SHALLOW WATER COVERS - EQUITY SILVER BASE INFORMATION ON PHYSICAL VARIABLES

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SHALLOW WATER COVERS - EQUITY SILVER

BASE INFORMATION ON PHYSICAL VARIABLES

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EXECUTIVE SUMMARY

A field program to collect baseline physical data for an existing tailings pond was completed between September 11th and 16th, 1995, at the Equity Silver Mine located near Houston, British Columbia. The program was undertaken as part of a multi-disciplinary study to evaluate the effectiveness of using shallow water covers to control acid generation from mine tailings. A specific objective of the study outlined in this report was to collect data from the Equity pond that could be used to evaluate a calculations procedure used to determine the depth of water cover required for bed stability in a man-made tailings pond.

The field program consisted of 3 components:

- a bathymetric survey of the pond;
- the collection of 13 surficial sediment samples and 2 sediment cores from each of 3 separate locations in the pond; and,
- the observation of bedforms within the pond at different locations.

The median (D_{50}) grain size of the sediment samples, based on the average of the 15 samples from each location, were 0.0512 mm at the shallowest location (1.3 m water depth), 0.0075 mm at the middle location (2.3 m water depth) and 0.0040 mm at the deepest location (3.4 m water depth). The sediment size distributions at each location, and hence water depth, were statistically distinguishable. Variation in median size between the 15 samples collected at each location was small. One standard deviation around the median grain size yielded a size range of 0.0248 - 0.0775 mm at the 1.3 m water depth location, 0.0049 - 0.0101 mm at the 2.3 m water depth location and 0.0036 - 0.0044 mm at the 3.4 m water depth location. These data are consistent with the transport of sediment away from the tailings outfall during discharge into the pond.

Sediment submerged weight density was averaged for the 15 samples collected at each water depth location. This density decreased with increasing water depth. Submerged weight density of the sediments was 1.645 $\pm$ 0.299 tonnes/m^3 at the 1.3 m water depth location, 1.220 $\pm$ 0.116 tonnes/m^3 at the 2.3 m water depth location and 1.068 $\pm$ 0.193 tonnes/m^3 at the 3.4 m water depth location. The decrease in *in situ* submerged weight density with increasing depth is consistent with the dewatering of tailings around the pond periphery following discharge. The average submerged weight density for the sediments in the pond as a whole is 1.318 $\pm$ 0.328 tonnes/m^3 regardless of covering water depth.

The 2 cores from each location revealed similar stratigraphy between cores. The cores collected at 1.3 m depth exhibited some stratigraphic differentiation with transitions evident between layers of unconsolidated and semi-consolidated tailings to a depth of approximately 0.70 m. The cores from the two deeper sites obtained approximately 0.65 m of core but only exhibited one transition from unconsolidated tailings to semi-consolidated tailings at approximately 0.35 m below the bed.

Using the presence of bed forms on the bottom of the pond as evidence of movement of bed sediments, indicated that wave-induced mobilization of sediments on the bed has occurred to a water depth of 1.3 to 1.4 m since tailings were deposited. The maximum open-water wind speed recorded at the site since cessation of tailings deposition was 18.6 m/s. Using the procedure outlined by Hay & Company Consultants Inc. (1995) indicated the depth of water cover required for no movement of Equity tailings during a wind speed of 18.6 m/s is 1.4 m. The close comparison between the disappearance of bed forms at 1.3 to 1.4 m depth and the prediction of a maximum depth of 1.4 m for the historic wind conditions provides confidence in the predictive equation. At present, the percentage of the Equity pond with water depths shallower than 1.4 m is 7%.

SOMMAIRE

Une étude de terrain a été exécutée entre le 11 et le 16 septembre, 1995, à la mine Equity Silver, située près de Houston, Colombie Britannique, afin de rassembler des données physiques relatives à un parc à résidus. Cette collecte de données fait partie d'une étude multidisciplinaire établie pour évaluer l'efficacité de l'emploi d'une barrière d'eau peu profonde pour contrôler la production d'acide provenant des résidus miniers acidogènes.

L'étude sur le chantier comprenait les trois éléments suivants:

- un relevé bathymétrique du bassin;
- une collecte de 13 échantillons de sédiments de surface et deux carottes de sédiments de trois différents endroits dans le bassin; et,
- l'observation des formations de lits de résidus dans le bassin à différents endroits.

Les grosseurs de grains médianes (D_{50}) des échantillons de sédiments, basées sur la moyenne des 15 échantillons obtenus de chaque endroit, sont les suivantes: 0.0512 mm pour l'endroit le moins profond (profondeur d'eau de 1.3 m), 0.0075 mm au milieu (profondeur d'eau de 2.3 m) et 0.0040 mm pour l'endroit le plus profond (profondeur d'eau de 3.4 m). La distribution de la grosseur des sédiments à chaque endroit, et donc la profondeur d'eau, peuvent être distinguées statistiquement. Les variations entre les grosseurs médianes des 15 échantillons ramassés à chaque endroit étaient mineures. A un écart type de la grosseur de grains médiane, les variations de grosseur de grains pour chaque endroit sont les suivantes: 0.0248 - 0.0775 mm à la profondeur d'eau de 1.3 m, 0.0049 - 0.0101 mm à la profondeur d'eau de 2.3 m et 0.0036 - 0.0044 mm à la profondeur d'eau de 3.4 m. Ces données sont compatibles avec le transport des sédiments du déversoir de résidus lors de la décharge dans le bassin.

La moyenne des densités des poids submergés des sédiments a été établie pour les 15 échantillons obtenus à chaque endroit. Les résultats ont indiqué que la densité a diminué avec la profondeur d'eau. Les densités des poids submergés des sédiments étaient 1.645 $\pm$ 0.299 tonnes/m^3 à une profondeur de 1.3 m, 1.220 $\pm$ 0.116 tonnes/m^3 à 2.3 m et 1.068 $\pm$ 0.193 tonnes/m^3 à 3.4 m. La diminution de la densité du poids submergé avec une profondeur d'eau croissante s'accorde avec l'assèchement des résidus autour du périmètre du bassin suivant la décharge. La densité du poids submergé moyenne pour les sédiments dans le bassin dans l'ensemble est 1.318 $\pm$ 0.328 tonnes/m^3, sans considérer la profondeur de l'eau par-dessus les sédiments.

Les carottes obtenus de chaque endroit ont révélé la même stratigraphie. Les carottes de 1.3 m de profondeur ont démontré des différenciations stratigraphiques, avec des transitions évidentes entre les couches de résidus non-consolidés et semi-consolidés qui se répétaient jusqu'à une profondeur d'approximativement 0.70 m. Les carottes des deux sites plus profonds comprenaient approximativement 0.65 m de carotte, mais ne démontraient qu'une seule transition de résidus non-consolidés à résidus semi-consolidés à approximativement 0.35 m au-dessous du lit.

L'interprétation de la présence des formations de lit au fond du bassin comme signe de mouvement des sédiments du lit indique que la mobilisation de ces sédiments par l'action des vagues a eu lieu jusqu'à une profondeur d'eau de 1.3 à 1.4 m depuis que les résidus ont été déposés. La vitesse maximum du vent enregistrée au site depuis l'arrêt du dépôt des sédiments est de 18.6 m/s. Les résultats de l'application de la procédure décrite par Hay & Company Consultants Inc. (1995) indiquent qu'une profondeur d'eau de recouvrement de 1.4 m est exigée pour empêcher le mouvement des résidus d'Equity à une vitesse du vent de 18.6 m/s. L'équation employée pour prévoir la profondeur d'eau est supportée par les résultats parallèles obtenues entre la disparition des formations de lit à profondeur de 1.3 à 1.4 m et la prédiction d'une profondeur maximum de 1.4 m en employant l'équation pour les conditions de vent historiques. Le pourcentage du bassin Equity avec des profondeurs d'eau de moins de 1.4 m est 7%.

1 INTRODUCTION

Acidic drainage occurs as the result of natural oxidation of sulphide minerals contained in rock which is exposed to the oxygen present in the atmosphere. The covering of sulphide bearing mine tailings by a shallow layer of water has been suggested as one means of control. This suggestion was based on work undertaken with respect to the geochemical properties and processes of acid rock under water cover that demonstrated the viability of water cover as a control technique. This work suggests that a physically stable bed will develop and maintain geochemical gradients which inhibit acid generation and diffusion of metals to the water column.

Equity Silver Mine, located near Houston, B.C., ceased operation in January, 1994. Tailings from the mine were deposited in a man-made impoundment where they were submerged under a shallow water cover to reduce the generation of acidic drainage. The tailings pond has no inflow or outflow with the exception of an emergency spillway to prevent dyke overtopping. Water exchanges between the pond and the surrounding environment are through precipitation and evaporation with a small amount of seepage occurring at the north edge of the impoundment.

The tailings pond at the Equity Silver Mine provides an excellent opportunity to evaluate the concept of subaqueous disposal of acid-generating tailings since it is man-made and isolated from the surrounding environment. The pond does not have the geochemical interactions associated with tailings disposal in a natural water body which are derived from the organic loading and inflow and outflow components of the hydrologic cycle.

One important aspect of subaqueous disposal of acid generating tailings is the depth of water cover required to ensure that re-suspension of tailings does not occur under wave action, or other events. Following on some initial observations of the Equity pond in 1994, a field program was implemented in September 1995 to establish the baseline characteristics of physical variables affecting bed stability. These data were then used to evaluate existing theoretical estimates of water cover depth and serve to calibrate future calculations. This report summarizes the data collection program, presents the data, and makes a comparison between the calculated depth of water cover required and field observations of the depth of water in which bed instability is evident.

1.1 Summary of Equity Operating History and Tailings Mineralogy

The Equity Mine started operation in August 1980 and terminated operations in January 1994. The ore minerals in the Equity pits consisted of chalcopyrite $CuFeS_2$, tennanite $(Cu,Fe,Zn,Ag)_{12}As_4S_{13}$, and tetrahedrite $(Cu,Fe,Zn,Ag)_{12}Sb_4S_{13}$. The quantities of these materials were highest in the Southern Tail pit which was developed first and decreased for the Main Zone and Waterline pits which were mined later. Other minerals present in the Southern Tail pit were pyrite, arsenopyrite and minor quantities of galena (PbS) and sphalerite (ZnS). The Main Zone and Waterline pits contained chalcopyrite, tennanite, tetrahedrite, arsenopyrite, pyrite and phyrotite.

The mill started production at 5,000 tons per day and used flotation to recover sulphide minerals. In January 1985 additional grinding was commissioned and the production rate increased to 9,000 tons per day. The last stage of mining was performed as an underground mine and the production rate was approximately 1,500 tons per day over the last two years.

In January 1985 a cyanide leach plant was also added for gold recovery using CIL which ran for the rest of the minelife. A cyanide destruction system was installed using SO2-air to treat tailings prior to discharging to the tailings pond.

A silver/copper concentrate was produced from the start-up, containing chalcopyrite $CuFeS_2$, tennanite $(Cu,Fe,Zn,Ag)_{12}As_4S_{13}$, and tetrahedrite $(Cu,Fe,Zn,Ag)_{12}Sb_4S_{13}$. As the recovery from the mill circuit was approximately 90% there were small residual quantities of these minerals in the tailings. Small quantities of arsenopyrite (0.5 to 1.0%) reported to the concentrate but these were not leachable and hence were shipped to the smelters.

The arsenopyrite, pyrite and phyrotite minerals were depressed in the mill flotation circuits and these minerals reported to the tailings pond.

The neutralized sludge from the ARD treatment plant was codisposed with the tailings in the tailings pond in the area of the pond nearest to the mill. A final layer of tailings without the sludges was deposited in this area during the last year of operation.

A leach plant started operation in October 1981, approximately one year after mine commissioning, and ran until April 1984. This plant removed arsenic and antimony from the concentrate minerals to produce a marketable product for the world smelter markets. This plant only ran for approximately 2½ years as the smelters eventually would accept the unleached concentrate products and continued use of the leach plant was not economic.

The byproducts of the leach process were all solid materials and hence there was no liquid discharge from the leach plant to the tailings pond.

The sodium sulphide leach plant produced byproduct calcium arsenate materials ($Ca(AsO_4)_2$), which were shipped off-site to a hazardous waste site in the U.S. A second product produced was sodium antimonate ($NaSbO_3$) which was sold to off-site chemical markets.

Considerable quantities of sodium sulphate was also produced which was sold to the local pulp mills in Prince Rupert. A single deposit of 2.500 tons of off-grade sodium sulphate (1000 ppm As), which could not be sold, was deposited in a till lined cell within the pond area. This cell was covered with till and then eventually flooded as the pond rose with the ongoing operations.

2 OBJECTIVES

The primary objective of this study was to obtain field measurements of physical parameters which could be used to evaluate, or calibrate, existing calculation procedures of the water depth required as cover to insure bed stability in a man-made tailings pond. As such, a field program was implemented during September 1995 to establish the baseline characteristics of the physical variables which affect bed stability in the Equity pond, namely the depth of water covering the tailings, the size distribution of the tailings, and the presence or absence of bedforms at the sediment water interface. The data summary produced by the field program will serve to advance the development of tailings pond design criteria which incorporate the concept of shallow water covers.

The objectives of the field sampling program included:

- a survey of the pond bathymetry at a nominal spacing of 50 m and production of a bathymetric contour map using Digital Terrain Modelling (DTM) software;
- observations of the morphology of the bed relative to the overlying water depth to identify to what depths bedforms have developed in the pond; and,
- completion of a sediment sampling program to characterize the grain size distribution of the sediments within the pond and collection of a suite of sediment cores to evaluate the stratigraphy of those sediments.

3 METHODOLOGY

3.1 Tailings Pond Bathymetry

The bathymetry of the tailings pond was surveyed from a small boat using a chart-recording depth sounder to obtain depth measurements and Global Positioning System (GPS), operating in differential mode, to obtain position.

Depths were measured using a Raytheon Model DE-719C depth sounder with the transducer mounted on the port side of the boat approximately 0.3 m below the surface of the water. Depth measurements were recorded on a strip chart set to move at a rate of 5 cm of chart per minute of time. The signal from the transducer was calibrated to the conditions within the pond prior to commencement of the survey. Calibrations were conducted at two known depths, namely 1.1 m and 2.1 m, to adjust for the speed of sound in the tailings pond water by setting the surface return signal to 0.0 m depth and adjusting the calibrate marker. The water depth at the boat launch site was measured prior to beginning the survey and again following the survey to see if any drift had occurred in the recorded depths. Assuming the depth measurements to be accurate to ±0.1 m, no drift in the measurements occurred during the course of the survey.

Position within the pond was obtained using two hand-held Trimble Navigation GPS receivers. One of the receivers was configured to operate as a base station on shore and the other as a rover station accompanying the depth sounder around the pond.

GPS operates on the principle of measuring the time it takes for a radio signal to travel from a satellite to the receiver on the ground. Two satellite signals allows for two dimensions to be determined, three satellites allows for elevation to be determined as well and four satellites allows time to be determined in addition to the other three. In general, a single GPS receiver can yield position measurements with accuracies of ±30 m when receiving signals from four or more satellites. Operating two receivers simultaneously under similar conditions, with one unit being kept stationary, allows for differential correction between the two units yielding position measurement accuracies of ±2-3 m. Differential correction was applied to the data collected during the survey.

Factory default settings were used on the GPS receivers with the following exceptions. The rover and base receivers were both set to record position data at a rate of 1 position every 15 seconds and were set to operate in 3-D Mode. Positions were recorded in Universal Transverse Mercator (UTM) coordinates on both receivers using metric units. The date and time for each units was adjusted to minus 07:00 hours

Universal Time Coordinated (UTC) due to the longitude of the site relative to the Greenwich Meridian and the fact that the survey was conducted during daylight savings time (PDT). The Percent Dilution of Precision (PDOP) cutoff was left at the factory default of 6; however, survey time windows with PDOP values of 3 or less were used for the survey to ensure that position errors were minimized. Using the explorer units in base and rover configurations timed to coincide with the Raytheon chart recorder running at 5 cm per minute, position fixes were taken every 15 seconds with a PDOP cut off of 4. The corrected positions are accurate to $\pm$ 3 m with a vertical resolution of $\pm$ 0.1 m. The estimated nominal spacing between survey points was calculated by dividing the total area of the pond by the total number of points surveyed. The pond area is 1,145,000 m^2 divided by a total of 1215 surveyed points to yield an average of 942 m^2 per survey point. This area translates into approximately 31 m mean spacing between points. The proposed spacing between points for the survey was 50 m.

The position data was post-processed for differential correction using the GeoPC software provided by Trimble Navigation. Differential correction means that the base station receiver records raw data from the satellites as well as the position information. Since the base station is stationary its position can be well established by GPS over a long time period by averaging a number of position measurements. Since the rover and base receivers are recording positions simultaneously, any error in position is recorded by both units at the same time. These errors can be corrected by adjusting the recorded rover position at a specific time by an amount equivalent to the difference between the average recorded base position and the base position recorded at that same time.

3.2 Sediment Sampling

Sediment samples were obtained from three locations which were marked with floats and their positions were surveyed during the pond bathymetry survey. A total of 13 surficial sediment grab samples and 2 sediment core samples were obtained at each location. Water depths at each location were recorded on deployment of the floats and again during the bathymetry survey.

Water depth varied between the three locations ranging from 1.3 m at the shallowest site and 2.3 m at the middle site to 3.4 m at the deepest site. These depths were chosen *a priori* based on i) existing calculations of required minimum water depth for the Equity pond, and ii) existing closure criteria of a minimum 1.5 m water cover depth. Sampling at the given depths would allow collection of sediment from both above and below the previously calculated limit of bed-sediment mobilization by wave activity. It was assumed that, even though the pond has depths below 3.4 m, 3.4 m would be sufficiently deep to provide samples from a bed not subject to wave re-suspension of sediment.

These 3 sediment sampling locations were situated such that they fell on an arbitrary line which was closely parallel to the dominant fetch of the pond as well as in an area where sediments were covered by water shallow enough to allow exposure to wave action. The dominant fetch of the pond is aligned north-south, coincident with the dominant wind directions, and maximum wave generation occurs at northern and southern ends for southerly and northerly winds respectively. Since the northern end of the pond is generally deep, with water cover depths greater than 2.0 m along the impoundment dyke, this end of the pond was deemed unsuitable for gathering sediment samples. The predominance of shallow areas and tailings deposits along the western and southern boundaries of the pond resulted in the sampling program being located primarily along the southern boundary.

The positioning of each of the sediment sample locations were determined from the water depth, as measured by the depth sounder, along an arbitrary line bearing approximately 26° from magnetic north starting from the southwest corner of the pond which also lined up with both the shallow and deep geochemical sampling locations associated with a separate project. The location of each of the sediment sample sites is shown in Drawing 1. The sediment samples were collected for grain size analysis and submerged weight density determinations.

The surficial sediment grab samples were obtained by means of a piece of PVC pipe, open at both ends, pushed into the bed to a depth of between 0.3 and 0.6 m. The inside diameter of the PVC pipe used at the 1.3 m and 2.3 m depth locations was 1.25 inches (0.032 m). This piece of pipe was too short for use at the 3.4 m depth location so a longer piece of PVC pipe was employed which had an inside diameter of 2 inches (0.051 m). It was felt that the slight increase in pipe diameter would not significantly affect results.

Once inserted into the bed, the top of the pipe was sealed with duct tape to provide the suction necessary to recover the sediment sample. The duct tape seal provided sufficient suction that enough sediment remained within the pipe upon retrieval. The pipe was retrieved and a plastic bag was placed over the end of the pipe containing sediment. The duct tape seal was removed and the weight of water within the pipe provided the force necessary to extrude the sediment into the bag. The bag was removed quickly once the sediment had been extruded and the remaining water returned to the pond.

It was initially proposed that the sediments be obtained as surficial grab samples using SCUBA equipped divers. Reconnaissance dives at the 3.4 m depth and 1.3 m depth locations indicated that diver disturbance of the bed reduced visibility to near zero within 30 seconds of reaching the pond bottom. Loss of visibility made it difficult to know what was being sampled. The use of the PVC pipes was decided on as a surrogate method and the samples obtained were good.

The surficial sediment samples were collected in a set pattern at each depth location as illustrated in Figure 1. Nine samples were collected in a random pattern within a 1 m radius of the depth location marker float. The remaining 4 samples were collected in an east-west alignment approximately 5 m and 10 m distant from the marker float. This pattern was selected to allow for the comparison of grain size data over both short and moderate distances to examine the local variability in sediment sizes.

Sediment core samples were obtained using a Pedersen corer which uses an 0.08 m core barrel approximately 1.0 m long. A plate collar was fitted to the core barrel to reduce the tendency of the device to sink into the loose bottom under its own weight. Once deployed at the bed, a trigger mechanism on the corer released a piston which sealed the top of the core barrel and provided suction for the retrieval of the core. The core barrels were capped on retrieval at both ends. Two cores were obtained at each separate water depth location, carried to shore and their stratigraphy and sedimentology recorded. The sediment cores were collected within approximately 2 m of the location marker float but no closer than 1 m to avoid the area already disturbed by the surficial sediment sampling.

From each core, the top 0.30 m of sediment was collected for grain size analysis and submerged weight density determination. Two samples were taken from one of the shallow water depth location cores to obtain additional data on a consolidated layer of tailings visible at approximately 0.64 to 0.74 m depth below surface. These sediment core subsamples were compared with the surficial sediment samples collected at the same water depth location.

Analysis of the submerged weight density of the sediments was carried out by Analytical Service Laboratories Ltd. (ASL) of Vancouver, British Columbia. The grain size analysis was carried out by Pacific Soils Analysis Ltd. (PSAL) of Richmond, British Columbia under subcontract to ASL.

The submerged weight density was determined by subsampling approximately 100-150 ml of the collected sample and determining the exact volume to the nearest millilitre. The sample was weighed to the nearest 0.1 g to provide wet sample weight and then oven-dried overnight. The subsample was reweighed after drying to provide the dry sample weight. Percent moisture in the sample was determined from one minus the ratio of dry sample weight to wet sample weight.

The grain size distribution of the samples was analyzed using a method adapted for Fisheries and Oceans Canada, Ottawa, as described in Methods for Sampling and Analysis of Marine Sediments and Dredge Materials, Ocean Dumping Report 1, 1978, edited by A. Walton. The sediment sample was oven-dried and sieved at 2 mm (sieve with unit of phi of -2) to remove any coarse particles. The remaining sample was then passed through standard sieves for the sand and silt fractions. The sediment passing through the finest mesh sieve was then analyzed for clay fractions using the pipette method. Particle size distributions were determined for units of phi of 2, 3, 4, 4.5, 5, 5.5, 6, 7, 8 and 9, where phi is the negative logarithm to the base 2 of grain size in mm. The grain size distribution was recorded as the percent of the sample passing each unit of phi.

Grain size statistics for each of the samples were determined graphically using the methods of Folk (1965), providing both estimates of the mean grain size and the standard distribution around the mean. The median grain size (D_{50}) was interpolated from the grain size graphs as well as the percentile values of D_5, D_{16}, D_{25}, D_{75}, D_{84} and D_{95} used for the statistical analysis based on Folk (1965). These statistics were averaged for all the samples collected at a water depth location to give an average value for each of these parameters relative to water depth.

3.3 Bedform Observations

Bedform observations were to be made from the boat during the bathymetric survey and during each SCUBA dive to obtain surficial sediment samples. However, the pond water was very murky and observations during the bathymetric survey were not possible. Nevertheless, two reconnaissance dives at the deepest and shallowest water depth locations allowed for short observations of the bed before visibility was reduced to zero. These bedform observations of September 1995 were supplemented with observations made earlier in September 1994.

3.4 Meteorological Data

Meteorological data at the site has been made available from a climate station installed by the University of Saskatchewan which is located approximately 1.5 km south of the tailings pond and has been in continuous operation since June, 1993. The station records air temperature, relative humidity, windspeed, wind direction, solar radiation, net radiation and rainfall.

For the purposes of determining the potential for wave mobilization of sediments in the tailings pond, wave hindcasting can be undertaken from records of windspeed. The climate station collects hourly averages of wind speed as well as daily maxima. At the time of writing, data on hourly averages of windspeed were only available for the period June 1993 through August 1994. However, data for the maximum hourly average per day, which were all that was necessary for this project, were available for the period from June 1993 through to the time of the field observations and sediment sample collections.

4 RESULTS

4.1 Tailings Pond Bathymetry

The pond bathymetry as of September 1995 is shown in Drawing 1 showing the pond bed elevations relative to geodetic datum. Compared with the bathymetry of November 1993, shown in Drawing 2 also set relative to geodetic datum, it can be seen that the tailings discharged prior to closure were placed in the west-central side of the pond. Shallow areas within the pond are primarily confined to the south and west sides where water depths as little as 0.4 m (pond bed elevations of 1291.3 m) are found.

Drawing 3 illustrates the September 1995 bathymetric survey as water depths. Drawing 4 illustrates the November 1993 survey in the same manner with a chart datum set at 1291.5 m. The water surface elevation of the pond, although designed to be maintained at 1291. 6 m geodetic, may change with precipitation inputs and evaporation losses.

The median depth of water in the pond is 4.3 m. This water depth can be determined by calculating the difference in depth between the pond water surface elevation at the time of survey and the median bed elevation as determined from a relationship between the pond area and the elevation of the pond bed illustrated in Figure 2. This relationship is called a hypsographic curve and is derived from the bathymetric contours. Since the pond water surface elevation at the time of survey was 1291.71 m and the median bed elevation, from Figure 2, is 1287.4 m, then the median water depth is 4.3 m. This median depth represents the water depth at which 50% of the pond area has a water cover this deep or more and 50% has a shallower water cover.

From the bed elevation - pond area relationship, it is possible to determine what percentage of the pond has a water cover shallower than a specified depth. The percentages of the pond covered by water depths shallower than 3 m are summarized in Table 1. As of the September 1995 survey, approximately 8% of the pond has water depths shallower than the 1.5 m depth set as the closure water depth.

4.2 Sediment Sampling

4.2.1 Grain Size and Density

The results of the sediment analyses are summarized in Table 2, which lists the submerged weight densities, moisture content and the median grain sizes (D_{50}) for each of the samples, where the median grain size marks the division of the sample into two equal parts by weight. Table 2 also lists the mean grain size and statistical parameters derived graphically using the method of Folk (1965), where mean grain size is the diameter equivalent of the arithmetic mean of the logarithmic frequency distribution of the sample. The sediment data is presented in Appendix 1.

The samples collected at each of the three water depth locations formed three statistically separate grain size populations at the 99.9% confidence level. This difference between the sediments sampled at each water depth location is representative of the sorting of the sediment sizes during discharge with the coarser material remaining nearer the perimeter of the pond and the finer material being transported further distances from the discharge point.

The samples collected also formed statistically separate submerged weight density populations at the 99.9% confidence level except for comparisons between the deep (3.4 m) and moderate (2.3m) water depth locations which were only statistically distinguishable at the 98% confidence level. This reduction in confidence level is representative of the greater proportion of fines and moisture retentive voids in the sediments at the deeper sites relative to the shallow site.

Statistical comparisons between the samples collected at the three water depth locations using moisture content indicated that the sediments at the shallow site were statistically distinguishable from the two deeper sites at the 99.9% confidence level. However, no statistical difference could be found between the moderate and deep site moisture contents at the 90% confidence level. This similarity in moisture content suggests that the dewatering process at deeper sites is related to the formation of the lutocline which is comprised of fine sediment, the coarser sediments having settled in shallower water. The statistical values are also provided in Table 2.

The shallow, 1.3 m water depth location sediments, Drawing 1, contained the highest proportion of fine sands and silts of the three water depth locations. The average median grain size (D_{50}) of the 16 samples collected was 0.0512 mm, one standard deviation yielding a range for the median grain size of 0.0248 - 0.0775 mm. The average mean grain size of the 16 samples collected at this water depth location was 0.0399 mm, one standard deviation yielding a range for the mean grain size of 0.0150 - 0.0649 mm. Variation within the 16 samples collected was greater than the other two locations, indicative of the lack of sorting during discharge of the tailings into the pond. The average grain size distribution for all the sediment samples collected at the 1.3 m depth is shown in Figure 3.

At the moderate depth of 2.3 m of water, Drawing 1, sediments were predominantly made up of silt sized material. The average median grain size (D_{50}) of the 15 samples collected was 0.0075, one standard deviation yielding a range for the mean grain size of 0.0049 - 0.0101 mm. The average mean grain size of the 15 samples collected was 0.0041 mm, one standard deviation yielding a range for the mean grain size of 0.0029 - 0.0052 mm. Variation within the 15 samples collected at this location was small, showing little variability through space. The average grain size distribution for all the sediment samples collected is shown in Figure 4.

At the deepest water depth, 3.4 m, sediments were composed of predominantly clay sized particles and were the finest of the three sampling locations. The average median grain size (D_{50}) of the 15 samples collected was 0.0040 mm, one standard deviation yielding a range for the median grain size of 0.0036 - 0.0044 mm. The average mean grain size of the 15 samples collected was 0.0022 mm, one standard deviation yielding a range for the mean grain size of 0.0020 - 0.0024 mm. Variation within the 15 samples collected was the smallest of the three sites indicative of the transport of similar sized particles to this location during deposition. This low variability could be expected as the coarser material has already settled by the time tailings have reached this distance during deposition. The average grain size distribution for all the sediment samples collected at the 3.4 m depth is shown in Figure 5.

The average submerged weight density for all the sediment samples collected from the pond was 1.318 $\pm$ 0.328 kg/m^3. However, density decreased with increasing water cover. The average submerged weight density of the sediments at 1.3 m depth was 1.645 $\pm$ 0.299 tonnes/m^3, 2.3 m this had decreased to 1.220 $\pm$ 0.116 kg/m^3 and decreased even further to 1.068 $\pm$ 0.193 kg/m^3 at 3.4 m. These changes in density are consistent with the development of a lutocline under the deeper water depths as the proportion of finer sediment sizes increases. Statistical comparison between water cover depth locations of these density measurements using a simple t-test indicates that they are statistically different at the 95% confidence level.

4.2.2 Sediment Core Logs

The core logs for each of the six cores collected are shown in Figure(s) 6-11.

Core 1-1, collected at a water depth of 1.3 m, had a 0.02 m cap of orange coloured floccules and fine organics that peeled like a skin when touched. This layer had a sharp contact with the grey, silty-clay, undifferentiated tailings which extended to 0.39 m. This layer collapsed on extrusion from the core barrel and was unconsolidated. It graded into a consolidated layer of similarly coloured, silty-sand sediments which extended to 0.59 m. This layer did not collapse on extrusion and graded into a layer of unconsolidated, sandy-silt tailings between 0.59 and 0.64 m which collapsed on extrusion. Below this layer, another layer of consolidated, silty-sand tailings was found to 0.72 m which had a sharp contact with another orange coloured layer of floccules. The silty-sand layer between 0.64 and 0.72 m did not collapse on extrusion. The last layer extended to 0.74 m, the end of the core. The core log is shown in Figure 6.

Core 1-2, collected at 1.3 m water depth, had a 0.01 m cap of orange coloured floccules and fine organics that peeled like a skin when touched. This layer had a sharp contact with the grey, silty-clay, undifferentiated tailings which extended to 0.41 m. This layer collapsed on extrusion from the core barrel and was unconsolidated. It graded into a consolidated layer of similarly coloured, silty-sand sediments which extended to 0.42 m. This layer did not collapse on extrusion and had a sharp contact with another orange coloured layer of floccules. The layer of floccules extended to 0.43 m and had a sharp contact with another layer of silty-sand, undifferentiated tailings which did not collapse on extrusion. The last layer extended to 0.52 m, the end of the core. The core log is shown in Figure 7.

Core 2-1, collected at 2.3 m water depth, had a 0.01 m cap of grey-yellow coloured floccules and fine organics that peeled like a skin when touched. This layer had a sharp contact with the grey, silty-clay, undifferentiated tailings which extended to 0.38 m. This layer collapsed on extrusion from the core barrel and was unconsolidated. It graded into a consolidated layer of similarly coloured, silty-clay sediments which extended to 0.71 m, the end of the core. This layer did not collapse on extrusion. The core log is shown in Figure 8.

Core 2-2, collected at 2.3 m water depth, had grey, silty-clay, undifferentiated tailings which extended to 0.35 m. This layer collapsed on extrusion from the core barrel and was unconsolidated. It graded into a consolidated layer of similarly coloured, silty-clay sediments which extended to 0.65 m, the end of the core. This layer did not collapse on extrusion. The core log is shown in Figure 9.

Core 3-1, collected at 3.4 m water depth, had grey, silty-clay, undifferentiated tailings which extended to 0.25 m. This layer collapsed on extrusion from the core barrel and was unconsolidated. It graded into a consolidated layer of similarly coloured, silty-clay sediments which extended to 0.60 m, the end of the core. This layer did not collapse on extrusion. The core log is shown in Figure 10.

Core 3-2, collected at 3.4 m water depth, had grey, silty-clay, undifferentiated tailings which extended to 0.35 m. This layer collapsed on extrusion from the core barrel and was unconsolidated. It graded into a consolidated layer of similarly coloured, silty-clay sediments which extended to 0.55 m, the end of the core. This layer did not collapse on extrusion. The core log is shown in Figure 11.

Cores 1-1 and 1-2 from the 1.3 m water depth revealed stratigraphy representative of episodic discharge. The sediments consisted of a top layer of primarily undifferentiated tailings which graded into more consolidated tailings with depth. Grain size appeared to grade from silty clay to silty sand also with depth. Consolidation increased with depth to a sharp contact with a crust-like layer at 0.72 m in Core 1-1 and 0.41 m in Core 1-2. A similar contact at 0.59 m in Core 1-1 appears to be present but the crust-like layer has not been preserved. These crust-like layers were very thin, being approximately 0.01 - 0.02 m thick. Immediately below these layers, the sediments once again graded from unconsolidated silty clay into semi-consolidated silty sand with increasing depth. The sediments forming the crust-like layer were coarser than the overlying sediments, being consistent with the history of the pond where deposition at a point could stop when the discharge point for tailings was relocated to another position within the pond. The relatively quiescent period between deposition could have led to some sorting of the surface layer and the development of the crust-like skin.

The stratigraphy of the cores collected at a depth of 2.3 m revealed unconsolidated silty-clay sediments grading into semi-consolidated silty-clay sediments at 0.38 m and 0.35 m below the bed. This is consistent with the development of a lutocline as the finer grained material slowly settles to the bed. There was no evidence for wave agitation or wave erosion layers in the top layers of either cores and the unconsolidated silty-clay layer collapsed on extrusion from the core barrel. There were no laminations visible within either of the cores collected.

Similarly, the stratigraphy of the cores collected at the 3.4 m depth revealed unconsolidated silty-clay sediments grading into semi-consolidated silty-clay sediments at 0.25 m and 0.35 m below the bed. Again, there was no evidence for wave agitation or wave erosion layers in these cores and the unconsolidated silty-clay layer collapsed on extrusion from the core barrel. There were no laminations visible within either of the cores collected at this water depth location.

4.3 Bedform Observations

Reconnaissance dives at both the deep sediment sampling location (3.4 m) and the shallow sediment sampling location (1.3 m) indicated that disturbance of the bed by diver motion reduced visibility to near zero within 30 seconds. Divers were thus unable to observe bedforms as they disappeared rapidly in clouds of resuspended material. However, during the dive descent, bedforms were not observed at 3.4 m but they were observed at the 1.3 m water depth location during the reconnaissance. No observations were made at 2.3 m.

The absence of bedforms at water depths of 3.4 m indicates that sediment is not being remobilized by wave activity. However, the lutoclinic nature of the sediments, which extends to an average depth of 0.30 m below the sediment water interface in cores taken at the 2.3 m and 3.4 m water depth locations, may preclude the development of bedforms. It is possible that the fluid response of the lutoclinic surface sediments to wave motion would result in the lutocline flattening to a "calm" state following removal of the wave stress and likely not preserving wave generated forms at the bed.

The presence of bedforms at 1.3 m depth indicates some remobilization of sediments and that wave action is being felt by the bed. Based on the observations made during 1995, the sediment in the bed is being mobilized down to some water depth between 1.3 and 3.4 m. Observations of bedforms made in locations where the water was less than 1.0 m deep revealed ripple marks indicative of bed mobilization by waves. The bedform observation data collected in 1995 is presented in Appendix 2.

Sediment resuspension in the tailings pond may be inhibited by the development of a surface skin layer in the sediments. This skin layer is estimated to be approximately 0.01 m thick based on diving observations. When disturbed, this layer tends to peel back from the disturbed site thereby exposing the sediments underneath which are rapidly suspended into the water column. While whole, this skin layer appears to provide some resistance to entrainment. The underlying sediments which were stirred up by either diving or sediment sampling remained suspended in the water column for a significant period of time.

Bedforms, such as wave-formed ripples, were very much in evidence around the pond perimeter as they had been during the site visit in 1994. These ripples were observed to be present on the bed over a depth range of 0.3 - 1.2 m based on depth measurements collected using a lead-line during the 1994 field visit. Ripples were also observed to be absent around the perimeter for water depths ranging from 1.1 m to greater than 1.4 m, as measured during the same field visit.

These data would suggest that the transition between water depths where the wave motion impacted on the bed and those water depths where it did not occurred between 1.0 m and 1.4 m water depth. This range of 1.0 m to 1.4 m water depth is likely related to the largest waves generated by the prevailing winds over the period of time since closure in 1993.

The existing bedform observations imply that, at water depths less than 1.3 m, the sediments forming the bed are susceptible to wave mobilization and have been mobilized by wave events since deposition in the pond. Sediments beneath water cover deeper than 1.4 m appear to have remained stable over the same time period.

4.4 Meteorological Data

The largest hourly wind recorded during September 1995, occurred on the 11th of the month. This day marked the start of the field program and may explain why the water appeared murkier than during the visit in September 1994. Winds during September 11, 1995 reached a maximum hourly average value of 12.1 m/s (43.6 km/hr). Prior to the field program conducted in September 1994, winds exceeded this magnitude on June 13, 1994 with a recorded speed of 12.5 m/s (45.0 km/hr). This wind event occurred approximately 2.5 months (85 days) prior to commencement of the September 1994 field sampling giving a sufficiently long enough time window to allow most of the fine material, resuspended by the June 13, 1994 event, to settle. Some high wind events did occur between June 13, 1994 and the onset of the September 1994 field visit, but only one of these topped 10.2 m/s (36.7 km/hr), windspeeds reaching 11.4 m/s (41.0 km/hr) on August 22, 1994, 15 days in advance of the 1994 field visit.

The largest hourly average windspeed recorded during the ice free period since the climate station began recording occurred on April 14th, 1994 when windspeeds reached 18.6 m/s (67.0 km/hr). The largest hourly average windspeed recorded during the entire record of the climate station occurred on November 30, 1994 when windspeeds reached 21.8 m/s (78.5 km/hr). The monthly maximum hourly windspeeds are presented in Table 3.

The available meterological data for the site indicates that winds are greatest when the pond is covered in ice. Since these winds cannot generate waves, it is only the winds occurring during the ice-free period which can generate wave activity and stir the bed sediments. Therefore the largest wind to have been able to generate waves and affect the bed occurred on April 14th, 1994 (67.0 km/hr).

A frequency analysis of windspeeds using the annual maximum series was undertaken. The annual maximum hourly windspeeds for the years 1993-95 were analyzed. An estimate of windspeeds with given return periods was produced. These windspeeds and return periods are summarized in Table 3. For two of the three years, 1994 and 1995, the annual maximum monthly wind under ice-free conditions occurred in April when winter strength winds may still prevail yet the ice-cover begins to break up and no longer prevents wave activity within the pond.

Since the period of record is only three years, estimates of windspeed for storms with a return period of greater than about 1 every 10 years should be used with caution. Applying these return periods, the wind which occurred on April 14th, 1994 is estimated to have a return period of approximately 8 years. The windspeed which occurred on September 11th, 1995, at the start of the 1995 site visit, is estimated to have a return period of less than a year.

4.5 Predicted Minimum Depth Calculation and Comparison

A prediction of the depth to which the waves generated by the largest wind could interact with the bed sediments can be made using the procedure outlined by Hay & Company Consultants Inc (1995). This procedure, derived from the work of Lawrence *et al.* (1991) and Komar and Miller (1975), relates the depth of water cover required for bed stability to wave height and sediment characteristics. Using wave hindcast procedures, the over-water distances at the Equity pond, and the bed sediment characteristics determined from the sampling program, the predicted minimum water cover depth for a variety of windspeeds was calculated and plotted as the solid line on Figure 12.

Data obtained from the Equity pond has provided an opportunity for a comparison between the calculated water depth required to preclude movement of sediments on the bed and actual observations of bed forms in the pond which are indicative of bed movement. As illustrated in Figure 12, bedforms were not observed in water depths greater than 1.4 m, whereas bed forms were evident in water depths shallower than 1.3 m. This transitional water depth of between 1.3 and 1.4 m is plotted on the wind speed ordinate of 18.6 m/s, which was the largest open-water wind speed the Equity pond has experienced since cessation of operations. This 18.6 m/s wind speed has an estimated return period of once in 8 years, on average, Table 3. The close comparison between the disappearance of bedforms at 1.3 to 1.4 m depth and the prediction of a minimum depth of 1.4 m for the historical wind conditions provides confidence in the predictive equation. The percentage of the pond area with water shallower than this is approximately 7 %.

Observations from other man-made ponds for which sediment characteristics and meteorological conditions are known would be useful additional verification data for the curve plotted on Figure 12.

5 CONCLUSIONS

The median grain size of the samples collected decreased with depth. The grain sizes are statistically distinguishable, forming 3 separate populations of grain sizes for each of the 3 locations where cores were taken and sampled. The sediments grade from predominantly very fine sand and coarse silt at 1.3 m depth through fine to very fine silt at 2.3 m depth to very fine silt to coarse clay at 3.4 m depth, Table 2. In addition to the change in grain size, the submerged weight density of the sediments decreased with depth from 1.645 tonnes/m^3 at 1.3m depth through 1.220 tonnes/m^3 at 2.3 m depth to 1.068 tonnes/m^3 at 3.4 m depth. In general, moisture content increased with depth but there was no statistical difference between the moisture content of the sediments at 2.3 m depth compared with those at 3.4 m depth.

The sediment cores taken indicated that the lutocline is well developed forming a clear break at around 0.35 m depth. The surface has a skin on it which resists entrainment, but if broken this skin is easily removed and the unconsolidated sediment beneath exposed.

Available bedform data from the field visits in September 1994 and 1995 indicate that the water depth at which wave mobilization of bottom sediments occurs lies between 1.3 m and 1.4 m relative to the historical wind climate. The largest hourly average wind recorded when the pond was ice-free was 18.6 m/s (67.0 km/h), and occurred on April 14th, 1994. Larger magnitude hourly average winds have been recorded over the winter months but the ice cover on the pond at this time precludes wave generation.

The close comparison between the disappearance of bedforms at 1.3 to 1.4 m depth and the predicted minimum depth of 1.4 m for the historical wind conditions at the Equity pond provides confidence in the predictive equation, Figure 12. Field observations from other man-made ponds would provide useful additional data for verification of the calculation procedure embodied in Figure 12. (Hay & Company Consultants Inc., 1995)

A water depth of 1.5 m is the set as the closure water depth in the Equity pond. Approximately 8 % of the pond is presently shallower than this depth, Figure 2. The maximum depth in the pond is approximately 6 m, the deeper sections of the pond being located towards the northern and eastern sections.

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7 REFERENCES

Folk, R.L. 1965. The Petrology of Sedimentary Rocks.

Hay & Company Consultants Inc. 1995. An Outline Report of Designing A Tailings Pond To Provide Water Cover For Acid Rock Drainage Control. Report Produced for Placer Dome Canada Inc., 25pp plus Appendices and Figures.

Komar, P.D. and M.C. Miller. 1975. Sediment threshold under oscillatory waves. Proceedings 14th Coastal Engineering Conference, ASCE, NY, 756-775.

Lawrence, G.A., P.R.B. Ward and M.D. MacKinnon. 1991. Wind-wave induced suspension of mine tailings in disposal ponds - a case study. Canadian Journal of Civil Engineering, 18, 1047-1053.

Walton, A. 1978. Methods for Sampling and Analysis of Marine Sediments and Dredge Materials, Ocean Dumping Report 1. Fisheries and Oceans Canada.

8 GLOSSARY

Several terms within the report may be unfamiliar or may have been used in another context. A glossary of these terms is presented below for clarity.

Consolidated	A property of sediments which expresses the state of dewatering of those sediments. Sediments which have dewatered sufficiently to hold together upon extraction from the bed are said to be consolidated.
Unconsolidated	A property of sediments which expresses the state of dewatering of those sediments. Sediments which have not dewatered sufficiently to hold together upon extraction from the bed but collapse when removed from a container and flow readily are said to be un-consolidated.
Stratigraphy	The characteristic of a column or core of sediment which describes the ordering of layers of sediment within the column or core. The vertical relationship between layers of sediments within a sediment core or column.
Hypsographic curve	A curve which graphically represents the relationship between an area and the percent of that area which is above and/or below specified elevation intervals. The curve indicates the distribution of an area over a range of elevations.
Submerged weight density	The density of a material while immersed in a fluid nominally calculated by subtracting the density of the surrounding fluid from the density of the sediment and then dividing the result by the density of the surrounding fluid. This calculation accounts for the buoyancy effect of a more viscous fluid than air interacting with the submerged sediment.

For the case of Equity samples, a surrogate value was calculated by dividing the wet sample weight by the wet sample volume.

Ice-rafting of sediments	The entrainment of sediment by ice-contact freezing and the subsequent transport of that sediment while frozen within the ice to another location by movement of ice. This movement of ice does not generally occur in contact with the bed but occurs as the covering ice floats free of the bed.
Lutocline, lutoclinic	A transitional layer between sediment and water where no clear interface exists, a lutocline is a layer wherein sediment solids concentration increases rapidly over a very short change in depth, the sediments changing from an ooze with high moisture content and low solids concentration to a form with lower moisture content and higher solids concentration.
Undifferentiated	A descriptive term for sediments indicating that no sorting, layering or otherwise differentiating process has occurred during deposition and that the sediments are essentially structureless and featureless and show no evidence of bedding planes.

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TABLES

TABLE 1: Percentages of Pond Area With Shallower Depths			
Pond Bed Elevation (m)	Water Depth (m)	Pond Area (%)	Notes
1281.2	3.0	26	
1284.2	2.5	18	
1286.7	2.0	12	
1288.7	**1.5**	**8**	**Closure Criteria Depth**
1290.2	1.0	4.5	
1291.2	0.5	2	
1291.7	0.0	0	Pond Edge

Water Surface Elevation of pond at time of Survey = 1291.7 m geodetic

TABLE 2: Surficial Sediment Grab and Sediment Core Sample Data													
	Measured and Derived Parameters			Graphical Parameters (after Folk, 1965)									
	Submerged	Percent	Median	Mean	Mean Minus	Mean Plus	Derived Grain Size Percentiles (% finer than)						
	Wgt. Density	Moisture	Grain Size	Grain Size	1 Std. Dev.	1 Std. Dev.	D_5	D_{16}	D_{25}	D_{50}	D_{75}	D_{84}	D_{95}
Sample ID#	(tonnes/m^3)	%	(D_{50}, mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1-0	1.998	27	0.0372	0.0275	0.0053	0.1429	*0.0002*	0.0061	0.0162	0.0372	0.0693	0.0915	0.1487
1-1	1.410	18	0.0743	0.0570	0.0122	0.2651	*0.0007*	0.0136	0.0335	0.0743	0.1436	0.1830	0.2333
1-2	1.978	19	0.0743	0.0670	0.0170	0.2647	*0.0009*	0.0221	0.0347	0.0743	0.1436	0.1830	0.2415
1-3	1.780	18	0.0884	0.0761	0.0220	0.2631	0.0021	0.0254	0.0385	0.0884	0.1593	0.1961	0.2588
1-4	2.168	32	0.0625	0.0544	0.0133	0.2221	*0.0009*	0.0162	0.0302	0.0625	0.1207	0.1593	0.2253
1-5	1.864	23	0.0718	0.0563	0.0117	0.2704	*0.0006*	0.0136	0.0292	0.0718	0.1487	0.1830	0.2415
1-6	1.820	21	0.0693	0.0611	0.0149	0.2511	*0.0008*	0.0186	0.0313	0.0693	0.1387	0.1768	0.2253
1-7	1.726	20	0.1015	0.0844	0.0269	0.2649	0.0024	0.0313	0.0490	0.1015	0.1649	0.1895	0.2333
1-8	1.103	85	0.0245	0.0124	0.0018	0.0877	*0.0001*	*0.0014*	0.0050	0.0245	0.0427	0.0563	0.1088
1+10W	1.731	30	0.0292	0.0169	0.0019	0.1544	*0.0002*	*0.0014*	0.0045	0.0292	0.0854	0.1207	0.2176
1+5W	1.381	49	0.0508	0.0335	0.0060	0.1861	*0.0003*	0.0063	0.0192	0.0508	0.0947	0.1166	0.2031
1+5E	1.483	45	0.0347	0.0254	0.0050	0.1277	*0.0004*	0.0053	0.0151	0.0347	0.0625	0.0884	0.1593
1+10E	1.610	37	0.0359	0.0240	0.0043	0.1350	*0.0002*	0.0045	0.0127	0.0359	0.0647	0.0854	0.1166
1-1C	1.668	43	0.0192	0.0085	0.0010	0.0723	*0.0001*	*0.0006*	0.0029	0.0192	0.0398	0.0490	0.0743
1-2C	1.162	62	0.0245	0.0248	0.0058	0.1070	*0.0010*	0.0063	0.0141	0.0245	0.0718	0.0981	0.1649
1-3C	1.438	43	0.0206	0.0097	0.0013	0.0733	*0.0001*	*0.0009*	0.0036	0.0206	0.0385	0.0474	0.0743
Average	1.645	36	0.0512	0.0399	0.0094	0.1805	0.0007	0.0109	0.0212	0.0512	0.0993	0.1265	0.1829
Avg. +1 Std. Dev.	1.944	54	0.0775	0.0649	0.0172	0.2567	0.0014	0.0204	0.0354	0.0775	0.1449	0.1810	0.2453
Avg. -1 Std. Dev.	1.346	17	0.0248	0.0150	0.0016	0.1042	0.0000	0.0013	0.0070	0.0248	0.0537	0.0720	0.1205

Sampling distances given in m west (W) and east (E) of marker float
Samples obtained by sediment core denoted with a "C"
Submerged Wgt. Density is the weight of the sediment in water
Percentile Grain Sizes in *Italics* are extrapolated from grain size graph

TABLE 2: Surficial Sediment Grab and Sediment Core Sample Data

	Measured and Derived Parameters			Graphical Parameters (after Folk, 1965)									
							Derived Grain Size Percentiles (% finer than)						
Sample ID#	Submerged Wgt. Density (tonnes/m^3)	Percent Moisture %	Median Grain Size (D_{50}, mm)	Mean Grain Size (mm)	Mean Minus 1 Std. Dev. (mm)	Mean Plus 1 Std. Dev. (mm)	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)
2-0	0.999	88	0.0068	0.0039	0.0004	0.0351	*0.00004*	*0.0003*	*0.0010*	0.0068	0.0206	0.0282	0.0412
2-1	1.191	70	0.0078	0.0037	0.0005	0.0290	*0.00004*	*0.0003*	*0.0011*	0.0078	0.0131	0.0192	0.0412
2-2	1.028	87	0.0068	0.0039	0.0005	0.0318	*0.00006*	*0.0003*	*0.0010*	0.0068	0.0199	0.0272	0.0398
2-3	1.164	70	0.0059	0.0034	0.0004	0.0303	*0.00004*	*0.0003*	*0.0008*	0.0059	0.0179	0.0254	0.0398
2-4	1.317	51	0.0081	0.0044	0.0005	0.0378	*0.00005*	*0.0004*	*0.0012*	0.0081	0.0237	0.0302	0.0427
2-5	1.164	68	0.0073	0.0041	0.0005	0.0352	*0.00004*	*0.0003*	*0.0011*	0.0073	0.0221	0.0282	0.0412
2-6	1.281	58	0.0059	0.0039	0.0004	0.0353	*0.00004*	*0.0003*	*0.0011*	0.0059	0.0237	0.0302	0.0442
2-7	1.303	64	0.0075	0.0040	0.0005	0.0344	*0.00004*	*0.0003*	*0.0011*	0.0075	0.0151	0.0263	0.0412
2-8	1.163	72	0.0078	0.0042	0.0005	0.0376	*0.00004*	*0.0003*	*0.0011*	0.0078	0.0221	0.0292	0.0427
2+10W	1.273	58	0.0042	0.0023	0.0003	0.0202	*0.00003*	*0.0002*	*0.0005*	0.0042	0.0118	0.0167	0.0263
2+5W	1.194	65	0.0059	0.0034	0.0004	0.0301	*0.00004*	*0.0003*	*0.0009*	0.0059	0.0179	0.0254	0.0398
2+5E	1.132	73	0.0096	0.0050	0.0006	0.0424	*0.00005*	*0.0004*	*0.0014*	0.0096	0.0254	0.0324	0.0474
2+10E	1.358	59	0.0156	0.0077	0.0009	0.0629	*0.00007*	*0.0007*	0.0024	0.0156	0.0347	0.0427	0.0825
2-1C	1.390	49	0.0061	0.0034	0.0004	0.0311	*0.00004*	*0.0003*	*0.0008*	0.0061	0.0186	0.0254	0.0385
2-2C	1.339	48	0.0070	0.0038	0.0004	0.0339	*0.00004*	*0.0003*	*0.0010*	0.0070	0.0206	0.0272	0.0398
Average	1.220	65	0.0075	0.0041	0.0005	0.0351	0.00004	0.0003	0.0011	0.0075	0.0205	0.0276	0.0432
Avg. +1 Std. Dev.	1.336	77	0.0101	0.0052	0.0006	0.0443	0.00005	0.0004	0.0015	0.0101	0.0260	0.0334	0.0550
Avg. -1 Std. Dev.	1.103	53	0.0049	0.0029	0.0003	0.0260	0.00003	0.0002	0.0007	0.0049	0.0149	0.0218	0.0315

Sampling distances given in m west (W) and east (E) of marker float
Samples obtained by sediment core denoted with a "C"
Submerged Wgt. Density is the weight of the sediment in water
Percentile Grain Sizes in *Italics* are extrapolated from grain size graph

TABLE 2: Surficial Sediment Grab and Sediment Core Sample Data													
	Measured and Derived Parameters			Graphical Parameters (after Folk, 1965)									
	Submerged	Percent	Median	Mean	Mean Minus	Mean Plus	Derived Grain Size Percentiles (% finer than)						
	Wgt. Density	Moisture	Grain Size	Grain Size	1 Std. Dev.	1 Std. Dev.	D_5	D_{16}	D_{25}	D_{50}	D_{75}	D_{84}	D_{95}
Sample ID#	(tonnes/m^3)	%	(D_{50}, mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
3-0	1.035	82	0.0040	0.0021	0.0002	0.0191	*0.00002*	*0.0002*	*0.0005*	0.0040	0.0110	0.0151	0.0254
3-1	1.249	68	0.0036	0.0020	0.0002	0.0185	*0.00002*	*0.0002*	*0.0005*	0.0036	0.0103	0.0151	0.0272
3-2	1.064	82	0.0036	0.0019	0.0002	0.0184	*0.00002*	*0.0001*	*0.0004*	0.0036	0.0107	0.0146	0.0245
3-3	1.073	81	0.0042	0.0023	0.0002	0.0210	*0.00002*	*0.0002*	*0.0005*	0.0042	0.0118	0.0167	0.0272
3-4	1.066	83	0.0042	0.0024	0.0003	0.0206	*0.00003*	*0.0002*	*0.0006*	0.0042	0.0118	0.0173	0.0282
3-5	1.194	68	0.0042	0.0024	0.0003	0.0203	*0.00003*	*0.0002*	*0.0006*	0.0042	0.0118	0.0167	0.0292
3-6	1.118	74	0.0042	0.0022	0.0002	0.0218	*0.00002*	*0.0001*	*0.0005*	0.0042	0.0123	0.0173	0.0282
3-7	0.445	17	0.0043	0.0024	0.0003	0.0219	*0.00003*	*0.0002*	*0.0006*	0.0043	0.0123	0.0179	0.0292
3-8	0.962	89	0.0040	0.0020	0.0002	0.0201	*0.00002*	*0.0001*	*0.0004*	0.0040	0.0110	0.0156	0.0263
3+10W	1.054	83	0.0045	0.0024	0.0003	0.0218	*0.00003*	*0.0002*	*0.0006*	0.0045	0.0127	0.0179	0.0282
3+5W	1.074	81	0.0032	0.0019	0.0002	0.0169	*0.00003*	*0.0001*	*0.0004*	0.0032	0.0103	0.0146	0.0263
3+5E	1.062	92	0.0042	0.0024	0.0003	0.0200	*0.00003*	*0.0002*	*0.0006*	0.0042	0.0118	0.0167	0.0272
3+10E	1.136	79	0.0042	0.0021	0.0002	0.0222	*0.00002*	*0.0001*	*0.0005*	0.0042	0.0118	0.0173	0.0324
3-1C	1.202	64	0.0042	0.0021	0.0002	0.0196	*0.00002*	*0.0001*	*0.0005*	0.0042	0.0110	0.0151	0.0237
3-2C	1.289	59	0.0035	0.0019	0.0002	0.0182	*0.00002*	*0.0001*	*0.0005*	0.0035	0.0103	0.0146	0.0254
Average	1.068	73	0.0040	0.0022	0.0002	0.0200	0.00002	0.0002	0.0005	0.0040	0.0114	0.0162	0.0272
Avg. +1 Std. Dev.	1.262	92	0.0044	0.0024	0.0003	0.0216	0.00003	0.0002	0.0006	0.0044	0.0122	0.0174	0.0294
Avg. -1 Std. Dev.	0.875	55	0.0036	0.0020	0.0002	0.0184	0.00002	0.0001	0.0004	0.0036	0.0106	0.0149	0.0251

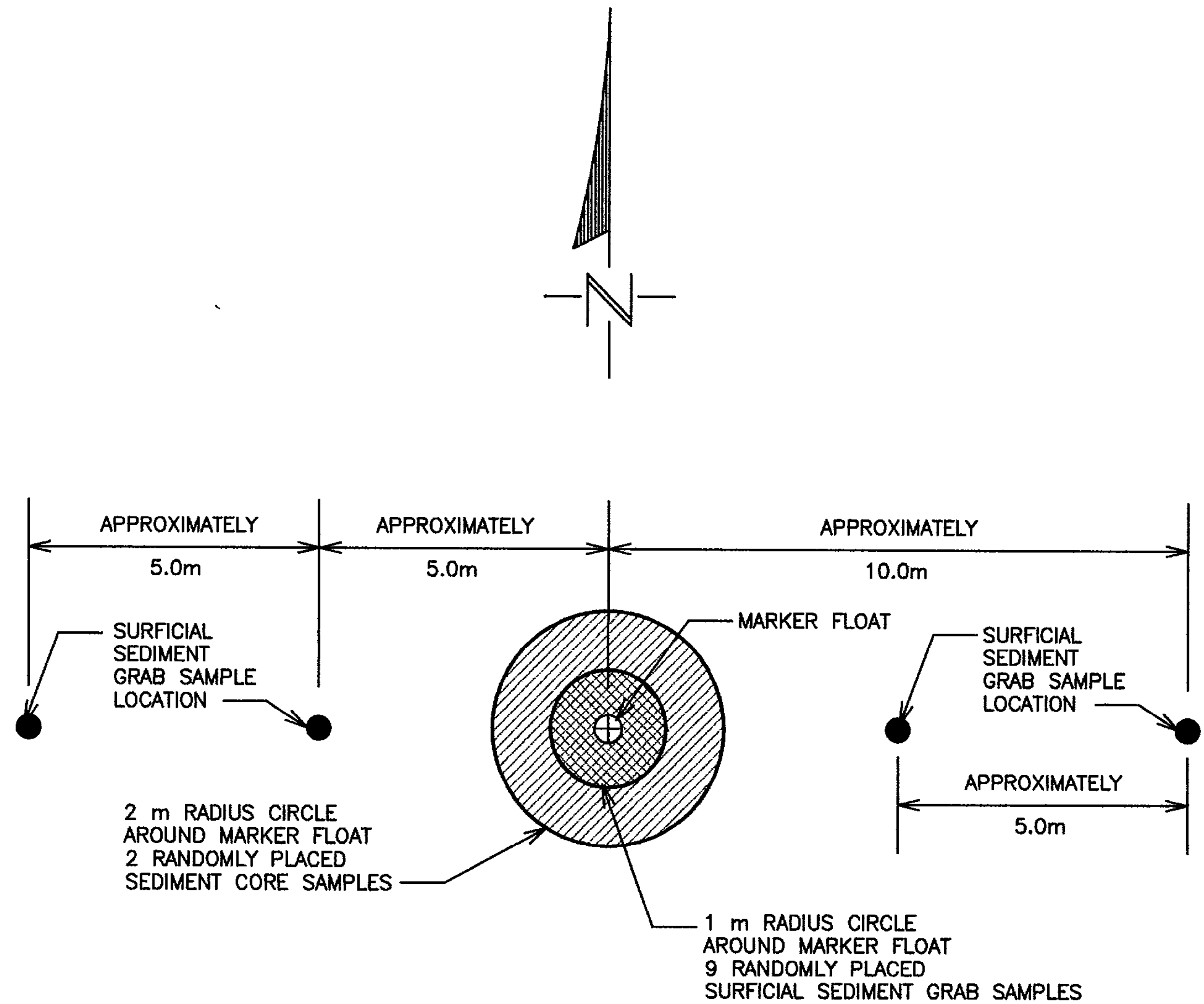
Sampling distances given in m west (W) and east (E) of marker float
Samples obtained by sediment core denoted with a "C"
Submerged Wgt. Density is the weight of the sediment in water
Percentile Grain Sizes in *Italics* are extrapolated from grain size graph

TABLE 2: Surficial Sediment Grab and Sediment Core Sample Data					
"t-test" statistics		Population Parameters Compared Using "t-test"			
Comparison Between Locations	Statistical Parameter	Median Grain Size (mm)	Mean Grain Size (mm)	Submerged Weight Density (tonnes/m^3)	Moisture Content (%)
Shallow (1.3 m) and Moderate (2.3 m)	Critical "t"	3.66	3.66	3.66	3.66
	Value of "t"	14.92	16.60	5.28	5.29
	DF	29	29	29	29
	Probability	p=0.001	p=0.001	p=0.001	p=0.001
Shallow (1.3 m) and Deep (3.4 m)	Critical "t"	3.66	3.66	3.66	3.66
	Value of "t"	23.96	23.62	6.41	5.73
	DF	29	29	29	29
	Probability	p=0.001	p=0.001	p=0.001	p=0.001
Moderate (2.3 m) and Deep (3.4 m)	Critical "t"	3.67	3.67	2.47	1.70
	Value of "t"	7.88	9.17	2.60	1.44
	DF	28	28	28	28
	Probability	p=0.001	p=0.001	p=0.02	not significant at p =0.1

TABLE 3: Windspeed Data and Estimated Return Frequencies				
Annual Maximum Series Data (for ice-free conditions)				
Year	Month	Day	Windspeed [m/s (km/h)]	
1993	June	13	13.5 (48.6)	
1994	April	14	18.6 (67.0)	
1995	April	13	14.2 (51.1)	
Estimated Return Periods (using Log Pearson Type III Distribution)				
Return Period (years)			Windspeed [m/s (km/h)]	
2			14.6 (52.6)	
5			17.2 (61.9)	
10			19.2 (69.1)	
20			21.4 (77.0)	
50			24.7 (88.9)	
100			27.5 (99.0)	
200			30.6 (110.2)	
Monthly Maximum Winds (raw data June 93 - Nov. 95)				
Year	Month	Day	Windspeed [m/s (km/h)]	
1993	June	13	**13.5 (48.5)**	
	July	13	12.9 (46.5)	
	August	23	10.4 (37.4)	
	September	23	12.1 (43.4)	
	October	26	13.2 (47.4)	
	November	21	*19.4 (69.8)*	*Ice Cover*
	December	3	*17.6 (63.4)*	*Ice Cover*
1994	January	8	*13.9 (50.2)*	*Ice Cover*
	February	12	*18.1 (65.1)*	*Ice Cover*
	March	12	*18.0 (64.9)*	*Ice Cover*
	April	14	**18.6 (67.0)**	
	May	11	16.7 (60.5)	
	June	13	12.5 (45.0)	
	July	7	9.8 (35.2)	
	August	22	11.4 (41.0)	
	September	15	14.0 (50.4)	(Field Visit, Sept. 6-12th)
	October	25	12.9 (46.4)	
	November	30	*21.8 (78.5)*	*Ice Cover*
	December	22	*16.6 (59.8)*	*Ice Cover*
1995	January	19	*14.5 (52.2)*	*Ice Cover*
	February	19	*20.3 (72.9)*	*Ice Cover*
	March	3	*16.2 (58.3)*	*Ice Cover*
	April	27	**14.2 (51.0)**	
	May	14	12.0 (43.3)	
	June	16	11.9 (42.7)	
	July	22	9.7 (34.8)	
	August	4	9.6 (34.6)	
	September	11	12.1 (43.5)	(Field Visit, Sept. 11-16th)
	October	17	12.6 (45.5)	
	November	4	*14.1 (50.7)*	*Ice Cover*

Presence of Ice-Cover estimated from monthly temperature maxima and minima

FIGURES



HAY & COMPANY CONSULTANTS INC.

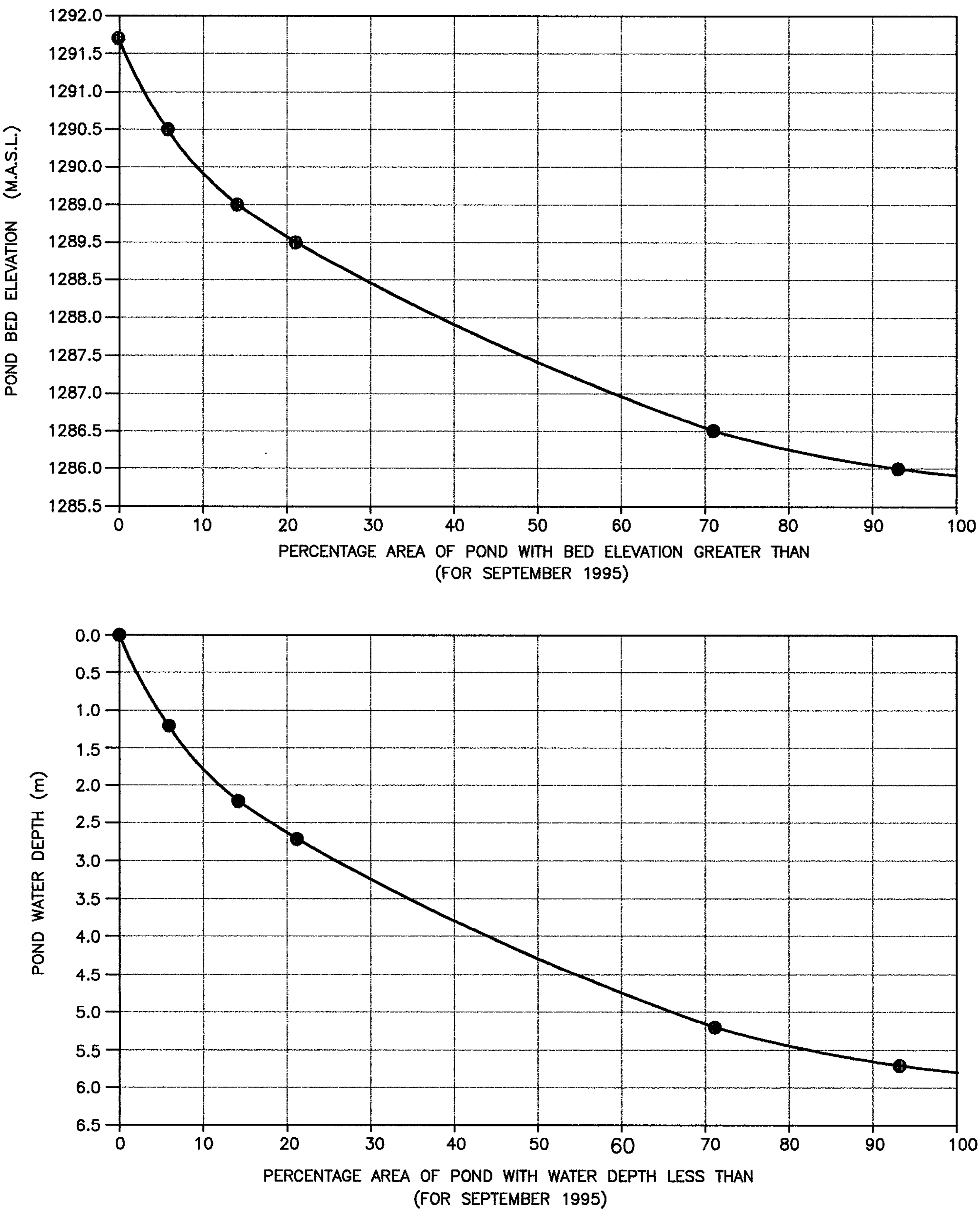
PLACER DOME CANADA / CANMET

SHALLOW WATER COVERS - EQUITY SILVER
BASE INFORMATION ON PHYSICAL VARIABLES

PATTERN OF SEDIMENT SAMPLE COLLECTION AT EACH WATER DEPTH LOCATION

FIG. 1

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29



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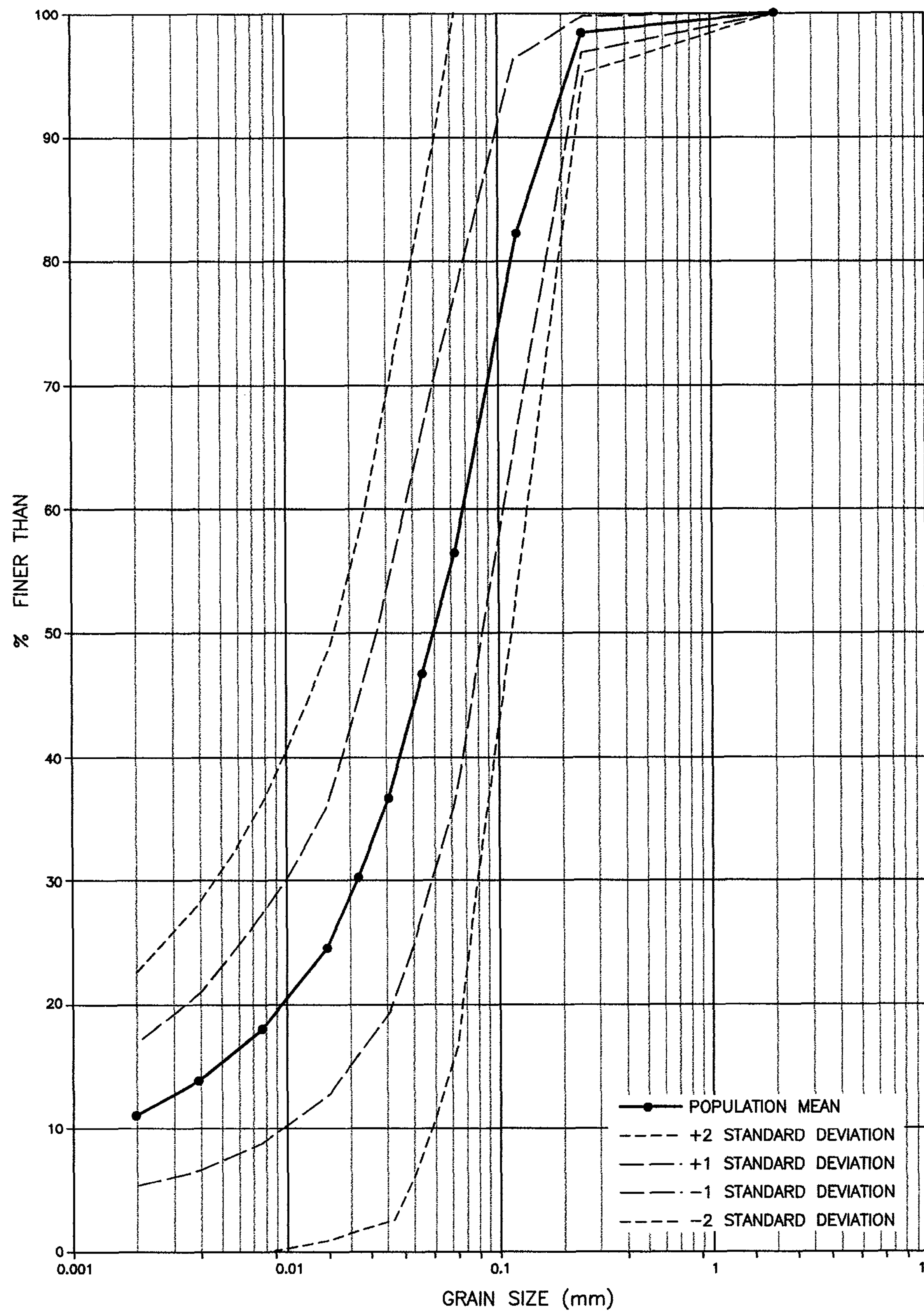
PLACER DOME CANADA / CANMET

SHALLOW WATER COVERS - EQUITY SILVER
BASE INFORMATION ON PHYSICAL VARIABLES

RELATIONSHIP BETWEEN POND AREA AND BED ELEVATION

FIG. 2

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29



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PLACER DOME CANADA / CANMET

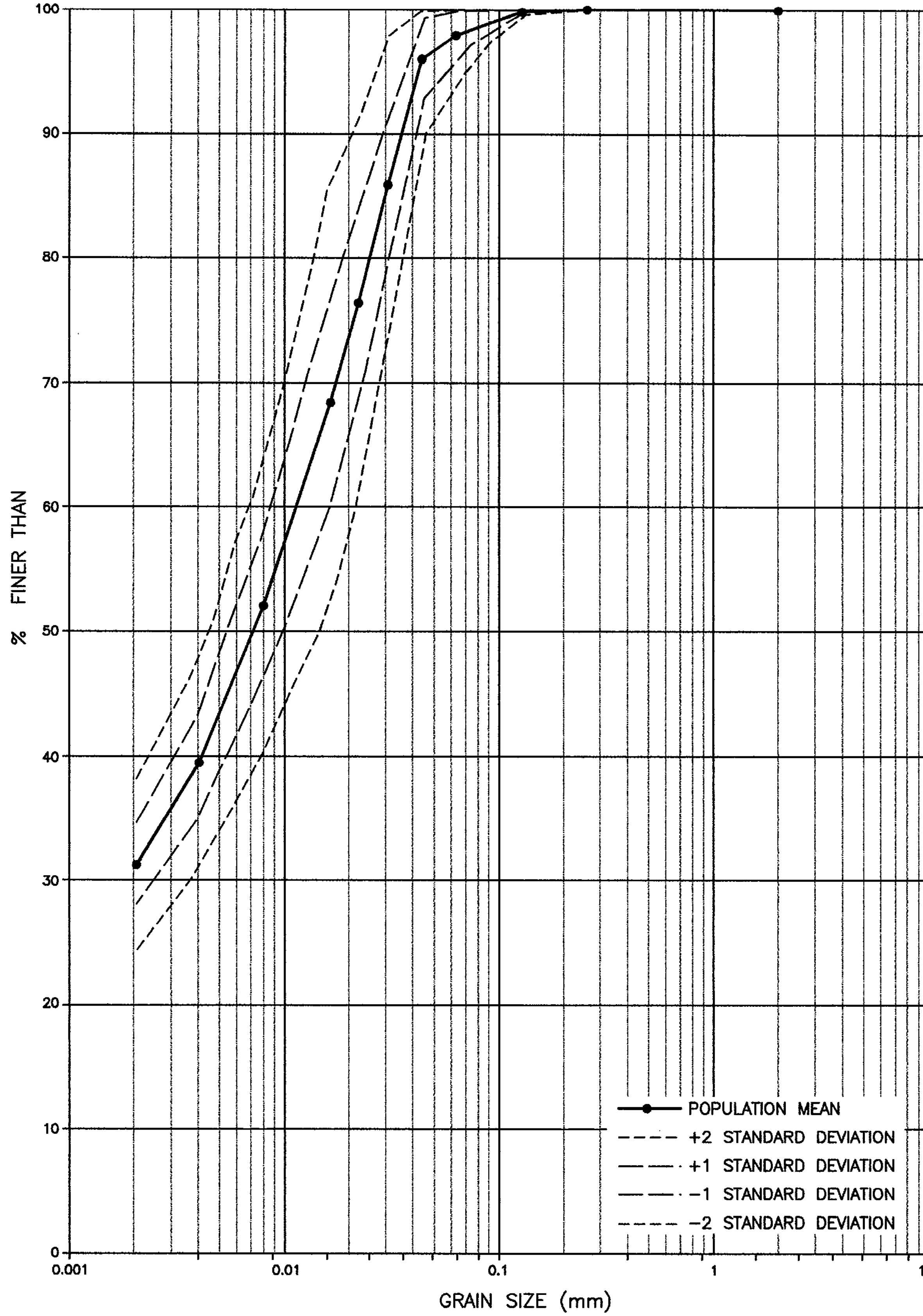
SHALLOW WATER COVERS - EQUITY SILVER

BASE INFORMATION ON PHYSICAL VARIABLES

GRAIN SIZES AT 1.3 m WATER DEPTH

FIG. 3

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29



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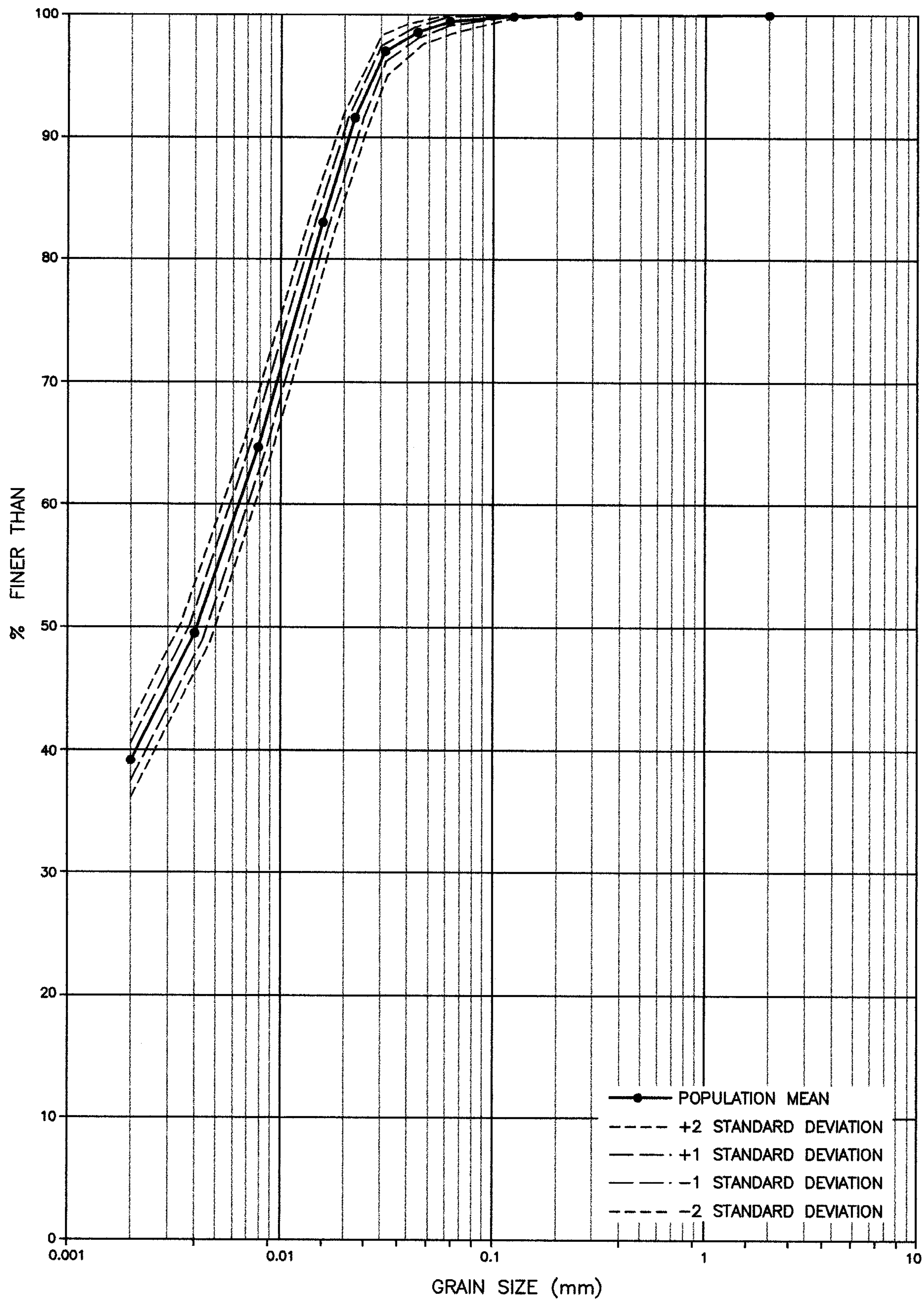
SHALLOW WATER COVERS - EQUITY SILVER

BASE INFORMATION ON PHYSICAL VARIABLES

GRAIN SIZES AT 2.3 m WATER DEPTH

FIG. 4

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29



HAY & COMPANY CONSULTANTS INC.

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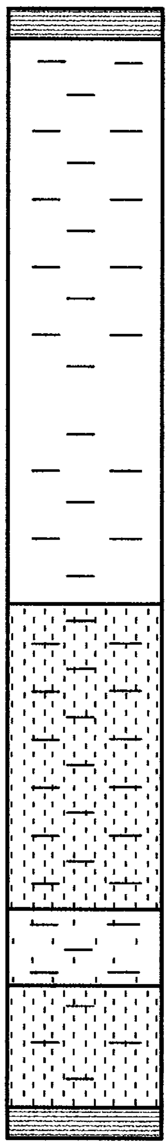
SHALLOW WATER COVERS - EQUITY SILVER

BASE INFORMATION ON PHYSICAL VARIABLES

GRAIN SIZES AT 3.4 m WATER DEPTH

FIG. 5

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29



CORE LOG	DEPTH	CORE NOTES
1	0.0 m 0.02 m	ORANGE–YELLOW FLOCCULES AND FINE ORGANICS LIKE ALGAE, PEELS LIKE A SKIN, VERY FINE, NO LAMINATIONS, NO GRIT, SHARP CONTACT WITH 2
2	0.39 m	UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, COLLAPSES ON EXTRUSION, GRADES INTO 3
3	0.59 m	SILTY–SAND, GREY, CONSOLIDATED, DOES NOT COLLAPSE ON EXTRUSION, GRADES INTO 4
4	0.64 m	SANDY–SILT, GREY, UNCONSOLIDATED, COLLAPSES ON EXTRUSION, GRADES INTO 5
5	0.72 m	SILTY–SAND, GREY, CONSOLIDATED, DOES NOT COLLAPSE ON EXTRUSION, SHARP CONTACT WITH 6
6	0.74 m	ORANGE–YELLOW FLOCCULES AND FINE ORGANICS, SOME GRIT PRESENT, COMPACTED

DATE: SEPTEMBER 15TH, 1995
WATER DEPTH: ≈ 1.3 m
CORING METHOD: PETERSEN CORER

HAY & COMPANY CONSULTANTS INC.

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SHALLOW WATER COVERS - EQUITY SILVER

BASE INFORMATION ON PHYSICAL VARIABLES

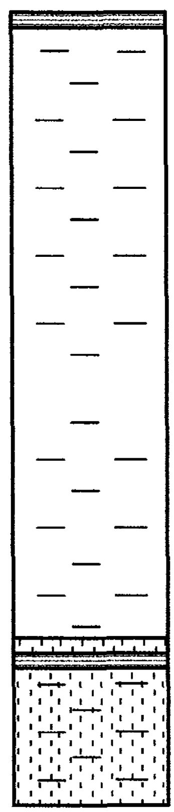
STRATIGRAPHIC CORE RECORD

CORE 1-1

FIG. 6

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29

CORE LOG | DEPTH | CORE NOTES



	Depth	Core notes
1	0.0 m – 0.01 m	ORANGE-YELLOW FLOCCULES AND FINE ORGANICS LIKE ALGAE, PEELS LIKE A SKIN, VERY FINE, NO LAMINATIONS, NO GRIT, SHARP CONTACT WITH 2
2		UNDIFFERENTIATED TAILINGS, SILTY-CLAY, GREY, NO LAMINATIONS, COLLAPSES ON EXTRUSION, GRADES INTO 3
3	0.41 m – 0.42 m	SILTY-SAND, GREY, CONSOLIDATED, DOES NOT COLLAPSE ON EXTRUSION, SHARP CONTACT WITH 4
4	0.42 m – 0.43 m	ORANGE-YELLOW FLOCCULES AND FINE ORGANICS, SOME GRIT PRESENT, COMPACTED, SHARP CONTACT WITH 5
5	0.43 m – 0.52 m	SILTY-SAND, GREY, CONSOLIDATED, DOES NOT COLLAPSE ON EXTRUSION

DATE: SEPTEMBER 15TH, 1995
WATER DEPTH: ≈ 1.3 m
CORING METHOD: PETERSEN CORER

HAY & COMPANY CONSULTANTS INC.

PLACER DOME CANADA / CANMET

SHALLOW WATER COVERS - EQUITY SILVER

BASE INFORMATION ON PHYSICAL VARIABLES

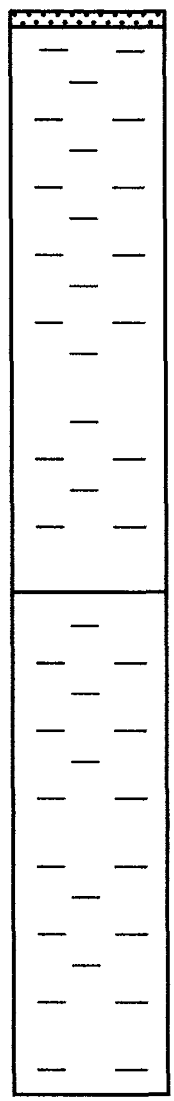
STRATIGRAPHIC CORE RECORD

CORE 1-2

FIG. 7

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29

CORE LOG | DEPTH | CORE NOTES



	Depth	Core notes
1	0.0 m – 0.01 m	GREY–YELLOW FLOCCULES AND FINE ORGANICS LIKE ALGAE, PEELS LIKE A SKIN, VERY FINE, NO LAMINATIONS, NO GRIT, SHARP CONTACT WITH 2
2	0.01 m – 0.38 m	UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, COLLAPSES ON EXTRUSION, GRADES INTO 3
3	0.38 m – 0.71 m	UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, DOES NOT COLLAPSE ON EXTRUSION, GRITTIER THAN LAYER 2

DATE: SEPTEMBER 15TH, 1995
WATER DEPTH: ≈ 2.3 m
CORING METHOD: PETERSEN CORER

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SHALLOW WATER COVERS - EQUITY SILVER

BASE INFORMATION ON PHYSICAL VARIABLES

STRATIGRAPHIC CORE RECORD

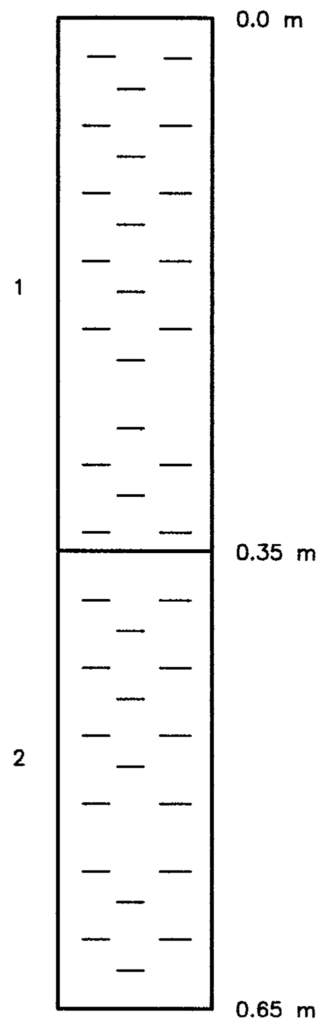
CORE 2-1

FIG. 8

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29

CORE LOG DEPTH

CORE NOTES



1 UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, COLLAPSES ON EXTRUSION, GRADES INTO 2

2 UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, DOES NOT COLLAPSE ON EXTRUSION, GRITTIER THAN LAYER 1

DATE: SEPTEMBER 15TH, 1995
WATER DEPTH: ≈ 2.3 m
CORING METHOD: PETERSEN CORER

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PLACER DOME CANADA / CANMET

SHALLOW WATER COVERS - EQUITY SILVER

BASE INFORMATION ON PHYSICAL VARIABLES

STRATIGRAPHIC CORE RECORD

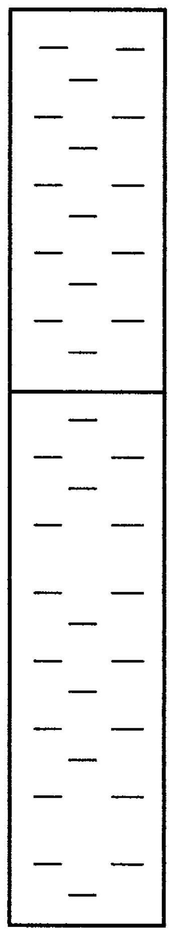
CORE 2-2

FIG. 9

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29

CORE LOG DEPTH

CORE NOTES



0.0 m

1 — UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, COLLAPSES ON EXTRUSION, GRADES INTO 2

0.25 m

2 — UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, DOES NOT COLLAPSE ON EXTRUSION, GRITTIER THAN LAYER 1

0.60 m

DATE: SEPTEMBER 15TH, 1995
WATER DEPTH: ≈ 3.4 m
CORING METHOD: PETERSEN CORER

HAY & COMPANY CONSULTANTS INC.

PLACER DOME CANADA / CANMET

SHALLOW WATER COVERS - EQUITY SILVER

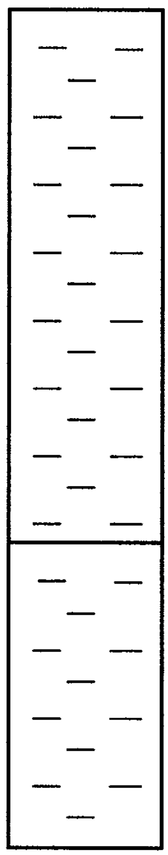
BASE INFORMATION ON PHYSICAL VARIABLES

STRATIGRAPHIC CORE RECORD

CORE 3-1

FIG. 10

CORE LOG DEPTH CORE NOTES



	Depth	Core Notes
	0.0 m	
1		UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, COLLAPSES ON EXTRUSION, GRADES INTO 2
	0.35 m	
2		UNDIFFERENTIATED TAILINGS, SILTY–CLAY, GREY, NO LAMINATIONS, DOES NOT COLLAPSE ON EXTRUSION, GRITTIER THAN LAYER 1
	0.55 m	

DATE: SEPTEMBER 15TH, 1995
WATER DEPTH: 3.4 m
CORING METHOD: PETERSEN CORER

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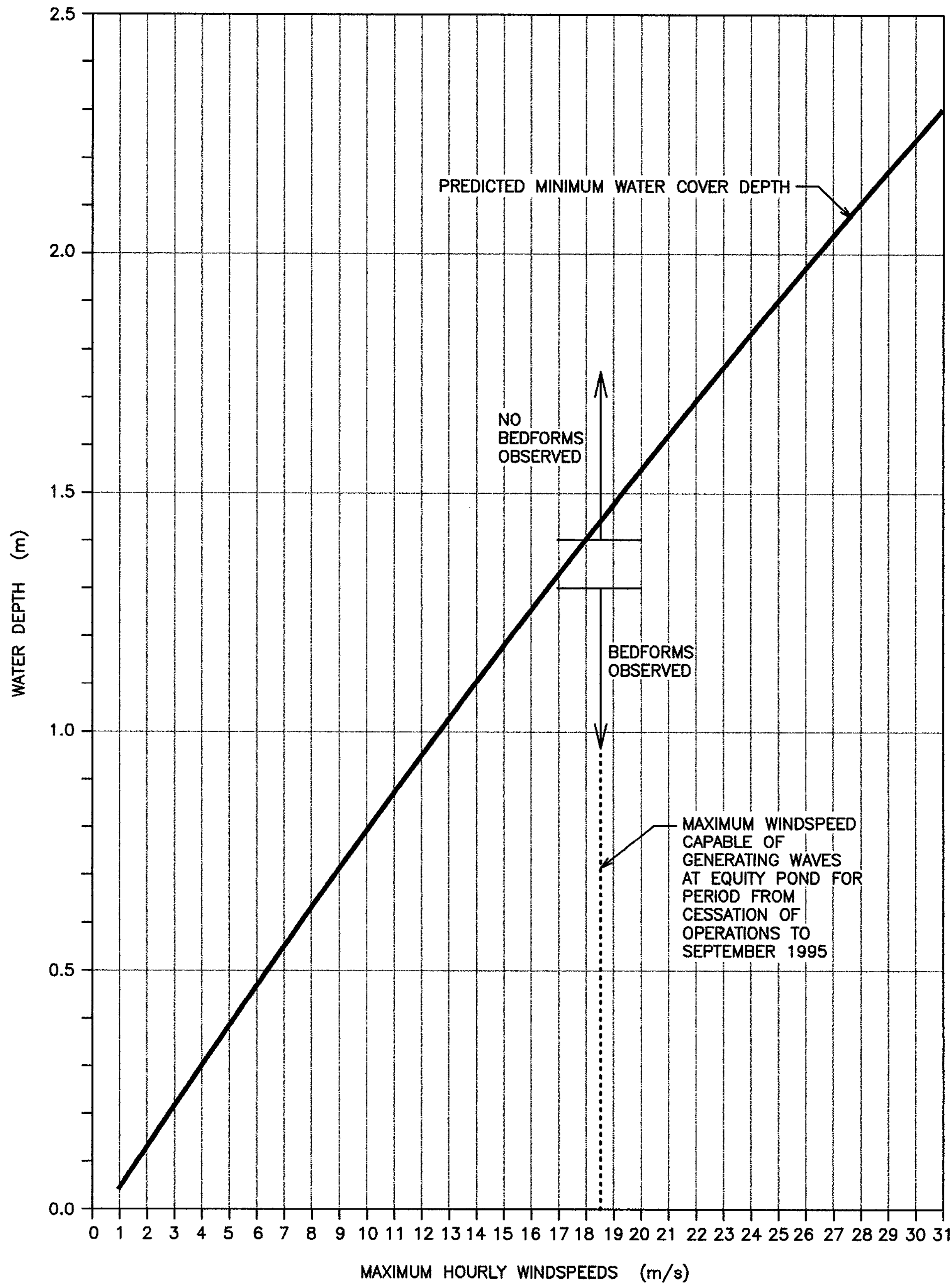
PLACER DOME CANADA / CANMET

SHALLOW WATER COVERS - EQUITY SILVER
BASE INFORMATION ON PHYSICAL VARIABLES

STRATIGRAPHIC CORE RECORD
CORE 3-2

FIG. 11

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29



HAY & COMPANY CONSULTANTS INC.

PLACER DOME CANADA / CANMET

SHALLOW WATER COVERS - EQUITY SILVER
BASE INFORMATION ON PHYSICAL VARIABLES

PREDICTED DEPTHS VERSUS WINDSPEED

FIG. 12

CAD FILE : PDI-003A / PDIFIGS.DGN / 1995 NOV 29

APPENDICES

Appendix 1

Sediment Sample Raw Data

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

analytical service laboratories ltd.

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

CHEMICAL ANALYSIS REPORT

Date: October 24, 1995

ASL File No. F3859

Report On: Soil Analysis

Report To: **Hay and Co.**
1 West 7th Avenue
Vancouver, BC
V5Y 1L4

Attention: Mr. Rowland Atkins

Received: September 19, 1995

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Katherine Thomas, B.Sc.
Project Chemist

Frederick Chen, B.Sc.
Supervisor, Trace Metals Lab

cc: Rescan Environmental Services
Sixth Flr, Coopers & Lybrand Bldg
1111 West Hastings Street
Vancouver, BC V6E 2J3
Attn: Mr. Jay McNee

cc: Placer Dome Inc.
P.O. Box 49330 Bentall Station
Suite 1600 - 1055 Dunsmuir Street
Vancouver, BC V7X 1P1
Attn: Mr. Jim Robertson

cc: Equity Silver Mines Ltd.
P.O. Box 1450
Houston, BC V0J 1Z0
Attn: Mr. Mike Aziz

REMARKS

File No. F3859

The detailed particle size analyses were carried out by Pacific Soils Analysis Inc. in Richmond, B.C. Their results are included in Appendix 2 of this report.

The Wet Sample Volume, Wet Sample Weight and Dry Sample Weight analyses were carried out as follows:

> Approximately 100-150 mL of each wet sediment sample was accurately weighed (Wet Sample Weight), and the exact volume (Wet Sample Volume), was recorded. These sample aliquots were then oven-dried and reweighed after drying (Dry Sample Weight).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3]

File No. F3859

	1-0	1-1	1-2	1-3	1-4
	95 09 13	95 09 13	95 09 13	95 09 13	95 09 13
Physical Tests					
Moisture %	27.0	18.3	19.4	17.7	32.1
Volume/Weight Measurements					
Wet Sample Volume (mL)	130	130	110	120	105
Wet Sample Weight (g)	259.7	183.3	217.6	213.6	227.6
Dry Sample Weight (g)	189.5	149.7	175.3	175.8	154.6

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3] File No. F3859

	1-5	1-6	1-7	1-8	1+10E
	95 09 13	95 09 13	95 09 13	95 09 13	95 09 13
Physical Tests					
Moisture %	22.5	20.8	20.3	85.2	37.4
Volume/Weight Measurements					
Wet Sample Volume (mL)	140	120	110	140	120
Wet Sample Weight (g)	260.9	218.4	189.9	154.4	193.2
Dry Sample Weight (g)	202.2	173.0	151.3	22.8	120.9

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3] File No. F3859

	1+5E	1+5W	1+10W	2+10E	2+5E
	95 09 13	95 09 13	95 09 13	95 09 13	95 09 13
Physical Tests					
Moisture %	44.5	49.4	30.1	58.8	72.7
Volume/Weight Measurements					
Wet Sample Volume (mL)	135	140	150	140	140
Wet Sample Weight (g)	200.2	193.4	259.6	190.1	158.5
Dry Sample Weight (g)	111.2	97.8	181.4	78.3	43.3

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3]

File No. F3859

	2+5W	2+10W	2-0	2-1	2-2
	95 09 13	95 09 13	95 09 13	95 09 13	95 09 13
Physical Tests					
Moisture %	65.1	58.3	87.6	69.8	86.5
Volume/Weight Measurements					
Wet Sample Volume (mL)	140	140	140	140	140
Wet Sample Weight (g)	167.2	178.2	139.9	166.8	143.9
Dry Sample Weight (g)	58.4	74.3	17.3	50.4	19.4

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3]

File No. F3859

	2-3	2-4	2-5	2-6	2-7
	95 09 13	95 09 13	95 09 13	95 09 13	95 09 13
Physical Tests					
Moisture %	70.2	50.8	67.6	57.9	64.2
Volume/Weight Measurements					
Wet Sample Volume (mL)	140	145	140	140	140
Wet Sample Weight (g)	163.0	191.0	162.9	179.4	182.4
Dry Sample Weight (g)	48.6	93.9	52.8	75.6	65.3

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3]

File No. F3859

	2-8	3+10E	3+5E	3+5W	3+10W
	95 09 13	95 09 14	95 09 14	95 09 14	95 09 14
Physical Tests					
Moisture %	71.5	78.9	91.9	81.1	83.4
Volume/Weight Measurements					
Wet Sample Volume (mL)	135	143	125	140	140
Wet Sample Weight (g)	157.0	162.5	132.7	150.3	147.5
Dry Sample Weight (g)	44.7	34.3	10.7	28.4	24.5

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3]

File No. F3859

	3-0	3-1	3-2	3-3	3-4
	95 09 14	95 09 14	95 09 14	95 09 14	95 09 14
Physical Tests					
Moisture %	82.0	68.4	81.5	80.9	83.2
Volume/Weight Measurements					
Wet Sample Volume (mL)	145	140	140	135	145
Wet Sample Weight (g)	150.1	174.9	148.9	144.8	154.5
Dry Sample Weight (g)	27.1	55.2	27.6	27.6	25.9

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3]

File No. F3859

	3-5	3-6	3-7	3-8	1-1C
	95 09 14	95 09 14	95 09 14	95 09 14	95 09 15
Physical Tests					
Moisture %	68.1	73.7	16.5	89.1	43.2
Volume/Weight Measurements					
Wet Sample Volume (mL)	140	140	140	135	160
Wet Sample Weight (g)	167.2	156.5	62.3	129.9	266.9
Dry Sample Weight (g)	53.3	41.1	52.0	14.2	151.7

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3] File No. F3859

	1-2C	1-3C	2-1C	2-2C	3-1C
	95 09 15	95 09 15	95 09 15	95 09 15	95 09 15
Physical Tests					
Moisture %	61.6	43.0	49.1	48.3	64.3
Volume/Weight Measurements					
Wet Sample Volume (mL)	110	140	125	135	145
Wet Sample Weight (g)	127.8	201.3	173.8	180.8	174.3
Dry Sample Weight (g)	49.1	114.8	88.4	93.4	62.2

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

RESULTS OF ANALYSIS - Sediment/Soil[1,2,3]

File No. F3859

	3-2C
	95 09 15
Physical Tests	
Moisture %	59.2
Volume/Weight Measurements	
Wet Sample Volume (mL)	140
Wet Sample Weight (g)	180.4
Dry Sample Weight (g)	73.6

Remarks regarding the analyses appear at the beginning of this report.
[1]Moisture results are expressed as percent.
[2]Wet Sample Volume is expressed as millilitres (mL).
[3]Wet Sample Weight and Dry Sample Weight are expressed as grams (g).

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

Moisture

This analysis is carried out gravimetrically by drying the sample to constant weight at 103 C.

APPENDIX 2

RESULTS OF SUBCONTRACTED ANALYSES

SAMPLE	Wet Vol ML	Wet Wt GM	Dry Wt GM	% passing each phi										
				2 mm	2.0 ϕ	3.0 ϕ	4.0 ϕ	4.5 ϕ	5.0 ϕ	5.5 ϕ	6.0 ϕ	7.0 ϕ	8.0 ϕ	9.0 ϕ
F 3859 - 1	130	259.7	189.5	100.0	99.9	92.9	71.7	59.2	41.2	29.3	24.2	17.3	13.3	10.9
2	130	183.3	149.7	100.0	97.7	67.6	44.4	33.2	22.4	22.0	17.0	10.8	8.3	6.9
3	110	217.6	175.3	100.0	96.1	69.9	43.0	33.3	22.0	15.8	13.0	9.7	7.6	6.5
4	120	213.6	175.8	100.0	94.8	62.8	37.6	28.9	19.0	13.4	11.0	7.8	6.4	5.2
5	105	227.6	154.6	100.0	97.8	76.0	49.9	38.1	25.5	18.8	15.5	11.2	9.0	7.2
6	140	260.9	202.2	100.0	95.6	68.5	45.7	36.6	26.5	19.5	16.6	12.0	9.4	7.9
7	120	218.4	173.0	100.0	99.0	70.7	45.7	36.4	24.7	18.0	13.9	10.5	8.2	6.8
8	110	189.9	151.3	100.0	99.0	58.6	29.4	22.9	15.8	12.0	10.0	7.2	6.0	4.9
9	140	154.4	22.8	100.0	99.0	96.9	87.0	76.4	59.2	46.9	38.7	29.8	22.9	18.2
10	120	193.2	120.9	100.0	99.0	97.1	73.5	62.6	42.8	33.2	27.1	20.0	14.7	12.4
11	135	200.2	111.2	100.0	99.0	93.0	74.7	62.8	43.4	31.4	25.2	18.3	14.1	11.0
12	140	193.4	97.8	100.0	98.8	85.4	57.4	46.6	34.3	26.9	22.5	16.8	13.3	10.7
13	150	259.6	181.4	100.0	97.7	84.1	67.0	62.5	51.8	43.8	37.9	29.3	23.7	18.0
14	140	190.1	78.3		100.0	99.8	90.6	85.2	70.4	57.8	49.5	37.8	29.1	23.3
15	140	158.5	43.3		100.0	99.9	97.1	94.2	82.7	69.7	60.3	45.9	35.6	27.9
16	140	167.2	58.4	100.0	99.9	99.8	98.6	97.1	88.8	80.1	71.0	55.6	42.5	33.5
17	140	178.2	74.3		100.0	99.9	99.5	99.3	99.1	91.2	81.9	63.2	48.9	38.8
18	140	139.9	17.3	100.0	99.9	99.8	98.2	96.7	86.4	76.6	67.6	52.2	39.7	31.6
19	140	166.8	50.4		100.0	99.9	98.5	97.2	86.6	84.3	83.3	49.7	38.3	30.5
20	140	143.9	19.4	100.0	99.9	99.7	98.0	97.3	87.6	76.9	67.3	52.3	40.2	31.5
21	140	163.0	48.6	100.0	99.9	99.8	98.6	96.7	89.6	80.2	71.2	54.9	42.3	33.6
22	145	191.0	93.9		100.0	99.9	97.4	95.2	84.3	71.6	63.1	49.1	37.4	29.7
23	140	162.9	52.8		100.0	99.9	98.2	97.4	87.6	75.0	65.5	51.2	39.0	30.8
24	140	179.4	75.6		100.0	99.9	97.9	95.0	84.2	72.4	62.6	59.2	37.0	29.6
25	140	182.4	65.3		100.0	99.9	98.6	97.0	87.1	81.2	75.2	50.5	38.2	30.1

PSAI

A S L   K. Thomas   Oct 24, 1995

SAMPLE	Wet Vol ML	Wet Wt GM	Dry Wt GM	% passing each phi										
				2mm	2.0	3.0	4.0	4.5	5.0	5.5	6.0	7.0	8.0	9.0
F 3859 - 26	135	157.0	44.7		100.0	99.9	98.4	95.7	85.8	74.7	65.0	49.7	37.9	30.4
27	143	162.5	34.3		100.0	99.9	98.6	98.2	94.5	88.7	81.5	63.4	48.8	39.6
28	125	132.7	10.7		100.0	99.8	99.0	98.2	97.0	91.0	82.6	64.0	48.8	38.5
29	140	150.3	28.4		100.0	99.8	99.2	98.1	97.2	92.4	85.2	68.2	53.0	41.8
30	140	147.5	24.5		100.0	99.8	98.7	97.7	96.5	88.9	79.6	61.9	46.8	37.8
31	145	150.1	27.1		100.0	99.9	99.7	99.4	97.9	92.5	84.1	64.7	49.3	39.2
32	140	174.9	55.2		100.0	99.7	99.0	97.6	97.1	92.3	84.7	67.7	51.1	40.9
33	140	148.9	27.6		100.0	99.9	99.8	99.0	98.0	93.5	85.4	66.4	51.0	40.7
34	135	144.8	27.6		100.0	99.9	99.5	98.2	97.0	90.8	82.7	63.2	48.6	38.2
35	145	154.5	25.9		100.0	99.9	99.8	98.1	96.6	90.2	81.4	63.3	48.7	37.8
36	140	167.2	53.3		100.0	99.9	99.6	99.0	96.3	89.4	81.8	63.7	49.0	38.3
37	140	156.5	41.1			100.0	99.5	98.0	96.9	90.4	81.8	62.8	48.2	38.3
38	140	62.3	52.0		100.0	99.9	99.7	97.9	95.9	90.9	81.1	62.2	47.8	37.4
39	135	129.9	14.2		100.0	99.9	99.6	99.0	97.5	91.9	83.9	65.4	49.1	40.0
40	160	266.9	151.7		100.0	99.7	93.5	80.5	63.4	53.6	45.7	34.8	26.9	22.4
41	110	127.8	49.1	100.0	99.1	92.1	70.4	69.1	60.5	45.7	26.1	18.0	9.5	7.4
42	140	201.3	114.8		100.0	99.9	93.2	80.9	63.8	51.2	43.9	33.2	25.4	20.4
43	125	173.8	88.4			100.0	98.6	98.1	89.7	78.8	70.6	54.7	41.6	33.5
44	135	180.8	93.4		100.0	99.8	98.8	97.3	88.4	76.8	66.9	51.3	39.1	31.5
45	145	174.3	62.2		100.0	99.9	99.6	98.8	98.1	94.3	85.1	64.1	48.9	38.7
46	140	180.4	73.6		100.0	99.8	99.6	98.8	97.3	92.7	85.4	66.5	51.4	40.4

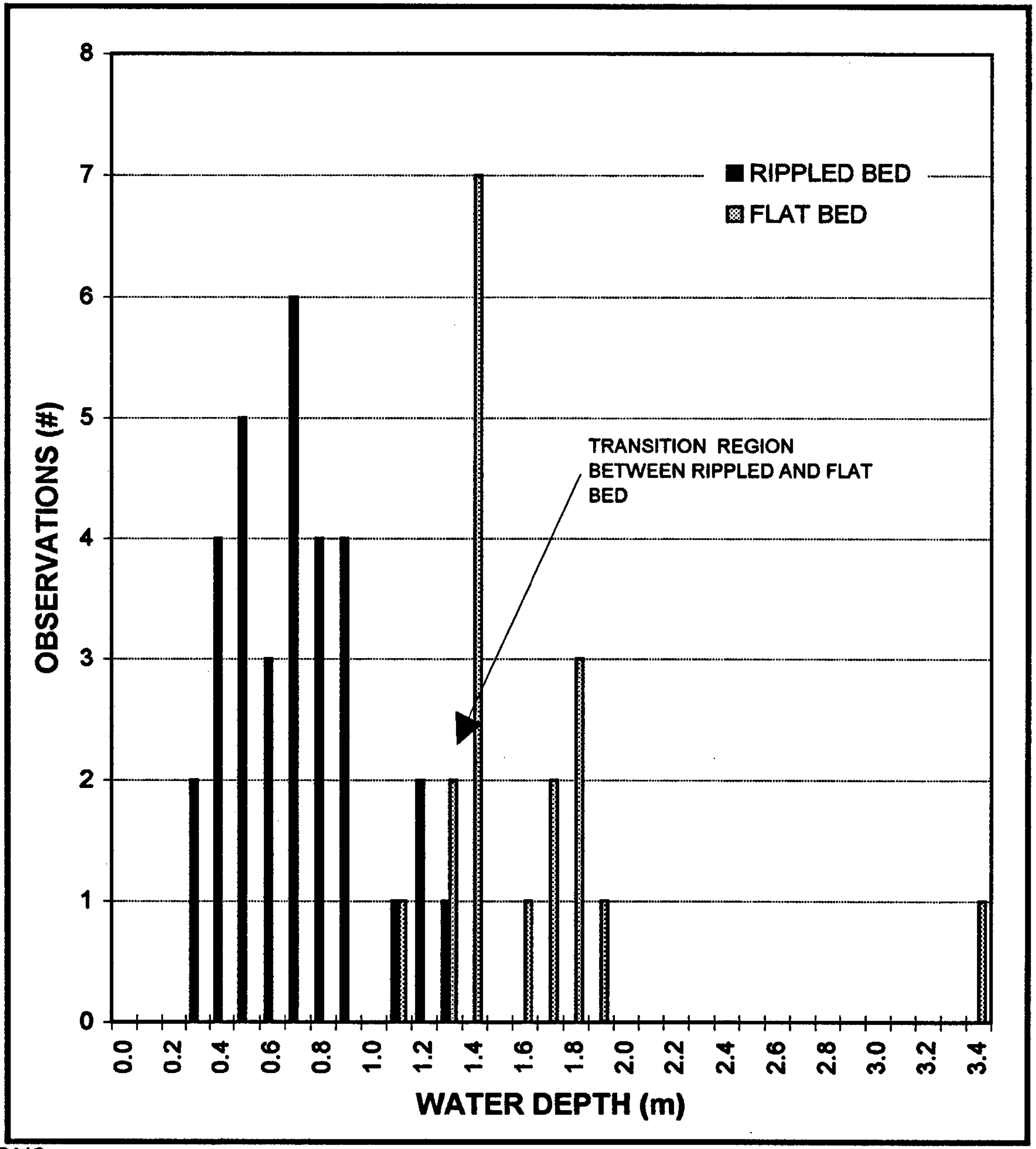
Appendix 2

Bedform Raw Data

BEDFORM OBSERVATIONS

WATER DEPTH (m)	NUMBER OF OBSERVATIONS RIPPLED BED	FLAT BED
0.0		
0.1		
0.2		
0.3	2	
0.4	4	
0.5	5	
0.6	3	
0.7	6	
0.8	4	
0.9	4	
1.0		
1.1	1	1
1.2	2	
1.3	1	2
1.4		7
1.5		
1.6		1
1.7		2
1.8		3
1.9		1
2.0		
2.1		
2.2		
2.3		
2.4		
2.5		
2.6		
2.7		
2.8		
2.9		
3.0		
3.1		
3.2		
3.3		
3.4		1

1 (shaded)	1995 OBSERVATIONS
3	1994 OBSERVATIONS



HAYCO

Appendix 3   Bathymetric Survey Raw Data

and

Appendix 4   Climate Station Summary Data

are provided on disk as MSExcel 5.0 files
Appendix 3 is "survey.xls"
Appendix 4 is "weather.xls"