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Overview of Highland Valley Tailings Storage Facility

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SYNOPSIS: This paper presents key features of the Highland Valley tailings storage facility comprising two tailings dams, a 107 m high H-H Dam and a 166 m high L-L Dam. The construction history to date including instrumentation observations is also reviewed. Although the tailings facility is situated in a low to moderate seismic area within the Interior Plateau of British Columbia, potential earthquake sources that might have an impact on the site have been carefully assessed. Both dams are designed to have adequate seismic resistance against design earthquakes appropriate for the site. The L-L Dam valley section, involving soft lacustrine deposits beneath the Starter Dam, has been buttressed by a compacted downstream berm founded on dense glacial till. As the geometry of the tailings storage and distribution facilities and waste dumps changes with time, the quantity and relative cost of various construction materials including natural borrow, cycloned sand and pit overburden also change. Ongoing construction is planned to maintain key earthquake and flood design criteria as well as to adjust the use and placement method of various materials to achieve an efficient and cost effective tailings storage operation. Inherent in the design of the two tailings dams, both constructed by the centerline method, is the flexibility which enables the storage capacity of the tailings facility to be increased beyond the present 1.8 billion tonnes if required at some future time.

INTRODUCTION

Highland Valley Copper, a world-class mining company producing copper concentrate and molybdenum, was formed as a partnership of Lornex Mining Corporation and Cominco on July 1, 1986. The partnership combines the former Lornex and Cominco mining operations comprising the Lornex and Valley orebodies. The two ore bodies, which are only 4 km apart, are both low-grade porphyry copper deposits and are located in Highland Valley, British Columbia, about 200 km northeast of Vancouver (see Fig. 1). Development of the Lornex orebody commenced in 1972, and the Valley orebody in 1983. Since then, the operation has experienced a series of expansions. The latest expansion occurred in 1986-1987. It included the installation of two 1.5 m by 2.3 m semi-mobile in-pit crushers and 2 km long, twin 1.5 m conveyor belts capable of delivering a total of 12 000 tonnes of ore per hour from the Valley pit to the Lornex mill. In 1988 the average ore throughput reaches 120 000 tonnes per day and the operation ranks as the third largest open pit copper mine in the world with the second largest milling capacity (Hansen 1987).

Highland Valley Copper stores its tailings mainly in the Highland Valley tailings facility (ultimate capacity: 1.8 billion tonnes). Auxiliary storages are provided by the Trojan tailings facility (ultimate capacity: 85 million tonnes) and several abandoned pits and one abandoned tailings pond (combined ultimate capacity: 110 million tonnes). This paper describes only the design features of the main facility. As indicated in the general arrangement illustrated in Fig. 2, the facility includes three tailings dams: these are, going from east to west, the H-H, J-J and L-L Dams,

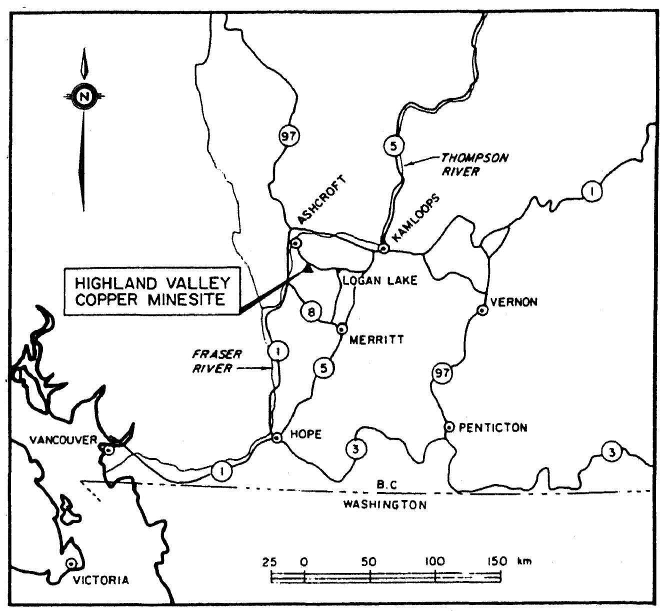

Fig. 1. Location of Highland Valley Copper Minesite

named after the alignment alternatives in the initial feasibility studies. A section through the Highland Valley from the Lornex mill to the L-L Dam is shown in Fig. 3. From 1970 to 1977 Canadian Bechtel Ltd. advised Lornex on tailings storage at the H-H and J-J Dams and the L-L Starter Dam. Since the completion of the L-L Starter Dam in 1977, Klohn Leonoff Ltd.

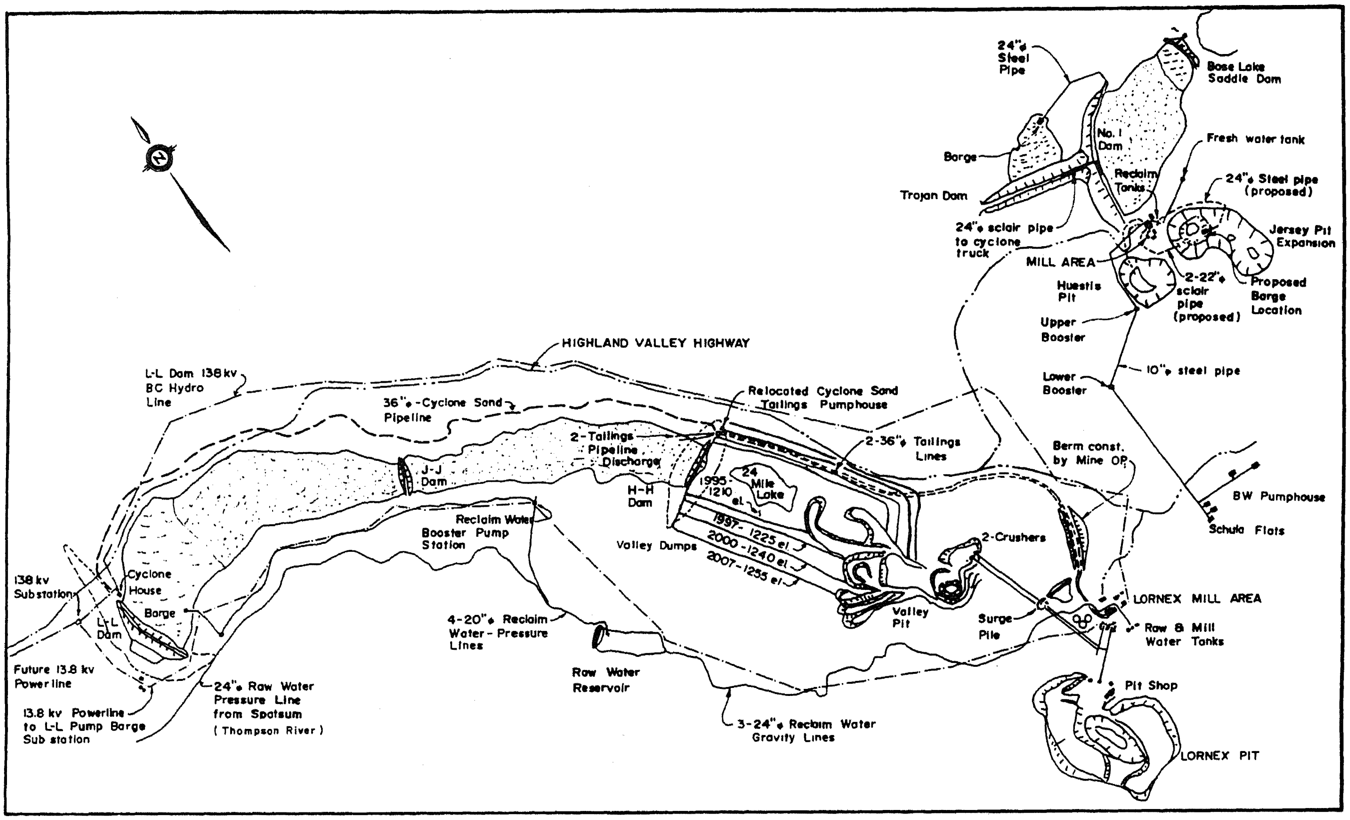

Fig. 2. General Arrangement of Highland Valley Tailings Facility

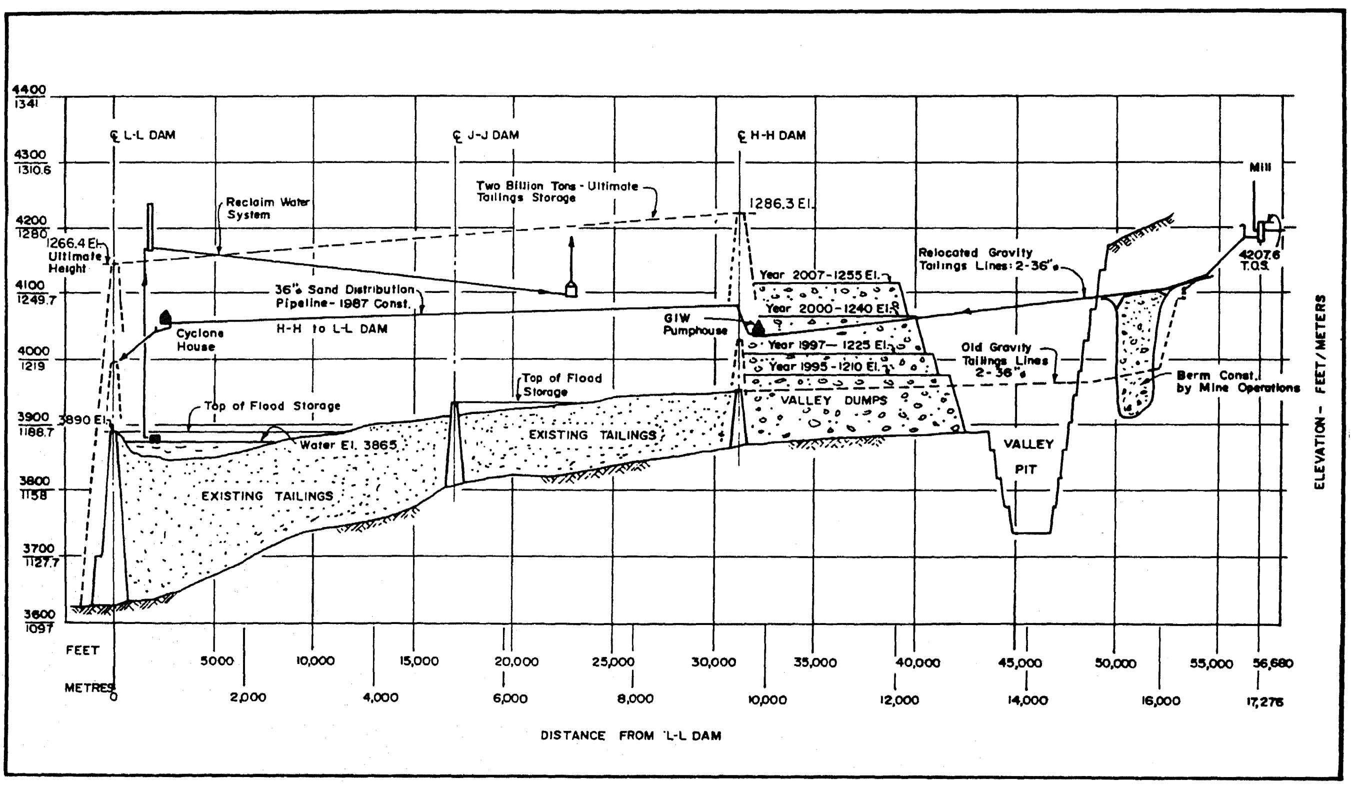

Fig. 3. Section Through Highland Valley Tailings Facility

has provided ongoing consultation and supervision of the raising of the L-L and the H-H Dams. The J-J Dam is scheduled to be buried by tailings in the near future.

This paper reviews key features of the tailings facility, the H-H Dam and the L-L Dam. The performance of the valley section of the L-L Dam, which is partly founded on lacustrine deposits, is also presented.

TAILINGS STORAGE FACILITY

The original Bechtel scheme envisaged the storage of 680 million tonnes of tailings initially in the Upper Pond bounded by the H-H and J-J Dams at a crest elevation of 1303 m. Thereafter, the remaining storage would be provided by the Lower Pond between the J-J and L-L Dams. The reason for adopting this scheme involving an ultimately redundant Middle (J-J) Dam was the lower initial capital cost of the scheme compared with the two-dam scheme involving the H-H and L-L Dams only. With the rapid rise of energy costs since 1973, the relative advantage of the three-dam scheme was eroded quickly. In 1975, Lornex decided to convert the tailings facility to the two-dam scheme.

The existing tailings storage facility is approximately 9.6 km long, and a pond is formed upstream of the L-L Dam. A portion of the tailings flows from the mill to the L-L Dam along a 914 mm diameter pipeline located on the north valley slope. Flow is mostly by gravity with some assistance by booster pumps located at the H-H Dam. Tailings delivered to the L-L Dam are cycloned at the north abutment to produce sand for dam construction. The remainder of the tailings is discharged via a 914 mm diameter pipeline into the tailings pond near the east abutment of the H-H Dam. Both the H-H and L-L Dams are to be raised annually from their respective present heights of 28 m and 93 m to ultimate heights of 107 m and 166 m to meet the ongoing tailings storage requirements of the mining operation.

Site Conditions

The Highland Valley is a broad, U-shaped valley located in the Interior Plateau of south central British Columbia. The Interior Plateau, a physiographic unit of the Canadian Cordillera, has a gently rolling topography with rounded glaciated hills rising to over 1850 m. The Highland Valley is bounded on the east by the broad, shallow Guichon Creek Valley and on the west by the deeply incised Thompson River Valley. There is a high point in the talweg (valley bottom) near the Valley Pit which creates a drainage divide at about 1220 m. From the divide, Pukaist Creek drains westward, directly into the Thompson River. Witches Brook drains eastward from the divide into the Thompson River via Guichon Creek and the Nicola River.

The Guichon Creek Batholith, a semi-concordant dome with an approximate width of 20 km, and length of 65 km oriented with its long axis in the direction slightly west of north, is the predominant bedrock feature in the Highland Valley. Potassium-argon (K/Ar) dating of the Batholith indicates an age of 200±8 million years (Ma). The Batholith is one of several large plutons in the southern portion of the structural province known as the Intermontane Belt. The intrusive rock is associated and possibly comagmatic with Late Triassic volcanic rocks (McMillan 1985). The Highland Valley porphyry copper deposits occur near the center of the Batholith.

Seismo-tectonic Setting and Design Earthquake

The Canadian Cordillera appears to be an assemblage of terrains separated by major fault traces, ophiolite exposures and oceanic marginal basin stratigraphy. Dickinson (1976) links these terrains with the overall geodynamics of an active continental margin. The system was progressively broadened by tectonic accretion of oceanic elements to the edge of the continental block. Abandoned ocean margins, therefore, are located throughout British Columbia. Such a margin is characterized by the Cache Creek terrain and the related Passayten-Fraser-Yalakom Fault Systems. Many of the major structures in British Columbia are associated with these ancient continental margins.

Ewing (1980) postulated the following tectonic model for the North American Cordillera between 40° N and 60° N latitude. In Paleocene time, continuous subduction took place in this area. South of 47° N latitude, subduction continued without interruption since that time. However, north of 47° N latitude, a Pacific-North American transform boundary was formed at about 53 Ma due to the amalgamation of the Pacific, Kula and northern Farallon plates. Concurrently, transform motion was in part taken up on the Fraser-Tintina strike-slip system inland, cross-cutting the volcanism produced from the remnant of the subducted slab. At about 42 Ma, inland transform motion stopped, and all transform motion took place on the Queen Charlotte transform.

Present major tectonic activity in southern British Columbia is limited to major plate boundaries, such as transform faults off the west coast of Vancouver Island, and faulting associated with the thrusting of the Juan de Fuca Plate under southern Georgia Strait and the Puget Lowland. The northern limit of the subducting Juan de Fuca Plate is at approximately 50° N within Georgia Strait. To the south and to the north of this small subducting plate, strike-slip faulting is the prevalent displacement mode between the North American and Pacific plates.

Heaton and Hartzell (1987) outlined a potential seismic hazard related to large subduction earthquakes on the Cascadia subduction zone off the west coast of Vancouver Island. The Cascadia subduction zone shares many characteristics with those subduction zones in Southern Chile, Columbia and Southwestern Japan, where relatively young volcanic lithospheres are involved in the subduction. If the Cascadia subduction zone is storing elastic energy, either a series of several large earthquakes of magnitude 8 (Mw - 8) or a giant earthquake of magnitude 9.5 would be required to fill this 1200 km seismic gap. Because of the substantial distance of this earthquake source from the site (about 480 km), its impact on the site is not significant.

Evidence for most recent tectonic activity in central British Columbia is Tertiary plateau basalts. The basalts, commonly associated with a tensional stress field, were extruded at the same time as crustal extension began in the Basin and Range Provinces in the United States (Noble 1972). Present crustal stress conditions in the Highland Valley are unknown. However, stress levels are expected to be minor compared to stress levels near the continental margin.

Figure 4 (from Ewing 1981) shows an idealized sketch of major Eocene tectonic features in south central British Columbia. Superimposed on the figure are the Highland Valley tailings facility and epicentral locations of earthquakes with indicated magnitudes within an area bounded by 50° N and 51° N and 120° W and 122° W. The plotted seismic events from 1899 to 1984 are those which caused a Modified Mercalli intensity of II or greater at the site. On the other hand, all earthquakes from 1985 to March, 1987 within the area are plotted. Design earthquakes selected for the tailings facility are magnitude 6.5 earthquakes associated with the Guichon Creek Fault and the Lytton Fault. Since the Guichon Creek Fault is closer to the facility, 15 km to the H-H Dam, and 23 km to the L-L Dam, the earthquake associated with the Guichon Creek Fault governs the design of the tailings dams.

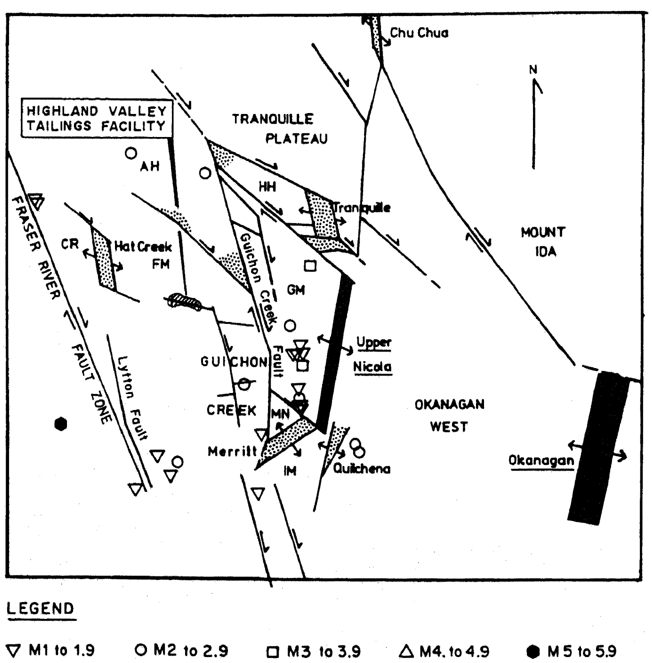

Fig. 4. Epicenters and Major Eocene Tectonic Features in the Vicinity of Highland Valley (after Ewing 1981).

Surface Water

Highland Valley is located in the rain shadow of the Coast Mountain Range in an extension of the upper Sonora Desert of the United States. Most of the precipitation comes down as snow in the winter. Approximately 60% of the runoff in the creeks flowing in the vicinity of the mine occurs during spring runoff in May and June. Main sources of fresh make-up water used in the mill process come from runoffs collected from catchment areas around the mine and tailings pond and a pump installation in the Thompson River about 22 km from the mine. Groundwater tapped by deep wells near the mine provides the balance of the requirement. After sixteen years of operation, the total volume of freewater in the tailings pond has not changed significantly, although it does undergo yearly fluctuation with runoff. Pumping from the Thompson River is minimized based on ongoing monitoring of freewater volume in the pond in order to minimize power consumption.

The tailings pond is operated as a closed system, and is designed to store a design flood inflow volume of 40 600 dam^3 without release. This design flood is arrived at from two different criteria as follows: (1) the sum of the average annual runoff, the 100-year flood and the 24-hour probable maximum flood (PMF); and (2) the sum of the average annual snowmelt runoff and the runoff from a 120-hour probable maximum precipitation (PMP) assumed to occur during the snowmelt period. An additional freeboard of 1 m is added for preventing overtopping of the L-L Dam by waves, although the tailings beach formed in front of the dam tends to mitigate the wave action.

Reclamation and Mine Closure

Reclamation plans and techniques are being developed on an ongoing basis. Growth performance of grasses and legumes in test plots located on the tailings is monitored and evaluated for future reference in reclamation planning. Ultimate land uses for the long and gently sloped (0.3%) tailings pond include: seed production, enhanced grazing for cattle and wildlife, hay production, tree farming and public recreation.

It is envisioned that creeks flowing into the tailings pond, which is sloping from the H-H Dam toward the L-L Dam, will naturally irrigate the reclaimed pond area and form a shallow lake located about 200 m upstream of the L-L Dam. A permanent spillway system will be located on one of the abutments of the L-L Dam. The spillway will consist of an approach channel, a control structure located in a rock cut and an outlet channel. Its location will be determined prior to mine closure upon detailed investigation. The spillway control structure may consist of concrete culverts embedded in a concrete free overflow crest structure. The culverts would pass normal flows, and most flood flows due to the attenuating function of surcharge storage provided by the L-L Dam above the invert elevation of the culverts. The overflow structure would generally not pass water unless the culverts became blocked or inflow rates approached those of a design PMP event.

In the event of a prolonged shutdown of mining operation prior to mine closure, a temporary spillway or other facilities will be provided to release flood water and protect the L-L Dam from overtopping.

Highland Valley Copper may consider developing the available water storage in the tailings pond for downstream irrigation usage and/or power generation after mine closure. This could entail provision of regulating gates on the culverts or stoplogs at the spillway to allow controlled release of stored water during the summer months. Water surplus to local irrigation requirements could be fed through the existing Thompson River pipeline to a hydroelectric plant installed in the Thompson River pumphouse.

H-H DAM

The H-H Dam, which forms the eastern limit of the tailings facility, is situated on Pukaist Creek, approximately 6.5 km northwest of the Lornex millsite. Figure 5 shows a typical section through the dam. The elevation of the valley floor at the damsite is about 1180 m with the valley walls gently sloping upward to a maximum elevation of 1820 m.

Results from several field investigation programs covering the foundation and abutments reveal the following subsoil profile at the damsite:

- medium dense surficial glaciofluvial sands and gravels, 2 to 18 m thick;
- very dense, well graded glacial till, 6 to 23 m thick;
- very dense interglacial sands and gravels and underlying inter-layered deposits, 0 to 135 m thick.

Depth to bedrock is in excess of 169 m near the center of the valley and decreases to about 5 m on the abutments near the ultimate crest elevation.

The Starter Dam, completed in 1972, is a zoned, earthfill structure with a 15.2 m wide central impervious core of glacial till and more pervious shells. A drainage zone is included in the downstream shell to control seepage through the dam. A cutoff trench was excavated at the center of the base of the impervious core to tie into the dense glacial till foundation. The trench was backfilled with impervious glacial till. Across the stream channel in the valley section, the cutoff trench was shifted upstream in order to reduce the amount of excavation and backfill required. Following the completion of the Starter Dam, the ongoing raising of the H-H Dam consists of the following major fill zones:

(1) central impervious core extending above the core of the Starter Dam;

(2) downstream shell composed of structural fill;

(3) downstream pervious fill underlying the downstream shell;

(4) upstream shell of random fill;

(5) upstream zone of tailings.

The Starter Dam, the impervious glacial till core and the downstream shell materials are compacted to a minimum of 97% standard Proctor density. Upstream of the central core, the random fill is lightly compacted by routing construction equipment over the area during fill placement.

The future raising of the H-H Dam will continue the current practice of using natural borrow material for the central core and downstream zones. However, the relative cost of using cycloned sand and/or stripped overburden materials from the Valley Pit as fill materials for the downstream zone will be investigated to check their economic viability. Table 1 indicates required embankment volumes for the H-H Dam per unit of tailings storage. The ratio of embankment volume to tailings storage is quite small, in the range of 3 to 5 $m^3/1000\ m^3$ after 1988. Because of this low ratio, it is not justified to install a very sophisticated cyclone sand facility at the H-H Dam. Moreover, as the western limit of Valley Pit waste dumps progresses towards the H-H Dam, the incremental cost of hauling pit overburden from the waste dumps to the dam will decrease. Thus, the source of downstream fill for the H-H Dam may shift from natural borrow materials to mine waste. After 1995 the waste dumps will abut against the H-H Dam and act as an enormous downstream buttress.

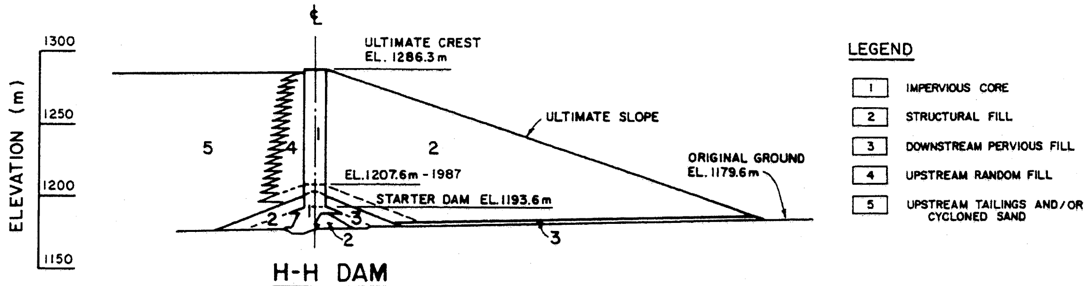

Fig. 5. Typical H-H Dam Section

TABLE 1

REQUIRED H-H DAM EMBANKMENT VOLUME PER UNIT OF TAILINGS STORAGE

YEAR	DESCRIPTION OF TAILINGS FACILITY	REQUIRED EMBANKMENT VOLUME PER UNIT OF STORAGE $M^3/1000\ M^3$
1976-1986	Storage Between J-J and L-L Dams	
1987	H-H Dam Raised Using Natural Borrow	10.60
1988	H-H Dam Raised Using Natural Borrow	3.33
1989-1994	H-H Dam Raised Using Mine Waste as Option	5.33
1995-1996	First Waste Dump Lift Buttressing H-H Dam	4.65
1997	Second Waste Dump Lift Buttressing H-H Dam	3.69

L-L DAM

The L-L Dam forms the western limit of the tailings facility. The L-L Dam is located on Pukaist Creek near the junction of the Highland Valley and the Thompson River Valley. The valley at the L-L Damsite is roughly U-shaped with a relatively flat floor at about elevation 1100 m and valley walls gently sloping to a maximum elevation of about 1829 m. Pukaist Creek meanders across the damsite and then cuts through a moraine of glacial till and starts its rapid descent to the Thompson River about 2.5 km downstream of the L-L Dam. Field investigation programs, carried out in stages covering the foundation and abutments, reveal the following subsoil profile:

- very soft to firm, sensitive swamp and lacustrine deposits involving volcanic silt-clay, varved clay, silt and silt-sand, up to 15.5 m thick in the valley section;
- up to 2.5 m of dense ablation till overlying very dense basal till of varying thickness;
- very dense, clean interglacial sands, up to 40 m thick in the valley section.

The depth of surficial soils overlying bedrock varies substantially along the centerline of the dam. On the south abutment, the overburden depth varies from about 1 m to 15 m. The soil thickens to about 75 m at the center of the valley. On the north valley slope, the soil layer peters out to negligible thickness at elevation 1230 m on a volcanic knoll then thickens to 29 m or greater near the ultimate crest elevation of the dam.

The L-L Starter Dam is a zoned earthfill structure, with a central till core and an upstream cutoff trench, constructed with locally borrowed soil over the soft swamp and lacustrine deposits (see Figs. 6 and 7). A system of vertical geo-drains and a horizontal sand and gravel blanket were used to accelerate the consolidation rate of the lacustrine deposits. The construction of the Starter Dam was also staged over two years: a 12.2 m high fill placed in 1976; and 30.5 m of fill placed in 1977. In addition, the foundation of the Starter Dam was extensively instrumented. Salient features of the design and construction of the Starter Dam were summarized by Burke and Smucha (1979).

The L-L Dam, which comprises a central till core, a downstream shell and upstream sluiced cycloned sand and tailings, is being raised using the centerline construction method (see Fig. 6). Two measures were taken to improve the foundation stability of the L-L Dam valley section (see Fig. 7) for both static and dynamic loadings and to allow the construction rate of the dam to accelerate according to the tailings storage need of the mining operation. These were:

(1) excavating the soft swamp and lacustrine deposits from beneath downstream construction stages of the dam and replacing them with compacted granular fill, and

(2) constructing a large buttress berm downstream of that portion of the Starter Dam founded on the soft deposits (Klohn, Lo and Olsen 1982).

Upon completion of the Starter Dam, a large portion of the tailings pumped to the L-L Dam was used to fill the void at the bottom of the valley immediately upstream of the dam. The filling involved on-dam cycloning, uniform spigotting, and end discharge from large pipes. From 1978 to 1979 all fill placed in the downstream zone of the dam came from natural borrow. Since 1980, the amount of cycloned sand used in the downstream zone has been steadily increased. By 1982, downstream fill came almost exclusively from cycloned sand. Cost-effective and efficient construction techniques involving direct hydraulic placement and mechanical compaction by bulldozers for handling and placing the sand have been developed since 1982 (Scott and Lo 1984). Table 2 shows required embankment volumes for the L-L Dam per unit of tailings storage since 1976. The ratio of embankment volume to tailings storage is quite large, in the range of 20 to 37 $m^3/1000\ m^3$. The ratio was even higher during the Starter Dam construction in 1976 to 1978, and again during accelerated construction in 1987 to make up flood storage lost with the burial of the J-J Dam. With the exception of above two periods, the ratio steadily drops from 37 in 1979 to 20 in 1992. Therefore, the cycloned sand delivery system designed for earlier years will develop excess capacity in later years. With greater volumes of cycloned sand available for dam construction in the future, techniques with potential to further reduce construction cost will be studied.

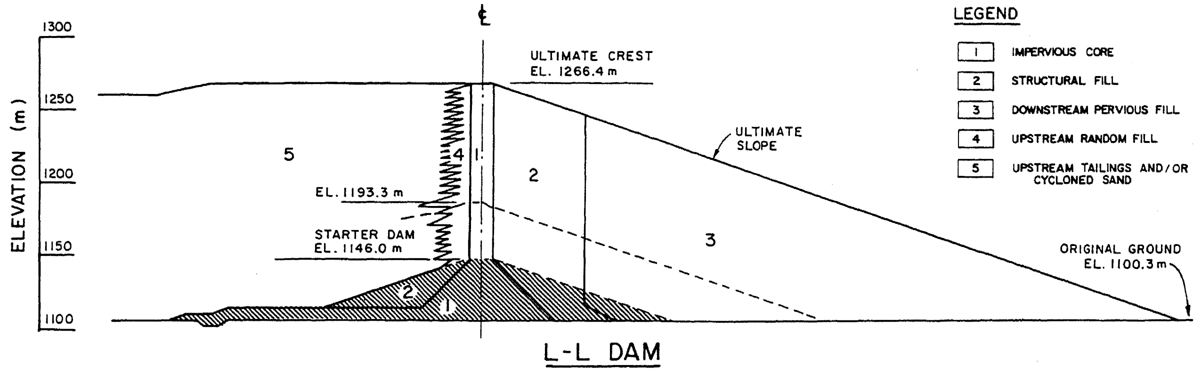

Fig. 6. Typical L-L Dam section

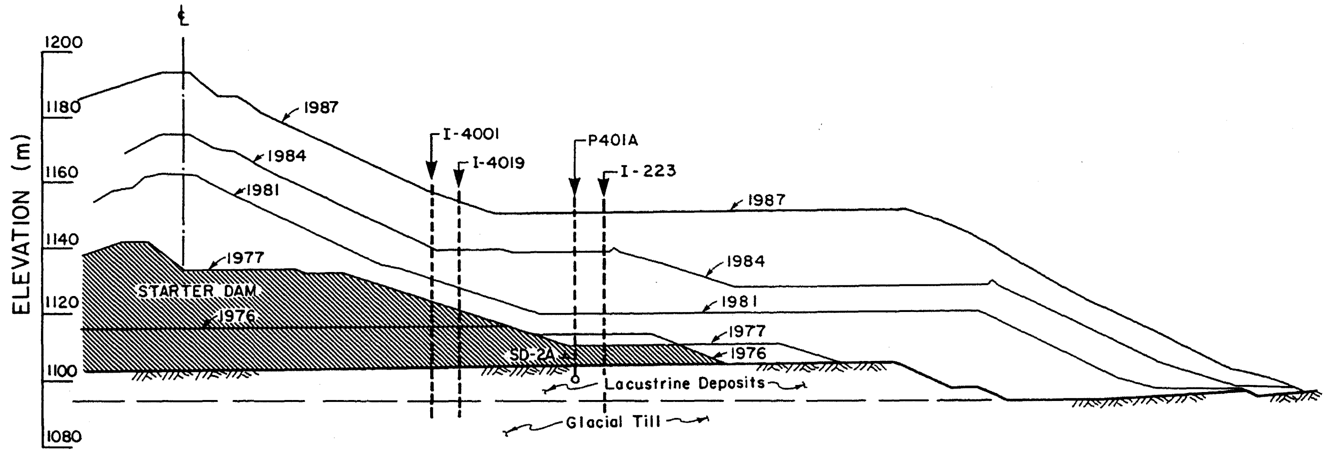

Fig. 7. L-L Dam Valley Section Over Lacustrine Deposits

TABLE 2
REQUIRED L-L DAM EMBANKMENT VOLUMES PER UNIT OF TAILINGS STORAGE

YEAR	DESCRIPTION OF TAILINGS FACILITY	REQUIRED EMBANKMENT VOLUME PER UNIT OF STORAGE $M^3/1000\ M^3$
1976-1978	Starter Dam Construction	142.54
1979-1986	Storage Between J-J and L-L Dam	37.05
1987	Accelerated Dam Construction for Flood Storage	44.59
1988-1991	Initial Storage Between H-H and L-L Dam	26.92
1992 Onwards	Ongoing Storage Between H-H and L-L Dam	19.83

The current L-L Dam design includes an alternative to incorporate a substantial zone of hydraulically placed, uncompacted sandfill in the downstream section above the saturation zone without compromising the resistance of the dam to seismic loadings. Techniques considered to place cycloned sand in this uncompacted zone include:

(1) cell construction technique involving discharge of underflow through pipeline as used at Brenda Mines and the upstream section of the L-L Dam in 1987;

(2) mobile, on-dam cyclone technique involving direct discharge of underflow from cyclone apexes as used at the Trojan Dam; and

(3) fixed, on-dam cyclone technique involving direct discharge of underflow from cyclone apexes as used at Gibraltar Mines.

In the evaluation of various techniques, the cost of delivering and cycloning the sand has to be weighed with the cost of placing the sand in the embankment.

Instrumentation Observations and Back Analysis

Comprehensive instrumentation installed for monitoring the foundation performance of the Starter Dam consists of shallow pneumatic and standpipe (Geonor and Casagrande) piezometers, deep standpipe piezometers and observation wells, inclinometers, and pneumatic settlement gauges. Figure 7 shows the location of some instrumentation to be discussed later. This instrumentation has been maintained and expanded to include standpipe piezometers monitoring the saturation level in the dam fill. Piezometers located in the downstream pervious fills continue to show low saturation levels. Readings from shallow foundation piezometers located in the lacustrine deposits reflect the usual pattern of pore pressure rise during fill placement and its gradual dissipation with time. Shallow foundation piezometers located in the glacial till beneath the Starter Dam and abutment sections show little influence of seepage from the tailings pond. Deep foundation piezometer and observation wells indicate little to minor change of groundwater regime at depth since water impoundment in the tailings pond in 1976. To date total foundation settlements for the Starter Dam range from 1 to 3 m. These settlements reflect the consolidation of the lacustrine deposits in response to the increasing embankment loading. Downstream horizontal foundation movements within the Starter Dam range from 100 mm to 500 mm. These movements reflect the ongoing foundation adjustments to the embankment loading under partially drained condition.

Piezometric (P401A) and settlement (SD-2A) data from the lacustrine deposits beneath the Starter Dam are shown on Figs. 8(b) and (c). Solid lines represent continuous observation data, while long dashed lines represent extrapolated data based on other operating instruments. A one-dimensional consolidation finite-difference computer program (Wong and Duncan 1985) was used to back analyze the ongoing consolidation in response to fill loading in the berm area (see Fig. 8a). The computed pore pressure and settlement are also shown in Figs. 8(b) and 8(c) as short dashed lines. Table 3 summarizes laboratory test data and the back-analyzed field observation data. For the compression index, C_c, the field values are about one-half of the laboratory values possibly due to sample disturbance involved in laboratory tests. For the coefficient of consolidation, C_v, the field values are about four times the laboratory values. Horizontal stratification and the presence of vertical geo-drains in field deposits are considered as additional contributing factors to this difference between field and laboratory values.

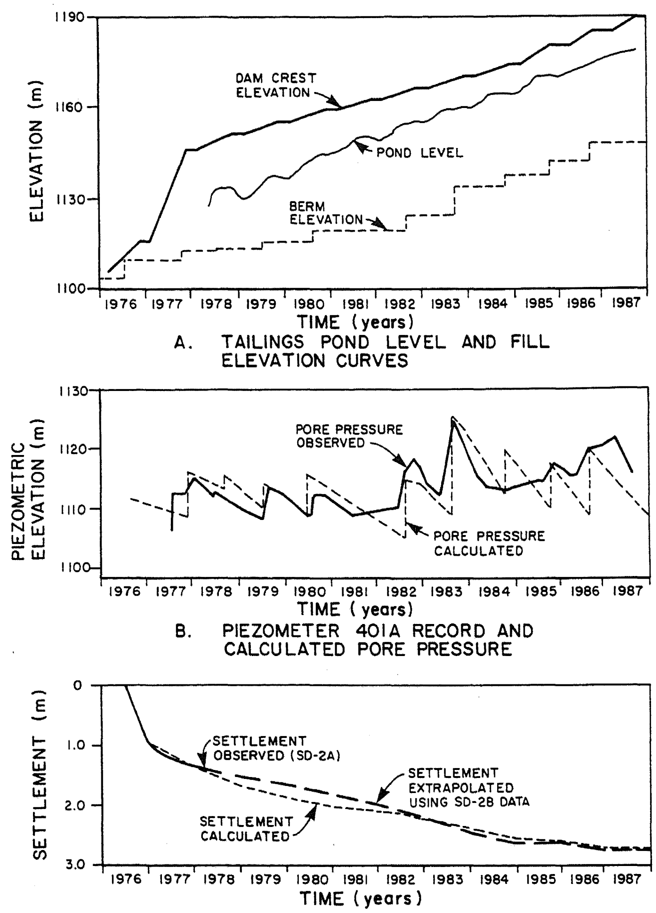

Fig. 8. Observed and Back Analyzed Pore Pressure and Settlement Data

Inclinometer (I-223) data in the mid-valley section showed horizontal displacements of about 200 mm from 1976 to 1977. In 1978, Inclinometer I-4001 was installed as a replacement for I-223. The inclinometer data for I-4001 is shown in Fig. 9 as displacement profiles and accumulated displacement-time plots for a reference point at the foundation level. Solid lines represent continuous observation data, while dashed lines represent extrapolated data based on an adjacent inclinometer (I-4019) installed in 1986 as a replacement for I-4001. The majority of movement is confined to the upper silt-clay/varved clay horizons. Inferred average field shear strains based on the initial thickness of these horizons are also shown in Fig. 9. Using the decreased thickness obtained from recorded settlements, the shear strain would be about 30% larger than that shown in Fig. 9 at the end of 1987.

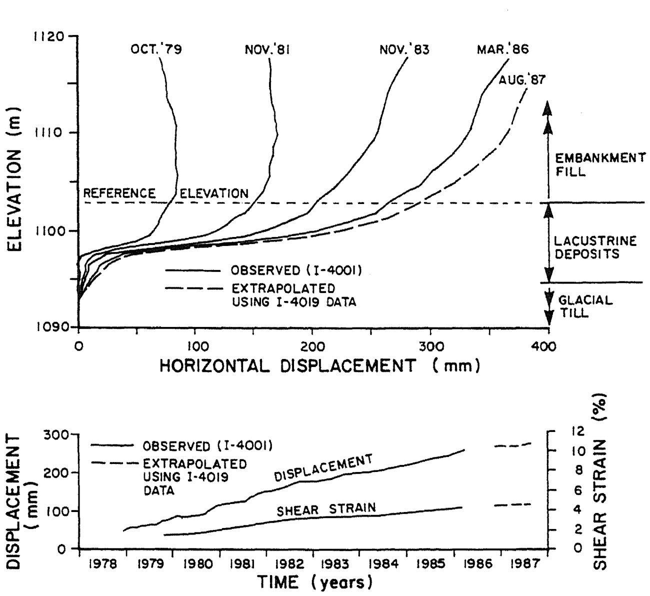

Fig. 9. Observed Inclinometer Data

The embankment loading induced foundation deformation of relatively soft lacustrine deposits between more rigid foundation soils at depth and compacted fill above can be closely simulated by laboratory simple shear tests. Four simple shear tests: two consolidated-drained (Tests 1 and 2) and two consolidated-undrained (constant volume Tests 3 and 4) were carried out at the University of British Columbia. Results of these tests are shown in Fig. 10. Under drained condition, large shear strains (in the order of 25%) are associated with the ultimate shear strength whereas under undrained condition the corresponding strains are much smaller (in the order of 2%). The accumulated field shear strain in the region of shown inclinometers, including that inferred from Fig. 9 and that occurred earlier, is in the order of 8% representing foundation deformation under partially drained condition.

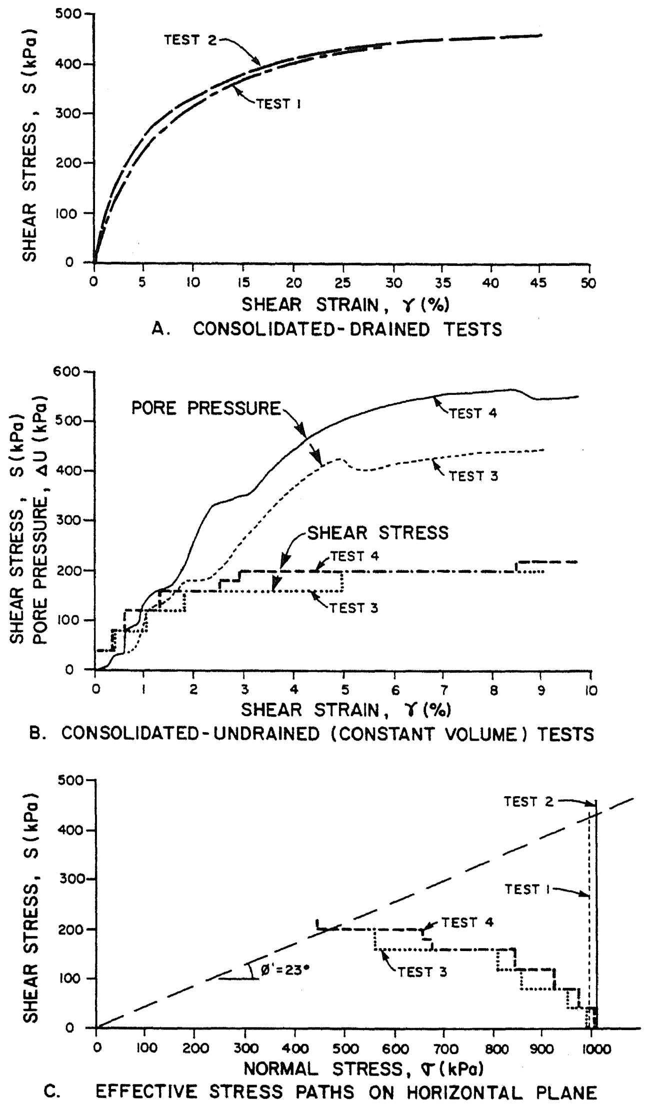

Fig. 10. Summary of Simple Shear Test Results

TABLE 3

CONSOLIDATION PARAMETERS FROM LABORATORY TESTS AND BACK-ANALYZED FIELD DATA

LACUSTRINE DEPOSITS	THICKNESS (m)	OEDOMETER TESTS: VOID RATIO e_o RANGE	TYPICAL	COEFFICIENT OF COMPRESSION C_c RANGE	TYPICAL	COEFFICIENT OF CONSOLIDATION C_v ($\times 10^{-4}$ cm^2/s) RANGE	TYPICAL	BACK-ANALYZED FIELD DATA: VOID RATIO e_o	PORE PRESSURE PARAMETER r_u ($=\Delta u/\Delta\sigma_v$)	COEFFICIENT OF COMPRESSION C_c	COEFFICIENT OF CONSOLIDATION C_v ($\times 10^{-4}$ cm^2/s)
clay-silt	5.2	4.7-4.9	4.9	2.7 -3.3	3.3	0.3-2.0	2	4.9	0.8	1.15	8
varved clay	4.0	0.8-2.1	1.4	0.10-1.07	0.65	4 -700	10	1.4	0.8	0.28	40

SUMMARY

Since its initial impoundment in 1972, the Highland Valley tailings storage facility has continued to serve the need of the mining operation to store its tailings at an ever increasing rate. Throughout its development, the geometry of the tailings storage and distribution facilities and waste dumps undergoes continued changes. Ongoing construction of the storage facility is planned to maintain key earthquake and flood design criteria as well as to adjust the use and placement method of various construction materials including natural borrow, tailings sand and mine waste as they become available. Various construction techniques are explored to develop an efficient and cost effective tailings storage operation. Satisfactory performance of the H-H and L-L Dams are experienced to date. Back analysis of the instrumented L-L Dam valley section founded partially on the lacustrine deposits provides valuable information for planning ongoing construction activities. The flexibility inherent in the design of the two dams constructed by the centerline method allows the storage capacity of the facility to be expanded even beyond the current design of 1.8 billion tonnes, if required in the future. The facility will eventually be reclaimed in an orderly fashion to allow for multiple uses of the reclaimed land as well as the stored water. A permanent spillway system will be installed at the L-L Dam to ensure the safe passage of flood water through the storage facility back into the natural course of the Pukaist Creek downstream.

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