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REPORT ON

INITIAL PHASE
GROUNDWATER AVAILABILITY ASSESSMENT
SUMMERLAND TROUT HATCHERY
SUMMERLAND, BRITISH COLUMBIA

Submitted to:

Freshwater Fisheries Society of BC
Summerland Trout Hatchery
RR1, Site 11, Comp. 8
Summerland, British Columbia
VOH 1Z0

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) is pleased to present this report to the Freshwater Fisheries Society of B.C. (FFSBC), summarizing the results of our initial assessment of groundwater availability at the Summerland Trout Hatchery (the "Hatchery"), located along Lakeshore Drive, in Summerland, B.C. (Figure 1). The project was conducted in accordance with the Terms of Reference outlined in our proposal entitled *"Workplan and Cost Estimate (FFSBC 002), Assessment of Groundwater Availability, Summerland Trout Hatchery, Summerland, BC"* (Golder Proposal Number P42-4029), dated March 26, 2004. The purpose of the investigation was to complete an assessment of the groundwater development potential in the area of the Hatchery that included an assessment of the reliability of the yield available from the existing source (natural springs), as well as the potential for the development of a 2,500 L/min (660 USgpm) or greater capacity water well at three potential locations on properties operated by the Hatchery.

2.0 BACKGROUND

It is understood that the existing water source for the Hatchery consists of a system of springs collectively known as Shaughnessy Springs. The springs are located within the upper reaches of a significant drainage gulley extending for approximately 400 m from the western shore of Lake Okanagan (at the Hatchery), in a westerly direction (Figure 2). Currently, an upper spring is used to provide water to the Hatchery's fish egg population, while a lower spring is used to supply water to the Hatchery's mature trout population. Gravity conveys the water from the two spring sources to the point of use by the Hatchery, near the edge of Lake Okanagan.

It is understood that the capacity of the springs has slowly declined in the past several years, and as such, is threatening the Hatchery's ability to meet fish production needs. Low annual precipitation over the last few years in the Interior of British Columbia, as well as changing land use and the conversion from on-site septic to municipal sewerage in the upland areas to the west of the Hatchery and gulley, are likely factors that have contributed to the declining yield of the springs. Based on this reduction of spring yields, and an increased demand for trout production, the Hatchery has requested that a groundwater availability assessment be conducted to assess the potential for an additional water supply to be developed.

3.0 SCOPE OF WORK

As part of this initial stage of assessment, Golder has completed the first five tasks outlined in our March 26, 2003 proposal submitted to the FFSBC. These tasks consisted of i) a project initiation meeting and information review, ii) an exploratory borehole program, iii) aquifer characterization, iv) assessment of development potential and v) the completion of this interim report. The initial four tasks are described in more detail in the following sections. Note that Task 6 (test well construction and testing) and Task 7 (data analyses and final reporting), both discussed in our proposal, were not completed in this initial portion of the investigation.

3.1 Task 1 - Project Initiation and Information Review

A project kickoff meeting was held on May 19, 2004 between Mr. Mark Siemens of the Hatchery and Mr. Remi Allard and Ms. Jacqueline Foley of Golder, to review the work scope prior to commencing with the investigation. Following the kickoff meeting, Golder conducted a desktop review of available information for the area including water well records from the Ministry of Water, Land and Air Protection (MWLAP) water well database, Golder in-house files, existing soil and topography maps and geological reports.

3.2 Task 2 – Exploratory Borehole Program

The originally proposed drilling program called for the hand augering of 9 boreholes in the spring areas and the drilling of 5 boreholes in the area of the Hatchery. Golder attempted to hand auger several boreholes in the area of the upper and lower springs on May 19, 2004. However, the hand auger equipment could not penetrate beyond a surficial layer of cobble, which exists in these areas. An Odex drilling rig operated by Geotech Drilling Services Ltd. of Vernon, B.C. was mobilized to the Hatchery on June 16, 2004, to complete the borehole program. A total of 10 boreholes (BH04-1, and MW1 through MW9) were drilled at the following locations (Figure 2):

- BH04-1 and MW1 were drilled at the Main Hatchery Site, along the western shore of Lake Okanagan;

- MW2 and MW3 were drilled in the area of the Hatchery's equipment storage yard, located on the west side of Lakeshore Drive;

- MW4 and MW5 were drilled in the lower spring area; and

- MW6 through MW9 were drilled in the area of the upper springs.

The actual numbers of boreholes drilled in the spring areas were less than originally proposed, as the steep topography of the area limited access for the larger Odex drilling rig. Moreover, in addition to the problematic layer of cobbles at the surface, heaving sand was encountered at greater depth, which proved difficult to penetrate with the Odex drilling equipment.

Drilling of the boreholes was monitored by a member of Golder's technical staff. Soil samples were collected at regular depth intervals during the drilling program using a split-spoon sampler. Monitoring wells, constructed of washed and wrapped 50 mm diameter, Schedule 40 PVC casing with a 1.5 m long 10 slot PVC screen, were installed within all boreholes, with the exception of BH04-1. A monitoring well could not be installed within BH04-1 due to heaving sand conditions within the drilling casing. The annular space around each monitoring well was backfilled with clean silica sand and the installation was sealed above the sand pack with a minimum 0.5 m of bentonite. Boreholes MW1 through MW3 were completed at the ground surface using a flush grade steel well box cemented in place. The remaining monitoring wells were completed with a 1 m long steel well box completed above ground surface. All wells contained a locking J-plug cap. Details of soil and groundwater conditions encountered during drilling and monitoring well construction are provided on the attached Record of Borehole Logs in Appendix I. In addition, several samples were selected from each borehole for grain size analyses, the results of which are presented in Appendix II.

To aid in the assessment of aquifer parameters, such as hydraulic conductivity and transmissivity, hydraulic response testing was conducted within selected monitoring wells (MW1, MW5, MW6, MW8 and MW9). Hydraulic response testing, in the form of falling and rising-head tests, was conducted using specialized equipment including a pressure transducer, data logger and constant volume slug. The results of hydraulic response testing are provided in Appendix III.

All boreholes were surveyed relative to a geodetic datum using a total station survey in order to determine the relative elevation and locations of each borehole, such that static water levels could be contoured to determine the groundwater flow direction and gradient.

3.3 Task 3 - Aquifer Characterization and Assessment of Development Potential

Data collected during the drilling program, as well as grain size analyses on selected soil samples, measured static water levels, and hydraulic response test results, were compiled to aid in aquifer characterization. The hydraulic conductivity was estimated using the results of the grain size analyses, as well as the analyses of insitu testing data using a commercially available software program (Aqtesolv; developed by Hydrosolve Inc.), while aquifer parameters such as transmissivity (the ability of the aquifer to transmit water) were estimated based on the product of hydraulic conductivity and an assumed aquifer thickness.

The results of the field investigation and aquifer characterization were reviewed to assess the relative groundwater development potential for the two main proposed development sites (upper spring and Main Hatchery Site).

4.0 STUDY AREA DESCRIPTION

The Study Area encompasses approximately 3.7 hectares and extends from Okanagan Lake, approximately 400 m to the west of the Lake (Figure 1). The Study Area contains the Hatchery in the eastern portion and a system of springs known as Shaughnessy Springs in the western portion. The springs are located within the upper reaches of a drainage gulley extending approximately 400 m to the west from the western shore of Lake Okanagan (at the Hatchery).

4.1 Topography and Geology

The main area of the Hatchery is located along the east side of Lakeshore Drive in Summerland at an elevation of approximately 343 m, the approximate elevation of Lake Okanagan. Ground elevations in the area of the upper springs were estimated to be approximately 370 meters above sea level (masl), while elevations in the area of the lower springs are approximately 360 masl.

The topography on the east side of Lakeshore Drive, in the area of the Hatchery is relatively flat, sloping slightly towards the east, while the topography on the west side of Lakeshore Drive rises moderately too steeply towards the west.

According to "Late Glacial History and Surficial Deposits of the Okanagan Valley, British Columbia (Nasmith, 1962), surficial deposits in the Study Area consist of glacial lake sediments, which may consist of thick deposits of sand, silt and clay. According to the Ministry of Water, Land and Air Protection (MWLAP), no wells are located within the Study Area. However, one water well is located approximately 215 m to the south of the Study Area, and was reportedly constructed in 1983 by the Fisheries Department. No details of subsurface soil or groundwater conditions, or well installation details were provided in the available borehole log for this well.

Concurrent with this study, a geothermal well has been recently completed by Trak Energy Corporation ("TEC") on the neighbouring property, approximately 120 m to the south of the Site. Although no formal report on the subsurface conditions encountered has been made available by TEC, conversations with Mr. Jeff Maxwell of TEC indicate that subsurface soil conditions in the area of the well consist of silt and sand to approximately 14 m depth, underlain by shale to the maximum depth drilled of approximately 110 m. Mr. Maxwell indicated that the well was flowing artesian and that the main water-bearing formation was encountered at a depth of approximately 110 m in the shale. No other wells have been identified within a 1 km radius of the Study Area.

4.2 Climate

The climate in the Summerland area consists of warm, dry summers and cool, moist winters. Golder reviewed available data from the nearest long-term reporting weather station which is the Summerland Research Station, located immediately southwest of the Study Area. The site has been reporting climate data since 1916 and is monitored by Environment Canada.

The mean annual total precipitation for the station is approximately 326.5 mm (Environment Canada, Canadian Climate Normals 1971-2000). The maximum annual precipitation for the site is 485 mm recorded in 1990. The minimum is 117 mm/year recorded in 1999. Complete data is not available for this site after 2000, however it is widely acknowledged that the Summerland area has been experiencing less than normal precipitation since 2001.

5.0 REVIEW OF 1986 MINISTRY OF ENVIRONMENT REPORT

The former BC Ministry of Environment (now MWLAP) completed a study in September 1986, entitled *"Assessment of Water Resources at the Summerland Trout Hatchery"*, which provides an overview of the aquifer system in the area of Summerland. The report presents a hydrogeological interpretation using information from available well logs, surficial mapping, air photo interpretation and known subsurface geological relationships that exist elsewhere in the Okanagan Valley. The aquifer system consists of two aquifers separated by an intermediate layer of glacial till. A shallow unconfined to semi-confined aquifer is present generally from ground surface to 425 m above sea level (masl), followed by a till sequence (confining unit) to 380 masl and a deeper aquifer below the till to an unknown depth. The entire sequence is partially isolated from Lake Okanagan by lacustrine deposits that form a silt escarpment along the edge of the lake.

The report indicates that "Shaughnessy Springs are likely fed by significant sand and gravel aquifer that underlies upland areas to the west." Shaughnessy Springs are located northeast of Summerland, along the lower reach of Eneas Creek. Furthermore, it was suggested that the recharge area for the aquifer extends west to the Summerland Reservoir (the Balancing Reservoir), with the primary sources of recharge noted as groundwater from Prairie Creek (located east of the reservoir) and the lower reaches of Eneas Creek.

6.0 RESULTS

6.1 Subsurface Conditions

A total of 10 boreholes were drilled to assess subsurface soil and groundwater conditions in the Study Area (Figure 2). Three cross-sections have been provided (Figure 3, 4 and 5), depicting the ground surface profile and subsurface conditions in a west to east direction along the extent of the gully (Section A-A') and in a north to south direction traversing the upper spring area (Section B-B' and Section C-C').

6.1.1 Main Hatchery Site (east side of Lakeshore Road)

Based on the results of the drilling program, subsurface soil conditions in the eastern portion of the Study Area at the Main Hatchery Site (BH04-1 and MW1) consist of sand and gravel fill to depths of 1.5 m below ground surface (mbgs), underlain with silt and/or a silt and fine sand to depths of up to 3 mbgs. The silt was underlain by fine sand to a depth of 16.8 mbgs, the maximum depth of BH04-1. BH04-1 was terminated at a depth of 16.8 mbgs due to heaving sand within the drill casing. MW1 was completed adjacent to BH04-1 to a depth of 6.1 mbgs.

These sands appear to exhibit a coarsening-downward trend indicating the potential for the materials at depths greater than 16 m (the maximum depth drilled) to be larger in grain size diameter (and hence higher in hydraulic conductivity) than those in the upper portions of the aquifer.

Groundwater was encountered within the two boreholes along Lake Okanagan at a depth of approximately 0.7 mbgs.

As noted previously, conversations with Mr. Jeff Maxwell of TEC indicate that the geothermal well located 120 m to the south of MW1 encountered shale (bedrock) below approximately 14 m depth. While the shale has not been intercepted in boreholes drilled on the Trout Hatchery property, there is insufficient information to predict with any degree of confidence, what depth the shale may exist on the site. However, it is possible that the prominent drainage gully which dominates in the area of the Hatchery may be associated with a buried bedrock channel, which in turn suggests that the depth to bedrock in this area may be greater than indicated by the geothermal drilling to the south.

Should the shale be encountered on the Trout Hatchery property at relatively shallow depths (15 m to 30 m), the possibility of successful well construction will be dependant on the grain size of the deposits overlying the shale. If coarser grained deposits are present overlying shallow shale, a conventional well producing the desired yield may still be possible. However, should fine grained deposits be encountered overlying potentially shallow shale, it is likely that a well producing the desired well yield of 2,500 L/min (660 USgpm) would not be feasible.

6.1.2 Hatchery Works Yard (west side of Lakeshore Road)

Two boreholes were drilled in the area of the Hatchery's equipment storage area (MW2 and MW3). Subsurface soil conditions varied slightly between borehole locations, with MW2 (located within the storage yard) underlain with sand and gravel fill to a depth of approximately 3 mbgs.

The fill was underlain with inter-layered silt and silt/fine sand to a depth of 9.8 mbgs, the maximum depth of the borehole. Subsurface soil conditions at MW3 consisted of fill to a depth of 2.7 mbgs, underlain by silt, with occasional fine sand seams to a depth of 9.8 mbgs.

Groundwater was encountered within both monitoring wells, with a reported static water level of approximately 2.9 mbgs at MW2 and 1.3 mbgs at MW3.

6.1.3 Lower Spring Area

Two boreholes were drilled in the area of the lower spring area (MW4 and MW5). Subsurface soil conditions were similar within both boreholes and consisted of an initial 0.9 m thickness of fill underlain with interlayered silt, silt and fine sand, and fine sand, to a maximum depth of approximately 11 mbgs (the maximum depth of MW4).

Groundwater was recorded at MW4 at a depth of approximately 0.3 mbgs, while groundwater at MW5 was reported to be at approximately 1.2 mbgs.

6.1.4 Upper Spring Area

Based on the proposed workplan outlined in our March 2004 proposal, Golder anticipated being able to drill several boreholes to assess subsurface conditions along the northern portion of the gully in the upper springs area. In addition, the intention was to complete all boreholes in this area to a minimum depth of 6 mbgs, such that the thickness of the aquifer could be assessed. However, due to difficult access conditions along the northern slope of the gully and to the north of the upper springs, as well as heaving sand conditions within the aquifer underlying the upper spring area, it was not possible to extend all boreholes to this depth. Hence, verification of aquifer thickness to 6 m depth and determination of the full width of the aquifer in this area has not been realized in this current drilling program.

A total of 4 boreholes were drilled in the area of the upper springs (MW6, MW7, MW8 and MW9). Boreholes MW6 and MW7 were drilled approximately 15 m to the west of the upper spring storage pond, and were drilled directly adjacent to each other to assess vertical hydraulic flow gradients in the aquifer. Subsurface soil conditions at MW6 and MW7 encountered approximately 0.6 m of fill underlain with inter-layered silt and silt/fine sand to a depth of 4.6 mbgs. This was further underlain with a 0.6 m thick sand and gravel, followed by a fine to coarse sand.

MW 6 was screened within the deeper sand and gravel, while the screen for MW7 was set to straddle the upper inter-layered silt and fine sand. The static water level at MW 6 was approximately 3.5 mbgs, while the static at MW7 was at approximately 3.8 mbgs, identifying a slight upward hydraulic gradient.

MW8, located approximately 6 m to the southwest of the pond area, encountered approximately 4 m of silt, underlain with approximately 1.5 m of silty sand and then 1 m of fine to medium sand. Subsurface soil conditions in the area of MW9 exhibited coarser material than the other wells in the upper spring's area, which consisted of fine to coarse sand to sand and gravel to depths of approximately 4.4 mbgs, the maximum depth drilled.

Groundwater conditions at both MW8 and MW9 were flowing artesian, with water levels above the ground surface.

6.2 Groundwater Flow Direction and Gradient

Based on available information, groundwater in the area of the upper and lower springs, in the southern portion of the gully, is inferred to be flowing in an east-northeasterly direction, into the base of the gully (Figure 2). The groundwater gradient within the spring area is approximately 0.08. Although no boreholes/monitoring wells could be drilled in the northern portion of the gully area due to steep conditions, it is likely that groundwater within this area flows in a southeasterly direction, also into the base of the gully.

The inferred direction of groundwater flow in the Main Hatchery Site is also towards the east-northeast (Figure 2). Although it was anticipated that the groundwater flow direction would be in a more easterly direction towards Okanagan Lake, the inferred flow direction is considered feasible, considering the steep topography to the southwest of the Study Area. The inferred groundwater gradient at the Main Hatchery Site is approximately 0.04.

6.3 Estimate of Aquifer Parameters

Preliminary estimates of hydraulic conductivity (K), transmissivity (T) and well yield have been made using information collected from the borehole log, grain size distribution curves of sampled aquifer material and the results of the insitu conductivity testing.

The hydraulic conductivity of subsurface soils was estimated using grain size distribution curves (based on Hazen's approximation ($K=d_{10}^2$) for soil samples collected from the aquifer, and the results of insitu hydraulic response testing, using the rising head and/or falling head method. Hydraulic conductivities for the various subsurface soils types are summarized in the table below. Grain size distribution curves and the results of the insitu testing (the latter shown using the program AQTESOLV) are presented in Appendix II and III, respectively.

Borehole/ Monitoring Well Location	**Borehole/ Monitoring Well No.**	**Soil Sample No. and Depth (m)**	**Soil Sample Description**	**Hydraulic Conductivity (m/sec)**	
				From Grain Size Analyses	**From Insitu Testing**
Main Hatchery Site	BH04-1	Sa3 (4.6-5.2)	Silty, fine SAND	$3x10^{-5}$	Not Tested (No well)
		Sa4 (9.2-9.7)	SILT and SAND	$1x10^{-5}$	
		Sa5 (12.2-12.8)	Silty, fine SAND	$3x10^{-5}$	
		Sa6 (15.2-15.8)	Fine SAND	$4x10^{-5}$	
	MW1	Sa5 (5.5-6.1)	Fine SAND	$4x10^{-5}$	$2x10^{-4}$
			Average K *Geometric Mean*	*$6x10^{-5}$* *$4x10^{-5}$*	
Lower Springs	MW4	Sa4 (6.1-6.7)	Fine SAND	$3x10^{-5}$	Not Tested
		Sa5 (7-7.6)	Fine SAND	$3x10^{-5}$	
		Sa7 (10.6-11)	Fine SAND	$4x10^{-5}$	
	MW5	Sa 5 (5.7-6.1)	Silty, fine SAND	$4x10^{-5}$	$1x10^{-4}$
			Average K *Geometric Mean*	*$5x10^{-5}$* *$4x10^{-5}$*	
Upper Springs	MW6	Not Applicable			$5x10^{-4}$
	MW8	Sa 6 (6.1-6.4)	Medium to coarse SAND, some gravel	$3x10^{-4}$	$2x10^{-3}$
	MW9	Sa 1 (1.5-2.1)	SAND and GRAVEL	$2x10^{-4}$	$3x10^{-3}$
		Sa 3 (3.8-4.4)	Sandy GRAVEL	$2x10^{-3}$	
			Average K *Geometric Mean*	*$1x10^{-3}$* *$1x10^{-3}$*	

Hydraulic conductivity values obtained from the insitu testing were generally one order of magnitude greater than those obtained from the grain size analyses.

Hydraulic conductivity values for the Main Hatchery Site and Lower Spring areas generally ranged from 1×10^{-5} m/sec to 2×10^{-4} m/sec, while those from the upper springs area ranged from 2×10^{-4} m/sec to 3×10^{-3} m/sec. These estimated hydraulic conductivity values are consistent with values associated with sand deposits of similar grain size.

Transmissivity values have been estimated for the aquifer at the Main Hatchery Site based on the relationship $T = K * b$ (where b = saturated thickness of the aquifer). Assuming a saturated thickness of 30 m (that would have to be confirmed with deeper drilling) and a hydraulic conductivity value ranging from 1×10^{-5} m/sec to 2×10^{-4} m/sec, the transmissivity value is estimated to range from 26 m^2/day to 520 m^2/day.

Borehole BH04-1 was drilled to a depth of 16 m at the Main Hatchery Site, this depth of completion limited by heaving sand conditions within the aquifer. However, a minimum saturated thickness of 30 m is considered likely given the close proximity to Lake Okanagan. It is also anticipated that there is a hydraulic connection between the Lake and the area of BH04-1 that would help to limit drawdown during pumping in any well constructed in this area.

7.0 POTENTIAL SOURCE YIELD ASSESSMENT

It is understood that the Hatchery would like to secure a water source capable of producing approximately 2,500 L/min (660 USgpm). Golder has evaluated the potential yield at the two main areas where potential for additional development may be possible (the Upper Spring area and the Main Hatchery Site). A discussion of each of the areas is provided in the following sections.

7.1 Main Hatchery Site

Subsurface materials at the Main Hatchery Site appear to be very fine grained and a conventional water well at this location is not expected to produce significant quantities of water for this reason. A filter packed well would be the best option for obtaining a water supply capable of meeting the required 2,500 L/min. A filter pack consisting of a medium to coarse sand with approximately 10% of materials containing sand grains finer than 0.35 mm diameter has been determined to be the most suitable size filter pack for a well at this location. Based on the estimated grain size of the filter pack, the required screen slot size would be 15 slot (0.38 mm or 0.015 inches). Based on this slot size, and assuming an 8 inch diameter well screen, the estimated length of screen required to produce 2,500 L/min is approximately 15 m (49 ft).

A preliminary estimate of the maximum extent of drawdown expected to occur in a well constructed adjacent to the lake was completed using the Logan Approximation as follows:

$$\mathbf{T = 2.43Qb/(s(2b\text{-}s))}$$

Where: T = Transmissivity (m^2/day)
Q = Well Pumping Rate (m^3/day)
b = saturated thickness of the aquifer (m)
s = drawdown (m)

Using an iterative calculation approach, a variety of scenarios were investigated to determine the required depth of completion for a well based on the desired capacity of 2,500 L/min, and assuming no unfavorable aquifer boundaries are present. Using a transmissivity of 520 m^2/day and an initial estimate for the well completion depth of 30 m, the maximum anticipated drawdown would be approximately 10 m (32.8 ft). Accounting for the required screen length determined in the previous section (15 m), drawdown during pumping (10 m) and a 50 percent factor of safety, this indicates that the best case (least cost) scenario is a well completed to approximately 37.5 m (125 ft) depth.

It is important to note that when solving for the anticipated drawdown using a conservative transmissivity value of 26 m^2/day, the resultant depth of completion for the well increases to over 300 m. It is unlikely in our opinion that aquifer materials are present to this depth at the Main Hatchery Site. However, while the Logan Approximation does not account for unfavorable aquifer boundary conditions, it does not account for favorable boundaries either, such as the recharge available from the lake. It is expected that the predicted drawdown using this method is over estimated and that the influence of the lake, will significantly reduce drawdown.

In summary, the above calculations indicate a significant difference in the estimated depth of completion for a filter packed well at the Main Hatchery Site. Given the uncertainty of completion depth and the relatively high cost of constructing a filter packed well as opposed to a conventional well, it is recommended to construct a test well using a filter pack design prior to proceeding with a full scale production well at this location. For planning of the next phase of work on this project, a realistic well completion depth for a filter packed well completed adjacent to the lake is in the order of 50 m.

7.2 Upper Spring Area

The gulley that hosts the springs is dominated by fine-grained lacustrine deposits, as identified along the northern and southern slopes of the gully. Groundwater seepage from the upper and lower springs has historically ranged from 2,650 L/min to 3,400 L/min (700 USgpm to 900 USgpm).

Based on a review of subsurface soil conditions in the area of the Upper Spring, it appears that fine to coarse sands are present underlying the spring and storage pond. The depth of these materials could not be determined with the drilling method utilized. However, the subsurface soils in this area generally appear to exhibit a coarsening-downward trend, and appear to be coarser within the center of the gully in the area of MW9, than along the outward reaches of the gully (MW8). Two possible theories regarding the presence of coarse-grained materials within the gully area are as follows:

- Coarse grained materials may have been initially deposited within the area during a period of glacial retreat, at a time when the glaciers were retracting from the walls of the valley, with streams depositing coarse materials between the valley walls and the ice lobes. Subsequent to that, the ice lobes formed a barrier allowing a large lake to form within the area known as Glacial Lake Penticton, depositing fine-grained lacustrine material over the coarser-grained materials. In the area of Shaughnessy Springs, the silts overlying the coarser-grained materials may have been eroded over time, allowing the "springs" to be exposed to the ground surface. The inference to be made from this theory is that the coarse grained materials may be present in extensive deposits (both vertically and laterally) within the area.

- The coarser grained materials within the gully area may be an erosional feature deposited during or following glaciations, and may represent a former stream channel, with coarser-grained materials in the centre of the stream and finer-grained materials along the outer edges of the stream. Should this be the case, it is likely that the coarse grained materials are limited in lateral extent.

The information obtained from the drilling program is inconclusive as to which theory is correct regarding the depositional environment and structure of subsurface soils in the area of the springs. However, it appears that the sand deposits extend laterally from the area of MW8 to MW 9 (approximately 13 m in width at a minimum), and likely extend to distances of at least 25 m (from the northern boundary of the spring pond area to MW8). This suggests the seepage zone, or extent of the aquifer, is at a minimum 25 m wide.

Currently the collection pond for the Upper Spring area is approximately 15 m in width and 1 m in depth, and produces approximately 840 L/min (230 USgpm). Using a seepage width of 25 m, and a saturated thickness of 6 m (in the area of MW9), the yield of the upper spring could potentially be increased to a maximum of 2,160 L/min (570 USgpm), based on a calculation of Darcy Flux as follows:

$$\mathbf{Q = W * b * K * i}$$

Where: Q = Flow volume (m^3/sec)
W = Width of seepage zone (25 m)
b = thickness of seepage zone (6 m)
K = hydraulic conductivity ($3x10^{-3}$m/sec)
I = hydraulic gradient

The above estimate is based on a hydraulic conductivity of $1x10^{-3}$ m/sec, obtained from insitu testing. When applying a more conservative hydraulic conductivity of $2x10^{-4}$ m/sec (based on the most conservative grain size distribution curve), a yield of 144 L/min was estimated. As it is known that existing flows are in the order of 840 L/min, this would suggest that conductivity values are greater than $2x10^{-4}$ m/sec and are more likely in the range of $1x10^{-3}$ m/sec, or higher.

The estimated yield from the Upper Spring could be refined upwards if a greater aquifer thickness is confirmed. However, development of additional capacity within the Upper Spring may not necessarily increase the combined yield produced by the upper and lower springs, as the increase in captured flow at the Upper Spring may diminish the flow captured at the Lower Spring. Furthermore, the drilling information (correlation of drill results in section) does not conclusively support the hydraulic connection between the upper and lower spring.

8.0 DEVELOPMENT OPTIONS ASSESSMENT

Based on the information collected to date, the following options are available to the Hatchery to develop a water source capable of delivering 2,500 L/min (660 USgpm).

Option 1 – Filter Pack Well Constructed at the Main Hatchery Site

The most reliable water source which could be developed for the Hatchery is a well located adjacent to Lake Okanagan.

A conventional water well design relies on a screen positioned at the base of a well casing (in the water-bearing formation, or aquifer), engineered to allow the maximum quantity of water to enter, while restraining the granular (porous) material in the aquifer from entering the well. Where flow is not limited by the aquifer, the design flow of a screen is a function of its length, diameter and size of the screen openings (slot size).

Based on the subsurface information collected in the Main Hatchery Site, a 200 mm (8 inch) diameter well incorporating 15 m of 15 slot (0.015 in) screen, surrounded by a minimum 75 mm (3 inch) thick medium to coarse sand filter pack, would be required to realize a well yield of 2,500 L/min. This is approximately 7 m less of screen than was estimated in our proposal for this project, which considered 10 slot screens of 150 mm diameter.

Construction of the 200 mm diameter well surrounded with a 75 mm thick filter pack will require the advancement of 400 mm (16 inch) diameter casing to the full boring depth, such that a conventional filter pack can be placed around the well screen and exposed by pulling back the larger casing. Several drilling methodologies exist for the construction of a filter packed well; including the cable tool, reverse circulation and dual air rotary drilling methods. Construction of a conventional filter pack well can be challenging, particularly the proper placement of the filter pack material.

As mentioned during previous discussions with Mr. Siemens of the Trout Hatchery, pre-packed well screens are an alternate option to the conventional filter packed well, and provide a higher degree of control when constructing the well. Potential benefits to using a pre-packed screen over the conventional filter packing method are as follows: i) less development time, ii) increased well efficiency and reduced pumping costs, iii) well construction time will likely be less and iv) overall maintenance of the well will likely be less.

Costs to complete a 200 mm diameter conventional filter packed well to a depth of approximately 50 m are anticipated to be in the order of $90,000 (excluding GST and not including engineering costs), 70% of which accounts for the 400 mm diameter steel casing, the 200 mm diameter stainless steel screens (minimum 15 m length) and rig time for the development of the screens after installation. Upon completion of the well construction, a minimum 24 to 48 hour pumping test would be conducted on the well, after which a water sample would be collected for water quality analysis.

Costs to complete a 200 mm diameter well using pre-packed screens to a depth of approximately 50 m are approximately $80,000 (excluding GST and not including engineering costs). Again, the majority of the costs account for the well screens and casing, as well as time for development time of the well after screen installation. It is important to note that the cost of steel well casing is extremely volatile at the present time and is increasing in cost per foot almost weekly, due to a high demand on steel in Asia. As such, costs to complete the water well at this time are higher than estimated in our initial verbal assessment and it is expected that costs will continue to increase. For comparison purposes, costs to complete a conventional well (without a filter pack and with a 15 m length screen) to a depth of approximately 50 m are approximately $50,000 (excluding GST and engineering costs).

As the projected cost for either a conventional or filter packed well are considerable and greatly dependant on the slot size and length of screen, as well as the depth of completion, it is strongly recommended a test well be constructed prior to the drilling of a final production well to confirm subsurface conditions, particularly the depth to bedrock, grain size characteristics and aquifer parameters.

It is recommended that the test well be constructed using 200 mm diameter casing and a 50 mm diameter well screen (3 m length), such that a 75 mm thick filter pack could be placed around the well screen. Costs to complete the test well to a depth of approximately 50 m with a 1.5 m length screen are approximately $18,500. This is slightly greater than originally noted in our initial draft report, as the original test well was to be drilled to a depth of 30.

Advantages of completing a test well at this location are as follows:

- Subsurface conditions could be confirmed, particularly the thickness of underlying sand deposits;

- the drilling methodology could be confirmed for the construction of the final production well;

- the hydraulic connection between the aquifer and lake could be verified with a short duration pumping test;

- the trend in subsurface materials becoming coarser with depth could be verified, which could reduce the total depth and length of screen required for the final production well;

- water samples can be collected from the test well for chemical analyses, such that the suitability of the water for fish culture can be assessed;
- the test well could be used as an observation well during the testing of the final production well; and,
- the test well could be used as a backup well when the larger well is off line for maintenance.

All of this information obtained from the construction and testing of a test well will aid in finalizing the design for the production well, potentially reducing the overall costs for screens and casing. Upon completion of the test well, a short 2 to 6 hour pumping test will be conducted to assess aquifer parameters, after which time a preliminary water sample could be collected and submitted for analyses.

Engineering costs (including reporting) for the above noted options will range from $7,000 to $12,000 (excluding GST).

Option 2 – Naturally Developed or Filter Pack Well at Upper Spring

Either a naturally developed well or a filter pack well could be constructed in the area of the springs, however neither is considered an economically feasible option, even if a greater thickness of aquifer materials is verified to exist below the springs. Based on static water levels encountered during test drilling, a well in the Upper Spring area will likely be flowing artesian, but the quantity of flow without pumping is not expected to be significant. In order to realize the desired yield, pumping would be required, which would call for considerable capital and operational costs as compared to the current gravity feed system which is utilized at the upper and lower springs.

When considering potential long term well yields, a well developed in the Upper Spring area will likely be more vulnerable to fluctuations in yield, as compared to a well located adjacent to the lake, which will provide a constant source of recharge. It is anticipated that the land use within the recharge area for the springs, which includes the majority of Summerland and the Eneas Creek drainage area, will change over time due to increasing development and varying degrees of irrigation water application. This may potentially alter runoff coefficients, which can negatively influence the spring's long term yields.

Option 3 – Modify Surface Collection System at Upper Spring

The efficiency and capacity of the Upper Spring can be increased by developing a greater width of the seepage area. Based on available information, it may be possible to obtain up to 2,160 L/min (570 USgpm) of water from the spring area, based on a seepage width of 25 m and a seepage thickness of 6 m.

Several construction methods are available to improve the productivity of the upper spring, and consist of i)expanding the collection pond area, thus increasing the width and depth of the pond, ii) building a cut-off wall upslope from the existing collection pond such that the water upslope would be diverted into the collection pond system, iii) drilling several boreholes into the area surrounding the collection pond, such that artesian conditions would allow water to naturally drain into the pond area, and iv) drilling one or more boreholes horizontally into the water producing formation upslope of the collection pond, and allowing gravity to naturally drain the water into the collection system.

On September 22, 2004, Golder met with Hatchery staff to discuss the results of this investigation, which were summarized in our draft report dated September 9, 2004. During the meeting, the options to modify the surface collection system at the Upper Spring area were discussed. Based on these discussions, the following provides additional detail regarding a low-impact method of increasing flow volumes to the Upper Spring collection system.

In order to augment the shallow groundwater seepage collection system already in place in the Upper Spring area, it is proposed that a minimum of two 150 mm (6 inch) diameter conventional water wells be drilled in the area to the southeast (near MW9) and southwest (MW8) of the collection pond. As flowing artesian groundwater conditions were encountered at MW9, it is likely that a substantial amount of groundwater flow exists at greater depth. The benefits of drilling and installing the artesian water wells within the upper Spring area are as follows: i) minimal disturbance to the existing collection pond and system during the drilling process, and ii) groundwater can be piped into the existing piping system using gravity, rather than pumping, thus reducing the overall capital costs.

Wells in the area of the Upper Springs could be drilled using a cable tool drill rig, to a target depth between 5 m and 15 m depth, thus accessing deeper groundwater. Stainless steel screens in the order of 1.5 m in length would likely be installed within each well.

Should it be necessary, Golder can provide more detailed methodologies for the other various spring enhancement options. While development costs are expected to be similar to the construction of a filter packed well adjacent to Lake Okanagan, any work on the upper spring will require the temporary use of an alternate water supply (to eliminate siltation) or the completion of the work during a non-critical water demand period at the Hatchery.

Comparison of Options

A comparison of the options presented above suggests that from both a reliability and development cost perspective, the best option is for the construction of a filter-packed well. Some pros and cons for each option are noted in the table below:

Option	Pro	Con
1 – Well Construction at Hatchery	• Provides the most reliable long-term yield. • No disturbance to existing system.	• Drilling of filter packed well will be challenging. • Initial well costs expensive.
2 - Well Construction in Upper Spring Area	• Some potential for artesian flows.	• Long term yield potentially not as reliable. • Well costs expensive.
3 – Increase Yield for Collection Pond Area at Upper Springs	• Most cost effective option.	• Flow from the existing pond may have to be stopped for pond construction. • Long term yield potentially not as reliable.

9.0 RECOMMENDATIONS

Although much more costly, it is recommended that the Summerland Trout Hatchery pursue the option of drilling a water well in the Trout Hatchery area, adjacent to Lake Okanagan. It is our opinion that completion of the test well and then the final well will provide the Trout Hatchery with the most reliable long term water yields. It is recommended that the Hatchery proceed in a staged approach for the construction of a filter packed well, to minimize the cost of pursuing this option, if results are not encouraging. In addition, water quality should be assessed in the proposed test well, and compared with water quality results from the spring area.

In conjunction with the test well construction and testing, it is recommended that the Hatchery commission a qualified civil consultant to conduct a cost analyses to bring in power to the Upper Spring area and to assess operational costs to pump water from the spring area.

10.0 LIMITATIONS

This report was prepared for the exclusive use of the Freshwater Fisheries Society of BC (FFSBC). Golder Associates Ltd. has relied in good faith on information provided by sources noted in this report. We accept no responsibility for any deficiency, misstatements or inaccuracy contained in this report as a result of omissions, misstatements or fraudulent acts of others. The report is based on data and information collected during the investigation conducted by Golder Associate Ltd.'s personnel.

The investigation program followed the standard of care expected of professionals undertaking similar work in British Columbia under similar conditions. This report provides a professional opinion, and therefore no warranty is either expressed, implied or made as to the conclusions, advice and recommendations offered in this report. This report does not provide a legal opinion regarding compliance with applicable laws. With respect to regulatory compliance issues, it should be noted that regulatory statutes and the interpretation of regulatory statutes are subject to change.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in the future, Golder should be requested to re-evaluate the conclusions of this report and to provide amendments, as required, prior to any reliance upon the information presented herein. The report, which specifically includes all tables and figures, is based on data and information collected during the investigations by Golder Associates Ltd. The report must be read and understood collectively, and can only be relied upon in its totality.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

11.0 CLOSURE

We trust this report provides you with the information you require to make an informed decision regarding the options available to you to increase the water supply volumes for the Trout Hatchery. We look forward to meeting with you to discuss these results and collectively determine a course of action for the Summerland Trout hatchery. Should you have any questions or comments, please do not hesitate to contact us at your earliest convenience.

Yours very truly,

GOLDER ASSOCIATES LTD.

Jacqueline Foley, M.Sc.
Hydrogeologist

Remi Allard, M.Eng., P.Eng
Senior Hydrogeologist

Reviewed By: Nick Sargent, M.Sc., P.Geo.
Associate & Senior Hydrogeologist

Encl.
JF/RA/NS/ae

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NOTE: THIS DRAWING TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT

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PROJECT

Summerland
Trout Hatchery

TITLE

KEY PLAN

Golder Associates

PROJECT NO.	04-1440-088		FILE Figure 01.wor
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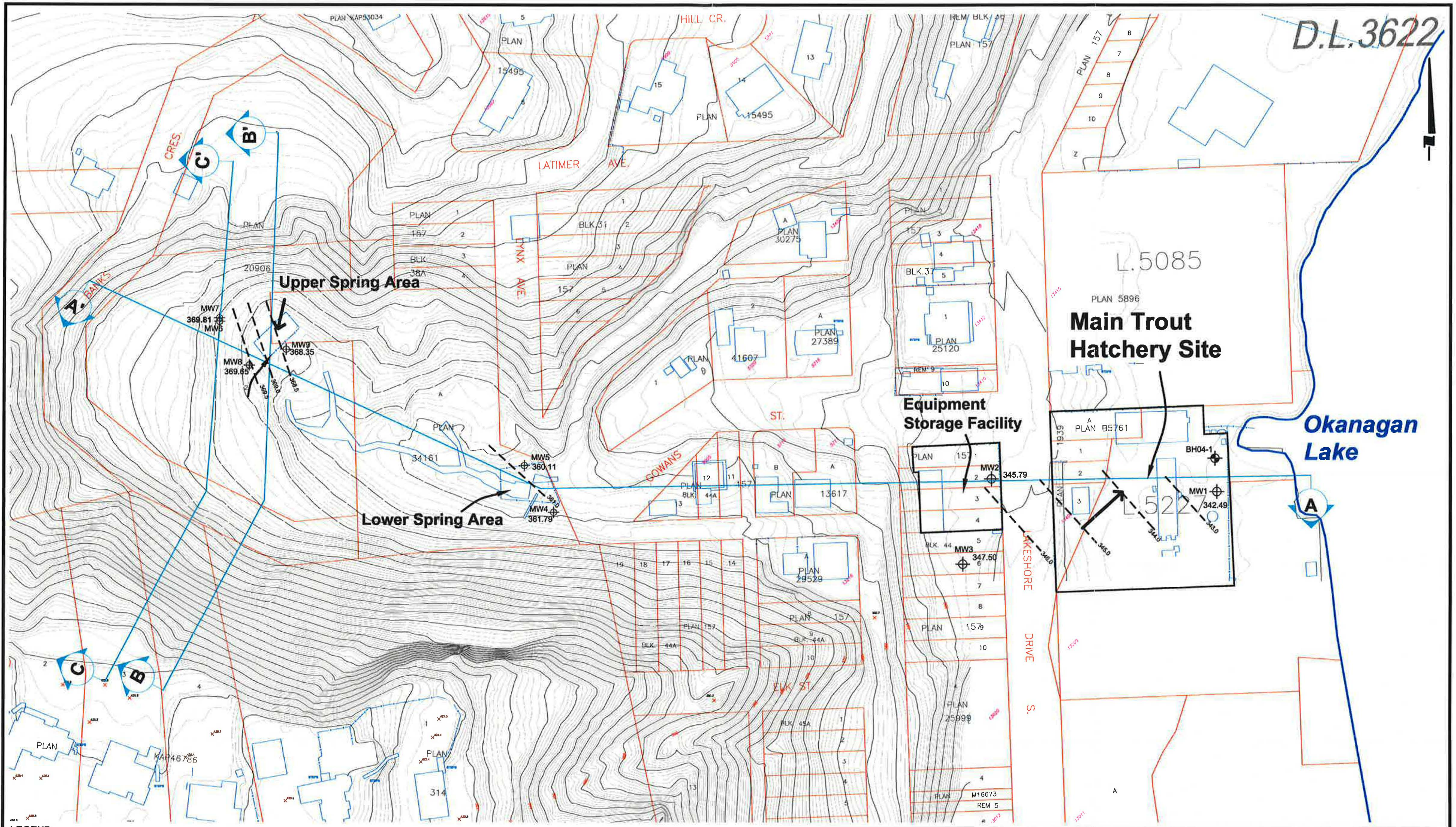
REVIEW		JF	



LEGEND:

- MW1 Monitoring Well
- BH04-1 Borehole
- A ---- A' Cross Section
- – – – – – Groundwater Elevation Contours
- 369.65 Groundwater Elevations
- ⟵ Inferred Direction of Groundwater Flow

0 10 20 30 40 50
Scale in Meters

Golder Associates
KELOWNA, B.C.

SCALE	1:1,250	TITLE	
DATE	08/30/04		
DESIGN	L.D.		
CADD	L.D.		
FILE No.	FIGURE_4.DWG	CHECK	
PROJECT No.	04-1440-088	REV. 0	REVIEW JF

SITE AND GROUNDWATER CONTOUR ELEVATION PLAN

GW Assessment - Summerland Trout Hatchery

FIGURE 2

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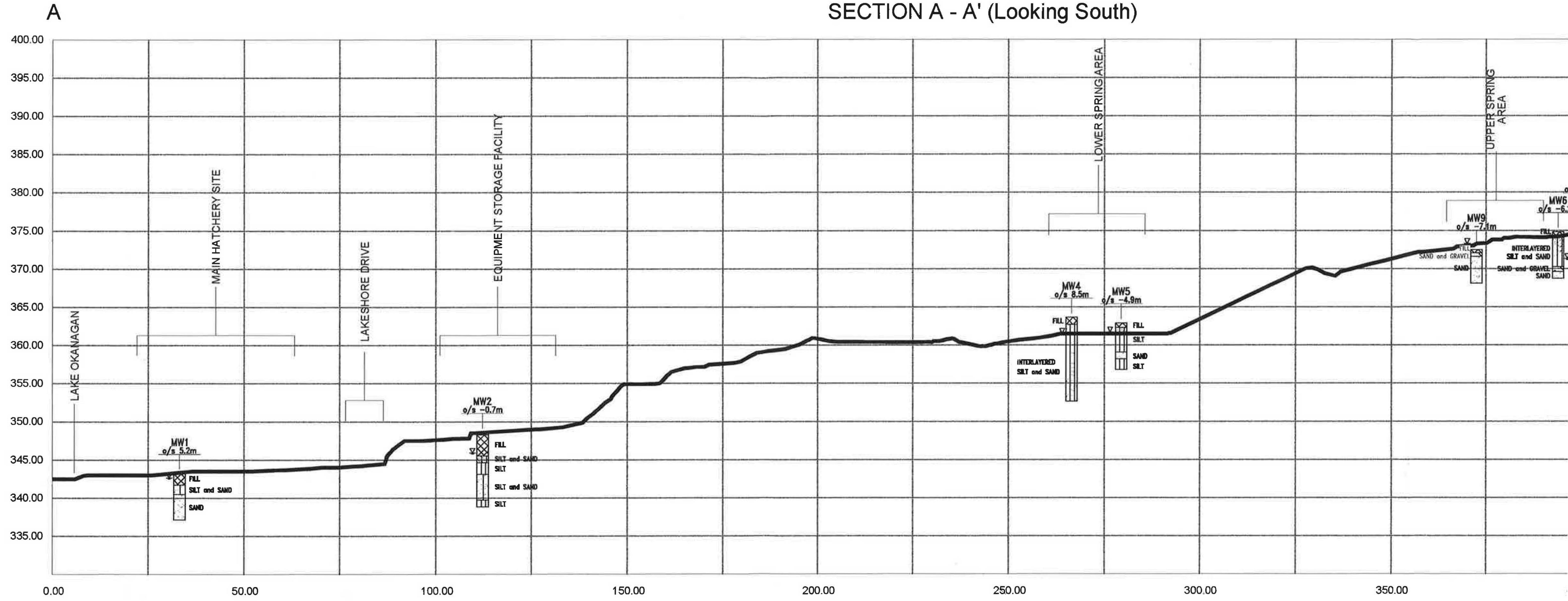
SECTION A - A' (Looking South)



Golder Associates
Kelowna, British Columbia

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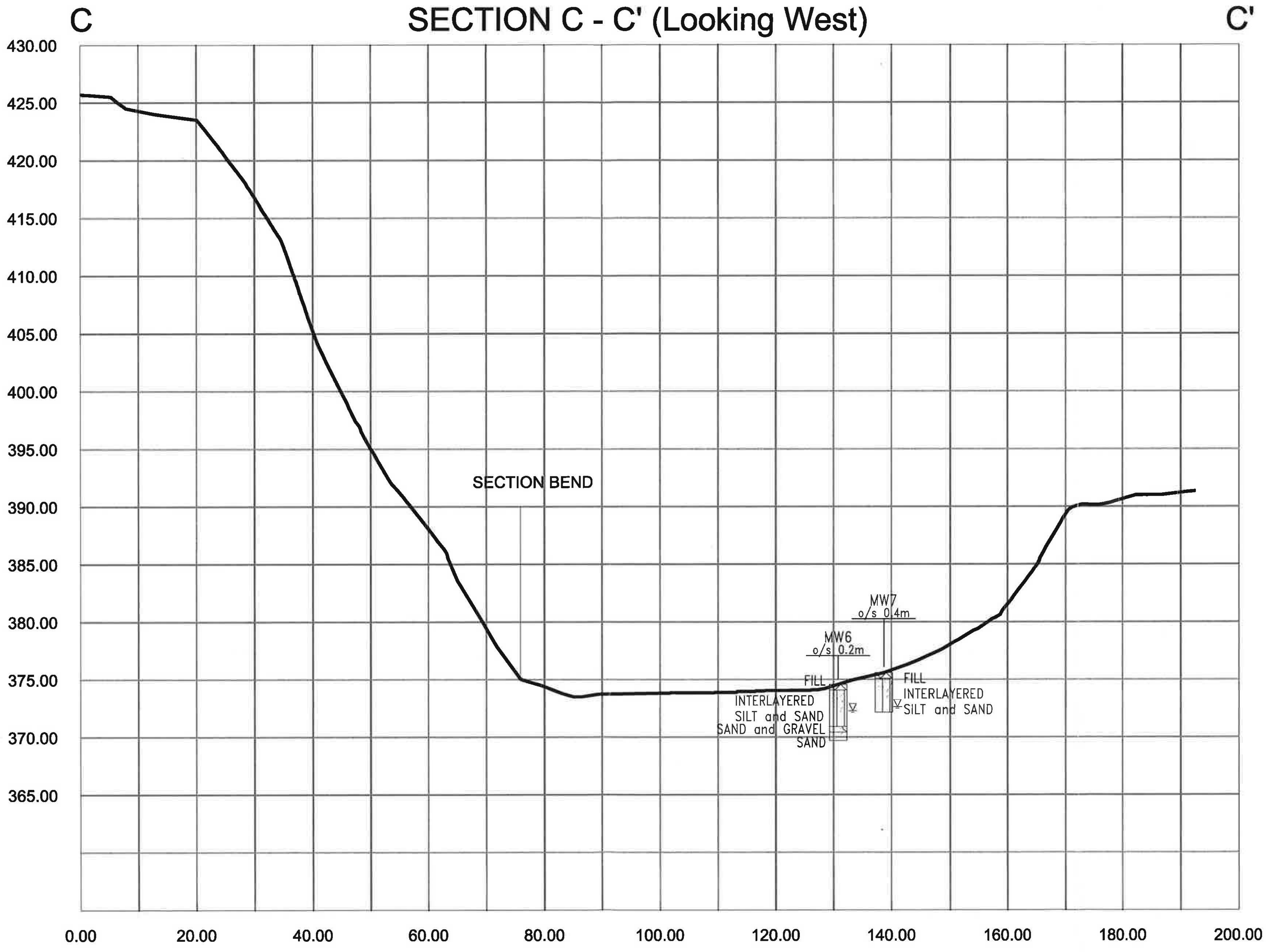
SECTION C - C' (Looking West)



Golder Associates
Kelowna, BC

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REV. 0

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REVIEW JF

TITLE

SECTION C - C'

GW Assessment - Summerland Trout Hatchery

FIGURE 5

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APPENDIX I

BOREHOLE LOGS

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: BH04-1

SHEET 1 OF 2

LOCATION: See Figure 2
N: 382.9601 E: -466.8241

BORING DATE: 14/06/04

DATUM: Local

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 10 20 30 40

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
0	Geotech Odex	GROUND SURFACE					
		ASPHALT	0.02				
1		Moist dark brown silty SAND and GRAVEL (FILL).		1	GRAB		
2		Wet grey SILT, some clay and sand.	1.52	2	GRAB		
3–9		Wet grey/brown slightly micacious fine SAND, trace to some silt.	3.05	3	SS		sieve
10		Wet grey fine SAND, trace silt, and fine sand, some silt layers.	9.30	4	SS		sieve

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DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: BH04-1

SHEET 2 OF 2

LOCATION: See Figure 2
N: 382.9601 E: -466.8241

BORING DATE: 14/06/04

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - O 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} / WATER CONTENT PERCENT Wp ⊢—O W—⊣ Wl 10 20 30 40	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10	Geotech Odex	Wet grey fine SAND, trace silt, and fine sand, some silt layers *(continued)*									
12					5	SS				sieve	
15		Wet grey fine SAND.		15.24	6	SS				sieve	
16					7	SS					
17		End of BOREHOLE.		16.76							
18											
19											
20											

BOREHOLE BOREHOLES.GPJ GLDR_CAN.GDT 3/9/04

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW1

SHEET 1 OF 1

LOCATION: See Figure 2
N: 371.1872 E: -466.1612

BORING DATE: 14/06/04

DATUM: Local

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

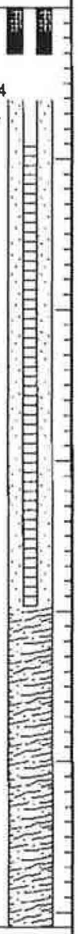
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp W Wl 10 20 30 40

BORING METHOD: Geotech Odex

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION MW1
0	GROUND SURFACE	343.22					
	ASPHALT	0.02					Steel flush mounted well protector. Bentonite seal.
	Moist brown SAND and GRAVEL, some silt (FILL).	342.61 0.61					25/6/04 ∇
	BOULDER	342.38 0.84					
1	Moist to wetted dark brown to black SILT and fine SAND, trace gravel (FILL). Slight organic odour.	341.70 1.52	1	GRAB			
2	Wet dark grey/brown SILT and fine SAND, trace orgainics and occasional shell fragments. Slight organic odour.	340.63	2	GRAB			50 mm dia. PVC well screen. Filter sand.
	Wet grey SILT, some clay and fine sand, some clayey silt, and silt and fine sand layers.	340.48 2.74	3	SS		sieve	
3	Wet grey fine SAND, some silt.	338.96 4.27					
4			4	GRAB			
5	Wet brown fine SAND, trace silt, some fine sand, some silt seams, with slight rust oxidation.						Native slough.
		337.13 6.10	5	SS		sieve	
6	End of BOREHOLE.						
7							
8							
9							
10							



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JF

BOREHOLE BOREHOLES.GPJ GLDR_CAN.GDT 3/9/04

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW2

SHEET 1 OF 1

LOCATION: See Figure 2
N: 375.7026 E: -545.4844

BORING DATE: 15/06/04

DATUM: Local

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

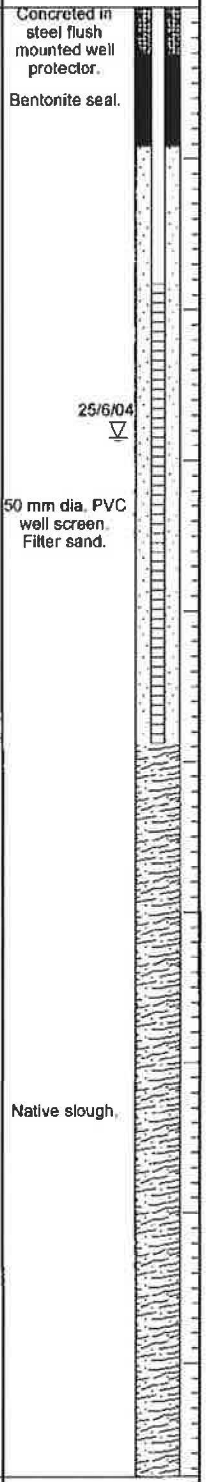
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 10 20 30 40

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	ADDITIONAL LAB TESTING
		GROUND SURFACE	348.64				
0	Geotech Odex	ASPHALT	0.02				
		Moist brown SAND, some silt and gravel (FILL)	348.33 0.30				
1		Moist dark brown silty SAND, occasional gravel (FILL).	346.65 1.98	1	GRAB		
2		Moist brown fine to coarse SAND and GRAVEL, trace to some silt (FILL).	345.59 3.05	2	SS		
3		Wet grey/brown SILT, some fine sand to sandy, trace clay.	344.67 3.96	3	GRAB		
4, 5		Wet grey SILT, trace to some fine sand, some brown silt and fine sand layers and occasional brown to dark brown root fibres.	343.15 5.49	4	SS		sieve
6, 7, 8		Wet grey/brown SILT and fine SAND, some grey fine sand, trace to some silt layers, occasional medium sand and brown root fibres.	339.80 8.84	5 6	SS SS		 sieve
9		Moist to wetted grey/brown SILT, some clayey silt layers and wet silt and fine sand seams, occasional medium sand.	338.86 9.75	7	SS		
10		End of BOREHOLE.					

PIEZOMETER OR STANDPIPE INSTALLATION

MW2



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR

CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW3

SHEET 1 OF 1

LOCATION: See Figure 2
N: 345.5961 E: -555.5066

BORING DATE: 15/06/04

DATUM: Local

BORING METHOD: Geotech Odex

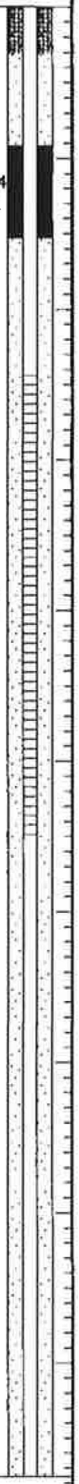
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○: 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl: 10 20 30 40

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION MW3
0	GROUND SURFACE	348.81					
	Moist grey/black SILT, some clay and fine sand, trace organics (FILL). Slight organic odour.	0.00	1	GRAB			Concreted in steel flush mounted well protector. Filter sand. Bentonite seal. 25/6/04 ∇
2	Grey/brown fine sandy SILT, trace clay (FILL).	346.99 1.83	2	GRAB			
3–4	Wet grey/brown SILT, some fine sand, trace clay, some silt and fine sand layers and occasional root fibres and poreholes.	346.07 2.74	3 4	SS SS		sieve	50 mm dia. PVC well screen. Filter sand.
5–7	Moistto wetted grey SILT, trace to some fine sand, trace clay, some silt and fine sand layers and seams.	343.78 5.03	5	SS		sieve	
8	Moist brown SILT, occasional wet fine sand, trace silt seams.	341.19 7.62	6	SS			Filter sand.
	moist to wetted grey SILT, trace clay and fine sand, occasional wet silt and fine sand seams.	340.74 8.08					
9	Wet grey SILT, some fine sand layers and occasional fine sand, trace to some silt seams.	339.97 8.84	7	SS		sieve	
10	End of BOREHOLE.	339.06 9.75					



BOREHOLE BOREHOLES.GPJ GLDR_CAN.GDT 3/9/04

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW4

SHEET 1 OF 2

LOCATION: See Figure 2
N: 363.8705 E: -699.4145

BORING DATE: 15/06/04

DATUM: Local

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ — 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl — 10 20 30 40

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	ADDITIONAL LAB. TESTING
0		GROUND SURFACE	362.08 0.00				
		Moist to wetted dark brown SILT and SAND, some gravel and organics (FILL).	361.16 0.91				
1		Moist to wetted dark brown SILT and fine SAND, some organics and roots.	360.10 1.98	1	SS		
2							
3		Wet grey/brown SILT, some fine sand, trace clay, cemented silt nodes, rootlets and root fibres.	357.51 4.57	2	SS		
4							
	Geotech Odex	Wet grey/brown SILT and fine SAND, some brown fine sandy silt seams and layers.	358.97 5.11	3	SS		
5		Wet brown SILT, some fine sand, trace cemented silt nodes.	356.13 5.94				
6		Wet brown fine SAND, grading to a fine to medium SAND.	355.52	4	SS		sieve
		Wet grey SILT, fine SAND and rounded GRAVEL.	6.63				
		Wet grey SILT, trace to some fine sand.	355.07 7.01				
7		Wet brown fine SAND grading to a fine to medium SAND.	354.61 7.47	5	SS		sieve
8		Wet grey fine SAND, some silt and silty fine sand layers, occasional fine to coarse sand seams, with slight rust brown oxidation.	352.63 9.45	6	SS		sieve
9		Wet brown fine SAND					
10							

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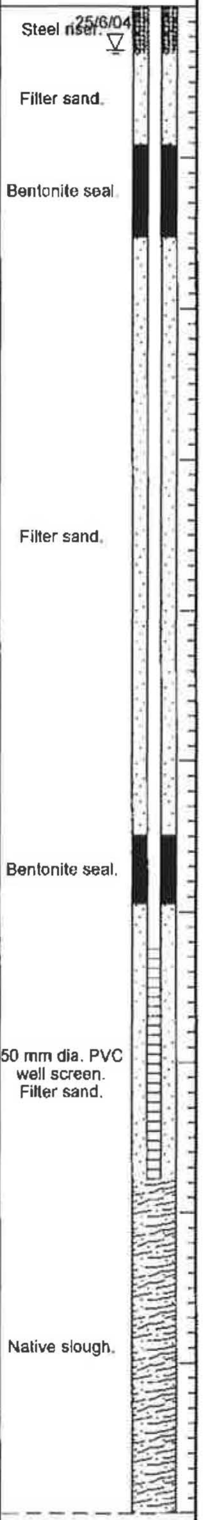
PIEZOMETER OR STANDPIPE INSTALLATION

MW4



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW9

SHEET 1 OF 1

LOCATION: See Figure 2
N: 421.2835 E: -793.2868

BORING DATE: 17/06/04

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 10 20 30 40	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION 23/06/04 ▽ MW9
		GROUND SURFACE		367.73							
0	Geotech Odex	GRAVEL, COBBLES and BOULDERS, some sand (FILL).		0.00							Concreted in steel riser well protector. Bentonite seal.
		Dark brown silty SAND and GRAVEL.		367.28 0.46							
1 2 3		Wet brown gravelly fine to coarse SAND, trace to some silt.		366.82 0.81	1 2	SS SS				sieve	Waterlevel at 0.6 m above ground surface. Native slough and filter sand mixture. 50 mm dia. PVC well screen.
4		Wet brown gravelly fine to coarseSAND, trace silt.		364.23 3.51	3	SS				sieve	Native slough.
5 6 7 8 9 10		End of BOREHOLE.		363.31 4.42							

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR

CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW4

SHEET 2 OF 2

LOCATION: See Figure 2
N: 363.8705 E: -699.4145

BORING DATE: 15/06/04

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION MW4
10	Geotech Odex	Wet brown fine SAND *(continued)*	▨								Native slough.
				351.10 10.97	7	GRAB				sieve	
11		End of BOREHOLE.									
12											
13											
14											
15											
16											
17											
18											
19											
20											

BOREHOLE BOREHOLES.GPJ GLDR_CAN.GDT 3/9/04

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW5

SHEET 1 OF 1

LOCATION: See Figure 2

BORING DATE: 16/06/04

DATUM: Local

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢——○W——⊣ Wl 10 20 30 40

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION MW5
0	Geotech Odex	GROUND SURFACE	361.35					
		Moist brown silty, gravelly SAND (FILL).	0.00					Concreted in steel riser well protector. Filter sand.
1		Moist to wetted fine sandy SILT, trace clay.	360.74 0.61	1	GRAB			Bentonite seal. 25/6/04 ▽
2		Moit to wetted grey/brown SILT, trace clay, some silt and fine sand seams, occasional fine to medium sand seams and cemented silt nodes.	359.83 1.52	2	SS			
3				3	SS			50 mm dia. PVC well screen. Filter sand.
4		Wet brown fine SAND.	357.54 3.81					
5		Wet grey/brown SILT, trace to some clay, some silt and fine sand seams, occasional medium to coarse sand.	356.63 4.72	4	SS			Native slough.
6				5	GRAB		sieve	
		End of BOREHOLE.	355.26 6.10					
7								
8								
9								
10								

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW6

SHEET 1 OF 1

LOCATION: See Figure 2
N: 431.0806 E: -816.6869

BORING DATE: 16/06/04

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
		GROUND SURFACE		373.26				
0	Geotech Odex	Moist brown SILT, some fine sand to sandy, some gravel and occasional cobble (FILL).	▨	0.00 372.65				
1		Moist brown SILT, some fine sand to sandy, trace organic and occasional roots.		0.61 371.43	1	GRAB		
2		Moist grey gravelly SILT and SAND.		1.83 370.82	2	SS		
		Moist greyish brown silty, gravelly SAND.		2.44 370.06	3	GRAB		sieve
3		Moist to wetted grey SILT, some clay and sand, occassional rounded gravel, trace silt and sand layers and seams, rootlets, with slight rust brown oxidation.		3.20 368.69	4	SS		
4		Wet brown fine to coarse SAND and GRAVEL, some silt to silty, trace grey silt, some clay seams.		4.57 368.08	5	SS		
5		Wet brown fine to coarse SAND, some silt and gravel.		5.18 367.16	6	GRAB		sieve
6		End of BOREHOLE.		6.10				
7								
8								
9								
10								

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
20 40 60 80

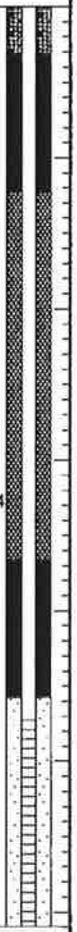
SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○
20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s
10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT
Wp ⊢—○W—⊣ Wl
10 20 30 40

PIEZOMETER OR STANDPIPE INSTALLATION

MW6



Concreted in steel riser well protector.

Bentonite seal.

Bentonite and filter sand mixture.

25/6/04

Bentonite seal.

50 mm dia. PVC well screen. Filter sand.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JT

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW7

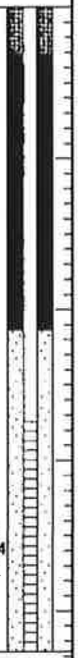
SHEET 1 OF 1

LOCATION: See Figure 2
N: 432.3112 E: -816.7524

BORING DATE: 17/06/04

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION MW7
		GROUND SURFACE		373.45							
0	Geotech Odex	Moist brown SILT, some fine sand to sandy, some gravel and occasional cobble (FILL).		0.00 372.84							Concreted in steel riser well protector.
		Moist brown SILT, some fine sand to sandy, trace organic and occasional roots.		0.61 371.62							
1											Bentonite seal.
		Moist grey gravelly SILT and SAND.		1.83 371.01							
2											
		Moist greyish brown silty, gravelly SAND.		2.44 370.10							
3											
		Moist to wetted grey SILT, some clay and sand, occassional rounded gravel, trace silt and sand layers and seams, rootlets, with slight rust brown oxidation.		3.35 369.18							50 mm dia. PVC well scr25/6/04 Filter sand. ▽
4											
		End of BOREHOLE.		4.27							
5											
6											
7											
8											
9											
10											



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AR
CHECKED: JF

PROJECT No.: 04-1440-088

RECORD OF BOREHOLE: MW8

SHEET 1 OF 1

LOCATION: See Figure 2
N: 415.678 E: -806.2562

BORING DATE: 17/06/04

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	ADDITIONAL LAB. TESTING
0		GROUND SURFACE	369.57				
	Geotech Odex	GRAVEL	369.42 0.15				
1		Moist to wetted dark brown to brownish grey SILT, some clay and sand, trace organics.	368.35 1.22	1	GRAB		
2		Moist to wetted grey SILT, some clay and sand, trace medium sand, some wet brown fine to coarse sand, some silt, occasional gravel seams, trace root fibres and poreholes.	365.61 3.96	2 3	SS SS		
4		Wet greyish brown silty fine to coarse SAND, some gravel and occasional grey silt, some clay seams.	364.09 5.48	4 5	GRAB SS		 sieve
6		Wet brown fine to medium SAND, some gravel, trace silt.	363.17 6.40	6	SS		sieve
		End of BOREHOLE.					
7							
8							
9							
10							

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80

SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V ⊕ U - ○ 20 40 60 80

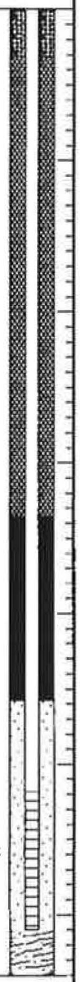
HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 10 20 30 40

PIEZOMETER OR STANDPIPE INSTALLATION

MW8

25/6/04
▽



Concreted in steel riser well protector.

Bentonite and filter sand mixture.

Bentonite seal.

50 mm dia. PVC well screen. Filter sand.

Native slough.

DEPTH SCALE
1 : 50

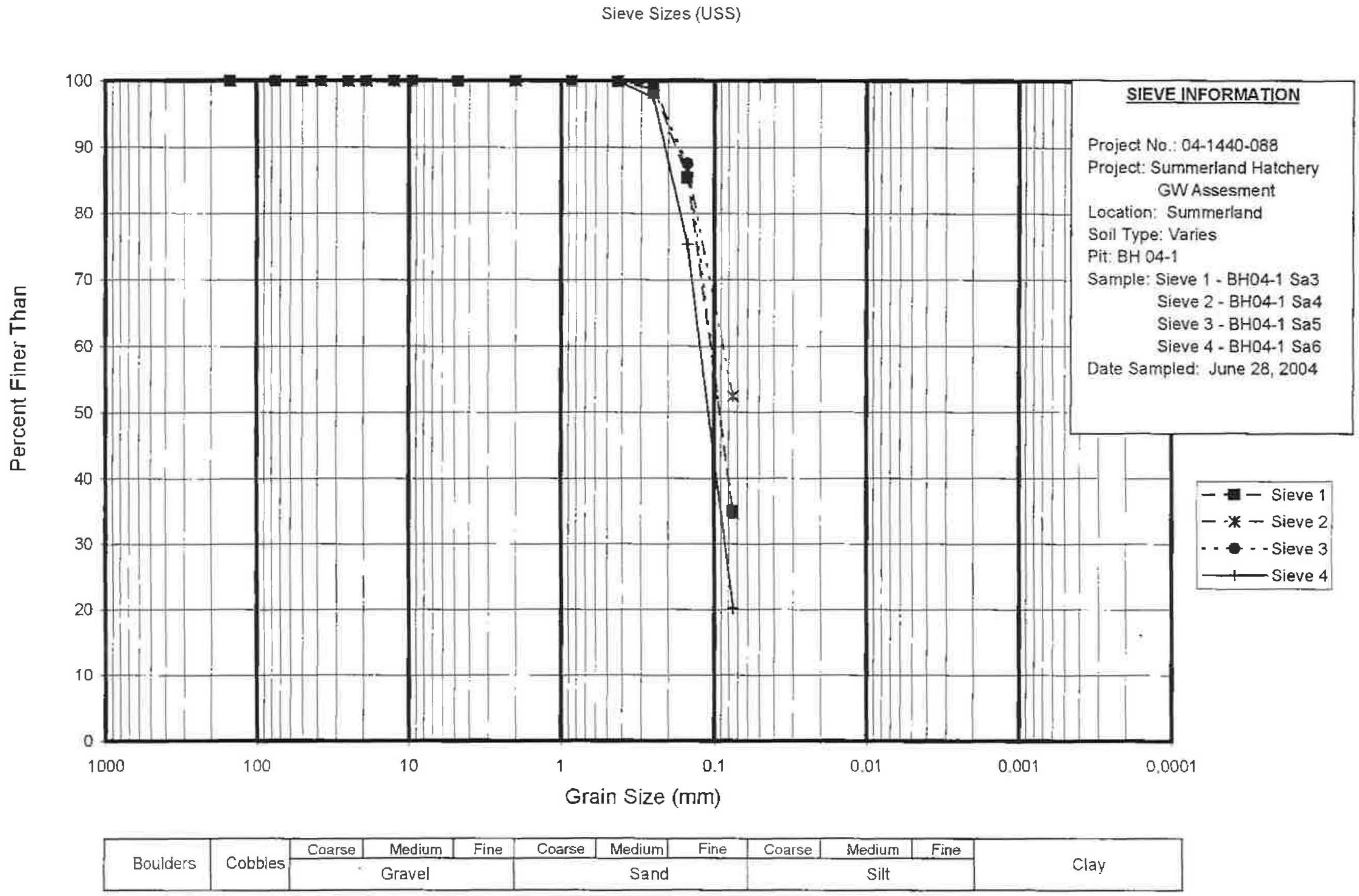
Golder Associates

LOGGED: AR
CHECKED: JF

APPENDIX II

GRAIN SIZE DISTRUBUTION CURVES

Grain Size Analysis

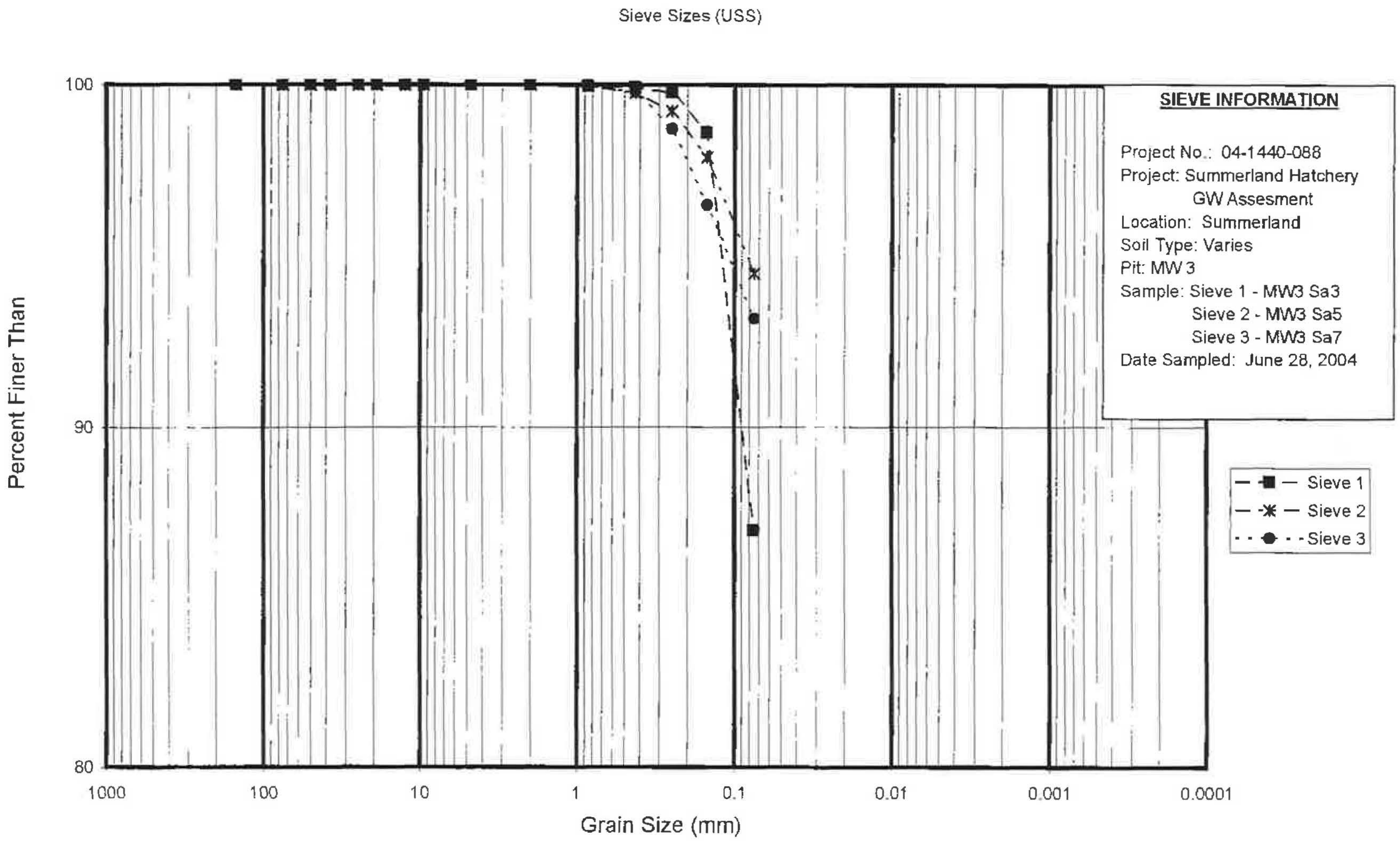


SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: BH 04-1
Sample: Sieve 1 - BH04-1 Sa3
Sieve 2 - BH04-1 Sa4
Sieve 3 - BH04-1 Sa5
Sieve 4 - BH04-1 Sa6
Date Sampled: June 28, 2004

Golder Associates

Grain Size Analysis

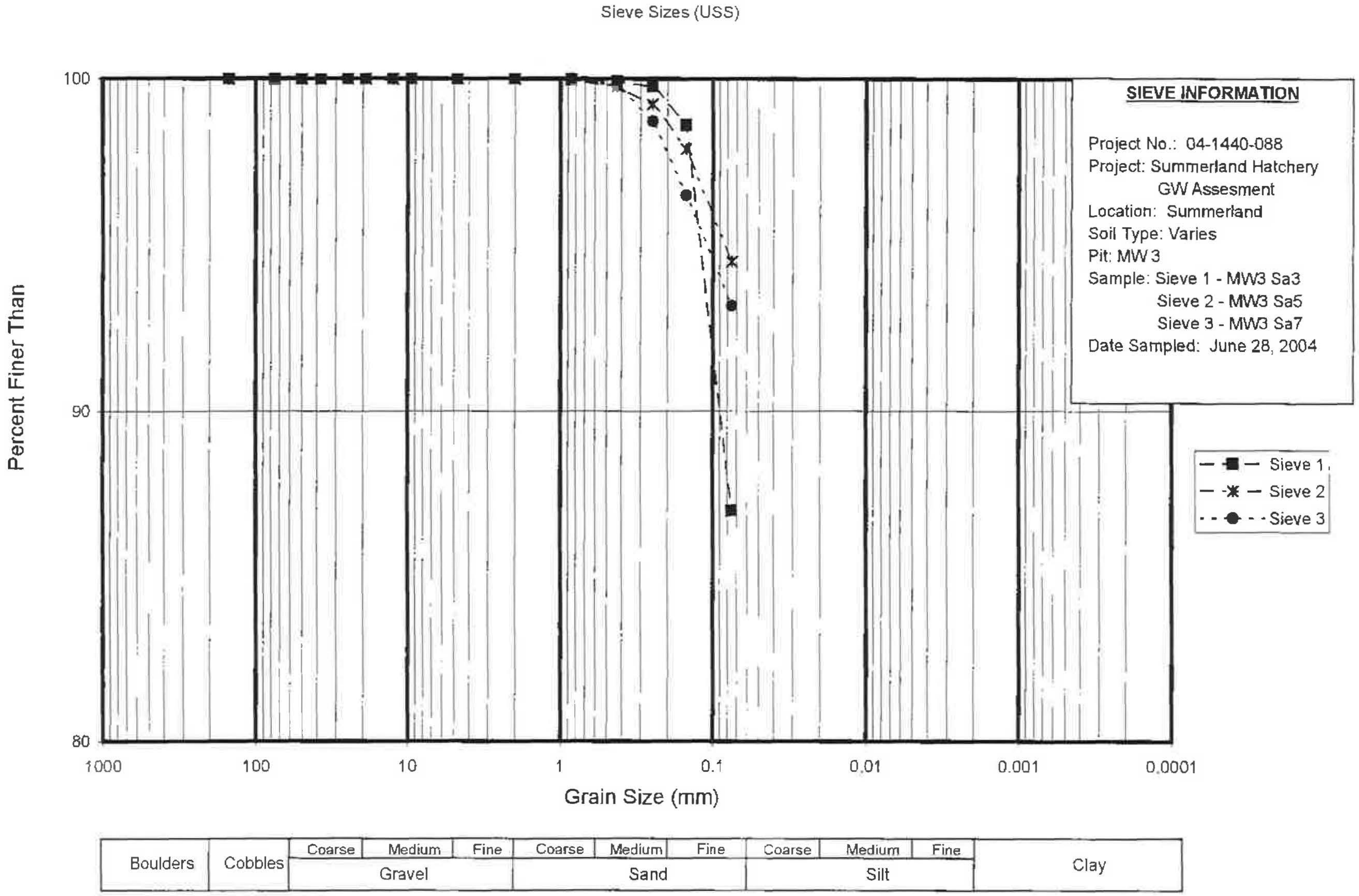


SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: MW 3
Sample: Sieve 1 - MW3 Sa3
Sieve 2 - MW3 Sa5
Sieve 3 - MW3 Sa7
Date Sampled: June 28, 2004

Boulders	Cobbles	Gravel			Sand			Silt			Clay
		Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine	

Grain Size Analysis

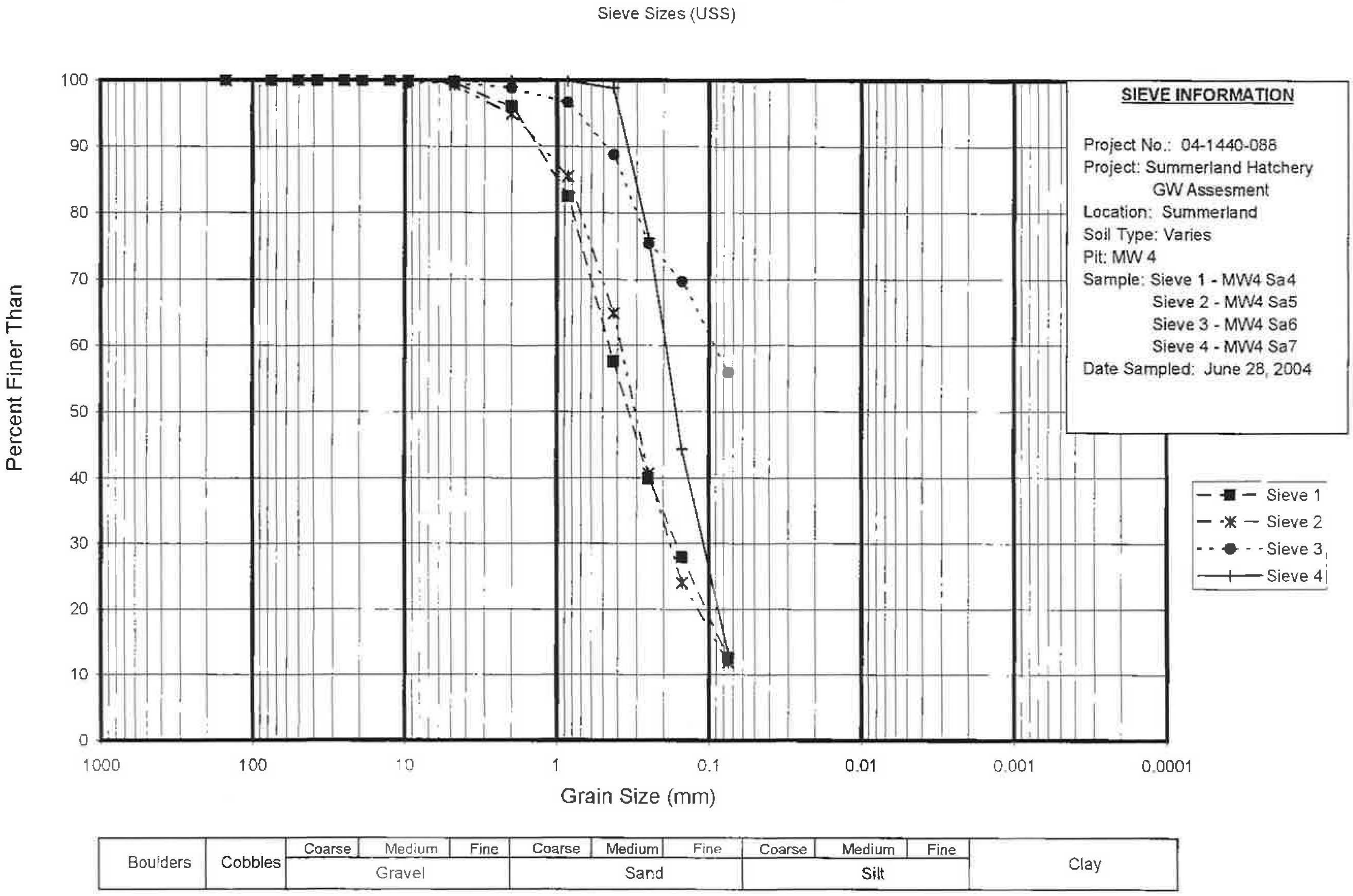


SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: MW 3
Sample: Sieve 1 - MW3 Sa3
Sieve 2 - MW3 Sa5
Sieve 3 - MW3 Sa7
Date Sampled: June 28, 2004

Golder Associates

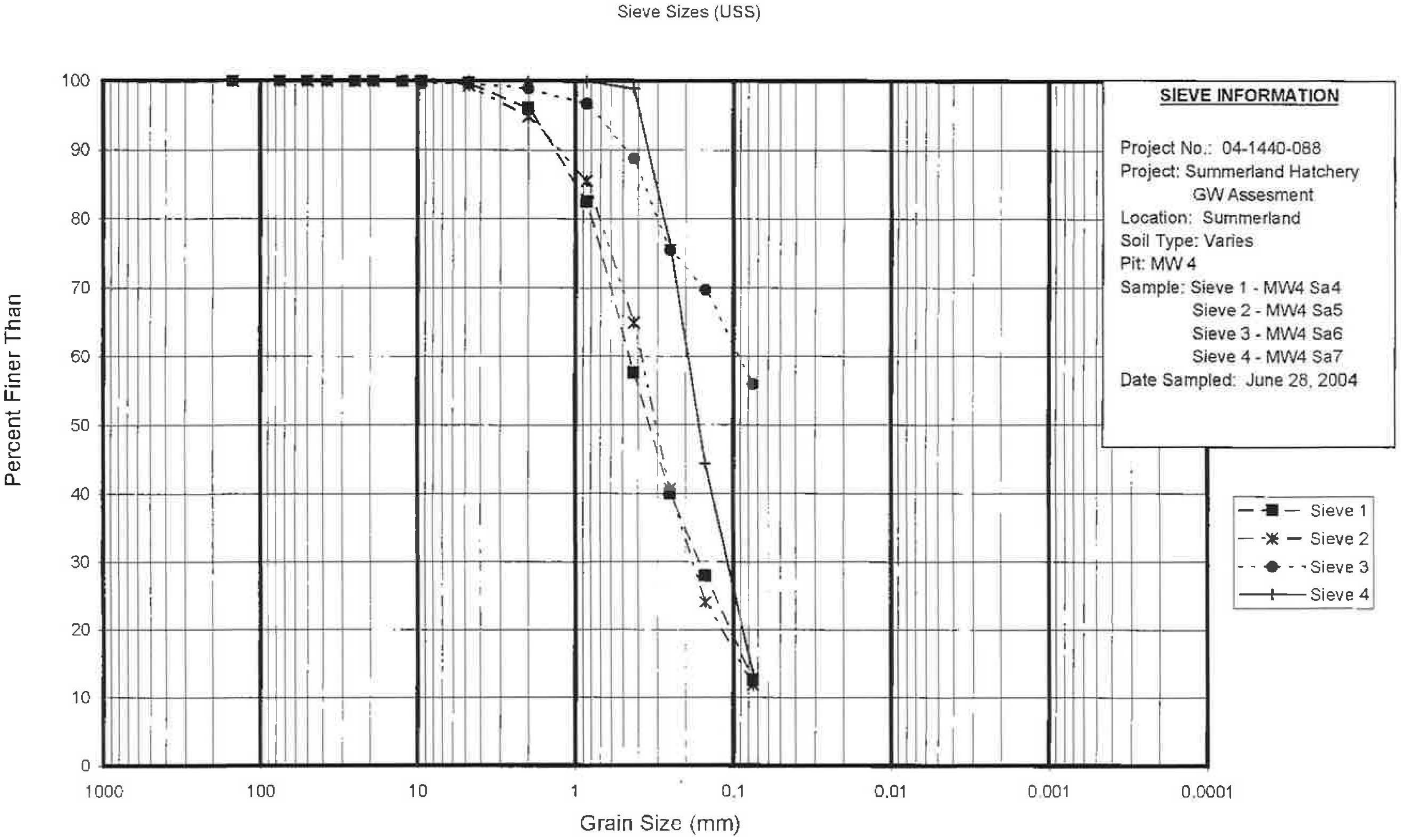
Grain Size Analysis



SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: MW 4
Sample: Sieve 1 - MW4 Sa4
Sieve 2 - MW4 Sa5
Sieve 3 - MW4 Sa6
Sieve 4 - MW4 Sa7
Date Sampled: June 28, 2004

Grain Size Analysis



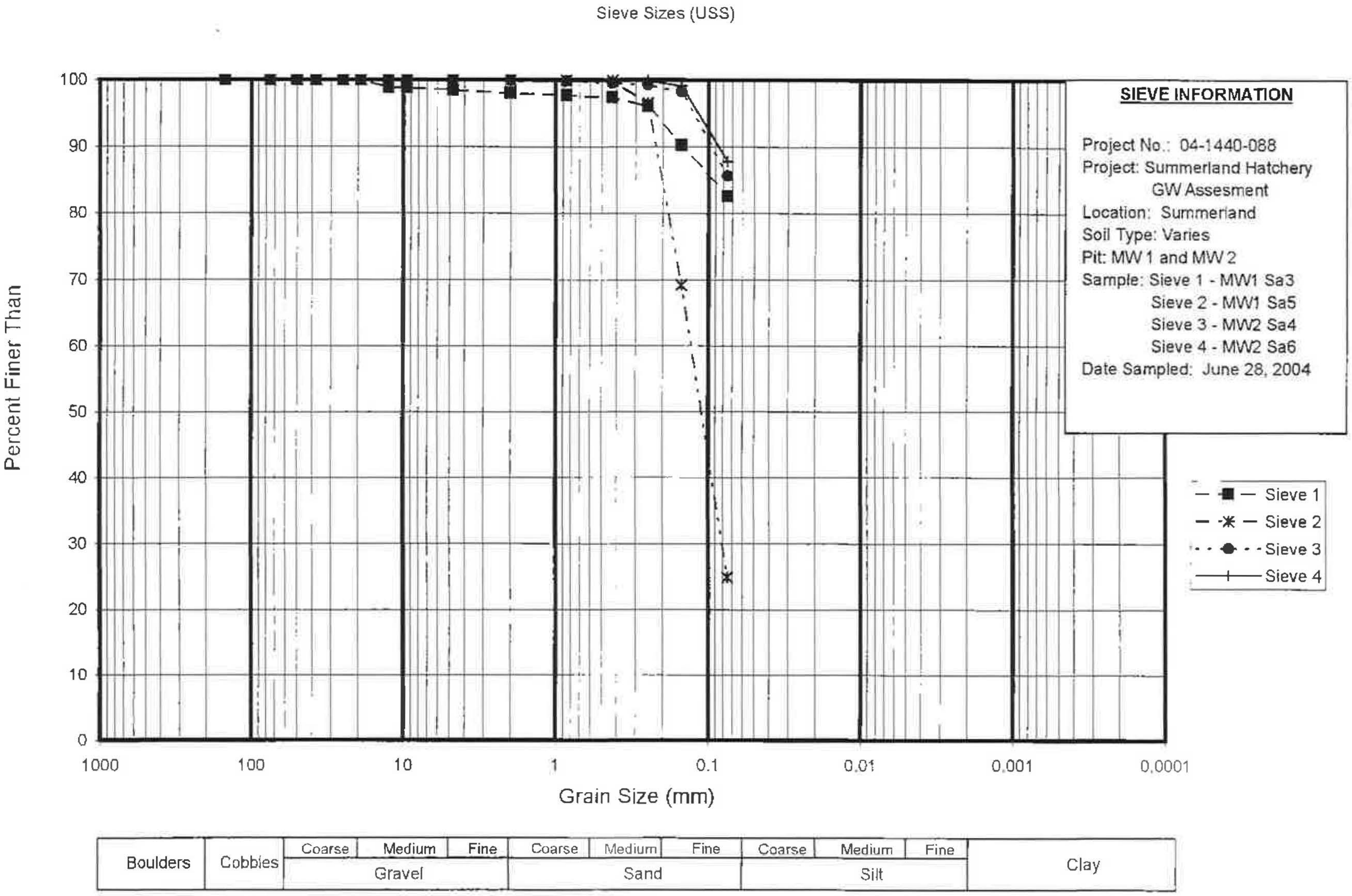
SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: MW 4
Sample: Sieve 1 - MW4 Sa4
Sieve 2 - MW4 Sa5
Sieve 3 - MW4 Sa6
Sieve 4 - MW4 Sa7
Date Sampled: June 28, 2004

Boulders	Cobbles	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine	Clay
		Gravel			Sand			Silt			

Golder Associates

Grain Size Analysis

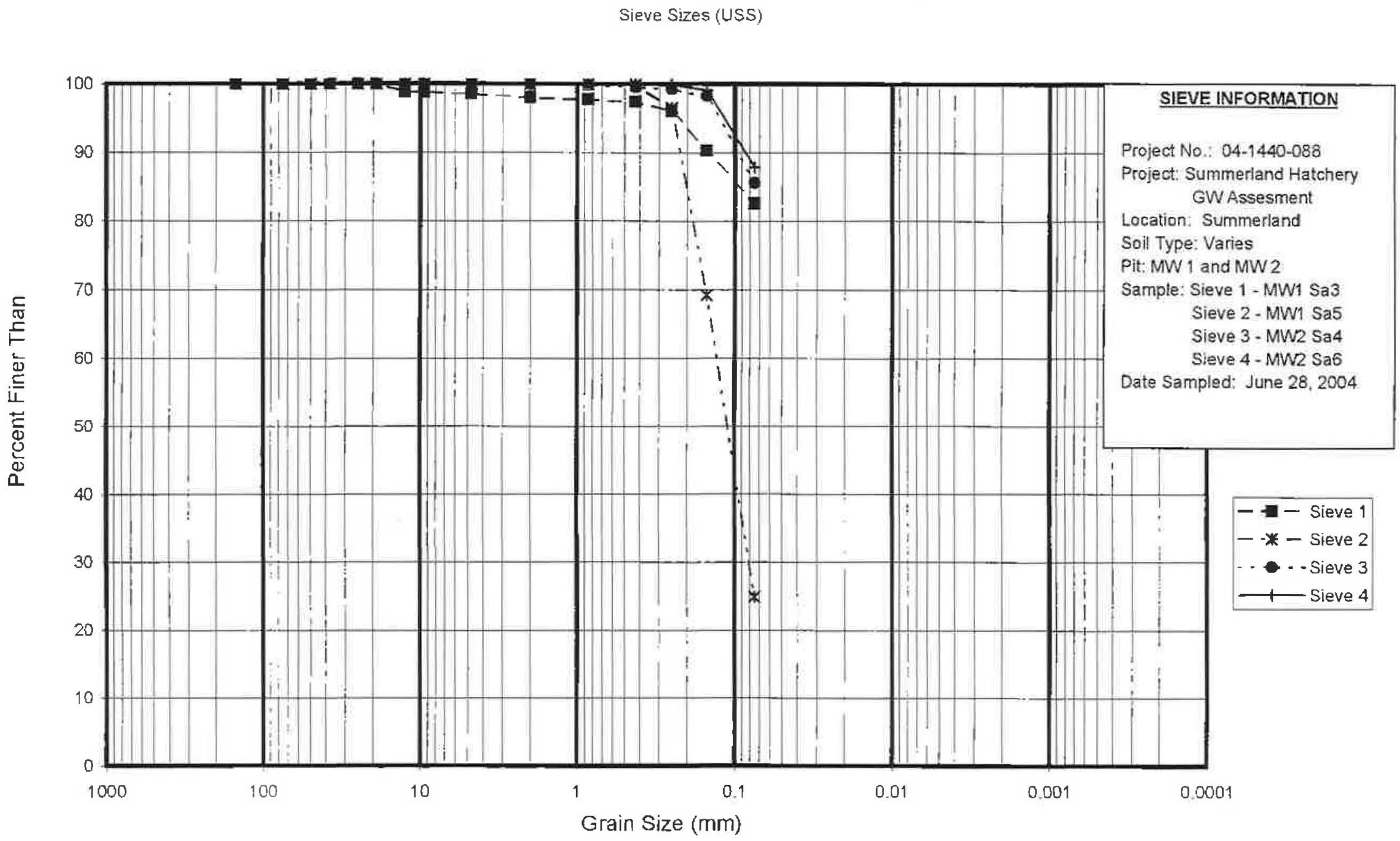


SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: MW 1 and MW 2
Sample: Sieve 1 - MW1 Sa3
Sieve 2 - MW1 Sa5
Sieve 3 - MW2 Sa4
Sieve 4 - MW2 Sa6
Date Sampled: June 28, 2004

Golder Associates

Grain Size Analysis



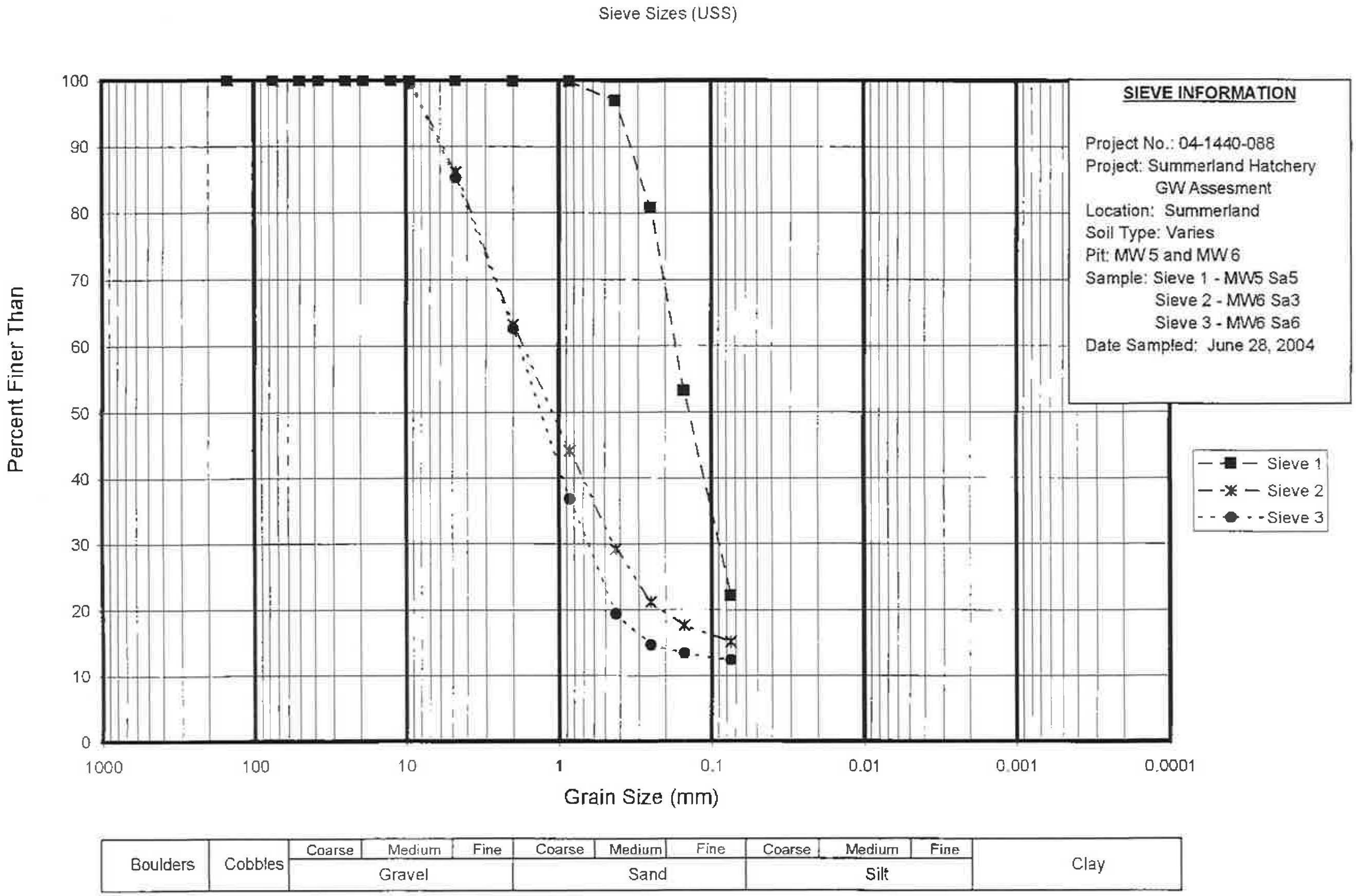
SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: MW 1 and MW 2
Sample: Sieve 1 - MW1 Sa3
Sieve 2 - MW1 Sa5
Sieve 3 - MW2 Sa4
Sieve 4 - MW2 Sa6
Date Sampled: June 28, 2004

Boulders	Cobbles	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine	Clay
		Gravel			Sand			Silt			

Golder Associates

Grain Size Analysis

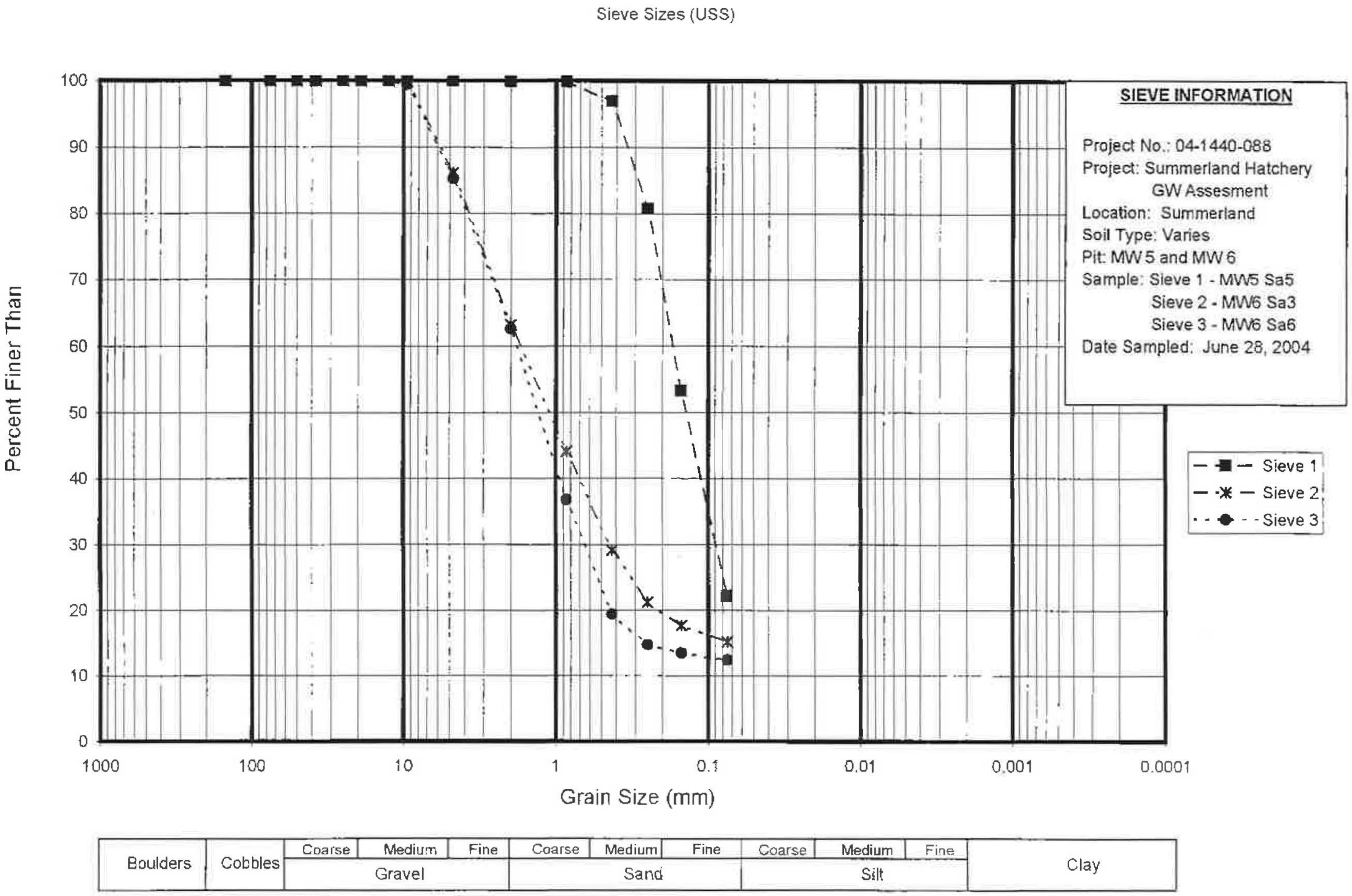


SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: MW 5 and MW 6
Sample: Sieve 1 - MW5 Sa5
Sieve 2 - MW6 Sa3
Sieve 3 - MW6 Sa6
Date Sampled: June 28, 2004

Boulders	Cobbles	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine	Clay
		Gravel			Sand			Silt			

Grain Size Analysis



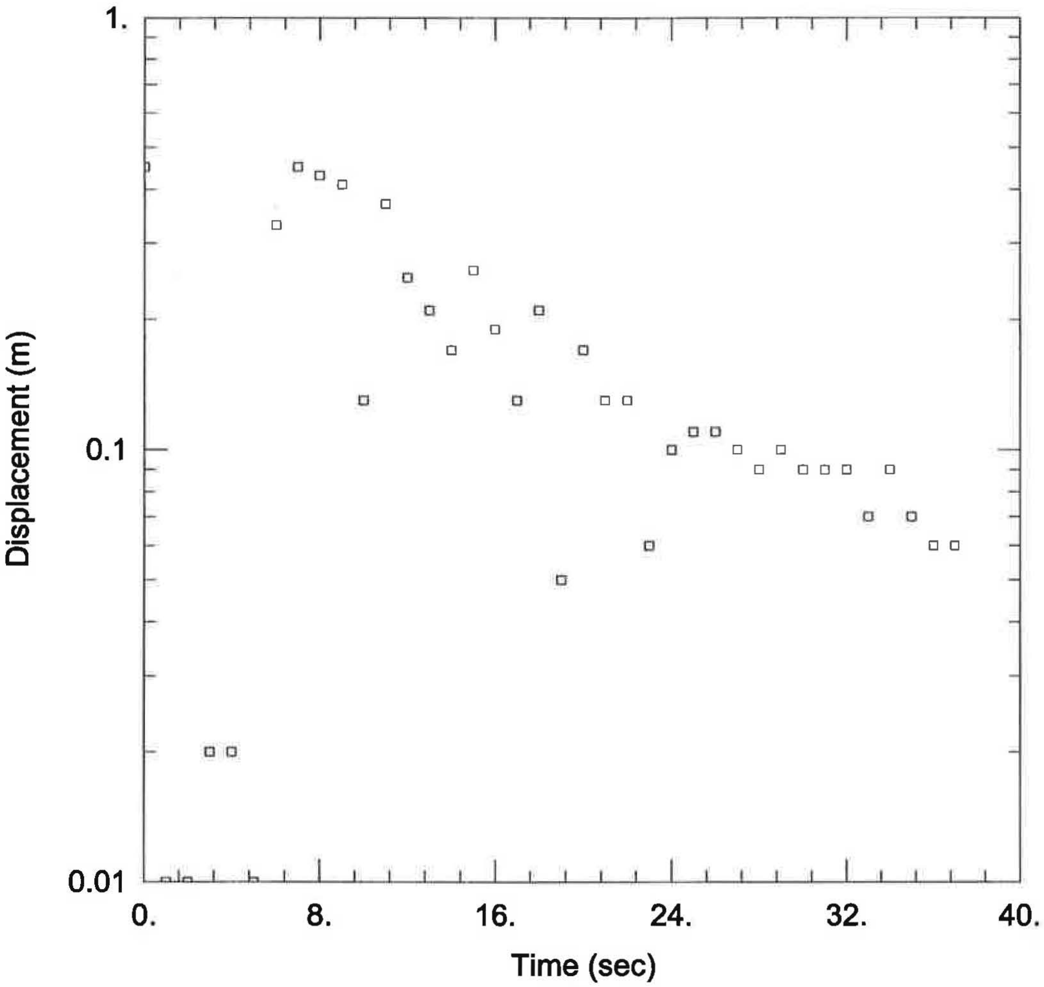
SIEVE INFORMATION

Project No.: 04-1440-088
Project: Summerland Hatchery
GW Assesment
Location: Summerland
Soil Type: Varies
Pit: MW 5 and MW 6
Sample: Sieve 1 - MW5 Sa5
Sieve 2 - MW6 Sa3
Sieve 3 - MW6 Sa6
Date Sampled: June 28, 2004

Golder Associates

APPENDIX III

AQTESOLV



SLUG-IN

Data Set: N:\...\MW1.aqt
Date: 08/26/04
Time: 13:39:15

PROJECT INFORMATION

Company: Golder Associates Ltd.
Client: FFSBC Summerland
Project: 04-1440-088
Location: Summerland
Test Well: MW1
Test Date: 12/08/2004

AQUIFER DATA

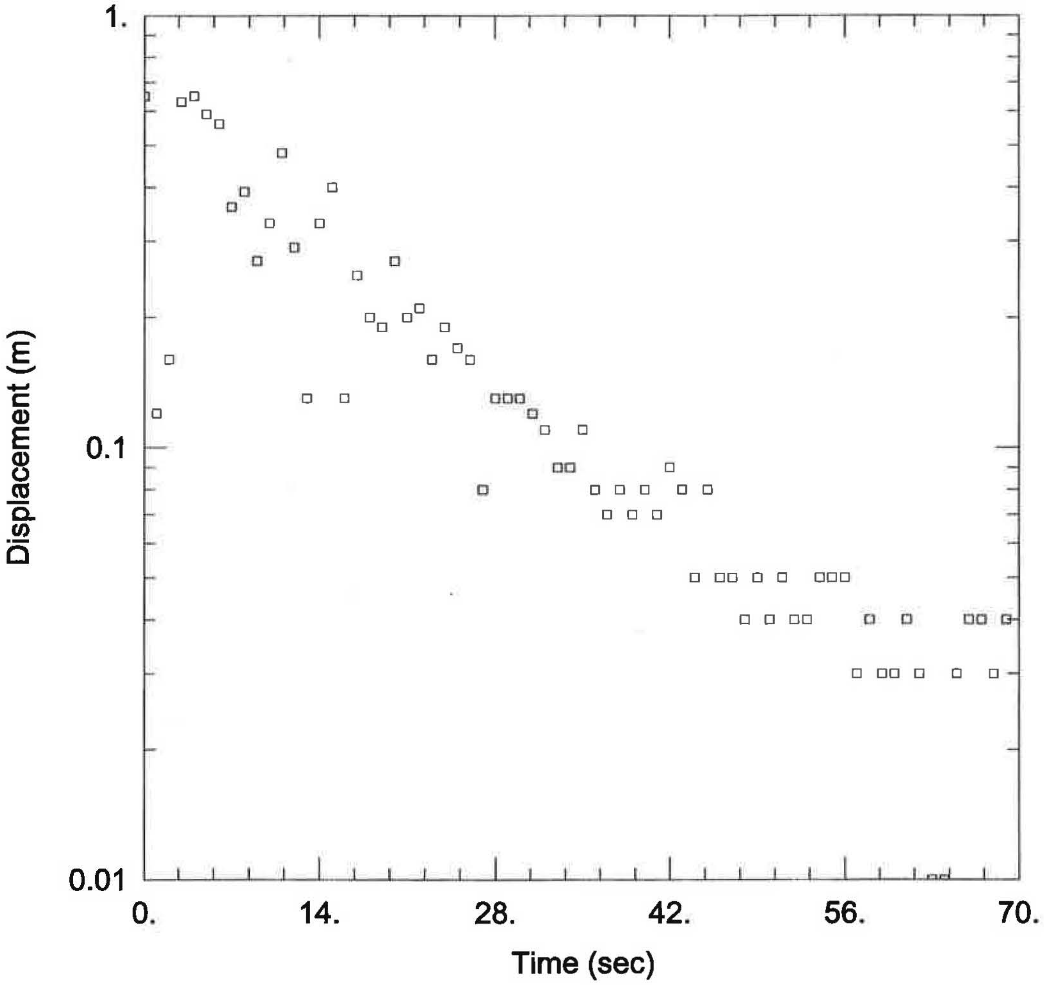
Saturated Thickness: 15. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW1)

Initial Displacement: 0.45 m
Total Well Penetration Depth: 3.353 m
Casing Radius: 0.1 m
Static Water Column Height: 3.182 m
Screen Length: 3.353 m
Wellbore Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.0002393 m/sec
y0 = 0.6218 m



WELL TEST ANALYSIS

Data Set: N:\...\MW6.aqt
Date: 08/26/04
Time: 13:57:18

AQUIFER DATA

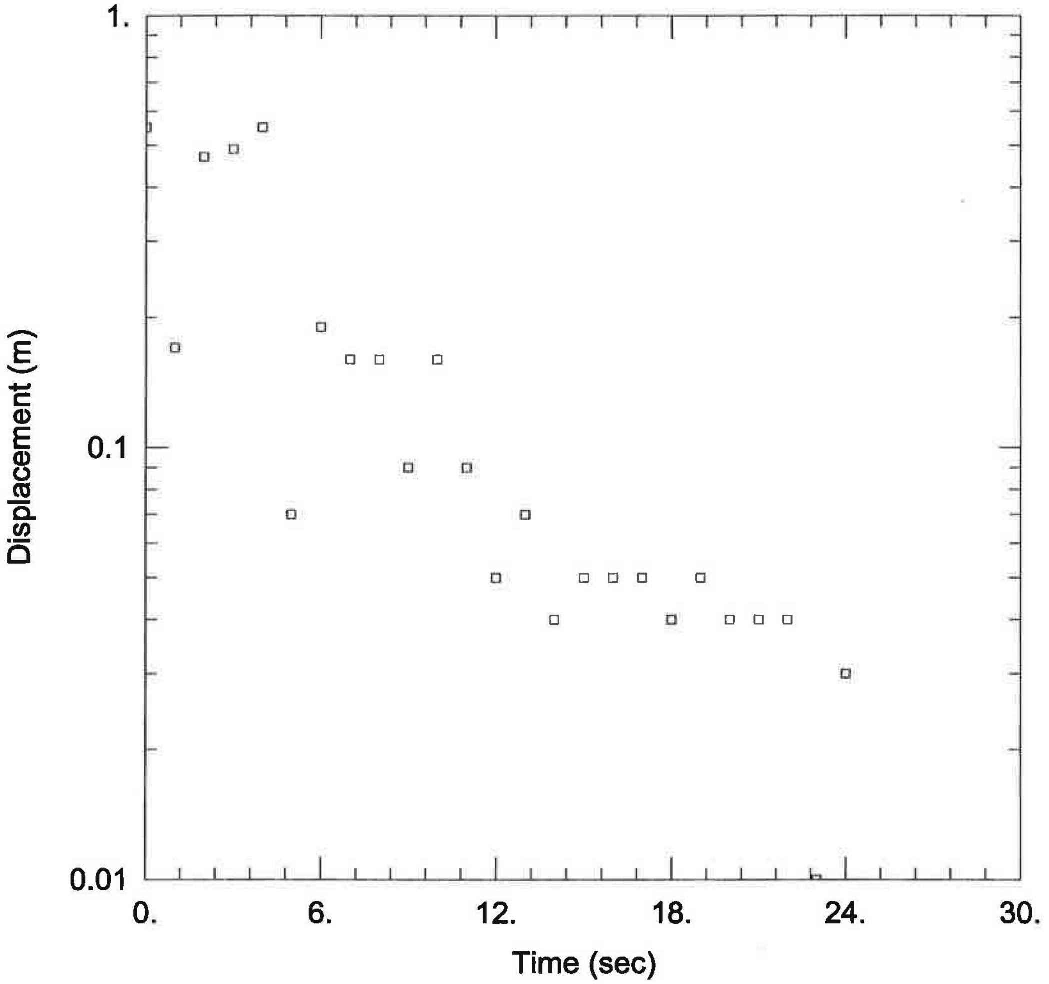
Saturated Thickness: 1.524 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW6)

Initial Displacement: 0.65 m
Total Well Penetration Depth: 1.524 m
Casing Radius: 0.1 m
Static Water Column Height: 1.616 m
Screen Length: 1.524 m
Wellbore Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.0003973 m/sec
y0 = 0.7059 m



WELL TEST ANALYSIS

Data Set: N:\...\MW8.aqt
Date: 08/26/04 Time: 13:56:51

PROJECT INFORMATION

Company: Golder Associates Ltd.
Client: FFSBC Summerland
Project: 04-1440-088
Location: Summerland
Test Well: MW8
Test Date: 12/08/2004

AQUIFER DATA

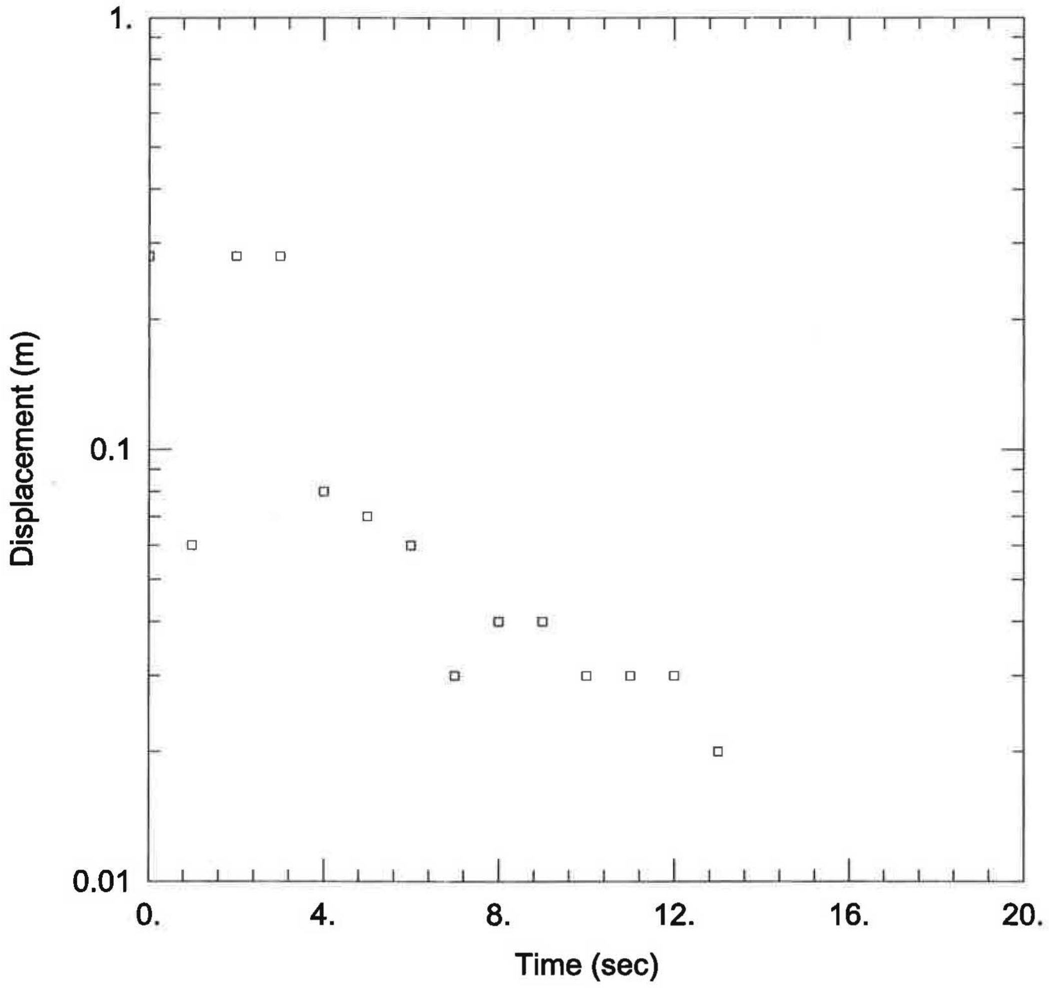
Saturated Thickness: 2.743 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW8)

Initial Displacement: 0.55 m
Total Well Penetration Depth: 2.134 m
Casing Radius: 0.1 m
Static Water Column Height: 5.489 m
Screen Length: 0.9144 m
Wellbore Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.00181 m/sec
y0 = 0.7859 m



WELL TEST ANALYSIS

Data Set: N:\...\MW9.aqt
Date: 08/26/04 Time: 13:56:20

PROJECT INFORMATION

Company: Golder Associates Ltd.
Client: FFSBC Summerland
Project: 04-1440-088
Location: Summerland
Test Well: MW9A
Test Date: 12/08/2004

AQUIFER DATA

Saturated Thickness: 3.125 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW9A)

Initial Displacement: 0.28 m
Total Well Penetration Depth: 3.125 m
Casing Radius: 0.1 m
Static Water Column Height: 3.125 m
Screen Length: 1.524 m
Wellbore Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.003059 m/sec
y0 = 0.6553 m