is given for hilly, timbered watersheds.

Estimated runoff at the Lower Chase dam is then calculated by the rational formula to give:

$$Q_{10} = 0.20 \times 1.03 \times 9.73 \times 640$$

$$= 1{,}282 \text{ cfs } (36.33 \text{ cms})$$

According to Appendix 3, taken from Culvert Hydraulics, Design and Installation, the 50 year flood can be estimated by multiplying the 10 year flood by 1.5 and the 100 year flood by multiplying the 10 year flow by 1.8. The runoff estimates for these frequency periods then are as follows:

Q_{50} = 1.5 x 1,280 = 1,920 cfs (54.41 cms)

Q_{100} = 1.8 x 1,280 = 2,300 cfs (65.17 cms)

b) Middle Chase River Dam

The measured catchment area for this dam is 8.34 square miles or 5,338 acres.

L = 5.66 miles or 29,568 feet

$$S = \frac{3,000}{5.66 \times 5,280} = 0.100$$

From Kirpich:

$$tc\ (hours) = \frac{0.00013 \times (29,568)^{0.770}}{(0.100)^{0.385}}$$

$$= 0.874 \text{ hours} = 52 \text{ minutes}$$

Q_{10} = 0.21 x 1.06 x 5,338 = 1,188 cfs (33.66 cms)

Q_{50} = 1.5 x 1,188 = 1,782 cfs ... say 1,800 cfs (51.00 cms)

Q_{100} = 1.8 x 1,188 = 2,138 cfs ... say 2,150 cfs (60.92 cms)

c) Upper Chase River Dam

Drainage catchment area for this dam is measured as 8.06 square miles or 5,158 acres. Time of concentration is given by:

L = 5.18 miles or 27,350 feet

$$S = \frac{2,950}{27,350} = 0.1078$$

$$tc\ (hours) = \frac{0.00013 \times (27,350)^{0.770}}{(0.1078)^{0.385}}$$

$$= 0.779\ hours$$

tc = 48 minutes

The estimate of the various flows; therefore

Q_{10} = 0.20 x 1.11 x 5,158 = 1,145 cfs (32.45 cms)

Q_{50} = 1.5 x 1,145 = 1,720 cfs (48.70 cms)

Q_{100} = 1.8 x 1,145 = 2,060 cfs (58.38 cms)

Table 1 provides a comparative summary of the 50 year and 100 year flow estimates with no allowance for the attenuating effect of the downstream reservoirs. A discussion of this effect follows.

TABLE 1

Dam	Q_{50}	Q_{100}
Lower Chase	1,920 cfs	2,300 cfs
Middle Chase	1,800 cfs	2,150 cfs
Upper Chase	1,720 cfs	2,060 cfs

4. Storage Effect of Reservoirs

Although the information shown in Table 1 indicates flood volumes which could cause serious problems at Upper Chase, Middle Chase and Lower Chase Dams, the estimates do not take into account the attenuating effect of the reservoirs on the peak runoff. Each reservoir located "on-line" will provide temporary detention of flow, the magnitude of which depends upon the water surface area, width of spillway outlet and height of freeboard available. The effect of this temporary storage can be estimated by flood routing techniques.

Appendix 3 illustrates the method using an assumed 100 year flood of about 2,100 cfs at the Upper Chase Dam (Inflow 1). The outflow at each reservoir for this storm is shown as a separate hydrograph (Outflows 1, 2 and 3). Upper Chase Reservoir is identified as 1, Middle Chase as 2 and Lower Chase as 3.

An allowance has been made for additional drainage accumulated between reservoirs and this is added to the inflow of Middle and Lower Chase Dams. This additional inflow is calculated as follows (bracketed figures are in cubic metres per second):

Middle Chase

Add Q_{10} = (5,338 - 5,158) x 0.2 x 1.11
= 40 cfs (1.13 cms)

Add Q_{50} = 40 x 1.5 = 60 cfs (1.69 cms)

Add Q_{100} = 40 x 1.8 = 72 cfs (2.04 cms)

Lower Chase

Add Q_{10} = (6,227 - 5,338) x 0.2 x 1.11
= 197 cfs (5.59 cms)

Add Q_{50} = 197 x 1.5 295 cfs (8.37 cms)

Add Q_{100} = 197 x 1.8 = 355 cfs (10.05 cms)

The net effect of storage in the three reservoirs on the 100 year storm can be seen on Appendix 5 by comparing the partial hydrograph peak at the top of the figure. This peak represents Outflow 3 without consideration of the storage effect of the three reservoirs. The increase in peak flow would be about 380 cfs (10.77 cms) or almost 20 percent. This would only be of concern if at some future date breaching of one or more of the three reservoirs is undertaken. At that time an inspection downstream should be made to ascertain the effects of the increased flow on the channel and surrounding properties.

Table 2 gives a comparison of drainage areas for each reservoir and compares the expected 100 year runoff flows at the inlet and outlet of each reservoir.

TABLE 2

Reservoir	Drainage Area Acres	Inlet cfs	Inlet cms	Outlet cfs	Outlet cms
Upper Chase	5,158	2,060	(58.38)	1,790	(50.73)
Middle Chase	5,338	1,850	(52.43)	1,750	(49.59)
Lower Chase	6,227	2,040	(57.81)	1,920	(54.41)

RESERVOIR DISCHARGE CAPACITIES

A determination of discharge capacity at each dam is required so that their efficiency in handling the estimated peak flows can be assessed.

a) Middle Chase Dam

At Middle Chase Reservoir the spillway discharge can be estimated by the general formula:

$Q = CLH^{1.5}$ where:

C = coefficient of discharge
L = effective length of the weir
H = measured head above the crest (excluding velocity of approach

The effective length of crest is sensitive to the number of contractions and may be determined from:

$L = L' - 0.1\ NH$ where:

L' = measured crest length
N = number of contractions

The coefficient of discharge "C" can vary and usually ranges from about 3.2 to 4.0. Its value can be estimated from a well known formula:

$$C = 3.27 - 0.40 \frac{H}{h} \text{ where:}$$

h = the depth of water below the dam crest

At Middle Chase Dam, where the discharge outlet closely resembles a normal spillway, the depths of water behind the dam has been measured as 29.5 feet (9 metres). The available discharge head over the dam is limited by the underside of the new bridge to about 5.0 feet (1.52 metres). Coefficient "C" can then be evaluated as:

$$C = 3.27 + (0.40 \times \frac{5.0}{29.5}) = 3.33$$

The north side of the spillway has a wing which will eliminate the contraction on that side. The vee-shape of the upstream edge will also negate any contraction effects from the new centre pier.

The effective length "L" may then be determined as:

$$L = 40.33 - (0.1 \times 1 \times 5) = 39.83 \text{ feet } (12.14 \text{ metres})$$

Capacity of the spillway at 5.0 feet (1.52 metres) discharge depth is determined as:

$$Qc = 3.33 \times 39.83 \times 5^{1.5} = 1{,}482 \text{ cfs } (42.04 \text{ cms})$$

This is considerably less than the

$$Q_{100} = 1{,}750 \text{ cfs } (54.41 \text{ cms})$$

previously estimated as being the 100 year storm runoff. In order to increase the spillway capacity to pass Q_{100} a number of actions can be taken.

First of all, the south end contraction can be eliminated by adding a rounded entrance and the effective crest length increases to

$$L = 40.33 - (0.1 \times 0 \times 5.0) = 40.33 \text{ feet } (12.29 \text{ metres})$$

and spillway capacity is increased by about 1-1/2 percent.

Secondly, the spillway crest which is mainly solid rock, can be lowered to accommodate the additional flow. The depth of flow "H" required to achieve a volume of 1,750 cfs (49.60 cms) can be estimated from:

$$H = \left(\frac{Q}{CL}\right)^{0.667} = \left(\frac{1{,}750}{3.33 \times 40.33}\right)^{0.667}$$

$$= 5.54 \text{ feet } (1.69 \text{ metres})$$

In other words, by lowering the existing crest by 0.54 feet (0.164 metres) the 100 year flood can be expected to pass the spillway without danger of inundating the existing bridge.

It should be noted here that the dam is in no danger of overtopping at this level. About 1.8 feet (0.55 metres) of freeboard remains although most of the new bridge would be completely inundated by the time this freeboard was utilized.

The existing crest is not level being about 0.64 feet (0.2 metres) lower at the south end. Lowering the crest to a uniform elevation of about 0.75 feet (0.228 metres) below the present north side level should be adequate to accommodate the 100 year run-off.

Middle Chase Dam has a history of flooding or near flooding in the past as previously mentioned. It is probable that this flood of concern was in the order of magnitude of the 50 year flood estimated to be about 1,500 cfs (42.50 cms).

b) <u>Upper Chase Dam</u>

Although the Upper Chase Dam was not included in the original investigations for stability, it was decided to include it in the hydrological analysis. Any lack of discharge capability at this top reservoir might prove to be the weak link in the reservoir chain.

Discharge capability might be controlled either by the discharge channel or the twin 72 inch diameter corrugated metal pipes immediately downstream bridging the Nanaimo Lakes Road.

At its maximum depth of 4.1 feet, the discharge flume will carry nearly 2,400 cfs (6802 cms) without overtopping the flume. The discharge outlet into the channel however is restricted to about 1,750 cfs (49.60 cms) before overtopping of the dam would occur.

The relatively smooth entrance into the twin 72 inch diameter pipes and their steep gradient ensures that they can handle maximum flows from the discharge channel particularly with high velocity heads expected at the entrances under maximum flow conditions.

If for any reason the entrance was to pond to a depth of 4-1/2 feet (1.37 metres) above the crown of the pipes, they would pass about 1,600 cfs (45.35 cms).

c) Lower Chase Dam

The discharge outlet from Lower Chase Reservoir is in the form of a divided spillway on a relatively flat (0.67 percent) gradient. If flow in the spillway is assumed to be 3.0 feet (0.91 metres) deep (top of concrete), the channels will carry about 1,900 cfs (53.84 cms) with the lake level just below the dam crest.

Table 3 gives a comparison of the estimated capacities of each reservoir outlet and compares these to the estimated discharges for the 100 year flow.

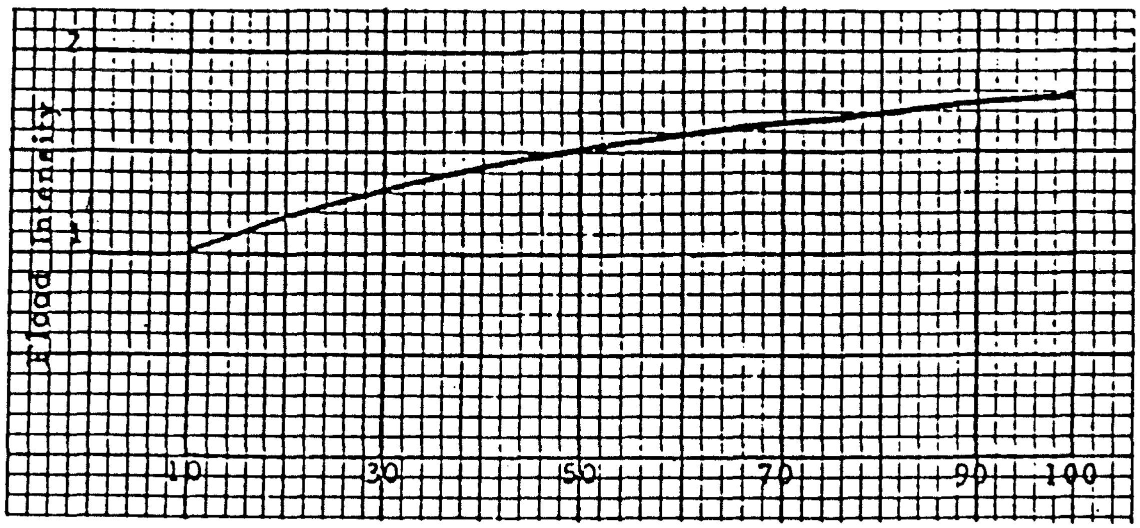
TABLE 3

Reservoir	Discharge Capacity cfs	(cms)	Q_{100} (Outlet) cfs	(cms)
Upper Chase	1,750	(49.60)	1,790	(50.73)
Middle Chase	1,480*	(41.95)	1,750	(49.59)
Lower Chase	1,950	(55.27)	1,920	(54.41)

* Capacity of Existing Spillway

$$I = \frac{F^{0.25}}{1.78}$$

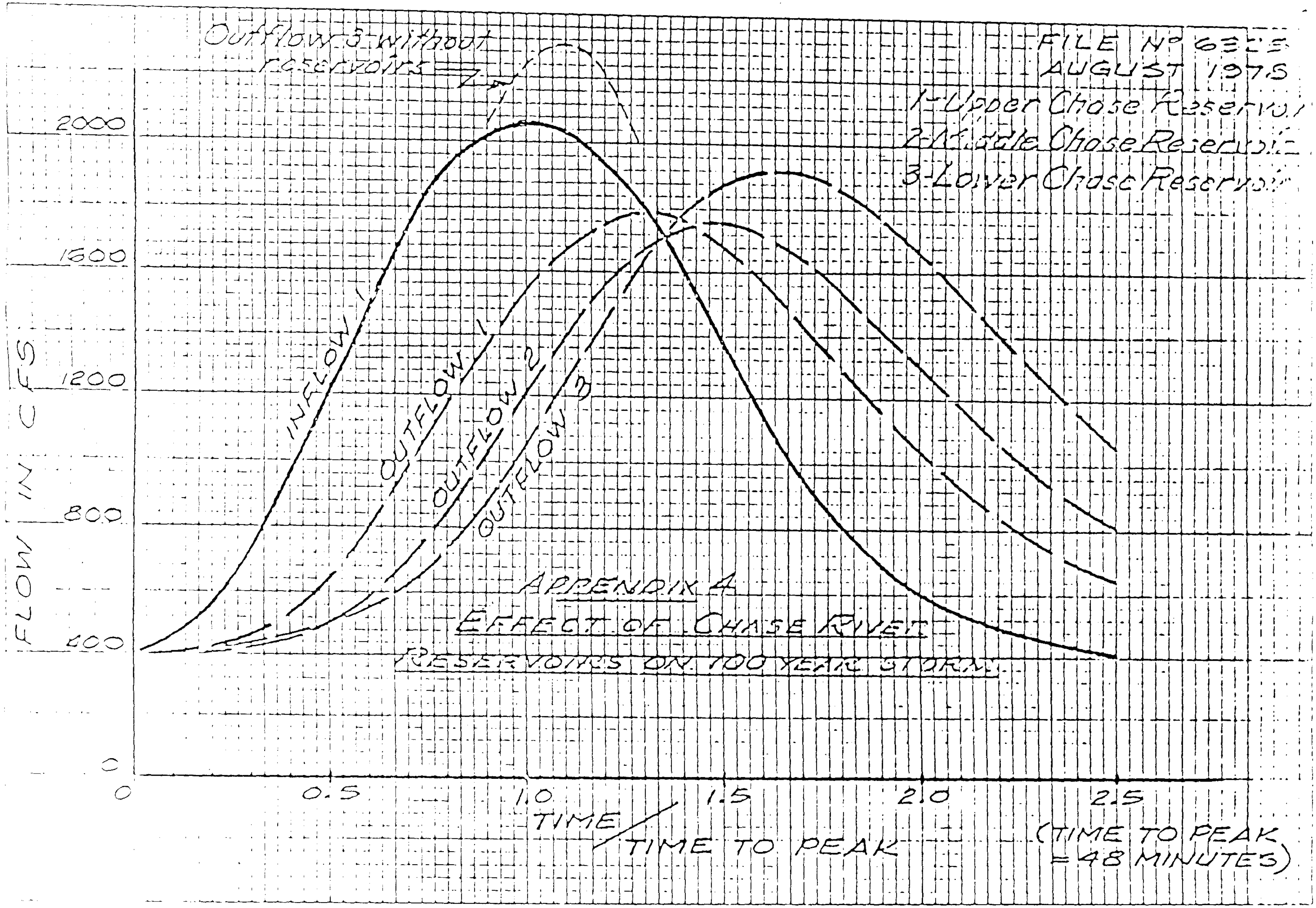
10 Year Flood = 1



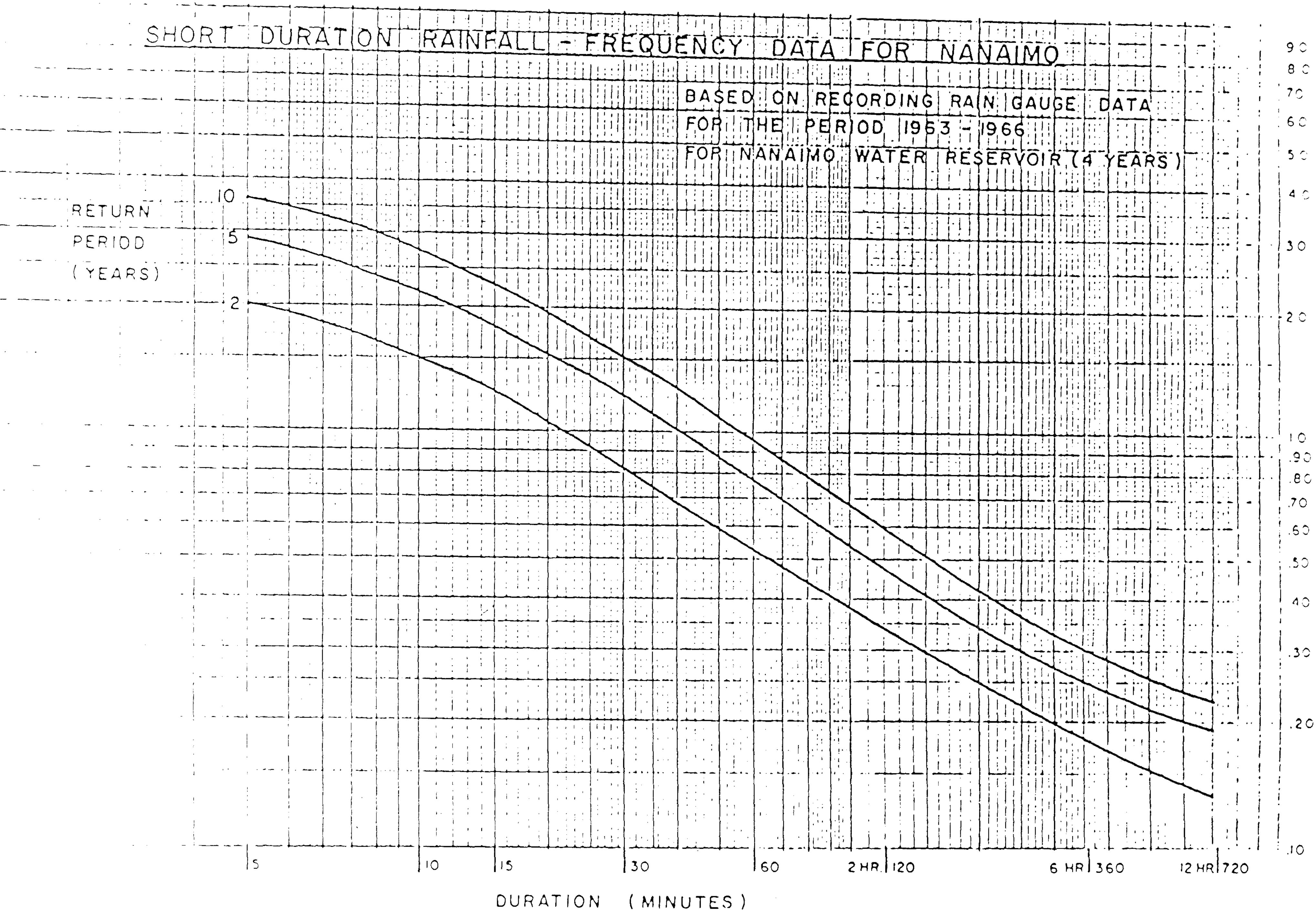
Frequency Years

Intensity of Floods of Various Frequencies

APPENDIX 3



FILE Nº
AUGUST 1975
1-Upper Chose Reservoi
2-Middle Chose Reservoi
3-Lower Chose Reservoi
Outflow 3 without reservoirs
INFLOW 1
OUTFLOW 1
OUTFLOW 2
OUTFLOW 3
APPENDIX 4
EFFECT OF CHASE RIVET
RESERVOIRS ON 100 YEAR STORM
FLOW IN CFS
2000
1600
1200
800
400
0
0
0.5
1.0
1.5
2.0
2.5
TIME / TIME TO PEAK
(TIME TO PEAK =48 MINUTES)


SHORT DURATION RAINFALL - FREQUENCY DATA FOR NANAIMO
BASED ON RECORDING RAIN GAUGE DATA
FOR THE PERIOD 1963 - 1966
FOR NANAIMO WATER RESERVOIR (4 YEARS)
RETURN
PERIOD
(YEARS)
10
5
2
90
80
70
60
50
40
30
20
1.0
.90
.80
.70
.60
.50
.40
.30
.20
.10
5
10
15
30
60
2 HR 120
6 HR 360
12 HR 720
DURATION (MINUTES)

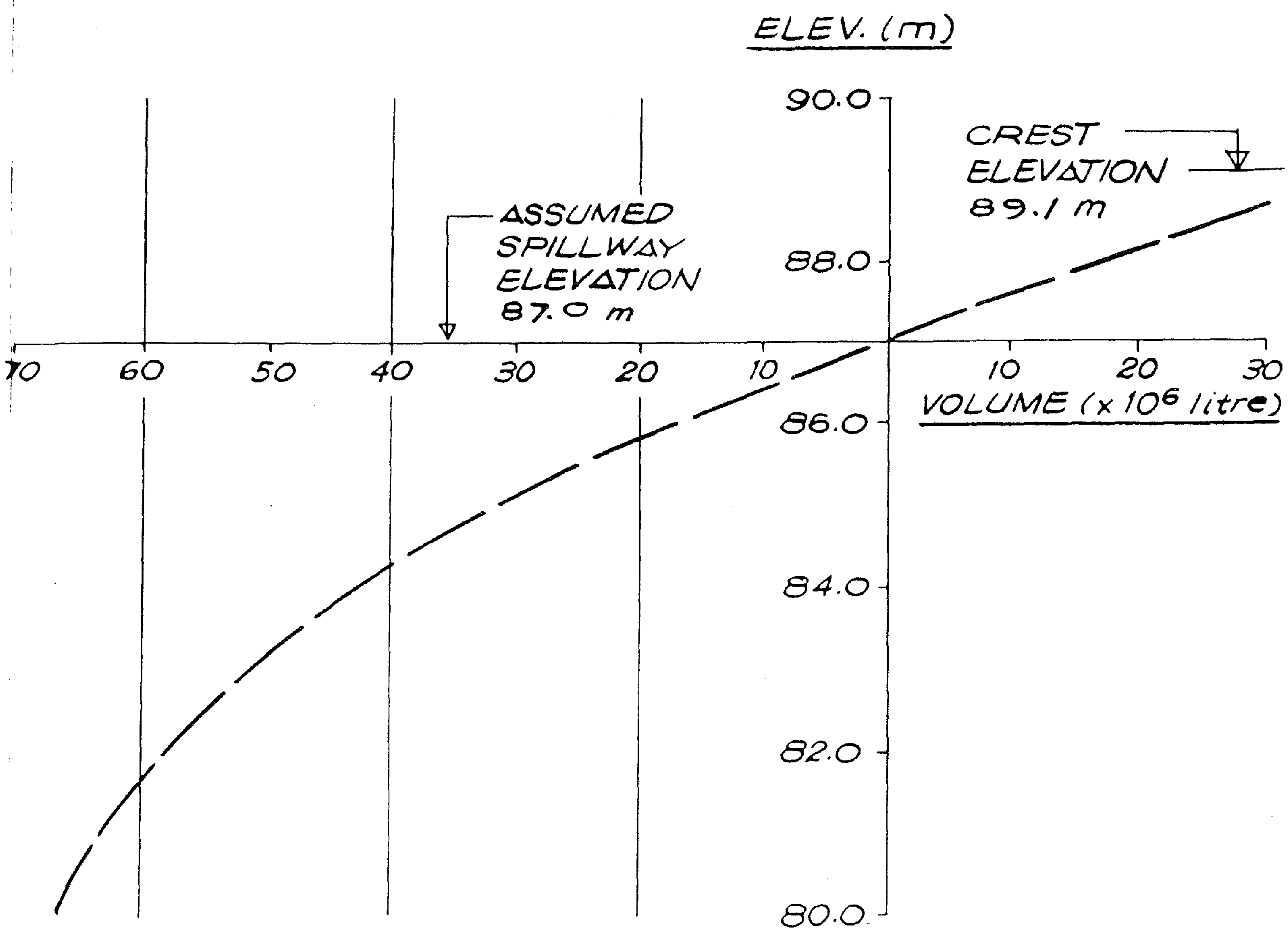
UPPER HAREWOOD COLLIERY DAM

Peak flow Estimation from Ministry of Environment Drainage Basin Data for South Vancouver IS.

Drainage Area 2575 hectares.

Daily Mean Unit Flow 400 l/sec per Km^2.

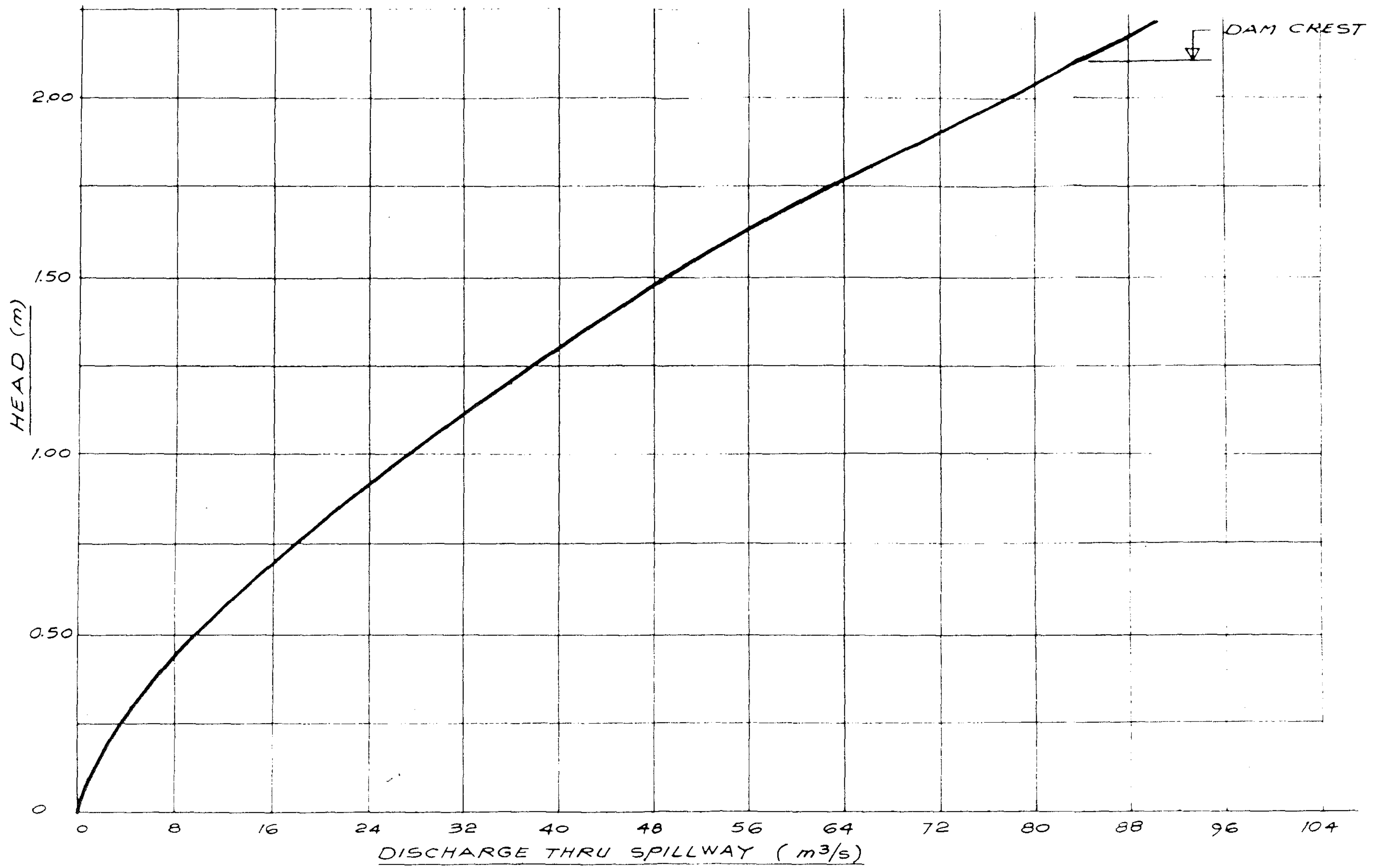
Daily Mean	10,300 l/sec
25 year Peak Flow	19,000 l/sec
50 year Peak Flow	28,500 l/sec
100 year Peak Flow	31,000 1/sec



UPPER HAREWOOD COLLIERY DAM *ESTIMATED RESERVOIR VOLUME CURVE

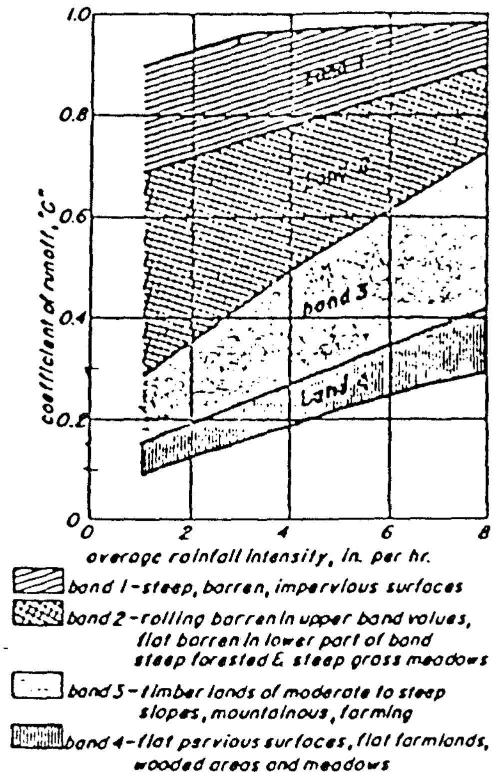
* FROM AVAILABLE CONTOUR PLANS

FIGURE 2



UPPER HAREWOOD COLLIERY
SPILLWAY CAPACITY

FIGURE 3



Runoff coefficient C related to rainfall intensity and topography.

Watershed		Slope %	Values of C
Cultivated	Rolling Hilly	5-10 10-30	0.60 0.72
Pasture	Rolling Hilly	5-10 10-30	0.36 0.42
Timber	Rolling Hilly	5 10-30	0.18 0,21
Flat farm land			.10-.25
Paved City centers			.60-.75
Residential dense			.50-.65
Suburban			.35-.55
Combination Rain, Snow-melt, and Frozen Surface			1.0+

Factors increasing C: frozen surface, saturated ground, compacted surface, dust on surface preventing penetration.

Factors decreasing C: poor drainage, swamps, pot holes, beaver dams, deep ploughing.

APPENDIX 3B
WESTWATER MINING LTD
GEOLOGIC REPORT

WESTWATER MINING LTD.

1914, Fifth Street S.W., Calgary, Alberta., T2S 2B3., (403) 228-7729

EBA Engineering Ltd.
#1 - 4376 Boban Drive
NANAIMO, British Columbia
V9R 5E8

1992 February 29

Our file: WR 98a5
Your job: 82041/82058

Attention: Bob Patrick

Re: Preliminary geological report on seven dams at Nanaimo.

On February 18th, 1992, you commissioned our firm to make an initial geological evaluation of seven dams within or adjacent to the City of Nanaimo. For each of these seven dams, as listed in Table 1 of this report, you asked us to make a brief report on the geology, possibility of underlying mine workings, and any archival details of construction or use which were readily available to us.

In preparing this report, I have made use of excerpts from a report by Golder Associates (1978) which were provided by your firm. I have also taken into consideration the results of a regional geological mapping programme which I conducted between 1983 and 1987. I wish to stress that I have not visited all of the dam sites, and have not done any detailed mapping at the sites which I have visited.

INTRODUCTION:

Geological conditions at seven dams are considered in this report. The dams are numbered '**i**' through '**vii**' in Table 1 and on the accompanying geological sketch map (Figure 1).

TABLE 1: DAMS CONSIDERED IN THIS REPORT:

Site:	Dam Name:	Original purpose:
i	Westwood Lake	Hydroelectric storage
ii	McGarrigle Creek	Hydroelectric diversion
iii	City Dam No.1	City water supply
iv	Upper Chase River	Water supply/diversion
v	Middle Chase River	Coal washery water supply
vi	Lower Chase River	Coal washery water supply
vii	Harewood Mine	Coal mine water supply

CONCLUSIONS:

1. It is unlikely that any of the seven dams under investigation have been undermined by any of the **documented** mining operations within the study area. It is, however, possible that the No.1 City Dam (site iii) has been undermined by **undocumented test adits** within the Wellington or Harewood

Seams, due to this dam being located upon the projected outcrops of these coal beds.

2. The No.1 City Dam is probably underlain by a major fault.

3. The McGarrigle Creek Dam is possibly underlain by a major fault.

4. The Lower Chase River Dam may also be near a fault, as yet unmapped due to thick Drift cover.

5. Part or all of every one of the seven dams may be underlain by unconsolidated deposits.

RECOMMENDATIONS FOR INITIAL TESTWORK:

1. I recommend that a programme of geological mapping be undertaken, to characterize the structural conditions within exposed bedrock at the various dam sites.

2. Drilling should be undertaken to establish the depth and configuration of the bedrock surface, and to characterize the unconsolidated deposits which may underlie the dams.

3. Particular attention should be given to the Upper Chase River and No.1 City Dams due to their interpreted proximity to the Chase River Fault. The Lower Chase River dam is also of concern in that it may be completely founded on unconsolidated deposits.

4. Mapping should be undertaken to determine whether active movement is occurring along the Chase River Fault, by searching for sheared pavements and distressed buildings along the projected trace of the fault.

GEOLOGICAL DESCRIPTION:

Table 2 presents a summary of the bedrock map-units present within the study area.

Coal is known to be exposed at only one location within the study area. In a west-facing rock bluff at the southeastern corner of the Upper Chase River Dam (site **iv**, also known as No.2 City Dam), approximately 40 centimetres of sheared, dirty coal is exposed about halfway up the bluff. This coal is probably correlative with the Harewood coal bed, which in this area lies 5 to 10 metres above the Wellington coal bed.

GEOLOGICAL STRUCTURE:

The geological structure of the study area is relatively simple, as shown on **Figure 1**. Cretaceous sedimentary rocks of the Nanaimo Group dip to the northeast at 6 to 35 degrees, while the pre-Cretaceous volcanic basement complex of the Vancouver Group dips steeply to the northeast, at 75 to 90 degrees. The contact of the Cretaceous sedimentary rocks over the basement complex is an erosional unconformity with considerable local relief.

Regional dip of the Cretaceous coal-measures is about 15 degrees to the northeast, and most local increases in dip may be ascribable to minor fault-associated folds, or differential compaction of the sedimentary rocks against irregularities in the pre-Cretaceous volcanic basement.

TABLE 2: GEOLOGICAL FORMATIONS WITHIN THE STUDY AREA:

QUATERNARY AND RECENT:

DRIFT (including undivided alluvium and colluvium): gravel, sand, stony till and clay; locally water-bearing. Up to 90 metres thick.

LATE CRETACEOUS (NANAIMO GROUP):

Unit 8 PENDER FORMATION (CRANBERRY MEMBER): mudstone and siltstone; minor coarse-grained sandstone and gritstone. 150 to 200 metres thick.

Unit 7 EXTENSION FORMATION (MILLSTREAM MEMBER): pebble-conglomerate and gritstone; minor coarse-grained sandstone, carbonaceous shale and COAL. 90 to 150 metres thick.

Unit 6 EXTENSION FORMATION (NORTHFIELD MEMBER): siltstone and fine to medium-grained sandstone, carbonaceous shale and COAL. Wellington Seam at base; Harewood Seam near top. 15 to 45 metres thick.

Unit 5 EAST WELLINGTON FORMATION: medium to coarse-grained sandstone; minor gritstone. 10 to 25 metres thick.

Unit 4 HASLAM FORMATION: silty mudstone and siltstone with numerous thin bands of fine-grained sandstone near top. 100 to 200 metres thick.

Unit 3 COMOX FORMATION (DUNSMUIR MEMBER): fine to medium-grained sandstone; minor siltstone. 0 to 75 metres thick.

Unit 2 COMOX FORMATION (BENSON MEMBER): pebble to boulder-conglomerate; minor pebbly sandstone and red silty mudstone. 0 to 120 metres thick.

LATE TRIASSIC (VANCOUVER GROUP):

Unit 1 KARMUTSEN FORMATION: basalt, andesite, basaltic breccia and aquagene tuff. 2500 to 4500 metres thick.

Five major faults (as shown on **Figure 1**) have been recognized on the basis of mine records, geological map patterns and borehole logs. Two of these, the Chase River and McGarrigle Faults, are of immediate significance to the present study, as they are interpreted to underlie some of the dam sites under investigation.

The Chase River Fault is a major northeast-striking cross-fault with downthrow of 150 to 250 metres to the south. The offset of the Chase River Fault also has a significant component of dextral strike-slip shear. The Chase River Fault does not outcrop within the study area, and its presence is inferred from the offset of geological contacts across the Chase River valley, as well as an exposure of disturbed strata along the southeastern shoreline of the No.1 City Reservoir. The Chase River Fault is well-exposed in mine workings under Nanaimo Harbour, and has been proven by drilling to the southwest of the study area. Its presence within the study area is regarded as **very probable.**

The McGarrigle Fault is inferred to underlie a long, narrow, northwest-trending Drift-filled valley which contains McGarrigle lake and the McGarrigle Dam (site **ii**). The McGarrigle Fault does not outcrop, and its presence is inferred on the basis of the anomalous narrow valley within the otherwise erosionally competent volcanic rocks of the Karmutsen Formation. Similar narrow valleys in the Karmutsen Formation elsewhere on Vancouver Island have, when drilled or trenched, been demonstrated to contain major shear zones or faults. The presence of the McGarrigle Fault within the study area is regarded as **possible.**

EXTENT OF MINE WORKINGS:

Workings of several abandoned underground coal mines are reported to be present within the study area; all of these mines worked either the Wellington Seam or the Harewood Seam. Their names and approximate dates of working are presented in **Table 3**, and the locations of their known entries are shown on **Figure 1.**

The workings of Wakesiah and Harewood Collieries are extensive and well-documented by plans on file with the Inspectorate of Mines. Several small mines (mapped as mines 21C through 21G) are connected to the Harewood workings. Robins' and Brown's Prospects (mapped as mines 21A and 21B) are both small prospect mines of limited lateral extent.

TABLE 3: Documented coal mines within the study area:

Entry:	Mine name:	Dates worked and notes:
	MINES WORKING WELLINGTON SEAM:	
19	Wakesiah Main Shaft	1918-1930
19A	Wakesiah Fan Shaft	1919-1930
	MINES WORKING HAREWOOD SEAM:	
20	Harewood Shaft	1899?-1923
21	Harewood Adit Level	1864-1950?
21A	Robins' Prospect	1908?
21B	Brown's Prospect	1908-1957?
21C	Harewood Prospect Shaft	1874?
21D	Furnace Portal	1874-1960?
21E	Lewis' No.2 Mine	1902-1950?
21F	Lewis' No.3 Mine	1918-1950?
21G	Southwest Heading	1921-1923

Wakesiah Colliery (mines 19 and 19A) was mostly worked by advancing longwall methods, resulting in near-total extraction of the mineable coal. Harewood Colliery (mines 20, 21 and 21C through 21G) was worked by a mixture of room-and-pillar, double-stall and longwall methods, and again nearly all of the mineable coal was extracted.

Sufficient exploration drilling has been done to demonstrate that it is unlikely that any remaining mineable coal reserves exist with the study area, with the possible exception of localized pods of thick coal within the Wellington and Harewood Seams near Brown's Prospect (mine 21B).

None of the documented mine workings are known to directly undermine or closely approach the dam sites under study. Additional undocumented prospect adits may conceivably have been driven along the outcrop of the Wellington and Harewood Seams along Chase River, prior to the construction of the No.1 City Dam (site **iii**); the outcrop trace of the coal seams is now covered by the reservoir impoundment at this site. The presence of such undocumented adits is regarded as **possible.**

PRELIMINARY SITE INTERPRETATIONS:

Preliminary site interpretations of the seven dams under investigation are based on regional-scale geological mapping carried out by the author between 1983 and 1987, along with a brief examination of the records of test holes drilled through some of the dams, and logs of nearby coal exploration boreholes.

Site i: Westwood Lake

The east abutment of the Westwood Lake Dam is founded upon volcanic rocks of the Karmutsen Formation, while the west abutment is located in a soil-covered area which is probably underlain by sand or sandy till, as indicated by Golder's No.2 borehole. The unconsolidated material is in turn probably underlain by conglomerates of the Benson Member.

Site ii: McGarrigle Creek

This site has not been visited by the author. Air photos and a personal communication from Mr. Bob Patrick of your firm suggest that the north abutment of the McGarrigle Creek Dam is founded on volcanic rocks of the Karmutsen Formation. The central and southern portions of the dam may be founded on unconsolidated colluvial and alluvial deposits.

Site iii: City Dam No.1

This site has not been visited by the author. Air photos and regional geological mapping suggest that this dam overlies the Chase River Fault. Its eastern abutment may be founded on conglomerates of the Millstream Member, while the central and western portions of the dam may be founded on unconsolidated alluvial deposits.

Site iv: Upper Chase River Dam (City Dam No.2):

Bedrock does not outcrop at Site **iv**. Recent road-building and sewer excavations approximately 200 metres north of this site show stony, sandy till or alluvium, while rock bluffs along the eastern shoreline of the No.1 City Dam reservoir, approximately 100 metres east of this site, show steep-dipping conglomerate and gritstone, probably correlative with the Northfield Member. The steep dips of these beds may indicate drag-folding along the Chase River Fault, or they may be due to cross-bedding of the strata. The Upper Chase River Dam is probably founded on unconsolidated alluvium or till.

Site v: Middle Chase River Dam

Bedrock, consisting of conglomerates of the Millstream Member, is exposed downstream of the Middle Chase River Dam, and at both abutments. Golder's borehole No.5 indicates that unconsolidated sandy silt underlies the centre of the dam: this material may represent a channel-fill of fine alluvium, or a basal till.

Site vi:Lower Chase River Dam

Bedrock, consisting of conglomerates of the Millstream Member, is exposed downstream of the Lower Chase River Dam. The bedrock, where exposed, dips 35 degrees downstream, suggestive of proximity to a fault. Mapping and drilling by Golder Associates suggest that the Lower Chase River Dam is founded upon unconsolidated sediments. Their borehole No.9 through the dam encountered dense but unlithified sandy silt with some gravel, which may represent fine alluvium or till. This dam was formerly the site of a railway bridge serving Wakesiah Colliery.

Site vii: Harewood Mine Dam

This site has not been visited by the author. Air photos and regional geological mapping suggest that the north abutment of the dam may be founded on conglomerate and sandstone of the Millstream Member, while the central and southern portions of the dam may be founded on unconsolidated alluvium.

DISCLAIMER:

This letter should not be construed as a substitute for your geotechnical assessment of the property. Please phone me on (403) 246-3456 if you have any questions.

Yours sincerely,

C.Gwyneth Cathyl-Bickford, FGAC
Chief Geologist

enclosure:
Drawing WR 9851/92, "Figure 1: Geological Sketch Map - Nanaimo City Dam Study", dated February, 1992.

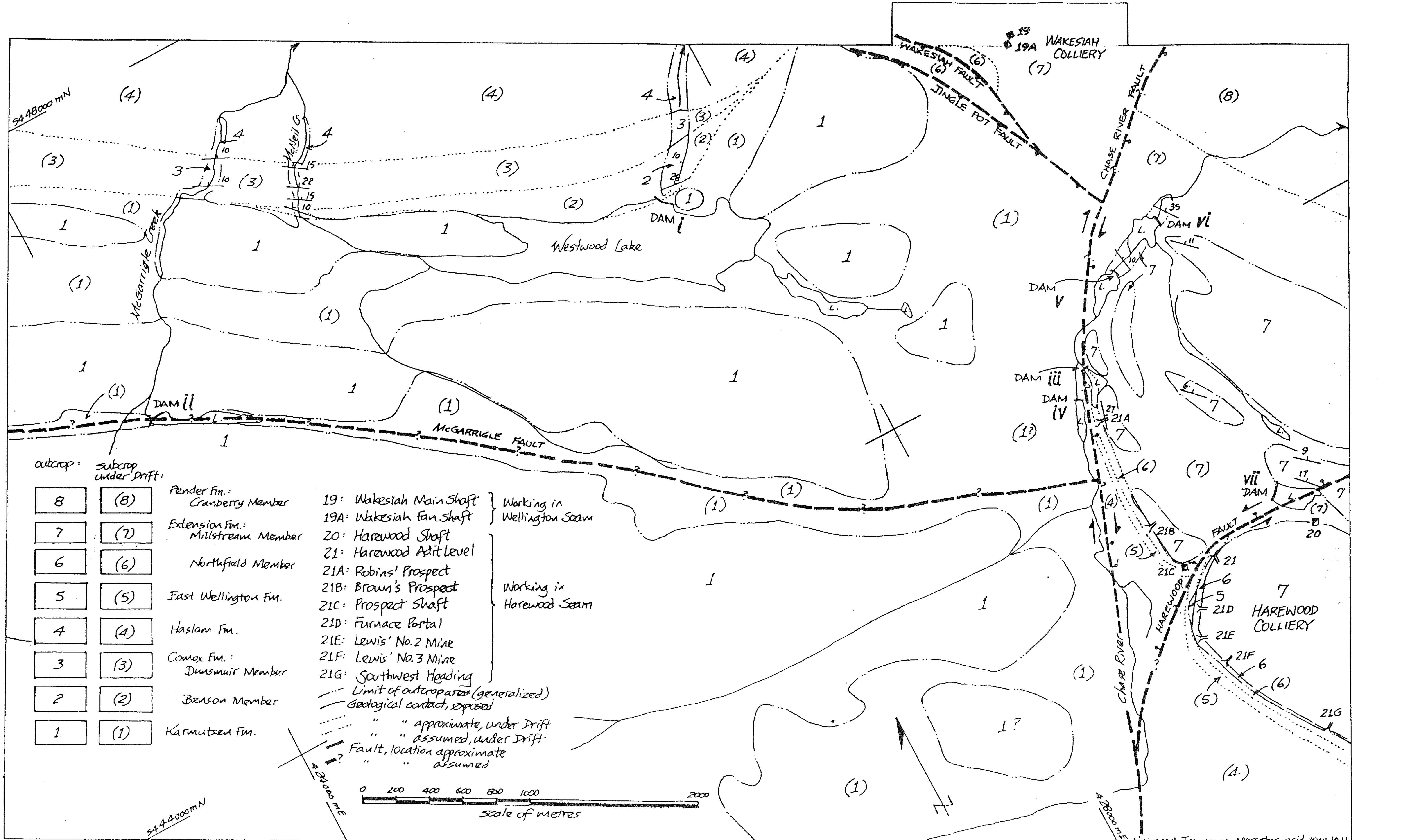


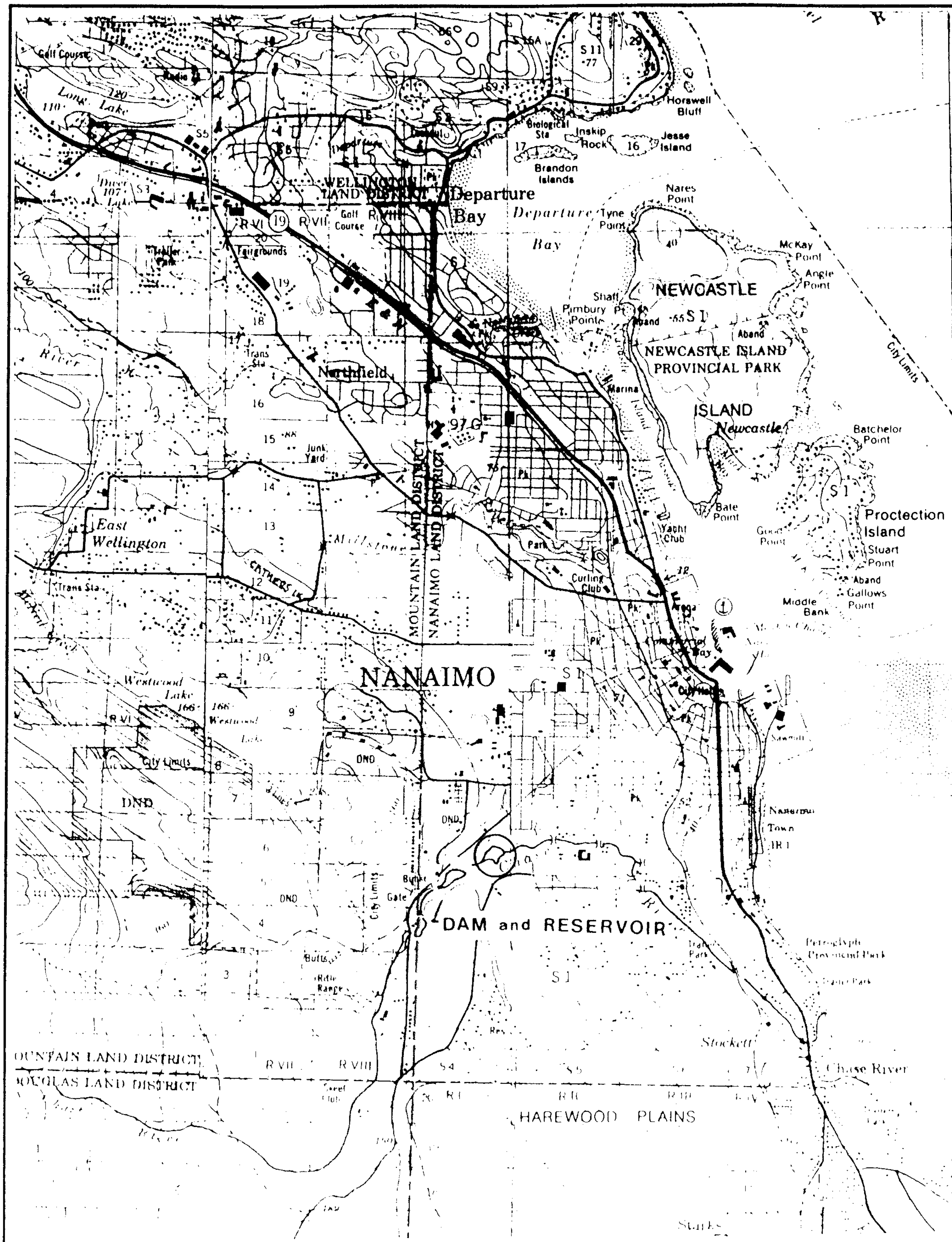
Figure 1: Geological Sketch Map ~ Nanaimo City Dam Study

GEOLOGY BY GWYNETH CATHYL-BICKFORD, 1984-1991. DRAWN BY B. STONECIPHER

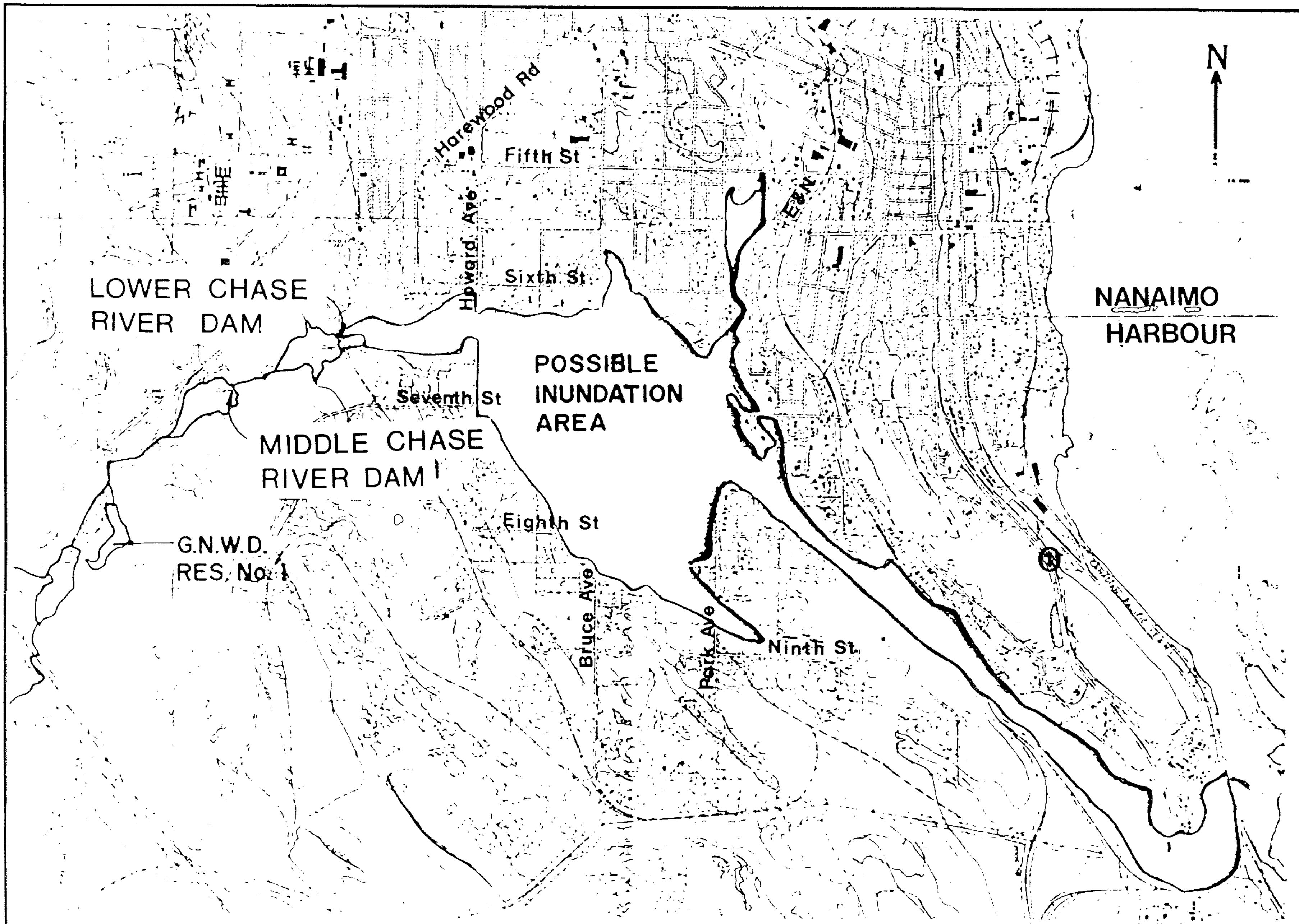
WESTWATER MINING LTD. ~ FEBRUARY 1992

DWG. WR 9851/92

APPENDIX 3C
FIGURES

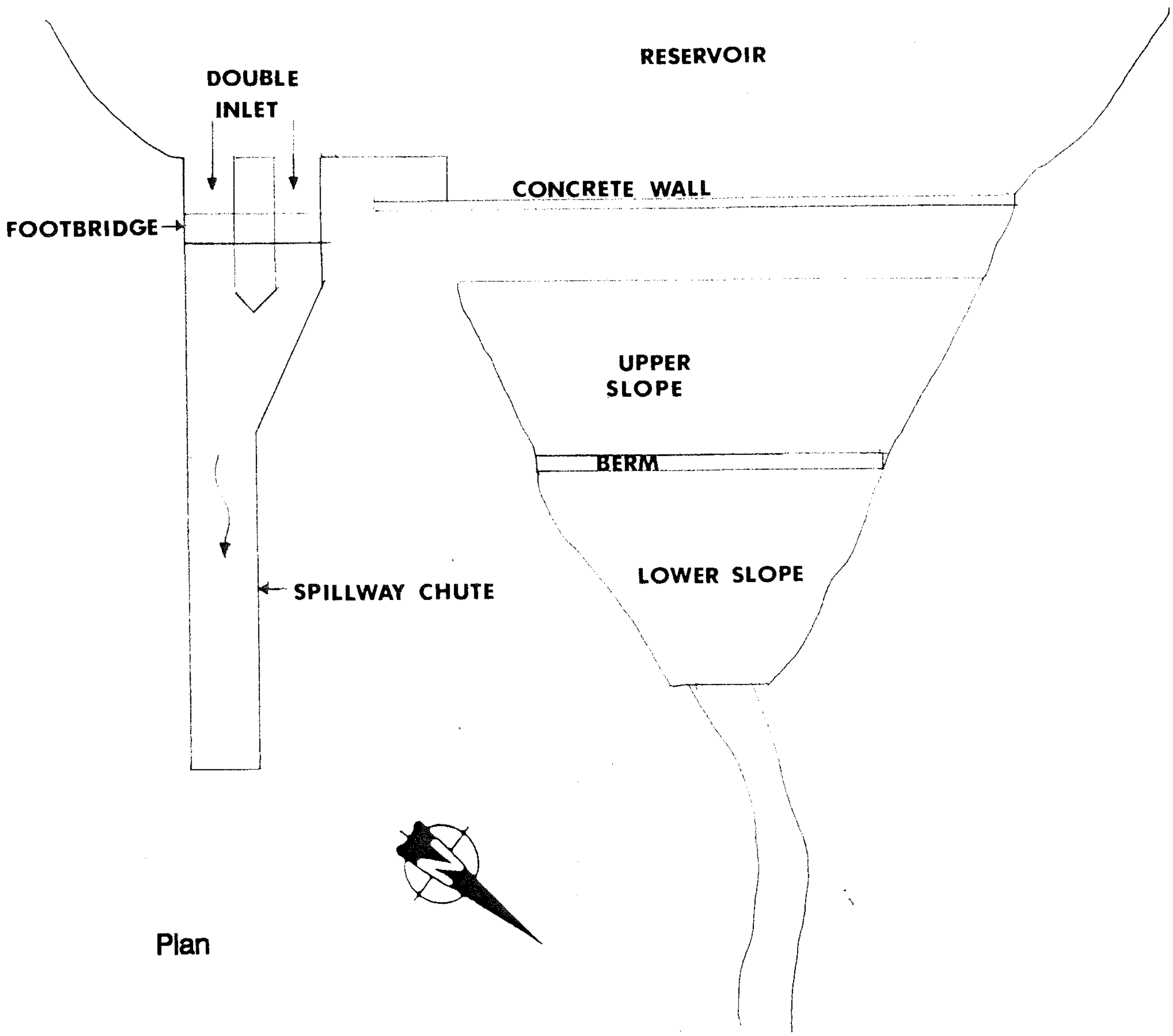


LOWER CHASE RIVER DAM Figure I



LOWER CHASE RIVER DAM

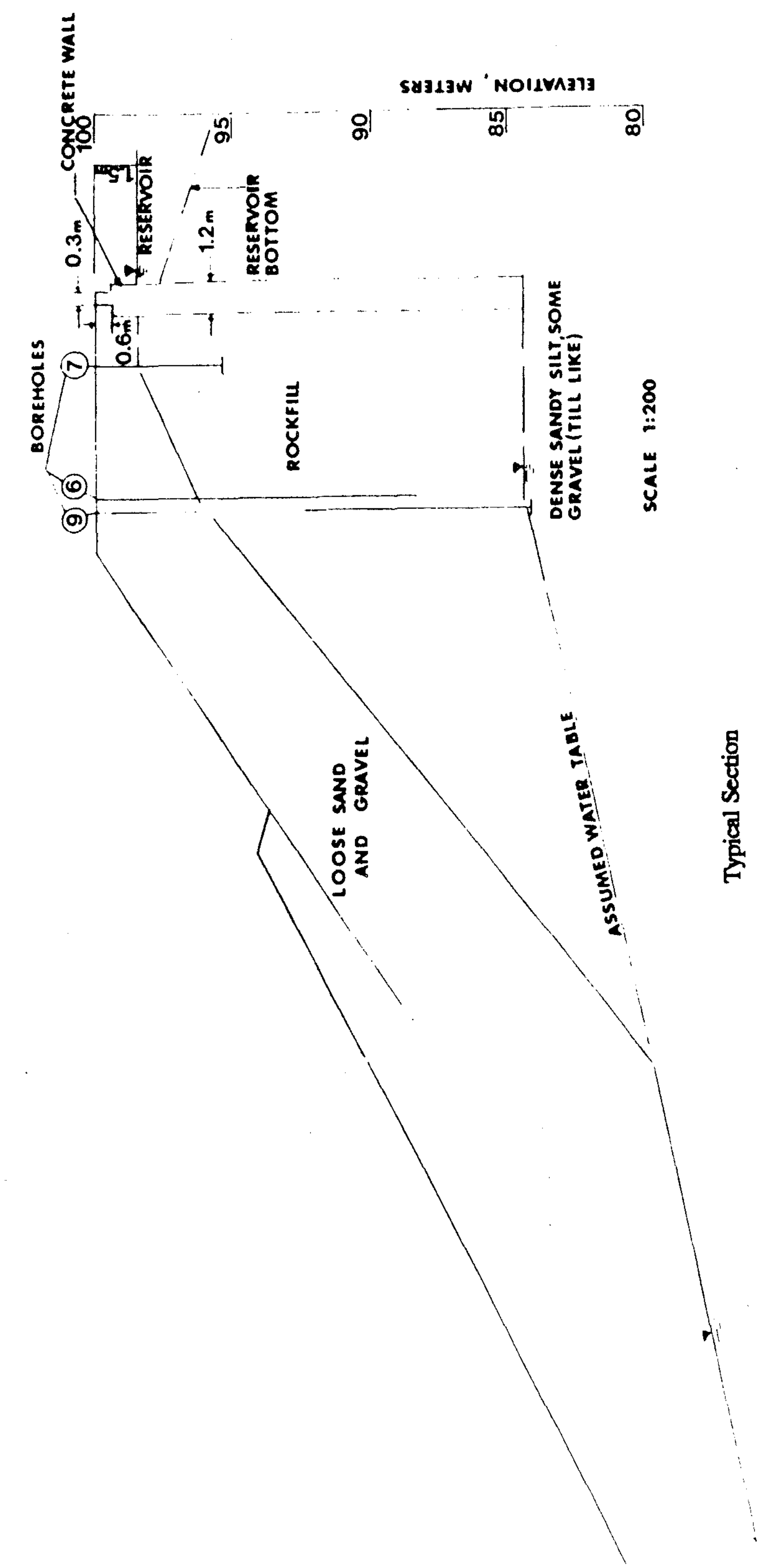
Figure 2



LOWER CHASE RIVER DAM

FIGURE 3

3065



LOWER CHASE RIVER DAM

FIGURE 4