THURBER ENGINEERING LTD.

THE SHORES – PHASE 1 SUBDIVISION
SINKHOLE INVESTIGATION AND
GEOTECHNICAL ASSESSMENT

Report to

District of Sechelt
Box 129, 2nd Floor, 5797 Cowrie Street, Sechelt, B.C., V0N 3A0

Caleb Scott, E.I.T.
Project Geotechnical Engineer

Denny Ma, P.Eng.
Senior Geotechnical Engineer

David J. Tara, P.Eng.
Review Principal

Thurber Engineering Ltd.
Vancouver, B.C.

July 16, 2015
File No: 14-214-4

900, 1281 West Georgia Street, Vancouver, BC V6E 3J7 T: 604 684 4384 F: 604 684 5124
thurber.ca

THURBER

TABLE OF CONTENTS

1. INTRODUCTION 1
2. SITE LOCATION AND DESCRIPTION 1
3. LEGAL BOUNDARIES 2
4. BACKGROUND 2
   4.1 Pre-construction 3
   4.2 Construction Period: 2005 and 2006 3
   4.3 Construction Period: 2007 to June 1, 2012 6
   4.4 Construction Period: June 1, 2012 to April 2013 9
   4.5 Construction Period: May 2013 to February 2015 11
5. RECENT EVENTS 12
6. 2015 INVESTIGATION 14
   6.1 Drilling Investigation 14
   6.2 Geophysical Investigation 16
7. GEOTECHNICAL SITE CONDITIONS 17
   7.1 Regional Geological Setting 17
   7.2 Regional Groundwater Hydrology 17
   7.3 Site Conditions 18
   7.4 Groundwater Site Conditions 24
8. GEOTECHNICAL ASSESSMENT 26
   8.1 General 26
   8.2 Changes in Groundwater Levels 26
   8.3 Hydraulic Groundwater Gradients 28
   8.4 Potential Pathways for Soil Migration 30
   8.5 Effects of Soil Particle Migration 33
   8.6 Assessment of Soil Disturbance in Recent Investigations 34
9. CONCEPTUAL SINKHOLE DEVELOPMENT PROCESS 38
   9.1 General 38
   9.2 High Groundwater Gradients 38
   9.3 Migration of Soil 39

9.4 Formation of Voids / Loosening of Soils 39
9.5 Collapse of Ground Surface or Infrastructure 39
10. GEOTECHNICAL CONCLUSIONS 40
10.1 General 40
10.2 Gale Avenue North at Lots 9 and 21 40
10.3 Lot 21 Sinkhole 41
10.4 Storm Sewer Corridor between Lots 9 and 10 42
10.5 Lot 28 Implications 43
10.6 Site-Wide Assessment 43
11. RECOMMENDATIONS 43
11.1 Mapping of Current Sinkhole Hazards 43
11.2 Addressing Potential for Future Sinkhole Development 44
11.3 Addressing Currently Identified Sinkholes 47
11.4 Long Term Monitoring 49
11.5 Potential Risks of Action 49
11.6 Residual Uncertainties and Risk 49
11.7 Site Closure 50

STATEMENT OF LIMITATIONS AND CONDITIONS

SYMBOLS AND TERMS FOR SOIL DESCRIPTION AND TEST HOLE LOGS

TABLES

Table 1 Timeline of Selected Events/Observations
Table 2 List of Documents Referenced
Table 3 Summary of Soil Stratigraphy

FIGURES

Figure 1 Site Location
Figure 2 Site Topography (2009)
Figure 3 Survey Control Grid – Seawatch Lane at Lot 28
Figure 4 Site Plan and Features of Interest
Figure 5 Test Hole Location and Site Plan
Figure 6A Test Hole Location Plan – Gale Avenue North
Figure 6B Test Hole Location Plan – Seawatch Lane

Figure 7 Inferred Groundwater Catchment Area
Figure 8 Geological Section A-A
Figure 9 Geological Section B-B
Figure 10 Geological Section C-C
Figure 11 Geological Section D-D
Figure 12 Geological Section E-E
Figure 13 Geological Section F-F
Figure 14 Geological Section G-G
Figure 15 Geological Section H-H
Figure 16 Geological Section I-I
Figure 17 Geological Section J-J
Figure 18 Geological Section K-K
Figure 19 Geological Section L-L
Figure 20 Geological Section M-M
Figure 21 Change in Groundwater Elevation since Initial Reading
Figure 22 Groundwater Contours and Average Hydraulic Gradient Vectors
Figure 23A Sinkhole Development Interpretation – Gale Avenue North
Figure 23B Sinkhole Development Interpretation – Seawatch Lane
Figure 24 Interpretation Section H-H
Figure 25 Interpretation Section I-I
Figure 26 Interpretation Section J-J
Figure 27 Interpretation Section K-K
Figure 28 Interpretation Section L-L
Figure 29 Interpretation Section M-M
Figure 30 Schematic Conceptual Model

PHOTOGRAPHS

Photo 1 November 4, 2014 Depression on Seawatch Lane
Photo 2 November 12, 2014 Depression on Seawatch Lane
Photo 3 November 12, 2014 Depression on Seawatch Lane
Photo 4 November 14, 2014 Repair of depression on Seawatch Lane
Photo 5 November 12, 2014 Subsidence adjacent to Lot 9
Photo 6 November 12, 2014 Subsidence below Lot 9 concrete driveway
Photo 7 February 27, 2015 Sinkhole in front of home on Lot 21
Photo 8 March 2, 2015 Subsidence adjacent to Lot 9
Photo 9 May 31, 2007 Inferred Seepage Erosion
Photo 10 August 29, 2008 Inferred drainage blanket construction

APPENDICES

Appendix 1 Thurber Engineering Ltd. 2015 Site Inspection Reports
Appendix 2 2015 Ground Surface Profile vs. As-Built Profiles
- Cross Section of Storm Line near Lots 9 and 10
Appendix 3 Thurber Engineering Ltd. 2015 Drilling Investigation Test Hole Logs

Appendix 4 Thurber Engineering Ltd. 2015 Drilling Investigation – Geotechnical Laboratory Test Results
Appendix 5 DMT Geosciences Ltd. Geophysical Investigation Report
Appendix 6 Thurber Engineering Ltd. Previous Investigation Test Hole Logs and Geotechnical Laboratory Test Results
Appendix 7 Geotechnical Investigation Test Hole Logs and Laboratory Test Results by Others
Appendix 8 Web Engineering Ltd. As-Built Drawing
Appendix 9 Excerpt from “Soil Mechanics in Engineering Practice”, 3rd Ed., (1996) by Karl Terzaghi, Ralph B. Peck, Gholamreza Mesri

THURBER

1. INTRODUCTION

On February 27, 2015 the District of Sechelt (the District) requested that Thurber Engineering Ltd. (Thurber) conduct a visual assessment of two sinkholes at The Shores – Phase 1 Subdivision (Seawatch). Thurber's program of work later expanded to include regular field reviews, a desktop study of the available historic site condition information, and limited preliminary geotechnical investigations in the vicinity of the daylighted sinkholes which included drilling and geophysical components.

Draft results of the drilling investigation were provided to the District in a memorandum dated April 28, 2015. Preliminary interpretive comments on the results of the drilling investigation and a discussion on characterization of sinkhole hazards for the overall site were provided in a memorandum dated May 11, 2015.

This report summarizes Thurber's assessment of the two sinkholes and the implications for geotechnical hazards within the overall site in the form of ground loss and sinkholes, and provides preliminary recommendations to the District for a phased approach to address these and future geotechnical hazards at this site. Thurber's scope of services does not encompass geotechnical issues such as assessment of slope and retaining wall stability which may be affecting the site, or a specific assessment of private properties. This report supersedes the April 28 and May 11, 2015 memoranda provided to the District.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. SITE LOCATION AND DESCRIPTION

The Seawatch development is located on the west side of Sechelt Inlet approximately 4.5 km northwest of Sechelt town centre. It is a 28 lot residential development of about 200 by 400 m in plan, centered at around 123°47'42.42"W, 49°30'28.60"N and located on the west side of the neighbourhood of West Porpoise Bay, in the municipal District of Sechelt, as shown in Figure 1.

Lot numbers and topographic contours are shown in Figure 2, based on Lidar data from the Sunshine Coast Regional District. However, the contours are based on data collected on September 12, 2009. It is our understanding that placement of site grading fill was not substantially completed on Lots 7 through 11 at that time. Current and detailed topographic contour data is not presently available throughout the site. The 28 lots within the development are broadly split into three groups, as discussed below.

- Lots 1 through 12 are located to the north of Gale Avenue North and along the north side of the development closest to Sechelt Inlet. The lots are setback 15 m from a property easement which is intended to prevent construction on marsh land bordering the Inlet.

- Lots 13 to 15 are located on the west side of the development.

- Lots 16 to 28 are located on the south side of the development, between Seawatch Lane to the south and Gale Avenue North to the north.

Topographically, the site slopes downward to the north, toward Sechelt Inlet (El. 0 m), with the high ground on Seawatch Lane (El. 45 m). To the south of the site, the ground slopes upward more gradually. A north-south trending ridge forms the west perimeter of the site, climbing southward. Excavations, fill embankments and rock stack retaining walls have been used to facilitate site grading requirements. Tiered rock stack walls on the order of 15 m high occur upslope of houses on Lots 19, 20 and 21 as well as at the downslope edge of Lots 22, 23, and 24.

3. LEGAL BOUNDARIES

Site survey services have been provided by John C. Theed, BC Land Surveyor (Theed) and the successor company Strait Land Surveying Ltd. (Strait Land). The base plan showing legal boundaries, house outlines and surface features, developed by Theed and updated by Strait Land, has been incorporated into the Figures presented herein.

Statutory Right of Ways belonging to the District are present on both sides of Gale Avenue North and Seawatch Lane (road allowances). District Right of Ways are also present for access to utility corridors along the north side of Lots 1 through 12 and between Lots 9 and 10. Property Easements in favor of Concordia Homes Ltd. are present on Lots 19 through 24 to provide access to the larger, tiered rock stack retaining walls.

Currently, houses on Lots 7, 8, 10, 13, 14, 19, 20, 21, 23, 24, 25, 26 and 27 (13 total) are completed and occupied (Lot 21 is presently evacuated). A nearly completed but unoccupied house stands on Lot 9. House foundations occupy Lots 11 and 15. No substantial house building has occurred on the remaining lots. The distinction between occupied and unoccupied / incomplete houses is shown on the plan Figures presented herein.

4. BACKGROUND

A desktop review of available documents was completed by Thurber on behalf of the District and summarized in a report dated July 20, 2012. The report highlighted key observations made by other parties prior to and during site development. The July 20, 2012 Thurber report should be referred to for a more detailed discussion and references to additional source documents.

Select observations, events, milestones and investigations considered relevant to the current assessment from available data or information sources are noted below and summarized chronologically on Table 1. A list of references can be found on Table 2. Where appropriate, we have added clarifications or relevant comments in square parenthesis.

Beginning in about 2005, the site was developed by Concordia Homes Ltd. (Concordia). Civil engineering for the development was provided by Web Engineering Ltd. (Web) and geotechnical engineering by GeoTacTics Engineering Ltd. (later incorporated as GeoTacTics

Media Engineering (2007) Ltd.). For discussion purposes, we have used the name GeoTacTics to refer to both companies.

4.1 Pre-construction

In a report from GeoTacTics to Concordia dated September 30, 2004, the presence of springs and localized shallow sloughing of steeper pitches on the slope was noted during a pre-construction site reconnaissance as quoted below:

> *"The general slope has been cut by a number of short drainage courses fed by springs mostly arising from the lower third of the Lower Slope. The drainage courses are spaced at about 30 m intervals across the slope as shown on Drawing 2. Some of the drainage courses, such as one east of Lots 1 and 28 and the one that passes through Lots 10, 19 and 20, are fed by a more substantial spring system and also carry a significant discharge of surface runoff during the wet season."* [Thurber notes that the drainage courses depicted in the referenced report have been approximately incorporated into Figure 4 of this report]

Note the report generally defines the 'Lower Slope' as below El. 50 m, including Lots 1 through 28. The GeoTacTics report recommended that site specific drainage measures be implemented as quoted below:

> *"On Lots 1 to 14, site specific measures….should be implemented to deal with active spring areas on the Lower Slope. Such measures could include placing clean, clear crushed gravel around the head of the springs to buttress the sidewalls and prevent further headward erosion. At the toe of the gravel buttress, perforated drain pipe could be installed in the upper end of a drainage course emanating from the spring and extending beyond the toe of the Lower Slope. The perforated pipe in the drainage course channels should be covered with clear crushed gravel."* [Thurber notes that there was no discussion about the use of a proper geotextile / granular filter, or temporary dewatering]

Thurber's review of a November 1, 2004 low resolution air photo available on Google Earth suggests the site had not yet been cleared of vegetation.

4.2 Construction Period: 2005 and 2006

In supplementary reports from GeoTacTics to Concordia dated February 17 and March 17, 2005, an initial subsurface investigation is described which comprised five shallow test pits, distributed throughout the site, which were completed on February 17, 2005. It is noted that the test pit logs were apparently completed by Jacques Whitford and Associates Ltd. (now Stantec Inc., as of January 2009).

Select observations and comments, considered relevant to the current investigation, during the period of July 27 to October 7, 2005 from Site Preparation Field Review memoranda

(9 available to Thurber) by GeoTacTics to Concordia are quoted below. These memoranda should be referred to for additional information.

July 27, 2005 GeoTacTics Memo to Concordia Excerpts (July 22, 2005 site visit):

- *"A small* [seepage related] *slide has already occurred where the* [Seawatch Lane] *Switchback abuts Lot 15."*
- *"The L-100 road alignment* [Gale Avenue North] *along the base of the Lower Slope is located on boggy ground developed by spring discharge"*
- *"Active seepage occurs from about Lot 24 westward, and a number of drainage courses have developed* [to] ~~*the*~~ *carry the seepage."*
- *"Aggressive measures will be required to intercept and control seepage."*

August 12, 2005 GeoTacTics Memo to Concordia Excerpts (July 31, August 7 and August 11, 2005 site visits):

- *"An uncommon erosion feature resulting in a sinkhole has been uncovered at about Sta. 5+20 on L-200* [Seawatch Lane at Lots 25, 26]*. The sinkhole has a diameter of about 20 feet and has been excavated out to a depth of about 18 feet."*

August 27, 2005 GeoTacTics Memo to Concordia Excerpts (August 25, 2005 site visit):

- *"Work was underway to intercept and divert seepage in the vicinity of Stas. 3+10 and 3+40 along L-100* [Gale Avenue North at Lots 9, 10, 20, 21]. *Preparation was underway to install a concrete manhole on the south side of L-100 near Sta. 3+10* [Thurber infers likely Manhole 10]. *The sinkhole uncovered at about Sta. 5+20 on L-200 had been partially backfilled; a layer of mass concrete was placed at the base with compacted locally excavated glacio-marine sediments above."*
- *"Where Manholes are installed as part of the interceptor drain systems, the subgrade soils are susceptible to rapid softening and degradation of strength where exposed. It is recommended that…a sheet of minimum 3/4-inch plywood by placed on the subgrade surface followed by 4 to 6 inches of ¾ inch clear crushed gravel as bedding"* [Thurber notes that a sketch was provided but there was no discussion about the use of a proper geotextile / granular filter, or temporary dewatering]
- *"Where water-softened conditions spread faster than the softened material can be removed, particularly along the outflow pipe trench from the manhole, it is recommended that a 2-foot layer of 8-inch minus rock be placed as a stabilizing base for the pipe bedding and trench backfill."*

September 17, 2005 GeoTacTics Memo to Concordia Excerpts (September 8, 2005 site visit):

- "*Initial fill placement for the L-100 turn-around* [Gale Avenue North round-about] *is following the recommendations for the drainage blanket at the base of the site grading fill and is satisfactory. The procedure involves placing an 18-inch basal layer of 3/4-inch clear crushed gravel on the stripped surface. The recommended 3-inch minus rock for the drainage blanket is no longer available and the ¾-inch clear crushed gravel is a suitable substitute. Filter fabric is placed on top of the gravel and then a layer of clean uniform sand from local excavation is placed."* [Thurber notes that geotextile / filter fabric was placed above drainage blanket and not between the native soil and drainage blanket]

- "*New areas of seepage have been encountered near Sta. 2+60 along L-100."* [Gale Avenue North at Lots 7, 23]

September 17, 2005 GeoTacTics Memo to Concordia Excerpts (September 15, 2005 site visit):

- *"At the time of the site visit, a section of the slope above Sta. 2+60 along L-100 had slid* [Gale Avenue North at Lot 23]*. The slide area was about 20 m in length and extended from the old logging road used by haul vehicles down to L-100 grade. A new spring with heavy flow had been uncovered at the toe of the slope prior to the slide. Based on visual estimate the flow from the new spring was in the order of 100 to 150 gpm."*
- *"In order to control the spring area at the base of the slide, it is recommended that slop below the spring be carefully removed to expose relatively undisturbed native soil. A layer of filter fabric should be placed on the stripped surface, followed by 3 feet of ¾-inch clear crushed gravel. A 12-inch layer of 6-inch rock should then be placed over the gravel as additional weighting material."*

October 5, 2005 GeoTacTics Memo to Concordia Excerpts (Sept. 28 and 30, 2005 site visits):

- *"GeoTacTics Engineering Ltd. and GES Geotech Inc. completed a Site Reconnaissance on September 30, 2005 to assess the tension cracks that were first observed on September 28, as well as to provide engineering recommendations to address the very large groundwater flows at the toe of the slope. A copy of the September 28, 2005 Site Reconnaissance Report by GES Geotech was handed to Tom Dolker* [Concordia Homes] *upon arrival." [*Thurber was not provided the referenced report from GES Geotech Inc.]
- *"the subject tension crack is located across a section of the L-200* [Seawatch Lane] *…now assessed to correspond to approximate Sta. 4+40* [near Lots 20 and 21]
- *"The extent of the crack in plan was…..approximately 40 – 50 m… in the shape of an arc."*
- *"The very large volume of groundwater that was observed* [inferred September 28] *exiting the toe of the slope in the eastern portion of the site was still continuing. The volume of flow has been estimated to be in the order of 200 gpm (1000 l/min.). Further, the volume of sand that was being washed out at this location had increased substantially. Based on a visual estimate….about 70 m^3 of sand per day. The 1-ft (0.3 m) rock that had been placed as a temporary means of helping stabilize the toe was found to have been partially covered with the sand that was being washed out."* [Thurber notes that this spring was apparently later surveyed to be at the north property line on Lot 21 near Sta. 3+00]
- *"A concept design was provided on site to address the issue of the large volume and flow of groundwater at the slope toe."* [Thurber notes that details of the referenced concept design were provided in the text of GeoTacTic's memo. It is also noted that the use of geotextile / filter fabric was not specified.]

October 7, 2005 GeoTacTics Memo to Concordia Excerpts (October 4 and 7, 2005 site visits):

- *"Seepage from the spring* [on north property line of Lot 21 near Sta. 3+00] *was continuing unabated, and efforts to buttress and filter the spring had been temporarily abandoned."*

- *"At the time of the October 7 site visit….. two sink holes had developed along the tension crack at the L-200 level."* [later surveyed to be near south edge of Seawatch Lane near Sta. 4+05 adjacent to Lot 19, and the other inferred to be the sinkhole shown on Lot 21 at El. 43.59 m]
- *"two other sinkholes were observed on the property."* [later surveyed to be on Gale Avenue North near property lines with Lots 24, 25 and the other on Crowston Road east of Lot 28]
- *"It is recommended that, rather than continually fighting the seepage and slope instability that are occurring as a result of excavation grade for L-100 being located at or below the line of spring activity, the grade of the road be raised by up to 5 m through the low area….. between about Stas. 2+60 and 3+70"* [Lots 7 through 11 and 19 through 23].
- *"The required drainage and buttressing of the spring area at the base of the slope would then be accomplished by extending the previously recommended rock and drain rock layers beneath the road fill to create a continuous drainage blanket beneath the road to a location where the seepage can be more conveniently collected."*

In a report from GeoTacTics to Concordia dated April 28, 2006, a total of 8 sinkholes were shown on a figure which had daylighted across the site up to that date. However, only 5 of these were described in documents available to Thurber. The 3 undescribed sinkholes lie on Lot 21. With regards to the spring near Sta. 3+00 at Lot 21 first noted in the October 5, 2005 Memo, the report states:

> *"It took 4 weeks to successfully construct a stable filter and buttress over the spring."* [Thurber notes that, based on GeoTacTics estimated soil volume loss of 70 cubic metres per day, this totals on the order of 2000 cubic metres soil over the 4 weeks]

It is unclear to Thurber what criteria was used to define a stable filter and buttress.

GeoTacTics provided Concordia with a May 9, 2006 addendum to the April 28, 2006 report, discussing sinkhole observations and treatment methods used.

Thurber's review of a June 23, 2006 low resolution air photo available on Google Earth suggests the site had by this time been substantially cleared of vegetation but that construction of house foundations had not yet commenced.

4.3 Construction Period: 2007 to June 1, 2012

A field review memo from GeoTacTics to Concordia dated June 1, 2007 contains the following excerpts:

- *"A layer of large (12- to 36-inch) rounded rock had been placed across the storm outfall corridor between Lots 9 and 10 to build a working pad for equipment and haul units."*

- *"The large rock for the access working pad had punched into the base in many places and saturated silt and fine sand had oozed to the surface through the gaps between the boulders."*
- *"Where additional fill is subsequently required above the access rock pad over the storm outfall corridor, a layer of ¾-inch clear crushed gravel is recommended to grade and level the surface in preparation for additional filling."* [Thurber notes that the memo did not include a discussion about the use of a proper geotextile or granular filter]
- *"Lot 10….had been stripped of organic debris and topsoil to a depth of about 12 to 18 inches, exposing the undisturbed marine silt and fine sand. Water-bearing lenses were exposed in the process."*
- *"Seepage flowed in braided channels over the surface, carrying with it a slurry of silt and sand."*
- [Regarding site preparation on Lot 10] "*The revised section would consist of a base layer of geotextile (Propex 2006 woven geotextile as supplied by Nilex, or available equivalent) placed immediately following stripping of softened soil from the surface of the test area. Over the geotextile, a 6-inch layer of ¾-inch clear crushed gravel would be spread as a weighting and drainage medium. On top of the clear crushed gravel, a 3-foot layer of well-graded 6-inch minus rock fill would be placed as the main ballast zone."* [Thurber notes that this is consistent with description provided in Golder's Nov. 15, 2012 report]

A facsimile from Web Engineering Ltd. to GeoTacTics dated June 8, 2007 notes that a sinkhole was noticed to be developing during a June 7, 2007 site visit on Lot 29 (proposed Phase 2 development) south of Seawatch Lane.

A letter from GeoTacTics to Concordia dated August 31, 2007 summarizes geotechnical inspections in July and August 2007. Select observations and comments, considered relevant to the current investigation, are quoted below organized by date of site visit. The source letter should be referred to for additional information.

July 18, 2007 GeoTacTics Site Visit on Behalf of Concordia:

- *"site preparation for the shoreline Lots 1 to 12, including construction of the drainage blanket beneath the site grading fill, had progressed eastward to about the center of Lot 5 as far as the major spring that had developed. The spring had been monitored for the previous 6 weeks and was discharging sediment-laden water. Several issues with the building of the drainage blanket were identified from experience with a similar spring north of L-100 on Lot 9 and 10. These issues were identified as the rapid deterioration (softening and erosion) of the subgrade after stripping and the build-up of water pressure as the spring was plugged."* [Thurber notes that this is similar to comments in Golder's Nov. 15, 2012 report regarding a possible trigger for the 2012 Lot 3 spring]
- *"Seepage from the covered spring is picked up and conveyed in a non-perforated drain pipe, separate from the main storm drain system, to discharge at the shoreline."*

- *"the sinkhole located on Lot 29 was inspected….the sinkhole had expanded significantly….since its discovery"*

July 23, 2007 GeoTacTics Site Visit on Behalf of Concordia:

- *"GeoTacTics' observed Concordia Homes Ltd. excavate, plug, and fill the sinkhole* [at Lot 29] *as per our previous recommendations. The final extent of the excavated area was significant, approximately 10.5 m deep and 12 m in diameter. GeoTacTics was directed not to chase the neck of the sinkhole beneath L-200* [Seawatch Lane]*, in order to limit the risk of undermining the existing services and road structure."*

August 2, 2007 GeoTacTics Site Visit on Behalf of Concordia:

- *"GeoTacTics was called upon to inspect the foundation for the stacked rock retaining wall adjacent to L-100 along Lots 24 through 27. At the time of the site visit, the stacked rock wall was about two thirds near completion. It was observed that this section of the retaining wall was not constructed to the design specifications laid out by GeoTacTics in the April 28, 2006 Geotechnical Report. In addition, no drainage along the base or behind the wall was constructed and no geotextile was used."*

On August 29, 2008 a site visit was conducted by Thurber on behalf of the District to complete a geotechnical engineering review of the relatively high rock stack retaining walls at Lots 19 to 25. Thurber's subsequent report to the District dated December 15, 2008 presented the results of this assessment which raised concerns regarding the assumptions made in the stability assessment by GeoTacTics and with the construction of the slope to the north of Lots 22 through 25. Specifically concerns were raised regarding the proximity of the constructed house foundations to the wall crest and the proximity of Gale Avenue North to the wall toe. In addition, comments were provided on the potential for formation of sinkholes at this site.

In a memorandum from GeoTacTics to Concordia dated January 17, 2009 a series of shallow slides were described on the constructed intermediate soil slopes between rock stack walls on Lot 25. The slides reportedly occurred on January 9. Surface erosion was also noted immediately north of Seawatch Lane adjacent to Lots 18 and 19.

In a series of memoranda from GeoTacTics to Concordia dated within the month of February 2009, shallow slope instabilities and surface erosion within constructed fill slopes and stockpiled fill were noted by GeoTacTics on Lots 1, 9 and 10.

A memo from GeoTacTics to Concordia dated March 7, 2009 states that:

"*final lot grading has not been completed on any of the 12 lots"* [Lots 1 through 12].

In a memo from GeoTacTics to Concordia dated June 17, 2009 the following was stated:

- *"The required underdrain was built for Lots 7 to 12 during the 2008 construction season."* [The 'underdrain' is assumed to refer to drainage blankets. Construction record documents from 2008 were not available for review by Thurber.]

- *"The required drainage blanket is in place beneath the site grading fill for Lots 3 to 5. As yet there is no drainage beneath the northern toe of the site grading fill being placed on Lots 1 and 2. The recommended interceptor drain at the toe of the site grading fill on Lots 3 to 6 is not yet complete and connected to the storm drain system."* [Thurber notes that based on available reports, it is unclear if / when / how this work was completed]

In a memo from GeoTacTics to Concordia dated July 21, 2009 the following was stated:

> *"On Lots 1 to 12, the site grading has satisfactorily buttressed the slope on the northern side of L-100, and there is no risk of catastrophic undermining of the road and the services buried beneath the road."*

A memo from GeoTacTics to the District dated June 5, 2012 describes a site visit on April 2, 2012 to visually inspect a sinkhole near the north curb of Gale Avenue North at Lot 9. The hole was described as 1.5 m square and 0.60 m deep with a cavity extending below Gale Avenue North. The memo reports that a section of asphalt 12 m long and 3 m wide was removed, and the cavity filled with compacted road base fill and the asphalt restored. Thurber notes that, based on the description and photographs, the location of this feature appears to be consistent with the location of settlement / sinkhole activity noted in November 2014, and February 2015.

Based on Thurber site visits described in the following section, house construction had not yet commenced on Lot 9 in June 2012.

4.4 Construction Period: June 1, 2012 to April 2013

According to verbal accounts from District staff and residents, a spring carrying significant quantities of sand and silt developed on Lot 3 on May 26, 2012 and on June 1, 2012 a sinkhole daylighted on Seawatch Lane adjacent to Lot 28 at about Sta. 5+080. Following the sinkhole collapse event, the District retained Thurber to provide geotechnical input. Thurber commenced regular inspections of the site beginning on June 2, 2012.

On behalf of the District, Thurber coordinated with Terraprobe Geosciences Corp. to conduct a screening level geophysical survey on June 5 and 6, 2012 of the site roads and select areas of Lots 27 and 28 to try to detect near surface voids. The survey was conducted using high frequency (250 and 700 MHz) ground penetrating radar (GPR), which provided relatively high resolution data, but depth of penetration was limited to about 3 m below ground surface. A number of anomalies were identified from the survey and described in a report by Terraprobe dated June 15, 2012 (attached to Thurber's report dated July 20, 2012).

The outline of the aforementioned July 20, 2012 Thurber report included: a discussion of the geotechnical hazards at the site including sinkholes; advised that the formation or daylighting of additional sinkholes at the site should be anticipated; a discussion of possible options for addressing the sinkhole hazard at the site and; recommendations for a phased geotechnical, hydrogeological and geophysical investigation to provide a basis for repair works. The report also raised concerns regarding the design and construction of drainage blankets and filters

across the lower slope, including the potential for erosion of the native soils at the interface with the drainage blankets. A discussion of potential options for repair of the drainage blankets and site dewatering was included in the report.

Concordia engaged Golder Associates Ltd. (Golder) to provide geotechnical engineering services in September 2012. A drilling investigation was completed under GeoTacTics direct supervision with oversight and direction from Golder from September 20 to 25, 2012. This investigation included the completion of 9 auger holes distributed across the site and the installation of groundwater monitoring wells at 8 of those locations. Golder summarized the results of the investigation and a geotechnical assessment of the site in a report dated November 15, 2012 issued to Concordia. Golder's assessment of the filters and drainage blankets on Lots 1 to 12 noted:

> *"it is considered likely or probable that, although it would provide suitable retention of soil particles within the sands and silts at this site, the Nilex 2006* [geotextile] *would not be capable of permitting the free flow of water into the drainage blanket within areas of concentrated seepage, such as the spring at Lot 3. It is also considered likely that a spring could develop due to a build-up of excess water pressure under the geotextile and drainage blanket until the blanket was displaced and/or the geotextile ruptured or individual sheets pulled apart."*

On behalf of the District, Thurber coordinated with Frontier Geosciences Inc. to complete geophysical surveys at the site from November 28 to December 6, 2012. Geophysical methods included the use of streaming potential and resistivity techniques. The survey results identified geophysical anomalies which were discussed in Frontier's report dated December 2012, (appended to Thurber's April 5, 2013 report). Generally, the geophysical investigation concluded that the general groundwater regime is consistent with assumptions and that expected wetter / drier zones were positively identified. It was recommended that, if these geophysical methods were to be used again at this site, geophysical survey work should be completed during the drier summer months.

Thurber conducted a supplementary drilling investigation between January 28 and February 1, 2013 consisting of fifteen test holes in eight test areas and the installation of 4 groundwater monitoring wells. The supplementary drilling was to investigate geophysical anomalies and sinkhole locations identified during previous investigations, as well as to further characterise the site geological, hydrogeological and groundwater conditions. The results and findings of the investigation were provided to the District in a report dated April 5, 2013.

The April 5, 2013 Thurber report reviewed rainfall data and observed that previous spring and sinkhole events typically occurred a few days after a period of significant rainfall. It was also noted that groundwater levels across the site respond to sustained rainfall events. The report noted that, generally, average hydraulic gradients at the site at that time were in the range of 0.1 to 0.2 south of Gale Avenue North and tended to increase northwards. It was inferred that portions of the current filter arrangement on the site were not performing as intended, based on the observed springs and sinkhole. It was also inferred that the critical average hydraulic

gradients have been exceeded on the site, for the in situ sandy silt/silty sand and sand deposits, resulting in actual piping of material and the development of sinkholes.

The April 5, 2013 report concluded that, while the investigations did not detect any voids below the site, this should not be inferred to imply that there are no voids. The report recommended that further monitoring and investigation be conducted on each lot prior to constructing additional houses. The report recommended conducting further investigations of the overall site to determine the extent of the drainage filter, how much of it must be reconstructed and to ensure that the replacement filter is capable of preventing piping and sinkhole development. Monitoring of filter performance was recommended to develop confidence in the robustness of the filter. Additional recommendations included more frequent monitoring of groundwater levels and the completion of surface surveying, particularly where sinkholes are known to have occurred.

Regular site visits by Thurber continued until March 5, 2013. It is noted that Thurber's involvement with the site on behalf of the District ceased following issue of the April 5, 2013 report.

In a letter dated March 14, 2013 from Baker & Baker, Barristers and Solicitors to Lidstone and Company Law Corporation it was stated:

> *"Concordia will retain Golder Associates ("Golder") as its Engineer of Record for the completion of Phase I. As recommended by Golder, Concordia will at its expense, remediate the Sinkhole and will take such measures as Golder recommends to repair the spring on lot 3 and any underground cavities which may be associated with the Sinkhole or the spring."*

Thurber understands the above reference to the 'Sinkhole' to refer to the 2012 sinkhole on Seawatch Lane.

4.5 Construction Period: May 2013 to February 2015

A seepage mitigation system was constructed on Lot 3 by Concordia on August 3, 2013 under Golder's supervision. The 2012 Seawatch Lane sinkhole, adjacent to Lot 28 and Lot 29, was treated using geogrid reinforcement mats. This work was completed on September 10, 2013 under the supervision of Golder, according to a letter from Golder to Concordia dated November 14, 2013. The sinkhole treatment and seepage mitigation system as-built drawings are dated June 11, 2015.

Photographs and information from residents indicate that, on November 4, 2014 (Photo 1), a depression up to 0.25 m deep (estimated from photographs to be about 1 m by 2 m in plan) was observed behind and below the south Seawatch Lane curb adjacent to Lot 29 (south of Lot 28). The reports also indicated minor deflection and cracking in the adjacent asphalt. During heavy rainfall on November 6, 2014 a resident reported that precipitation runoff was observed to be flowing into the depressed area and that silty water was also discharging from the storm outfall northeast of Lot 1. Photographs of the depressed area taken on November 12, 2014 were

provided to Thurber by the District, and are presented as Photos 2 and 3. According to information from neighbouring residents, on November 14, 2014 concrete was pumped into the void below the curb and the depressed area was backfilled by Concordia (Photo 4). On December 4 and 22, 2014 a berm was apparently constructed by Concordia over the backfilled depression, likely intended to direct runoff precipitation away from the area. Minor, but slowly increasing, settlement of the asphalt adjacent the backfilled depression was noted by residents, and later in 2015 by Thurber as reported in field inspection reports.

Subsidence was noted by the District on November 12, 2014 beneath Gale Avenue North adjacent to Lot 9 and beneath the Lot 9 concrete driveway as shown in Photos 5 and 6. A letter from Western Geotechnical Consultants Ltd. (Western Geotechnical) to the District dated February 27, 2015 discusses the settlement noted in November 2014 and temporary measures taken at that time as quoted below:

> *"Verbal recommendations for monitoring and further investigation had been provided to the developer. A temporary solution involving high slump concrete had been proposed and implemented by the developer to ensure that the road remained functional during the investigation and review period."*

Information from a resident indicates that this work near Lot 9 was completed on or about November 14, 2014.

On Lot 21 in November 2014, a verbal account from the owners of this Lot included observations of cracks in the concrete driveway and drywall surfaces in the house. Otherwise, no observed surface settlement was noted by the residents in front of the house.

Refer to Table 1 for a chronological list of select events and observations.

5. RECENT EVENTS

In the period of February 5 to 13, 2015, about 108 mm of rainfall was recorded (Environment Canada National Climate Data) at the Sechelt AUT weather station, about 8 km southeast from the site (shown on Figure 1).

On February 14, 2015 a magnitude 3.4 seismic event was recorded about 29 km northeast of the site (Natural Resources Canada, public earthquake records).

Around 7:00 AM on February 26, 2015 a sinkhole was observed to have daylighted on Lot 21 adjacent to the front of the house (Photo 7), according to a letter from Western Geotechnical to the District dated February 27, 2015. The letter reports that the sinkhole was approximately 2 m deep and 5 m by 6 m in plan with evidence of a larger affected area. Deflection of the house foundations and cracking of the concrete driveway and interior finished surfaces were noted. The house on Lot 21 was evacuated. At the time of writing, the evacuation of the house remains in effect.

On the same day, subsidence was observed by Western Geotechnical to have reactivated beneath Gale Avenue North and adjacent to Lot 9 (Photo 8), in the same area noted in November 2014. Sediment laden water was observed to be discharging out of the storm sewer outfall which runs between Lots 9 and 10. As a precaution, Gale Avenue North was closed to traffic between Lots 9 and 21 with local traffic detoured to Seawatch Lane. The closure of this section of Gale Avenue North remains in effect.

At the request of the District, Thurber began regular inspections of the site, starting on February 27, 2015. The inspections included visual review of the site and the collection of groundwater level data from the accessible groundwater monitoring wells installed in 2012 and 2013. Interim inspections were also conducted by District personnel. The Thurber inspection reports are attached for reference in Appendix 1 and a few significant observations are discussed below.

Groundwater levels were noted to have risen significantly in upslope areas since the last readings were taken in 2013, particularly adjacent to Lots 21, 22, 28 and above Lot 3. On the Lots north of Gale Avenue North, springs and wet areas were noted during inspections, and later surveyed. Over an area about 2 m by 2 m in plan a depression was noted in the asphalt in the area of the 2012 Seawatch Lane sinkhole and adjacent to the approximate area of the November 2014 curb repair. A survey grid was created on Seawatch Lane in this area and survey pins later installed to facilitate monitoring of surface deformation (Figure 3). By July 8, 2015 the affected area had expanded to about 3 m by 2.5 m in plan. As a precaution, the south (eastbound) lane of Seawatch Lane was temporarily closed to vehicle traffic in this area.

Figure 4 highlights observations and features of geotechnical interest based on Thurber's recent site inspections, and also includes past features taken from Dwg. 14-214-2-1 of Thurber's July 20, 2012 report. For visual clarity the locations of previous slope instabilities, the most recent of which apparently occurred in 2009, have not been included on Figure 4. Such detail, if required, can be found in Thurber's April 5, 2013 report.

As a temporary safety measure, on March 6, 2015 the District backfilled the sinkhole on Lot 21, on behalf and with permission of the Lot 21 owners. Prior to backfilling the affected topsoil and landscaping were removed. Backfill material comprised well graded sand with gravel (as shown in test hole log TH15-23, presented in a later section). As this work was completed as a temporary emergency measure, the backfill was not compacted. The backfilled sinkhole was covered with polyethylene sheeting to mitigate the infiltration of surface water.

To investigate the source of the suspended sediment noted to be discharging from the storm sewer outfall between Lots 9 and 10 on February 26, 2015, the District retained ABC Pipe Cleaning Services Ltd. (ABC Pipe Cleaning) to complete a video camera survey on March 19, 2015. Inspection included the storm sewer line between Lots 9 and 10 between manholes 10 (south of Gale Avenue North) and the storm outfall to the north. Manhole 12, which is located north of Gale Avenue North, could not be located as it may have been buried with fill during construction (survey suggests about 3.3 m of cover). Attempts by the District to locate manhole 12 were unsuccessful. The results of the camera survey suggested that the current profile of the storm line differed significantly in some segments from the 'as-built' profiles that the District has

on file. A number of drains were observed in the survey to enter the storm line, though drawings or construction records of these drains were not available. Indications of damage to the pipe and infiltration of groundwater were noted by ABC Pipe Cleaning between manholes 12 and 4A (which is located near the storm outfall). The existing ground surface profile was surveyed by Strait Land and a cross section produced dated March 23, 2015. The District later annotated the section with observations from the camera survey. This annotated section is included in Appendix 2.

6. 2015 INVESTIGATION

6.1 Drilling Investigation

The District commissioned Thurber to conduct a drilling investigation to provide a basis for a geotechnical assessment of the closed section of Gale Avenue North between the sinkholes on Lot 21 and adjacent to Lot 9. Test holes were also drilled on Lot 28, with the owner's permission, to address concerns regarding the observed subsidence in the asphalt in the area of the 2012 Seawatch Lane sinkhole repair.

The drilling investigation was limited in duration and scope, constrained due to the high density of utilities in the area and the presence of private property and structures. Test holes were drilled at 29 locations (TH15-01 through TH15-29) on April 13 to 17, 2015 using a track mounted auger drill rig operated by Downrite Drilling Ltd. The surface locations and elevations of the test holes were surveyed by Strait Land on April 27, 2015 and are shown on Figure 5. Previous drilling and test pitting investigations are also shown on Figure 5 for reference. The locations of groundwater monitoring wells are also shown. Greater detail is provided in the Gale Avenue North area on Figure 6A and in the 2012 Seawatch Lane sinkhole area on Figure 6B.

The test holes were typically drilled using solid stem auger methods. TH15-01 was drilled using both solid stem and hollow stem auger methods. The soil and groundwater conditions were logged by a Thurber geotechnical engineer. The test hole logs present the results of the drilling investigation and are included in Appendix 3. Representative disturbed samples of the soils encountered were collected from the auger flights or the SPT sampler at regular intervals and returned to our laboratory for testing. Routine visual classification, water content and fines content (percent passing the 75 µm sieve) determination were completed and are displayed on the test hole logs. Grain size analyses were performed on 9 selected samples and the test results are included in Appendix 4. Groundwater conditions were noted where observed in the test holes during or following completion of drilling.

A Dynamic Cone Penetration Test (DCPT) was typically completed prior to augering at each test hole location. The DCPT tip is similar in size and shape to the Standard Penetration Test (SPT) split spoon sampler and is driven using the same hammer. DCPTs provide a qualitative estimate of in situ density for granular soil and are useful for identifying stiffness and strength contrasts within and between different strata. However, the DCPT is not a standardized test and cannot be used to determine the actual in situ density or strength of granular soil.

The DCPT was found to be an effective tool for investigation of affected areas surrounding known sinkholes and was therefore used extensively during this investigation. An inherent limitation of the DCPT is that hammer blow counts are typically counted per 300 mm of penetration ('N' values), thus the maximum vertical resolution of the profile is limited to 300 mm increments.

All test holes were backfilled with drill cuttings and bentonite chips, in general compliance with the BC Groundwater Protection regulations.

6.1.1 Gale Avenue North

A total of 24 test holes were completed in the Gale Avenue North area adjacent to Lots 8, 9, 10, 20 and 21 as shown on Figure 6A. Seven of these included substantial augering for the investigation of soil stratigraphy and groundwater conditions.

Nineteen test holes required drilling through the existing asphalt on Gale Avenue North. Typically the asphalt and initial 0.5 to 1 m of road fill was removed (initial drill-out) prior to commencement of the DCPT to avoid damage to the drilling equipment and to avoid premature refusal of the test on a hard layer. In some cases, where the near-surface fill was found to be very dense, the initial drill-out was increased to maximum depths of 4 m to investigate for evidence of soil loosening below the near-surface fill. Premature auger refusal was encountered at TH15-15 due to the presence of relatively dense, coarse granular fill (interpretation of this observation is discussed in Section 8). These observations are identified on the test hole logs.

A groundwater observation well / standpipe piezometer (TH15-03) was installed on Gale Avenue North adjacent to Lot 10 to add to the existing groundwater monitoring network at the site.

Three test holes were drilled within the road allowance north of Gale Avenue North adjacent to Lot 9. A DCPT (TH15-29) was advanced within the apparent boundaries of the sinkhole adjacent to Lot 9. The DCPT at TH15-14 was terminated prematurely due to a drilling equipment breakdown.

A test hole (TH15-13) was also drilled within the storm sewer Statutory Right of Way between Lots 9 and 10. The test hole and DCPT were terminated prematurely due to refusal on an obstruction believed to be a cobble or boulder (interpretation of this observation is discussed in Section 8).

A test hole (TH15-23) was drilled within the apparent boundaries of the backfilled sinkhole on Lot 21 with the owner's permission. The purpose of this test hole was to investigate the depth to which soil loosening was apparent and to log the soil stratigraphy and groundwater conditions at this location for comparison with drilling data collected on Gale Avenue North.

6.1.2 Lot 28 near Seawatch Lane

Test holes were drilled at 5 locations (TH15-24 through TH15-28) on Lot 28 in a line paralleling Seawatch Lane, as shown on Figure 6B. All test holes were located approximately 6 m from the back of the north curb of Seawatch Lane. This setback was required to avoid contacting or damaging the geogrid reinforcements used in the 2012 Seawatch Lane sinkhole repair. The setback distance was determined based on a telephone conversation with Golder.

DCPT profiling was challenging at the test hole locations on Lot 28 due to dense surficial soils. Pre-augering was required to form a pilot hole through the dense surficial soils prior to attempting a DCPT. Soil cuttings on the augers were typically heavily disturbed due to the challenging drilling conditions. In some instances an SPT was completed prior to commencement of the DCPT to gauge the suitability of the conditions for a DCPT.

6.2 Geophysical Investigation

Initial review and interpretation of the results of the drilling investigation provided a greater level of detail and understanding of the loosening around the recent sinkholes, within the narrow areas investigated, then was previously available. Due to the ability of geophysical methods to cover larger areas more efficiently than drilling, a preliminary geophysical investigation was commissioned. The investigation focussed on areas recently drilled in order to calibrate geophysical methods to the soil conditions of interest (soil stiffness) identified in the drilling investigation. Based on the calibration, the methods were used to evaluate other limited areas along the roadways to determine the suitability of geophysical methods for use across the overall site as a screening tool to scan for potential zones of loosening or voids that have not been identified. Site-wide screening was not part of the scope of the current geophysical investigation.

DMT Geosciences Ltd. (DMT) selected the geophysical methods to complete the investigation. All available previous surveys and drilling investigations were provided to DMT to aid their assessment. DMT ultimately selected ground penetrating radar (GPR) which included the use of low frequencies (80 MHz and 160 MHz), and multichannel analysis of surface waves (MASW) methods.

The geophysical investigation was completed from May 26 to 29, 2015 by DMT. The investigated lines were later surveyed by Strait Land on June 1 and June 12, 2015. DMT submitted a report on this investigation, dated July 14, 2015, which is included in Appendix 5.

Where possible, geophysical survey lines were selected to intersect drill hole surface locations. The geophysical surveying was focussed primarily within the areas of the drilling investigation on Gale Avenue North and on Lot 28. These survey lines were extended, beyond the drilling locations, as site access and time constraints allowed.

Additional geophysical surveying was also completed in the area of the 2012 Seawatch Lane sinkhole to investigate the recent subsidence and cracking observed in the asphalt. GPR was also used to conduct preliminary scans along additional lines on Gale Avenue North, Seawatch

Lane, and on Lots 9, 20, 21, 27 and 28 with the owners' permissions. A plan showing the locations of geophysical survey lines is provided in the DMT report.

The geotechnical interpretation of the geophysical results will be discussed in Section 8.

7. GEOTECHNICAL SITE CONDITIONS

7.1 Regional Geological Setting

The BC Ministry of Energy, Mines and Natural Gas online BCGS Geoscience Map indicates that the site is underlain by dioritic intrusive rocks of Late Jurassic Age.

However, surficial overburden present on the site prevented accurate mapping of the bedrock within the site footprint. Bedrock has not been encountered within the depths of any of the drilling investigations at the site. The deepest test holes completed were up to about 20 m near the south and middle of the development and up to about 10 m in the lower slope area.

Based on presently available information, the composition, structure and depth of the bedrock are not considered significant to the formation of sinkholes at this site.

Regional surficial geology maps suggest that the site is generally underlain by a complex sequence of glacial moraine and glacial marine sediments which include gravel, sand, silt and minor clay which were likely overridden by glacial ice during the last ice age. Recent investigations have enhanced our understanding of the surficial geology at the site.

For a more detailed discussion of the bedrock and regional surficial geology, please refer to the April 5, 2013 Thurber report.

7.2 Regional Groundwater Hydrology

Specific subsurface data was not available for the assessment of groundwater flow beyond the limits of the site. Therefore, inferences are based on available remote sensing data.

Groundwater and surficial flows are likely to approach the site primarily from the south, approximately following the surface topography. The groundwater recharge catchment area (analogous to a watershed) may extend beyond Heritage Road to the south, and is likely bounded by a ridge feature to the west and possibly by a minor ridge feature to the east as depicted in Figure 7. This area totals about 1 square kilometre and includes a substantial agricultural grazing area cleared of substantial tree cover sometime before 2004 according to available air photos. As groundwater flow patterns often do not coincide with surficial topography, the actual groundwater catchment may differ substantially from that depicted.

Groundwater and surficial flows approaching the site from the northwest are expected to be largely intercepted and diverted eastwards by Snake Creek and the Snake Creek Fault toward Sechelt Inlet.

7.3 Site Conditions

7.3.1 General

The site geology discussed in Thurber's April 5, 2013 report has been updated based on the results of the recent drilling investigation. Test hole logs from the 2015 investigation are included in Appendix 3. For completeness, test hole/pit logs and grain size analyses from previous investigations by Thurber and from other third party reports are included in Appendices 6 and 7, respectively. The test hole logs provide detailed descriptions of the soil encountered and should be used in preference to the generalized descriptions provided in the text of this report.

Geological sections (labelled A-A through G-G) were generated from the test hole logs through the Seawatch development site and are presented as Figures 8 to 14. The locations of these sections are depicted in plan view on Figure 5. For visual clarity only select test hole locations and soil columns are depicted on these sections.

Within the areas recently investigated, Figures 15 to 20 present geologic cross sections labelled H-H to M-M, which include DCPT profiles. The locations of these sections are depicted in plan view on Figures 6A and 6B.

The features and descriptions depicted on the sections are discussed in the following sections.

7.3.2 Native Soil

The recent drilling investigation encountered relatively significant variability in the composition and position of geological strata (soil groups). This variability suggests a high degree of complexity at the site. The native soils were typically bedded and well sorted (containing a relatively small variation in particle sizes) which is consistent with a glacial-marine/glacial-fluvial depositional environment as described in the regional surficial geology maps.

For discussion purposes in this report, the native soil sequence encountered at the site has been divided into the following soil groups listed in order of increasing depth from ground surface:

1. Upper Sand
2. Upper Silty Sand / Sandy Silt
3. Lower Sand
4. Lower Silty Sand / Sandy Silt
5. Basal Silt

A description of these soil groups and where they were encountered is summarized on Table 3. This generalized sequence was compiled from the available drilling data throughout the site. Actual conditions varied locally within the test holes. The complete sequence (soil groups 1 to 5) has not been encountered in any single test hole completed at the site. The overlying soil groups in this sequence are typically absent in lower areas of the site.

A relatively well graded gravelly sand and silt deposit including cobbles (interpreted to be moraine till) is exposed at the top of a road cut at the southwest perimeter of the site and in the borrow pit area about 200 m to the south of site. Both exposures are higher in elevation than Seawatch Lane, are relatively thin (on the order of a few metres), and are seen to be overlying the Upper Sand deposit. The 2005 test pit logs describe materials which appear to be consistent with the moraine till. The test pits were completed prior to construction and encountered the material at high and low elevations within the site. However, the moraine till was not encountered in any test hole logs after site grading was completed. It is theorized that this unit may have existed as a relatively thin non-conforming mantle, overlying all of the soil groups described.

The density/consistency of in situ native soils, where loosening due to the sinkhole formation process was not evident, was typically dense to very dense or stiff to very stiff. This is consistent with the glacially overridden regional context. Within the areas investigated, the soil density / consistency was found to be substantially less in some test holes and particularly in close proximity to the recent sinkholes. Interpretation of these results will be discussed in Section 8.

7.3.3 Site Grading Fill

Gradation of the site grading fill was found to be variable, typically ranging from gravely sand with some silt to sand and silt with some gravel and occasional cobbles and wood debris. Grain size analyses were completed on samples of site grading fill collected during the 2015 drilling investigation in the Gale Avenue North area. Gravel content in the site grading fill varied between about 15% and 30% in tested samples. Fines content in tested samples of the site grading fill varied from about 25% to 45%.

The notable contrast between the native soil and site grading fill is the gravel content. Gravel was generally absent or present only in trace amounts in the native soils. Other distinguishing features of the site grading fill include a broader range of particle sizes and a lack of apparent bedding structure relative to the native soil. As discussed in Section 7.3.2, some of the site grading fill likely is the moraine till deposit excavated from the borrow pit south of the development or elsewhere on the site, reworked and re-placed as fill.

The interpreted fill thickness ranges from 0 to about 10 m thick across the site, as shown on the geological sections (Figure 8 to 20). The fill was thickest near the middle of the site, to the north of Gale Avenue North. The encountered fill thickness in this area varies significantly from the anticipated fill thickness at Lots 1 through 12 shown on the ‘as-built’ drawings dated January 12, 2009 (Web Drawing 1437-G-01 Rev. 4, included as Appendix 8) provided to the District. A memo from GeoTacTics to Concordia dated March 7, 2009 states that:

> “*final lot grading has not been completed on any of the 12 lots”* [Lots 1 through 12].

From the limited available records it is surmised that additional fill was later placed in this area prior to the construction of houses. This may explain the difference between the 'as-built' and actual fill thickness.

7.3.4 Filters and Drainage Blanket

Thurber's understanding of the available construction records suggests that drainage blankets were typically used at the site where seepage and spring issues were encountered, specifically along Gale Avenue North, on Lots 1 through 12, and later on Lots 13 through 15. The design and materials used in the drainage blankets varied over time and in response to encountered challenges. As-built records related to drainage blanket construction were not available to Thurber.

Thurber's recent drilling investigation on Gale Avenue North did not recover soils consistent with the drainage blanket. However, the drill experienced auger and / or DCPT refusal within the site grading fill at several locations. Based on the drilling depth and our understanding of the site conditions, it is inferred that refusal was likely encountered at the top of one of the drainage blankets which are reported to comprise coarse gravels, cobbles or boulders.

7.3.4.1 Gale Avenue North

Regarding site drainage and the placement of site grading fill, where necessary for roads and building pads, the April 28, 2006 GeoTacTics report included the following excerpts:

> *"A design was provided on site to control large spring flows where encountered at the toe of the slope."* [Later referred to as a 'buttress and filter' system]
>
> *"The 'buttress and filter' system will be repeated along the slope toe as necessary to address new areas of seepage as they develop."*
>
> *"a drainage blanket should be constructed across the entire width of the road fill hydraulically connecting the 'buttress and filter' to the downslope side of the road fill"*
>
> *"Where embankment fill is required to a thickness of more than 4 feet, a drainage layer consisting of 18 inches of clean sand or clean sand and gravel should be placed at the base of the fill."*

The referenced 'buttress and filter' was described as comprising a 12 foot wide by 30 foot long (about 3.8 by 9.1 m) buttress at the locations of large springs. The described 'buttress and filter' comprised a layer of geogrid reinforcement, and zones of ¾-inch clear crushed gravel, 6-inch rock and 1-foot rock.

Notably, no requirement was typically specified to install a suitable geotextile or granular filter at the native soil / drainage layer interface at the locations of 'buttress and filter' spring control systems.

A review of available construction inspection documentation from 2005 (highlights in Section 4) suggests that the largest spring flows encountered during excavation for Gale Avenue North were located near the south right of way boundary, adjacent to Lot 21 (September 28, 2005) and Lot 23 (September 15, 2005). Construction documentation suggests that the 'buttress and filter' system or variations of it were used in these locations.

The location of the spring adjacent to Lot 21 was labelled 'gray spring' shown on Figure 2 in the April 28, 2006 GeoTacTics report, and at El. 20.12 m. The stated precision in the elevation suggest that the location was surveyed and not approximated. The location of this feature has been approximately incorporated into the figures presented herein.

7.3.4.2 Lot 1 through Lot 12

In the Golder November 15, 2012 report it was noted:

> *"To minimize the risk of continuing piping and development of sinkholes, it is understood that a drainage blanket was installed on the slopes within Lots 1 to 12, to the north of Gale Avenue North."*

The April 28, 2006 GeoTacTics report (quoted in the previous section) describes a drainage blanket design which was to be used below site grading fill where the embankment fill thickness was greater than 4 feet. However, a June 1, 2007 GeoTacTics construction inspection memo describes a revised design for the drainage blanket first used in a test section on Lot 10 as quoted below:

> "*The revised section would consist of a base layer of geotextile (Propex 2006 woven geotextile as supplied by Nilex, or available equivalent) placed immediately following stripping of softened soil from the surface of the test area. Over the geotextile, a 6-inch layer of ¾-inch clear crushed gravel would be spread as a weighting and drainage medium. On top of the clear crushed gravel, a 3-foot layer of well-graded 6-inch minus rock fill would be placed as the main ballast zone."*

Based on several undated photos taken during construction, Golder described a drainage blanket and filter system on Lots 1 through 12 which seems to be consistent with the revised GeoTacTics design described above. These materials and the general configuration are also consistent with an August 29, 2008 photograph (Photo 9) taken looking towards Lots 3 through 5 during a Thurber site visit to review the rock stack retaining walls.

7.3.4.3 Lots 13, 14, and 15

In a report dated November 5, 2012 from Golder to Concordia, the drainage blanket constructed at Lots 13, 14 and 15 was described as follows:

> *"A geotextile was placed over stripped silt subgrade surface prior to placement of site grade fill, which consisted of a 0.3 m layer of 20 mm minus clear crushed gravel directly overlying the geotextile"*

The Golder report references a letter report from GeoTacTics dated June 26, 2008 and other reports specifically related to Lots 13 to 15. Reports by GeoTacTics completed in 2008 were not available to Thurber for review.

7.3.5 Upper Sand

The interpreted Upper Sand soil group was encountered in previous investigations in the test holes completed near Seawatch Lane but was typically absent at lower elevations. It is also encountered in a cut bank in the southwest corner of the development near Seawatch Lane and within the borrow pit area to the south. This soil group is inferred to be the upper stratigraphic unit at the site. Notably this unit was not encountered on Lot 28 near the location of the 2012 Seawatch Lane sinkhole. The upper sand unit was not encountered during the 2015 drilling investigation.

Grain size analyses within this soil group from previous investigations suggest that the Upper Sand is predominantly comprised of fine sand, with recorded fines contents varying between about 10% and 30%. Recorded moisture contents were generally around 10%.

Groundwater monitoring wells near the south side of the site indicate that the groundwater table is located below the Upper Sand.

7.3.6 Upper Silty Sand/Sandy Silt

The interpreted Upper Silty Sand / Sandy Silt soil group appears in all of the test hole logs completed at higher elevations near Seawatch Lane. It forms the surficial stratigraphic unit on Lot 28 and is inferred to be at or near surface in the area of the 2012 Seawatch Lane sinkhole.

The Upper Sandy Silt / Silty Sand soil group is a general name used to describe a complex soil sequence comprising interbedded silt, fine sand and mixtures of fine sand and silt. This complexity influences the hydrogeologic properties of this soil group and may influence groundwater pathways and gradients.

Grain size analyses suggest that distinct zones within this soil group have fines contents on the order of 60% to 100% and in one case 30%. Recorded moisture contents were generally in the range of about 20% to 30%.

Groundwater monitoring wells indicate that the groundwater table is located within or near the base of this soil group near the south side of the site.

7.3.7 Lower Sand

The interpreted Lower Sand soil group is similar in grain size distribution to the Upper Sand. However, the two groups are separated by the Upper Silty Sand / Sandy Silt soil group. This separation may influence the groundwater hydrology at the site. Therefore, Thurber has made a distinction between them.

Test holes completed along Seawatch Lane were typically terminated within this soil group. The Lower Sand was generally not encountered in test holes along Gale Avenue North with notable exceptions at the west and east ends of the site where the ground surface rises. It is likely that the Lower Sand would have been daylighted while excavating temporary slopes at the south edge of Gale Avenue North and behind the rock stack retaining walls located near the middle of the site.

In the Lower Sand, the recorded moisture contents ranged from about 10% to 30% which is notably higher than moisture content values in the Upper Sand.

Groundwater monitoring wells indicate that the groundwater table is located above or near the top of this soil group, which is consistent with the measured moisture contents. Based on our understanding of the available records (Section 4), the most substantial springs encountered during excavation appear to have originated from this and underlying soil groups.

7.3.8 Lower Silty Sand/Sandy Silt

The interpreted Lower Silty Sand / Sandy Silt soil group typically appears in all of the test hole logs completed along Gale Avenue North. It typically forms the stratigraphic unit immediately below the site grading fill on Gale Avenue North.

The Lower Sandy Silt / Silty Sand soil group is a general name used to describe a complex soil sequence comprising interbedded silts, sands and mixtures of sand and silt. This complexity influences the hydrogeologic properties of this soil group and may influence groundwater pathways and gradients.

Grain size analyses suggest that distinct zones within this soil group have fines contents on the order of 25% to 90%. Recorded moisture contents were generally in the range of about 20% to 30%.

Groundwater monitoring wells indicate that the groundwater table is located above or near the top of this soil group.

7.3.9 Basal Silt

The interpreted Basal Silt soil group was encountered in all of the test holes completed at, or continuing down to, lower elevations. The base of this soil group has not been identified in any of the site investigations to date. In the 2015 investigation, this soil group was encountered in one test hole completed on Gale Avenue North (TH15-01).

This soil group exhibits variations in gradation and bedding structure but is generally more uniform when compared with the interbedded silt and sand mixtures above.

Grain size analyses within this soil group from previous investigations suggest that the Basal Silt is predominantly comprised of silt, with recorded fines contents varying between about 80% and

100%. Recorded moisture contents were generally about 30%. Atterberg Limit test results from two samples of the Basal Silt indicate the silt is generally non-plastic.

Groundwater monitoring wells, and drilling and surface observations indicate that the groundwater table is located above or near the top of this soil group.

Uniform silt typically has a lower permeability which would typically impede the flow of groundwater.

7.4 Groundwater Site Conditions

7.4.1 General

Groundwater conditions at the site were interpreted from surface observations, drilling observations, and monitoring well data.

Monitoring wells are PVC pipes installed vertical within the ground with a perforated/slotted section (screened interval) near the bottom within a zone of soil that is to be monitored. The screened interval allows groundwater flow into the pipe so that the groundwater pressure within the soil, averaged across the screened interval, can be calculated by measuring the height of the water column that forms within the monitoring well (groundwater level).

Based on investigation data, the native soils at this site comprise a complex sequence of sand, silt and intermediate mixtures of the two. Sand is generally more permeable than silt and so groundwater levels in monitoring wells that are screened within sand will typically respond faster than wells screened in silt.

The complex and significant spatial variation observed in soil structure and gradation at the site results in a corresponding complexity and variability in the hydrogeological properties of the soil. For example, soil porosity and hydraulic conductivity influences how groundwater moves through the soil and the rate at which it moves. The generalized soil groups presented above were selected to group soils with similar hydrogeologic characteristics. As was noted, the presence of distinct zones and inter-beds within these soil groupings should not be discounted as they likely affect groundwater behaviour at the local level which may have a significant influence on sinkhole development as discussed in a later section.

The Basal Silt soil group, described in the previous section, likely forms the hydrogeological basement for groundwater flow at this site, directing the majority of flow along its upper boundary to ground surface as springs and surface seepage (or into constructed drainage blankets).

The following sections describe groundwater conditions observed at the site based on historic and recent data.

7.4.2 Pre-2012 Period

Groundwater monitoring wells were not installed at the site prior to September 2012 so our interpretation of groundwater conditions during early construction is based on the surface observations contained in third party reports and construction documents available to Thurber (Section 4). Therefore, groundwater levels in this period cannot be quantified. However, a comparison of surface groundwater observations in this period with the groundwater levels collected after 2012 suggests that groundwater patterns were broadly similar.

Pre-construction documents describe spring features and boggy wet areas at the site, particularly on the lower slope (north side).

Construction inspection documents describe relatively extensive areas exhibiting groundwater seepage and large groundwater springs, during excavation into the native soil (for site grading) along Gale Avenue North and the Lots to the north (Lots 1 through 15).

In an effort to manage the groundwater issues, drainage blankets comprised of coarse fill are understood to have been installed to address the springs and seepage issues (Sections 4 and 7).

As groundwater monitoring wells were not installed, the effects of excavation and these drainage measures on the groundwater levels cannot be quantified.

7.4.3 2012 to 2013 Monitoring Period

A significant spring developed on Lot 3 in May 2012 (Section 4). Shortly thereafter, a sinkhole daylighted on Seawatch Lane.

During the September 2012 and January 2013 drilling investigations that followed, groundwater monitoring wells were installed around the site at the locations shown on Figure 5. Groundwater levels at these monitoring wells were recorded from September 2012 to May 2013. Groundwater levels do not appear to have been recorded after May 2013 until recently.

Unfortunately, a stable baseline condition for the groundwater levels at the site is not available due to the limited period over which data was collected. The presence of a significant spring (at the time uncontrolled) on Lot 3 may also have temporarily reduced groundwater pressures at the site, further complicating interpretation of the 2012 / 2013 data. For a detailed discussion of the 2012 and 2013 monitoring data, refer to the April 5, 2013 Thurber report.

7.4.4 2013 to 2015 Monitoring Period

From available correspondence, Thurber understands a seepage mitigation system was installed on Lot 3 in August 2013 (Section 4).

As noted above, apparently no groundwater monitoring data was recorded between May 2013 and February 2015.

Verbal accounts from residents suggest that many of the wet areas on the lower slope, observed in Thurber's 2015 site inspections, were also present during this period.

7.4.5 2015 Monitoring Period

Monitoring of groundwater levels resumed in response to the daylighting of the sinkhole on Lot 21 on February 26, 2015 and has generally continued on a weekly basis. An additional groundwater monitoring well was installed during the 2015 drilling investigation at TH15-03 on Gale Avenue North adjacent to Lot 10. The 2015 data collected by Thurber is included in the site inspection reports (Appendix 1). Additional data was collected during this period by District personnel and was provided to Thurber. Groundwater monitoring data measured in 2012, 2013, and 2015 is presented on Figure 21, in terms of change in groundwater surface elevation relative to the initial reading.

Groundwater levels, based on the 2015 investigation and monitoring data, are depicted on geological sections A-A through G-G (Figures 8 to 14). Groundwater surfaces between monitoring wells are inferred. Groundwater elevation is expected to vary significantly between test holes as well as seasonally and in response to intense or prolonged precipitation events.

8. GEOTECHNICAL ASSESSMENT

8.1 General

The following sections summarize our assessment of the geologic process that may be responsible for formation of the observed sinkholes at the site. Our assessment and interpretations are based on the available current and historic data collected through investigations and third-party reports, and make use of engineering judgement where appropriate. As discussed in a later section, further investigation is recommended to confirm the assumptions and interpretations of our conceptual model.

8.2 Changes in Groundwater Levels

8.2.1 Early Construction

A quantitative assessment of groundwater levels cannot be completed during this period, as monitoring wells were not installed until 2012.

Based on available records, logging of old-growth forests and clearing of lands for agricultural use within the interpreted groundwater catchment areas (Figure 7) likely occurred several decades before development of the site. Vegetation and topsoil cover at the site were cleared/disturbed prior to development. It is likely that the loss of vegetative cover within the groundwater catchment area increased the potential for surface infiltration of precipitation and runoff. This has likely increased the amount of groundwater flow entering the site, potentially exacerbating a naturally occurring high gradient area.

The occurrence of significant springs as a result of excavation during initial site grading may have been caused by the removal of soils that were impeding groundwater flow towards ground surface. As a consequence of releasing these springs, groundwater levels may have reduced upstream of the springs (analogous to pulling the plug on a tub of water).

The subsequent construction of drainage blankets and the placement of site grading fill at seepage/spring locations may have impeded the release of groundwater, and possibly resulted in a rise or partial restoration in groundwater levels upstream, compared to the excavated state (analogous to putting the plug back in).

8.2.2 2012 and 2013 Monitoring Period

The occurrence of a relatively large sediment laden spring on Lot 3 in May 2012 may have reduced groundwater levels upstream (approximately south) of the spring, by eroding soils impeding the flow of groundwater and temporarily dewatering the area. Unfortunately a stable baseline condition for the groundwater levels at the site is not available for comparison, due to the limited period over which groundwater data was collected.

Fluctuations in measured groundwater levels during the 2012 / 2013 monitoring period were generally within 0.5 m of initial readings. Notable exceptions to this were monitoring wells located upstream of Lot 3 and on Lot 28, possibly related to the 2012 Lot 3 spring and 2012 Seawatch Lane sinkhole. As shown on Figure 21 during this period, the sharp seasonal rise in groundwater levels began in November 2012 and the peak was observed in January 2013. In notable exception, the groundwater level at the well located above Lot 3 (TH13-07) had not yet peaked when Thurber last measured it in March 5, 2013.

Based on the data collected during the 2012 / 2013 monitoring period, groundwater elevation contours and average hydraulic groundwater gradients, inferred between monitoring wells, were plotted and discussed in the April 5, 2013 Thurber report.

8.2.3 2015 Monitoring Period

The groundwater levels measured in upslope monitoring wells appear to change relatively rapidly and more significantly, as shown on Figure 21. This may reflect the fact that these upslope monitoring wells are generally screened in relatively coarser soils than the downslope monitoring wells. It may also reflect the greater variability in groundwater recharge from the south (a function of precipitation) compared to groundwater discharge to the north (a function of comparably consistent ground conditions). Intervals screened during monitoring well installation are typically defined on the test hole logs included in the Appendices.

During the gap in data between May 13, 2013 and February 27, 2015, groundwater levels appear to have risen substantially (more than 1 m) at several monitoring well locations, including wells located on Lot 28, above Lot 3, above Lot 21, and on Lot 22. The largest increase occurred at monitoring well (BH12-05) on Lot 28 which recorded a rise of about 3 m since last recorded in May 2013. The construction of a seepage mitigation system on Lot 3 in August 2013 during this gap in data, may possibly have resulted in a rise or restoration in

groundwater levels to the south and up-gradient, relative to the eroded state. However, as data is not available, the timing and nature of these changes cannot be reliably assessed.

During the 2015 monitoring period, the measured groundwater level elevations appear to peak between late March and early April, after which a gradual decline is measured. Based on observed groundwater levels in the past, the seasonal / annual peak may have occurred earlier, in the winter months, prior to the resumption of groundwater monitoring.

8.3 Hydraulic Groundwater Gradients

8.3.1 General

The difference in hydraulic pressure between the water table in the highlands to the south of the site and the ocean to the north of the site is relatively consistent, likely varying seasonally and in response to storm events and tides.

Relatively high groundwater hydraulic gradients (difference in pressure over distance) can promote the movement of soil particles (like sediment in a river), if the particles are free to move (i.e. not adequately constrained).

At this site, the flow of groundwater is understood to be the probable driving force behind the redistribution of soil beneath the ground surface, resulting in the formation of sinkholes which has been observed across the site since construction.

This interpretation appears to be consistent with the description of subsurface erosion mechanisms and case studies presented by Terzaghi, Peck and Mesri (1996). The relevant excerpt is included as Appendix 9. Note that this reference discusses subsurface erosion as a failure mechanism of earth dams. At this site, the conditions are, in many ways, analogous to a dam.

8.3.2 Calculated Hydraulic Gradients

Hydraulic groundwater gradients between monitoring wells were calculated from the 2015 groundwater monitoring data and are provided as vectors in Figure 22 along with inferred groundwater level elevation contours between monitoring wells. Due to the complexity in the site sub-surface stratigraphy and the relatively wide spacing between groundwater monitoring wells, these values are, at best, averages.

The actual hydraulic gradients are expected to vary at a local scale, depending on the soil permeability as well as lateral and vertical continuity of the interbedded soil layers. Lower permeability soil zones or layers inhibit the flow of groundwater and increase hydraulic gradients. The complexity in observed soil stratigraphy (Section 7) suggests that actual gradients are likely higher in localized areas of the site than the values calculated.

8.3.3 Changes in Hydraulic Gradients

The likely and observed changes in groundwater levels, discussed in Section 8.2, correspond to likely and observed changes in groundwater hydraulic gradients across the site.

A comparison of the calculated hydraulic gradients, provided in the April 5, 2013 Thurber report, and the 2015 gradients depicted on Figure 22 suggests that gradients have risen across the majority of the site, between 2013 and 2015.

8.3.4 Critical Exit Hydraulic Gradients

The critical exit hydraulic gradient is the estimated minimum localized groundwater gradient at which migration of soil particles occurs for a given soil in a given state. The term 'exit' is key, in that for migration of soil particles to occur, the gradient must exceed the critical gradient in a location where a suitable pathway exits. Discussion of suitable pathways for soil migration is presented in the following section.

The November 15, 2012 Golder report suggested critical exit hydraulic gradients at the site may be in the range of 0.2 to 0.3 based on Indraratna and Radampola (2002) or 0.12 to 0.17 based on criteria by Lane (1935) for very fine sand and silt to medium sands, respectively.

The 2015 calculated hydraulic gradients (shown on Figure 22) range from about 0.1 to 0.3 and are typically above 0.17 across the majority of the site. Thus, the calculated gradients are near or above the critical gradient ranges suggested by Golder. As previously discussed, the actual hydraulic gradients at the site are anticipated to be locally higher than the calculated hydraulic gradients.

As noted in the Terzaghi, Peck and Mesri (1996) excerpt, subsurface erosion commonly occurs at hydraulic gradients which are lower than the theoretical calculated critical values.

Fine sand is the dominant component of many of the soil groups described in Section 7. The July 20, 2012 Thurber report described the work by Briaud (2011) demonstrating that the critical velocity required to initiate erosion of fine sand is relatively low, compared to other soil types. As such, relatively small exit seepage gradients are required to dislodge the sand particles and initiate the piping process. The available records (Section 4) describe sediment laden springs followed by the formation of sinkholes during early construction, and similarly at Lot 3 and Seawatch Lane in 2012. This pattern indicates that the critical exit hydraulic gradients have been exceeded in some locations and instances at this site.

Based on past events at the site and in the absence of more closely spaced groundwater data to assess hydraulic gradients at a local scale, it is likely that critical exit hydraulic gradients potentially are exceeded across a significant portion of the site. Therefore, piping erosion may occur, provided a suitable pathways for soil migration exists.

8.4 Potential Pathways for Soil Migration

8.4.1 General

Piping erosion may occur at or below ground surface wherever pathways for soil migration exist, provided the critical exit hydraulic gradient has been exceeded at the location of these pathways. A pathway must be present for soil particles to migrate without obstruction by other soil particles or objects. The following sections discuss potential pathways for soil migration which are thought to exist at this site.

8.4.2 Excavation

Based on available documents, during initial site grading work, clearing of vegetation and topsoil and excavation into native soils resulted in increased spring flows laden with suspended soil particles. It is likely that this soil migration was initiated by the removal of natural filters and the increase in hydraulic gradient as a result of excavation. Photographs of these springs are typically not available to Thurber. However, a photo taken May 31, 2007 during early site grading appears to show seepage erosion regressing back into a native soil bank (Photo 9).

The results of soil migration were evident in the numerous sinkholes reported to have daylighted across the site during site grading work. The reports indicate that the sinkholes were backfilled but no further investigation was completed to identify the lateral extents or depth of the affected area around the sinkholes or how the locations of the sinkholes were positioned relative to the observed springs, situated down-gradient. The distribution of springs and sinkholes across the site and the length of time over which the sediment laden springs were reported to have flowed suggests a network of voids and / or loosened zones may have been created between the sinkholes and springs during site grading work.

It is possible that many of these voids and / or loosened zones which formed during site grading work are still present. Soil within loosened zones would have a higher void ratio and permeability and could promote preferential groundwater flow. The loosened zones likely have a higher susceptibility to further migration of soil particles under the current hydraulic gradients at the site.

8.4.3 Filters and Drainage Blankets

Thurber's understanding of the available construction records suggests that drainage blankets were typically used at the site where seepage and spring issues were encountered. The available information on the construction and distribution of drainage blankets was discussed in Section 7. Generally the drainage blankets and spring control measures included the use of coarse, poorly graded gravel or cobbles / boulders. These materials are not considered suitable for use as filters for the native soils at this site and were apparently positioned downstream of sediment-laden groundwater flow. Geotextile filters were specified below the drainage blanket in some areas (Sections 4 and 7), but not others.

Thurber's recent drilling investigation on Gale Avenue North did not recover materials consistent with the drainage blanket described. However, the drill experienced auger and / or DCPT refusal within the site grading fill at several locations where a drainage blanket is thought to have been specified. Based on the drilling depth it is inferred that refusal was encountered at the top of the drainage blanket which is reported to comprise coarse gravel or blast-rock.

In two recent test holes on Gale Avenue North (TH15-04 and TH15-15) a geotextile fabric was encountered. However, the fabric was not positioned at the base of the site grading fill and thus would not be an effective filter between the native soils and the fill materials. At TH15-04, drilling was advanced below the fill and into the native soils, and did not encounter materials consistent with the described drainage blankets. At TH15-15, the geotextile fabric was encountered immediately above where the drilling augers encountered refusal, which was inferred to be on coarse granular particles (possibly a drainage blanket).

Records indicate geotextile filters may have been used at the base of the drainage blankets on Lots 1 through 15. However, the selected geotextile product may not have been suitable. In their November 15, 2012 report Golder assessed the woven geotextile filter thought to have been used on Lot 3. Golder stated:

> *"it is considered likely or probable that, although it would provide suitable retention of soil particles within the sands and silts at this site, the Nilex 2006* [geotextile] *would not be capable of permitting the free flow of water into the drainage blanket within areas of concentrated seepage, such as the spring at Lot 3. It is also considered likely that a spring could develop due to a build-up of excess water pressure under the geotextile and drainage blanket until the blanket was displaced and/or the geotextile ruptured or individual sheets pulled apart."*

We agree with Golder's comments regarding the potential for filter fabric rupture or separation of adjacent filter fabric panels. We consider that a similar mechanism could occur or may have occurred elsewhere on the site if a similar filter fabric was used as part of the drainage blanket.

Only a few photographs are available to Thurber documenting the installation of the drainage blanket. During a 2008 site visit by Thurber to review the rock-stack walls at the site, Photo 10 was taken from mid-slope looking down towards Lots 3 through 5. The photograph appears to show that clear crushed gravel was stockpiled on native surfaces and placed such that the gravel spilled beyond the edges of the filter fabric panels and was in direct contact with native soil. The potential for filter incompatibility is high if the stockpiled clear crushed gravel was not adequately cleaned from the native soil surface and / or if the clear crush was placed directly onto the native soil without a geotextile filter cloth separating it from the clear crush. Vigilante construction inspection is required to ensure that there are proper overlaps of geotextile fabric panels. Puncture of the fabric is also a concern, where angular crushed materials are placed directly on top of a geotextile.

If the filter fabric has failed to adequately separate the native soils from the coarse drainage blanket gravels, soil migration into the drainage blanket could likely be occurring. Due to the apparent extensive use of drainage blankets and the relatively high void ratio of such materials,

sufficient capacity likely exists within the drainage blanket for the movement and deposition of substantial quantities of native soil. Perforated drain pipes were also reported to have been used in some cases within the drainage blankets to collect water. Thus, the drainage blankets and the perforated pipes represent potential pathways for the transmission and deposition of eroded soil particles.

Where drainage blankets were installed on sloping ground, the potential also exists for subsurface erosion of native soils as a result of scour at the base of the drainage blankets. The potential for subsurface erosion by scour processes was discussed by Terzaghi, Peck and Mesri (1996).

Thurber's April 5, 2013 report concluded that the 2012 spring and sinkhole events suggest that the filter and drainage blanket systems have not performed as intended. Based on current available information available to Thurber and observations of continued sinkhole development, we believe that conclusion is still valid.

8.4.4 Buried Utilities

Other potential pathways for native soil particle migration may be into utility trench backfill and utility pipes, if they are damaged. This pathway is particularly relevant where buried utilities exist below groundwater level.

Soil migration into the trench backfill could be possible if clear crushed gravel or other coarse grained soil was used without suitable implementation of filtration. The April 28, 2006 GeoTacTics report discusses the design of drainage measures in areas exhibiting seepage. The report specified the use of 3/4-inch clear crushed gravel or other relatively coarse fills as backfill for utilities, though typically without a stated requirement for geotextile filters between native soils and backfill. As-built records for the site utilities refer to this report for geotechnical recommendations. Thus it is considered likely that this pathway exists for soil migration.

If utilities buried below the groundwater level were damaged, this could provide another potential pathway for soil migration to occur. The District has retained Urban Systems Ltd. (Urban) to review the utility infrastructure on site. Thurber has been informed by Urban that the utilities appear to generally be in poor to fair condition, given their age. If coarse backfill was used as utility trench backfill, it may have contributed to damage of the utilities during installation.

A June 1, 2007 GeoTacTics memo (referenced in Section 4) described the placement of rounded boulders across the storm outfall corridor between Lots 9 and 10 to build a working pad for heavy equipment. The use of coarse particles above the storm corridor and / or the loading from heavy equipment traffic could have damaged the buried storm sewer pipe.

Sediment laden water was observed by others to be discharging from the storm sewer outfall between Lots 9 and 10 immediately following the daylighting of the sinkhole on Lot 21 on February 26, 2015, suggesting soil migration into the storm sewer. It is believed that collapse of

the sinkhole may have introduced silt below groundwater level resulting in the observed pulse of sediment laden water at the storm outfall.

During the recent investigation, the sediment content of the water discharging at the storm outfall between Lots 9 and 10 was also observed to increase during the drilling of TH15-01 (near the sinkhole adjacent to Lot 9). Notably this test hole was the only recent test hole in this area to advance with auger methods to a significant depth below the water table. It is believed that drilling of this test hole introduced silt into more permeable sand zones through smearing by the drill augers which resulted in flow into the storm sewer.

Camera survey of the storm pipe suggests that segments of the pipe which are inferred to be below groundwater level may be damaged. Sediment laden water has also been observed at the outfall following precipitation events which suggests that increased groundwater flow may be carrying native soil into damaged segments of the storm sewer line.

These observations suggest that adequate filters and trench dams (or seepage collars) may not have been installed between the native soil and trench backfill during construction of the storm sewer between Lots 9 and 10.

Similarly, information reports from residents indicate that sediment laden water was observed at the storm sewer outfall north of Lot 1 in November 2014 during a period where subsidence was observed in the area of the 2012 Seawatch Lane sinkhole.

The storm sewer outfall north of Lot 12 contains deposits of fine sand and silt within the outfall structure and in the sediment collection pond downstream. This indicates that sediment transport was active at some point prior. However, based on current information it is not clear if the sediment originated from the sub-surface (entering through a perforated drain or a break in the pipe below water table) or from the surface (entering through catch basins due to runoff erosion).

8.5 Effects of Soil Particle Migration

Voids and conduits are formed due to sub-surface soil migration. If the shear strength of the soil above the void or conduit is insufficient to arch over the void, it will collapse and the void will be filled with soil fallen from above. The fallen soil will be in a loose state and will be uncompacted. If the shear strength of the soil above the void or conduit is sufficient to arch over the void, the void may remain open. However, if erosion continues, the void or conduit will grow and may become sufficiently large such that the strength of the soils above is unable to arch and bridge over the void and the soil will collapse.

Collapse of voids can manifest at ground surface as settlement. The magnitude and rate of settlement depends on the depth and size of the void, the rate of soil erosion, and the strength of the overlying soil. Brittle failure of voids near surface will likely result in the daylighting of a sinkhole.

The presence of asphalt, concrete driveways, foundations, retaining walls and utility infrastructure may attenuate settlements observed at ground surface if the structure can bridge over the voids. However, these factors may mask the hazard while the erosion continues until the surface structure can no longer bridge over the void or weakened soil, resulting in collapse.

Collectively, the erosion of supporting soils by groundwater flow, loosening / undermining of supported soils, rising and dropping groundwater levels, and eventual collapse are the process by which sinkholes are understood to have formed at this site (collectively termed the sinkhole development process).

8.6 Assessment of Soil Disturbance in Recent Investigations

8.6.1 April 2015 Drilling Investigation

Based principally on DCPT penetration resistance profiling, loose fill and native soil were encountered during the recent drilling investigation in the vicinity of the recent sinkholes near Gale Avenue North and near the area of the 2012 Seawatch Lane sinkhole. Voids were also encountered or observed below the asphalt on Gale Avenue North suggesting that settlement has occurred.

The loose zones and voids encountered likely indicate soil that has been disturbed due to soil migration, void formation and collapse. Furthermore, the areas closest to the sinkhole had the lowest penetration resistance profiles. This contrasts with the relatively dense / stiff native soils and well compacted fill encountered in areas considered to be undisturbed. The DCPT profiles shown on the geological cross sections in Figures 15 to 20 illustrate the variability in relative soil stiffness / density.

Based on the DCPT profiling completed to date, we believe that the DCPT has been an effective tool to assess the relative density of the subsurface soils at a given test hole location. It is believed that the loose zones identified are indicative of soil migration below the water table and the collapse of overlying soils. These areas may potentially expand or increase in severity, progressing into the formation of a sinkhole(s) in the future.

8.6.2 Contouring of DCPT Profiles

To illustrate our interpretation of the DCPT results, plans and cross sections were generated and are presented as Figures 23A and 23B and Figures 24 to 29, respectively. To differentiate between disturbed / loosened soil and undisturbed soil it was necessary to select thresholds or intervals in DCPT blow counts in order to sort and contour the data. The Canadian Foundation Engineering Manual provides categories for the density or consistency of soils based on generalized ranges of SPT blow counts (‘N’ values). Similar blow count ranges were adopted for contouring of the DCPT blow counts.

Areas considered likely to have been loosened by the sinkhole formation process were assumed to have DCPT blow counts below 20. At this site, native soils and compacted fill interpreted to be undisturbed by the sinkhole formation process typically had DCPT blow counts

greater than 30 and often greater than 50 corresponding to dense and very dense or very stiff and hard soil, respectively. However, accepting the likely variability in the density of compacted fill and native soils, a DCPT value of 20 was selected to screen for significantly affected areas during this assessment. Where DCPT blow counts were less than 4, the soil was considered to be severely disturbed / loosened. Where the DCPT blow count was 1 or dropped due to self-weight, it was interpreted as soil which had collapsed likely due to a void, or in some cases, actual voids where confirmed by additional observations. Legends are provided on the Figures to define the categories used.

Interpreted boundaries of the loosened and severely loosened zones between test holes were extrapolated. The interpreted base of fill and interpreted water table are also shown for reference. Test holes which encountered evidence of loosening are shown in plan on Figures 23A and 23B.

8.6.3 Assessment of DCPT Profiling

DCPT profiling in the recent test holes and screening of the data into contours was used to visualize and help better understand the magnitude of potentially loosened soil. The results indicate that the affected areas extend well beyond the visible sinkholes at ground surface. In some cases, the boundaries of loosened zones extended beyond the lateral limits of investigation.

In the Gale Avenue North area, the DCPT was able to determine the presence of loosened soil down up to depths of about 13 m at the sinkhole adjacent to Lot 9, which corresponds to El. 10 m (near the top surface of the Basal Silt soil group). Generally, loosened soil in this area appeared to be within the fill and above the groundwater surface, or to depths of around 7 m. This suggests that erosion may be initiating at the fill / native soil contact which is approximately where the interpreted groundwater surface is located in this area. This is consistent with both piping erosion and subsurface scour erosion mechanisms.

At the 2015 Lot 21 sinkhole, loosened soil was encountered to a depth of about 7.5 m (El. 19 m).

On Lot 28, little or no fill is present and the groundwater surface is well below ground surface. Loosened native soil was evident in two test holes (notably in line with the 2007 and 2012 sinkholes in this area) below about 6 m depth and extending down to about 19 m depth in one test hole as depicted on Figure 29. Above 6 m depth, the native soils were very dense. The elevation to which the loosing is evident (about El. 20 m) is notably similar to the elevation of the 2012 Lot 3 spring (about El. 16 m). This similarity may indicate that the 2012 Seawatch Lane sinkhole (adjacent to Lot 28) was a result of piping erosion along a relatively horizontal pathway at depth between the sinkhole and Lot 3 spring.

The DCPT results suggest that subsurface erosion and loosening may be an issue that extends across a significant portion of the site and to significant depths below ground surface.

The presence of severely loosened soils immediately below relatively brittle bridges of very dense surface soils or structures such as asphalt and concrete increases the risk of sudden daylighting of future sinkholes.

Based on our assessment of the DCPT data within the areas investigated, we believe that the DCPT could be used as a screening tool to investigate locations where loosened soil or potential voids may exist and may help identify areas which are at higher risk of developing sinkholes in the future. However, to assess large areas a large number of test holes would be required which may not be practical. As such, the DCPT should be used in conjunction with alternative methods such as geophysical investigations. Further discussion on geophysical investigations are provided below.

8.6.4 Assessment of Geophysical Investigation Results

Geophysical investigations completed in May 2015 by DMT included the use of GPR and MASW techniques. DMT's report provides details of the investigation methods, results and assessment and should be referenced for further details. A copy of the report is included in Appendix 5. This section provides Thurber's assessment and comments related to the report.

The results of the GPR appear to be useful as a screening tool to look for evidence of disturbed soils below surface (anomalies). While useful as an initial screening tool, due to its ability to survey a large area relatively quickly and access tighter spaces, the GPR method is not able to quantify any identified disturbance. Furthermore, there are limitations with the GPR method's ability to detect evidence of disturbed soils and the technique may not detect all disturbed soils. Further investigation using other methods is needed to assess the identified anomalies.

DMT also completed investigations using MASW testing and their report presents MASW profiles completed along Gale Avenue North and Seawatch Lane. The profiles show contours of averaged shear wave velocities (V_s) which is a property related to soil stiffness. Generally, lower V_s values indicate soil with lower stiffness (such as loose soil) while higher V_s values indicate soil with higher stiffness which are typically denser.

DMT presented the interpreted results from both geophysical techniques in comparison to the interpreted results of Thurber's recent drilling investigation in order to calibrate the geophysical results to the affected zones identified in the drilling investigation.

In general the results of the geophysical surveys correlate reasonably well with the results from Thurber's recent drilling investigation. In the vicinity of the sinkhole at Lot 9, the GPR identified potential disturbed ground conditions. The averaged shear wave velocity profile developed from the MASW survey in this area also was found to correspond reasonably well to the drilling information.

The trend in the shear wave velocity profile, in the area immediately adjacent to the Lot 9 sinkhole, is not consistent with the trend in the drilling data which identified very loose soil conditions and the presence of a near surface void below the road. The presence of a void(s)

below the road and the lack of supporting ground to the north of the roadway curb in this area (due to sinkhole) may have influenced data collection through this zone. However, this affect cannot be quantified. The offset of the MASW survey line from the drilling locations may also have affected the correlation of the results. However, the GPR data does show a definite anomaly at the same location. Based on the results of both investigation methods, it appears that a combination of the GPR and MASW would provide a more complete assessment of possible anomalies which would need to be confirmed by drilling.

The DMT report also notes that the investigation methods were only able to identify affected areas of a substantial size, which is a function of the depth of the anomalous zone, the density of overlying soil, and limitations of the equipment and methods. For example, the affected zone on the south side of Gale Avenue North (Line I-I), centred at test hole TH15-11, was not identified using the MASW method.

Geophysical surveying was also completed on Seawatch Lane in the vicinity of the 2012 Seawatch Lane sinkhole adjacent to Lot 28. Drilling investigation information is not available on Seawatch Lane in the vicinity of the 2012 sinkhole. Therefore, direct calibration of these results was not possible. The 2012 sinkhole was repaired by Concordia in 2013. The geophysics results suggest that a relatively loose zone is present below the area that was repaired. It is unclear if the current extents of the loose zone, suggested by the geophysics, were present prior to the repair of the sinkhole or if it has experienced loosening since repairs were completed. It is noted that there has been recent surface settlement in the area that has been repaired. We understand that Golder has been contacted by the District to provide comments regarding the observed settlements and anticipated performance of the repair.

On Lot 28, using MASW techniques a one dimension shear wave velocity profile was produced near the location of test hole TH15-25. The results show a sharp decrease in shear wave velocity at about 6 m depth at this location, which is consistent with the results of the DCPT profiling.

DMT calibrated the results of their investigations with the available drilling information. A limited number of GPR survey lines were completed beyond the areas recently drilled. These surveys were generally restricted to one traverse line along existing roadways. The results identified a number of GPR anomalies as shown in DMT's report. The anomalies identified using GPR were determined to have similar characteristics as the anomalies identified in the disturbed / loosened areas (from the recent drilling investigation). However, as the GPR cannot quantify the density of an anomaly, additional MASW and / or drilling would be required in order to further assess the identified anomalies.

Based on our understanding and assessment of the results of the geophysical investigation, we believe that GPR and MASW techniques could be used as screening tools to investigate for locations where loosened soil or potential voids may exist and to provide guidance for a targeted drilling investigation to confirm and assess those areas identified. It should be noted that there are inherent and site specific limitations for all ex situ investigation methods, including the geophysical techniques used in the recent investigation.

THURBER

9. CONCEPTUAL SINKHOLE DEVELOPMENT PROCESS

9.1 General

The mechanics of subsurface erosion were described by Terzaghi, Peck and Mesri (1996) in the excerpt provided (Appendix 9). The distinguishing features described have important similarities to conditions understood to be present at this site, and provide useful context for the following discussion.

Based on our observations of site conditions (Section 7) and interpretations (Section 8), we infer that a few key processes contribute to subsurface erosion and the development of sinkholes at the site. The processes are described below and Figure 30 provides an annotated schematic to assist with visualization. Discussion in this section updates the processes that were presented in the April 5, 2013 Thurber report based on the assessment of new information collected and re-assessment of existing data.

In general, the processes contributing to the formation of sinkholes at the site are as follows:

1. High groundwater gradients
2. Migration of soil into available pathways
3. Formation of voids or loosening of subsurface soils
4. Collapse of ground surface or infrastructure

Processes 1 and 2 together form the mechanism that creates the problem. Processes 3 and 4 are effects or consequences of that mechanism, as Process 3 in some cases leads to Process 4.

9.2 High Groundwater Gradients

Groundwater monitoring data indicate that groundwater levels have risen since 2012 when monitoring began, especially along the south side of the site. As groundwater flows north towards the Inlet, an increase in groundwater levels to the south generally results in increased hydraulic gradients across the site.

The groundwater recharge catchment south of the site may be extensive as shown on Figure 7. Groundwater flow through the site is thought to originate from the south. Precipitation and rainfall events in the area contribute to increased groundwater levels throughout the site.

The sloping site topography and presence of interbedded silt and sand layers is believed to influence groundwater flow and may influence hydraulic gradients locally.

Construction activities related to site development may have also have affected hydraulic gradients across the site.

Available documents and observations indicate that critical exit hydraulic gradients have been, and likely are, exceeded in some areas of the site. The relatively large increase in observed

ground activity in the winter months and through the late spring suggests that critical exit gradients may seasonally be exceeded over larger areas.

9.3 Migration of Soil

Elevated hydraulic gradients will not, in isolation, result in erosion and soil migration. A pathway for soil migration must also exist in order for sub-surface soil erosion and piping to occur.

Available documents indicate that there were challenges related to seepage and soil migration control during construction which resulted in sinkholes and that drainage blankets were installed which likely included the use of relatively coarse, poorly graded gravels and blast rock.

The native soils comprise fine non-cohesive sand and silt. The presence of coarse grained fill introduces a filter incompatibility with the native soil if appropriate transitions and / or filters are not placed to restrict soil migration. Available construction documents suggest that a properly constructed filter between the drainage blankets and native soil might not be continuous across the site.

Our review also noted that some utilities were installed in trenches backfilled with clear crushed gravel. The documents do not indicate that filter fabric was used to separate the gravel from the native soil or that trench dams (or seepage collars) were used to impede preferential groundwater flow in the backfilled trenches. Review of existing utility information by Urban noted that utilities within the Seawatch development are generally in poor to fair condition, given their age. As such, soil could migrate into the trench backfill and possibly into damaged utilities.

Scour erosion of native soils may also occur along the base of the constructed fills if drainage blankets or utility backfill were placed on sloping ground without suitably performing geotextile or granular filters.

9.4 Formation of Voids / Loosening of Soils

Together, critical exit hydraulic gradients and available pathways for soil migration, will result in subsurface erosion through scour or piping. Subsurface erosion results in a loss of soil volume and the formation of conduits and voids below surface, which will continue to expand over time, provided gradients are sufficient to continue the erosion process.

The overlying soil will arch or bridge over the void or conduit if the shear strength of the soil is sufficient. If the size of the void or conduit becomes too large, the shear strength of the soil may not be sufficient to maintain a bridge and the soil will collapse into the void. The collapsed soil will typically be in a loose and uncompacted state.

9.5 Collapse of Ground Surface or Infrastructure

Depending on the strength of the overlying soil or infrastructure, the size of the void, and location below ground surface, a collapse will manifest at surface either as surface settlement or as a daylighting sinkhole in some cases. High rainfall and / or rising groundwater levels are

likely triggering mechanisms for void collapse as partially saturated soils loose strength on becoming saturated.

Thurber's recent investigations encountered a number of locations with loose soil which extend beyond the immediate vicinity of the known sinkholes. Based on the process described above, we believe that zones of loose soil may indicate possible locations where soil migration and collapse has happened or is happening. Identifying the loose soil zones will also help identify areas where there is higher risk of development of a sinkhole daylighting in the future.

10. GEOTECHNICAL CONCLUSIONS

10.1 General

This site has a history of geotechnical issues including slope instability, surface and sub-surface erosion, voids and sinkhole collapse, many of which may be interrelated. Thurber's scope was limited to the assessment of the recent sinkholes on Lot 21 and adjacent to Lot 9 and to respond to concerns regarding the implications of these new sinkholes on the overall site for geotechnical hazards in the form of ground loss and sinkholes. Thurber's scope of services does not encompass geotechnical issues such as assessment of slope and retaining wall stability.

The processes which led to the formation of the two recent sinkholes could continue to develop future sinkholes if the cause is not addressed. It is not possible to predict the exact time or location when the next sinkhole will occur but recent investigations show that sinkholes likely will occur where loose soil exists. Further assessment of areas where loose soil exists will help identify areas where there is greater risk of development of a sinkhole.

It is also noted that, in recent years, sinkholes and areas exhibiting subsidence appear to most commonly occur near locations where sinkholes or subsidence have been observed previously. This also suggests that subsurface erosion and sinkhole development are ongoing processes and are likely to continue unless the mechanism is addressed.

10.2 Gale Avenue North at Lots 9 and 21

Our observations and the results of our drilling investigation on a limited section of Gale Avenue North adjacent to Lots 8 to 10 and Lots 20 to 21 suggest that the road has been undermined to the south/southeast of the sinkhole adjacent to Lot 9. The undermining was found to extend at least below the westbound lane on the north side of the roadway as shown on Figure 23A. The full lateral extents of the undermining could not be determined due to the presence of utilities and private property, constraining the extents of the drilling investigation. However, the undermining potentially may also extend below the eastbound lane on the south side of the roadway, and possibly onto Lot 9 to the north. This potential should be considered and investigated prior to re-opening of the road or occupancy of the house on Lot 9.

The investigation identified a relatively extensive area of loose soil which suggest early signs of potential soil migration and possible void formation. The loosening appears to generally extend

between the base of the site grading fill and the base of the pavement structure near ground surface. Severe loosening was encountered to depths of up to 10 m below the road and road allowance adjacent to Lot 9, and loosening was encountered to depths of up to 13 m locally.

Signs of sinkhole activity were previously noted in April 2012 and November 2014 in the area of the present sinkhole adjacent to Lot 9. However, these signs may not have been recognized as precursors to sinkhole development. This suggests that development of a sinkhole ultimately is an ongoing process.

As the depth and extent of loose soil below the road is significant, there is risk of sinkhole development within this zone. As such, re-opening of the road to vehicle traffic is not advised until repairs can be implemented and the process causing the soil loosening is addressed.

10.3 Lot 21 Sinkhole

In early February a period of intense rainfall (108 mm over 9 days) was recorded at the Sechelt AUT weather station about 8.0 km southeast of site (Environment Canada National Climate Data). This was followed by 12 relatively dry days ending with the daylighting of the sinkhole on Lot 21 on February 26, 2015. While there was a time lag, it is possible the preceding storm period caused elevated groundwater levels which may have triggered soil collapse and daylighting of the sinkhole. This interpretation is consistent with comments made in the April 5, 2013 Thurber report that, historically at this site, sinkhole events occur at or after a delay of a few days following a period of significant rainfall.

Groundwater monitoring data is not available in the days and months prior to the Lot 21 event. However, it is considered unlikely the sub-surface erosion / undermining which led to the daylighting of the 2015 Lot 21 sinkhole occurred within a short period of time. Rather it is likely the erosion / undermining process took place over an extended period (possibly years). The preceding storm event may have elevated groundwater levels and gradients which would have accelerated erosion / undermining at the fill / native soil boundary. This may also have resulted in a loss of soil cohesion as partially saturated soils became saturated. Thus the preceding storm event may have merely reduced the ‘soil bridge’ strength to a point of collapse (analogous to ‘the straw that broke the camel’s back’). The observation of subsidence at the sinkhole adjacent to Lot 9 in November 2014 and again in February 2015 suggests that the sinkhole formation process is ongoing in the area and not an isolated event. This interpretation is consistent with oral accounts from the Lot 21 owners and the results of the recent drilling investigation which identified relatively extensive zones of loosening, suggesting an ongoing systemic problem.

The February 14, 2015 magnitude 3.4 seismic event (described in Section 5) may have increased loading of the soils overlying the developing sinkhole on Lot 21. However, due to the relatively small magnitude of the event and distance from the site, it is unlikely to be the primary trigger of the daylighting of the Lot 21 sinkhole.

A direct connection was not found within the limits of the recent investigation between the affected loosened soils and voids encountered on Gale Avenue North adjacent to Lot 9, and the

Lot 21 sinkhole. However, the test hole completed through the backfilled sinkhole on Lot 21 suggests that soil loosening extends to about El. 19 m.

The available construction records suggest that a large, sediment laden, groundwater spring was encountered near the north property line of Lot 21 at about El. 20 m during initial site grading in 2005 (shown approximately on Figures 23A and 28). Piping erosion as a result of the spring is understood to have likely caused the formation of several sinkholes south of the spring during that period. According to available construction records, the spring was addressed by the installation of a drainage buttress and filter system (a variation of drainage blanket discussed in Sections 4 and 7) which, to our knowledge, did not include a geotextile or granular filter separation between the native soils and the coarse fill particles in the buttress.

The reported position of the drainage buttress immediately down-gradient (north) of the 2015 Lot 21 sinkhole and at similar elevation to the loosened soil recorded in the recent investigation, suggest a connection. Based on the available information and our understanding of the sinkhole process at this site, it is considered likely that the 2015 Lot 21 sinkhole formed as a result of soil migration into the drainage buttress installed to the north.

It is also noted that a GPR survey identified an anomaly in the backyard of Lot 21 beyond the footprint of the house, which should be investigated further. Prior to re-occupancy of the house on Lot 21, detailed investigation should be considered to assess the potential for sinkhole development below the house foundations.

10.4 Storm Sewer Corridor between Lots 9 and 10

Camera survey evidence suggests that the storm sewer pipe, which connects Gale Avenue North to the foreshore between Lots 9 and 10, may be damaged in some segments and accepting infiltration of groundwater and possibly sediment from the sub-surface. A review of available construction documents suggests this pipe may have been damaged during construction. It also suggests that measures do not appear to have been constructed to mitigate seepage through the relatively coarse pipe backfill material. Substantial groundwater springs were reported in this area during construction. It is also possible this pipe may also have been damaged by sub-surface erosion, which may have undermined some segments of the pipe.

The observed groundwater infiltration and, in some cases, sediment transport suggest that this pipe may be one of many potential pathways for soil migration in this area. Other potential pathways in the immediate area include utility trench backfill and constructed drainage blankets. Thus repair of this pathway is likely to only partially address soil migration in the area.

If the overall site management strategy is to include repair or replacement of this pipe, consideration should be given to re-routing the pipe alignment to a more accessible location. Accessing the existing storm sewer pipe would be challenging and may not be feasible, given the depth of installation, narrow access corridor, and proximity of surface structures. Careful consideration of the following factors should be included in the deactivation of the existing storm pipe and in the design and construction of a replacement pipe.

- Narrow access corridor between private properties and structures,
- Substantial depth of cover above the existing storm sewer pipe,
- Condition of the existing pipe and the material surrounding it,
- Groundwater and temporary dewatering requirements,
- Shoring requirements,
- Potential for continued subsurface erosion

10.5 Lot 28 Implications

Evidence of loosened soil was identified to substantial depths on Lot 28. This suggests that the sinkholes which daylighted on Lot 29 (2007) and on Seawatch Lane (2012) may be symptoms of a more widespread issue oriented roughly North-South. Further investigation should be considered prior to development of Lot 28 and to assess the potential for sinkhole development on Lot 27 and on Gale Avenue North to the north of this area.

10.6 Site-Wide Assessment

Since early 2012, three sinkholes have daylighted at the site that Thurber is aware of, including the recent sinkholes on Lot 21 and adjacent to Lot 9. These sinkholes are evidence that the processes causing soil particle migration and sub-surface erosion are still active.

Detailed investigation was not completed on a site-wide basis so we are unable to assess the sinkhole hazards across the site based on the available data. However, our understanding of the previous reports, interpretation of geologic conditions and recent investigations suggest that the potential exists for sinkhole formation throughout much of the site including all Lots and roadways. Similar voids and loosened zones of soil to those encountered during the recent investigation could exist adjacent to or underneath existing utilities in the investigated areas and beneath roads, walls, utilities or private properties / structures elsewhere on the site. The District, occupants and users of the site should recognize the potential for sinkhole hazards.

A high-level GPR survey was completed in limited areas along the site roadways beyond the areas recently drilled. The survey identified geophysical anomalies, with similar characteristics to the anomalies identified within the drilled areas where disturbed soils have been identified. These anomalies should be investigated further (refer to DMT's report, Appendix 5, for more information).

11. RECOMMENDATIONS

11.1 Mapping of Current Sinkhole Hazards

If the site is to remain open to the public, we recommend that reasonable efforts be made to map locations where loose soil and voids could possibly exist in order to identify areas which have a higher potential for developing sinkholes in the future. Mapping ideally should be completed across the site in accessible areas, regardless of public or private property. However,

this may be challenging to implement, so the mapping could be limited to public areas and the risks communicated to the private land owners.

The use of geophysics should be considered prior to drilling, due to the relative efficiency of geophysical methods to screen relatively large areas.

DMT's recent investigation results suggest that, to increase the likelihood of sinkhole detection, two or more geophysical methods should be used. GPR and MASW could be used as primary screening tools across the site to identify areas with anomalies consistent with known sinkholes at this site. The results of the geophysical mapping would help identify areas requiring follow-up investigation with higher density geophysical surveying and drilling.

The recent drilling investigation encountered rapid changes in the lateral extents of disturbed soil areas. Thus, geophysical survey line locations and density should be selected to balance resolution and practicality. Conducting surveys using wider-spaced survey lines would be more economical, but will have a higher chance of missing anomalies than closer spaced survey lines. If geophysical anomalies are identified, the spacing of GPR and MASW surveys could be locally adjusted to try to characterize the anomaly further. Drilling investigations, including DCPT profiling, should be considered as follow up to provide a quantitative basis for geotechnical assessment of geophysical anomalies.

Regardless of the methods used to investigate the potential for developing sinkholes elsewhere on the site, there will still be residual uncertainty risk to the site due to potential challenges during investigation. These challenges include:

- The dense nature of the undisturbed ground conditions,
- Property access constraints,
- Access limitations due to physical obstructions at ground surface (i.e. walls, buildings),
- Safety considerations for operators,
- Equipment limitations

There are also inherent limitations and uncertainties in all geotechnical and geophysical investigation techniques. The residual risk of unidentified loose zones which may develop into sinkholes cannot be quantified. This risk must be recognized and accepted in any future investigation of this site.

Completion of a sinkhole hazard map would provide the District with information that could be used to communicate with stakeholders within the development (private land owners, utility owners, etc.) and to inform risk management and repair strategies at the site.

11.2 Addressing Potential for Future Sinkhole Development

High groundwater gradients and pathways for soil migration together are believed to form the mechanism which has caused and will continue to cause subsurface soil erosion and possibly

formation of sinkholes at the site. The ideal management strategy may employ one or more of the concepts described below.

11.2.1 Addressing Potential Pathways for Soil Migration

Opportunities may exist to address some of the potential pathways for soil migration (as discussed in Section 8). As water under pressure naturally tends to find weaknesses in any system, it would be important for all pathways to be addressed.

If significant site disturbance is permitted, this strategy may be able to address the majority of the pathways. However, potential pathways for soil migration are thought to exist at substantial depth below significant portions of the site. The feasibility of identifying and addressing all pathways would be challenging given the required depth of treatment and the presence of existing infrastructure. In addition, it may be possible that attempting to install filters where soil pipes or voids exist could inhibit groundwater flow, thereby transferring groundwater pressure to other areas of the site or neighbouring properties. Substantial excavations would likely be required. Groundwater management could also be problematic, and any excavation below or near the groundwater table will require localized temporary dewatering.

11.2.2 Addressing Groundwater Gradients

We recommend consideration be given to reducing the groundwater hydraulic gradient to reduce the risk of sinkholes developing in the future. Dewatering of the site would involve the targeted removal of water from the ground to reduce groundwater pressure and gradients. If successful, a dewatering approach would have the advantage of site-wide reduction in sinkhole formation potential with comparatively less site disturbance and potential for foreseeable adverse consequences. As an added general benefit, dewatering would likely dry out wet areas on the lower slopes.

Any dewatering strategy should consider the potential benefits from the assessment and upgrading of the surface water management plan and infrastructure at the site. Land use restrictions should be considered to prevent activities, such as irrigation or the use of storm water infiltration systems, which may decrease the effectiveness of the dewatering system.

Dewatering could take the form of vertical pumping wells installed in lines parallel to Seawatch Lane and Gale Avenue North. Alternatively horizontal drains could be installed into the upper and lower slopes. Both methods would require management of the (likely substantial) quantities of water produced, as well as long-term monitoring and maintenance of the installed systems to ensure that they are performing as intended. Both approaches would also have a practical service life, thus the future requirement for maintenance and possibly partial or full replacement of the system should also be considered.

The effects of groundwater chemistry on dewatering system service life and maintenance requirements should also be considered. During installation, water turbidity should be monitored closely for evidence of soil migration into the dewatering system so that any issues may be

addressed at an early stage. Permitting requirements for the discharge of produced water should also be considered.

11.2.2.1 Horizontal Drains

Based on our current understanding, we do not recommend the use of horizontal drains at this site due to potential challenges related to installation and consequences of failure of a drain.

Horizontal drains are installed by drilling from the bottom of the slope horizontally or sub-horizontally into targeted zones within the slope. Groundwater will flow towards and out of the drain by gravity. The benefit of horizontal drains is that they do not require external pumping. However, due to the complexity of the soil stratigraphy at the site, intercepting the ideal water-bearing layers that are causing the issues would be challenging and would require substantial drilling investigation to identify potential target zones. There is also significant risk in drilling horizontal drains into high groundwater gradient zones as blow out of groundwater could occur during drilling. Further, if the filters or seals on the horizontal drain are not properly constructed or fail, this could exacerbate soil erosion and piping failure which may lead to further sinkhole development.

11.2.2.2 Vertical Pumping Wells

We recommend consideration be given to the installation of vertical pumping wells. Relatively large diameter wells with down-hole pumps installed in each hole would be used to draw down the groundwater table. Wells would likely be drilled near Seawatch Lane to intercept groundwater flow as it enters the site and reduce the hydraulic gradient across the site. Wells would also likely be required south of Gale Avenue North to lower the groundwater level below the existing drainage blankets.

Vertically installed pumping / dewatering wells will not experience significant upward hydraulic gradients which will mitigate potential piping / washout concerns. Vertical wells can be designed to cross multiple soil horizons and intersect multiple water bearing zones to facilitate drawdown of the groundwater table.

The disadvantage of pumping wells is the requirement for long term provision of pumps and powering / maintaining of those pumps for the service life of the development. Well screens will have to be carefully selected to account for high fines content to avoid inducing soil migration in the area surrounding the well screen and the potential for premature clogging or soil loss.

If dewatering of the site is achieved using pumping wells, this will increase the groundwater gradient upstream (generally south) of the wells. If piping has regressed further south than the position of the wells, the pumping of the wells may cause the piping erosion process to migrate further south, which could conceivably lead to undermining / sinkholes to the south of the site. How far this piping could migrate south cannot be accurately quantified but the affected area could conceivably extend as far south as the current borrow area. Thus this approach may require the implementation of restrictions on future development south of the site.

Due to the complex hydrogeological conditions at this site, the installation of several pilot wells and a series of pumping tests, will be required. The tests will provide a basis for the assessment of the feasibility of vertical wells for dewatering and to determine the required scale and design parameters for the system. Ideally, prior to pumping well installation, a pilot dewatering program would include the use of sonic drilling methods in upland areas to guide well installation and to install additional groundwater monitoring well locations for the interpretation of pumping test results and monitoring of groundwater at the site. The performance of the system during seasonal increases in groundwater flow will be an important consideration.

It should be noted that careful monitoring during any pumping program will be required and that there is a risk that taking any active measures could induce movement or instability where meta-stable conditions exist.

11.3 Addressing Currently Identified Sinkholes

11.3.1 Ground Improvement Considerations

Ground improvement is recommended to address the hazards associated with the loose zones and voids identified near recent sinkholes, during the drilling investigation.

If site wide mapping of sinkhole hazards is implemented, it would help identify areas of concern and provide a basis for estimating the extents of soil that need to be remediated.

Based on the soil and groundwater conditions as well as site specific access constraints, some ground improvement options may not be as effective as others. Prior to proceeding to full-scale ground improvement, a trial or pilot program will need to be conducted to demonstrate the feasibility of the proposed method at this site and to determine the parameters for application elsewhere on the site. One option for a pilot repair area is the presently closed section of Gale Avenue North.

An effective dewatering system will need to be in place prior to implementing any ground improvement as such measures may cause changes to the groundwater regime that may subsequently cause further soil erosion beyond the area being treated.

Due to the complexity of the soil and groundwater conditions at the site, monitoring and geotechnical review, during and following construction of soil remediation, are required to address any issues which arise early on. Depending on the method of ground improvement selected, field investigation may be required to design and verify repairs.

As a result of repair activities, some utilities, pavement structure and possibly existing houses may be damaged and may require repair. These considerations should be included in the assessment of remedial options for the site.

A discussion of potential options for the repair or ground improvement of areas affected by the sinkhole formation process are discussed below.

11.3.2 Excavation and Replacement

In ideal circumstances, the excavation of affected soils and replacement with compacted fill may be the least expensive, simplest and most conventional approach to ground improvement. Re-use of existing fill would likely be possible to reduce the requirement for importing fill. Opportunities may exist to combine repair of filters and / or utilities (addressing pathways) with this ground improvement approach.

This method may be possible where space allows such as in some relatively undeveloped areas of the site. However, excavation geometry may make excavation and replacement in areas with existing houses, steep slopes, retaining walls, roads and utility infrastructure challenging and may require significant shoring and replacement / reconstruction to achieve required treatment depths, unless the infrastructure is temporarily relocated or removed.

Groundwater management could also be problematic, and any excavation below or near the groundwater table will require localized dewatering.

Depending on the depth and size of the affected areas encountered during mapping, there may be opportunities to address some loosened zones using this method. However, this method may not be practical in areas where loosened soils extend over large lateral extents and to significant depths.

11.3.3 Dynamic Compaction

Another approach to ground improvement is surface-based compaction methods such as dynamic compaction (repeatedly dropping a large weight on the ground surface) or Rapid Impact Compaction (RIC). These methods can be relatively efficient. However, they are also highly destructive of surfaces, buried utilities, and nearby buildings and disruptive to site users. Also, effectiveness is usually limited to depths of 5 to 10 m. As such, use of these methods at this site is not considered practicable.

11.3.4 Vibro-Compaction

Vibro-compaction methods are useful in applications where deep granular soils require densification. However due to the generation of excess pore water pressures under the applied vibrations, they are typically only practical in soils containing low fines. While the soils at this site have generally been found to be granular or non-plastic, the proportion of fines in the soil is generally substantial thus successful ground improvement with this method is likely not feasible. Further, even if these methods were feasible, they typically cause subsidence of adjacent infrastructure which could be problematic.

11.3.5 Piles or Stone Columns

Piles or stone columns (vibro-replacement) are primarily intended to provide load bearing support to surface structures. The provision of bearing support to surface structures and surfaces at the site could be achieved with these methods. However, all utilities, walls, houses,

roads, driveways, etc. would require support from these elements. Unless closely spaced, these methods do not substantially improve the ground which surrounds them. Installing piles or stone columns at close spacing over a large area would likely be cost prohibitive and highly disruptive. Furthermore, installing piles or stone columns will likely not address soil migration issues or reduce the risk of developing sinkholes in the future. This approach is therefore likely not practicable at the site.

11.3.6 Grouting

The injection of cementitious grout slurries under pressure into the ground for the improvement of soil could be a feasible solution for this site. Compaction grouting methods may be the most effective ground improvement option in areas of limited access, or where ground improvement is required near existing structures and / or utilities, and where the required depth and extents of loose zones are significant. However, the engineering design and implementation is highly specialized and will require consultation with grouting specialists and specialized contractors.

The drawback with this approach is the reduction of soil pore space, due to infilling with grout, which will reduce the groundwater permeability of the soils. This could redirect groundwater flow and increase hydraulic gradients in other previously unaffected areas. As such, ground remediation using grouting will require prior implementation of an effective dewatering system for the site to permanently reduce the groundwater table below the grouted zones.

11.4 Long Term Monitoring

The District will need to consider regular monitoring of the site in the long term, irrespective of the approach implemented to address the sinkhole issues. Monitoring is anticipated to comprise regular surface and groundwater monitoring prior to, during, and following implementation of dewatering and ground improvements works, if conducted. Regular monitoring and geotechnical review provides the opportunity for establishment of baseline conditions at the site, the observation of trends, and the modification of site management strategies, if required.

11.5 Potential Risks of Action

Any active measures which are undertaken, even if positive in nature (i.e. dewatering, drilling, excavation or grouting) could destabilize unknown meta-stable/precarious ground conditions if they exist. The consequent effects of any remedial actions on groundwater flow must also be considered, to avoid transferring groundwater pressure and risk elsewhere.

11.6 Residual Uncertainties and Risk

There exists uncertainties and residual risks associated with sinkhole hazards that have not been detected or observed. We are not able to quantify these risks, but we note that they are present and should be recognized and considered when making future decisions regarding the development and land use at this site and on the adjacent lands.

To mitigate exposure to these residual risks, construction of additional houses or other structures at this development or the lands immediately south of the site needs to consider the potential for development of future sinkholes. Further development will likely increase exposure to sinkhole hazards and risk to the public and property. We recommend that a period of monitoring and observation be adopted within which no new development is permitted in this area. Independent geotechnical review is recommended for any new development, excavation, or practice that may influence groundwater conditions at this site such as excessive irrigation.

11.7 Site Closure

Our investigation and assessment indicates that the presence of voids and loose zones is likely not confined to isolated areas within the development. The identified voids and loose zones could develop into sinkholes in the future if measures are not taken to address the processes which contribute to sinkhole development.

It may be that the required remedial measures, site management, and acceptance of residual risk are not feasible, practical or economic. In such a case, a feasible option from a geotechnical standpoint may be the long term closure and deactivation of the site or portions of the site. It is noted that closure of the site would have some technical challenges that need to be addressed. However, the potential exposure of the public to the sinkhole hazard could likely be mitigated.

Prior to consideration of partial or full site closure, we recommend the implementation of a sinkhole hazard mapping program and pilot testing of a dewatering system in order to better understand the distribution and extent of hazards across the site, and to assess the feasibility of implementation of an effective dewatering system at the site. We feel obtaining this information will help the District make a more informed decision on available options. It is noted that, should the District decide that the risks or costs are not justifiable at any stage of the investigation or assessment, they could decide to halt any further work.

THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

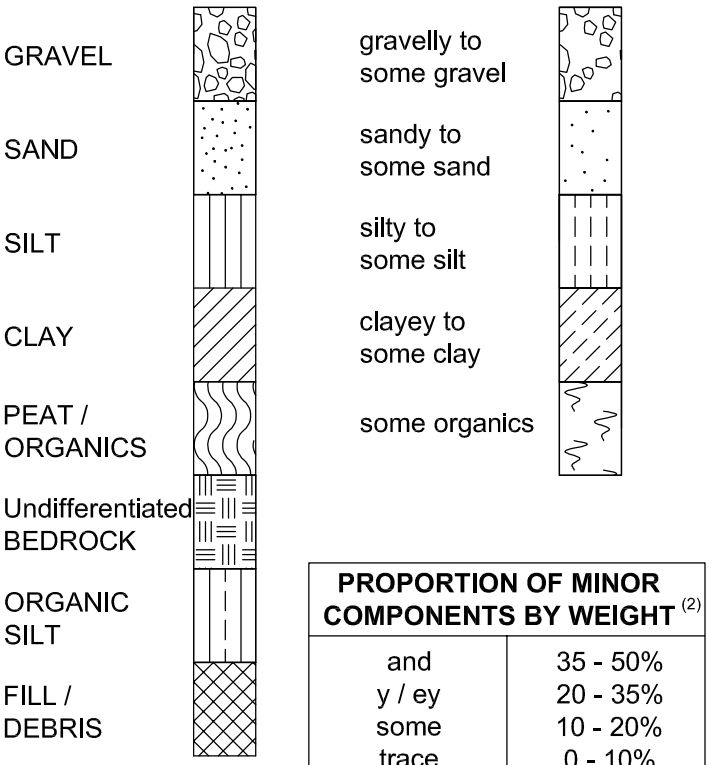
Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

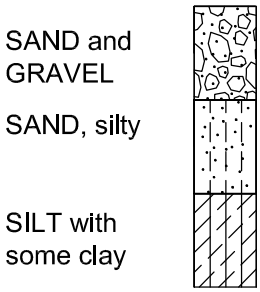
The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

SYMBOLS AND TERMS
FOR SOIL DESCRIPTION AND TEST HOLE LOGS

BASIC SOIL SYMBOLS



SYMBOL VARIATIONS - EXAMPLES (1)



DENSITY OF GRANULAR SOILS	
Description	SPT N (5) (6)
Very Loose	0 - 4
Loose	4 - 10
Compact	10 - 30
Dense	30 - 50
Very Dense	> 50

PROPORTION OF MINOR COMPONENTS BY WEIGHT (2)	
and	35 - 50%
y / ey	20 - 35%
some	10 - 20%
trace	0 - 10%

CONSISTENCY OF COHESIVE SOILS	
Description	Undrained Shear Strength (kPa) (6)
Very Soft	< 12
Soft	12 - 25
Firm	25 - 50
Stiff	50 - 100
Very Stiff	100 - 200
Hard	> 200

PENETRATION TESTS	
Dynamic Cone Penetration	
Standard Penetration	
Becker Closed Casing	
Becker Open Casing	
Bounce Chamber Pressure	

CLASSIFICATION BY PARTICLE SIZE				
		Size Range (6)		
			U.S. Standard Sieve Size	
Name		(mm) (3)	Retained	Passing
Boulders		> 200	8 inch	-
Cobbles		75 - 200	3 inch	8 inch
Gravel:	coarse	19 - 75	0.75 inch	3 inch
	fine	5 - 19	No. 4	0.75 inch
Sand:	coarse	2 - 5	No. 10	No. 4
	medium	0.4 - 2	No. 40	No. 10
	fine	0.075 - 0.4	No. 200	No. 40
Fines (Silt or Clay) (4)		< 0.075	-	No. 200

(1) Only selected examples of the possible variations or combinations of the basic symbols are illustrated.
(2) Example: SAND, silty, trace of gravel = sand with 20 to 35% silt and up to 10% gravel, by dry weight. Percentages of secondary materials are estimates based on visual and tactile assessment of samples.
(3) Approximate metric conversion.
(4) Fines are classified as silt or clay on the basis of Atterberg limits.
(5) SPT N values on test hole logs are uncorrected field values.
(6) Reference Canadian Foundation Engineering Manual 4th Edition, 2006.

THURBER

THURBER

TABLES

Table 1. Timeline of Selected Events/Observations

Date of Event	Event / Observation / Activity	Location	Source	Description / Comments
September 30, 2004	Report	General Site	GeoTacTics (September 30, 2004)	A report was issued which formed the initial geotechnical basis for development at the site. Springs were noted and drainage measures discussed.
February 17, 2005	Investigation	General Site	GeoTacTics (February 17, 2005)	Initial geotechnical investigation of the overall site was completed.
July 22, 2005	Seepage Issues/Slope Instability	Gale Avenue North and Lot 15	GeoTacTics (July 27, 2005)	Challenges with seepage and slope stability noted during first construction season.
July 31 to August 11, 2005	Sinkhole	Seawatch Lane adjacent Lots 25, 26	GeoTacTics (August 12, 2005)	First reported sinkhole encountered at site.
August 25, 2005	Seepage Issues/ Storm Sewer	Gale Avenue North and Lots 9, 10	GeoTacTics (August 27, 2005)	Measures described to address challenges with seepage on Gale Avenue North and during installation of storm sewer at Lots 9 / 10.
September 8, 2005	Drainage Blanket / Seepage Issues	Gale Avenue North at Roundabout and at Lot 23	GeoTacTics (September 17, 2005)	Drainage blanket installation progressing at roadway roundabout without filter fabric below. New seepage issues during excavation of Gale Avenue North at Lot 23.
September 15, 2005	Spring / Slope Instability / Drainage	Gale Avenue North at Lot 23	GeoTacTics (September 17, 2005)	Slide occurred above large sediment laden spring at Lot 23. Drainage measures for spring management proposed.
September 28 and 30, 2005	Spring / Tension Crack / Drainage	Gale Avenue North and Seawatch Lane at Lots 20 and 21	GeoTacTics (October 5, 2005)	Large new sediment laden spring at Lot 21/Gale Avenue North. Tension crack noted on Seawatch Lane above Lots 20 / 21. Conceptual design to address the spring was discussed, did not reference requirement for filter fabric.
October 7, 2005	Spring / Tension Crack / Sinkholes	Gale Avenue North, Seawatch Lane, Crowston Road, Lots 20, 21, 24 and 25	GeoTacTics (October 7, 2005)	Spring at Lot 21 and Gale Avenue North continuing. Tension crack on Seawatch Lane expanding. Four new sinkholes on: Seawatch Lane, Lot 21, Gale Avenue North at Lots 24/25, and Crowston Road east of Lot 28.
Prior to April 28, 2006	Sinkholes / Spring	Gale Avenue North at Lot 21	GeoTacTics (April 28, 2006)	Three additional un-dated sinkholes shown in Figure 2 of report on Lot 21. Installation of drainage measures at spring at Lot 21 and Gale Avenue North reportedly took 4 weeks.
June 1, 2007	Seepage Issues / Storm Sewer	Lot 10	GeoTacTics (June 1, 2007)	Seepage issues on Lot 10 during site preparation. New drainage blanket concept. Backfill and heavy traffic over Lots 9/10 storm sewer.
June 7, 2007	Sinkhole	Lot 29 at Seawatch Lane	Web (June 8, 2007)	Sinkhole on Lot 29 discovered.
July 18, 2007	Springs / Drainage Blanket	Lots 5 to 12	GeoTacTics (August 31, 2007)	Provides update on status of drainage blanket construction on Lots 5 to 12. New springs described on Lots 9/10 and on Lot 5 as well as challenges with construction of drainage blanket.
July 23, 2007	Sinkhole Repair	Lot 29 at Seawatch Lane	GeoTacTics (August 31, 2007)	Field review of sinkhole treatment on Lot 29. Excavation of sinkhole was reportedly about 10.5 m deep and 12 m diameter. Treatment did not follow sinkhole below Seawatch Lane.
April 2, 2012	Sinkhole	Gale Avenue North at Lot 9	GeoTacTics (June 5, 2012)	Depression adjacent to Gale Avenue North at Lot 9 is first described, including a cavity extending below north curb of road. Area backfilled.
May 26, 2012	Spring	Lot 3	Thurber (July 20, 2012)	Spring at Lot 3 noted, carrying sand and silt.
June 1, 2012	Sinkhole	Seawatch Lane at Lots 28 / 29	Thurber (July 20, 2012)	Asphalt collapse on Seawatch Lane due to sinkhole.
June 5 and 6, 2012	Investigation	General Site	Thurber (July 20, 2012)	High level geophysical survey on roads and Lots 27 and 28, using Ground Penetrating Radar (high frequency).
September 20 to 25, 2012	Investigation	General Site	Golder (November 15, 2012)	Drilling investigation and groundwater monitoring wells installed.
November 28 to December 6, 2012	Investigation	General Site	Thurber (April 5, 2013)	High level geophysical survey, using Streaming potential and Resistivity.
January 28 to February 1, 2013	Investigation	General Site	Thurber (April 5, 2013)	Supplementary drilling investigation and installation of additional groundwater monitoring wells.
August 3, 2013	Spring Mitigation System	Lot 3	Correspondence from Concordia (June 25, 2015)	Spring mitigation system constructed on Lot 3.
September 10, 2013	Sinkhole Repair	Seawatch Lane at Lots 28 and 29	Golder (November 14, 2013)	Sinkhole treatment completed at Seawatch Lane.
November 4, 2014	Depression	Seawatch Lane at Lots 28 and 29	Verbal account and Photographs	Depression noted behind and below south curb of Seawatch Lane in area of 2012 sinkhole.
November 12, 2014	Depression	Gale Avenue North at Lot 9	District photos and Western (February 27, 2015)	Depression noted extending below north curb of Gale Avenue North and Lot 9 driveway. Later temporarily repaired.
February 26, 2015	Sinkholes	Lot 21 and Gale Avenue North at Lot 9	Western (February 27, 2015)	Sinkhole on Lot 21 north of house. Depression reactivated below north curb of Gale Avenue North and Lot 9 driveway.
April 13 to 17, 2015	Investigation	Gale Avenue North at Lots 9 and 21 and on Lot 28	(this report)	Drilling investigation and groundwater monitoring wells installed.
May 26 to May 29, 2015	Investigation	Gale Avenue North at Lots 9 and 21 and on Lot 28	(attached to this report)	Low frequencey Ground Penetrating Radar and M.A.S.W. geophysical survey in areas recently drilled and high-level GPR survey elsewhere on roads.

Definitions:

Concordia =	Concordia Homes Ltd.
District =	District of Sechelt
GeoTacTics =	GeoTacTics Engineering Ltd. (later incorporated as GeoTacTics Media Engineering (2007) Ltd.)
Golder =	Golder Associates Ltd.
Thurber =	Thurber Enginering Ltd.
Web =	Web Engineering Ltd.
Western =	Western Geotechnical Consultants Ltd.

THURBER

Table 2. List of Documents Referenced

Document Date	Type	Author	Addressed To	Title of Document
September 30, 2004	Letter	GeoTacTics	Concordia	Preliminary Geotechncial Assessment Proposed Shores Subdivision, Sechelt, B.C.
February 17, 2005	Letter	GeoTacTics	Concordia	Preliminary Geotechncial Assessment Proposed Shores Subdivision, Sechelt, B.C.
March 17, 2005	Letter	GeoTacTics	Concordia	Addendum to February 17, 2005 Letter: Preliminary Geotechncial Assessment Proposed Shores Subdivision, Sechelt, B.C.
July 27, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 01, The Shores, Sechelt, B.C.
July 31, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 02, The Shores, Sechelt, B.C.
August 12, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 03, The Shores, Sechelt, B.C.
August 27, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 04, The Shores, Sechelt, B.C.
September 17, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 05, The Shores, Sechelt, B.C.
September 17, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 06, The Shores, Sechelt, B.C.
September 26, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 07, The Shores, Sechelt, B.C.
October 5, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 08, The Shores, Sechelt, B.C.
October 7, 2005	Memo	GeoTacTics	Concordia	Site Preparation Field Review 09, The Shores, Sechelt, B.C.
April 28, 2006	Letter	GeoTacTics	Concordia	Geotechnical Assessment Phase 1, The Shores Subdivision Sechelt BC
May 9, 2006	Letter	GeoTacTics	Concordia	Addendum to Geotechnical Assessment, Phase 1, The Shores Subdivision Sechelt BC
June 1, 2007	Memo	GeoTacTics	Concordia	Site Servicing Field Review 18, The Shores, Sechelt, B.C. (Project No. CO-83)
June 8, 2007	Fax	Web	GeoTacTics	Concordia Homes; Siltation Control
August 31, 2007	Letter	GeoTacTics	Concordia	July and August Geotechncial Inspection Summary - The Shores Phase 1, Sechelt B.C.
September 5, 2007	Memo	GeoTacTics	Concordia	Construction Field Review 06 - Lot 26 Garage Foundation Inspection
November 6, 2007	Memo	GeoTacTics	Concordia	Construction Field Review 05 - Inspection of Foundation Excavation, Lot 19, Phase 1 - The Shores
November 6, 2007	Memo	GeoTacTics	Concordia	Construction Field Review 05 - Inspection of Foundation Excavation, Lot 20, Phase 1 - The Shores
December 15, 2008	Letter	Thurber	District	The Shores Subdivision - Phase 1, Geotechnical Engineering Review of Rock Stack retaining walls
January 17, 2009	Memo	GeoTacTics	Concordia	Slope Remediation, Lots 18 to 25, Phase 1, Seawatch
February 17, 2009	Letter	GeoTacTics	District	Geotechncial Issues for Sign-off of Substantial Completion, Site Services Seawatch Phase 1, Sechelt, B.C. for Concordia Homes Ltd.
February 28, 2009	Letter	GeoTacTics	Concordia	Temporary Slope Buttressing, Lots 1 to 12 Seawatch Phase 1, Sechelt, B.C. For Concordia Homes Ltd.
March 7, 2009	Letter	GeoTacTics	Concordia	Lot Grading, Lots 1 to 12 Seawatch Phase 1, Sechelt, B.C. For Concordia Homes Ltd.
June 11, 2009	Memo	GeoTacTics	Web	Site Inspection Field Review 25, Phase 1, Seawatch
June 17, 2009	Memo	GeoTacTics	Web	Site inspection Field Review 26, Phase 1, Seawatch
June 24, 2009	Memo	GeoTacTics	Web	Site inspection Field Review 27, Phase 1, Seawatch
July 21, 2009	Memo	GeoTacTics	Web	Site inspection Field Review 28, Phase 1, Seawatch
December 18, 2009	Letter	GeoTacTics	District	As-Built Stacked Rock Retaining Walls for Lots 19 to 24 Inclusive Seawatch Phase 1, Sechelt, B.C. For Concordia Homes Ltd
February 2, 2010	Letter	GeoTacTics	District	Filling and Temporary Site Grading Lots 1 to 18, Seawatch Phase 1, Sechelt, B.C. for Concordia Homes Ltd.
June 5, 2012	Memo	GeoTacTics	District	Field Review 01 - "The Shores", Gale Avenue North, Sechelt, BC
July 20, 2012	Letter	Thurber	District	The Shores Subdivision - Phase 1, Geotechnical Assessment
November 5, 2012	Letter	Golder	Concordia	Geotechnical Review and Assessment - Lots 13 to 15, Seawatch Residential Subdivision, Sechelt, BC
November 15, 2012	Letter	Golder	Concordia	Geotechnical Review and Assessment, Phase 1 Seawatch Residential Subdivision, Sechelt, BC
April 5, 2013	Report	Thurber	District	The Shores - Phase 1 Subdivision, Geotechnical Investigation and Geotechnical Assessment
November 14, 2013	Letter	Golder	Concordia	Summary of Sinkhole Treatment, Seawatch Sudivision Phase 1, Sechelt, BC
February 27, 2015	Letter	Western	District	Emergency Response - Geotechnical Inspection, 6670 North Gale Avenue, Sechelt, BC

Note: Numerous other documents were referenced in the preparation of this report but which are not explicitely mentioned in the report and therefore are not listed here.

Definitions:

Concordia = Concordia Homes Ltd.
District = District of Sechelt
GeoTacTics = GeoTacTics Engineering Ltd. (later incorporated as GeoTacTics Media Engineering (2007) Ltd.)
Golder = Golder Associates Ltd.
Thurber = Thurber Enginering Ltd.
Web = Web Engineering Ltd.
Western = Western Geotechnical Consultants Ltd.

Table 3. Summary of Soil Stratigraphy

Sequence	Soil Stratum	Typical Description*	Top Surface Elevation (m)	Thickness (m)	Present In
1	Upper Sand	Grey SAND with trace silt, occasionally trace to some silt and trace gravel.	46 to 45	11 to 14	BH12-09, TH13-01, -02, -03b, -03c
2	Upper Silty Sand/ Sandy Silt	Grey or brown, silty SAND / sandy SILT and occasional trace gravel.	39 to 32	4 to 7	BH12-05, -08, -09, TH13-01, -02, -05c, TH15-24, -25, -26, -27, -28
3	Lower Sand	Grey SAND with trace silt, occasionally trace to some silt and trace gravel.	32 to 24	3 to 9	BH12-05, -07, -08, -09, TH13-05c, -07, TH15-25A
4	Lower Silty Sand/ Sandy Silt	Brown, silty SAND / sandy SILT.	22 to 15 (9 to 8 in lower slope)	3 to 10	BH12-01, -02, -03, -06, -07, TH13-07, TH15-01, -02, -04, -23
5	Basal Silt	Grey SILT with trace to some sand, trace clay and occasionally trace gravel.	18 to 4	-	BH12-02, -03, -06, -07, TH13-08, -09, TH15-01

*** Strata exhibit locally distinct beds or zones which do not conform to the generalized descriptions provided.**

FIGURES

Plotted: July 15, 2015



\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03357.dwg

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SITE LOCATION

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

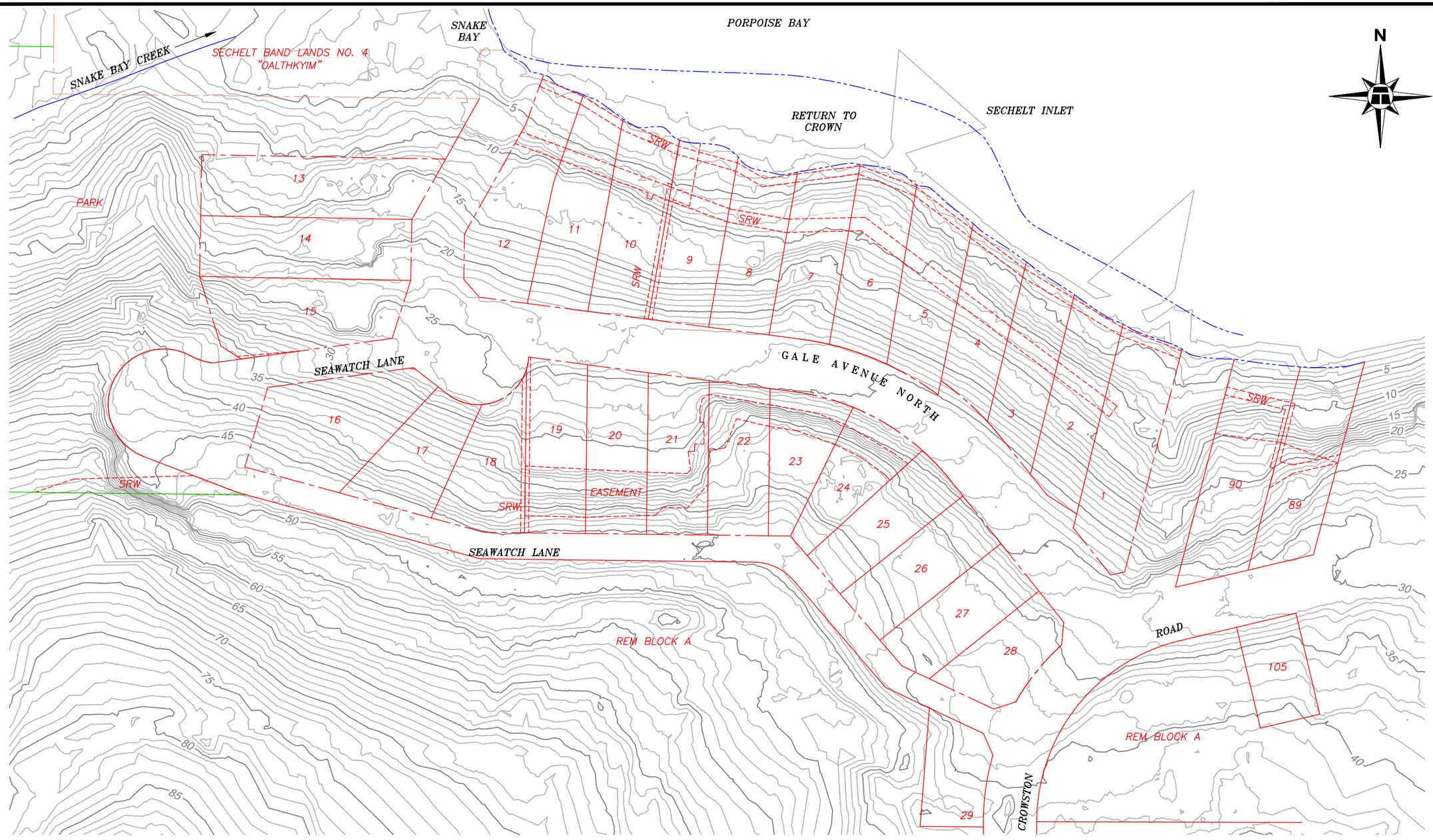
DATE	SCALE
JULY 16, 2015	AS SHOWN

PROJECT No.	FIG. No.	REV.
14-214-4	1	-

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



PROPERTY LEGEND:

- SUBJECT PROPERTY
- PROPERTY LINES
- NATURAL BOUNDARY
- COVENANT
- RIGHT-OF-WAY

NOTES:

1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. CONTOURS DERIVED FROM LIDAR DATA FLOWN ON SEPTEMBER 12, 2009 SUPPLIED BY THE SUNSHINE COAST REGIONAL DISTRICT.

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SITE TOPOGRAPHY (2009)

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE	SCALE
JULY 16, 2015	AS SHOWN

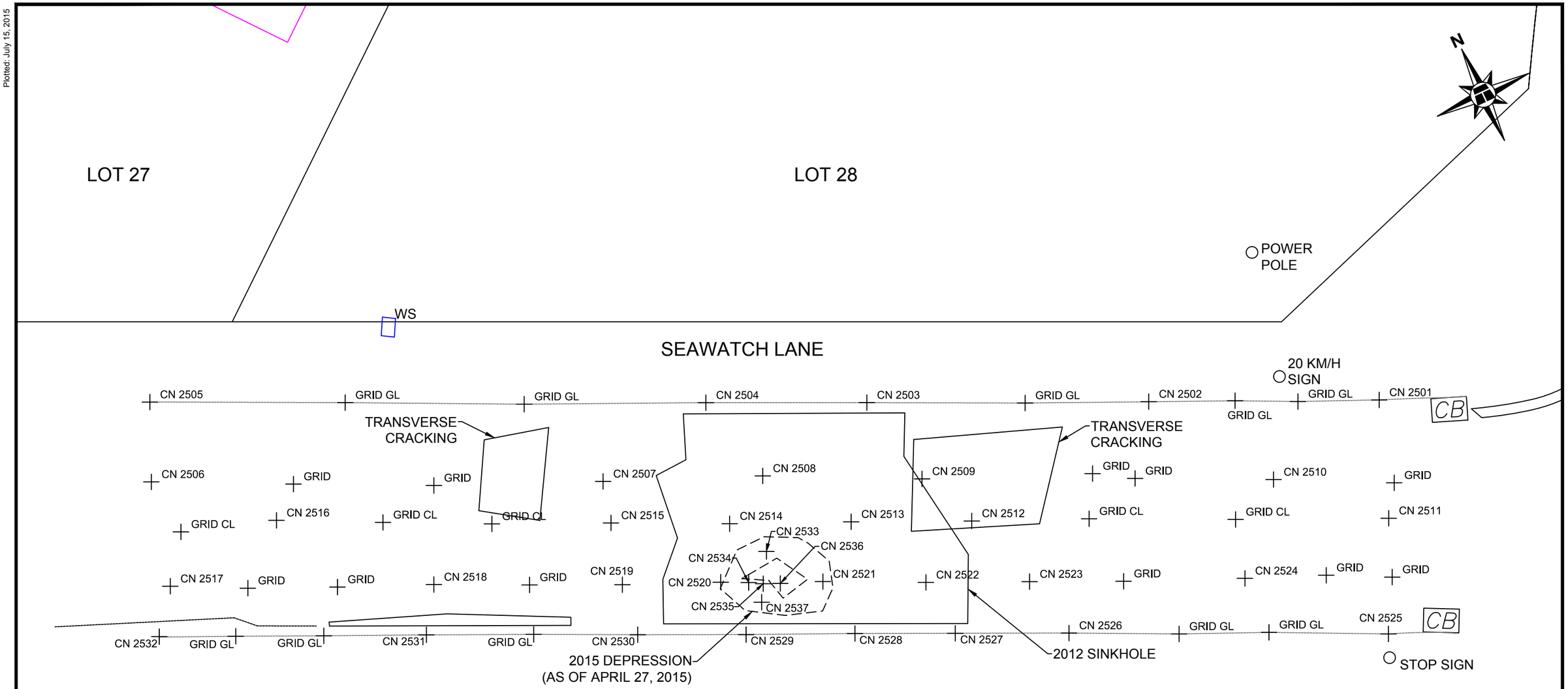
PROJECT No.	FIG. No.	REV.
14-214-4	2	-

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



NOTES:
1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. SURVEY CONTROL GRID AND FEATURES FROM STRAIT LAND SURVEYING (FILES 'ACAC-34-15 APRIL 27 2015.DWG' & 'SEAWATCH MONITORING NAILS.TXT' DATED MAY 25, 2015).

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SURVEY CONTROL GRID
SEAWATCH LANE AT LOT 28

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE	SCALE
JULY 16, 2015	AS SHOWN

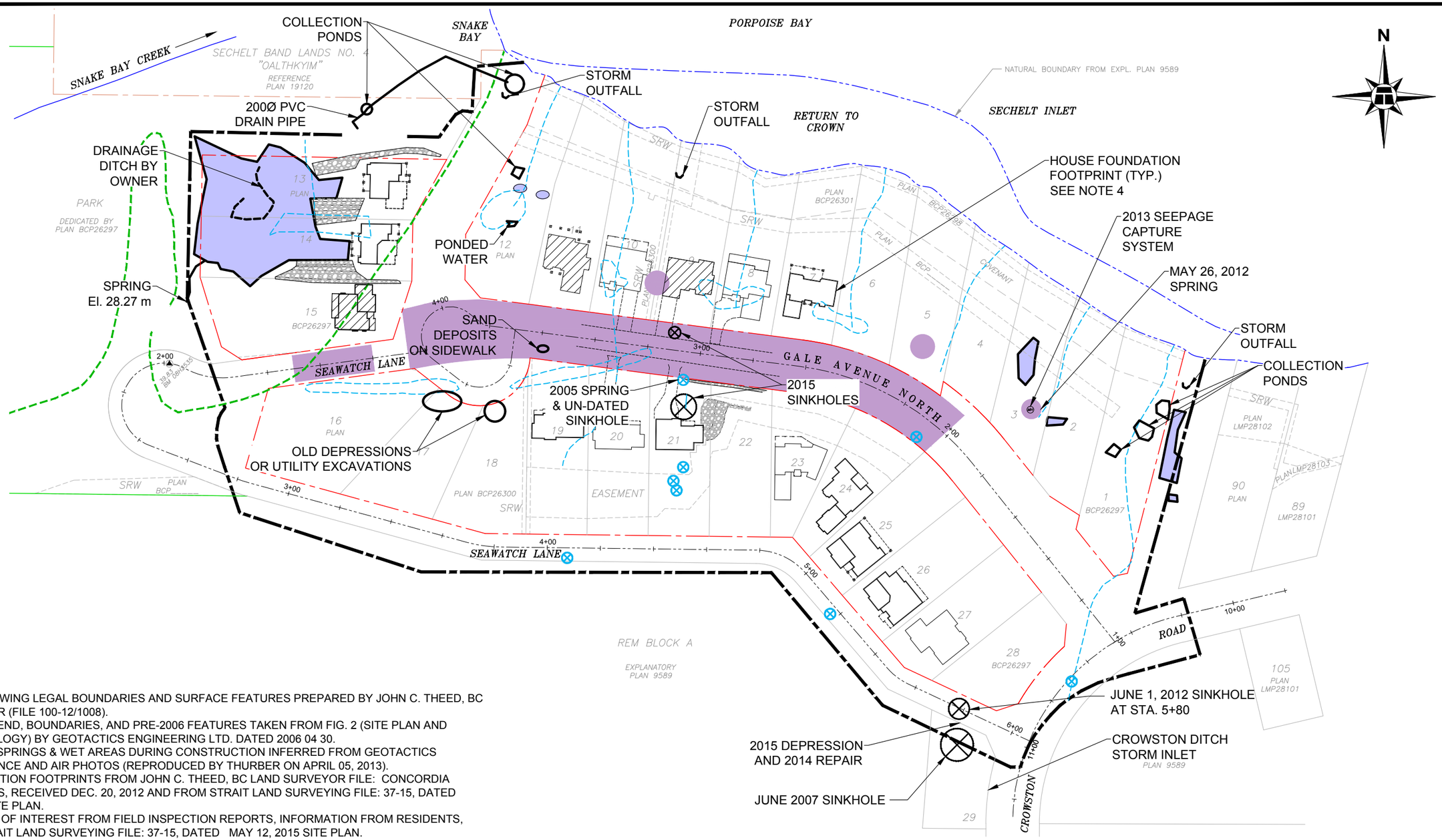
PROJECT No.	FIG. No.	REV.
14-214-4	3	-

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03364.dwg

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



NOTES:

1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. LOCATIONS OF SPRINGS & WET AREAS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2013).
4. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
5. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.

PROPERTY LEGEND (SEE NOTE 2):

SUBJECT PROPERTY	COVENANT
PROPERTY LINES	RIGHT-OF-WAY
NATURAL BOUNDARY	PHASE 1 BOUNDARY
IR RESERVE	ENVIRONMENTAL COVENANT LINE
PARK BOUNDARY	STREAMS

FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):

PRE 2006 SINKHOLE	HOUSE INCOMPLETE OR UNOCCUPIED
PRE 2006 SPRING OR STREAM	PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION
POST 2006 SINKHOLE	2015 SPRING OR WET AREA
ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED)	

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SITE PLAN AND FEATURES OF INTEREST

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

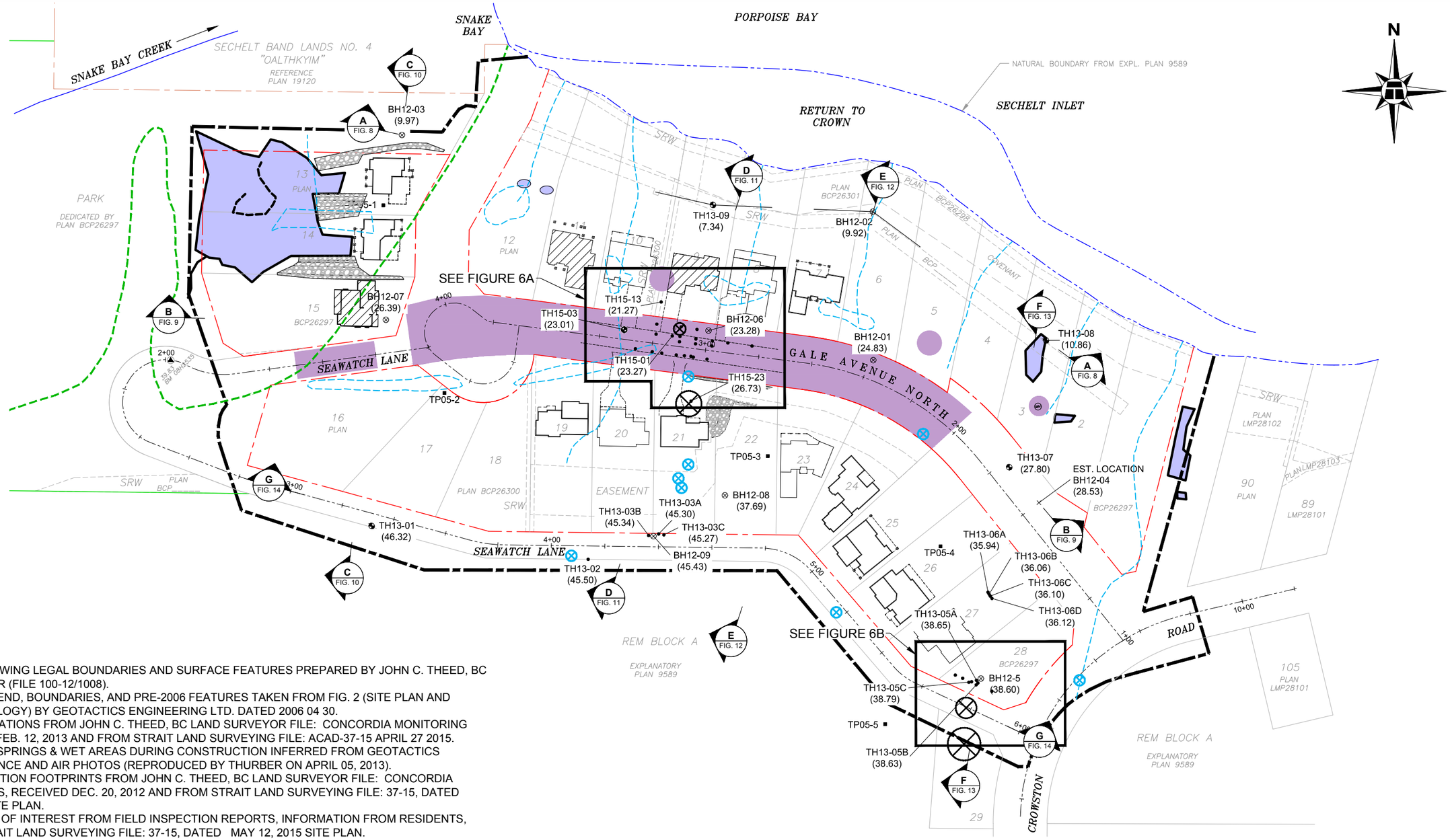
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 4	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14VED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015



NOTES:
1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. TEST HOLE LOCATIONS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA MONITORING WELLS, DATED FEB. 12, 2013 AND FROM STRAIT LAND SURVEYING FILE: ACAD-37-15 APRIL 27 2015.
4. LOCATIONS OF SPRINGS & WET AREAS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2013).
5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
6. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.

PROPERTY LEGEND (SEE NOTE 2):

SUBJECT PROPERTY	COVENANT
PROPERTY LINES	RIGHT-OF-WAY
NATURAL BOUNDARY	PHASE 1 BOUNDARY
IR RESERVE	ENVIRONMENTAL COVENANT LINE
PARK BOUNDARY	STREAMS

TEST HOLE LEGEND:

⊛	TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
•	TEST HOLE BY THURBER
⊗	BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER
×	BOREHOLE BY GOLDER
■	TEST PIT BY OTHERS (FEB 2005, SEE NOTE 2)
(38.65)	ELEVATION OF WELL COVER OR GROUND SURFACE (m)

FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):

PRE 2006 SINKHOLE	HOUSE INCOMPLETE OR UNOCCUPIED
PRE 2006 SPRING OR STREAM	PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION
POST 2006 SINKHOLE	2015 SPRING OR WET AREA
ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED)	

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

TEST HOLE LOCATION AND SITE PLAN

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

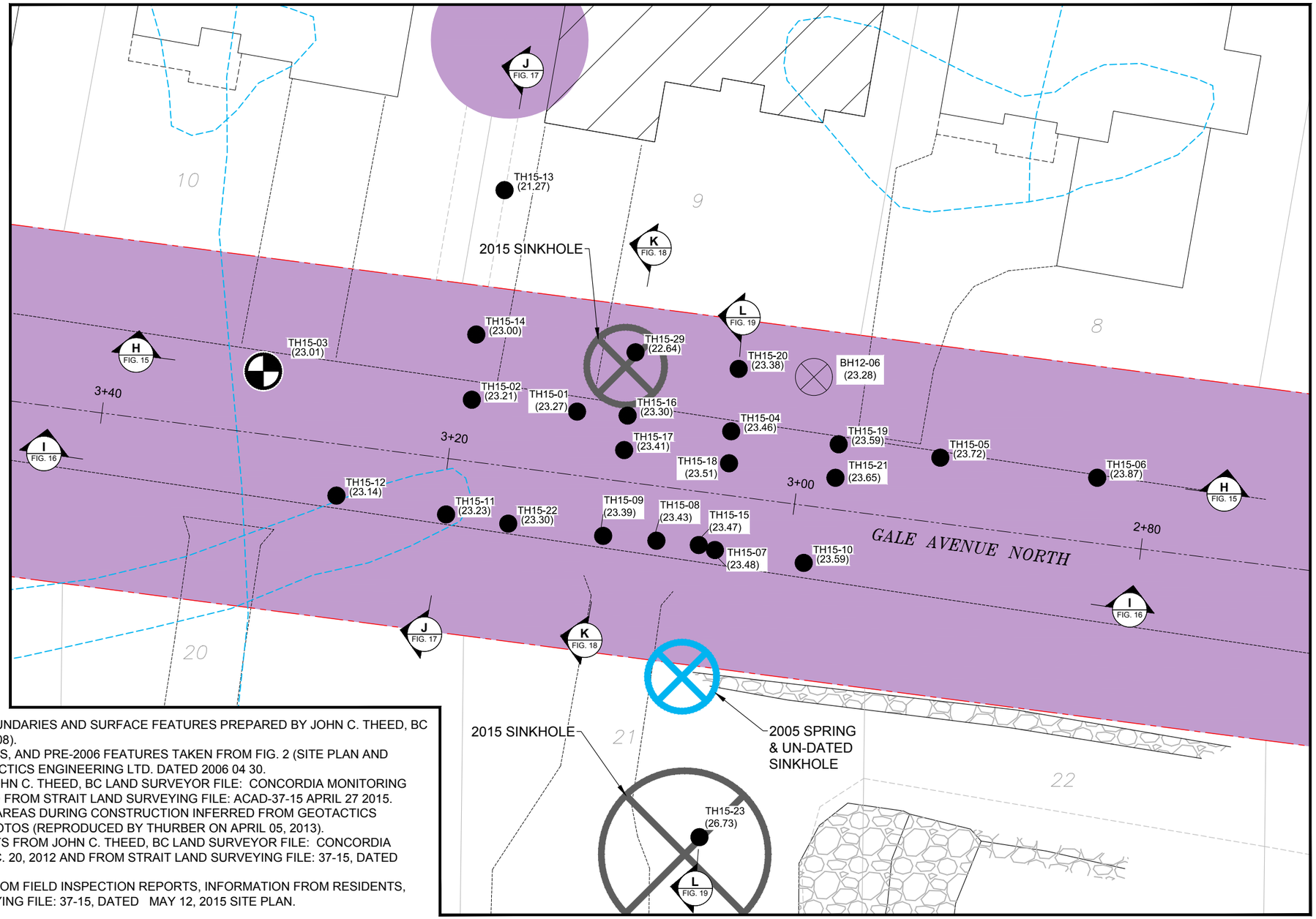
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 5	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\114\VED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015



NOTES:
1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. TEST HOLE LOCATIONS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA MONITORING WELLS, DATED FEB. 12, 2013 AND FROM STRAIT LAND SURVEYING FILE: ACAD-37-15 APRIL 27 2015.
4. LOCATIONS OF SPRINGS & WET AREAS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2013).
5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
6. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.

PROPERTY LEGEND (SEE NOTE 2):

SUBJECT PROPERTY	COVENANT
PROPERTY LINES	RIGHT-OF-WAY
NATURAL BOUNDARY	PHASE 1 BOUNDARY
IR RESERVE	ENVIRONMENTAL COVENANT LINE
PARK BOUNDARY	STREAMS

TEST HOLE LEGEND:

	TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
	TEST HOLE BY THURBER
	BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER
(38.65)	ELEVATION OF WELL COVER OR GROUND SURFACE (m)

0 2.5 5 7.5 10 12.5m

FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):

PRE 2006 SINKHOLE	HOUSE INCOMPLETE OR UNOCCUPIED
PRE 2006 SPRING OR STREAM	PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION
POST 2006 SINKHOLE	2015 SPRING OR WET AREA
ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED)	

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

TEST HOLE LOCATION PLAN
GALE AVENUE NORTH

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

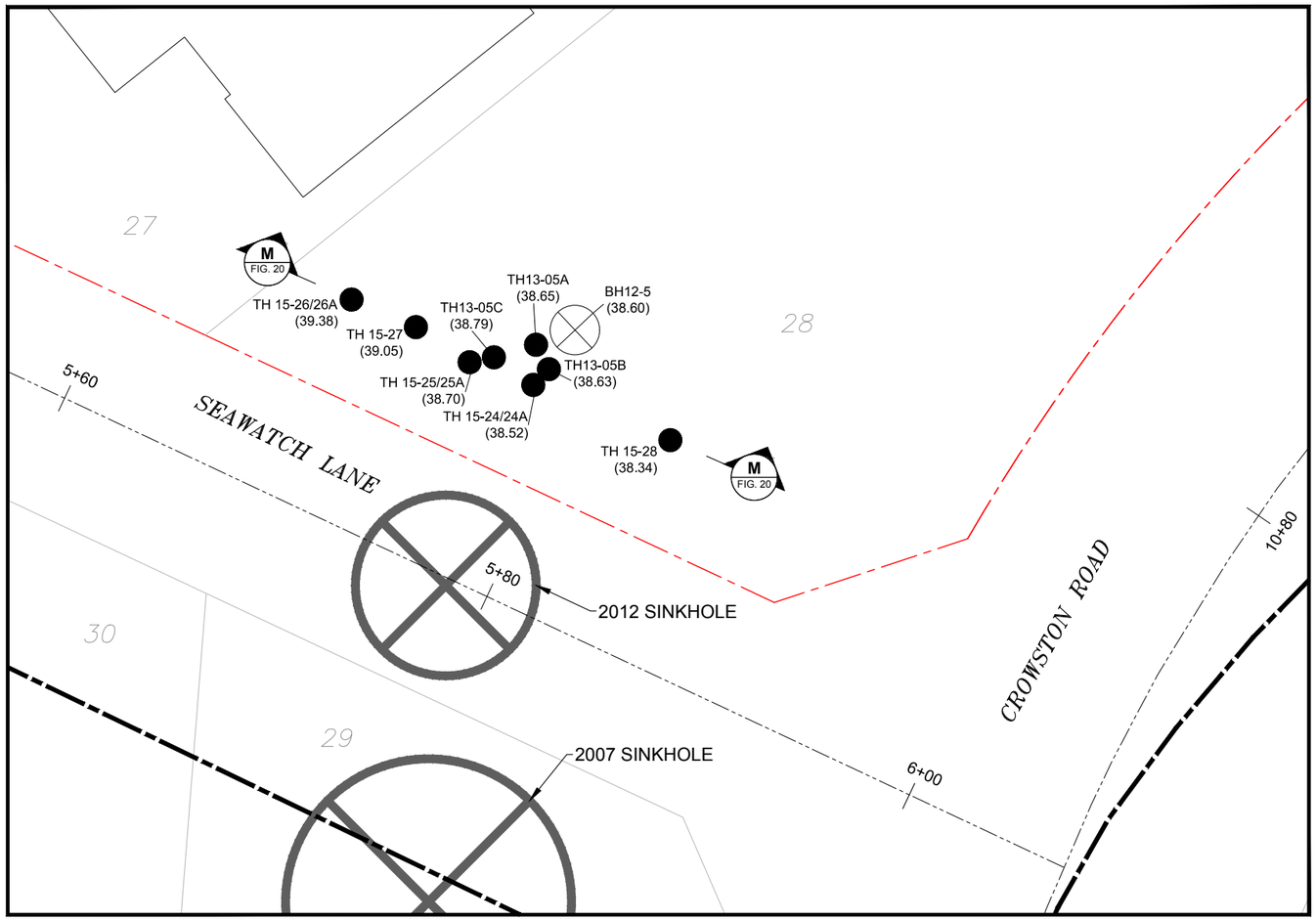
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 6A	REV.: -

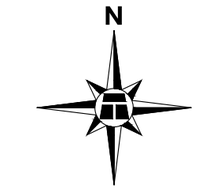
CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015





NOTES:

1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. TEST HOLE LOCATIONS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA MONITORING WELLS, DATED FEB. 12, 2013 AND FROM STRAIT LAND SURVEYING FILE: ACAD-37-15 APRIL 27 2015.
4. LOCATIONS OF SPRINGS & WET AREAS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2013).
5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
6. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.

PROPERTY LEGEND (SEE NOTE 2):

- SUBJECT PROPERTY
- PROPERTY LINES
- NATURAL BOUNDARY
- IR RESERVE
- PARK BOUNDARY
- COVENANT
- RIGHT-OF-WAY
- PHASE 1 BOUNDARY
- ENVIRONMENTAL COVENANT LINE
- STREAMS

TEST HOLE LEGEND:

- TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
- TEST HOLE BY THURBER
- BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER
- (38.65) ELEVATION OF WELL COVER OR GROUND SURFACE (m)

0 2.5 5 7.5 10 12.5m

FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):

- PRE 2006 SINKHOLE
- PRE 2006 SPRING OR STREAM
- POST 2006 SINKHOLE
- ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED)
- HOUSE INCOMPLETE OR UNOCCUPIED
- PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION
- 2015 SPRING OR WET AREA

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

TEST HOLE LOCATION PLAN
SEAWATCH LANE

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

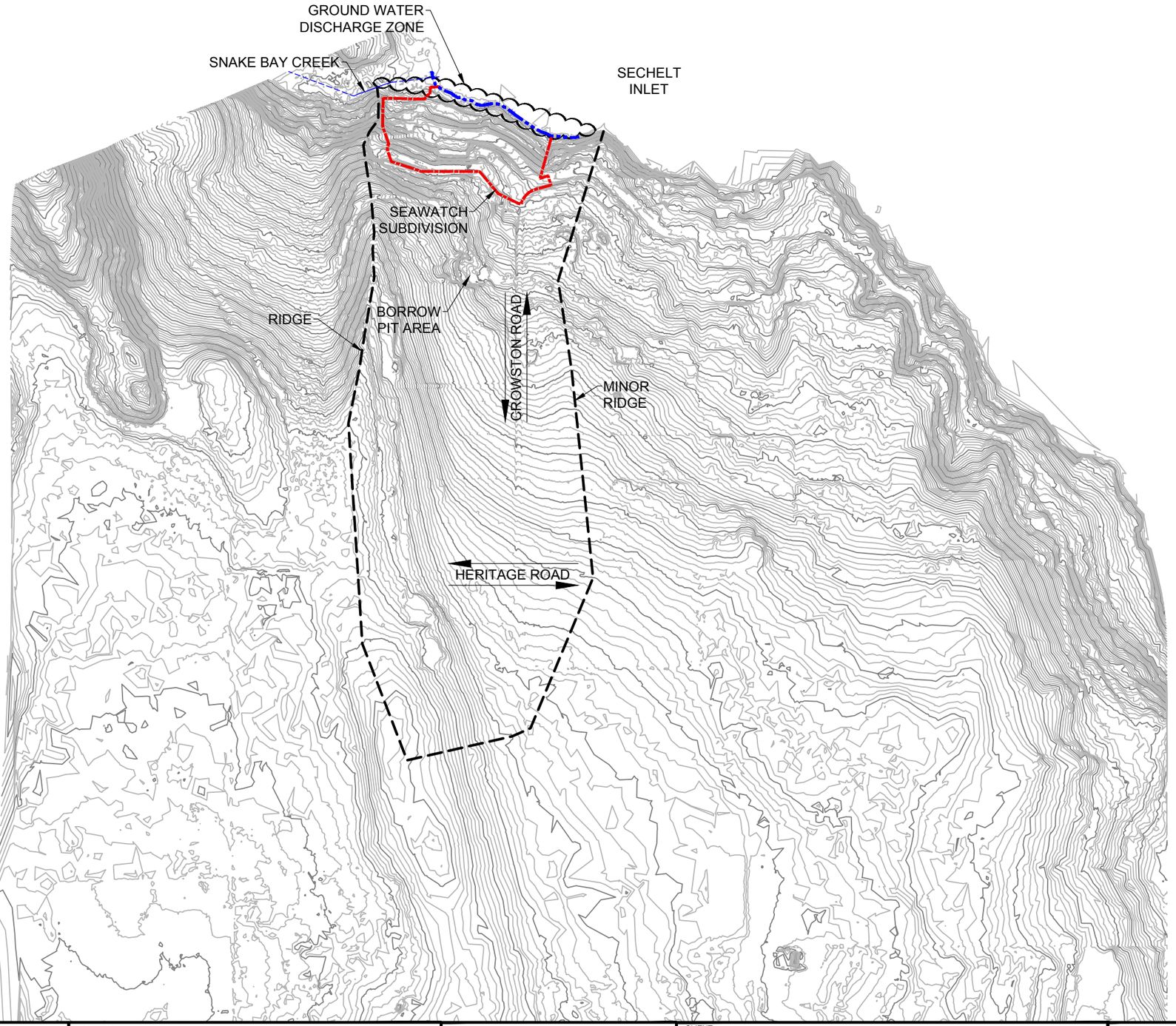
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 6B	REV.: -

4 CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\114\VED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



LEGEND:

- - - INFERRED POSSIBLE BOUNDARY OF GROUND WATER CATCHMENT AREA

NOTES:

1. INFERRED GROUND WATER CATCHMENT BOUNDARY IS BASED ON THE INTERPRETED APPROXIMATE SURFACE WATER WATERSHED.
2. CONTOURS DERIVED FROM LIDAR DATA FLOWN ON SEPTEMBER 12, 2009 SUPPLIED BY THE SUNSHINE COAST REGIONAL DISTRICT.

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

INFERRED GROUND WATER CATCHMENT AREA

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 7	REV.: -

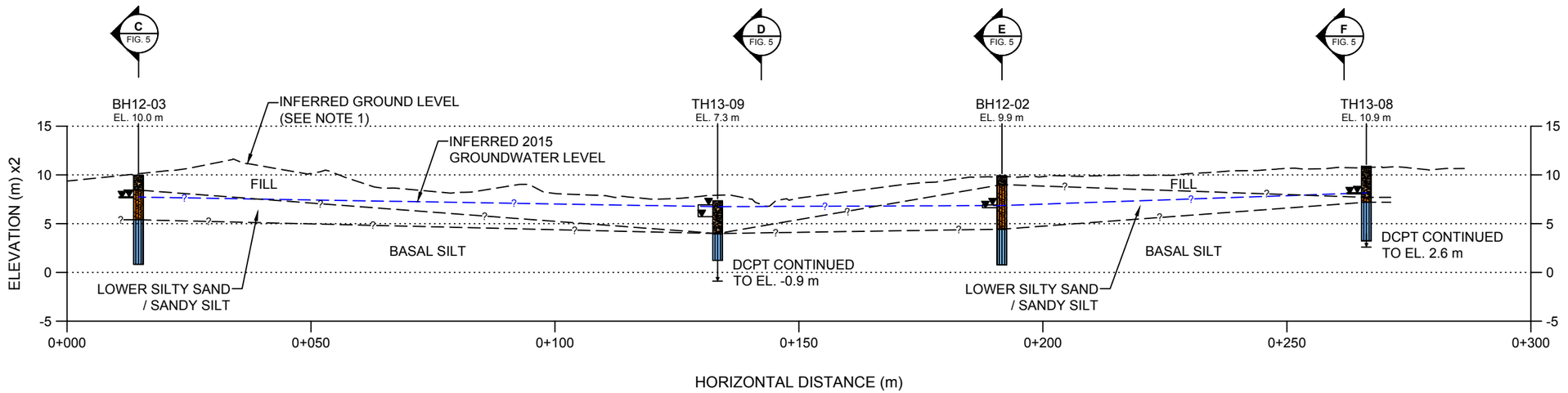
\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03357.dwg

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015

x2 VERTICAL EXAGGERATION



SECTION A

LEGEND FOR SOIL STRATIGRAPHY:	
	Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
	Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
	Typically silty SAND to sandy SILT and occasionally trace gravel
	Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. GROUND LEVEL INFERRED FROM THE FOLLOWING FILES FROM JOHN C. THEED BC LAND SURVEYOR:
   - 'CONCORDIA AS-BUILT' DATED MAY 29, 2009
   - 'CONCORDIA GOLDER SECTIONS' DATED OCTOBER 23, 2012
   - 'THURBER GEOSCIENCES' DATED DECEMBER 17, 2012
2. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
3. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
4. GROUNDWATER MONITORING WELL SCREENED INTERVALS ARE DEFINED ON THE TEST HOLE LOGS.

LEGEND FOR GROUNDWATER:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE

GROUNDWATER LEVEL RECORDED DURING DRILLING

MAXIMUM AND MINIMUM GROUNDWATER LEVEL OVER 2015 MONITORING PERIOD UP TO JULY 8

0 5 10 15 20 25m
VERTICAL SCALE

0 10 20 30 40 50m
HORIZONTAL SCALE

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION A-A

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE	SCALE
JULY 16, 2015	AS SHOWN

PROJECT No.	FIG. No.	REV.
14-214-4	8	-

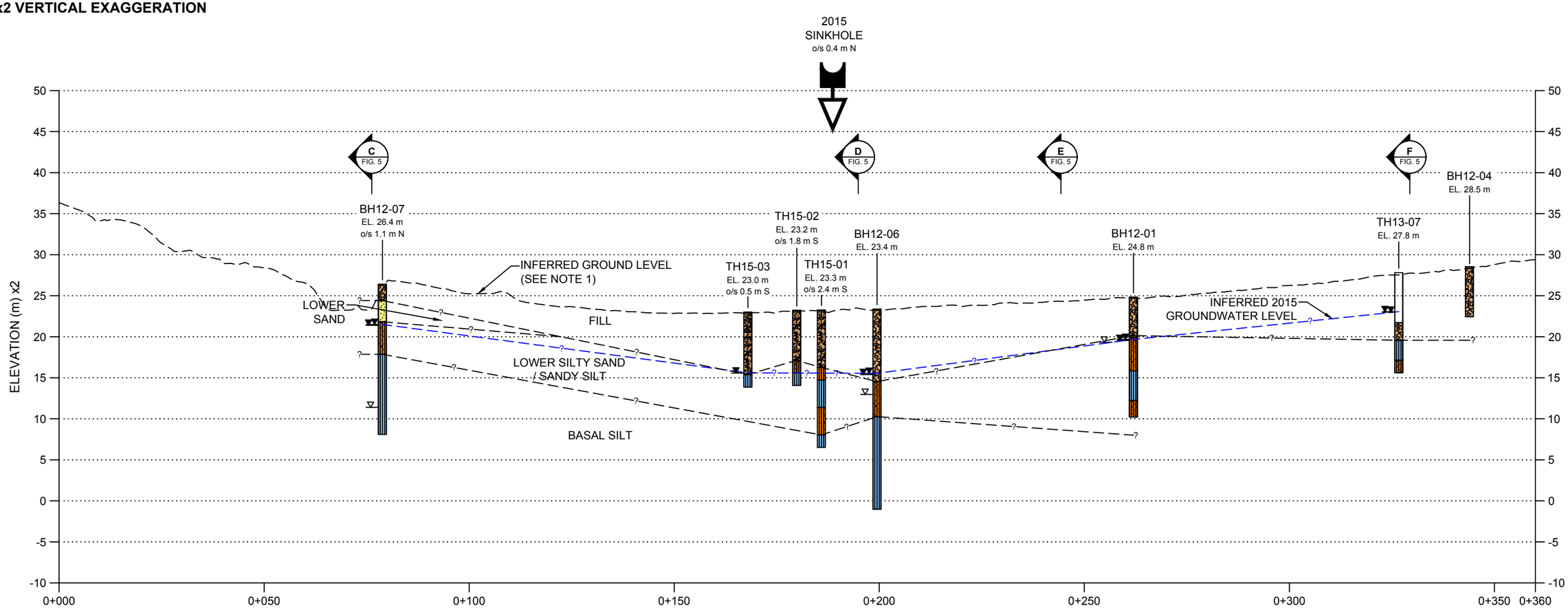
CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER21\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015

x2 VERTICAL EXAGGERATION



SECTION B

LEGEND FOR SOIL STRATIGRAPHY:	
	Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
	Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
	Typically silty SAND to sandy SILT and occasionally trace gravel
	Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. GROUND LEVEL INFERRED FROM LIDAR DATA FLOWN ON SEPTEMBER 12, 2009 PROVIDED BY THE SUNSHINE COAST REGIONAL DISTRICT.
2. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
3. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
4. GROUNDWATER MONITORING WELL SCREENED INTERVALS ARE DEFINED ON THE TEST HOLE LOGS.

LEGEND FOR GROUNDWATER:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE

GROUNDWATER LEVEL RECORDED DURING DRILLING

MAXIMUM AND MINIMUM GROUNDWATER LEVEL OVER 2015 MONITORING PERIOD UP TO JULY 8

0 5 10 15 20 25m
VERTICAL SCALE

0 10 20 30 40 50m
HORIZONTAL SCALE

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION B-B

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE	SCALE
JULY 16, 2015	AS SHOWN

PROJECT No.	FIG. No.	REV.
14-214-4	9	-

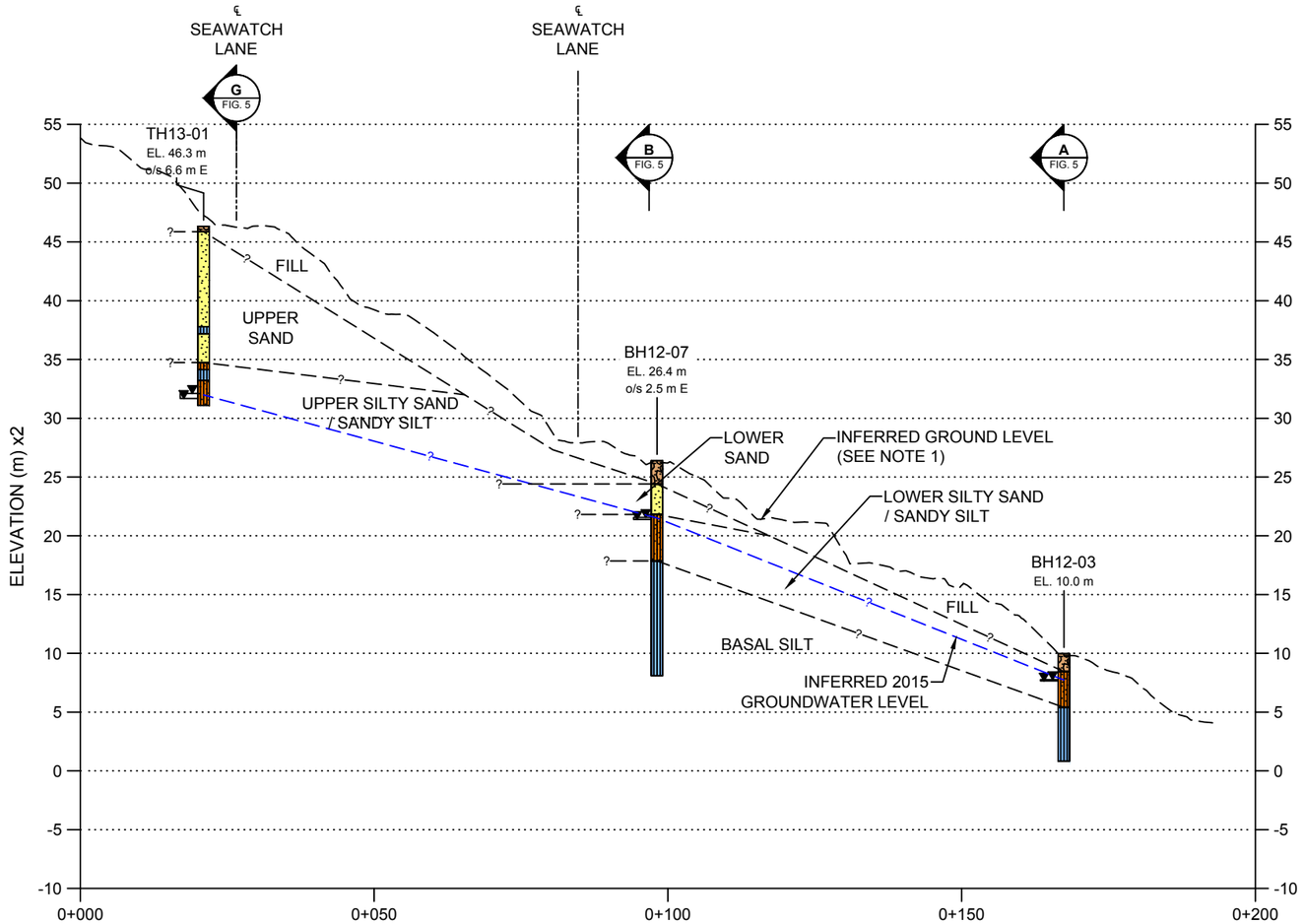
CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER21\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015

x2 VERTICAL EXAGGERATION



SECTION C

LEGEND FOR SOIL STRATIGRAPHY:	
	Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
	Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
	Typically silty SAND to sandy SILT and occasionally trace gravel
	Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. GROUND LEVEL INFERRED FROM LIDAR DATA FLOWN ON SEPTEMBER 12, 2009 PROVIDED BY THE SUNSHINE COAST REGIONAL DISTRICT.
2. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
3. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
4. GROUNDWATER MONITORING WELL SCREENED INTERVALS ARE DEFINED ON THE TEST HOLE LOGS.

LEGEND FOR GROUNDWATER:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
GROUNDWATER LEVEL RECORDED DURING DRILLING
MAXIMUM AND MINIMUM GROUNDWATER LEVEL OVER 2015 MONITORING PERIOD UP TO JULY 8

0 5 10 15 20 25m
VERTICAL SCALE

0 10 20 30 40 50m
HORIZONTAL SCALE

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION C-C

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 10	REV.: -

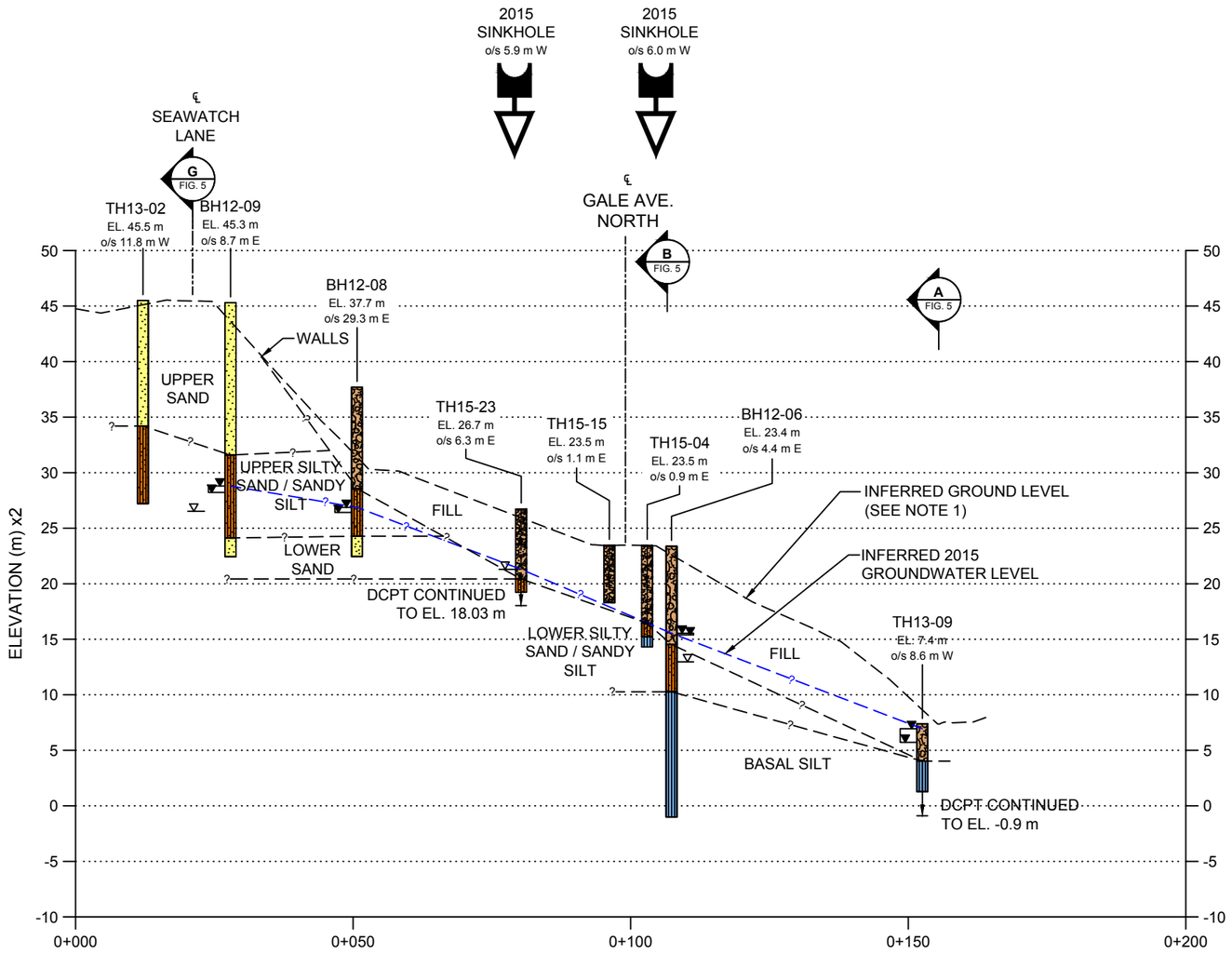
CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015

x2 VERTICAL EXAGGERATION



SECTION D

LEGEND FOR SOIL STRATIGRAPHY:

- Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
- Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
- Typically silty SAND to sandy SILT and occasionally trace gravel
- Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. GROUND LEVEL INFERRED FROM FROM STRAIT LAND SURVEYING'S MARCH 03, 2015 SURVEY.
2. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
3. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
4. GROUNDWATER MONITORING WELL SCREENED INTERVALS ARE DEFINED ON THE TEST HOLE LOGS.

LEGEND FOR GROUNDWATER:

- BH12-06 / o/s 3.7 m N — TEST HOLE ID WITH OFFSET DISTANCE FROM SECTION LINE
- GROUNDWATER LEVEL RECORDED DURING DRILLING
- MAXIMUM AND MINIMUM GROUNDWATER LEVEL OVER 2015 MONITORING PERIOD UP TO JULY 8

0 5 10 15 20 25m
VERTICAL SCALE

0 10 20 30 40 50m
HORIZONTAL SCALE

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION D-D

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 11	REV.: -

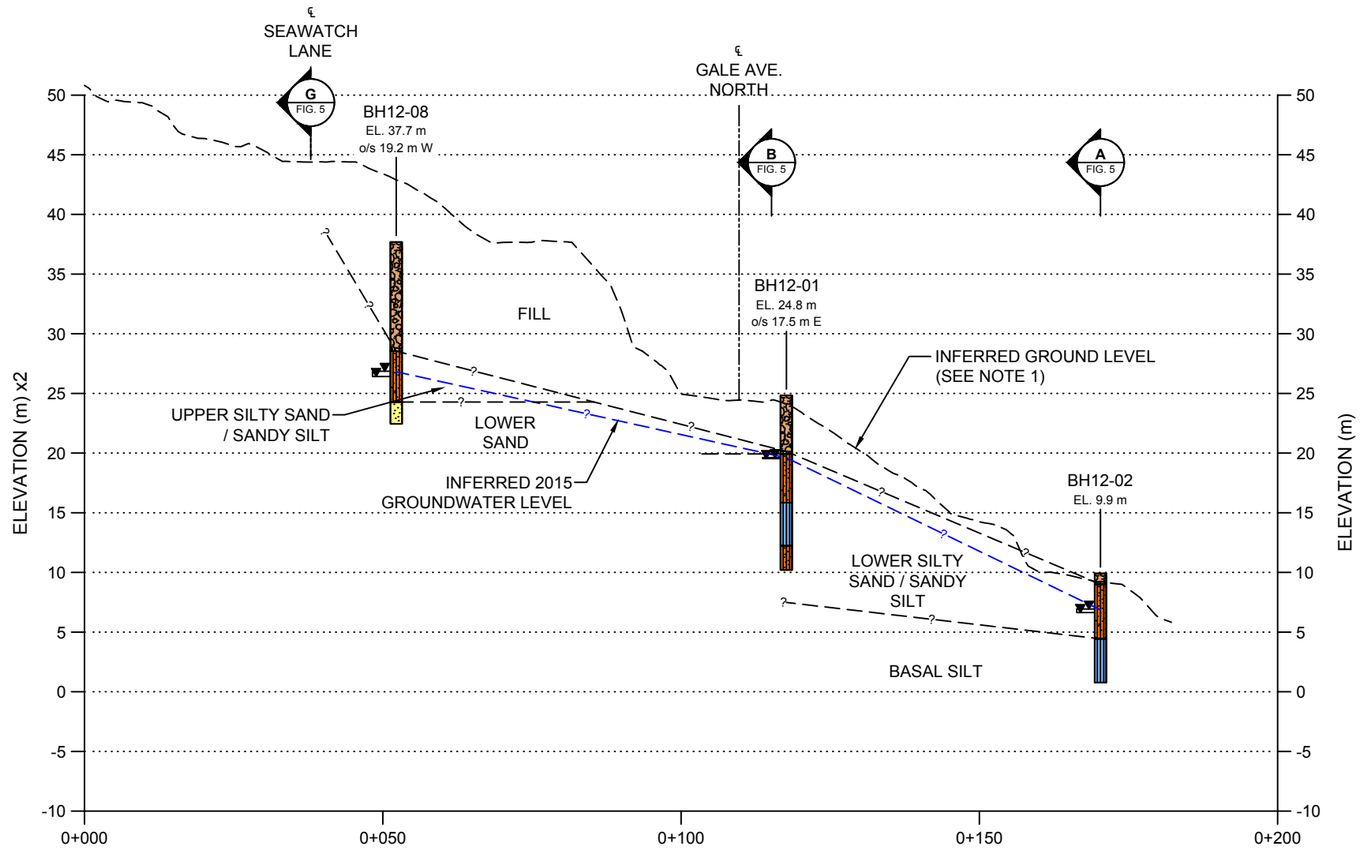
CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015

x2 VERTICAL EXAGGERATION



SECTION E

LEGEND FOR SOIL STRATIGRAPHY:	
	Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
	Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
	Typically silty SAND to sandy SILT and occasionally trace gravel
	Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. GROUND LEVEL INFERRED FROM LIDAR DATA FLOWN ON SEPTEMBER 12, 2009 PROVIDED BY THE SUNSHINE COAST REGIONAL DISTRICT.
2. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
3. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
4. GROUNDWATER MONITORING WELL SCREENED INTERVALS ARE DEFINED ON THE TEST HOLE LOGS.

LEGEND FOR GROUNDWATER:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
▽ GROUNDWATER LEVEL RECORDED DURING DRILLING
▼ MAXIMUM AND MINIMUM GROUNDWATER LEVEL OVER 2015 MONITORING PERIOD UP TO JULY 8

0 5 10 15 20 25m
VERTICAL SCALE

0 10 20 30 40 50m
HORIZONTAL SCALE

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION E-E

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 12	REV.: -

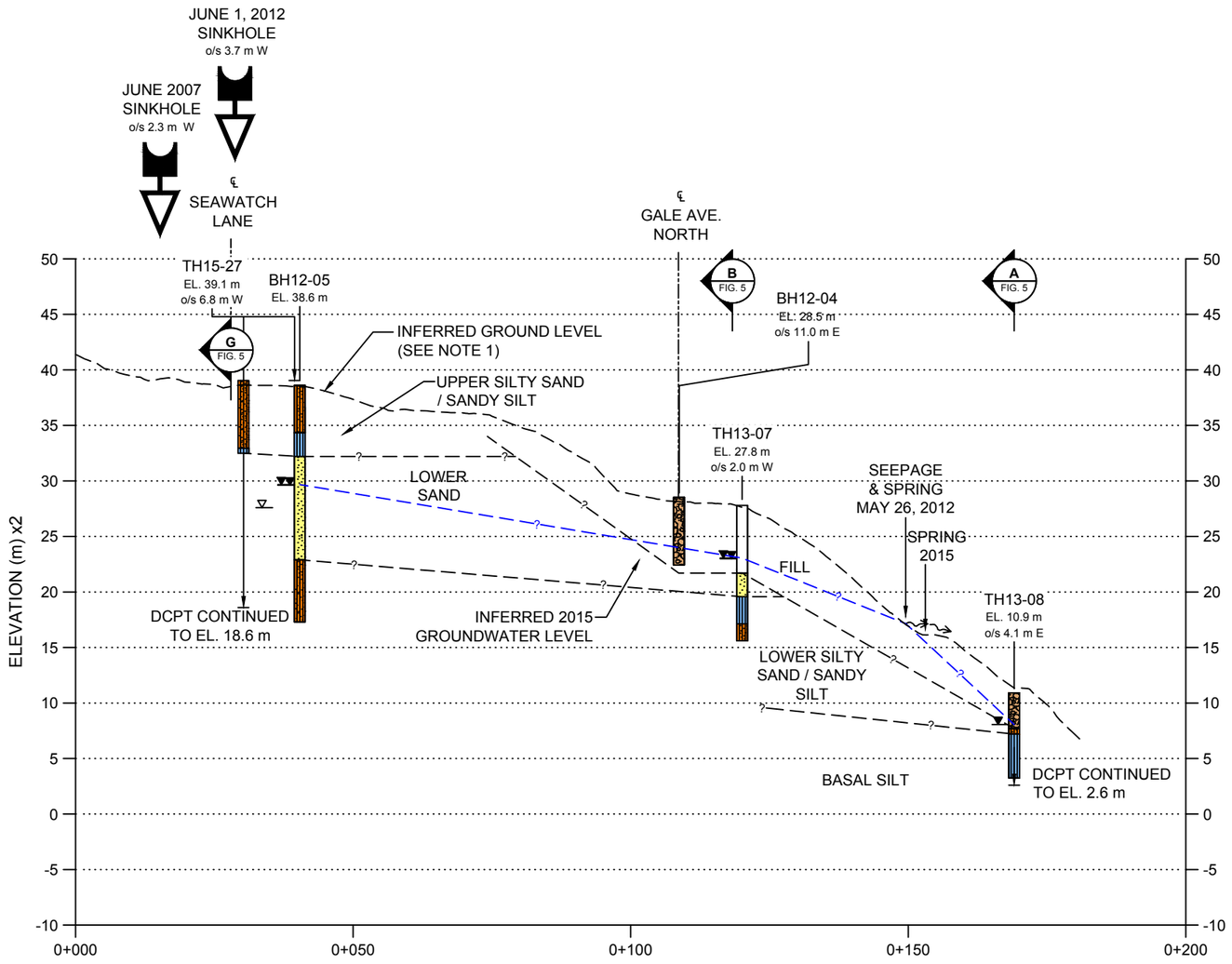
CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015

x2 VERTICAL EXAGGERATION



SECTION F

LEGEND FOR SOIL STRATIGRAPHY:

- Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
- Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
- Typically silty SAND to sandy SILT and occasionally trace gravel
- Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. GROUND LEVEL INFERRED FROM LIDAR DATA FLOWN ON SEPTEMBER 12, 2009 PROVIDED BY THE SUNSHINE COAST REGIONAL DISTRICT.
2. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
3. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
4. GROUNDWATER MONITORING WELL SCREENED INTERVALS ARE DEFINED ON THE TEST HOLE LOGS.

LEGEND FOR GROUNDWATER:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE

▽ GROUNDWATER LEVEL RECORDED DURING DRILLING

▼ MAXIMUM AND MINIMUM GROUNDWATER LEVEL OVER 2015 MONITORING PERIOD UP TO JULY 8

0 5 10 15 20 25m
VERTICAL SCALE

0 10 20 30 40 50m
HORIZONTAL SCALE

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION F-F

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 13	REV.: -

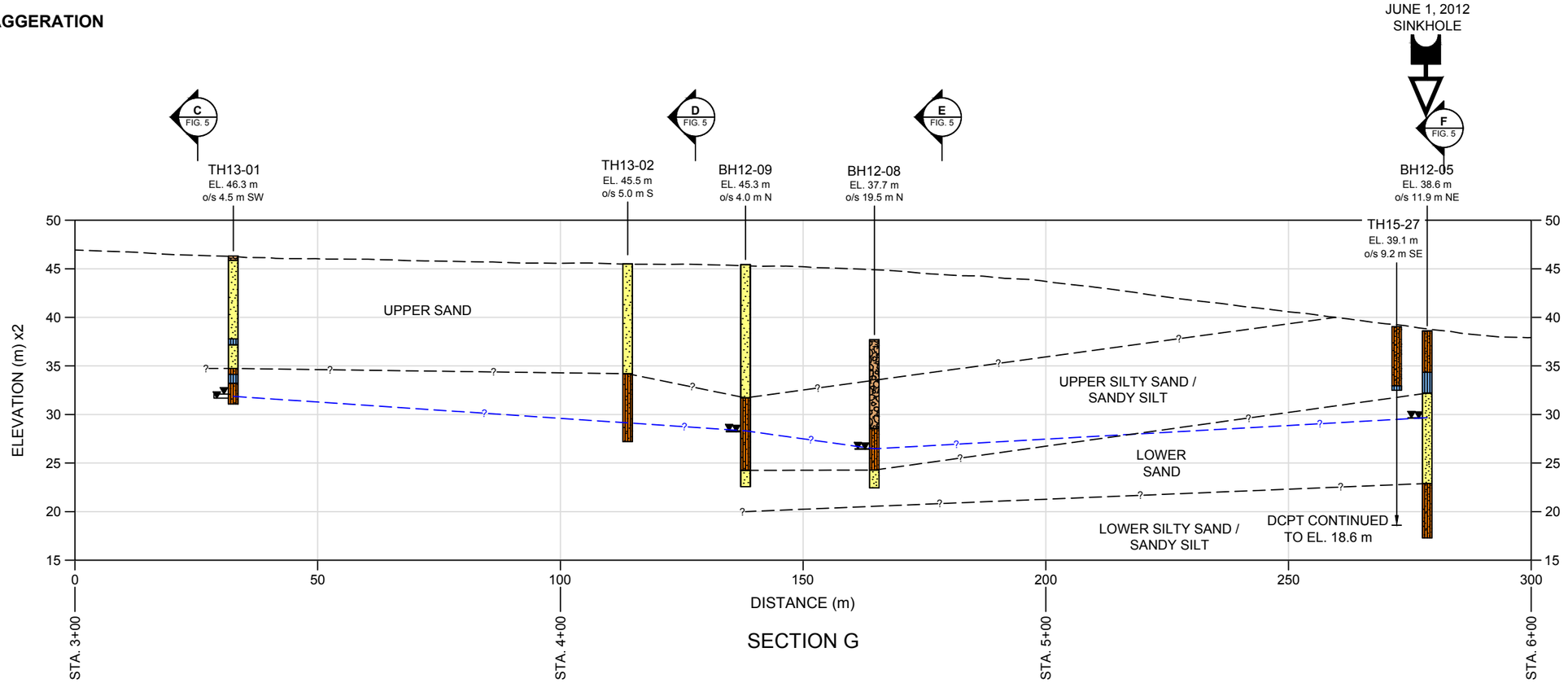
CANCEL PRINTS BEARING EARLIER LETTER

\\WANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015

x2 VERTICAL EXAGGERATION



SECTION G

LEGEND FOR SOIL STRATIGRAPHY:	
	Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
	Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
	Typically silty SAND to sandy SILT and occasionally trace gravel
	Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. GROUND LEVEL INFERRED FROM FROM STRAIT LAND SURVEYING'S MARCH 03, 2015 SURVEY.
2. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
3. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
4. GROUNDWATER MONITORING WELL SCREENED INTERVALS ARE DEFINED ON THE TEST HOLE LOGS.

LEGEND FOR GROUNDWATER:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE

GROUNDWATER LEVEL RECORDED DURING DRILLING

MAXIMUM AND MINIMUM GROUNDWATER LEVEL OVER 2015 MONITORING PERIOD UP TO JULY 8

0 5 10 15 20 25m

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION G-G

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

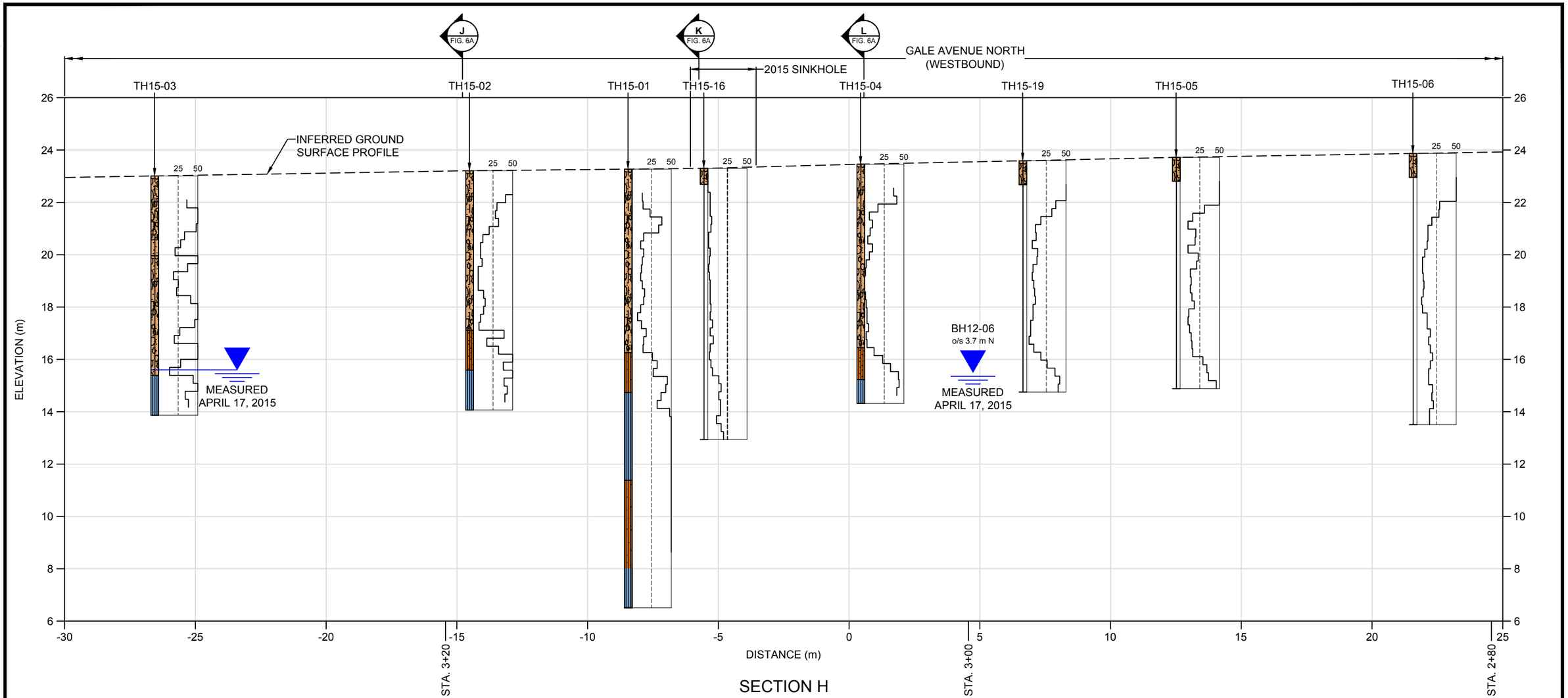
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 14	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION H

LEGEND FOR SOIL STRATIGRAPHY:

- Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
- Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
- Typically silty SAND to sandy SILT and occasionally trace gravel
- Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:

1. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
2. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
3. STRATIGRAPHY AND DCPT PROFILES ARE APPROXIMATE. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION. BLOW COUNTS GREATER THAN 50 ARE SHOWN HERE AS 50.

0 2.5 5.0 7.5m

LEGEND:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION H-H

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

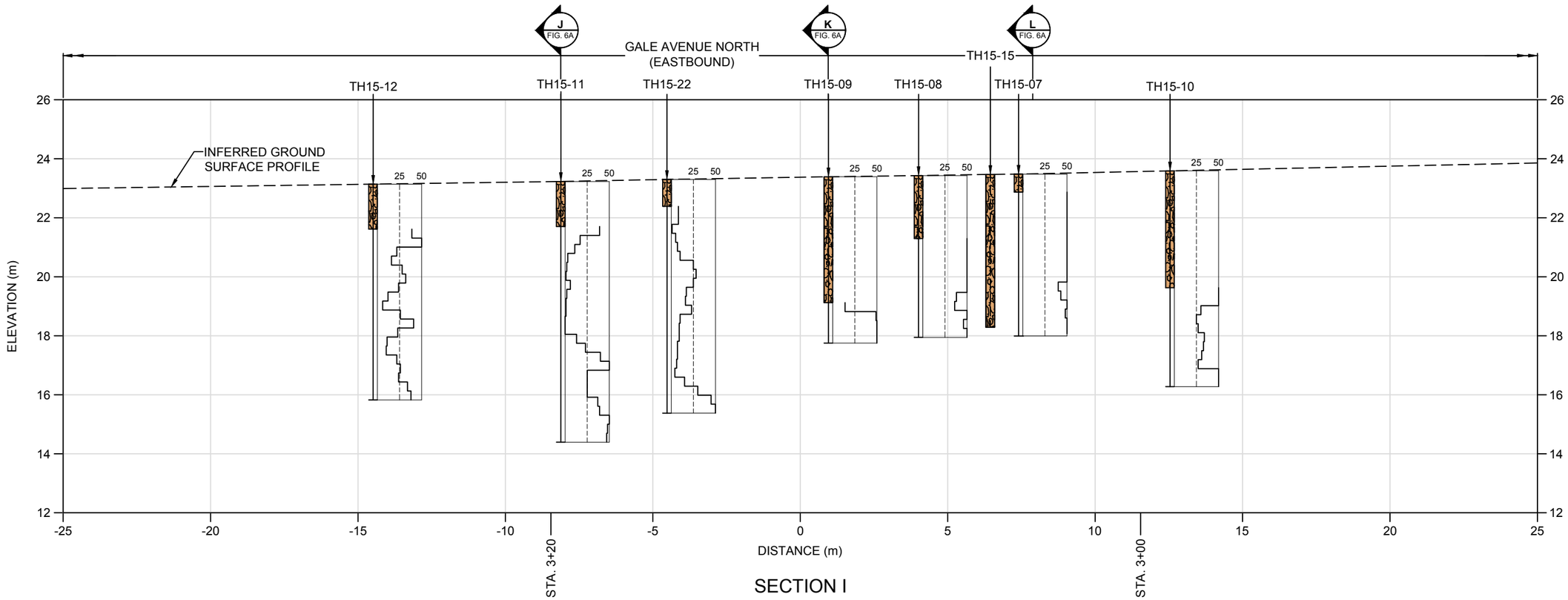
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 15	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION I

LEGEND FOR SOIL STRATIGRAPHY:	
	Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
	Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
	Typically silty SAND to sandy SILT and occasionally trace gravel
	Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
2. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
3. STRATIGRAPHY AND DCPT PROFILES ARE APPROXIMATE. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION. BLOW COUNTS GREATER THAN 50 ARE SHOWN HERE AS 50.

0 2.5 5.0 7.5m

LEGEND:
BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION I-I

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE	SCALE
JULY 16, 2015	AS SHOWN

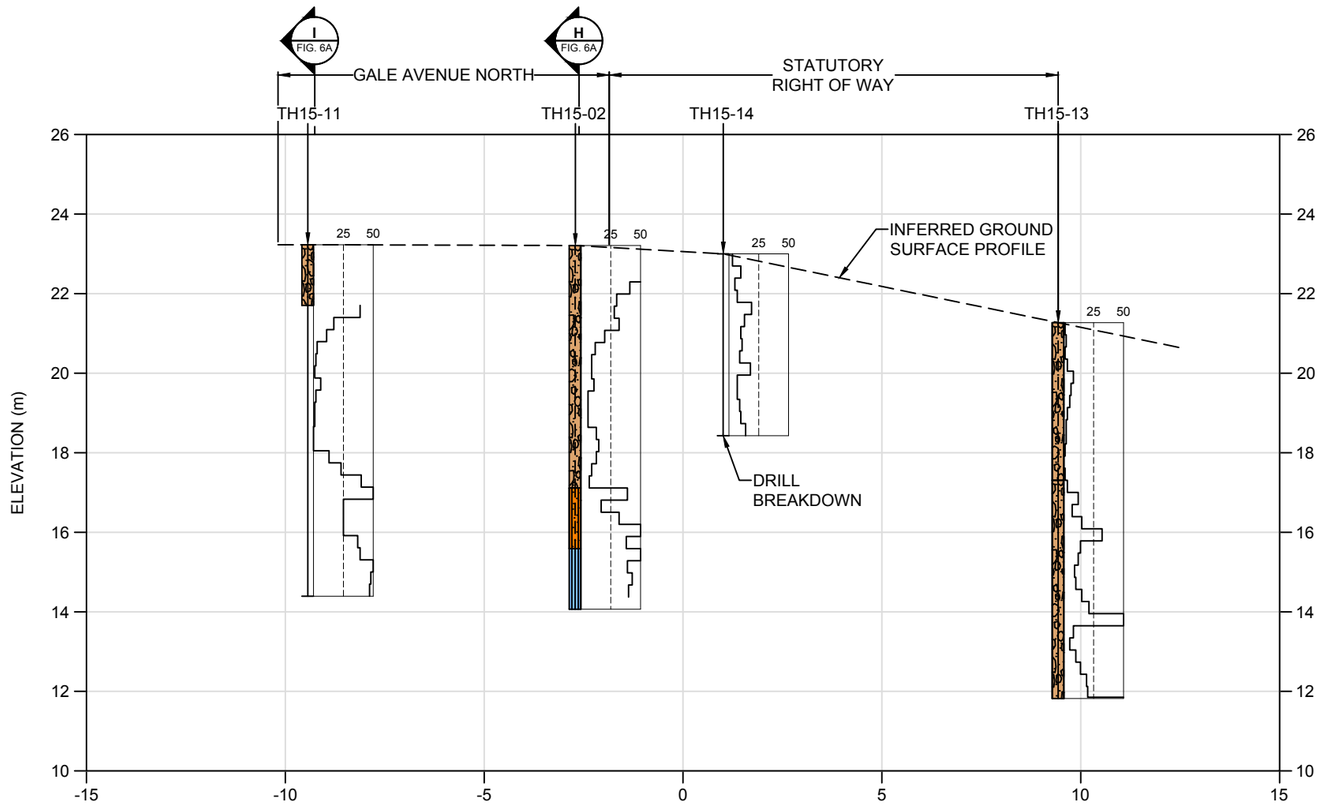
PROJECT No.	FIG. No.	REV.
14-214-4	16	-

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER21\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION J

AT STA. 3+19.6

LEGEND FOR SOIL STRATIGRAPHY:

- Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
- Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
- Typically silty SAND to sandy SILT and occasionally trace gravel
- Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:

1. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
2. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
3. STRATIGRAPHY AND DCPT PROFILES ARE APPROXIMATE. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION. BLOW COUNTS GREATER THAN 50 ARE SHOWN HERE AS 50.

0 2.5 5.0 7.5m

LEGEND:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT
DISTRICT OF SECHELT

GEOLOGICAL SECTION J-J

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

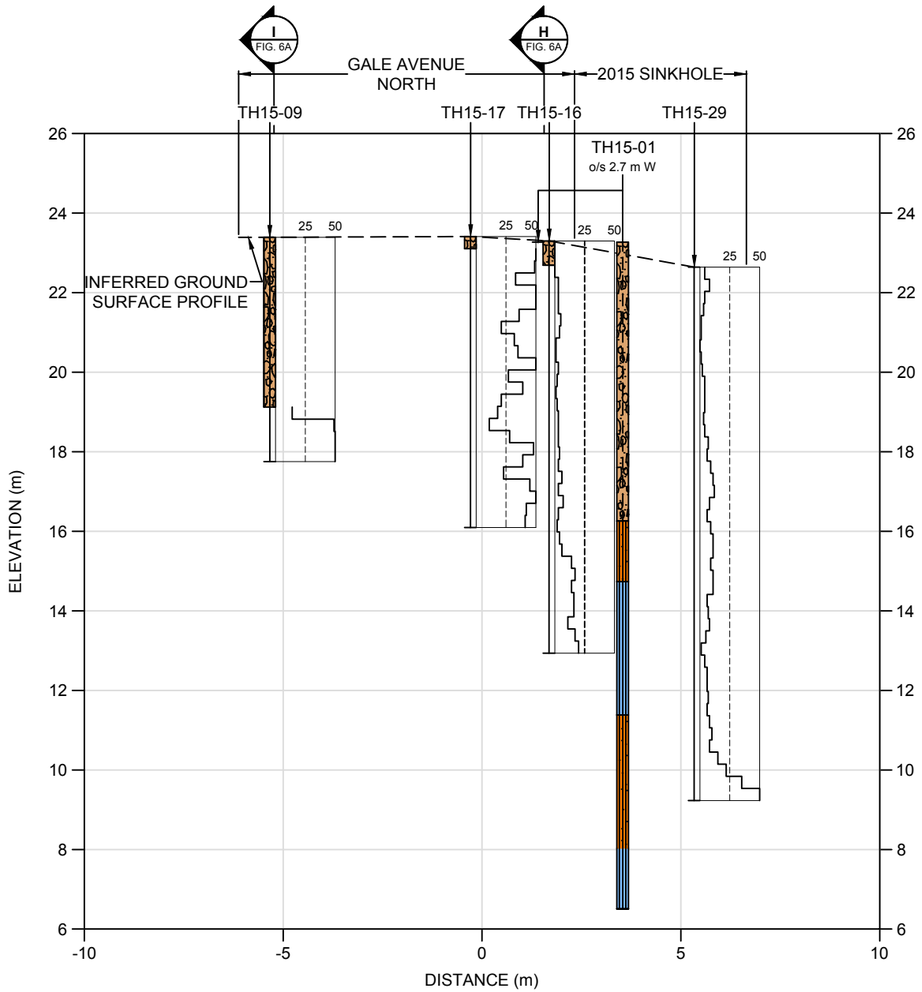
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 17	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION K
AT STA. 3+10.5

LEGEND FOR SOIL STRATIGRAPHY:

- Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
- Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
- Typically silty SAND to sandy SILT and occasionally trace gravel
- Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
2. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
3. STRATIGRAPHY AND DCPT PROFILES ARE APPROXIMATE. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION. BLOW COUNTS GREATER THAN 50 ARE SHOWN HERE AS 50.

0 2.5 5.0 7.5m

LEGEND:
BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION K-K

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

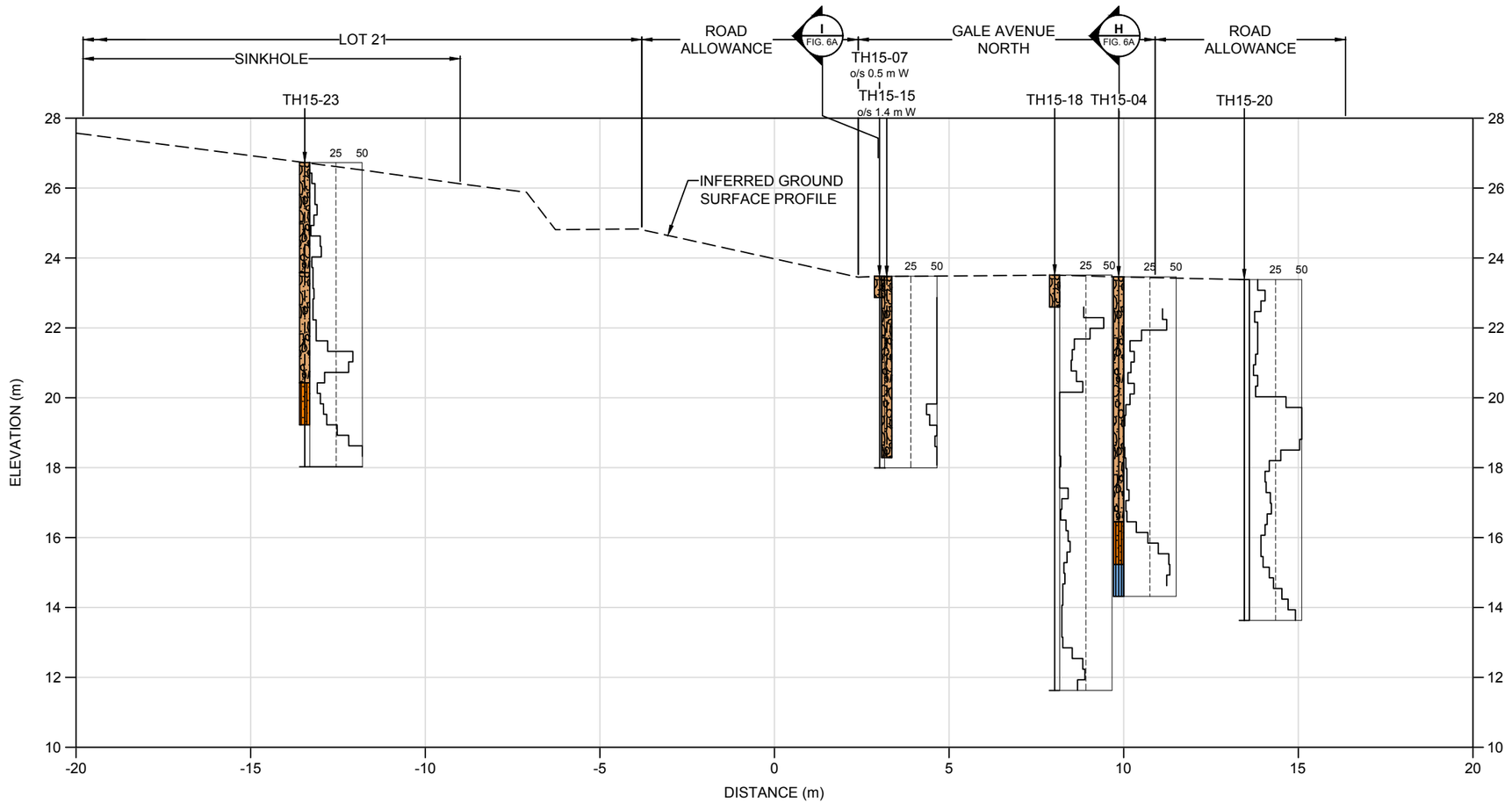
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 18	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\AC\ADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION L

AT STA. 3+03.8

LEGEND FOR SOIL STRATIGRAPHY:

- Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
- Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
- Typically silty SAND to sandy SILT and occasionally trace gravel
- Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:

1. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
2. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
3. STRATIGRAPHY AND DCPT PROFILES ARE APPROXIMATE. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION. BLOW COUNTS GREATER THAN 50 ARE SHOWN HERE AS 50.

0 2.5 5.0 7.5m

LEGEND:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION L-L

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

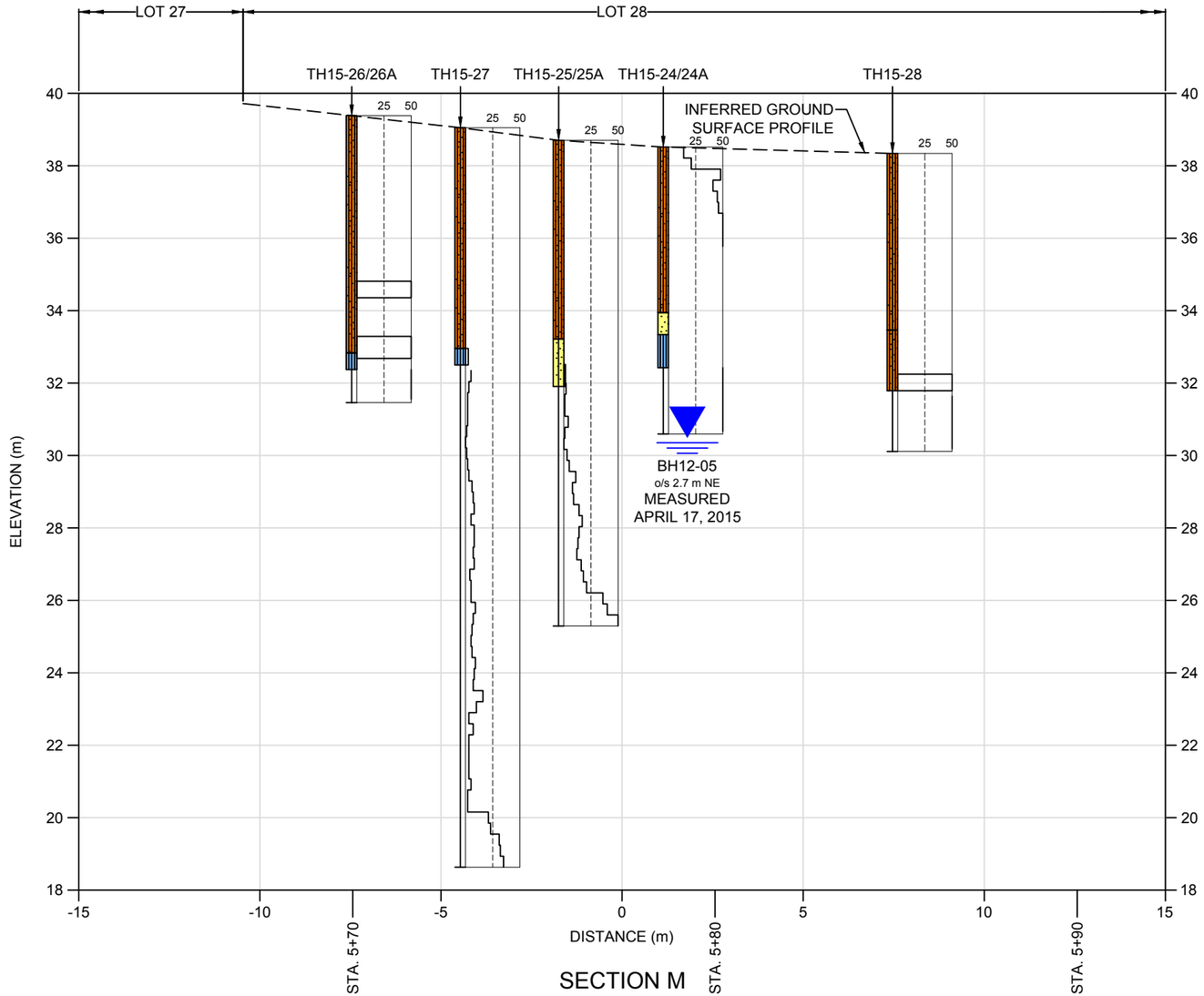
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 19	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION M

LEGEND FOR SOIL STRATIGRAPHY:

- Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
- Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
- Typically silty SAND to sandy SILT and occasionally trace gravel
- Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:
1. TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHELT, BC', PROJECT NO. 12-1447-0230.
2. INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
3. STRATIGRAPHY AND DCPT PROFILES ARE APPROXIMATE. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION. BLOW COUNTS GREATER THAN 50 ARE SHOWN HERE AS 50.

0 2.5 5.0 7.5m

LEGEND:
BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GEOLOGICAL SECTION M-M

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

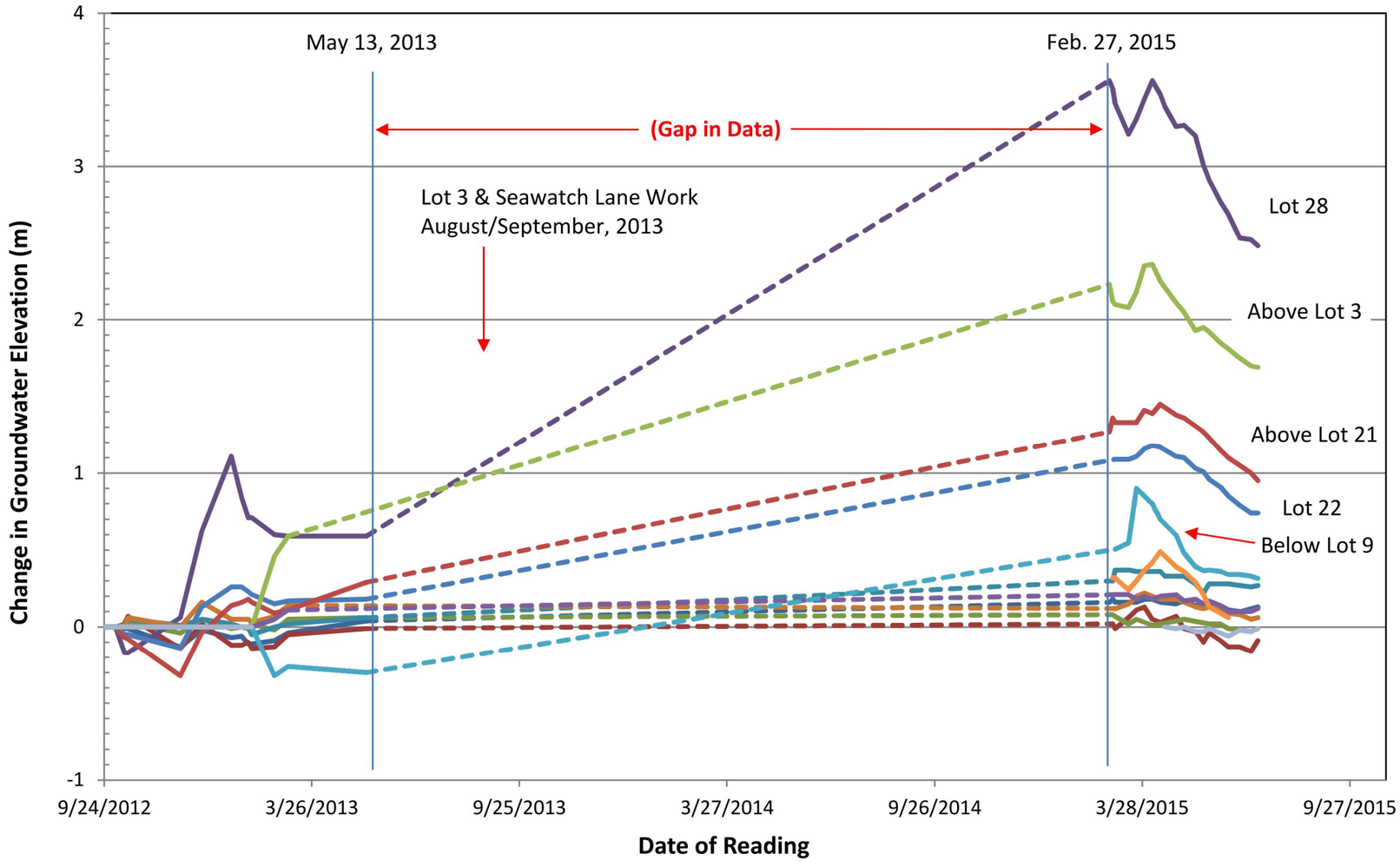
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 20	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



Monitoring Wells

BH12-01 BH12-02 BH12-03 BH12-05 BH12-06 BH12-07 BH12-08
BH12-09 TH13-07 TH13-08 TH13-09 TH13-01 TH15-03

LEGEND:

NOTES:
1. PLOTS ARE BASED ON GROUNDWATER MONITORING DATA AVAILABLE TO THURBER.

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

CHANGE IN GROUNDWATER ELEVATION SINCE INITIAL READING

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE	SCALE
JULY 16, 2015	AS SHOWN

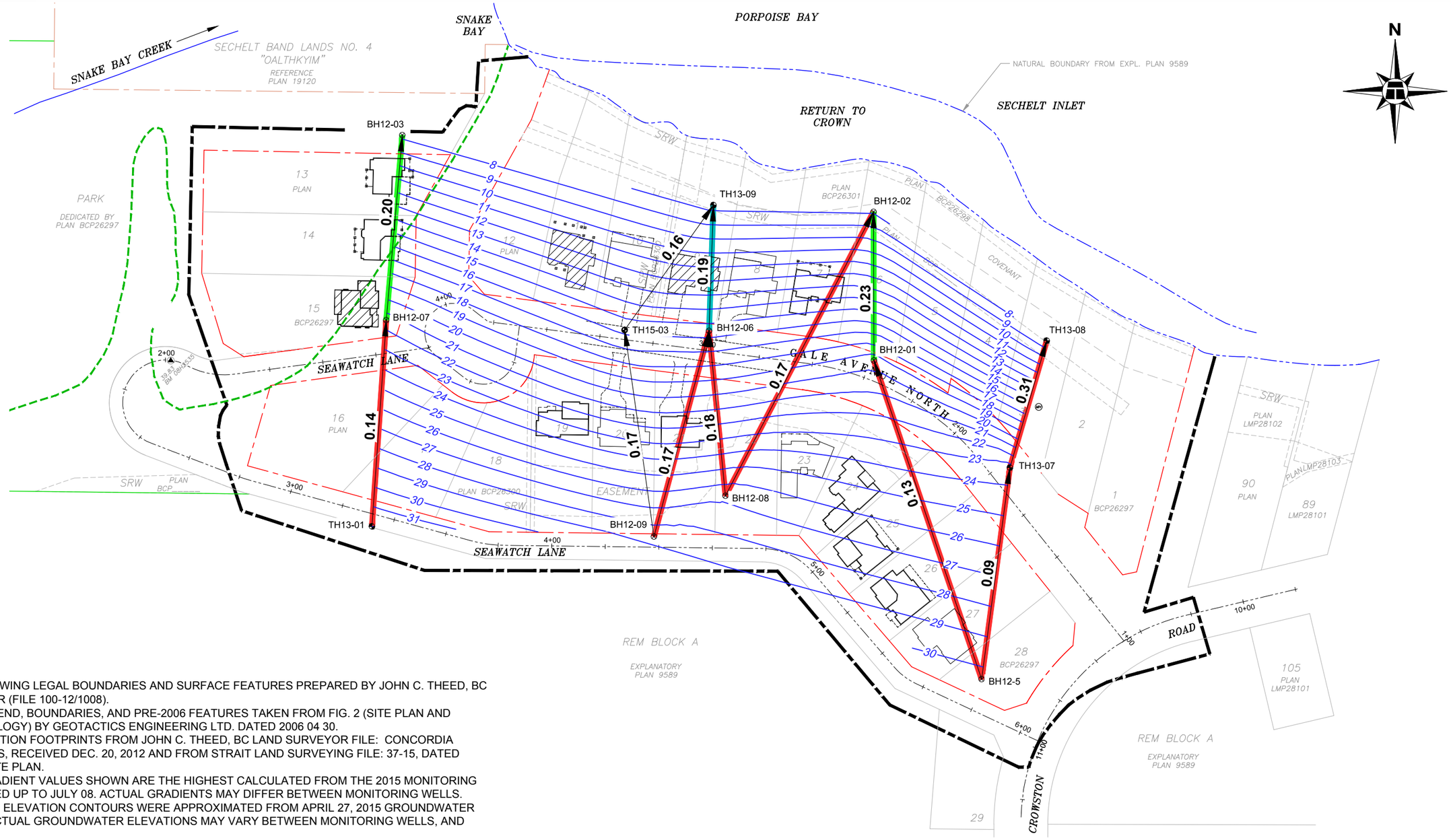
PROJECT No.	FIG. No.	REV.
14-214-4	21	-

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



NOTES:

1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
4. HYDRAULIC GRADIENT VALUES SHOWN ARE THE HIGHEST CALCULATED FROM THE 2015 MONITORING DATA COLLECTED UP TO JULY 08. ACTUAL GRADIENTS MAY DIFFER BETWEEN MONITORING WELLS.
5. GROUNDWATER ELEVATION CONTOURS WERE APPROXIMATED FROM APRIL 27, 2015 GROUNDWATER ELEVATIONS. ACTUAL GROUNDWATER ELEVATIONS MAY VARY BETWEEN MONITORING WELLS, AND SEASONALLY.

PROPERTY LEGEND (SEE NOTE 2):

- SUBJECT PROPERTY
- PROPERTY LINES
- NATURAL BOUNDARY
- IR RESERVE
- PARK BOUNDARY
- COVENANT
- RIGHT-OF-WAY
- PHASE 1 BOUNDARY
- ENVIRONMENTAL COVENANT LINE
- STREAMS

TEST HOLE LEGEND:

- TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
- BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER

0 25 50 75m

GROUNDWATER MAP LEGEND:

- 20 — GROUNDWATER ELEVATION CONTOUR (m) (SEE NOTE 6)
- 0.20 — AVERAGE HYDRAULIC GRADIENT VECTOR (SEE NOTE 5)
- HYDRAULIC GRADIENT INCREASED DURING 2013 TO 2015 GAP IN DATA
- HYDRAULIC GRADIENT DECREASED DURING 2013 TO 2015 GAP IN DATA
- NO SIGNIFICANT CHANGE IN HYDRAULIC GRADIENT DURING 2013 TO 2015 GAP IN DATA

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

GROUND WATER CONTOURS AND AVERAGE HYDRAULIC GRADIENT VECTORS

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

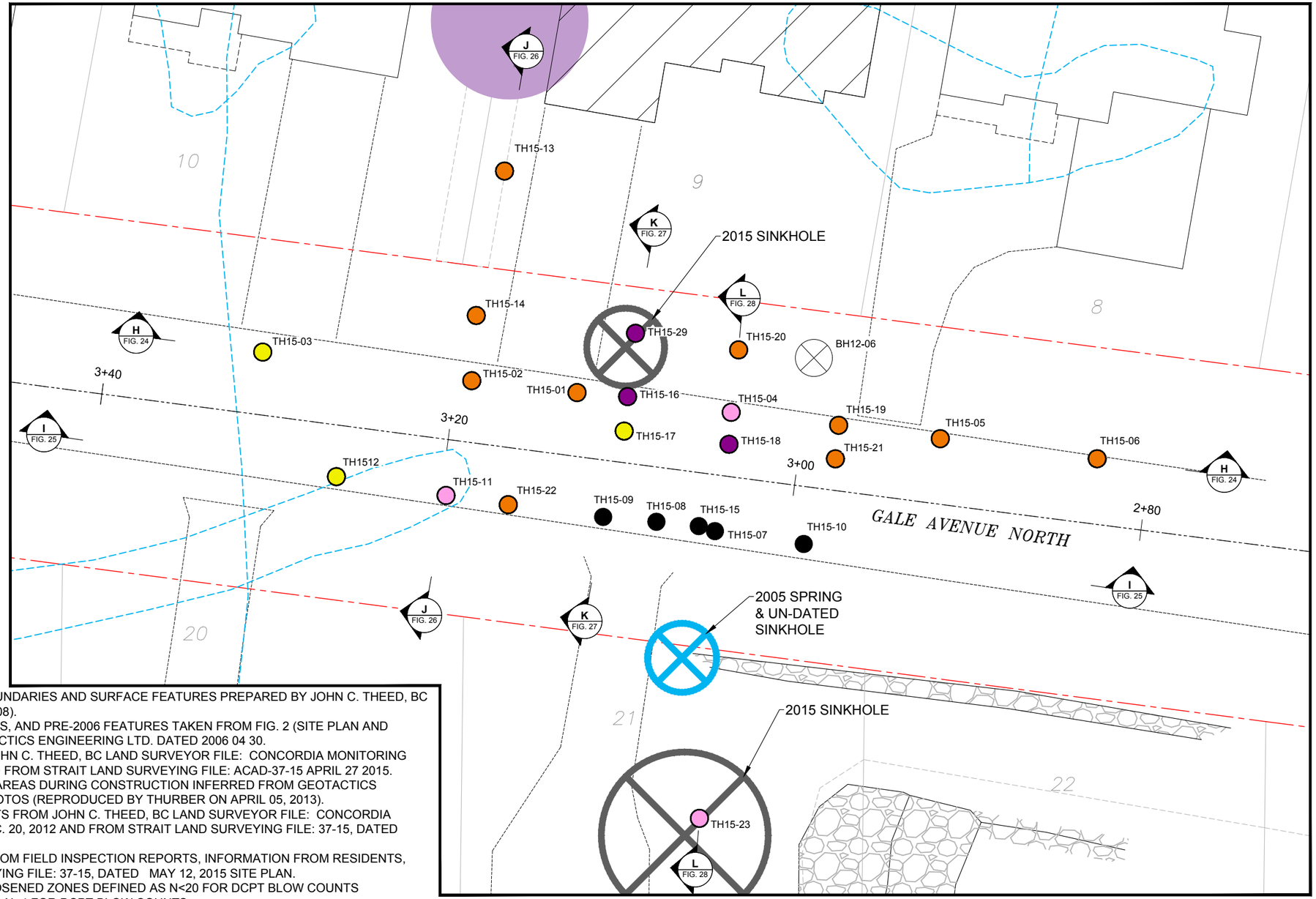
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 22	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015



N

NOTES:
1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. TEST HOLE LOCATIONS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA MONITORING WELLS, DATED FEB. 12, 2013 AND FROM STRAIT LAND SURVEYING FILE: ACAD-37-15 APRIL 27 2015.
4. LOCATIONS OF SPRINGS & WET AREAS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2013).
5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
6. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
7. FOR SCREENING PURPOSES LOOSENED ZONES DEFINED AS N<20 FOR DCPT BLOW COUNTS VERY LOOSE ZONES DEFINED AS N<4 FOR DCPT BLOW COUNTS.

PROPERTY LEGEND (SEE NOTE 2):

SUBJECT PROPERTY	COVENANT
PROPERTY LINES	RIGHT-OF-WAY
NATURAL BOUNDARY	PHASE 1 BOUNDARY
IR RESERVE	ENVIRONMENTAL COVENANT LINE
PARK BOUNDARY	STREAMS

TEST HOLE LEGEND:
- TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
- TEST HOLE BY THURBER
- BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER
- (38.65) ELEVATION OF WELL COVER OR GROUND SURFACE (m)

INTERPRETATION LEGEND (SEE NOTE 7):
- **VOIDS AND / OR VERY LOOSE ZONES > 5 m TOTAL THICKNESS**
- **VERY LOOSE ZONES 1 to 5 m TOTAL THICKNESS**
- **LOOSENED ZONES > 3 m TOTAL THICKNESS**
- **LOOSENED ZONES 0.5 TO 3 m TOTAL THICKNESS**
- **SIGNS OF LOOSENING NOT ENCOUNTERED WITHIN ZONE INVESTIGATED**

0 2.5 5 7.5 10 12.5m

FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):

PRE 2006 SINKHOLE	HOUSE INCOMPLETE OR UNOCCUPIED
PRE 2006 SPRING OR STREAM	PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION
POST 2006 SINKHOLE	2015 SPRING OR WET AREA
ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED)	

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SINKHOLE DEVELOPMENT INTERPRETATION
GALE AVENUE NORTH

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

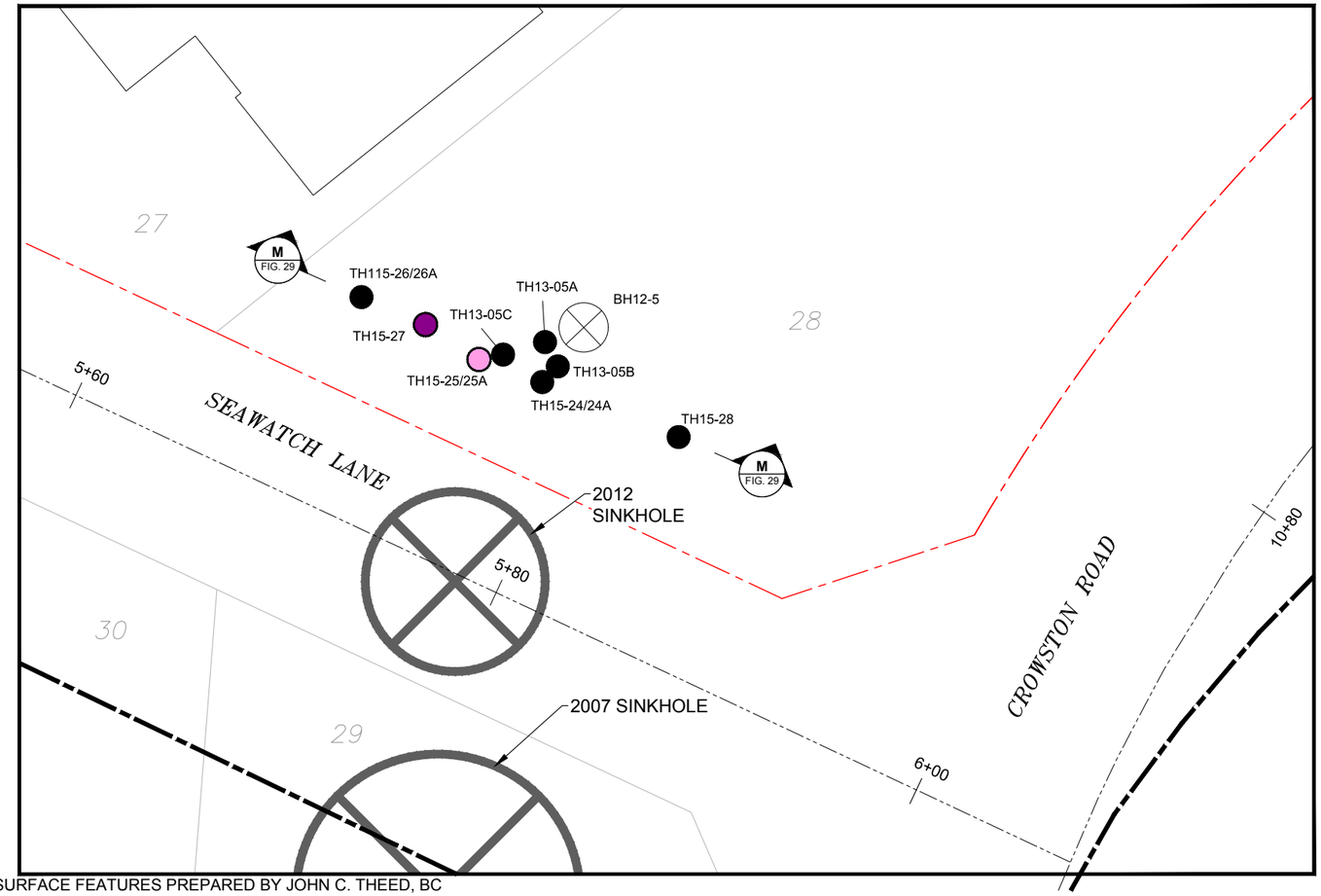
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 23A	REV.: -

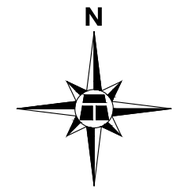
CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 16, 2015





NOTES:

1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. TEST HOLE LOCATIONS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA MONITORING WELLS, DATED FEB. 12, 2013 AND FROM STRAIT LAND SURVEYING FILE: ACAD-37-15 APRIL 27 2015.
4. LOCATIONS OF SPRINGS & WET AREAS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2013).
5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
6. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
7. FOR SCREENING PURPOSES LOOSENED ZONES DEFINED AS N<20 FOR DCPT BLOW COUNTS VERY LOOSE ZONES DEFINED AS N<4 FOR DCPT BLOW COUNTS.

PROPERTY LEGEND (SEE NOTE 2):

- SUBJECT PROPERTY
- PROPERTY LINES
- NATURAL BOUNDARY
- IR RESERVE
- PARK BOUNDARY
- COVENANT
- RIGHT-OF-WAY
- PHASE 1 BOUNDARY
- ENVIRONMENTAL COVENANT LINE
- STREAMS

TEST HOLE LEGEND:

- TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
- TEST HOLE BY THURBER
- BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER
- (38.65) ELEVATION OF WELL COVER OR GROUND SURFACE (m)

INTERPRETATION LEGEND (SEE NOTE 7):

- **VOIDS AND / OR VERY LOOSE ZONES > 5 m TOTAL THICKNESS**
- **VERY LOOSE ZONES 1 to 5 m TOTAL THICKNESS**
- **LOOSENED ZONES > 3 m TOTAL THICKNESS**
- **LOOSENED ZONES 0.5 TO 3 m TOTAL THICKNESS**
- **SIGNS OF LOOSENING NOT ENCOUNTERED WITHIN ZONE INVESTIGATED**

0 2.5 5 7.5 10 12.5m

FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):

- PRE 2006 SINKHOLE
- PRE 2006 SPRING OR STREAM
- POST 2006 SINKHOLE
- ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED)
- HOUSE INCOMPLETE OR UNOCCUPIED
- PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION
- 2015 SPRING OR WET AREA

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SINKHOLE DEVELOPMENT INTERPRETATION
SEAWATCH LANE

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

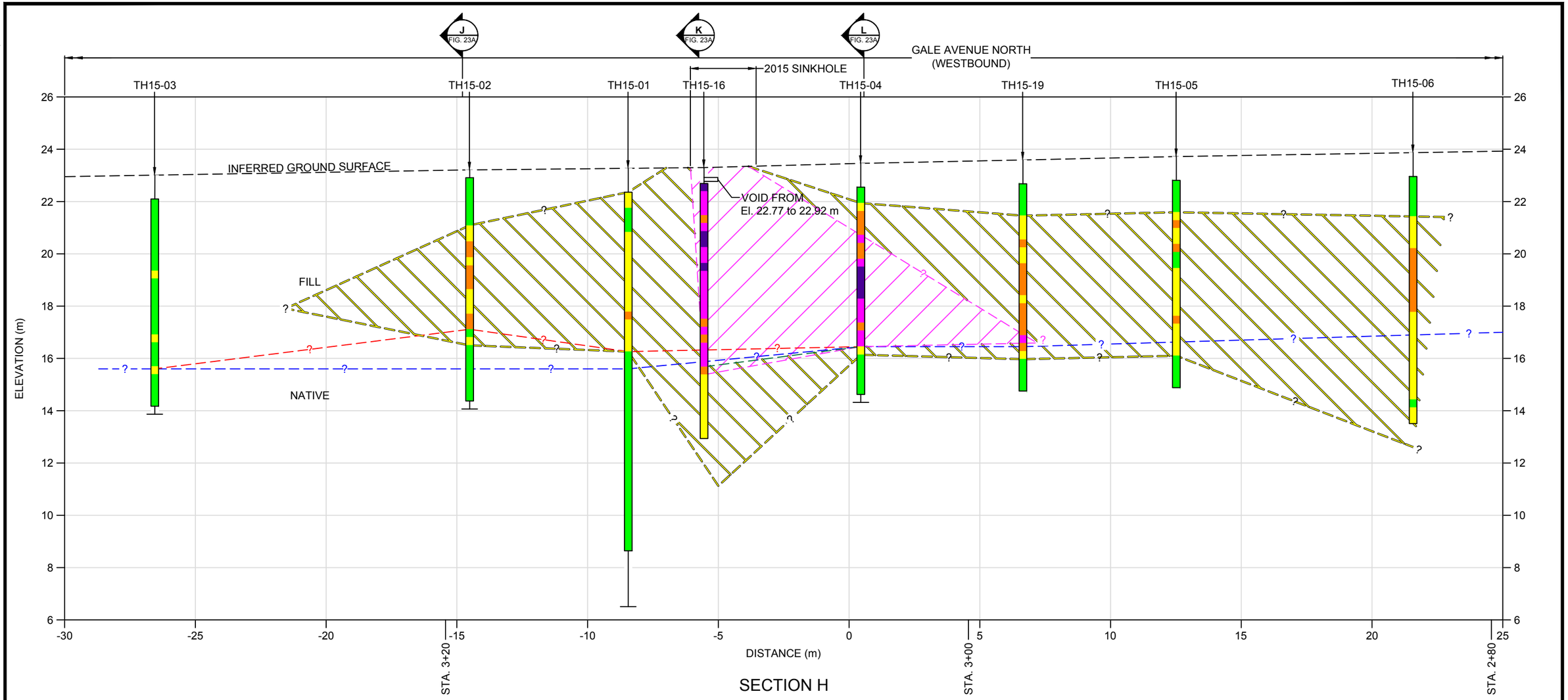
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 23B	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION H

LEGEND FOR INTERPRETATION:	
	(N = 0 to 1 or Static Weight of Hammer) Void or Very Severe Apparent Loosening
	(N = 2 to 4) Severe Apparent Loosening
	(N = 5 to 10) Moderate Apparent Loosening
	(N = 11 to 20) Minor Apparent Loosening
	(N = 21 or greater) No Apparent Loosening
- - -	Interpreted Base of Fill
- - -	Interpreted Water Table
- - -	Interpreted Extent of Severely Loosened Zone
- - -	Interpreted Extent of Loosened Zone

NOTES:

1. INTERPRETATIONS MADE ON THE BASIS OF DRILLING OBSERVATIONS AS DETAILED IN THE TEST HOLE LOGS.
2. INFERRED BOUNDARIES MAY VARY BETWEEN TEST HOLES.
3. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION.

0 2.5 5.0 7.5m

LEGEND:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

INTERPRETATION SECTION H-H

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE	SCALE
JULY 16, 2015	AS SHOWN

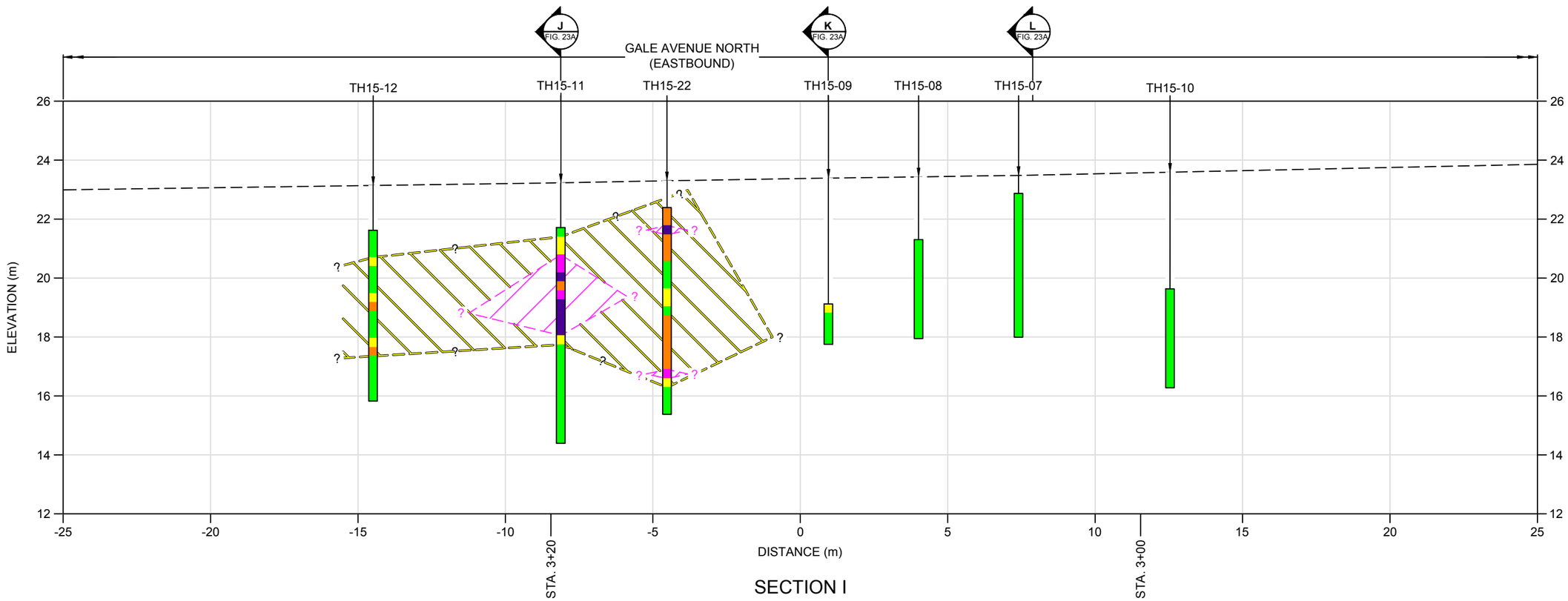
PROJECT No.	FIG. No.	REV.
14-214-4	24	-

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION I

LEGEND FOR INTERPRETATION:
(N = 0 to 1 or Static Weight of Hammer) Void or Very Severe Apparent Loosening
(N = 2 to 4) Severe Apparent Loosening
(N = 5 to 10) Moderate Apparent Loosening
(N = 11 to 20) Minor Apparent Loosening
(N = 21 or greater) No Apparent Loosening
Interpreted Base of Fill
Interpreted Water Table
Interpreted Extent of Severely Loosened Zone
Interpreted Extent of Loosened Zone

NOTES:

1. INTERPRETATIONS MADE ON THE BASIS OF DRILLING OBSERVATIONS AS DETAILED IN THE TEST HOLE LOGS.
2. INFERRED BOUNDARIES MAY VARY BETWEEN TEST HOLES.
3. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION.

0 2.5 5.0 7.5m

LEGEND:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE (OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

INTERPRETATION SECTION I-I

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE	SCALE
JULY 16, 2015	AS SHOWN

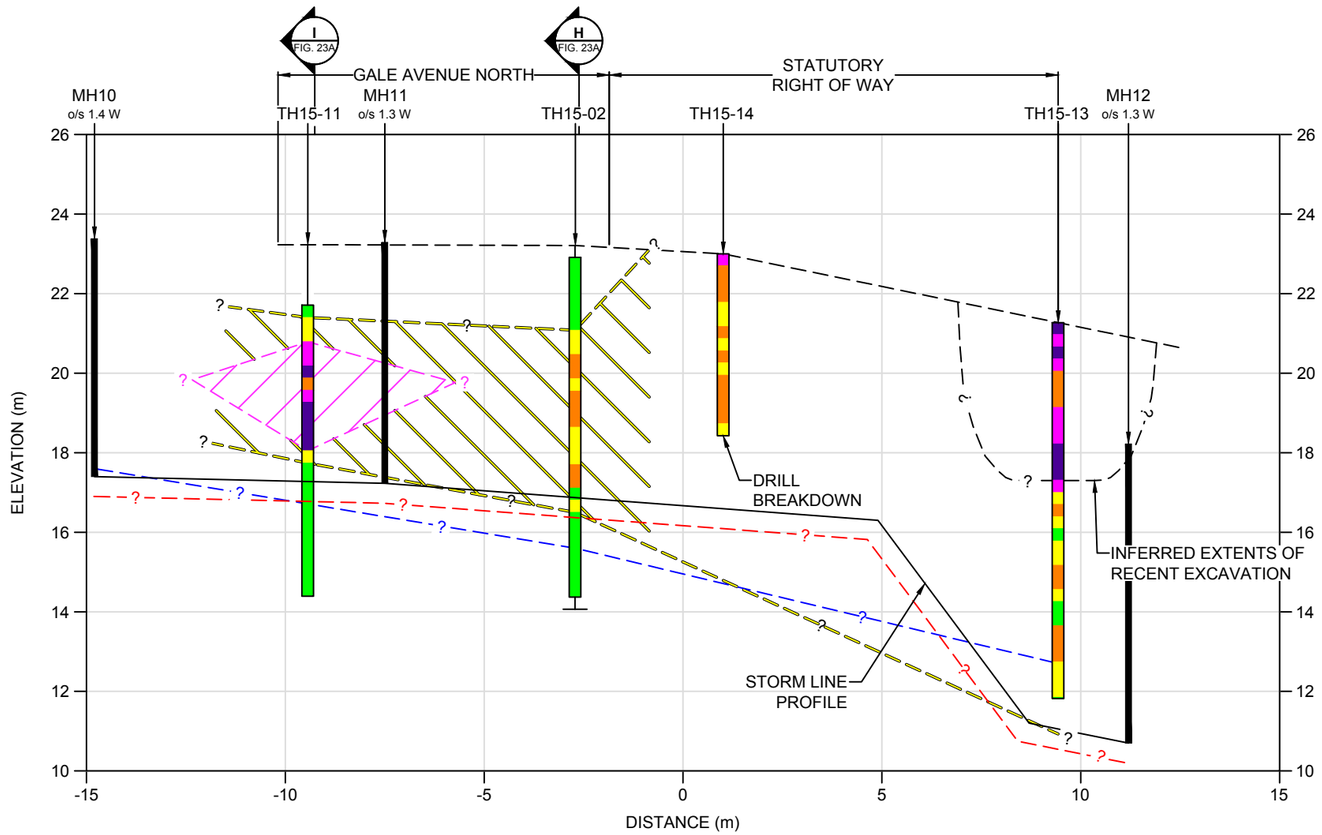
PROJECT No.	FIG. No.	REV.
14-214-4	25	-

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER21\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION J
AT STA. 3+19.6

LEGEND FOR INTERPRETATION:	
	(N = 0 to 1 or Static Weight of Hammer) Void or Very Severe Apparent Loosening
	(N = 2 to 4) Severe Apparent Loosening
	(N = 5 to 10) Moderate Apparent Loosening
	(N = 11 to 20) Minor Apparent Loosening
	(N = 21 or greater) No Apparent Loosening
- - -	Interpreted Base of Fill
- - -	Interpreted Water Table
- - -	Interpreted Extent of Severely Loosened Zone
- - -	Interpreted Extent of Loosened Zone

NOTES:

1. INTERPRETATIONS MADE ON THE BASIS OF DRILLING OBSERVATIONS AS DETAILED IN THE TEST HOLE LOGS.
2. INFERRED BOUNDARIES MAY VARY BETWEEN TEST HOLES.
3. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION.
4. STORM LINE PROFILE APPROXIMATED FROM FILE: 03-23-2015 GROUND COMPARISON BASED ON PIPE VIDEO INTERPRETATION.

0 2.5 5.0 7.5m

LEGEND:
BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

INTERPRETATION SECTION J-J

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

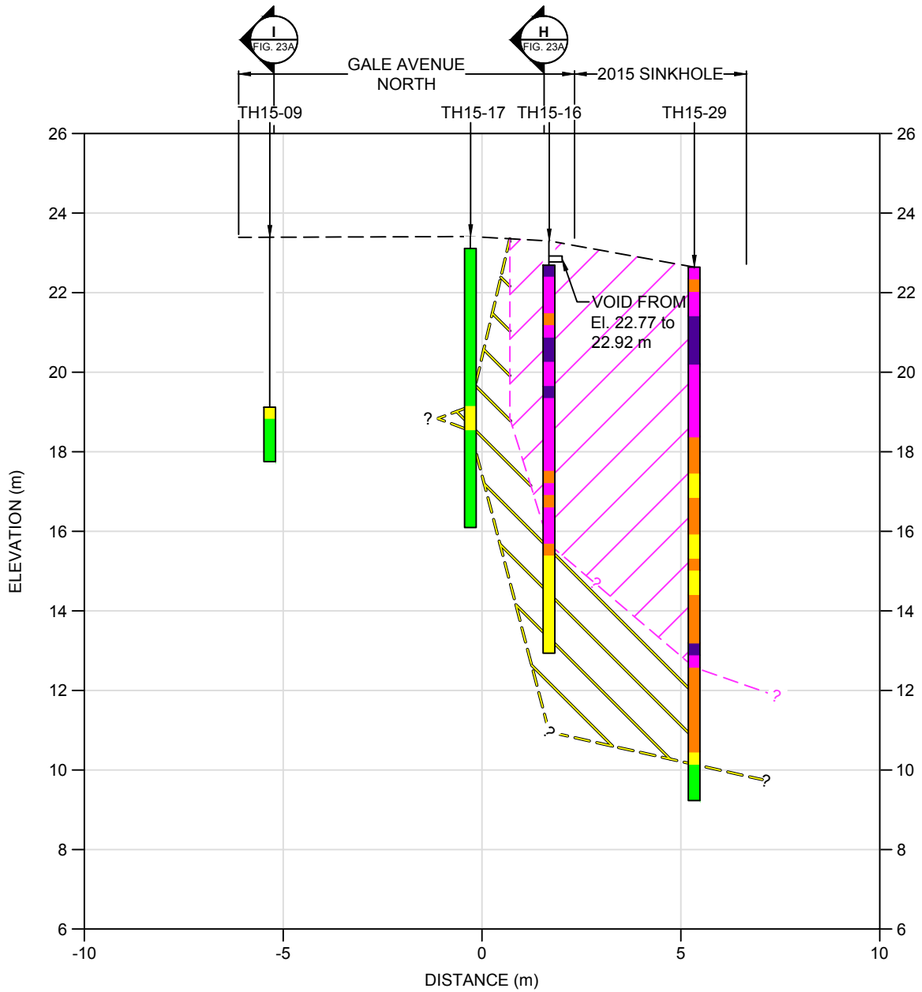
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 26	REV.: -

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION K
AT STA. 3+10.5

LEGEND FOR INTERPRETATION:
(N = 0 to 1 or Static Weight of Hammer) Void or Very Severe Apparent Loosening
(N = 2 to 4) Severe Apparent Loosening
(N = 5 to 10) Moderate Apparent Loosening
(N = 11 to 20) Minor Apparent Loosening
(N = 21 or greater) No Apparent Loosening
Interpreted Base of Fill
Interpreted Water Table
Interpreted Extent of Severely Loosened Zone
Interpreted Extent of Loosened Zone

NOTES:

1. INTERPRETATIONS MADE ON THE BASIS OF DRILLING OBSERVATIONS AS DETAILED IN THE TEST HOLE LOGS.
2. INFERRED BOUNDARIES MAY VARY BETWEEN TEST HOLES.
3. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION.

0 2.5 5.0 7.5m

LEGEND:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

INTERPRETATION SECTION K-K

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

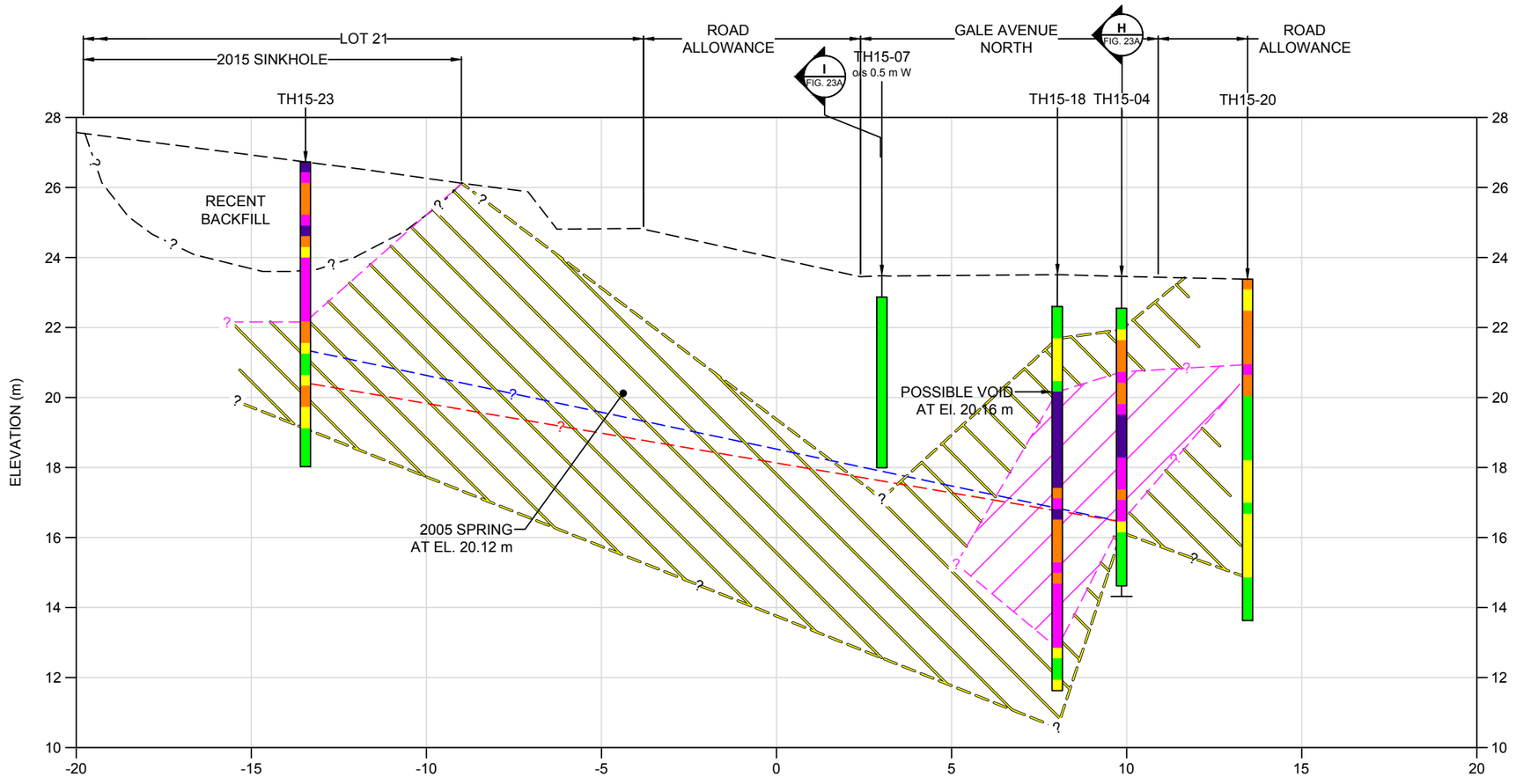
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 27	REV.: -

CANCEL PRINTS BEARING EARLIER LETTER

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION L

AT STA. 3+03.8

LEGEND FOR INTERPRETATION:
(N = 0 to 1 or Static Weight of Hammer) Void or Very Severe Apparent Loosening
(N = 2 to 4) Severe Apparent Loosening
(N = 5 to 10) Moderate Apparent Loosening
(N = 11 to 20) Minor Apparent Loosening
(N = 21 or greater) No Apparent Loosening
Interpreted Base of Fill
Interpreted Water Table
Interpreted Extent of Severely Loosened Zone
Interpreted Extent of Loosened Zone

NOTES:

1. INTERPRETATIONS MADE ON THE BASIS OF DRILLING OBSERVATIONS AS DETAILED IN THE TEST HOLE LOGS.
2. INFERRED BOUNDARIES MAY VARY BETWEEN TEST HOLES.
3. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION.

0 2.5 5.0 7.5m

LEGEND:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE (OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

INTERPRETATION SECTION L-L

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

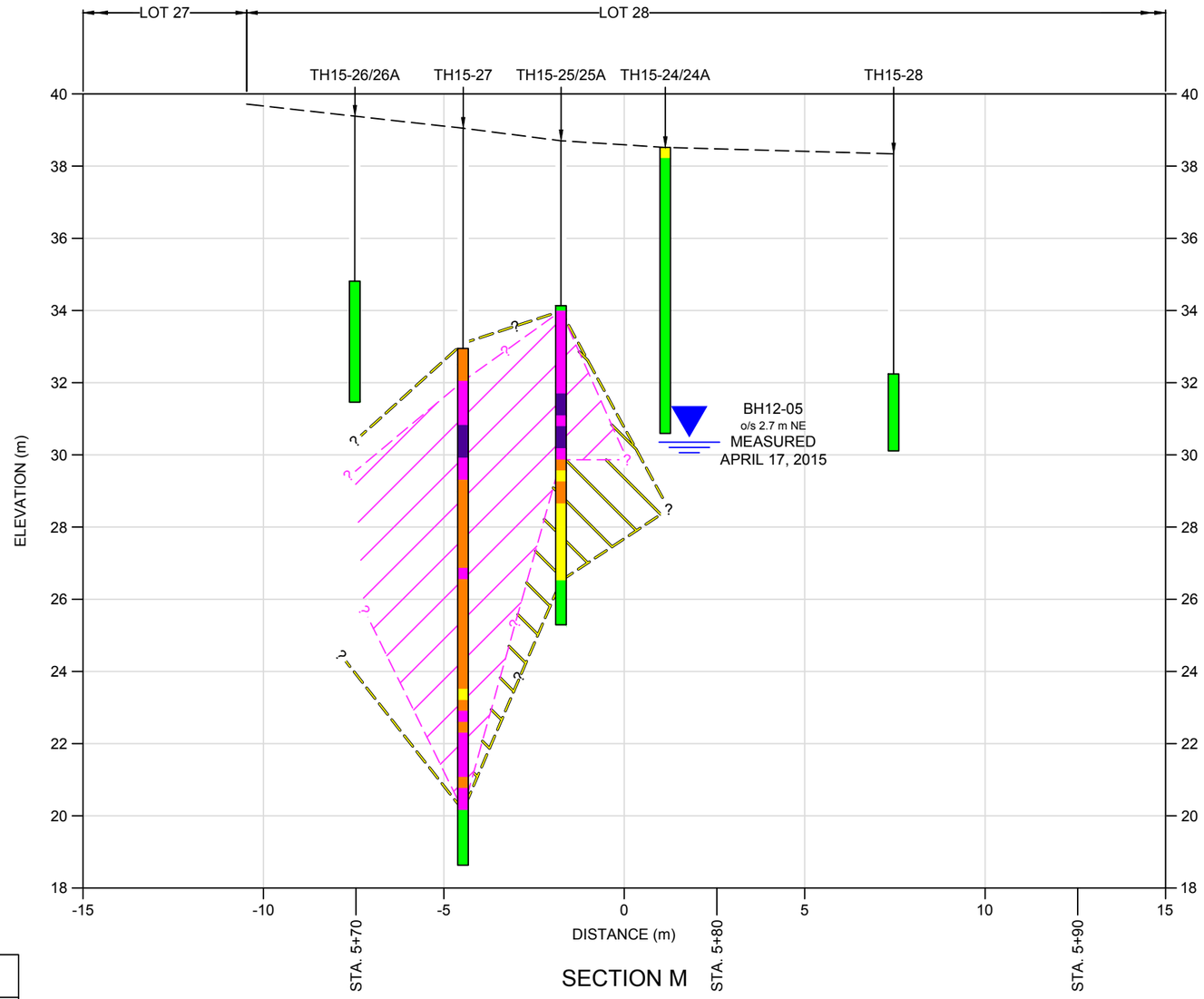
DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 28	REV.: -

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015



SECTION M

LEGEND FOR INTERPRETATION:
(N = 0 to 1 or Static Weight of Hammer) Void or Very Severe Apparent Loosening
(N = 2 to 4) Severe Apparent Loosening
(N = 5 to 10) Moderate Apparent Loosening
(N = 11 to 20) Minor Apparent Loosening
(N = 21 or greater) No Apparent Loosening
Interpreted Base of Fill
Interpreted Water Table
Interpreted Extent of Severely Loosened Zone
Interpreted Extent of Loosened Zone

NOTES:

1. INTERPRETATIONS MADE ON THE BASIS OF DRILLING OBSERVATIONS AS DETAILED IN THE TEST HOLE LOGS.
2. INFERRED BOUNDARIES MAY VARY BETWEEN TEST HOLES.
3. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION.

0 2.5 5.0 7.5m

LEGEND:
BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

INTERPRETATION SECTION M-M

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: AS SHOWN	
PROJECT No.: 14-214-4	FIG. No.: 29	REV.: -

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Plotted: July 15, 2015

?

ZONE WHERE SINKHOLE POTENTIAL MAY EXIST

NORTH

SURFACE WATER INFILTRATION

SEAWATCH LANE

SINKHOLE

WALLS (SCHEMATIC)

GROUNDWATER SURFACE

UPPER SAND

UNDERMINED / LOOSENED ZONE

GROUNDWATER SURFACE INTERSECTS NATIVE GROUND SURFACE (CONSTRUCTION SPRING)

POST CONSTRUCTION: POTENTIAL EROSION WHERE GROUNDWATER FLOWS INTO DRAINAGE BLANKET

SINKHOLE i.e. LOT 21

GALE AVENUE NORTH

SINKHOLE i.e. ADJ. LOT 9

UPPER SANDY SILT TO SILTY SAND

LOWER SAND

LOWER SANDY SILT TO SILTY SAND

GROUNDWATER RECHARGE

?

FILL

POTENTIAL EROSION INTO DRAINAGE BLANKETS & SUBMERGED UTILITIES

SPRINGS & DRAINS

OCEAN

BASAL SILT

POTENTIAL PIPING PATHWAY

SPRING DURING CONSTRUCTION (TYP.)

NOTES:
1. SOIL STRATIGRAPHY BASED ON GENERALIZED PROFILE NEAR CENTRE OF SITE.

LEGEND:
- GROUNDWATER LINE
- GROUNDWATER FLOW DIRECTION

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SCHEMATIC CONCEPTUAL MODEL

THE SHORES - PHASE 1 SUBDIVISION SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: JULY 16, 2015	SCALE: N.T.S.	
PROJECT No.: 14-214-4	FIG. No.: 30	REV.: -

\\VANSERVER2\Server\CAD Files\ACADDATA\PROJECTS\14\VED03358.dwg

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

THURBER

PHOTOGRAPHS



Photo 1 - November 4, 2014 Depression adjacent to Lot 29 on Seawatch Lane

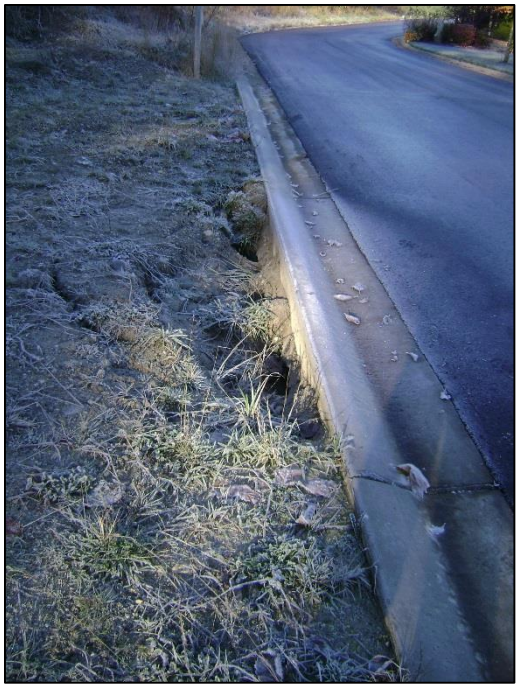


Photo 2 - November 12, 2014 Depression adjacent to Lot 29 on Seawatch Lane



Photo 3 - November 12, 2014 Depression adjacent to Lot 29 on Seawatch Lane



Photo 4 - November 14, 2014 Repair of depression on Seawatch Lane



Photo 5 - November 12, 2014 Subsidence adjacent to Lot 9



Photo 6 - November 12, 2014 Subsidence below Lot 9 concrete driveway



Photo 7 - February 27, 2015 Sinkhole in front of home on Lot 21



Photo 8 - March 2, 2015 Subsidence below Gale Avenue North adjacent to Lot 9. Area is the same as subsidence noted in November 2014.



Photo 9 - May 31, 2007 Inferred Seepage Erosion



Photo 10 - August 29, 2008 Inferred drainage blanket construction over native soil

THURBER

APPENDIX 1

Thurber Engineering Ltd. 2015 Site Inspection Reports

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-001

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: February 27, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of two new sinkholes, site status and groundwater level monitoring

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
David J. Tara (DJT)	Ron Davis (RD)	From 13h00 to 16h30 WEATHER: Sun/Cloud ~10°C

ACTIVITIES/OBSERVATIONS:

1. Two new sinkholes have developed on site. One sinkhole is located at the edge of the curb in front of Lot 9 (6660 Gale Avenue North) as shown in Photos 1 and 2. Note granular fill at ground surface.



Photo 1. Overview of sinkhole adjacent to curb in front of Lot 9.



Photo 2. Gap under driveway on Lot 9.

2. The second sinkhole is located in front of the residence on Lot 21 (6657 Gale Avenue North) as shown in Photo 3.



Photo 3. Sinkhole on Lot 21. Note gap under stairs and tension cracks radiating out from centre.

3. Crack in concrete driveway on Lot 21 adjacent to sinkhole shown in Photo 4.



Photo 4. Crack in driveway slab at Lot 21.

4. Numerous cracks and damage inside Lot 21 residence shown in Photos 5 to 8.



Photo 5. Crack in garage floor.



Photo 6. Crack in drywall at back of garage.

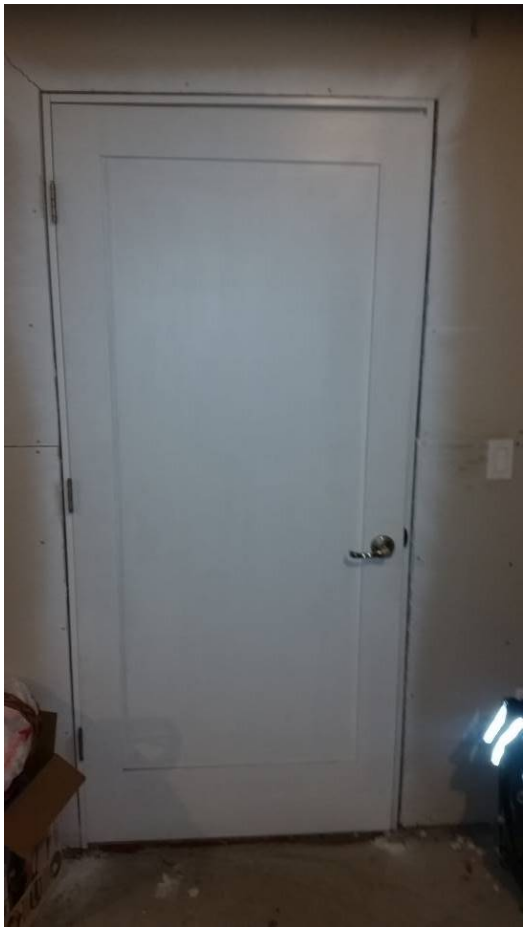


Photo 7. Distortion at interior door in basement.



Photo 8. Crack at bottom right corner of front window.

5. Observed slight sag in asphalt surface on Seawatch Lane at location of June 2012 sinkhole.
6. Observed large flow of sediment laden water exiting storm sewer that runs between Lots 9 and 10 as shown in Photos 9 and 10.



Photo 9. Flow exiting from storm sewer.



Photo 10. View down storm sewer.

7. Observed flow from storm sewers at north end below Lot 12 (Photo 11) and south end (Photo 12). Flow is clear and relatively low.



Photo 11. Storm sewer outlet below Lot 12.



Photo 12. Cawston Road storm sewer outlet.

8. RD lifted storm sewer manhole lids to south of Lot 9/10 storm sewer. Flows relatively low and not sediment laden.

9. Remedial works for previous 2012 springs at Lot 3 comprise a series of concrete barrels as shown in Photo 13.



Photo 13. Remedial works at Lot 3 spring.

10. Seepage exiting bench to south of and on fill slope to north of remedial works at Lot 3 spring as shown in Photos 14 and 15, respectively.



Photo 14. New spring on bench to south of remedial works at Lot 3 spring.



Photo 15. New spring on slope below remedial works at Lot 3 spring.

11. Recorded water levels in accessible groundwater monitoring wells as shown below.

Depth to Groundwater [m]					
Test Hole No.	Jan. 29, 2013	Feb. 1, 2013	Feb. 21, 2013	Mar. 5, 2013	Feb. 27, 2015
BH12-01	5.5	5.5	5.5	5.43	5.23
BH12-02	3.2	3.3	3.3	3.17	N/A
BH12-03	2.3	2.3	2.3	2.24	2.21
BH12-05	10.8	10.8	10.9	10.87	7.90
BH12-06	8.2	8.3	8.2	8.18	N/A
BH12-07	5.0	5.0	5.0	4.91	N/A
BH12-08	11.8	11.8	11.9	11.84	N/A
BH12-09	18.0	18.0	18.1	18.05	16.89
TH13-01		Not stabilized	Not stabilized	Dry	Not measured
TH13-07		6.5	6.0	5.91	4.27
TH13-08		2.9	2.9	2.79	N/A
TH13-09 shallow		0.9	0.9	0.85	N/A
TH13-09 deep		1.3	1.6	1.56	N/A

N/A = not accessible.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

12. Based on my observations, the following tasks should be undertaken as soon as possible:

    i. A video assessment of the storm sewer between Lots 9 and 10 and of all lines feeding into the storm sewer on Gale Avenue North and elsewhere. The purpose of this assessment is to determine if and where there is a physical break in the pipe.
    ii. If possible, measure the flow in the storm sewer between Lots 9 and 10 near Gale Avenue North and at the final manhole before the outlet.
    iii. Survey the locations (horizontally and vertically) of the sinkhole adjacent to the driveway on Lot 9 and the sinkhole at the front of the dwelling on Lot 21. Also survey location of remedial works at Lot 3 spring and at new springs on bench (to south) and slope (to north) of remedial works.
    iv. As some of the monitoring wells/piezometers appear to have been covered with soil, locate piezometers at BH12-08 (Lot 22), BH12-07 (Lot 15), BH12-06 (Lot 9), TH13-09 (SRW on Lot 9), BH12-02 (SRW on Lot 6) and TH13-08 (SRW on Lot 3).

13. Thurber to conduct a complete round of baseline monitoring of groundwater monitoring wells as soon as they are located.
14. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side.
15. District of Sechelt personnel should inspect the site daily for signs of movement particularly between the two sinkholes.
16. District of Sechelt should develop an emergency plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: David J. Tara, P.Eng. EMAIL: dtara@thurber.ca	REVIEWED BY: David Hill, P.Eng

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-002

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: March 02, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of two new sinkholes, site status and groundwater level monitoring

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	District of Sechelt crews ABC Pipe Cleaning Services	From 14h00 to 16h45 WEATHER: Sun ~10°C

ACTIVITIES/OBSERVATIONS:

1. Two new sinkholes have developed on site and were first described in our report February 27, 2015. During this site visit District of Sechelt crews were working with utilities in Lot 9 and an ABC Pipe Cleaning Services truck was parked below Lot 12 (possibly to check storm lines as per Feb. 27 recommendation).
2. One sinkhole is located at the edge of the curb in front of Lot 9 (6660 Gale Avenue North) as shown in Photos 1 and 2. Note granular fill at ground surface. The ground appears to have settled further away from the curb and driveway slab since February 27 although human disturbance makes it difficult to quantify.



Photo 1. Overview of sinkhole adjacent to curb in front of Lot 9. Lot 21 sinkhole in yellow tape behind.



Photo 2. Gap under driveway on Lot 9.

3. The second sinkhole is located in front of the residence on Lot 21 (6657 Gale Avenue North) as shown in Photo 3. The stairs behind have rotated away from the dwelling and the ground has settled away from the driveway slab as shown in Photos 4 and 5.



Photo 3. Sinkhole on Lot 21. Note scarp in garden appears to have regressed about 1 m radially since Feb 27.



Photo 4. Undermining of driveway slab at Lot 21.

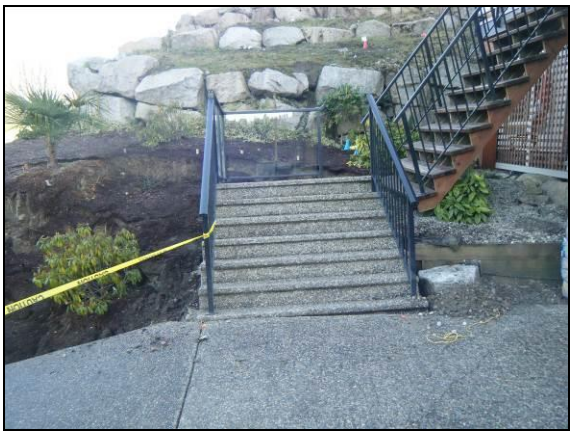


Photo 5. Rotation of stairs at Lot 21.

4. Seepage continues from multiple springs on the slope in Lot 3 just below the dwelling bench and above the lower sewer right of way (SRW) bench. The springs coalesce before the lower bench, flow visually estimated at approximately 20L per minute (order of magnitude).

5. Seepage was also noted from the gulley adjacent the beach access trail at the east edge of the development (Crowston Road). Water appeared to well up from beneath the forest litter covering the ground with no apparent surface flow above. The seepage rate appeared to be on the order of 1L per minute and was currently clear but with evidence that sand had been deposited at surface during higher flows. The elevation of these seeps is approximately the same as those observed in Lot 3.

6. Recorded water levels in accessible groundwater monitoring wells as shown below.

Test Hole No.	Feb. 1, 2013	Feb. 21, 2013	Mar. 5, 2013	Feb. 27, 2015	Mar. 2, 2015
BH12-01	5.5	5.5	5.43	5.23	5.21
BH12-02	3.3	3.3	3.17	N/A	3.10
BH12-03	2.3	2.3	2.24	2.21	2.21
BH12-05	10.8	10.9	10.87	7.90	7.95
BH12-06	8.3	8.2	8.18	N/A	7.90
BH12-07	5.0	5.0	4.91	N/A	N/A
BH12-08	11.8	11.9	11.84	N/A	N/A
BH12-09	18.0	18.1	18.05	16.89	16.80
TH13-01	Not stabilized	Not stabilized	Dry	Not measured	14.38
TH13-07	6.5	6.0	5.91	4.27	4.38
TH13-08	2.9	2.9	2.79	N/A	N/A
TH13-09 shallow	0.9	0.9	0.85	N/A	N/A
TH13-09 deep	1.3	1.6	1.56	N/A	N/A

N/A = not accessible.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

7. Based on my observations, the following tasks should be undertaken as soon as possible:

   i. Survey the locations (horizontally and vertically) of the sinkhole adjacent to the driveway on Lot 9 and the sinkhole at the front of the dwelling on Lot 21. Also survey location of remedial works at Lot 3 spring and at new springs on bench (to south) and slope (to north) of remedial works.
   ii. As some of the monitoring wells/piezometers appear to have been covered with soil, locate piezometers at BH12-08 (Lot 22), BH12-07 (Lot 15), TH13-09 (SRW on Lot 9), and TH13-08 (SRW on Lot 3).

8. Thurber to monitor groundwater monitoring wells including baseline readings of inaccessible wells as soon as they are located.
9. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side.
10. District of Sechelt personnel should inspect the site daily for signs of movement particularly between the two sinkholes and during periods of precipitation.
11. District of Sechelt should develop an emergency plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
12. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings in Lots 9 and 21 during and following heavy rain events.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: David J. Tara, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-003

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: March 04, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of two new sinkholes, site status and groundwater level monitoring

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	District of Sechelt personnel Dick Butler, Golder Associates	From 11h00 to 14h15 WEATHER: Sun ~10°C

ACTIVITIES/OBSERVATIONS:

1. Two new sinkholes have developed on site and were first described in our report February 27, 2015. Gale Avenue North remains closed in front of Lots 9, 10, and 21. Prior to this visit Strait Land Surveyors Inc. had located the remaining groundwater monitoring wells and had exposed all but two. The final two were hand excavated by CHS at the locations marked by survey.
2. One sinkhole is located at the edge of the curb in front of Lot 9 (6660 Gale Avenue North) as shown in Photos 1 to 3. Note granular fill at ground surface. No changes since March 2 were visually apparent. The crack at the edge of the sinkhole runs parallel to Gale Avenue North for 3.3 m and extends horizontally up to 0.75 m beneath the road. It has also undermined the adjacent concrete driveway. One of the Sonotube columns which supports the porch at the back of Lot 9 appears to have moved downslope as shown in Photo 4 (to be monitored for further signs of displacement).



Photo 1. Overview of sinkhole adjacent to curb in front of Lot 9.



Photo 2. Undermined Gale Ave N. at Lot 9.



Photo 3. Undermined driveway at Lot 9.



Photo 4. Slightly incline support column supporting porch at back of Lot 9 adjacent to District right of way.

3. The second sinkhole is located in front of the residence on Lot 21 (6657 Gale Avenue North) as shown in Photo 5. No changes since March 2 were visually apparent. No seepage, ponded water, or wet ground was observed on Lots 9 or 21 in the vicinity of the sinkholes.



Photo 5. Sinkhole on Lot 21.

4. The perimeter drain on Lot 21 had been exposed between the failing stairs and the building corner as shown in Photo 6. The drain was punctured, possible during exposure, and partially filled with drain rock. The drain pipe and the surrounding fill were dry.



Photo 6. Perimeter drain exposed.



Photo 7. Puncture in perimeter drain.

5. Seepage continues from multiple springs on the slope in Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench. The springs coalesce on the lower SRW bench where they appear to be collected into a French drain which discharges below the bench. Discharge from the drain is silty and estimated at approximately 10L per minute with a marked pail and stopwatch. The slope on Lot 2 is also wet with minor seepage but currently does not reach the SRW below (sand deposits on SRW bench indicate has in past).

6. Flow from storm outfall below the SRW between Lots 9 and 10 is silty. Outlet is partly infilled (about 2/3rds) by deposited fine sand and silt as shown in Photo 8. Fine sand and silt along creek below outlet with cloudy flow, matching generally the gradation of the beach deposits below. Sand beach delta extends approximately from Lots 6 to 13 as shown in Photo 9. To the east the beach is rocky as shown in Photo 10.



Photo 8. Partially infilled storm outlet below SRW between Lots 9 and 10.



Photo 9. Beach below storm outfall at Lots 9 and 10.



Photo 10. Rocky beach below Lots 1 through 5.

7. Groundwater monitoring well BH12-06 appears to have been damaged during landscaping of the lawn on Lot 9. Groundwater monitoring wells TH13-09 (shallow and deep) were buried with 0.3 to 0.4 m of fill and the flush mount cover removed (Photo 11).



Photo 11. Exposed TH13-09 monitoring wells.

8. Recorded water levels in groundwater monitoring wells as shown below. Well depth in brackets.

Test Hole No.	Feb. 21, 2013	Mar. 5, 2013	Feb. 27, 2015	Mar. 2, 2015	Mar. 4, 2015
BH12-01	5.5	5.43	5.23	5.21	5.23 (7.0)
BH12-02	3.3	3.17	N/A	3.10	3.13 (6.2)
BH12-03	2.3	2.24	2.21	2.21	2.22 (5.8)
BH12-05	10.9	10.87	7.90	7.95	8.05 (12.1)
BH12-06	8.2	8.18	N/A	7.90*	7.83 (11.3)*
BH12-07	5.0	4.91	N/A	N/A	4.93 (6.55)
BH12-08	11.9	11.84	N/A	N/A	10.92 (14.1)
BH12-09	18.1	18.05	16.89	16.80	16.83 (19.6)
TH13-01	Not stabilized	Dry	Not measured	14.38	14.38 (14.65)
TH13-07	6.0	5.91	4.27	4.38	4.40 (10.4)
TH13-08	2.9	2.79	N/A	N/A	2.69 (6.05)
TH13-09 shallow	0.9	0.85	N/A	N/A	0.77 (1.23)*
TH13-09 deep	1.6	1.56	N/A	N/A	0.82 (2.85)*

N/A = not accessible. *Well damaged/cover removed, measured from adjacent ground surface.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

9. Groundwater monitoring well BH12-06 on Lot 9 should have a new flush mount cover installed and the new cover elevation should be surveyed.
10. Groundwater monitoring wells TH13-09 shallow and deep should be extended to the adjacent ground surface and a new flush mount cover installed and surveyed.
11. It should be noted that BH12-07, BH12-08, and TH13-08 had been covered with fill but the flush mounts were still intact. We recommend that all well covers be protected and access to the wells maintained. Alternatively, consideration could be given to extending the wells and covers where required and re-surveying.
12. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side.
13. District of Sechelt personnel should inspect the site daily for signs of movement particularly between the two sinkholes and during periods of precipitation.
14. District of Sechelt should develop an emergency plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
15. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings in Lots 9 and 21 during and following heavy rain events.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: David J. Tara, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-004

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: March 9, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of storm sewer corridor between Lots 9 and 10, borrow pit on Crowston Road, and site status.

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
David J. Tara (DJT)	Sanath Bandara (SB), DoS Richard Avedon-Savage (RAS), ISL	From 15h00 to 17h40 WEATHER: Sun and cloud ~10℃

ACTIVITIES/OBSERVATIONS:

1. Two new sinkholes have developed on site and were first described in our report February 27, 2015.
2. Gale Avenue North remains closed in front of Lots 9, 10, and 21.
3. Sinkhole located at the edge of the curb in front of Lot 9 (6660 Gale Avenue North) relatively unchanged.
4. Sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) backfilled with granular material and covered with polyethylene sheeting as shown in Photos 1 and 2.



Photos 1 and 2. Sinkhole on Lot 21.

5. Seepage continues from below the spring on the slope on Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench.
6. Flow from storm outfall below the SRW between Lots 9 and 10 is relatively clear as shown in Photo 3. Outlet is partly infilled (about 70%) by deposited sand shown in photo.



Photo 3. Partially infilled storm outlet below SRW between Lots 9 and 10.

7. Ground surface at repaired sinkhole in Seawatch Lane slightly depressed as shown in Photo 4 (shadow in red dashed area).



Photo 4. Slight depression at repaired Seawatch Lane sinkhole.

8. The borrow area situated upslope of site inside of area defined by red dashes shown on excerpt of 2012 aerial photo (Photo 5) was visually inspected. Material appears to have been removed and the site grading modified in 2013 or 2014 since the last inspection of this area by Thurber. Seepage was observed along the south slope and appeared to be accumulating (ponding) as shown in Photo 6.



Photo 5. Borrow area south of site.



Photo 6. Water ponding in borrow area south of site.

9. Water flowing in Crowston Road ditch appears to infiltrate into the soil at the base of the ditch prior to arriving at the storm water inlet at the intersection of Seawatch Lane and Crowston Road.

10. No groundwater monitoring completed.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

11. As per our Items 9 and 10, groundwater monitoring wells BH12-06 and TH13-09 should be repaired (extended and have new flush mount covers installed) and re-surveyed.
12. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
13. District of Sechelt personnel should continue inspect the site daily and during periods of precipitation for signs of movement particularly between the two sinkholes.
14. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
15. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
16. As the ponded water in the borrow area described in Item 8 may be a source of infiltration that could contribute to the observed changes in the groundwater regime at the site, consideration should be given to re-establishing drainage of ponded water in the borrow area.
17. To further limit infiltration of groundwater from the Crowston Road ditch, consideration should also be given to extending the Crowston Road storm sewer further south.
18. We recommend that the piezometers be monitored at least every other week and after periods of intense rainfall. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. Thurber can provide this service if required.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: David Tara, P.Eng.	REVIEWED BY: David Hill, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-005

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: March 16, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of two new sinkholes, site status and groundwater level monitoring

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	None.	From 10h45 to 13h45 WEATHER: Sun ~10°C

ACTIVITIES/OBSERVATIONS:

1. Two sinkholes that have previously developed on site were first described in our report February 27, 2015.
2. Gale Avenue North remains closed in front of Lots 8, 9, and 21 as shown in Photo 1.
3. Since our last site visit on March 9, 2015 (water levels on March 4) according to public weather station data approximately 20 mm of rain has fallen primarily focussed on March 11 and 14. This represents approximately 75% of the recorded rainfall for the past 30 days.
4. Sinkhole located at the edge of the curb in front of Lot 9 (6660 Gale Avenue North) appears relatively unchanged as shown in Photo 2. No visually apparent changes to Lot 9 structure as viewed from storm sewer corridor.
5. Sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) was backfilled with granular material and covered with polyethylene sheeting as described in our report dated March 9, 2015. The polyethylene sheeting had been partially blown off during a storm event (Photo 3). No visually apparent settlement of backfill.



Photo 1. Closed section of Gale Avenue North



Photo 2. Undermined Gale Ave N. at Lot 9 (Lot 21 behind)



Photo 3. Backfilled sinkhole at Lot 21, polyethylene sheeting windblown and partially exposed backfill.

6. Seepage continues from multiple springs on the slope in Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench. The springs coalesce on the lower SRW bench where they appear to be collected into a French drain which discharges below the bench. Discharge from the drain appears clear and flow rate is similar to that measured during March 4 inspection. The slope and dwelling bench on Lot 2 are also wet with minor seepage but currently does not reach the SRW below (sand deposits on SRW bench indicate seepage has reached the SRW in the past).

7. On Lot 1 the water in the collection ponds is 0.05 m deep on the dwelling bench, 0.20 m deep on the SRW bench, and dry in the pond just below the SRW. Drain outlets from the ponds are collected and discharged at the storm outfall north of Lot 1 (see Photo 4).

8. Flow from storm outfall below the SRW between Lots 9 and 10 is clear. Outlet is partly infilled (about 2/3rds) by deposited fine sand and silt as shown in Photo 5.





Photo 4. Storm and collection pond outlet below Lot 1. Photo 5. Storm outlet below SRW between Lots 9 and 10.

9. No visually apparent changes to slight depression in Seawatch Lane at Lot 28. No visually apparent settlement or cracking of Gale Avenue North between Lots 9 and 21.

10. The borrow area situated upslope of site as described in our March 9, 2015 report was visually inspected. Seepage continues from the south pit wall and appeared to be accumulating (ponding) as shown in Photo 6. No visually apparent changes to the extents of the pond since March 9 despite recent rainfall.

11. Water flowing in east Crowston Road ditch appears to infiltrate into the soil at the base of the ditch prior to arriving at the storm water inlet at the intersection of Seawatch Lane and Crowston Road. In the west ditch the flowing water now reaches the storm water inlet at Seawatch Lane (Photo 7) which wasn't observed during the March 9, 2015 inspection. The increased volume of water may be in response to recent rainfall.



Photo 6. Ponded water at borrow area.



Photo 7. Crowston Road west ditch, inlet at Seawatch Lane

12. Recorded water levels in groundwater monitoring wells as shown below. (Well depth in brackets on March 4)

Test Hole No.	Mar. 5, 2013	Feb. 27, 2015	Mar. 2, 2015	Mar. 4, 2015	Mar. 16, 2015
BH12-01	5.43	5.23	5.21	5.23 (7.0)	5.23
BH12-02	3.17	N/A	3.10	3.13 (6.2)	3.06
BH12-03	2.24	2.21	2.21	2.22 (5.8)	2.27
BH12-05	10.87	7.90	7.95	8.05 (12.1)	8.25
BH12-06	8.18	N/A	7.90*	7.83 (11.3)*	7.83*
BH12-07	4.91	N/A	N/A	4.93 (6.55)	4.90
BH12-08	11.84	N/A	N/A	10.92 (14.1)	10.92
BH12-09	18.05	16.89	16.80	16.83 (19.6)	16.83
TH13-01	Dry	Not measured	14.38	14.38 (14.65)	14.46
TH13-07	5.91	4.27	4.38	4.40 (10.4)	4.42
TH13-08	2.79	N/A	N/A	2.69 (6.05)	2.69
TH13-09 shallow	0.85	N/A	N/A	0.77 (1.23)*	0.64*
TH13-09 deep	1.56	N/A	N/A	0.82 (2.85)*	0.87*

N/A = not accessible. *Well damaged/cover removed, measured from adjacent ground surface.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

1. The polyethylene sheeting covering the backfilled sinkhole at Lot 21 should be re-secured by whomever is responsible as per Item 5. For example, sand bags may provide ballast. The stakes currently used to secure the poly appear to be insufficient based on the current conditions observed.
2. As per Items 9 and 10 of our report dated March 4, 2015, groundwater monitoring wells BH12-06 and TH13-09 should be repaired (extended and have new flush mount covers installed) and re-surveyed.
3. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
4. District of Sechelt personnel should continue inspect the site daily and during periods of precipitation for signs of movement particularly between the two sinkholes.
5. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
6. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
7. As the ponded water in the borrow area described in Item 10 may be a source of infiltration that could contribute to the observed changes in the groundwater regime at the site, consideration should be given to re-establishing drainage of ponded water in the borrow area.
8. To further limit infiltration of groundwater from the Crowston Road ditch, consideration should also be given to extending the Crowston Road storm sewer further south.
9. We recommend that the piezometers be monitored at least every other week and after periods of intense rainfall. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. Thurber can provide this service if required.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: Denny Ma, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-006

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: March 23, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of two new sinkholes, site status and groundwater level monitoring

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	None.	From 10h45 to 14h45 WEATHER: Cloud ~10°C

ACTIVITIES/OBSERVATIONS:

1. Two sinkholes that have previously developed on Lots 9 and 21 were first described in our report February 27, 2015.
2. Gale Avenue North remains closed in front of Lots 8, 9, and 21 as shown in Photo 1. No visually apparent settlement or cracking of Gale Avenue North between Lots 9 and 21.
3. Since our last site visit on March 16, 2015 according to public weather station data approximately 30 mm of rain has fallen primarily focussed on March 19 and 20. This represents approximately 50% of the total recorded rainfall for the past 30 days.
4. Sinkhole located at the edge of the curb in front of Lot 9 (6660 Gale Avenue North) appears relatively unchanged as shown in Photo 2. Sinkhole has undermined Gale Avenue North at least 1 m horizontally from curb. Corner of undermined concrete driveway has cracked. No visually apparent changes to Lot 9 structure as viewed from Statutory Right of Ways.



Photo 1. Closed section of Gale Avenue North



Photo 2. Undermined Gale Ave N. at Lot 9 (Lot 21 behind)

5. Sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) was backfilled with granular material and covered with polyethylene sheeting as described in our report dated March 9, 2015. The polyethylene sheeting had been restored and secured as per our March 16 recommendation (Photo 3). No visually apparent settlement of backfill. Stairs in sinkhole are dipping approximately 10 degrees to northeast and have apparently moved approximately 20 mm towards sinkhole since March 16 (Photo 4).



Photo 3. Backfilled sinkhole at Lot 21



Photo 4. Rotated stairs at Lot 21 sinkhole

6. Flow from storm outfall below the SRW between Lots 9 and 10 appears relatively clear. Outlet is partly infilled (about 50%) by deposited fine sand and silt as shown in Photo 5. Reduced amount of infill since March 16 may have been a result of erosion of the infill during peak flows.





Photo 5. Storm outlet below SRW between Lots 9 and 10. Photo 6. Storm & drain outlets below SRW and Lot 1.

7. Seepage continues from multiple springs on the slope in Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench. The springs coalesce on the lower SRW bench where they appear to be collected into a French drain which discharges below the bench. Discharge from the drain appears clear and flow rate is similar to that measured during March 4 inspection. The slope and dwelling bench on Lot 2 are also wet with minor seepage but currently does not reach the SRW below (sand deposits on SRW bench indicate seepage has reached the SRW in the past).
8. On Lot 1 the water in the collection ponds is 0.30 m deep on the dwelling bench, 0.20 m deep on the SRW bench, and dry in the pond just below the SRW. Drain outlets from the ponds are collected and discharged at the storm outfall north of Lot 1 (see Photo 6).
9. No visually apparent changes to slight depression in Seawatch Lane at Lot 28. Asphalt is depressed on the order of 25 m over an area approximately 2 m by 2 m in plan (Photo 7). Surface runoff onto Seawatch Lane from un-vegetated area to south adjacent to Lots 26 – 28 is reporting to storm water catch basin at Seawatch & Crowston (Photo 8). Further to west runoff from south is intercepted by a rock drain which leads to a storm grate adjacent Lot 24. Rock drain was saturated in some areas.
10. The borrow area situated upslope of site as described in our March 9, 2015 report was visually inspected. Seepage continues from the south pit wall and appeared to be accumulating (ponding) as shown in Photo 9. No visually apparent changes to the extents of the pond since March 16 despite recent rainfall.
11. Water flow in the east and west Crowston Road ditches (south of Seawatch Lane) has increased (likely in response to recent precipitation) and now reaches the storm water inlet at the intersection of Seawatch Lane and Crowston Road (Photo 10). Flow depth at inlet lip is approximately 50 mm.



Photo 7. Seawatch Lane depressed area marked



Photo 8. Runoff onto Seawatch Lane (into gutter)



Photo 9. Ponded water at borrow area.



Photo 10. Crowston Road west ditch, inlet at Seawatch Lane

12. Wet areas on Lot 14 (6885 Gale Ave N.) and Lot 13 (6889 Gale Ave N.) were visually inspected and discussed with lot owners Mr. Pickell and Mr. Pednaud, respectively. They report that they have observed the wet areas and a spongy ground surface along with minor spring seepage since purchasing. The backyards on Lots 13 and 14 are grade separated by rock-stock walls. The ground surface on the wider benches which form the backyards was observed to be saturated with minor ponded water near the toe of the walls. The yards are well grassed and the walls did not show signs of distress (Photo 11). Further back in the lots, beyond the landscaped yards the ground surface is sloping and wet with minor spring seepage evident from multiple points (Photo 12). The Lot 13 owner has attempted to collect runoff and seepage out of slope and into rock drains which discharge downslope (at the north end) of the lot towards Snake Creek (Photo 13). Both lots have been cleared of deep rooting vegetation (Lot 14 quite recently cleared of alder saplings). Old growth stumps on the lots are typically cedar with secondary growth of alder and presently grass and skunk cabbage which are all hydrophilic species.
13. At the very back (west) end of Lots 13 and 14 is a natural gulley/draw which likely collects runoff during peak flows but is presently vegetated with no signs of a developed eroded channel (likely ephemeral runoff).
14. Below (north of) Lot 13 a drain pipe exits the slope below the rock-stack wall and discharges into a clarification pond which is in turn drained and discharges at the storm outfall below Lot 12 and SRW. Water discharging from drain currently appears to be relatively clear. The clarification pond is nearly full of sand and silt and very little storage capacity remains to promote clarification (Photo 14). Lot 13 owner, Mr. Pednaud, commented that he regularly has to dig out the sand/silt to keep the pond outlet clear and functioning. Outflow from the storm outfall below Lot 12/SRW is relatively clear with a lower rate of flow than at outfalls below Lots 9/10 and Lot 1.



Photo 11. Wet area below wall, Lot 14



Photo 12. Seepage from slope, Lot 14



Photo 13. Rock drains in back of Lot 13



Photo 14. Silt filled clarification pond below Lot 13

15. Recorded water levels in groundwater monitoring wells as shown below. Well depth were measured on March 4 and are given in brackets. Data in red has a reduced reliability as discussed in Item 16.

Test Hole No.	Feb. 27, 2015	Mar. 2, 2015	Mar. 4, 2015	Mar. 16, 2015	Mar. 23, 2015
BH12-01	5.23	5.21	5.23 (7.0)	5.23	5.23
BH12-02	N/A	3.10	3.13 (6.2)	3.06	3.01
BH12-03	2.21	2.21	2.22 (5.8)	2.27	2.24
BH12-05	7.90	7.95	8.05 (12.1)	8.25	8.15
BH12-06	N/A	7.90*	7.83 (11.3)*	7.83*	7.84*
BH12-07	N/A	N/A	4.93 (6.55)	4.90	4.85
BH12-08	N/A	N/A	10.92 (14.1)	10.92	10.90
BH12-09	16.89	16.80	16.83 (19.6)	16.83	16.83
TH13-01	Not measured	14.38	14.38 (14.65)	14.46	14.40
TH13-07	4.27	4.38	4.40 (10.4)	4.42	4.32
TH13-08	N/A	N/A	2.69 (6.05)	2.69	2.72
TH13-09 shallow	N/A	N/A	0.77 (1.23)*	0.64*	0.46*
TH13-09 deep	N/A	N/A	0.82 (2.85)*	0.87*	0.34*

N/A = not accessible. *Well damaged/cover removed, measured from adjacent ground surface.

16. Temporary cover of wells at TH13-09 was found to be dislodged at time of inspection. This potentially allowed precipitation to enter wells. A significant change in measured water levels at TH13-09 since March 16 is noted but may be a result of dislodged cover. Temporary cover was replaced and re-secured.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

17. As per Items 9 and 10 of our report dated March 4, 2015, groundwater monitoring wells BH12-06 and TH13-09 should be repaired (extended and have new flush mount covers installed) and re-surveyed. The importance of this is demonstrated by the reduced reliability of the measured groundwater level at TH13-09 as per Item 15 and 16.
18. Consideration should be given to providing a long term low maintenance solution to address the silt filled clarification pond below Lot 13 (Item 14).
19. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
20. District of Sechelt personnel should continue to inspect the site daily and during periods of precipitation for signs of movement particularly between the two sinkholes.
21. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
22. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
23. Consideration should be given to re-establishing drainage of ponded water in the borrow area to the south of the development as described in Item 10.
24. To further limit infiltration of groundwater from the Crowston Road ditch, consideration should also be given to extending the Crowston Road storm sewer further south.
25. We recommend that the piezometers be monitored at least every other week and after periods of intense rainfall. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. Thurber can provide this service if required.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: Denny Ma, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-007

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: March 30, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of two new sinkholes, site status and groundwater level monitoring

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	None.	From 10h45 to 14h45 WEATHER: Cloud ~10°C

ACTIVITIES/OBSERVATIONS:

1. Two sinkholes that have previously developed on Lots 9 and 21 were first described in our report February 27, 2015.
2. Gale Avenue North remains closed in front of Lots 8, 9, and 21 as shown in Photo 1. No visually apparent settlement or cracking of Gale Avenue North between Lots 9 and 21.
3. Since our last site visit on March 23, 2015 several substantial precipitation events have occurred. Updated weather station data was not available at time of reporting.
4. Sinkhole located at the edge of the curb in front of Lot 9 (6660 Gale Avenue North) appears relatively unchanged since last inspection as shown in Photo 2. Sinkhole has undermined Gale Avenue North at least 1 m horizontally from curb. Corner of undermined concrete driveway has cracked. No visually apparent changes to Lot 9 structure as viewed from Statutory Right of Ways.



Photo 1. Closed section of Gale Avenue North



Photo 2. Undermined Gale Ave N. at Lot 9 (Lot 21 behind)

5. Sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) was backfilled with granular material and covered with polyethylene sheeting as described in our report dated March 9, 2015. No visually apparent settlement of backfill (Photo 3). The stairs on the edge of the sinkhole have apparently moved approximately 20 mm towards the sinkhole since March 23 (Photo 4).



Photo 3. Backfilled sinkhole at Lot 21



Photo 4. Rotated stairs at Lot 21 sinkhole

6. Flow from the storm outfall below the SRW between Lots 9 and 10 appears relatively clear. Outlet is partly infilled (about 20%) by deposited fine sand and silt as shown in Photo 5. Reduced amount of infill since March 23 may have been a result of erosion of the infill during peak flows.



Photo 5. Storm outlet below SRW between Lots 9 and 10.



Photo 6. Drain outlet below Lot 3.

7. Seepage continues from multiple springs on the slope in Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench. The springs coalesce on the lower SRW bench where they appear to be collected into a French drain which discharges below the bench. Discharge from the drain appears clear and flow rate is similar to that measured during March 4 inspection (Photo 6). The slope and dwelling bench on Lot 2 are also wet with minor seepage but currently does not reach the SRW below (sand deposits on SRW bench indicate seepage has reached the SRW in the past).

8. On Lot 1 the water in the collection ponds is 0.30 m deep on the dwelling bench, 0.20 m deep on the SRW bench, and dry in the pond just below the SRW. Drain outlets from the ponds are collected and discharged at the storm outfall north of Lot 1.

9. No visually apparent changes to slight depression in Seawatch Lane at Lot 28. Asphalt is depressed on the order of 25 mm over an area approximately 2 m by 2 m in plan. Minor transverse cracking noted in asphalt in area of 2012 sinkhole repair (Photo 7). Surface runoff onto Seawatch Lane from un-vegetated area to south adjacent to Lots 26 – 28 is reporting to storm water catch basin at Seawatch & Crowston (Photo 8).

10. The borrow area situated upslope of site as described in our March 9, 2015 report was visually inspected. Seepage continues from the south pit wall and appeared to be accumulating (ponding) as shown in Photo 9. No visually apparent changes to the extents of the pond since March 23 despite recent rainfall.

11. Water flow in the east and west Crowston Road ditches (south of Seawatch Lane) was similar to levels observed on March 23 and reaches the storm water inlet at the intersection of Seawatch Lane and Crowston Road (Photo 10). Flow depth at inlet lip is approximately 50 mm.



Photo 7. Seawatch Lane depressed area marked



Photo 8. Runoff onto Seawatch Lane (into gutter)



Photo 9. Ponded water at borrow area.



Photo 10. Crowston Road west ditch, inlet at Seawatch Lane

12. Wet areas on Lot 14 (6885 Gale Ave N.) and Lot 13 (6889 Gale Ave N.) were first visually inspected and described in our report dated March 23, 2015. The ground surface on the wider benches which form the backyards was observed to be saturated with minor ponded water near the toe of the walls (Photo 11). The yards are well grassed and the walls did not show signs of distress however erosion of the backfill through the cracks in the rocks with deposition below the wall was evident in several locations (Photo 12). Further back in the lots, beyond the landscaped yards the ground surface is sloping and wet with minor spring seepage evident from multiple points (Photo 13). The runoff appeared to be silty with some fine sand deposited in the shallow eroded channels (Photo 14).

13. Below (north of) Lot 13 a drain pipe exits the slope below the rock-stack wall and discharges into a clarification pond which is in turn drained and discharges at the storm outfall below Lot 12 and the SRW. Water discharging from the drain currently appears to be relatively clear. The clarification pond is nearly full of sand and silt and very little storage capacity remains to promote clarification (Photo 15). Outflow from the storm outfall below Lot 12/SRW is relatively clear with a lower rate of flow than at outfalls below Lots 9/10 and Lot 1 (Photo 16).



Photo 11. Wet area below wall, Lot 14



Photo 12. Deposition of eroded backfill, Lot 14



Photo 13. Seepage from slope, Lot 14



Photo 14. Silty runoff from springs in Lot 14



Photo 15. Silt filled pond below Lot 13



Photo 16. Storm outfall below Lot 12

14. Recorded depth to groundwater in monitoring wells are summarized below. Well depth were measured on March 4 and are given in brackets.

Test Hole No.	Mar. 2, 2015	Mar. 4, 2015	Mar. 16, 2015	Mar. 23, 2015	Mar. 30, 2015
BH12-01	5.21	5.23 (7.0)	5.23	5.23	5.21
BH12-02	3.10	3.13 (6.2)	3.06	3.01	2.99
BH12-03	2.21	2.22 (5.8)	2.27	2.24	2.26
BH12-05	7.95	8.05 (12.1)	8.25	8.15	8.02
BH12-06	7.90*	7.83 (11.3)*	7.83*	7.84*	7.84
BH12-07	N/A	4.93 (6.55)	4.90	4.85	4.83
BH12-08	N/A	10.92 (14.1)	10.92	10.90	10.85
BH12-09	16.80	16.83 (19.6)	16.83	16.83	16.75
TH13-01	14.38	14.38 (14.65)	14.46	14.40	14.33
TH13-07	4.38	4.40 (10.4)	4.42	4.32	4.15
TH13-08	N/A	2.69 (6.05)	2.69	2.72	2.70
TH13-09 shallow	N/A	0.77 (1.23)*	0.64*	0.46*	0.47*
TH13-09 deep	N/A	0.82 (2.85)*	0.87*	0.34*	0.42*

N/A = not accessible. *Well damaged/cover removed, measured from adjacent ground surface.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

15. As per Items 9 and 10 of our report dated March 4, 2015, groundwater monitoring wells BH12-06 and TH13-09 should be repaired (extended and have new flush mount covers installed) and re-surveyed.
16. Consideration should be given to providing a long term low maintenance solution to address the silt filled clarification pond below Lot 13 (Item 13).
17. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
18. District of Sechelt personnel should continue to inspect the site daily and during periods of precipitation for signs of movement particularly between the two sinkholes.
19. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
20. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
21. Consideration should be given to re-establishing drainage of ponded water in the borrow area to the south of the development as described in Item 10.
22. To further limit infiltration of groundwater from the Crowston Road ditch, consideration should also be given to extending the Crowston Road storm sewer further south.
23. We recommend that the piezometers be monitored at least every other week and after periods of intense rainfall. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. Thurber can provide this service if required.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: Denny Ma, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-008

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: April 06, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of two new sinkholes, site status and groundwater level monitoring

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	None.	From 10h45 to 14h00 WEATHER: Sun~10°C

ACTIVITIES/OBSERVATIONS:

1. Two sinkholes that have previously developed on Lots 9 and 21 were first described in our report February 27, 2015.
2. Gale Avenue North remains closed in front of Lots 8, 9, and 21 as shown in Photo 1. No visually apparent settlement or cracking of Gale Avenue North between Lots 9 and 21.
3. Since our last site visit on March 30, 2015 according to public weather station data approximately 10 mm of rain has fallen primarily focussed on March 31. This represents approximately 10% of the total recorded rainfall for the past 30 days.
4. The sinkhole located at the edge of the curb and driveway in front of Lot 9 (6660 Gale Avenue North) appears relatively unchanged since last inspection as shown in Photos 2 and 4. The extents of the area showing differential settlement are approximately 4.5 by 4.5 m (excluding area below paved surfaces). Sinkhole has undermined Gale Avenue North at least 1 m horizontally from curb. Total settlement may be up to 230 mm. The small tree on the edge of the settled area is leaning towards the sinkhole at approximately 15 degrees from vertical (Photo 3). Corner of undermined concrete driveway has cracked. No visually apparent changes to Lot 9 structure as viewed from Statutory Right of Ways.



Photo 1. Closed section of Gale Avenue North



Photo 2. Undermined Gale Ave N. at Lot 9 (Lot 21 behind)

5. Sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) was backfilled with granular material and covered with polyethylene sheeting as described in our report dated March 9, 2015. No visually apparent settlement of backfill (Photo 5). The stairs on the edge of the sinkhole have apparently not moved towards the sinkhole since March 30.
6. Flow from the storm outfall below the SRW between Lots 9 and 10 appears relatively clear. Outlet is partly infilled (about 25%) by deposited fine sand and silt. Slightly increased amount of infill since March 30 may have been a result of deposition of the infill during reduced flows.



Photo 3. Rotated tree at Lot 9 sinkhole



Photo 4. Lot 9 undermined driveway



Photo 5. Backfilled sinkhole at Lot 21



Photo 6. Drain outlet below Lot 3.

7. Seepage continues from multiple springs on the slope in Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench. The springs coalesce on the lower SRW bench where they appear to be collected into a French drain which discharges below the bench. Discharge from the drain appears clear and flow rate is similar to that measured during March 4 inspection (Photo 6). On Lot 2, the dwelling bench and the slope below it are also wet with minor springs but runoff currently does not reach the SRW below (sand deposits on SRW bench indicate seepage has reached the SRW in the past).

8. On Lot 1 the water in the collection ponds is 0.25 m deep on the dwelling bench, 0.25 m deep on the SRW bench, and dry in the pond just below the SRW. Drain outlets from the ponds are collected and discharged at the storm outfall north of Lot 1. The beach access path east of Lot 1 is wet and muddy with minor seepage springs.

9. No visually apparent changes to slight depression in Seawatch Lane at Lot 28 (Photo 7). Asphalt is depressed on the order of 25 mm over an area approximately 2 m by 2 m in plan. No visually apparent changes to minor transverse cracking noted in asphalt in area of 2012 sinkhole repair. Surface runoff from un-vegetated area to south of Lots 26 – 28 is flowing onto Seawatch Lane and is being directed into storm water catch basin at Seawatch & Crowston (Photo 8).

10. The borrow area situated upslope of site as described in our March 9, 2015 report was visually inspected. Seepage continues from the south pit wall and appeared to be accumulating (ponding) as shown in Photo 9. No visually apparent changes to the extents of the pond since March 30.

11. Water flow in the east and west Crowston Road ditches (south of Seawatch Lane) was partially reduced compared to levels observed on March 30. The flow in the east ditch infiltrates/disappears somewhere downhill of the culvert adjacent the borrow area access and the flow does not reach the culvert which directs the east ditch flow into the west ditch. Flow in the west ditch reaches the storm water inlet at the intersection of Seawatch Lane and Crowston Road (Photo 10). Flow depth at inlet lip is approximately 10 mm, thus inflow has apparently decreased significantly since March 30.



Photo 7. Seawatch Lane depressed area marked



Photo 8. Runoff onto Seawatch Lane (into gutter)



Photo 9. Ponded water at borrow area.



Photo 10. Crowston Road west ditch, inlet at Seawatch Lane

12. Wet areas on Lot 14 (6885 Gale Ave N.) and Lot 13 (6889 Gale Ave N.) were first visually inspected and described in our report dated March 23, 2015. The ground surface on the wider benches which form the backyards was observed to be saturated with minor ponded water near the toe of the walls (Photo 11). The yards are well grassed and the walls did not show signs of distress however erosion of the backfill through the cracks in the rocks with deposition below the wall was evident in several locations (Photo 12). Further back in the lots, beyond the landscaped yards the ground surface is sloping and wet with minor silty spring seepage evident from multiple points (Photo 13 and 14). Part of the runoff was found to originate near the top of the gulley west of Lot 15 just below the curve in Seawatch Lane. Ground surface in the gulley is muddy and soft with growth of hydrophilic plants (ie: skunk cabbage). Despite the relatively dry weather since March 30 the wet areas observed in Lots 13, 14, and 15 do not appear to have changed.

13. Below (north of) Lot 13 a drain pipe exits the slope below the rock-stack wall and discharges into a clarification pond which is in turn drained and discharges at the storm outfall below Lot 12 and the SRW. Water discharging from the drain currently appears to be relatively clear. The clarification pond is nearly full of sand and silt and very little storage capacity remains to promote clarification (Photo 15). Part of the flow discharging from the drain is seeping through the downslope berm, which forms the pond, and towards Sechelt Band Lands – runoff is relatively clear. Outflow from the storm outfall below Lot 12/SRW is relatively clear with some fine sand bed-load transport evident but with a lower rate of flow than at outfalls below Lots 9/10 and Lot 1 (Photo 16).

14. The owner of Lot 27, Mr. Mike Paddison, suggested the drainage cleanouts below the rock stack walls across the development site should be checked and cleaned out as required. Specifically Mr. Paddison pointed out the drain cleanout below Lot 18 (undeveloped) is presently full of sand and silt and the covering cap cracked.



Photo 11. Wet area below wall, Lot 14



Photo 12. Deposition of eroded backfill, Lot 14



Photo 13. Seepage from slope, Lot 13



Photo 14. Wet areas, Lot 14



Photo 15. Silt filled pond below Lot 13



Photo 16. Storm outfall below Lot 12

15. Recorded depth to groundwater in monitoring wells are summarized below. Well depth were measured on March 4 and are given in brackets.

Test Hole No.	Mar. 4, 2015	Mar. 16, 2015	Mar. 23, 2015	Mar. 30, 2015	Apr. 6, 2015
BH12-01	5.23 (7.0)	5.23	5.23	5.21	5.21
BH12-02	3.13 (6.2)	3.06	3.01	2.99	3.07
BH12-03	2.22 (5.8)	2.27	2.24	2.26	2.28
BH12-05	8.05 (12.1)	8.25	8.15	8.02	7.90
BH12-06	7.83 (11.3)*	7.83*	7.84*	7.84*	7.84*
BH12-07	4.93 (6.55)	4.90	4.85	4.83	4.85
BH12-08	10.92 (14.1)	10.92	10.90	10.85	10.83
BH12-09	16.83 (19.6)	16.83	16.83	16.75	16.77
TH13-01	14.38 (14.65)	14.46	14.40	14.33	14.28
TH13-07	4.40 (10.4)	4.42	4.32	4.15	4.14
TH13-08	2.69 (6.05)	2.69	2.72	2.70	2.72
TH13-09 shallow	0.77 (1.23)*	0.64*	0.46*	0.47*	0.57*
TH13-09 deep	0.82 (2.85)*	0.87*	0.34*	0.42*	0.43*

N/A = not accessible. *Well damaged/cover removed, measured from adjacent ground surface.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

16. As per Items 9 and 10 of our report dated March 4, 2015, groundwater monitoring wells BH12-06 and TH13-09 should be repaired (extended and have new flush mount covers installed) and re-surveyed.
17. Consideration should be given to providing a long term low maintenance solution to address the silt filled clarification pond below Lot 13 (Item 13).
18. Consideration should be given to checking and cleanout of wall drainage systems across the development as per Item 14.
19. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
20. District of Sechelt personnel should continue to inspect the site daily and during periods of precipitation for signs of movement particularly between the two sinkholes.
21. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
22. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
23. Consideration should be given to re-establishing drainage of ponded water in the borrow area to the south of the development as described in Item 10.
24. To further limit infiltration of groundwater from the Crowston Road ditch, consideration should also be given to lining the ditch or to extending the Crowston Road storm sewer further south.
25. We recommend that the piezometers be monitored at least every other week and after periods of intense rainfall. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. Thurber can provide this service if required.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: David Tara, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-009

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: April 13 to 17, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Drilling investigation and groundwater level monitoring

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	District of Sechelt personnel	From 07h00 to 17h00 (generally) WEATHER: Mixed

ACTIVITIES/OBSERVATIONS:

1. Two sinkholes that have previously developed on Lots 9 and 21 were first described in our report February 27, 2015.
2. A limited scope drilling investigation was completed under Thurber's supervision between April 13 and 17 in the areas surrounding the recent sinkholes. A new groundwater monitoring well (TH15-03) was installed on Gale Avenue North adjacent to Lot 10 (Photo 2).
3. Gale Avenue North remains closed in front of Lots 9 and 21. No visually apparent settlement or cracking of Gale Avenue North between Lots 9 and 21 was observed.
4. Since our last site visit on April 6 the weather has been relatively dry. An intense but relatively brief precipitation event occurred while at site on April 13.
5. The sinkhole located at the edge of the curb and driveway in front of Lot 9 (6660 Gale Avenue North) appears relatively unchanged since last inspection. No visually apparent changes to the Lot 9 structure as viewed from Statutory Right of Ways.
6. Sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) was backfilled with granular material and partially covered with polyethylene sheeting as described in our report dated March 9, 2015. No visually apparent settlement of backfill (Photo 5). The stairs on the edge of the sinkhole have apparently not moved significantly towards the sinkhole since March 30.
7. Flow from the storm outfall below the SRW between Lots 9 and 10 appeared relatively clear on April 13, somewhat silty on April 14 and progressively clearer later in the week. The outlet is partly infilled (about 25%) by deposited fine sand and silt. Slightly increased sediment load on April 14 may have been influenced by drilling operations or the storm event on April 13 (Photo 6).
8. No visually apparent changes to slight depression in Seawatch Lane at Lot 28 (Photo 5). Asphalt is depressed on the order of 25 mm over an area approximately 2 m by 2 m in plan. No visually apparent changes to minor transverse cracking noted in asphalt in area of 2012 sinkhole repair. Surface runoff from un-vegetated area to south of Lots 26 – 28 is flowing onto Seawatch Lane and is being directed into storm water catch basin at Seawatch & Crowston.



Photo 1. Drilling of TH15-01 adjacent Lot 9 sinkhole

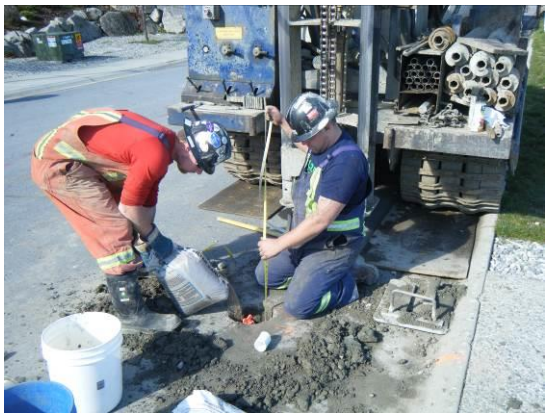


Photo 2. Installation of monitoring well TH15-03

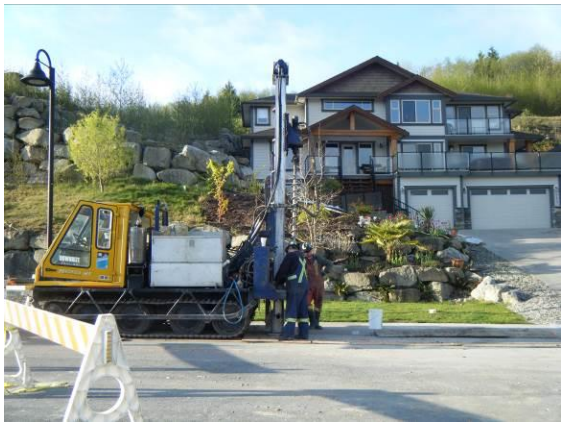


Photo 3. Drilling of TH15-10 adjacent Lot 21



Photo 4. Drilling of TH15-23 at Lot 21 sinkhole



Photo 5. Drilling of TH15-24 in Lot 28



Photo 6. Storm outfall at Lots 9/10 on April 15, 2015

9. Recorded depth to groundwater in monitoring wells are summarized below. Well depths are given in brackets when measured.

Test Hole No.	Apr. 6, 2015	Apr. 13, 2015	Apr. 14, 2014	Apr. 15, 2015	Apr. 17, 2015
BH12-01	5.21	5.23	N/M	N/M	N/M
BH12-02	3.07	3.09	N/M	N/M	N/M
BH12-03	2.28	2.27	N/M	N/M	N/M
BH12-05	7.90	7.99	N/M	N/M	8.07
BH12-06	7.84*	7.84*	7.85 **	7.86	7.87
BH12-07	4.85	4.87	N/M	N/M	N/M
BH12-08	10.83	10.84	N/M	N/M	N/M
BH12-09	16.77	16.71	N/M	N/M	N/M
TH13-01	14.28	14.21	N/M	N/M	N/M
TH13-07	4.14	4.25	N/M	N/M	N/M
TH13-08	2.72	2.70	N/M	N/M	N/M
TH13-09 shallow	0.57*	0.73*	N/M	N/M	N/M
TH13-09 deep	0.43*	0.48*	N/M	N/M	N/M
TH15-03 (installed Apr. 14)	-	-	7.38 (9.13)	7.39	7.38

N/M = not measured. *Well damaged/cover removed, measured from adjacent ground surface.

** Well cover replaced/repaired.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

10. The results and interpretation of the drilling investigation (Item 2) will be presented in a forthcoming report.
11. As per Items 9 and 10 of our report dated March 4, 2015, groundwater monitoring wells BH12-06 and TH13-09 were repaired.
12. The repaired groundwater monitoring well covers and recent test hole locations are scheduled to be surveyed in the week of April 27.
13. Consideration should be given to installing additional poly sheeting at the backfilled Lot 21 sinkhole to better direct surface runoff away from the area.
14. Consideration should be given to providing a long term low maintenance solution to address the silt filled clarification pond below Lot 13.
15. Consideration should be given to checking and cleanout of wall drainage systems across the development.
16. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
17. District of Sechelt personnel should continue to inspect the site daily and during periods of precipitation for signs of movement particularly between the two sinkholes.
18. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
19. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
20. Consideration should be given to re-establishing drainage of ponded water in the borrow area to the south of the development as described in Item 10.
21. To further limit infiltration of groundwater from the Crowston Road ditch, consideration should also be given to lining the ditch or to extending the Crowston Road storm sewer further south.
22. We recommend that the piezometers be monitored at least every other week and after periods of intense rainfall. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. Thurber can provide this service if required.
23. The next site visit is scheduled for the week of April 27, 2015.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: David Tara, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-010

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: April 27, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of sinkholes, site status, surface surveying and groundwater levels.

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	Strait Land Surveying Crew	From 11h00 to 15h30 WEATHER: Heavy rain to overcast

ACTIVITIES/OBSERVATIONS:

1. Two sinkholes that have previously developed on Lots 9 and 21 were first described in our report February 27, 2015.
2. A limited scope drilling investigation was completed under Thurber's supervision between April 13 and 17 in the areas surrounding the recent sinkholes. A new groundwater monitoring well (TH15-03) was installed on Gale Avenue North adjacent to Lot 10.
3. A Strait Land Surveying crew was on site after 12h00 to survey the locations of the recent test holes and other features of note as directed by Thurber (Photo 1). The remainder of the survey work will be completed at the earliest availability of the surveyors.
4. Gale Avenue North remains closed in front of Lots 9 and 21 (Photo 2). No visually apparent settlement or cracking of Gale Avenue North between Lots 9 and 21 was observed. Cracks are present in the driveways of Lots 9 and 21 (Photo 3) whereas they are not apparent in the driveways of Lots 8, 10, and 20 (Photo 4).
5. Since our last site visit on April 17 there have been several precipitation events. Updated public weather station data from Sechelt is not presently available however the total precipitation in Gibsons since April 17 was approximately 29 mm with the most intense event on April 23.
6. The sinkhole located at the edge of the curb and driveway in front of Lot 9 (6660 Gale Avenue North) appears relatively unchanged since last inspection (Photo 1). No visually apparent changes to the Lot 9 structure as viewed from Statutory Right of Ways.
7. Sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) was backfilled with granular material and partially covered with polyethylene sheeting as described in our report dated March 9, 2015. No visually apparent settlement of backfill. The stairs on the edge of the sinkhole have apparently moved towards the sinkhole approximately 1 cm since April 13 (Photo 5).
8. Flow from the storm outfall below the SRW between Lots 9 and 10 appeared relatively clear (Photo 6). The outlet is partly infilled (about 25%) by deposited fine sand and silt.
9. No visually apparent changes to slight depression in Seawatch Lane at Lot 28 (Photo 7). Asphalt is depressed on the order of 25 mm over an area approximately 2 m by 2 m in plan. No visually apparent changes to minor transverse cracking noted in asphalt in area of 2012 sinkhole repair. Adjacent to Lot 27 the asphalt has cracked parallel to the curb (Photo 8). One of the residents also pointed out that it appeared there may be some minor differential settlement between the asphalt lane and the south concrete curb/gutter adjacent to Lots 26 and 27 (Photo 9). Survey crew completed a baseline grid survey of the lane adjacent Lot 28 to facilitate monitoring of surface deformations.
10. Based on a discussion with the residents of Lots 26 and 27, the drainage of the south side of Seawatch Lane has a complex history. An unlined shallow drainage ditch was apparently present for some time which directed runoff from the lands to the south of Seawatch Lane eastward towards Crowston Road. During peak rainfall events this ditch apparently passed significant flows. In November 2014 a depression formed in the ditch on the order of 0.3 m deep and 4 m long which appeared to undermine the curb adjacent Lot 29 and the 2012 sinkhole repair. It is unclear if the depression was formed by settlement or erosion during peak flows in the ditch (possibly

eroding the 2012 sinkhole backfill).The depression and undermining were apparently initially repaired with concrete. When this repair appeared to settle the ditch was backfilled adjacent Lots 27 and 28 and re-graded to form a sloping berm to direct runoff into the curb gutter. According to the residents an un-lined French drain may have been installed in the ditch prior to backfilling. An un-lined drainage ditch remains south of Seawatch Lane adjacent to Lots 24 and 25 and 26. The ditch is larger and has been filled with gravel adjacent Lots 24 and 25 and a storm grate installed adjacent Lot 25. The storm grate appears to have been installed too high to capture all of the flow through the ditch (Photo 10 from March 23). Flow that is not captured by the storm grate flows through the ditch adjacent Lot 26 and into the gutter and/or into the French drain.

11. Seepage continues from multiple springs on the slope in Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench. The springs coalesce on the lower SRW bench where they appear to be collected into a French drain which discharges below the bench. Discharge from the drain appears clear and the flow rate is similar to that measured during March 4 inspection. On Lot 2, the dwelling bench and the slope below it are also wet with minor springs but runoff currently does not reach the SRW below (sand deposits on SRW bench indicate seepage has reached the SRW in the past).
12. On Lot 1 the water in the collection ponds is lower than on April 13, and dry in the pond just below the SRW. Drain outlets from the ponds are collected and discharged at the storm outfall north of Lot 1. The beach access path east of Lot 1 is wet and muddy with minor seepage springs.
13. Wet areas on Lot 14 (6885 Gale Ave N.) and Lot 13 (6889 Gale Ave N.) were first visually inspected and described in our report dated March 23, 2015. The extents of the wet areas observed in Lots 13, 14 and 15 do not appear to have changed. Survey of the wet areas will be completed as soon as possible by Strait Land Surveying.
14. The borrow area situated upslope of site as described in our March 9, 2015 report was visually inspected. Seepage from the south pit wall was obscured by surface runoff flows which were entering the pit from the south and west. Water appeared to be accumulating (ponding) as shown in Photo 11. No visually apparent changes to the extents of the pond since April 6.
15. Water flow in the east and west Crowston Road ditches (south of Seawatch Lane) was partially increased compared to levels observed on April 6. The flow in the east ditch infiltrates/disappears somewhere downhill of the culvert adjacent the borrow area access and the flow does not reach the culvert which directs the east ditch flow into the west ditch. Flow in the west ditch reaches the storm water inlet at the intersection of Seawatch Lane and Crowston Road. Flow depth at inlet lip is approximately 25 mm, thus surface inflow has apparently increased since April 6 (Photo 12).



Photo 1. Surveying and sinkhole adjacent Lot 9



Photo 2. Closed section of Gale Ave N



Photo 3. Cracks in the Lot 9 driveway



Photo 4. Absence of cracks in the Lot 10 driveway



Photo 5. Stairs and backfilled Lot 21 sinkhole



Photo 6. Storm outfall below Lots 9/10



Photo 7. Seawatch Lane near Lot 28 depressed area



Photo 8. Seawatch Lane cracking parallel to curb



Photo 9. Possible settlement of gutter



Photo 10. Storm grate adjacent Lot 25 (March 23)



Photo 11. Ponded water at borrow area to south



Photo 12. Storm inlet at Crowston Road west ditch

16. Recorded depth to groundwater in monitoring wells are summarized below. Well depths are given in brackets when measured.

Test Hole No.	Apr. 13, 2015	Apr. 14, 2014	Apr. 15, 2015	Apr. 17, 2015	Apr. 27, 2015
BH12-01	5.23	N/M	N/M	N/M	5.24
BH12-02	3.09	N/M	N/M	N/M	3.05
BH12-03	2.27	N/M	N/M	N/M	2.25
BH12-05	7.99	N/M	N/M	8.07	8.20
BH12-06	7.84*	7.85 **	7.86	7.87	7.87
BH12-07	4.87	N/M	N/M	N/M	4.87
BH12-08	10.84	N/M	N/M	N/M	10.90
BH12-09	16.71	N/M	N/M	N/M	16.78
TH13-01	14.21	N/M	N/M	N/M	14.31
TH13-07	4.25	N/M	N/M	N/M	4.39
TH13-08	2.70	N/M	N/M	N/M	2.69
TH13-09 shallow	0.73*	N/M	N/M	N/M	**0.73 (1.37)
TH13-09 deep	0.48*	N/M	N/M	N/M	**0.76 (3.04)
TH15-03 (installed Apr. 14)	-	7.38 (9.13)	7.39	7.38	7.39

N/M = not measured. *Well damaged/cover removed, measured from adjacent ground surface.

** Well cover replaced/repaired.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

17. The results and interpretation of the drilling investigation (Item 2) will be presented in a forthcoming report.
18. As per Items 9 and 10 of our report dated March 4, 2015, the repaired groundwater monitoring wells BH12-06 and TH13-09 were surveyed.
19. Survey of features of note will be completed as soon as possible by Strait Land Surveying.
20. Consideration should be given to installing additional poly sheeting at the backfilled Lot 21 sinkhole to better direct surface runoff away from the area.
21. Consideration should be given to providing a long term low maintenance solution to address the silt filled clarification pond below Lot 13.
22. Consideration should be given to checking and cleanout of wall drainage systems across the development.
23. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
24. District of Sechelt personnel should continue to inspect the site daily and during periods of precipitation for signs of movement particularly between the two sinkholes.
25. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
26. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
27. Consideration should be given to re-establishing drainage of ponded water in the borrow area to the south of the development.
28. To further limit infiltration of groundwater from the Crowston Road ditch, consideration should also be given to lining the ditch or to extending the Crowston Road storm sewer further south.
29. To further limit infiltration of surface water, consideration should also be given to lining the ditch south of Seawatch Lane along its full length as described in Item 10. .
30. We recommend that the piezometers be monitored at least every other week and after periods of intense rainfall. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. Thurber can provide this service if required.
31. The next site visit is scheduled for the week of May 4, 2015.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: David Tara, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-011

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: May 04, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Visual assessment of sinkholes, site status and groundwater levels.

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS)	Sanath Bandara (District of Sechelt) Serge Fjetland (District of Sechelt) Public Works Crew, D. of Sechelt.	From 11h00 to 14h45 WEATHER: Partly cloudy, dry.

BACKGROUND

1. Two sinkholes that have previously developed on Lots 9 and 21 were first described in our report dated February 27, 2015.
2. A limited scope drilling investigation was completed under Thurber's supervision between April 13 and 17 in the areas surrounding the recent sinkholes. A new groundwater monitoring well (TH15-03) was installed on Gale Avenue North adjacent to Lot 10.
3. A Strait Land Surveying crew was on site on April 27, 2015 to survey the locations of the recent test holes and other features of note as directed by Thurber. Survey included a baseline grid survey of the lane adjacent Lot 28 to facilitate monitoring of surface deformations. The remainder of the survey work will be completed at the earliest availability of the surveyors.

ACTIVITIES/OBSERVATIONS:

4. District of Sechelt personnel were on site to conduct their regular inspections. Thurber's inspection was completed in conjunction with Mr. Serge Fjetland (District of Sechelt, Engineering Technologist) to coordinate inspection efforts and focus and to provide water level measurement training.
5. Gale Avenue North remains closed in front of Lots 9 and 21 (Photo 1). No visually apparent settlement or cracking of Gale Avenue North between Lots 9 and 21 was observed.
6. Since our last site visit on April 27 the weather has been relatively dry. Updated public weather station data from Sechelt is not presently available however the total precipitation in Gibsons since April 27 was about 5 mm.
7. The sinkhole located at the edge of the curb and driveway in front of Lot 9 (6660 Gale Avenue North) appears relatively unchanged since last inspection (Photo 2). No visually apparent changes to the Lot 9 structure as viewed from Statutory Right of Ways.
8. Sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) was backfilled with granular material and partially covered with polyethylene sheeting as described in our report dated March 9, 2015. The polyethylene coverage has been improved (Photo 3) as per our report dated April 27, Item 20. No visually apparent settlement of backfill was observed. The stairs on the edge of the sinkhole have apparently not moved substantially since April 27 (Photo 4).
9. Flow from the storm outfall below the SRW between Lots 9 and 10 appeared relatively clear (Photo 5). The outlet is partly infilled by deposited fine sand and silt. We understand the District has begun periodically sampling and testing the turbidity (soil content) of the water at the outfall.
10. No visually apparent changes to slight depression in Seawatch Lane at Lot 28 (Photo 6). Asphalt is depressed on the order of 25 mm over an area approximately 2 m by 2 m in plan. No visually apparent changes to minor transverse cracking noted in asphalt in area of 2012 sinkhole repair. No visually apparent changes to the curb and asphalt cracks adjacent to Lot 27. The curb gutters, berms, and ditches on the south side of Seawatch Lane were dry.

11. Seepage continues from multiple springs on the slope on Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench. The springs coalesce on the lower SRW bench where they appear to be collected into a French drain which discharges below the bench. Discharge from the drain appears clear (Photo 7). A slow seep/spring continues on Lot 2 at the dwelling bench, including a sand boil about 100 mm in diameter (Photo 8). Flow from the springs on Lots 2 and 3 is relatively clear. The manhole covers for the Lot 3 spring seepage collection works were lifted - captured flow from the springs was relatively clear.

12. On Lot 1 the collection ponds were dry except for the pond on the SRW bench in which there was water about 80 mm in depth. The PVC drain at the storm outfall north and east of Lot 1 continues to discharge (Photo 9) – it is unclear where this drain/flow originates (flow is relatively clear). The beach access path east of Lot 1 continues to be wet and muddy despite the dry weather which suggests there may be a diffuse groundwater spring in this area.

13. Water levels in the ponds on Lot 12 were about 0.4 m deep on the dwelling bench and about 0.3 m deep in the pond below the bench. The slow seep/spring on Lot 12 remains wet but with no visible/substantial flow (Photo 10). Shallow (<10 mm deep) ponded water remains on the SRW bench below Lot 12 (elsewhere the bench was generally dry) in an area about 2 by 2 m in plan. Discharge from the storm outfall north and west of Lot 12 is a slow trickle.

14. Drain discharge continues into the clarification pond north of Lot 13 which is in turn drained and discharges at the storm outfall below Lot 12 and the SRW. Water discharging from the drain currently appears to be relatively clear. The clarification pond is nearly full of sand and silt and very little storage capacity remains to promote clarification.

15. Wet areas on Lot 14 (6885 Gale Ave N.) and Lot 13 (6889 Gale Ave N.) were first visually inspected and described in our report dated March 23, 2015. The extents of the wet areas observed in Lots 13, 14 and 15 appear to have reduced somewhat since April 27. The developed portion of the backyards on Lots 13 and 14 are now dry except a muddy area about 2 by 2 m in plan at the toe of the rock stack wall on Lot 14 near the west end (Photo 11). Wet areas and apparent springs/seeps in the undeveloped portion of the backyards on Lots 13, 14, and 15 remain active but with relatively clear flow. Survey of the wet areas will be completed as soon as possible by Strait Land Surveying.

16. The borrow area situated upslope of site as described in our March 9, 2015 report was visually inspected. Seepage from the south pit wall appears to have dissipated and surface runoff flows which enter the pit from the south and west appear to have reduced. Water appeared to be accumulating (ponding) as shown in Photo 12. No visually apparent changes to the extents of the pond since April 27.

17. Water flow in the east and west Crowston Road ditches (south of Seawatch Lane) had decreased compared to levels observed on April 27. The flow in the east ditch infiltrates/disappears somewhere downhill of the culvert adjacent the borrow area access and the flow does not reach the culvert which directs the east ditch flow into the west ditch. Flow in the west ditch now also infiltrates/disappears before it reaches the storm water inlet at the intersection of Seawatch Lane and Crowston Road (Photo 13). Flow depth at the storm inlet lip is now 0 mm, thus surface inflow has apparently decreased since April 27 (Photo 14). We understand the surface flow entering the storm inlet in the west ditch apparently stopped at some point between April 27 and May 1 when District personnel first observed the inlet to be dry. Discharge at the storm outfall north and east of Lot 1 has reduced but continues to flow (Photo 9); flow is relatively clear.



Photo 1. Closed section of Gale Ave N



Photo 2. Sinkhole adjacent Lot 9



Photo 3. Backfilled Lot 21 sinkhole



Photo 4. Stairs and backfilled Lot 21 sinkhole



Photo 5. Storm outfall below Lots 9 and 10



Photo 6. Seawatch Lane near Lot 28 depressed area



Photo 7. Drain below SRW bench at Lot 3



Photo 8. Spring on Lot 2, Sand Boil Circled (silty because disturbed)



Photo 9. Storm and drain outfall NE of Lot 1



Photo 10. Slow spring/seep on Lot 12



Photo 11. Wet area on Lot 14



Photo 12. Ponded water at borrow area to south



Photo 13. Dry Crowston Rd West Ditch



Photo 14. Crowston Rd Storm Inlet

18. Recorded depths to groundwater in monitoring wells are summarized below. Well depths are given in brackets when measured. Water levels are relatively stable or dropping consistent with the dry weather.

Test Hole No.	Apr. 13, 2015	Apr. 14, 2014	Apr. 17, 2015	Apr. 27, 2015	May 4, 2015
BH12-01	5.23	N/M	N/M	5.24	5.22
BH12-02	3.09	N/M	N/M	3.05	3.13
BH12-03	2.27	N/M	N/M	2.25	2.24
BH12-05	7.99	N/M	8.07	8.20	8.19
BH12-06	7.84*	7.85 **	7.87	7.87	7.87
BH12-07	4.87	N/M	N/M	4.87	4.89
BH12-08	10.84	N/M	N/M	10.90	10.91
BH12-09	16.71	N/M	N/M	16.78	16.80
TH13-01	14.21	N/M	N/M	14.31	14.34
TH13-07	4.25	N/M	N/M	4.39	4.45
TH13-08	2.70	N/M	N/M	2.69	2.73
TH13-09 shallow	0.73*	N/M	N/M	**0.73 (1.37)	0.87
TH13-09 deep	0.48*	N/M	N/M	**0.76 (3.04)	0.85
TH15-03 (installed Apr. 14)	-	7.38 (9.13)	7.38	7.39	7.38

N/M = not measured. *Well damaged/cover removed, measured from adjacent ground surface.

** Well cover replaced/repaired.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

19. The results and interpretation of the drilling investigation (Item 2) will be presented in a forthcoming report.
20. Survey of features of note will be completed as soon as possible by Strait Land Surveying.
21. Consideration should be given to providing a long term low maintenance solution to address the silt filled clarification pond North of Lot 13.
22. Consideration should be given to checking and cleanout of wall drainage systems across the development.
23. Consideration should be given to re-establishing drainage of ponded water in the borrow area to the south of the development.
24. To further limit infiltration of surface water from the Crowston Road ditch, consideration should also be given to lining the ditch or to extending the Crowston Road storm sewer further south.
25. To further limit infiltration of surface water, consideration should also be given to lining the ditch south of Seawatch Lane along its full length.
26. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
27. District of Sechelt personnel should continue to inspect the site daily and during periods of precipitation for signs of movement particularly between the two sinkholes.
28. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
29. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
30. We recommend that the piezometers be monitored at least every other week during periods of low precipitation and weekly during periods of higher precipitation. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. We understand District of Sechelt personnel will take over routine monitoring of the piezometers and weekly site inspections.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: David Tara, P.Eng.

THURBER ENGINEERING LTD.

Suite 900 – 1281 West Georgia Street
Vancouver, BC V6E 3J7
Phone: (604) 684-4384
Fax: (604) 684-5124

FIELD REVIEW REPORT NO.: 14-214-4-012

THURBER FILE NO.: 14-214-4

FIELD REVIEW REPORT	DATE: May 13, 2015
TO: Lidstone and Company	ATTENTION: Paul Hildebrand EMAIL: hildebrand@lidstone.info

PROJECT NAME: Sinkholes at Lots 9 and 21, The Shores Subdivision Sechelt, BC

CONTRACTOR(S): Concordia Homes Ltd.

PURPOSE OF INSPECTION: Site status, site meeting with District and Urban Systems, meeting with Residents.

REFERENCE DRAWING / DOCUMENTS: See Thurber Engineering Ltd. Report dated April 5, 2013

THURBER PERSONNEL ON SITE:	CLIENT/CONTRATOR PERSONNEL ON SITE:	TIME ON SITE:
Caleb H. Scott (CHS) David J. Tara (DJT)	Sanath Bandara (District of Sechelt) Serge Fjetland (District of Sechelt) Glen Shkurhan (Urban Systems Ltd) Jayson Vadasz (Urban Systems Ltd)	From 08h45 to 13h45 WEATHER: Overcast, dry.

BACKGROUND

1. Two sinkholes that have previously developed on Lots 9 and 21 were first described in our report dated February 27, 2015.
2. A limited scope drilling investigation was completed under Thurber's supervision between April 13 and 17 in the areas surrounding the recent sinkholes. A new groundwater monitoring well (TH15-03) was installed on Gale Avenue North adjacent to Lot 10.
3. A Strait Land Surveying crew was on site on April 27, 2015 to survey the locations of the recent test holes and other features of note as directed by Thurber. Survey included a baseline grid survey of the lane adjacent Lot 28 to facilitate monitoring of surface deformations. The remainder of the survey work was completed on May 7 and 8.
4. The District of Sechelt has taken on routine weekly inspections and groundwater level monitoring at the site using a customized checklist developed by Thurber. The results of the District's inspections should be forwarded for review by Thurber.

ACTIVITIES/OBSERVATIONS:

5. Thurber's inspection was completed in conjunction with District of Sechelt personnel and representatives from Urban Systems Ltd. (Urban).
6. Gale Avenue North remains closed in front of Lots 9 and 21. No visually apparent settlement or cracking of Gale Avenue North between Lots 9 and 21 was observed.
7. Since our last site visit on May 4 the weather has been relatively dry. Public weather station data from Sechelt reports the total precipitation since May 4 was about 4.5 mm, concentrated in one event on May 5.
8. The sinkhole located at the edge of the curb and driveway in front of Lot 9 (6660 Gale Avenue North) appears relatively unchanged since last inspection.
9. The sinkhole located in front of the residence on Lot 21 (6657 Gale Avenue North) was backfilled with granular material and partially covered with polyethylene sheeting as described in our report dated March 9, 2015. The polyethylene coverage was improved as noted in our report dated May 4, 2015 however runoff during storm events appears to continue to erode the sand backfill on the edge of the driveway. No visually apparent settlement of backfill was observed.
10. Spider cracking was noted in a concrete driveway panel at Lot 19 (Photo 1), possibly indicating erosion or settlement of the backfill below the slab. Sand deposits on the sidewalk and driveway at Lot 19 were first noted on April 6, 2015, pointed out by Mr. Mike Paddison. According to our recollection of Mr. Paddison's account on April 6, the sand appears to be transported by water flowing out of the joints in the driveway and from the gravel shoulder on the west side of the driveway during heavy rains. No flowing water or sand transport has been observed during Thurber's inspections and no changes were apparent to the sand deposits on the sidewalk/driveway (Photo 2).

11. Flow from the storm outfall below the SRW between Lots 9 and 10 appeared relatively clear. The outlet is partly infilled by deposited fine sand and silt. We understand the District has begun periodically sampling and testing the turbidity (soil content) of the water at the outfall.

12. Additional settlement since our May 4 site visit was noted at the depression in the asphalt of Seawatch Lane adjacent to Lot 28 (Photo 3 – not apparent in photo). Asphalt is depressed on the order of 25 mm over an area approximately 2 m by 2 m in plan. In the centre of this area additional settlement and hair-line cracking in a longitudinal alignment has developed on the order of an additional 25 mm. No visually apparent changes to minor transverse cracking noted in asphalt in the area of the 2012 sinkhole repair. The curb gutters, berms, and ditches on the south side of Seawatch Lane were dry.

13. Seepage continues from multiple springs on the slope on Lot 3 just below the dwelling bench and above the lower statutory right of way (SRW) bench. The springs coalesce on the lower SRW bench where they appear to be collected into a French drain which discharges below the bench.

14. Downslope of the SRW bench at Lot 4, wet areas and slow seeps were noted along with hydrophilic vegetation such as skunk cabbage.

15. A discharging drain pipe was rediscovered below the SRW bench adjacent to Lot 5 (Photo 4). Flow rate was on the order of 5 to 10L/min and the flow was relatively clear. The diameter and configuration of the pipe were similar to the discharging drain pipe observed below the SRW bench at Lot 3. Flow from these pipes may originate in the drainage blankets which may have been installed in the lots above.

16. On Lot 1 the collection ponds were dry. The PVC drain at the storm outfall north and east of Lot 1 continues to discharge relatively clear water. Flow from this drain may originate from the drainage blanket below Lot 1, if present. Discharge from the storm water outfall northeast of Lot 1 has reduced in flow rate and is relatively clear. The beach access path east of Lot 1 continues to be wet and muddy despite the dry weather which suggests there may be a diffuse groundwater spring in this area.

17. Water levels in the ponds on Lot 12 were lower than noted on May 4. The slow seep/spring on Lot 12 remains wet but with no visible/substantial flow. The ponded water on the SRW bench below Lot 12 has dried up. The outlet to the collection pond on Lot 12 is now longer functioning due to erosion on the downstream side. During the wet season water from the pond may flow overland towards the rock stack retaining wall at the north end of the lot.

18. Drain discharge continues into the clarification pond north of Lot 13 which is in turn drained and discharges at the storm outfall below Lot 12 and the SRW.

19. Wet areas on Lot 14 (6885 Gale Ave N.) and Lot 13 (6889 Gale Ave N.) were first visually inspected and described in our report dated March 23, 2015. The extents of the wet areas observed in Lots 13, 14 and 15 appeared to be similar to May 4. The developed portion of the backyards on Lots 13 and 14 are now dry except a muddy area about 2 by 2 m in plan at the toe of the rock stack wall on Lot 14 near the west end (Photo 11). Wet areas and apparent springs/seeps in the undeveloped portion of the backyards on Lots 13, 14, and 15 remain active but with relatively clear flow. Survey of the wet areas was completed by Strait Land Surveying on May 7th/8th.

20. The borrow area situated upslope of site as described in our March 9, 2015 report was visually inspected. Seepage from the south and west pit walls appears to have dissipated, although the walls remain wet (Photo 5). Surface runoff flows which enter the pit from the south and west appeared to be similar to May 4. The water level of the pond appeared to have dropped on the order of 0.3 m since May 4 (Photo 6).

21. Water flow in the west Crowston Road ditch (south of Seawatch Lane) had decreased compared to levels observed on May 4. The flow in the east ditch has dried up as far as the borrow access road. Flow in the west ditch infiltrates/disappears before it reaches the storm water inlet at the intersection of Seawatch Lane and Crowston Road.

22. At 12:00 PM the above listed representatives from the District, Urban, and Thurber met with Residents as scheduled on Gale Avenue North in front of Lot 21 (Photo 7). The purpose of the meeting was to discuss the results of the recent drilling investigation and to answer any questions regarding their interpretation. In addition to this discussion the following concerns/questions were raised by the Residents:

    a. The residents would like to see a clear strategic plan and timeline for further investigations, reports and repairs.

    b. The residents would like to understand what criteria would be used to assess the viability of the site as a whole and would like to be involved in that discussion should it occur.

    c. The residents would like to see mitigating repairs begin as soon as possible where appropriate.

    d. The residents would like any further investigations to proceed as soon as possible.

    e. The residents would like to know if further investigation and repairs are being delayed due to concerns regarding who will ultimately pay for the work.

    f. Thurber and Urban advised that additional information and analysis is required before design of the replacement of the storm line between Lots 9 and 10 can proceed.

    g. The residents would like an assessment of the drainage systems in the rock stack retaining walls at site to be included in a comprehensive investigation of the site.

    h. Given that Gale Ave North remains closed and a depression is developing in the asphalt on Seawatch Lane, the residents would like to know how the District plans to maintain access to their homes.

    i. The residents had difficulty understanding and interpreting the draft results of the recent drilling investigation. However they would like to continue to receive updated results, interpretations and reports as they become available.



Photo 1. Cracks in driveway at Lot 19



Photo 2. Sand deposits on sidewalk/driveway at Lot 19



Photo 3. Depressed asphalt on Seawatch Lane at Lot 29



Photo 4. Drain pipe below SRW at Lot 5



Photo 5. Borrow pit wall is wet



Photo 6. Borrow area pond, water level dropped



Photo 7. Meeting with Residents

INSTRUCTIONS / RECOMMENDATIONS / REMARKS

23. Thurber will assist the District in any way possible to address the concerns raised by the residents in Item 22.
24. The results and interpretation of the drilling investigation (Item 2) will be presented in a forthcoming report.
25. Consideration should be given to repairing the collection pond on Lot 12 to direct water away from the retaining wall below.
26. Consideration should be given to the placement of additional polyethylene sheeting at Lot 21 to direct runoff from the backfilled sinkhole into the gravel driveway shoulder to mitigate erosion.
27. Consideration should be given to the installation of wind resistant barricades at the Gale Avenue North road closure.
28. The drain pipe below Lot 5 should be surveyed at the next opportunity.
29. Consideration should be given to providing a long term low maintenance solution to address the silt filled clarification pond north of Lot 13.
30. Consideration should be given to re-establishing drainage of ponded water in the borrow area to the south of the development.
31. Gale Avenue North should remain closed between the two sinkholes and to at least 10 m to either side until further notice.
32. District of Sechelt personnel should continue to regularly inspect the site and during periods of precipitation for signs of movement particularly between the two sinkholes.
33. District of Sechelt should develop an emergency response plan to deal with utilities (gas, water, sewer, electrical, etc.) in Gale Avenue North should the road collapse.
34. Work crews and the public should keep a safe distance (>10 m) from the closed section of road and dwellings on Lots 9 and 21 during and following periods of heavy rainfall.
35. We recommend that the piezometers be monitored at least every other week during periods of low precipitation and weekly during periods of higher precipitation. Further, we recommend that the site be visually inspected for changes or signs of distress at the same time. We understand District of Sechelt personnel has taken on routine monitoring of the piezometers and weekly site inspections.

FURTHER EXAMINATION REQUIRED: ☒ YES ☐ NO ☐ NOT APPLICABLE	REPORT BY: Caleb H. Scott, E.I.T.	REVIEWED BY: David Tara, P.Eng.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: May 26, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber) Recent Rainfall: Dry weather since May 21

Developments since last inspection: Geophysical surveying begins today by DMT Geosciences.

This form should only be used in conjunction with the instructions printed on Page 5. File Version # 2

Item #	Location	Description	Changed?	Comments, description, qualifiers, measurements, photo numbers, etc.
1	Gale Avenue N (closed section)	Status of Road Closure	No	Remains closed. Barriers have been sand bagged for wind stability.
2	Gale Avenue N (closed section)	Cracking/settlement of asphalt/curbs?	No	
3	Gale Avenue N at Lot 9	Cracking/settlement of asphalt/curbs?	No	
4	Sinkhole in front of Lot 9	Settlement, undermining of road/driveway.	Yes	Appears slight increase in separation/undermining between ground and Gale Ave North road structure at south perimeter of apparent sinkhole. Undermining extends horizontally below road to the south about 1 m and to the southwest about 1.5 m.
5	SRW at Lots 9/10 from MH10 to outlet	Any settlement/depressions, springs in storm corridor?	No	
6	Gale Avenue N at Lot 21	Cracking/settlement of asphalt/curbs?	No	
7	Sinkhole at Lot 21	Soil cracking, backfill settlement, poly covering, stair movement?	No	Stair reference measurements were 41 cm and 151 cm. No visually apparent changes.
8	Sinkhole at Lot 21	Condition of driveway and dwelling.	No	
9	Gale Avenue N (east of closed section)	Cracking/settlement of asphalt/curbs?	No	
10	Gale Avenue N (east of closed section)	Seepage/sand deposits from under driveways/roads/structures?	No	
11	Rock Stack Walls at Lots 19-21	Signs of instability, distress	No	
12	Gale Avenue N (west of closed section)	Cracking/settlement of asphalt/curbs?	No	
13	Gale Avenue N (west of closed section)	Seepage/sand deposits from under driveways/roads/structures?	No	
14	Crowston Road (Seawatch to Gale Ave N)	Cracking/settlement of asphalt/curbs?	No	
15	Crowston Road at Lot 29	Storm inlet, any flow? Rate/turbidity?	No	Ditch dry at inlet, no inflow into storm system.
16	Crowston Road ditches at Borrow Access	Flow rate in West/East ditches?	No	East ditch dry from culvert to Borrow access road. West ditch flow on the order of 1L/min at Borrow access, dries up about half way to storm inlet just before the erosion down cutting in the ditch channel.
17	Borrow area south of site	Ponding, seepage and runoff on walls, instabilities?	Yes	Pond level dropped about 0.15 m since May 13, or about 0.5 m since May 4. South and west pit walls remain wet with minor seepage and wall erosion.
18	Seawatch Lane at Lot 28	Status of Cracking/Depression in asphalt	Yes	Appears slight increase in settlement and cracking in apparent rut in middle of depressed area of asphalt.
19	Seawatch Lane at Lot 28	Survey of control points (if required)	Yes	Grid re-surveyed by Strait Land on May 25 and numbered survey pins installed at about 30% of grid locations to facilitate monitoring by District.
20	Seawatch Lane at Lot 29	Any new erosion, settlement/depressions in curb/ditch?	Yes	Hairline crack in curb to west of current depression in asphalt. Consistent with anecdotal location of 2014 curb repair.
21	Lot 28	Any new erosion/rilling, settlement/depressions, springs?	No	
22	Seawatch Lane at Lots 24 - 27	Cracking/settlement of asphalt/curbs?	No	
23	Seawatch Lane at Lots 15 - 23	Cracking/settlement of asphalt/curbs?	No	
24	Lot 22	Status of apparent scarp at south end of lot	No	
25	Lot 22	Any new erosion/rilling, settlement/depressions, springs?	No	
26	Rock Stack Walls at Lots 22 to 24	Signs of instability, distress	No	
27	Seawatch Ln at cut slope (Sta. 2+20 to 2+60)	Status, signs of instability, major recent erosion?	No	
28	Path east of Lot 1	Wet areas / springs / seeps	No	Extents of wet area unchanged. Muddy despite dry weather.
29	Lot 1 - Collection Ponds	Water levels, turbidity?	No	All dry.

Supplementary comments can be made in the space provided on Pages 3 & 4. Please refer back to the initial item number. New items can also be written in.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: May 26, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Item #	Location	Description	Changed?	Comments, description, qualifiers, measurements, photo numbers, etc.
30	Lot 1	Any new erosion/rilling, settlement/depressions, springs?	No	
31	Storm outfall NE of Lot 1	Turbidity/rate of flow, compared to inflow at Crowston Rd	No	Flow clear with rust coloured deposits on concrete/in pipe. Flow on order of less than 5 L/min.
32	PVC drain at Storm outfall NE of Lot 1	Turbidity / rate of outflow	No	Flow clear with rust coloured deposits on concrete/in pipe. Flow on order of 5 to 10 L/min.
33	Lot 2	Any new erosion/rilling, settlement/depressions, springs?	No	
34	Lot 2	Existing slow spring. Rate/turbidity of flow. Sand boil.	Yes	Spring appears to have stopped. Small puddle remains at source of spring but with no flow and no apparent sand boiling.
35	Lot 3	Any new erosion/rilling, settlement/depressions, springs?	No	
36	Lot 3	Existing spring area. Rate/turbidity of flow. Size of area.	No	Clear flow on order of 20 L/min, extents of wet area unchanged - about 3 m wide where crosses SRW bench.
37	Lot 3 Spring Control Works	Lift MH covers, Rate/turbidity of flow up from sand?	No	Could hear flow entering pipes from surface. Covers not lifted.
38	SRW below Lot 3 and Lot 5	Rate/turbidity of flow from PVC drain on downslope side of bench.	No	Drains discharging below SRW at Lots 3 and 5, flowing clear and both on order of 5 to 10 L/min.
39	Lot 4	Any new erosion/rilling, settlement/depressions, springs?	No	
40	Lot 5	Any new erosion/rilling, settlement/depressions, springs?	No	
41	Lot 6	Any new erosion/rilling, settlement/depressions, springs?	No	
42	SRW below Lots 1 through 6	Erosion, settlement, springs, ponding of water, etc.?	No	
43	SRW below Lots 7 through 12	Erosion, settlement, springs, ponding of water, etc.?	No	
44	Storm outfall below Lots 9/10	Turbidity/rate of flow, infilling of outlet, sample (if req.)	No	Clear flow. No apparent change to outlet infilling.
45	Lot 11	Any new erosion/rilling, settlement/depressions, springs?	No	
46	Lot 12	Any new erosion/rilling, settlement/depressions, springs?	No	
47	Lot 12	Status of slow spring/seep and ponds.	Yes	Apparent springs and ponds have all dried up.
48	Storm outfall below Lot 12	Turbidity/rate of flow, infilling of outlet.	No	Clear flow, on order of 1 to 5 L/min.
49	PVC drain at Storm outfall below Lot 12	Turbidity / rate of outflow	No	Clear flow on order of 5 to 10 L/min.
50	Drains and Collection Pond North of Lot 13	Turbidity / rate of outflow, infilling of pond.	No	Clear flow on order of 5 to 10 L/min. Seepage continues through pond wall onto lands to north.
51	Lot 13	Any new erosion/rilling, settlement/depressions, springs?	No	
52	Lot 13	Status of wet areas	No	Developed portion of backyard now dry. Undeveloped/lower backyard still wet, extents apparently unchanged.
53	Lot 14	Any new erosion/rilling, settlement/depressions, springs?	No	
54	Lot 14	Status of wet areas	No	Developed portion of backyard now dry. Undeveloped/lower backyard still wet, extents apparently unchanged.
55	Lot 15	Any new erosion/rilling, settlement/depressions, springs?	No	
56	Lot 15	Status of wet areas	No	
57	Lots 16 to 18	Any new erosion/rilling, settlement/depressions, springs?	No	Apparent springs continue in undeveloped portion of backyard.
58	Seawatch Lane at Lot 29	Apparent hole in asphalt		Hole was not present during survey on May 25. Hole about 2.5 m from centre of asphalt depression area, about 5 cm diameter, exposing a narrow void below the asphalt extending about 18 cm at a shallow angle (sub-horizontal) towards the south curb.

Supplementary comments can be made in the space provided on Pages 3 & 4. Please refer back to the initial item number. New items can also be written in.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: May 26, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Item #	Date	Location	Description	Changed?	Comments, description, qualifiers, measurements, photo numbers, etc.
59				(Yes / No)	
60					
61					
62					
63					
64					
65					
66					
67					
68					
69					
70					
71					
72					
73					
74					
75					
76					
77					
78					
79					
80					
81					
82					
83					
84					
85					
86					
87					

Supplementary comments can be made in the space provided on Pages 3 & 4. Please refer back to the initial item number. New items can also be written in.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: May 26, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Item #	Date	Location	Description	Changed?	Comments, description, qualifiers, measurements, photo numbers, etc.
88				(Yes / No)	
89					
90					
91					
92					
93					
94					
95					
96					
97					
98					
99					
100					
101					
102					
103					
104					
105					
106					
107					
108					
109					
110					
111					
112					
113					
114					
115					
116					

Supplementary comments can be made in the space provided on Pages 3 & 4. Please refer back to the initial item number. New items can also be written in.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date Range: _____ File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber) on May 26, 2015

This form should only be used in conjunction with the instructions printed on Page 5.

Groundwater Monitoring

Well Name	BH12-01	BH12-02	BH12-03	BH12-05	BH12-06	BH12-07	BH12-08	BH12-09	TH13-01	TH13-07	TH13-08	TH13-09 (Shallow)	TH13-09 (Deep)	TH15-03	
Surface El. (m)	24.83	9.92	9.97	38.6	23.37	26.39	37.69	45.43	46.32	27.8	10.86	7.38	7.38	23.01	
Well Depth (m)	7.0	6.2	5.8	12.1	11.3	6.6	14.1	19.6	14.7	10.4	6.1	1.4	3.0	9.1	
Date Measured	Depth to Groundwater (m) - to nearest centimeter (if well dry, write 'Dry')														**Comments**
i.e.: May 4, 2015	5.22	3.13	2.24	8.19	7.87	4.89	10.91	16.80	14.34	4.45	2.73	0.87	0.85	7.38	
May 14th, 2015	5.25	3.15		8.26	7.92	4.92	10.98		14.41	4.57	2.72	0.97	0.93	7.41	Missed 2 Boreholes, due to lack of map.
May 21st, 2015	5.25	3.22		8.45	7.98	4.93	11.00	16.89	14.49	4.55	2.75	1.00	0.95	7.41	Difficulty locating 12-03
May 26, 2015	5.24	3.16	2.27	8.55	7.92	4.92	11.05	16.93	14.57	4.58	2.73	0.99	0.95	7.39	Readings by Thurber.

Example Comments: Well damaged, water flowing into well from surface, unstable reading, well depth decreased, explanation if not measured, etc.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date Range: _____ File Number: _____ Inspector: _____

This form should only be used in conjunction with the instructions printed on Page 5.

Groundwater Monitoring

Well Name	BH12-01	BH12-02	BH12-03	BH12-05	BH12-06	BH12-07	BH12-08	BH12-09	TH13-01	TH13-07	TH13-08	TH13-09 (Shallow)	TH13-09 (Deep)	TH15-03	
Surface El. (m)	24.83	9.92	9.97	38.6	23.37	26.39	37.69	45.43	46.32	27.8	10.86	7.38	7.38	23.01	
Well Depth (m)	7.0	6.2	5.8	12.1	11.3	6.6	14.1	19.6	14.7	10.4	6.1	1.4	3.0	9.1	
Date Measured	**Depth to Groundwater (m) - to nearest centimeter (if well dry, write 'Dry')**														**Comments**
i.e.: May 4, 2015	5.22	3.13	2.24	8.19	7.87	4.89	10.91	16.80	14.34	4.45	2.73	0.87	0.85	7.38	

Example Comments: Well damaged, water flowing into well from surface, unstable reading, well depth decreased, explanation if not measured, etc.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Instructions for use of this form and additional information.
A copy of these instructions should be available on site during all inspections.

Instructions for Use

1. Inspections and water level measurements should only be performed by experienced personnel authorized by the District of Sechelt.
2. The use of consistent staff is vital to maximizing the potential for perception of changes to the site.
3. The inspector should adhere to all WorkSafe BC regulations. Unbackfilled sinkholes should be treated as open and potentially unstable excavations.
4. If the inspector observes an imminent hazard which they believe to pose an immediate threat to person, property or the environment, the inspector should take immediate steps to protect their own safety and the safety of others and contact the relevant emergency services or utility providers. If the observed hazard is of geotechnical nature, Thurber should be contacted immediately (604-684-4384).
5. Signs of instability should be reported to Thurber within 24 hours of observation. Signs of instability may include but are not limited to the following: ground cracking, signs of ground settlement/displacement, slumping/sloughing, rapid erosion or muddy water seeping from the ground. With regards to retaining walls, signs of instability may include but are not limited to the following: rapid/significant loss of backfill, water seeping out of the wall face, wall face observed to be leaning more than previously, wall observed to be bulging (not straight) more than previously and/or loss of facing boulders.
6. Particular care should be taken during inspections in the winter months when seasonal rainfalls typically increase the hydraulic groundwater gradients which are believed to be related to the formation of sinkholes at this site.
7. Detailed inspections and groundwater monitoring should be completed weekly at minimum during the months of November through June and every two weeks at minimum during the months of July through October.
8. Additional inspections may be required by Thurber or in response to new developments or remedial works.

Instructions for Filing/Distribution

1. Completed inspection forms should be digitized (ideally typed into this template, or at a minimum scanned), with photos and plan markups attached in a timely manner.
2. Completed inspection forms and files should be archived and copied into a field binder for reference during future inspections.
3. Digitized copies of completed inspection forms should be provided to Thurber in a timely manner for interpretation and review.
4. Additional pages or materials may be attached to the back of this form as required. If significant modification of this form is required, please contact Thurber.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: May 26, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Inspection Photographs



Photo File #	9085	**Item #**	18 and 19
Location:	**Seawatch Lane at Lot 29**		
Comment:	**Asphalt Depression & Hole**		



Photo File #	9137	**Item #**	18
Location:	**Seawatch Lane at Lot 29**		
Comment:	**Hole in Asphalt**		



Photo File #	9096	**Item #**	4
Location:	**Apparent sinkhole adjacent Lot 9**		
Comment:			



Photo File #	9103	**Item #**	**7**
Location:	**Backfilled sinkhole at Lot 21**		
Comment:			



Photo File #	9110	**Item #**	54
Location:	**Wet Area at back of Lot 14**		
Comment:	**Rusty deposits in some areas**		



Photo File #	9116	**Item #**	36
Location:	**SRW below Lot 3**		
Comment:	**Tall grass where water flowing.**		



Photo File #	9089	**Item #**	50
Location:	**Drain discharge at pond north of Lot 13**		
Comment:	**Clear Flow**		



Photo File #	9093	**Item #**	**47**
Location:	**Lot 12**		
Comment:	**Ponds dried up**		

Tips: 1) Use the 'right-click, Change Picture' feature in Microsoft Excel for ease and to maintain formatting.
2) Compress photos to 220 dpi for ease of file sharing/storage. [Picture Tools>Format>Compress Pictures> deselect ' Apply only to this photo' and select Print (220 dpi)]

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: May 26, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Inspection Photographs



Photo File #	9117	**Item #**	38
Location:	**SRW below Lot 3**		
Comment:	**Drain discharging clear**		



Photo File #	9121	**Item #**	38
Location:	**SRW below Lot 5**		
Comment:	**Drain discharging clear**		



Photo File #	9118	**Item #**	31
Location:	**Storm outfall NE of Lot 1**		
Comment:	**Clear, low flow with rusty deposits.**		



Photo File #	9119	**Item #**	**32**
Location:	**Storm outfall NE of Lot 1**		
Comment:	**PVC drain flows clear.**		

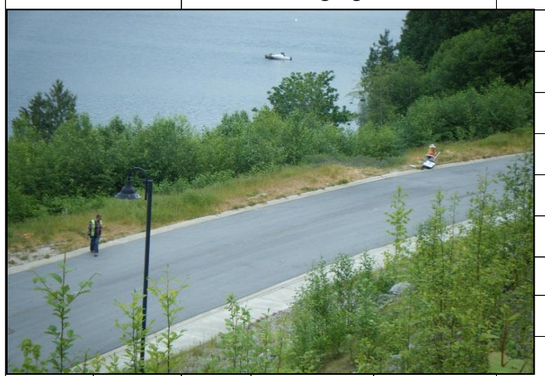


Photo File #	9128	**Item #**	Developments
Location:	**Gale Avenue North**		
Comment:	**Geophysics GPR survey in progress**		



Photo File #	9143	**Item #**	17
Location:	**Borrow Area south of site**		
Comment:	**Pond water level dropping**		



Photo File #	9145	**Item #**	
Location:			
Comment:	**Ground Penetrating Radar (GRP) equipment**		

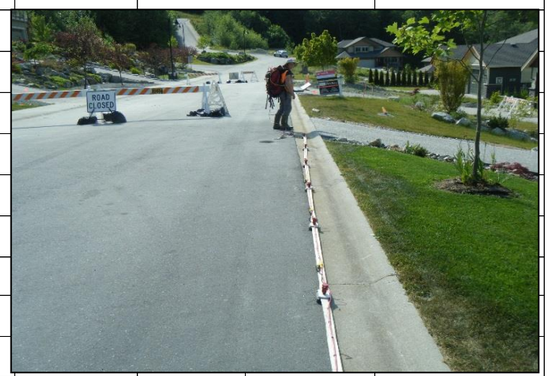
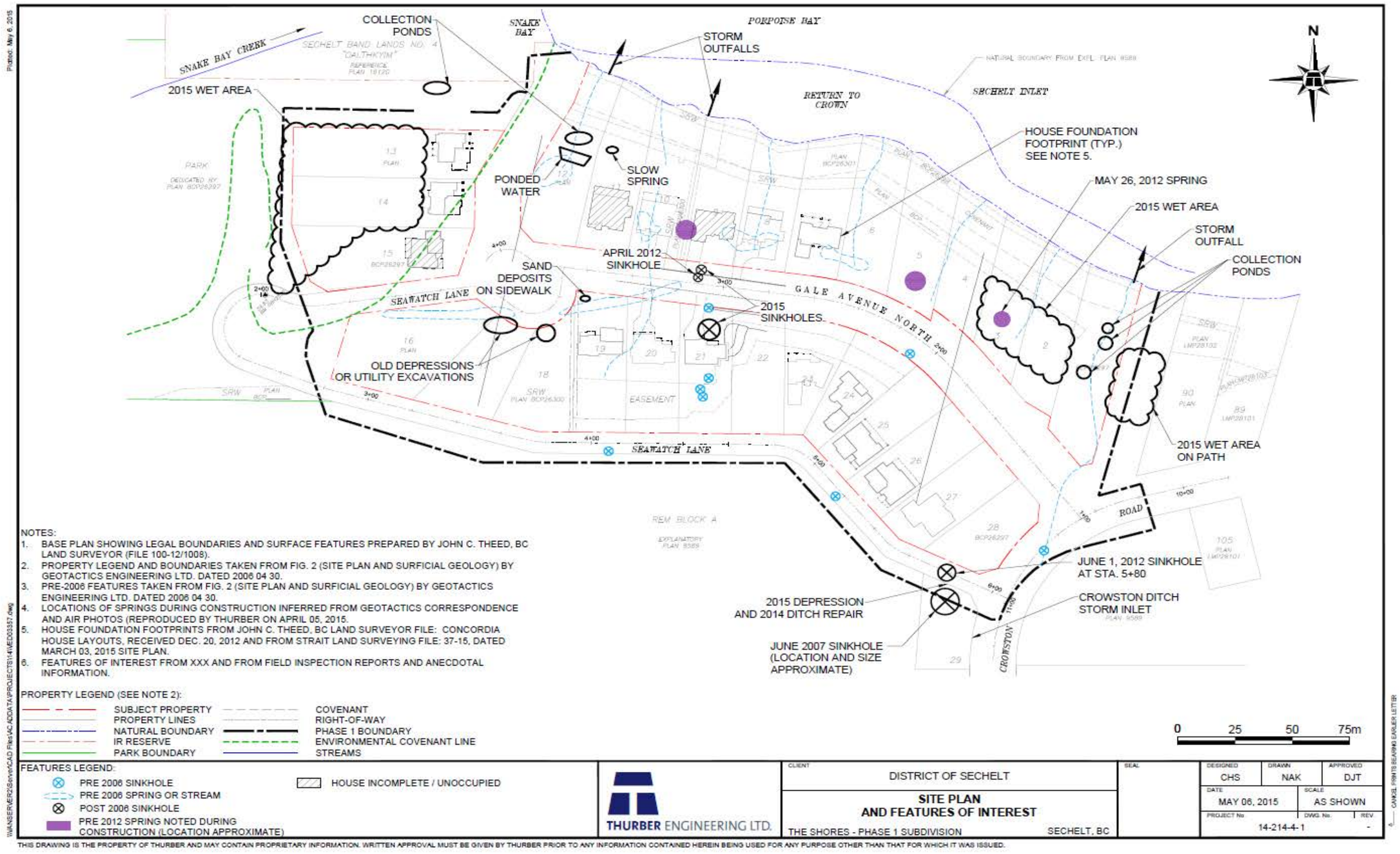


Photo File #	9147	**Item #**	
Location:			
Comment:	**MASW Geophysical survey setup**		

Tips: **1) Use the 'right-click, Change Picture' feature in Microsoft Excel for ease and to maintain formatting.**
2) Compress photos to 220 dpi for ease of file sharing/storage. [Picture Tools>Format>Compress Pictures> deselect ' Apply only to this photo' and select Print (220 dpi)]

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.



NOTES:
1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND AND BOUNDARIES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
4. LOCATIONS OF SPRINGS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2015.
5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MARCH 03, 2015 SITE PLAN.
6. FEATURES OF INTEREST FROM XXX AND FROM FIELD INSPECTION REPORTS AND ANECDOTAL INFORMATION.

PROPERTY LEGEND (SEE NOTE 2):

SUBJECT PROPERTY	COVENANT
PROPERTY LINES	RIGHT-OF-WAY
NATURAL BOUNDARY	PHASE 1 BOUNDARY
IR RESERVE	ENVIRONMENTAL COVENANT LINE
PARK BOUNDARY	STREAMS

FEATURES LEGEND:
- PRE 2006 SINKHOLE
- PRE 2006 SPRING OR STREAM
- POST 2006 SINKHOLE
- PRE 2012 SPRING NOTED DURING CONSTRUCTION (LOCATION APPROXIMATE)
- HOUSE INCOMPLETE / UNOCCUPIED

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SITE PLAN AND FEATURES OF INTEREST

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

SEAL

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE: MAY 06, 2015	SCALE: AS SHOWN	
PROJECT No: 14-214-4-1	DWG. No.	REV: -

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

This figure is issued in DRAFT.
It is reproduced here only as a reference and for markup by the District of Sechelt inspector.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: July 8, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber) Recent Rainfall: About 10 mm rain in last 30 days, concentrated on June 19.

Developments since last inspection: Last District (weekly inspection) on July 2, 2015. Last Thurber inspection on May 26, 2015. Golder inspected area of 2012 Seawatch Lane sinkhole and Lot 3 on June 16, 2015. Forest fire about 2 km north of site.

This form should only be used in conjunction with the instructions printed on Page 5. File Version # 2

Item #	Location	Description	Changed?	Comments, description, qualifiers, measurements, photo numbers, etc.
1	Gale Avenue N (closed section)	Status of Road Closure	No	Remains closed.
2	Gale Avenue N (closed section)	Cracking/settlement of asphalt/curbs?	Yes	Crack in asphalt sub-parallel to road near west side of Lot 9 (first noted by resident around June 4). Crack is closed, about 2m long with ends marked by District. Spread to east about 50 mm since marked.
3	Gale Avenue N at Lot 9	Cracking/settlement of asphalt/curbs?	Yes	Hole in asphalt surface about 0.1x0.15 m in plan, not backfilled. (Cavity below the overhanging asphalt previously measured by District staff to be about 0.15 by 0.75m in plan and 0.2m deep . Loose soil to at least 0.9 m depth, investigated with steel probe.)
4	Sinkhole in front of Lot 9	Settlement, undermining of road/driveway.	No	No visually apparent changes. (see photo)
5	SRW at Lots 9/10 from MH10 to outlet	Any settlement/depressions, springs in storm corridor?	No	No visually apparent changes.
6	Gale Avenue N at Lot 21	Cracking/settlement of asphalt/curbs?	No	No visually apparent changes.
7	Sinkhole at Lot 21	Soil cracking, backfill settlement, poly covering, stair movement?	No	No visually apparent changes. (see photo)
8	Sinkhole at Lot 21	Condition of driveway and dwelling.	No	No visually apparent changes. (see photo)
9	Gale Avenue N (east of closed section)	Cracking/settlement of asphalt/curbs?	No	No visually apparent changes.
10	Gale Avenue N (east of closed section)	Seepage/sand deposits from under driveways/roads/structures?	No	No visually apparent changes.
11	Rock Stack Walls at Lots 19-21	Signs of instability, distress	No	No visually apparent changes.
12	Gale Avenue N (west of closed section)	Cracking/settlement of asphalt/curbs?	Yes	Crack in curb adjacent to storm sewer catch basin on south side of road near Lot 19.
13	Gale Avenue N (west of closed section)	Seepage/sand deposits from under driveways/roads/structures?	No	No visually apparent changes.
14	Crowston Road (Seawatch to Gale Ave N)	Cracking/settlement of asphalt/curbs?	No	No visually apparent changes.
15	Crowston Road at Lot 29	Storm inlet, any flow? Rate/turbidity?	No	Ditch dry at inlet, no inflow into storm system.
16	Crowston Road ditches at Borrow Access	Flow rate in West/East ditches?	No	Ditches dry as far south as borrow access road. Vegetation density increasing, hard to see.
17	Borrow area south of site	Ponding, seepage and runoff on walls, instabilities?	Yes	Pond is now dry (no standing water). Base of pond is about 1.0 m below high water mark. Pond base is soft wet silt about 25 mm thick, overlying loose wet sand with water table at about 50 mm depth. Borrow pit walls are still wet with 1 active seep.
18	Seawatch Lane at Lot 28	Status of Cracking/Depression in asphalt	No	No visually apparent changes to north side of Lane.
19	Seawatch Lane at Lot 28	Survey of control points (if required)	No	Last surveyed June 12 (no changes at installed control points), though data not saved.
20	Seawatch Lane at Lot 29	Any new erosion, settlement/depressions in curb/ditch?	No	Depressed asphalt area now about 3 by 2.5 m in plan. No apparent changes since last District inspection. South lane remains closed to traffic in this area.
21	Lot 28	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
22	Seawatch Lane at Lots 24 - 27	Cracking/settlement of asphalt/curbs?	No	No visually apparent changes.
23	Seawatch Lane at Lots 15 - 23	Cracking/settlement of asphalt/curbs?	No	No visually apparent changes.
24	Lot 22	Status of apparent scarp at south end of lot	No	No visually apparent changes.
25	Lot 22	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
26	Rock Stack Walls at Lots 22 to 24	Signs of instability, distress	No	No visually apparent changes.
27	Seawatch Ln at cut slope (Sta. 2+20 to 2+60)	Status, signs of instability, major recent erosion?	No	No visually apparent changes.
28	Path east of Lot 1	Wet areas / springs / seeps	No	Extents of wet area unchanged. Muddy despite dry weather.
29	Lot 1 - Collection Ponds	Water levels, turbidity?	No	All dry.

Supplementary comments can be made in the space provided on Pages 3 & 4. Please refer back to the initial item number. New items can also be written in.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: July 8, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Item #	Location	Description	Changed?	Comments, description, qualifiers, measurements, photo numbers, etc.
30	Lot 1	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
31	Storm outfall NE of Lot 1	Turbidity/rate of flow, compared to inflow at Crowston Rd	No	Flow clear with rust coloured deposits/algae on concrete/in pipe. Flow on order of less than 5 L/min.
32	PVC drain at Storm outfall NE of Lot 1	Turbidity / rate of outflow	No	Flow clear with rust coloured deposits on concrete/in pipe. Flow on order of 5 to 10 L/min.
33	Lot 2	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
34	Lot 2	Existing slow spring. Rate/turbidity of flow. Sand boil.	Yes	Dry at surface. Grass taller in this area where spring was.
35	Lot 3	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
36	Lot 3	Existing spring area. Rate/turbidity of flow. Size of area.	No	Clear flow on order of 20 L/min, extents of wet area unchanged - about 3 m wide where crosses SRW bench. Loose wet soil in some areas to at least 0.5 m depth, measured with steel probe.
37	Lot 3 Spring Control Works	Lift MH covers, Rate/turbidity of flow up from sand?	No	Clear flow. Coarse sand particles observed to be boiling (lifting under upward gradient) but not flowing into outflow pipe.
38	SRW below Lot 3 and Lot 5	Rate/turbidity of flow from PVC drains on downslope side of bench.	No	Drains discharging below SRW at Lots 3 and 5, flowing clear and both on order of 5 to 10 L/min.
39	Lot 4	Any new erosion/rilling, settlement/depressions, springs?	No	Wet seepage area downslope of SRW bench persists (near toe of fill slope).
40	Lot 5	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
41	Lot 6	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
42	SRW below Lots 1 through 6	Erosion, settlement, springs, ponding of water, etc.?	No	No visually apparent changes.
43	SRW below Lots 7 through 12	Erosion, settlement, springs, ponding of water, etc.?	No	No visually apparent changes.
44	Storm outfall below Lots 9/10	Turbidity/rate of flow, infilling of outlet, sample (if req.)	No	Clear flow. No apparent change to outlet infilling. Flow on order of 100 L/min despite dry weather.
45	Lot 11	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
46	Lot 12	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes. Below (north) SRW at Lot 12, alders have been cut down, exposing PVC drain outfall (presently dry) north of Lot 11/12 boundary near east side of cleared area.
47	Lot 12	Status of slow spring/seep and ponds.	No	All presently dry.
48	Storm outfall below Lot 12	Turbidity/rate of flow, infilling of outlet.	No	Clear flow, on order of 1 to 5 L/min. Sand deposits in outfall structure appear inactive (monitor for reactivation).
49	PVC drain at Storm outfall below Lot 12	Turbidity / rate of outflow	No	Clear flow on order of 5 to 10 L/min.
50	Drains and Collection Pond North of Lot 13	Turbidity / rate of outflow, infilling of pond.	No	Vegetation overgrown, did not observe.
51	Lot 13	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
52	Lot 13	Status of wet areas	No	Developed portion of backyard still dry. Undeveloped/lower backyard still wet, extents apparently unchanged. Lush green oasis despite dry weather.
53	Lot 14	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
54	Lot 14	Status of wet areas	No	Developed portion of backyard still dry. Undeveloped/lower backyard still wet, extents apparently unchanged. Lush green oasis despite dry weather.
55	Lot 15	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
56	Lot 15	Status of wet areas	No	Undeveloped backyard still wet with small clear springs, despite dry weather.
57	Lots 16 to 18	Any new erosion/rilling, settlement/depressions, springs?	No	No visually apparent changes.
58				

Supplementary comments can be made in the space provided on Pages 3 & 4. Please refer back to the initial item number. New items can also be written in.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: July 8, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Item #	Date	Location	Description	Changed?	Comments, description, qualifiers, measurements, photo numbers, etc.
59	7/8/2015	Lot 29	Any new erosion, settlement/depressions.	Yes	Behind berm on north side of Lot, about a dozen small depressions about 0.1 to 0.15 m deep and in diameter with dense bases. Likely plucked cobbles/boulders or surface erosion but should add to monitoring program.
60					
61					
62					
63					
64					
65					
66					
67					
68					
69					
70					
71					
72					
73					
74					
75					
76					
77					
78					
79					
80					
81					
82					
83					
84					
85					
86					
87					

Supplementary comments can be made in the space provided on Pages 3 & 4. Please refer back to the initial item number. New items can also be written in.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: July 8, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Item #	Date	Location	Description	Changed?	Comments, description, qualifiers, measurements, photo numbers, etc.
88				(Yes / No)	
89					
90					
91					
92					
93					
94					
95					
96					
97					
98					
99					
100					
101					
102					
103					
104					
105					
106					
107					
108					
109					
110					
111					
112					
113					
114					
115					
116					

Supplementary comments can be made in the space provided on Pages 3 & 4. Please refer back to the initial item number. New items can also be written in.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date Range: _____ File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber) on July 8, 2015

This form should only be used in conjunction with the instructions printed on Page 5.

Groundwater Monitoring

Well Name	BH12-01	BH12-02	BH12-03	BH12-05	BH12-06	BH12-07	BH12-08	BH12-09	TH13-01	TH13-07	TH13-08	TH13-09 (Shallow)	TH13-09 (Deep)	TH15-03	
Surface El. (m)	**24.83**	**9.92**	**9.97**	**38.6**	**23.37**	**26.39**	**37.69**	**45.43**	**46.32**	**27.8**	**10.86**	**7.38**	**7.38**	**23.01**	
Well Depth (m)	**7.0**	**6.2**	**5.8**	**12.1**	**11.3**	**6.6**	**14.1**	**19.6**	**14.7**	**10.4**	**6.1**	**1.4**	**3.0**	**9.1**	
Date Measured	**Depth to Groundwater (m) - to nearest centimeter (if well dry, write 'Dry')**														**Comments**
i.e.: May 4, 2015	5.22	3.13	2.24	8.19	7.87	4.89	10.91	16.80	14.34	4.45	2.73	0.87	0.85	7.38	
May 14th, 2015	5.25	3.15	-	8.26	7.92	4.92	10.98	-	14.41	4.57	2.72	0.97	0.93	7.41	Missed 2 Boreholes, due to lack of map.
May 21st, 2015	5.25	3.22	-	8.45	7.98	4.93	11.00	16.89	14.49	4.55	2.75	1.00	0.95	7.41	Difficulty locating BH12-03
May 26, 2015	5.24	3.16	2.27	8.55	7.92	4.92	11.05	16.93	14.57	4.58	2.73	0.99	0.95	7.39	Readings by Thurber.
June 5, 2015	5.25	3.21	2.27	8.69	7.92	4.93	11.10	17.01	DRY	4.65	2.76	0.99	0.96	7.42	TH13-01 DRY, Tried 3x to get reading
June 12, 2015	5.28	3.25	2.30	8.77	7.92	4.96	11.16	17.06	14.64	4.69	2.8	1.02	0.98	7.44	Water in TH13-01
June 22, 2015	5.29	3.25	2.31	8.93	7.93	4.97	1.22	17.11	DRY	4.75	2.8	0.99	1.00	7.40	TH13-01 DRY again
July 2, 2015	5.27	3.28	2.32	8.94	7.94	5.00	11.27	17.16	DRY	4.80	2.80	1.01	1.01	7.41	
July 8, 2015	5.26	3.21	2.30	8.98	7.93	4.99	11.27	17.21	DRY	4.81	2.78	1.02	1.03	7.39	Readings by Thurber.

Example Comments: Well damaged, water flowing into well from surface, unstable reading, well depth decreased, explanation if not measured, etc.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date Range: _____ File Number: _____ Inspector: _____

This form should only be used in conjunction with the instructions printed on Page 5.

Groundwater Monitoring

Well Name	BH12-01	BH12-02	BH12-03	BH12-05	BH12-06	BH12-07	BH12-08	BH12-09	TH13-01	TH13-07	TH13-08	TH13-09 (Shallow)	TH13-09 (Deep)	TH15-03	
Surface El. (m)	24.83	9.92	9.97	38.6	23.37	26.39	37.69	45.43	46.32	27.8	10.86	7.38	7.38	23.01	
Well Depth (m)	7.0	6.2	5.8	12.1	11.3	6.6	14.1	19.6	14.7	10.4	6.1	1.4	3.0	9.1	
Date Measured	**Depth to Groundwater (m) - to nearest centimeter (if well dry, write 'Dry')**														**Comments**
i.e.: May 4, 2015	5.22	3.13	2.24	8.19	7.87	4.89	10.91	16.80	14.34	4.45	2.73	0.87	0.85	7.38	

Example Comments: Well damaged, water flowing into well from surface, unstable reading, well depth decreased, explanation if not measured, etc.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Instructions for use of this form and additional information.
A copy of these instructions should be available on site during all inspections.

Instructions for Use

1. Inspections and water level measurements should only be performed by experienced personnel authorized by the District of Sechelt.
2. The use of consistent staff is vital to maximizing the potential for perception of changes to the site.
3. The inspector should adhere to all WorkSafe BC regulations. Unbackfilled sinkholes should be treated as open and potentially unstable excavations.
4. If the inspector observes an imminent hazard which they believe to pose an immediate threat to person, property or the environment, the inspector should take immediate steps to protect their own safety and the safety of others and contact the relevant emergency services or utility providers. If the observed hazard is of geotechnical nature, Thurber should be contacted immediately (604-684-4384).
5. Signs of instability should be reported to Thurber within 24 hours of observation. Signs of instability may include but are not limited to the following: ground cracking, signs of ground settlement/displacement, slumping/sloughing, rapid erosion or muddy water seeping from the ground. With regards to retaining walls, signs of instability may include but are not limited to the following: rapid/significant loss of backfill, water seeping out of the wall face, wall face observed to be leaning more than previously, wall observed to be bulging (not straight) more than previously and/or loss of facing boulders.
6. Particular care should be taken during inspections in the winter months when seasonal rainfalls typically increase the hydraulic groundwater gradients which are believed to be related to the formation of sinkholes at this site.
7. Detailed inspections and groundwater monitoring should be completed weekly at minimum during the months of November through June and every two weeks at minimum during the months of July through October.
8. Additional inspections may be required by Thurber or in response to new developments or remedial works.

Instructions for Filing/Distribution

1. Completed inspection forms should be digitized (ideally typed into this template, or at a minimum scanned), with photos and plan markups attached in a timely manner.
2. Completed inspection forms and files should be archived and copied into a field binder for reference during future inspections.
3. Digitized copies of completed inspection forms should be provided to Thurber in a timely manner for interpretation and review.
4. Additional pages or materials may be attached to the back of this form as required. If significant modification of this form is required, please contact Thurber.

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: July 8, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Inspection Photographs



Photo File #	9154	**Item #**	17
Location:	**Borrow Area**		
Comment:	**Pond dry, walls still wet.**		



Photo File #	9156	**Item #**	20
Location:	**Area of 2012 Seawatch Lane Sinkhole**		
Comment:	**South lane closed**		



Photo File #	9157	**Item #**	20
Location:	**Area of 2012 Seawatch Lane Sinkhole**		
Comment:	**Depressed area on Seawatch Lane**		



Photo File #	9159	**Item #**	**1**
Location:	**Gale Avenue North**		
Comment:	**Road Closure**		



Photo File #	9169	**Item #**	7 and 8
Location:	**Lot 21**		
Comment:	**No visually apparent changes.**		



Photo File #	9170	**Item #**	4
Location:	**Sinkhole Adjacent to Lot 9**		
Comment:	**No apparent changes.**		



Photo File #	9172	**Item #**	3
Location:	**Gale Ave N at Lot 9. (At cone in photo to left)**		
Comment:	**Hole in asphalt with cavity below.**		



Photo File #	9155	**Item #**	**15**
Location:	**Storm inlet at Crowston Road**		
Comment:	**Dry**		

Tips: **1) Use the 'right-click, Change Picture' feature in Microsoft Excel for ease and to maintain formatting.**
2) Compress photos to 220 dpi for ease of file sharing/storage. [Picture Tools>Format>Compress Pictures> deselect ' Apply only to this photo' and select Print (220 dpi)]

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.

Date: July 8, 2015 File Number: Thurber 14-214-4 Inspector: Caleb Scott, EIT (Thurber)

This form should only be used in conjunction with the instructions printed on Page 5.

Inspection Photographs



Photo File #	9186	**Item #**	31
Location:	**Storm outfall NE of Lot 1**		
Comment:	**Drain discharging clear (algae below)**		



Photo File #	9187	**Item #**	32
Location:	**Drain outfall NE of Lot 1**		
Comment:	**Drain discharging clear**		



Photo File #	9188	**Item #**	38
Location:	**Drain outfall N of Lot 3**		
Comment:	**Drain discharging clear**		



Photo File #	9191	**Item #**	**38**
Location:	**Drain outfall N of Lot 5**		
Comment:	**Drain discharging clear**		

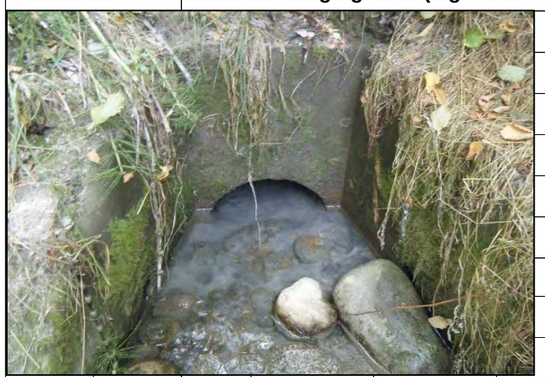


Photo File #	9192	**Item #**	44
Location:	**Storm outfall N of Lots 9, 10**		
Comment:	**Clear water.**		



Photo File #	9193	**Item #**	46
Location:	**North of SRW at Lot 11/12**		
Comment:	**Alders cleared, exposing PVC drain.**		



Photo File #	9202	**Item #**	54
Location:	**Lot 14 backyard**		
Comment:	**Wet areas persist despite dry weather**		

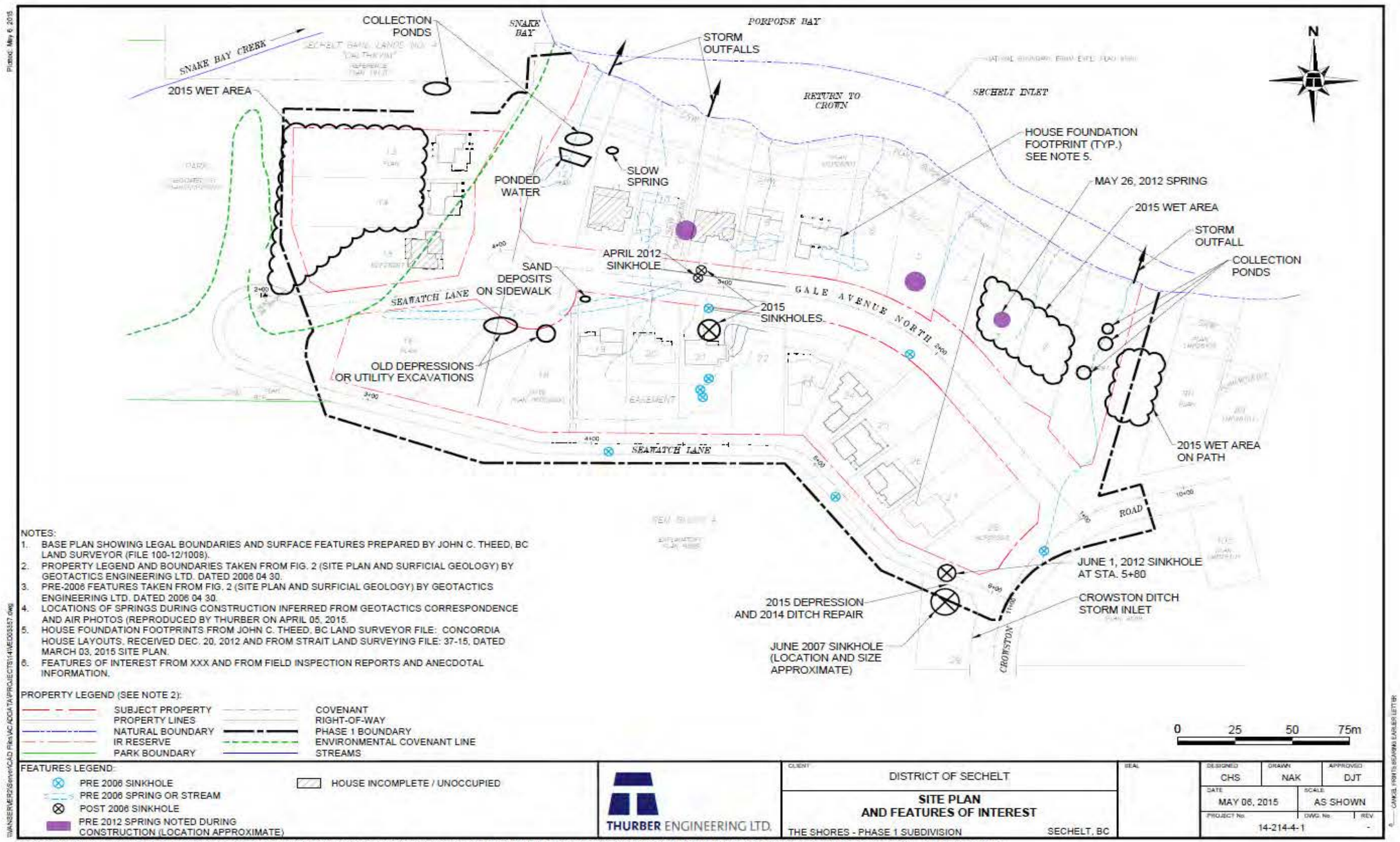


Photo File #	9198	**Item #**	**48**
Location:	**Storm outfall north of Lot 12**		
Comment:	**Clear flow (sand deposits inactive)**		

Tips: **1) Use the 'right-click, Change Picture' feature in Microsoft Excel for ease and to maintain formatting.**
2) Compress photos to 220 dpi for ease of file sharing/storage. [Picture Tools>Format>Compress Pictures> deselect ' Apply only to this photo' and select Print (220 dpi)]

THE SHORES PHASE 1 SUBDIVISION - SITE INSPECTION REPORT

The structure of this form was developed by Thurber Engineering Ltd. (Thurber) for the exclusive use of the District of Sechelt. This form may be revised as required by Thurber.
A condition of the use of this form is that Thurber's performance of its professional services is subject to the Statement of Limitations and Conditions.



NOTES:
1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND AND BOUNDARIES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
4. LOCATIONS OF SPRINGS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2015.
5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MARCH 03, 2015 SITE PLAN.
6. FEATURES OF INTEREST FROM XXX AND FROM FIELD INSPECTION REPORTS AND ANECDOTAL INFORMATION.

PROPERTY LEGEND (SEE NOTE 2):
- SUBJECT PROPERTY
- PROPERTY LINES
- NATURAL BOUNDARY
- IR RESERVE
- PARK BOUNDARY
- COVENANT
- RIGHT-OF-WAY
- PHASE 1 BOUNDARY
- ENVIRONMENTAL COVENANT LINE
- STREAMS

FEATURES LEGEND:
- PRE 2006 SINKHOLE
- PRE 2006 SPRING OR STREAM
- POST 2006 SINKHOLE
- PRE 2012 SPRING NOTED DURING CONSTRUCTION (LOCATION APPROXIMATE)
- HOUSE INCOMPLETE / UNOCCUPIED

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

SITE PLAN AND FEATURES OF INTEREST

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT

DATE: MAY 06, 2015 — SCALE: AS SHOWN

PROJECT No: 14-214-4-1 — DWG. No. — REV: -

Plotted: May 6, 2015

\\VANSERVER2\Server\CAD Files\VAC-ADCAD\PROJECTS\14-214\ED03357.dwg

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

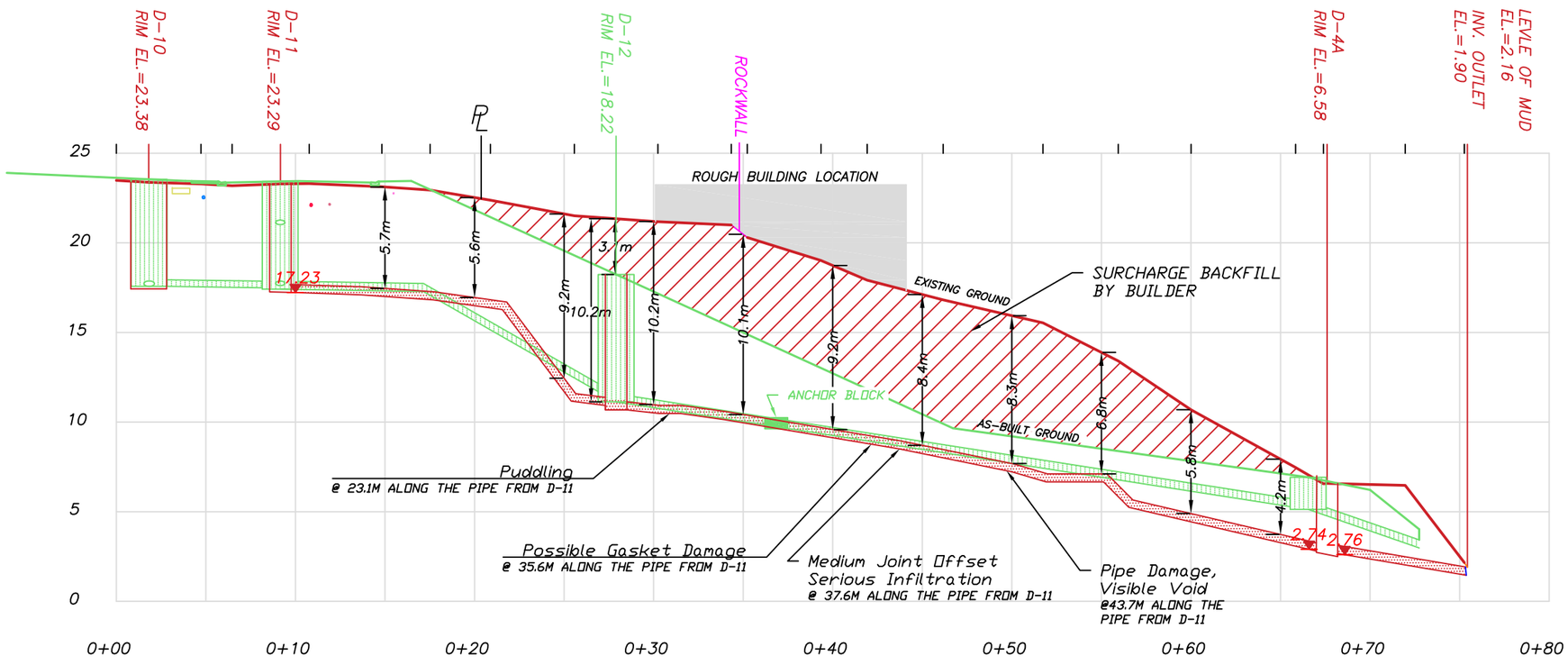
This figure is issued in DRAFT.
It is reproduced here only as a reference and for markup by the District of Sechelt inspector.

THURBER

APPENDIX 2

2015 Ground Surface Profile vs. As-Built Profiles Cross Section of Storm Line near Lots 9 and 10

2015 GROUND PROFILE VS ASBUILT PROFILES
CROSS SECTION OF STORM LINE



ASBUILT GROUND

ASBUILT PIPE PROFILE

EXISTING GROUND

EXISTING PIPE PROFILE AS PER VIDEO DATED 19-03-2015

NORTH



NOTE: PROFILE OF PIPE DETERMINED BY VISUAL INTERPRETATION OF VIDEO, COMPLETED 19-03-2015, AND AS SUCH, IS ONLY APPROXIMATE

NOTE: ELEVATIONS ARE IN METERS AND ARE DERIVED FROM DISTRICT OF SECHELT CONTROL MONUMENT 08H2535

3/23/2015

THURBER

APPENDIX 3

Thurber Engineering Ltd. 2015 Drilling Investigation Test Hole Logs

Sheet 1 of 2

LOG OF TEST HOLE

TEST HOLE NO. **TH15-01**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484265.36, E 442403.69

TOP OF HOLE ELEV: 23.3 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 13, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit – Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

DEPTH (m)	COMMENTS		SOILS DESCRIPTION	ELEVATION (m)
0		SW-SM/GW-GM	75 mm of ASPHALT over; Compact, brown, moist, gravelly SAND with trace to some silt (FILL).	23
1	Start of DCPT			
		SM	- grey, silty sand with some gravel below 0.9 m depth	22
2			- gravelly zone from 1.8 to 3.0 m depth	21
3		SM	- grey-brown with trace wood debris from 2.4 to 3.0 m depth	20
4				
		SM		19
5				
		ML/SM	- silty sand to silt and sand with some gravel below 5.5 m depth	18
6				
7				17
		ML	Very stiff, grey-brown, moist to wet, fine sandy SILT over SILT with some fine sand.	
	Note increasing rod friction with depth may influence DCPT counts			16
8		ML	- wet below about 7.6 m depth - fining downwards to SILT with some fine sand	15
9		ML	Very stiff, grey-brown, wet SILT with a trace of fine sand.	14
10		ML		13
11				12
12		ML		
			Very stiff, grey-brown, wet, fine sandy SILT.	11
13		ML		10
14	142 146		- grey below 13.7 m depth	9
	End of DCPT 150 blows for final 300 mm	ML		
15				

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 2 of 2

LOG OF TEST HOLE

TEST HOLE NO. **TH15-01**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484265.36, E 442403.69

TOP OF HOLE ELEV: 23.3 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 13, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%) ○ Disturbed ● Undisturbed | WATER LEVEL Plastic Limit Liquid Limit | SAMPLES ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa) ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%) ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm) ■ GASTECH reading ⊠ PID reading

DEPTH (m)	10 20 30 40 50 60 70 80 90 100	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
15				8
16			Dark grey, wet SILT with a trace of fine sand.	7
17				6
18			End of auger hole at required depth. Auger hole open to 2.4 m depth with perched water at 1.5 m depth upon completion. Hollow stem augers used to re-establish open hole to termination depth. Test hole fully backfilled with bentonite chips and asphalt patched.	5
19				4
20				3
21				2
22				1
23				0
24				-1
25				-2
26				-3
27				-4
28				-5
29				-6
30				

ML

ML

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-02**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484266.04, E 442397.66

TOP OF HOLE ELEV: 23.2 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 13 & 14, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m) | ELEVATION (m) | 10 20 30 40 50 60 70 80 90 100

COMMENTS

DEPTH (m)	ELEVATION (m)		SOILS DESCRIPTION
0	23		75 mm of ASPHALT over; Compact to dense, grey-brown, moist SAND with some gravel and trace to some silt (FILL).
1	22	ML/SM	- silty sand to sand and silt with some gravel below 0.9 m depth - compact below 1.2 m depth
2	21		
3	20	SM/ML	- loose to compact below 2.7 m depth
4	19	SM	
5	18		
6	17	GM/SM	- gravelly zone below about 5.8 m depth Compact to dense, grey-brown, moist to wet, silty, fine SAND with a trace of fibrous organics.
7	16	SM	132
8	15	ML	Very stiff, grey, wet SILT with a trace of fine sand.
9	14	ML	End of DCPT End of auger hole at required depth. Auger hole open to 6.1 m depth with no water observed upon completion. Test hole fully backfilled with bentonite chips and soil cuttings and the asphalt patched.
10	13		
11	12		
12	11		
13	10		
14	9		
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-03**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484267.67, E 442385.73

TOP OF HOLE ELEV: 23.0 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 14, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m) | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

COMMENTS

SOILS DESCRIPTION

Depth (m)	Elevation (m)		
0	23		75 mm of ASPHALT over; Compact, grey-brown, moist SAND and GRAVEL with some silt (FILL). - gravel particles are angular to sub-rounded, generally up to 25 mm diameter with trace coarse gravel and cobbles to 175 mm diameter
1	22	SM/GM	DCPT started
2	21		
3	20	SM/ML	Compact, grey-brown, moist SAND and SILT with traces of gravel and wood debris (FILL).
			110
4	19	GM/SM	Compact, grey-brown, moist, silty SAND to SILT and SAND with some gravel and a trace of wood debris (FILL).
5	18		138
6	17	ML/SM	
7	16		- gravelly zone below about 7.3 m depth
		GM/SM	Water level measured 6 hours and 72 hours after installation.
8	15	ML	Very stiff, grey, wet SILT with a trace of fine to medium sand.
9	14	ML	End of DCPT
			End of auger hole at required depth. Auger hole open to 8.2 m with water below 7.9 m depth upon completion. A standpipe piezometer was installed with screened interval from 7.6 to 9.1 m depth.
10	13		
11	12		
12	11		
13	10		
14	9		
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-04**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484264.23, E 442412.51

TOP OF HOLE ELEV: 23.5 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 14, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Compact to dense, grey-brown, moist, gravelly, silty SAND to SAND and SILT (FILL).	23
1	DCPT started	ML/SM	22
2		- loose to compact below 1.5 m depth	21
3		ML/SM	20
4		- very loose below 3.7 m depth	19
5		SM	18
6		SM - fragment of geotextile fabric at 5.5 m depth	17
7		Very stiff, grey-brown, wet, fine sandy SILT over SILT with some fine sand. ML	16
8		Very stiff, grey-brown, wet SILT with a trace of fine sand. ML	15
9	End of DCPT	End of auger hole at required depth. Auger hole open to 4.9 m depth with no water observed upon completion. Auger hole fully backfilled with bentonite chips and soil cuttings and the asphalt patched. ML	14
10			13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-05**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484262.72, E 442424.48

TOP OF HOLE ELEV: 23.7 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 14, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100 | ELEVATION (m)

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Compact to dense (inferred), grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1	DCPT started		
		End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	22
2			21
3			20
4			19
5			18
6			17
7			16
8			15
9	End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	14
10			13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-06**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484261.57, E 442433.47

TOP OF HOLE ELEV: 23.9 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 14, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit, Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): Peak, Residual, Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve, △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	10 20 30 40 50 60 70 80 90 100	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0			75 mm of ASPHALT over;	23
1		DCPT started	Compact to dense (inferred), grey-brown, moist SAND with some gravel and trace to some silt (FILL).	22
2			End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	21
3				20
4				19
5				18
6				17
7				16
8				15
9				14
10		End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	13
11				12
12				11
13				10
14				9
15				

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-07**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484257.43, E 442411.58

TOP OF HOLE ELEV: 23.5 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 14, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100 | **COMMENTS** | SOILS DESCRIPTION | ELEVATION (m)

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Compact to dense (inferred), grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
0	DCPT started		
1	110		
1	194		
2	120		22
2	102		
3			21
4			20
5			19
5	End of DCPT 100 blows for final 225 mm	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	18
6			17
7			16
8			15
9			14
10			13
11			12
12			11
13			10
14			9
15			

End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.

(Refer to TH15-15 for nearby soil log)

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-08**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484257.97, E 442408.23

TOP OF HOLE ELEV: 23.4 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 14, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit – Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over;	23
1		Compact to dense (inferred), grey-brown, moist, gravelly, silty SAND (FILL). SM	22
2	DCPT started	- trace of wood debris	
3		End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	21
4			20
5			19
6	End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	18
7			17
8			16
9			15
10			14
11			13
12			12
13			11
14			10
15			9

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-09**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484258.24, E 442405.18

TOP OF HOLE ELEV: 23.4 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 14 & 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit – Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over;	23
1		Compact to dense (inferred), grey-brown, moist, gravelly SAND with a trace to some silt (FILL).	22
2			21
3			20
4	Difficult augering DCPT started		19
5		End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	18
6	End of DCPT 100 blows for final 150 mm	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	17
7			16
8			15
9			14
10			13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-10**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484256.69, E 442416.66

TOP OF HOLE ELEV: 23.6 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | ELEVATION (m) | 10 20 30 40 50 60 70 80 90 100

DEPTH (m)	ELEVATION (m)	COMMENTS	SOILS DESCRIPTION
0	23		75 mm of ASPHALT over; Compact to dense (inferred), grey-brown, moist, gravelly SAND with a trace to some silt (FILL). - gravel particles up to 75 mm diameter
3	20	Difficult augering	
4	19	DCPT started	End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.
7	16	End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.
15	9		

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-11**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484259.47, E 442396.19

TOP OF HOLE ELEV: 23.2 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100 | ELEVATION (m)

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Compact to dense (inferred), grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1			22
1.5	DCPT started		
2			21
3			20
4			19
4.6	DCPT penetrated under Hammer Weight only from 4.6 to 5.2 m depth		
5			18
6			17
7			16
8			15
8.8	End of DCPT	End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	
9		DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	14
10			13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-12**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484260.55, E 442389.91

TOP OF HOLE ELEV: 23.1 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Compact to dense (inferred), grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1			22
2	DCPT started	End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	21
3			20
4			19
5			18
6			17
7	End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	16
8			15
9			14
10			13
11			12
12			11
13			10
14			9
15			

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-13**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484278.04, E 442399.53

TOP OF HOLE ELEV: 21.3 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	COMMENTS		SOILS DESCRIPTION	ELEVATION (m)
0	DCPT started from surface		Very loose, grey-brown, moist to wet, gravelly silty SAND with some organics (FILL).	21
1		GM/SM		20
2				19
3		GM/SM		18
4	Inferred maximum depth of recent excavation		- wet from 3.7 to 4.0 m depth	17
		ML/SM	Loose to compact, grey, moist, gravelly SAND and SILT (FILL).	
5				16
6		ML/SM	- moist to wet below 5.8 m depth	15
7		SM/GM	- silty sand and gravel below about 7.0 m depth	14
8				13
9		SM/GM	- wet below 8.5 m depth	12
10	DCPT refusal 150 blows for final 50 mm		End of test hole at auger refusal on inferred cobble/boulder (dry rock flour on bit). Test hole open to 5.9 m depth with no water observed upon completion. Test hole fully backfilled with bentonite chips and soil cuttings.	11
11				10
12				9
13				8
14				7
15				

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-14**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484269.77, E 442397.92

TOP OF HOLE ELEV: 23.0 m

METHOD: DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	10 20 30 40 50 60 70 80 90 100	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		DCPT started from surface	(No drillout)	22
1				21
2				20
3				19
4		End of DCPT due to hammer breakdown	DCPT hole backfilled with bentonite chips upon completion.	18
5				17
6				16
7				15
8				14
9				13
10				12
11				11
12				10
13				9
14				
15				

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-15**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484257.72, E 442410.65

TOP OF HOLE ELEV: 23.5 m

METHOD: Solid Stem Auger

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit – Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over;	23
1		Dense (inferred), grey-brown, moist, gravelly SAND and SILT with trace cobbles to 100 mm diameter (FILL). ML/SM	22
2	Refer to TH15-07 for nearby DCPT		21
3		ML/SM - moist to wet, with some gravel below 3.0 m depth	20
4		SM/ML	19
5	Difficult augering, drill action suggests gravelly/cobbly	- fragment of geotextile fabric at 4.9 m depth - no recovery below 4.9 m depth	18
6		End of test hole at auger refusal. Auger hole open to 3.4 m depth with no water observed upon completion. Auger hole fully backfilled with bentonite chips and soil cuttings.	17
7			16
8			15
9			14
10			13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-16**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484265.13, E 442406.58

TOP OF HOLE ELEV: 23.3 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100 | ELEVATION (m)

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1	DCPT penetrated under Hammer Weight only from 0.53 to 0.9 m depth	- VOID, from 0.38 to 0.53 m depth and appearing to extend laterally beyond the test hole diameter	22
2	Void consistent with the undermining observed below Gale Ave North curb at the Lot 9 sinkhole about 1 m to the north	End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	21
3			20
4			19
5			18
6			17
7			16
8			15
9			14
10	End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-17**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484263.15, E 442406.38

TOP OF HOLE ELEV: 23.4 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 15, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	10 20 30 40 50 60 70 80 90 100	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		DCPT started	75 mm of ASPHALT over; Compact to dense, grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1			End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	22
2				21
3				20
4				19
5				18
6				17
7		End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	16
8				15
9				14
10				13
11				12
12				11
13				10
14				9
15				

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-18**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484262.4, E 442412.39

TOP OF HOLE ELEV: 23.5 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 16, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100 | ELEVATION (m)

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Compact, grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1	DCPT started	End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	22
2			21
3			
	DCPT penetrated under Hammer Weight only from 3.4 to 5.0 m depth	- possible void below 3.4 m depth (refer to hole closure notes below)	20
4			19
5			18
6	DCPT penetrated under Hammer Weight only from 5.8 to 6.1 m depth		17
7			16
8			15
9			14
10			13
11			12
12	End of DCPT	Hole Closure Notes: Upon completion of DCPT, about 6.5 bags of bentonite chips were dropped down the DCPT hole from surface after which the hole was still open to 3.4 m depth (this represents 6 times the typical volume required to backfill a hole of this volume). At least the final three bags resulted in no notable change in depth of open hole suggesting a possible cavity at 3.4 m depth. Granular fill cuttings were used to bridge the DCPT hole and backfill above 3.4 m depth. Asphalt was patched.	11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-19**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484263.49, E 442418.67

TOP OF HOLE ELEV: 23.6 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 16, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100 | ELEVATION (m)

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Compact to dense (inferred), grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1	DCPT started		
		End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	22
2			21
3			20
4			19
5			18
6			17
7			16
8			15
9	End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	14
10			13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-20**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484267.8, E 442412.94

TOP OF HOLE ELEV: 23.4 m

METHOD: DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 16, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | ELEVATION (m) | 10 20 30 40 50 60 70 80 90 100

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0	DCPT started	(Grass surface - No drillout)	23
1			22
2			21
3			20
4			19
5			18
6			17
7			16
8			15
9			14
10	End of DCPT	DCPT hole backfilled with bentonite chips and the grass sod restored upon completion.	13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-21**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484261.57, E 442418.48

TOP OF HOLE ELEV: 23.7 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 16, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	10 20 30 40 50 60 70 80 90 100	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0			75 mm of ASPHALT over; Compact to dense (inferred), grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1		DCPT started		
			End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	22
2				21
3				20
4				19
5				
6		- 1 blow for 150 mm penetration at 5.5 depth		18
7				17
8		End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	16
9				15
10				14
11				13
12				12
13				11
14				10
15				9

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-22**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484258.94, E 442399.75

TOP OF HOLE ELEV: 23.3 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 16, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		75 mm of ASPHALT over; Compact (inferred), grey-brown, moist SAND with some gravel and trace to some silt (FILL).	23
1	DCPT started	End of auger hole at required depth. Auger hole backfilled with soil cuttings prior to DCPT.	22
2			21
3			20
4			19
5			18
6			17
7			16
8	End of DCPT	DCPT hole backfilled with bentonite chips and the asphalt patched upon completion.	15
9			14
10			13
11			12
12			11
13			10
14			9
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-23**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484240.99, E 442410.69

TOP OF HOLE ELEV: 26.7 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 16, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit – Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	COMMENTS		SOILS DESCRIPTION	ELEVATION (m)
0	DCPT started		Very loose to loose, grey-brown, moist, gravelly, fine to coarse SAND with trace to some silt and trace organics (Recent Sinkhole Backfill).	26
1		SP-SM/GP-GM		
2	Due to uneven ground surface, test hole inclined about 80 to 85 degrees from horizontal, dipping towards the south. Reported depths are measured along test hole axis. Elevations have been corrected for an 80 degree inclination.			25
3		GM/SM	- moist to wet below 2.4 m depth	24
4		SM/GM	Very loose to loose, grey, moist to wet, gravelly silty SAND with a trace of organics (FILL).	23
5			- compact below 5.2 m depth - wet below 5.5 m depth	22
6		SM	[Base of fill]	21
7		SM	Loose to compact, grey, wet, silty, fine SAND.	20
8	Compact to dense below 7.6 m depth			19
9	End of DCPT		End of auger hole at required depth. Auger hole open to 3.4 m depth with no water observed upon completion. Auger hole fully backfilled with bentonite chips (10 bags).	18
10				17
11				16
12				15
13				14
14				13
15				

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-24/24A**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484134.91, E 442517.24

TOP OF HOLE ELEV: 38.5 m

METHOD: Solid Stem Auger / DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 16 & 17, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0	TH15-24A was pre-drilled with solid stem auger to 6.1 m depth. Difficult augering, cuttings heavily disturbed.	(Following refusal of DCPT at 2.7 m depth [TH15-24], the test hole was restarted [TH15-24A] about 0.3 m away.)	38
1		Very dense (inferred from drill action), grey, moist, silty fine to medium SAND to SAND and SILT with a trace of gravel.	37
2	115		36
3	200 DCPT refusal (TH15-24) at 2.7 m depth. DCPT hole backfilled with bentonite chips and soil cuttings.		35
4			34
5		(Soil boundary inferred from change in drill action) Brown, wet SAND.	33
6	111 DCPT restarted (TH15-24A) at 6.1 m depth	(Soil boundary inferred from change in drill action) Hard (inferred), moist SILT.	32
7	140 126 163 155	End of auger hole at required depth. Auger hole open to 5.8 with water below 5.5 m depth upon completion. Auger hole backfilled with bentonite chips and soil cuttings.	31
8	End of DCPT 183 blows for final 225 mm	DCPT hole backfilled with bentonite chips upon completion.	30
9			29
10			28
11			27
12			26
13			25
14			24
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-25/25A**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484135.88, E 442514.51

TOP OF HOLE ELEV: 38.7 m

METHOD: Solid Stem Auger / DCPT / SPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 17, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0	TH15-25A was pre-drilled with solid stem auger to 6.1 m depth. Difficult augering, cuttings heavily disturbed.	(Following refusal of DCPT at 4.6 m depth [TH15-25], the test hole was restarted [TH15-25A] about 0.3 m away.)	38
1		Very dense (inferred from drill action), grey, moist, silty fine to medium SAND to SAND and SILT with a trace of gravel.	
2			37
3			36
4			35
4.6	DCPT at 4.6 m depth (TH15-25), 150 blows for 150 mm (refusal) TH15-25 backfilled with bentonite chips and soil cuttings.		34
5			
5.5		(Soil boundary inferred from change in drill action)	33
6	SPT at 6.1 m depth	Very loose, grey, moist to wet, fine to coarse SAND with traces of gravel and silt. SW-SM	
6.7	DCPT restarted (TH15-25A) at 6.7 m depth		32
7		End of auger hole at required depth. Auger hole backfilled with bentonite chips and soil cuttings.	
8			31
8.5	DCPT penetrated under Hammer Weight only from 8.2 to 8.5 m depth		30
9			
10			29
11			28
12			27
13			26
13.5		DCPT hole backfilled with bentonite chips upon completion.	25
14			
15			24

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-26/26A**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484138.57, E 442509.45

TOP OF HOLE ELEV: 39.4 m

METHOD: Solid Stem Auger / DCPT / SPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 17, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%) ○ Disturbed ● Undisturbed | WATER LEVEL Plastic Limit – Liquid Limit | SAMPLES ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa) ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%) ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm) ■ GASTECH reading ⊠ PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0	TH15-26 and 15-26A were pre-drilled with solid stem auger to 4.6 and 7.0 m depth respectively. Difficult augering, cuttings heavily disturbed.	Very dense (inferred from drill action), grey, moist, silty fine to medium SAND to SAND and SILT with a trace of gravel.	39
1			38
2			37
3			36
4	Grab sample from auger	SM	35
5	118 SPT (TH15-26)	SM	34
6		(Following loss of SPT sampler TH15-26 was backfilled with bentonite chips and soil cuttings. Test hole was restarted [TH15-26A] about 0.3 m away.)	33
7	160 SPT (TH15-26) sampler sheared off at threads during retrieval.	ML (Boundary inferred from change in blow counts) Very stiff to hard, grey mottled brown, moist SILT with a trace of fine sand.	32
8	191 DCPT (TH15-26A) 113 blows for final 200 mm	End of auger hole (15-26A) at required depth. DCPT hole open to 7.6 m depth with no observed water upon completion. Test hole was backfilled with bentonite chips and cuttings.	31
9			30
10			29
11			28
12			27
13			26
14			25
15			

Sheet 1 of 2

LOG OF TEST HOLE

TEST HOLE NO. **TH15-27**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484137.38, E 442512.21

TOP OF HOLE ELEV: 39.0 m

METHOD: Solid Stem Auger / DCPT / SPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 17, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0	Pre-drilled with solid stem auger to 6.1 m depth. Difficult augering, cuttings heavily disturbed.	Dense (inferred from drill action), grey, moist, silty, fine to medium SAND to SAND and SILT with a trace of gravel.	39
1			38
2			37
3			36
4			35
5	No evidence of change from drill action or soil cuttings at 6.0 m		34
6	SPT	(Boundary inferred)	33
	DCPT started	ML Very loose to loose, damp, grey-brown, SILT with a trace of sand.	
7		End of auger hole at required depth. Auger hole backfilled with bentonite chips and soil cuttings.	32
8			31
9			30
10			29
11			28
12			27
13			26
14			25
15			

LOG OF TEST HOLE

TEST HOLE NO. TH15-27

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484137.38, E 442512.21

TOP OF HOLE ELEV: 39.0 m

METHOD: Solid Stem Auger / DCPT / SPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 17, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
15			23
16			22
17			21
18			20
19			19
20	End of DCPT	DCPT hole open to 9.8 with water at 8.8 m depth upon completion. DCPT hole backfilled with bentonite chips.	18
21			17
22			16
23			15
24			14
25			13
26			12
27			11
28			10
29			
30			

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-28**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484132.54, E 442523.11

TOP OF HOLE ELEV: 38.3 m

METHOD: Solid Stem Auger / DCPT / SPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 17, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%) ○ Disturbed ● Undisturbed | WATER LEVEL Plastic Limit – Liquid Limit | SAMPLES ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa) ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%) ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm) ■ GASTECH reading ⊠ PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

DEPTH (m)	COMMENTS		SOILS DESCRIPTION	ELEVATION (m)
0	Pre-drilled with solid stem auger to 6.1 m depth. Difficult augering, cuttings heavily disturbed.		Very dense (inferred from drill action), grey, moist, silty fine to medium SAND to SAND and SILT with a trace of gravel.	38
1				37
2				36
3				35
4				34
5			(Boundary inferred from change in drill action and disturbed cuttings)	33
6	SPT	ML/SM	Very dense, laminated, grey, wet, fine SAND and SILT. - dark grey/black bedding marker	32
7	DCPT started		End of auger hole at required depth.	31
8	128 122 End of DCPT 160 blows for final 225 mm		DCPT hole open to 4.9 m depth with no water observed upon completion. Test hole backfilled with bentonite chips and soil cuttings.	30
9				29
10				28
11				27
12				26
13				25
14				24
15				

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH15-29**

LOCATION: Refer to Fig. 5 (14-214-4)
N 5484268.75, E 442407.03

TOP OF HOLE ELEV: 22.6 m

METHOD: DCPT

DRILLING CO.: Downrite Drilling Ltd.

INSPECTOR: CHS

THURBER

CLIENT: Sechelt, District of

PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes

DATE: April 17, 2015

FILE NO.: 14-214-4

REVIEWED BY: DJT

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit – Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

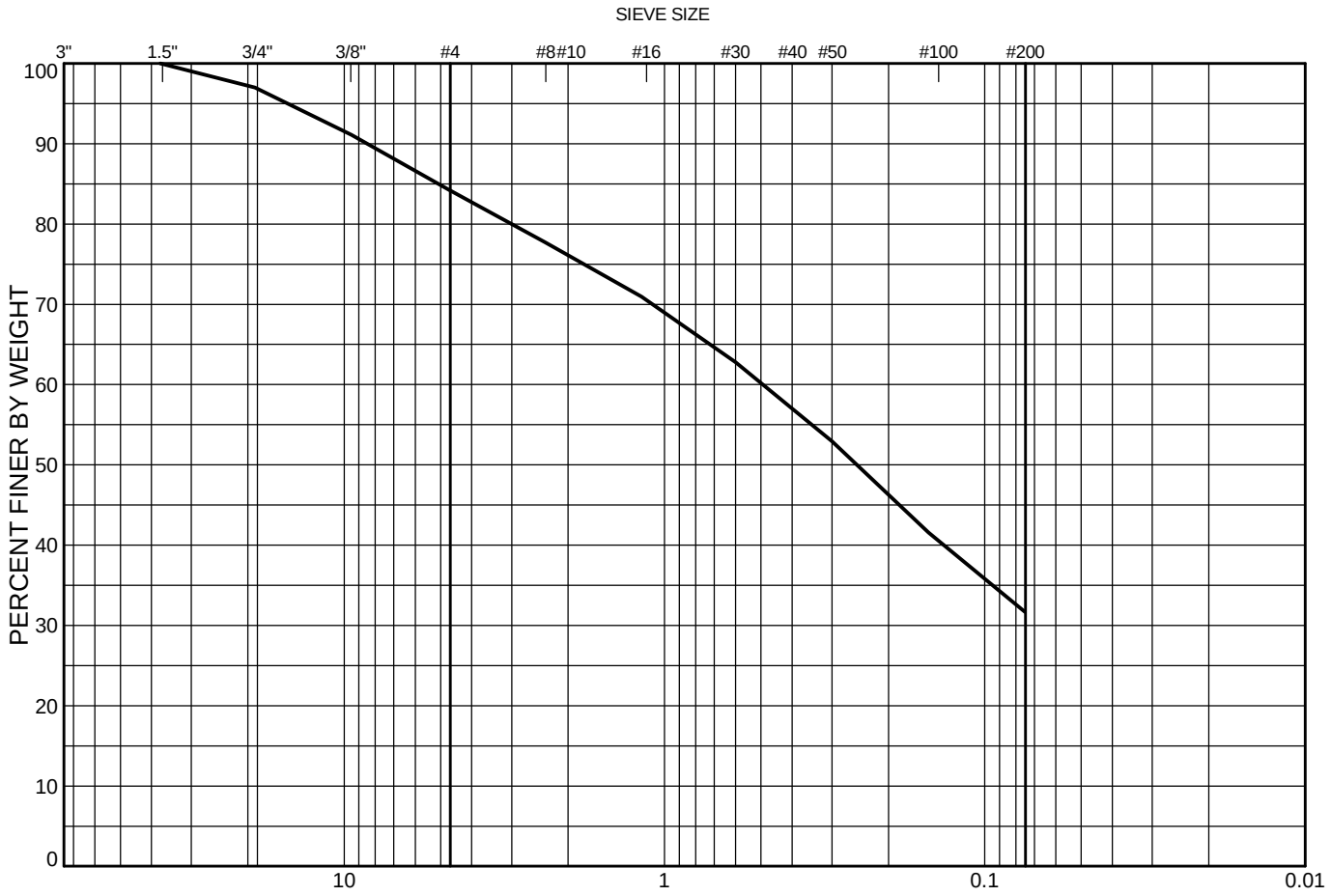
DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0	DCPT started	(No drillout)	22
1			21
2			20
3			19
4			18
5			17
6			16
7			15
8			14
9			13
10			12
11			11
12			10
13	End of DCPT	DCPT hole backfilled with bentonite chips upon completion.	9
14			8
15			

LOG OF TEST HOLE (14-214-4) 14-214-4.GPJ THURBER BC.GDT 7/14/15- THURBER BC.GLB

THURBER

APPENDIX 4

Thurber Engineering Ltd. 2015 Drilling Investigation Geotechnical Laboratory Test Results



Sample Location: **TH15-01**
Sample: 4
Sample Depth: 4.3 m
Date Sampled: April 13, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**15.6%**
Sand	**52.7%**
Fines	**31.7%**
Moisture Content	**9.6%**

D10	
D30	
D60	**0.493**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	**100.0**
0.75	19	**97.0**
0.375	9.5	**91.1**
#4	4.75	**84.4**
#8	2.36	**77.7**
#16	1.18	**70.9**
#30	0.6	**62.8**
#50	0.3	**53.0**
#100	0.15	**41.6**
#200	0.075	**31.7**

Description:

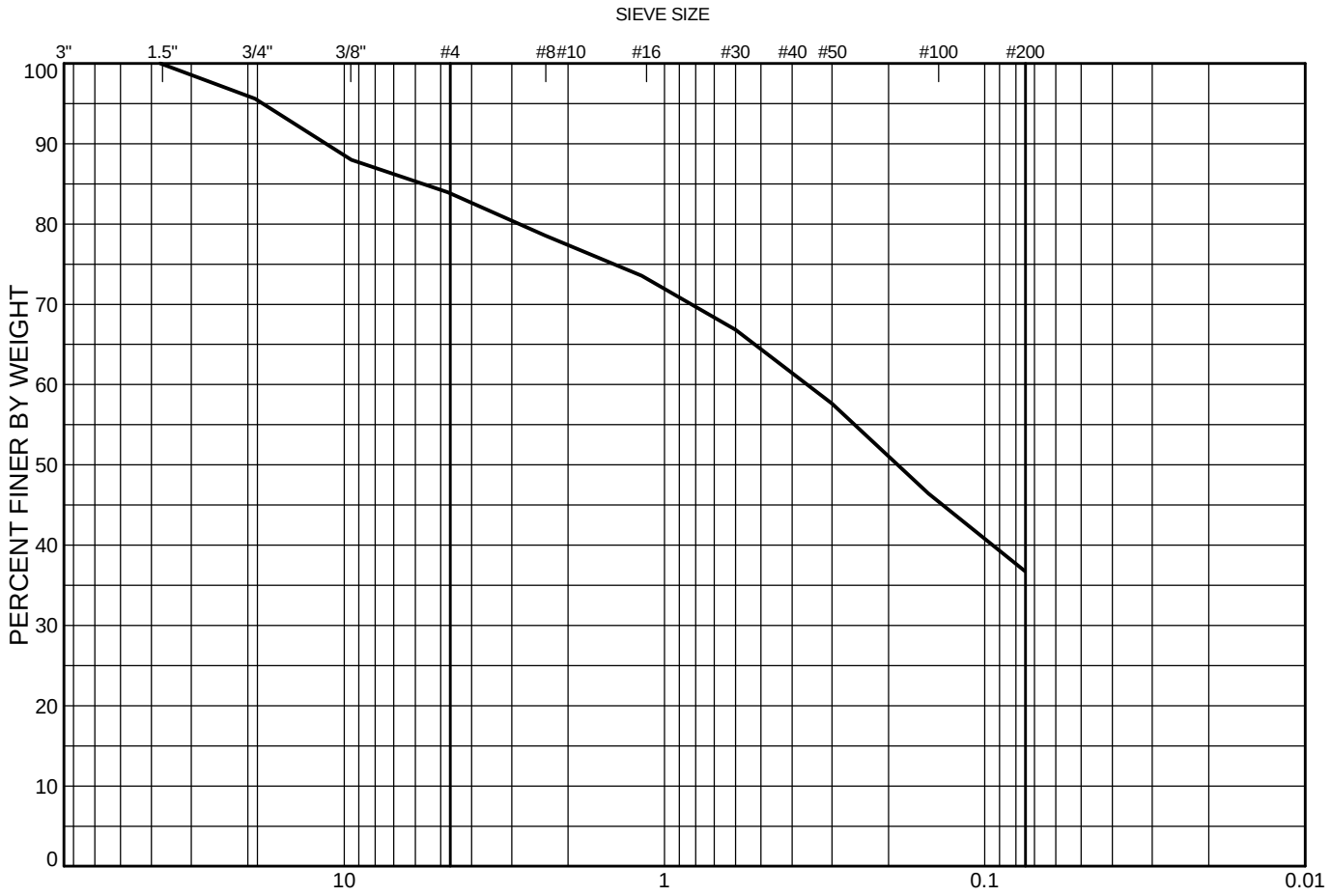
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH15-01**
Sample: 5
Sample Depth: 5.5 m
Date Sampled: April 13, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Description:

Comments:

Gravel	**16.1%**
Sand	**47.2%**
Fines	**36.8%**
Moisture Content	**11.1%**

D10	
D30	
D60	**0.359**
Cu	
Cc	

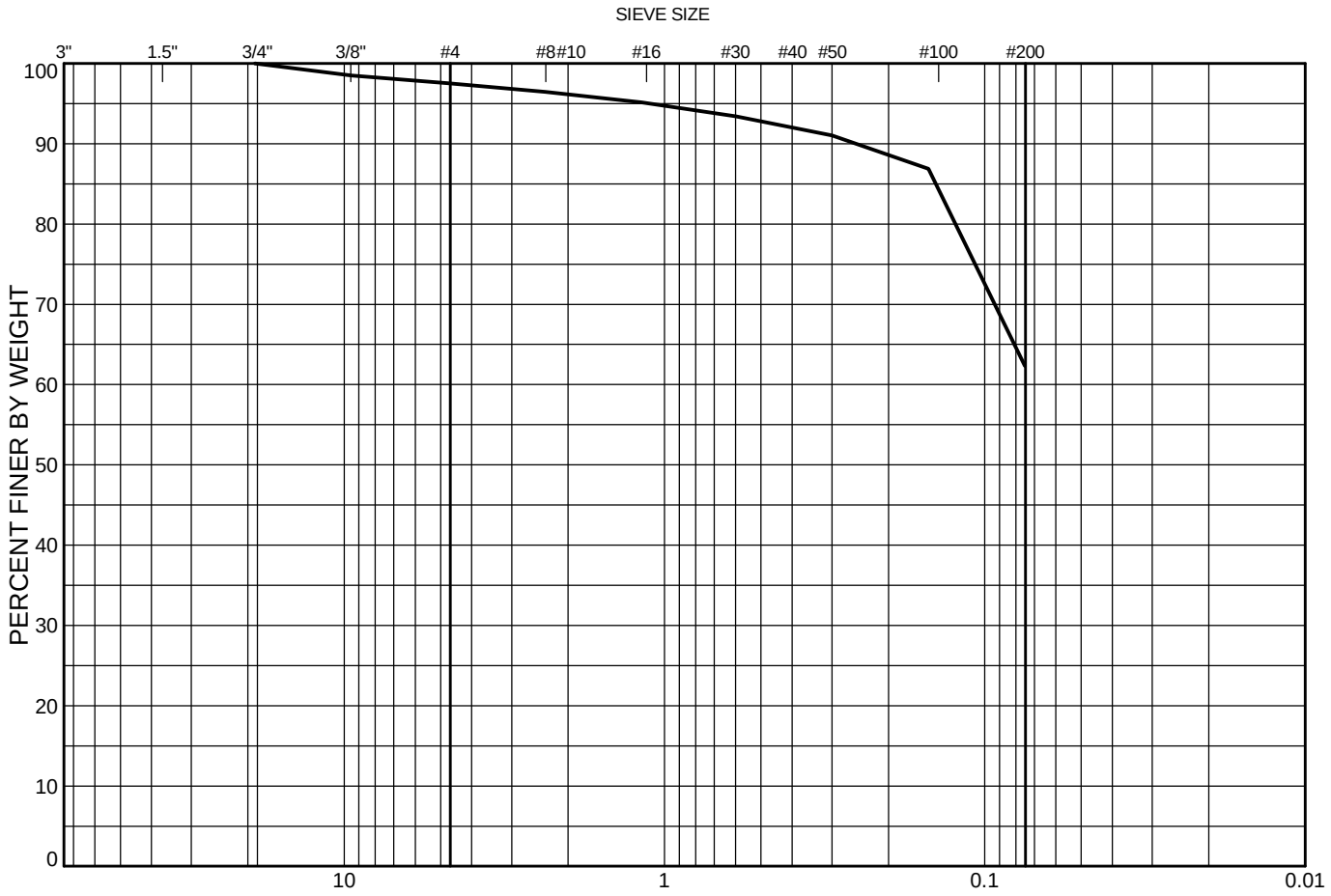
Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	**100.0**
0.75	19	**95.6**
0.375	9.5	**88.0**
#4	4.75	**83.9**
#8	2.36	**78.6**
#16	1.18	**73.6**
#30	0.6	**66.8**
#50	0.3	**57.6**
#100	0.15	**46.4**
#200	0.075	**36.8**

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH15-01**
Sample: 6
Sample Depth: 7.3 m
Date Sampled: April 13, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**2.5%**
Sand	**35.2%**
Fines	**62.3%**
Moisture Content	**24.5%**

D10	
D30	
D60	
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	**100.0**
0.375	9.5	**98.5**
#4	4.75	**97.5**
#8	2.36	**96.5**
#16	1.18	**95.1**
#30	0.6	**93.4**
#50	0.3	**91.1**
#100	0.15	**86.9**
#200	0.075	**62.3**

Description:

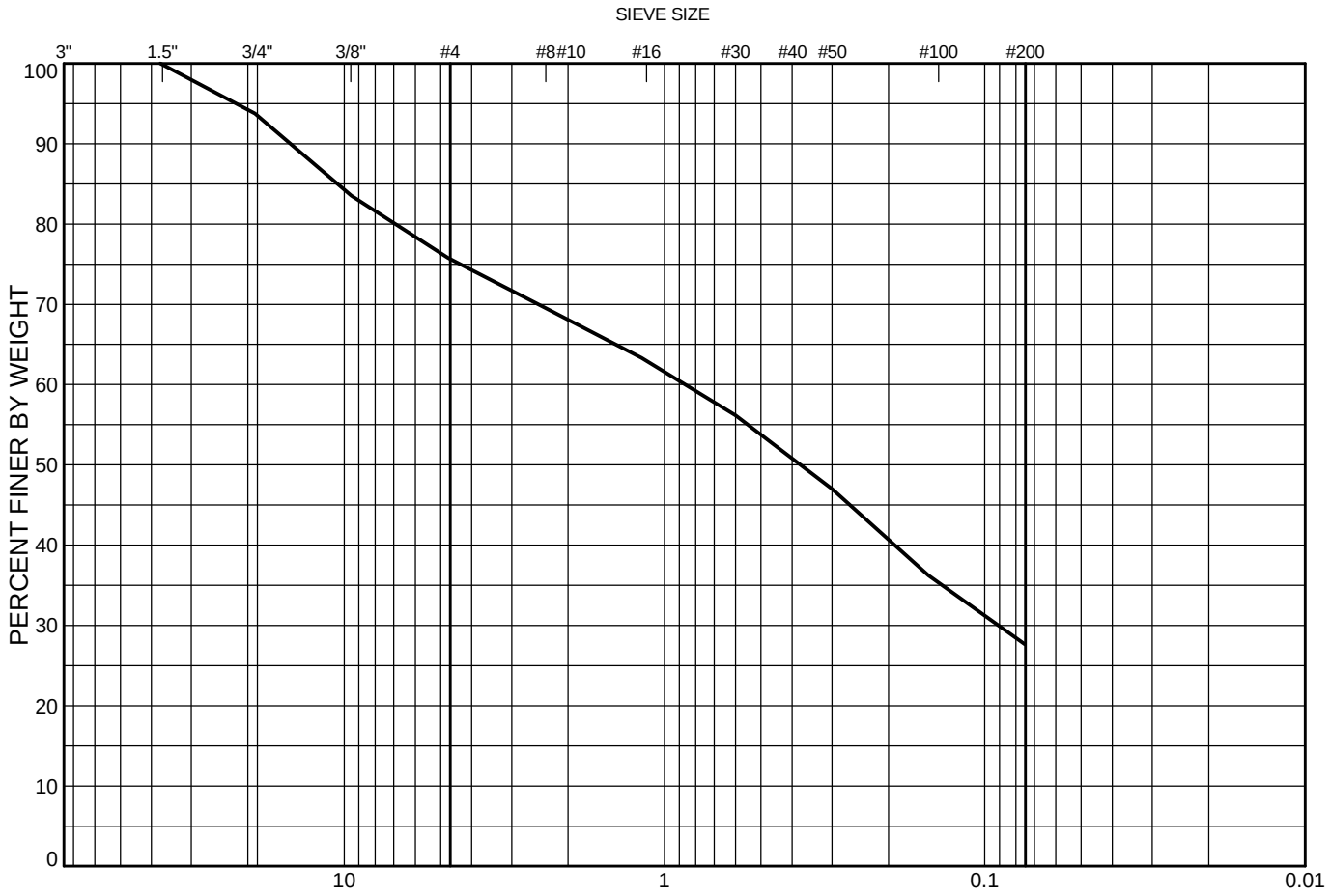
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH15-04**
Sample: 3
Sample Depth: 4.3 m
Date Sampled: April 14, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**24.2%**
Sand	**48.1%**
Fines	**27.7%**
Moisture Content	**9.2%**

D10	
D30	**0.091**
D60	**0.861**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	**100.0**
0.75	19	**93.8**
0.375	9.5	**83.5**
#4	4.75	**75.8**
#8	2.36	**69.6**
#16	1.18	**63.3**
#30	0.6	**56.2**
#50	0.3	**47.0**
#100	0.15	**36.2**
#200	0.075	**27.7**

Description:

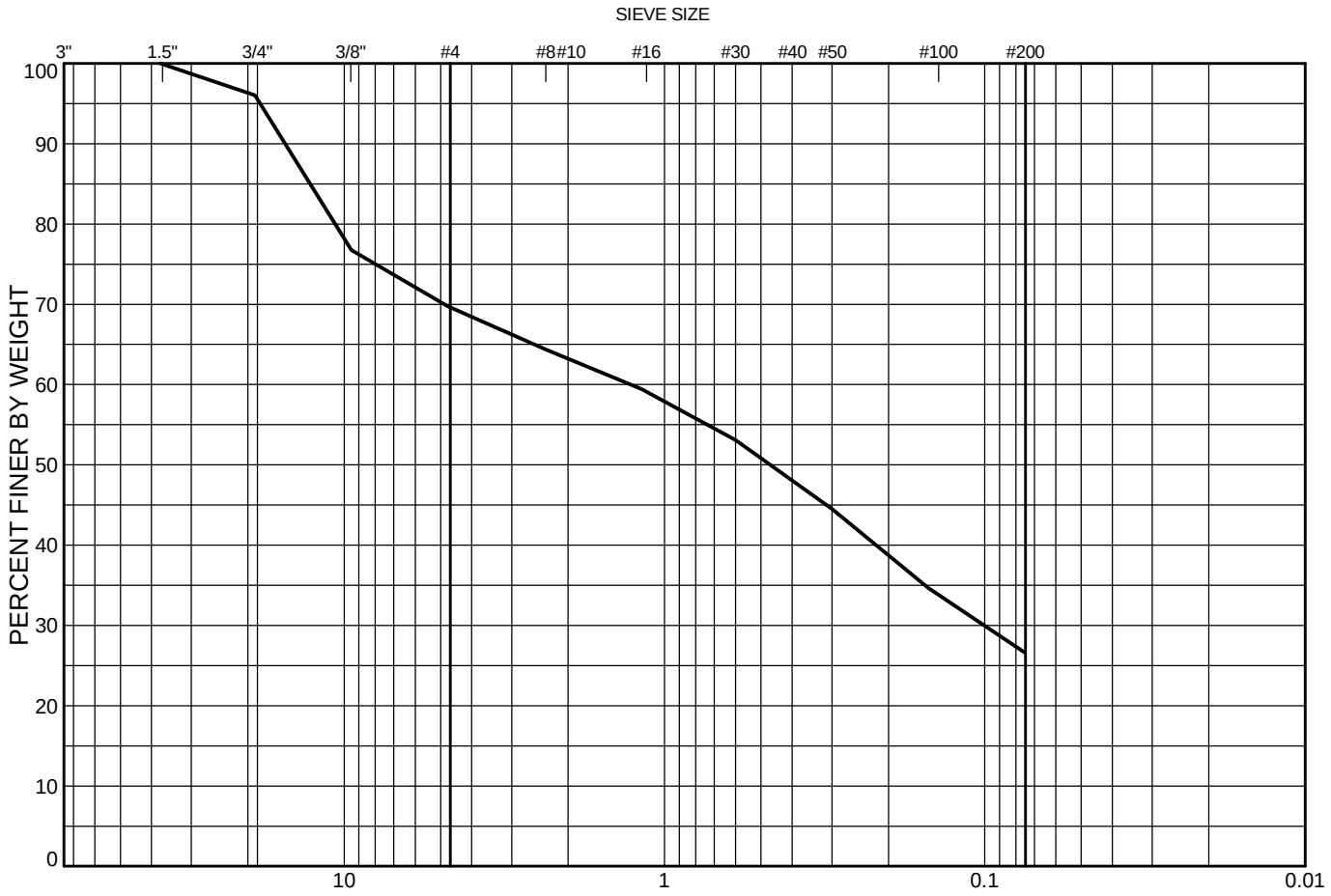
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH15-04**
Sample: 4
Sample Depth: 5.5 m
Date Sampled: April 14, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**30.3%**
Sand	**43.1%**
Fines	**26.6%**
Moisture Content	**9.9%**

D10	
D30	**0.1**
D60	**1.277**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	**100.0**
0.75	19	**96.0**
0.375	9.5	**76.8**
#4	4.75	**69.7**
#8	2.36	**64.4**
#16	1.18	**59.4**
#30	0.6	**53.1**
#50	0.3	**44.5**
#100	0.15	**34.7**
#200	0.075	**26.6**

Description:

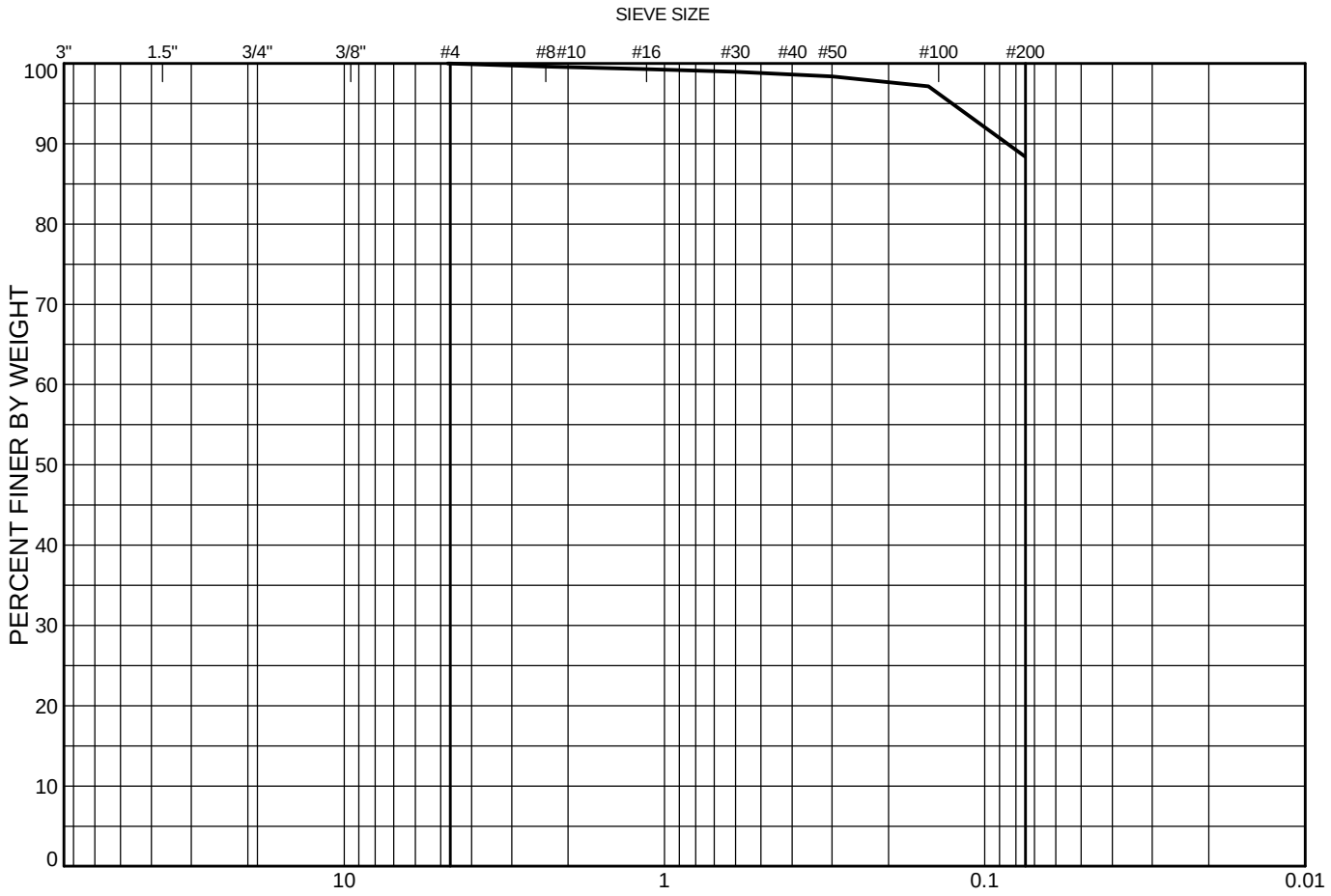
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH15-04**
Sample: 5
Sample Depth: 7.3 m
Date Sampled: April 14, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.0%**
Sand	**11.6%**
Fines	**88.4%**
Moisture Content	**31.4%**

D10	
D30	
D60	
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	**100.0**
#8	2.36	**99.6**
#16	1.18	**99.3**
#30	0.6	**99.0**
#50	0.3	**98.4**
#100	0.15	**97.1**
#200	0.075	**88.4**

Description:

Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH15-15**
Sample: 3
Sample Depth: 4.3 m
Date Sampled: April 15, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**18.3%**
Sand	**38.1%**
Fines	**43.6%**
Moisture Content	**9.9%**

D10	
D30	
D60	**0.261**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	**100.0**
0.75	19	**98.0**
0.375	9.5	**86.7**
#4	4.75	**81.7**
#8	2.36	**78.0**
#16	1.18	**73.9**
#30	0.6	**68.8**
#50	0.3	**61.9**
#100	0.15	**52.5**
#200	0.075	**43.6**

Description:

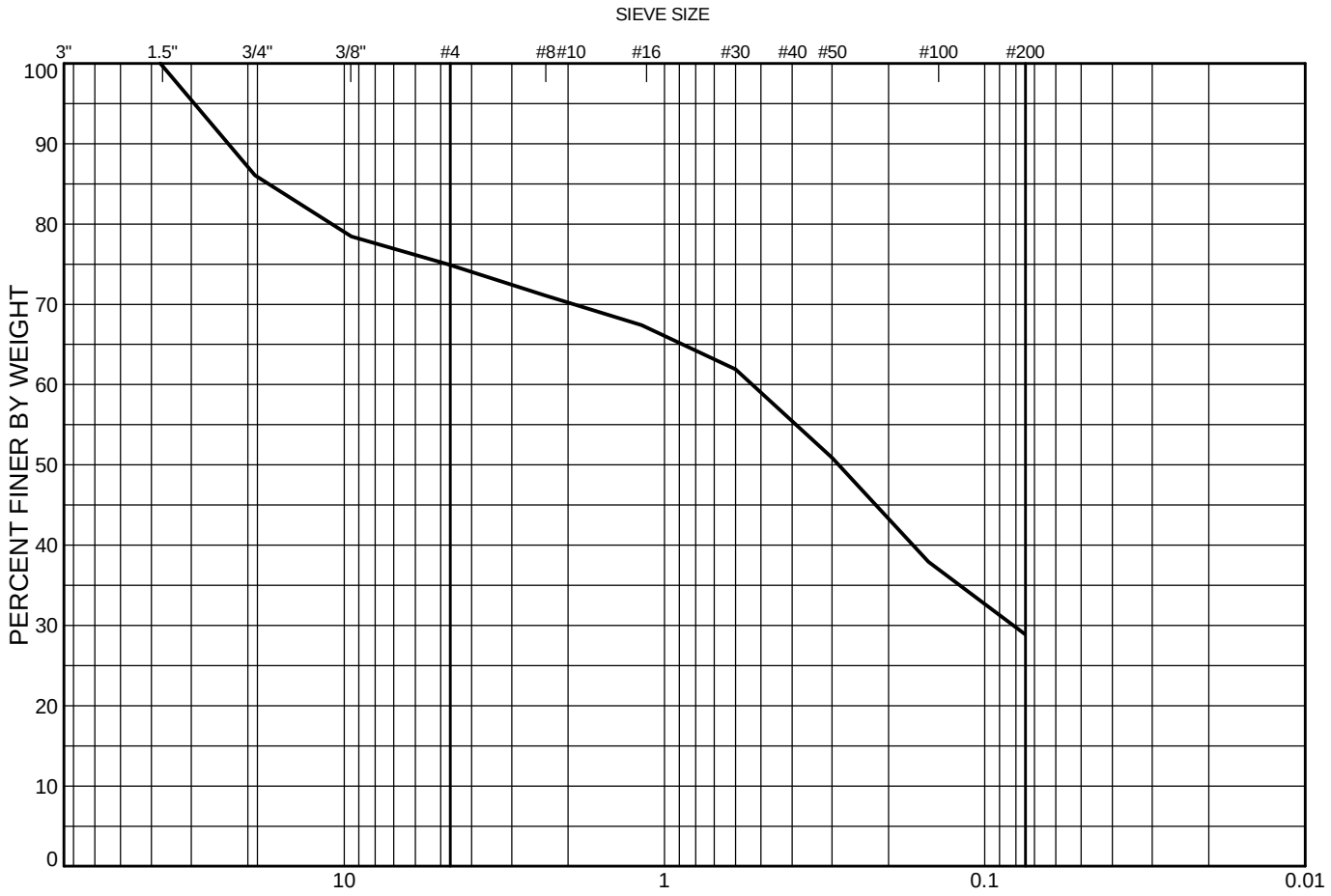
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH15-23**
Sample: 4
Sample Depth: 5.8 m
Date Sampled: April 16, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**25.0%**
Sand	**46.1%**
Fines	**28.9%**
Moisture Content	**13.9%**

D10	
D30	**0.081**
D60	**0.532**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	**100.0**
0.75	19	**86.1**
0.375	9.5	**78.5**
#4	4.75	**75.0**
#8	2.36	**71.1**
#16	1.18	**67.4**
#30	0.6	**61.9**
#50	0.3	**50.9**
#100	0.15	**37.9**
#200	0.075	**28.9**

Description:

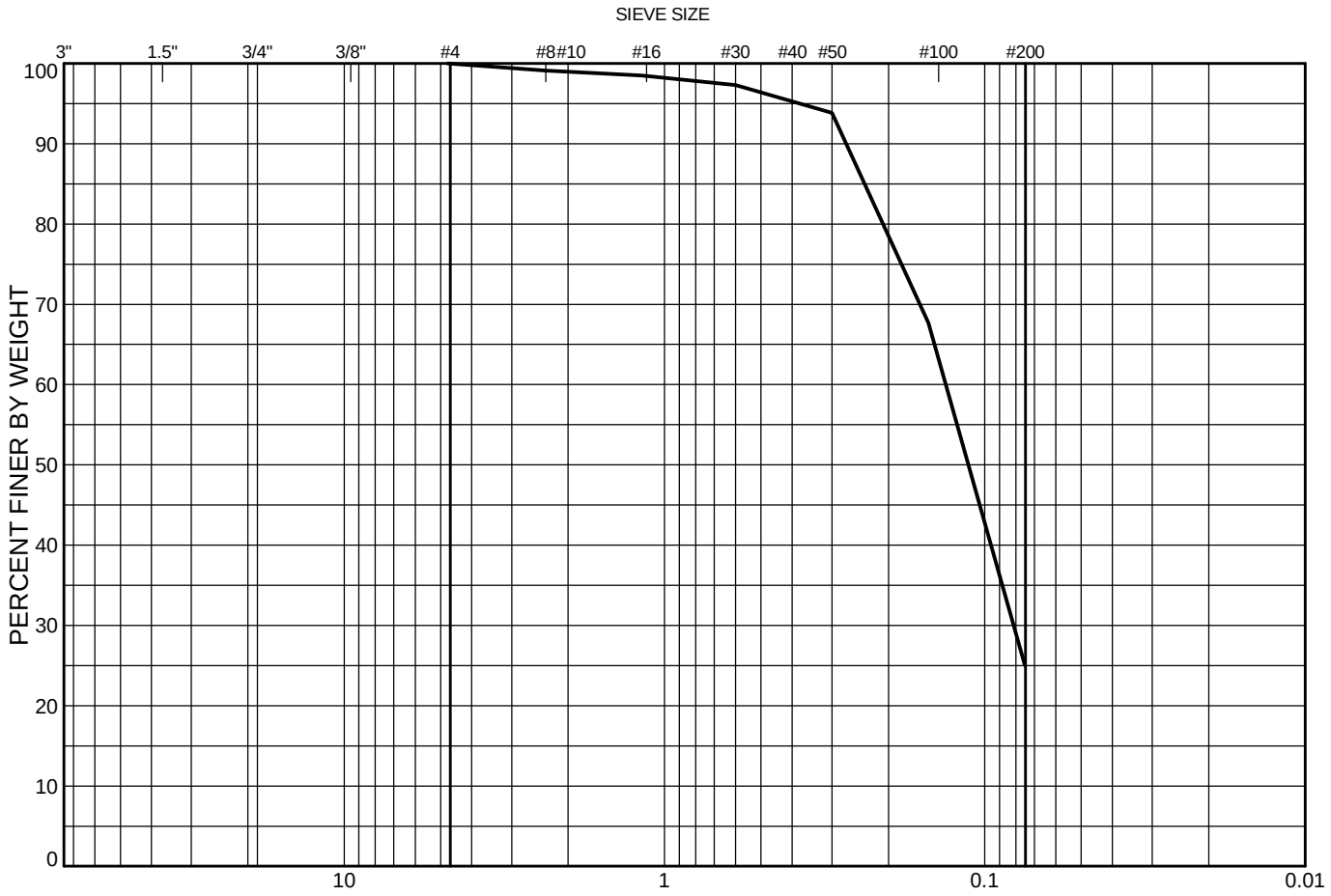
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH15-23**
Sample: 5
Sample Depth: 7.0 m
Date Sampled: April 16, 2015
Sampled By: CHS
Date Received: April 20, 2015
Date Tested: April 20-23, 2015
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.0%**
Sand	**75.0%**
Fines	**25.0%**
Moisture Content	**25.4%**

D10	
D30	**0.081**
D60	**0.132**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	**100.0**
#8	2.36	**99.1**
#16	1.18	**98.5**
#30	0.6	**97.3**
#50	0.3	**93.8**
#100	0.15	**67.7**
#200	0.075	**25.0**

Description:

Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

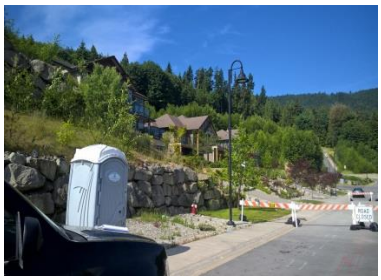
GRAIN SIZE DISTRIBUTION

CLIENT: Sechelt, District of
PROJECT: Seawatch at The Shores Subdivision
Lots 9 & 21 Sinkholes
FILE NO.: 14-214-4

THURBER

APPENDIX 5

DMT Geosciences Ltd. Geophysical Investigation Report









The Shores-Phase 1 Subdivision Geophysical Investigation

Effective Date: July 14, 2015
Issue Date: July 14, 2015
File Number: VGAA.044

Prepared for:

Thurber Engineering Ltd.

Prepared by:

DMT Geosciences Ltd.
Vancouver, BC, Canada

TABLE OF CONTENTS

TABLE OF CONTENTS i
LIST OF FIGURES i
ABBREVIATIONS ii
1.0 INTRODUCTION 1
1.1 Site Description 1
2.0 METHODS 3
2.1 Ground Penetrating Radar (GPR) 3
2.2 Multichannel Analysis of Surface Waves (MASW) 4
3.0 RESULTS AND INTERPRETATION 6
3.1 GPR 160 MHz antennas compared with 80 MHz antennas 6
3.2 Gale Avenue Focus Area 8
3.2.1 Gale Avenue GPR Data 8
3.2.2 Gale Avenue MASW 13
3.3 Seawatch Focus Area 17
3.4 Reconnaissance GPR Survey 22
4.0 CONCLUSION AND RECOMMENDATIONS 29
5.0 APPENDIX 30
5.1 Areas with short non-coherent reflections 31
5.2 Bright Reflections 32
5.3 Diffractions 34

LIST OF FIGURES

Figure 1-1: Site location and survey lines. 2
Figure 2-1: GPR section 4
Figure 2-2: Basic MASW inversion process 5
Figure 3-1 Comparison between 160 MHz and 80MHz GPR 7
Figure 3-2 Site location and survey lines of Gale Avenue Focus Area. 8
Figure 3-3 GPR line DAT_0111 along Line H-H. 10
Figure 3-4 GPR Line DAT_0112 over Line I-I. 11

Figure 3-5 GPR Line DAT_0115 12

Figure 3-6 GPR Line over Lot 20 and Lot 21.....13

Figure 3-7 Cross-section of data collected over Line H-H.....15

Figure 3-8 Cross-section of data collected over Line I-I.....16

Figure 3-9 Site location and survey lines of Seawatch Focus Area. 17

Figure 3-10 GPR line through Line N-N (DAT0118). 19

Figure 3-11 GPR line through Line N-N (DAT0120). 20

Figure 3-12 MASW line along Line N-N 21

Figure 3-13 MASW Sounding over Line M-M. 22

Figure 3-14 Map showing target areas.....24

Figure 3-15 GPR line through Area 1 and 2 (DAT0111).. 25

Figure 3-16 GPR line through Area 2 (DAT0112).. 26

Figure 3-17 GPR line through Area 3 (DAT0154). 27

Figure 3-18 GPR line through Area 4 (DAT0147). 28

ABBREVIATIONS

GPR	Ground Penetrating Radar
MASW	Multichannel Analysis of Surface Waves
UTM	Universal Transverse Mercator

1.0 INTRODUCTION

DMT Geosciences Ltd. was commissioned by Thurber Engineering Ltd. to conduct a geophysical investigation to map soil stiffness anomalies and subsurface soil interfaces in the vicinity of The Shores – Phase 1 Subdivision near Sechelt, British Columbia. Based on the soil stratigraphy data provided by Thurber, soil stratigraphy is complex and varies around the site. It is our understanding that there sand, silt and sandy silt/silty sand deposits and that there is potential piping of fine sand and non-plastic silt that may be occurring. This piping and material loss can lead to the development of voids and sink holes. It was anticipated that differences in stiffness between the interpreted soil units at this site and differences in stiffness between undisturbed soil and soil affected by the sinkhole formation process would be measurable. We conducted a combination of geophysical surveys to measure soil stiffness anomalies and subsurface soil interfaces that may be present on site to assist the targeting of areas for further investigation as these areas may have potential for the development of sinkholes. This included a test over known sinkholes. Data acquisition occurred May 26th through May 29th, 2015. Two geophysical methods were collected: Ground Penetrating Radar (GPR) and Multichannel Analysis of Surface Waves (MASW).

DMT is only able to identify anomalous areas and areas that fit the assumed subsurface geophysical signature of potential underground hazards as targets for follow up. It is beyond the scope of DMT's expertise to identify hazards that may pose a risk to surface activity. DMT's conclusions and the data need to be evaluated by a qualified Professional Geotechnical Engineer who can follow up on the targets identified by DMT and evaluate the potential for underground hazards and the risk they pose.

1.1 Site Description

The site location is located approximately 4.5 km north-west of Sechelt, British Columbia and is a 28 residential lot development roughly 200 by 400 m. Site location and survey lines are shown in Figure 1-1. GPR collection was done along the perimeter of Seawatch Lane in the south and Gale Ave in the north. Several parallel GPR lines were collected on Gale Ave between Lots 7 and 11 with 3 transverse lines between Lots 9 and 21. A tight GPR survey grid was also collected near the south-east portion of Seawatch Lane where a sinkhole collapse that occurred in 2012 had been filled and on the adjacent Lot 28. Several GPR lines were collected on Lot 27 and one GPR line was collected running parallel to Seawatch Lane behind the houses on Lots 20 and 21. Because of the limited time frame, priority areas were determined for the MASW survey. Three MASW 2D profile lines were collected (Lines H-H, I-I and N-N) while another 1D profile was collected at Thurber test hole TH15-25 along Line M-M (Figure 1-1). The Easting and Northing coordinates are the Zone 10N UTM projection of the NAD83 datum.

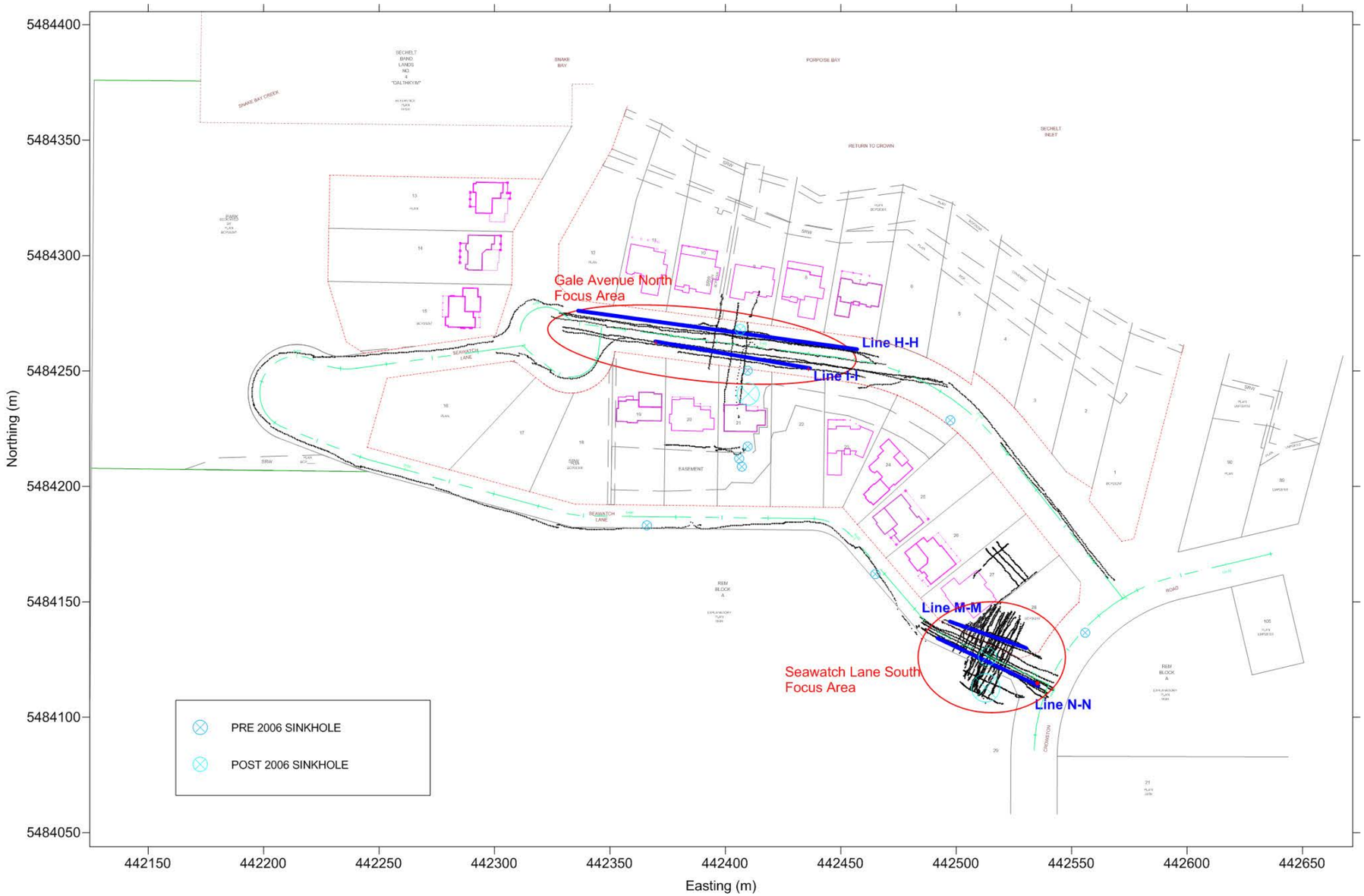


Figure 1-1: Site location and survey lines. Black points and lines indicate GPR collection and blue lines indicate the MASW lines.

2.0 METHODS

2.1 Ground Penetrating Radar (GPR)

Radio detection and ranging (radar) uses high frequency (10 MHz to 1000 MHz) electromagnetic (EM) waves to image the subsurface by precisely measuring the time taken by the emitted waves to reach an interface of contrasting electrical impedance and return to the receiver. Two-dimensional profiles of the subsurface recorded by the GPR system are referenced to signal travel times. The conversion from travel time to depth requires the accurate determination of the velocity of the medium traversed, often by correlation with borehole logs, the results of complementary geophysical methods and/or published velocities for various subsurface materials. For this survey an analysis of diffractions identified in the data was used to determine an average velocity of 0.1m/s. As velocities can vary within a survey area, depths calculated will be approximate only. Verification with drill data and possible recalculation of depths with a different velocity may be necessary.

The velocity and attenuation of radar signals within the subsurface depend on the dielectric and conductivity properties of subsurface materials. Variations in the electrical properties of soils and rocks are usually associated with changes in grain size and/or water content which, in turn, cause part of the emitted signal to be reflected. The reflected signal is detected by the receiver where it is amplified, digitized and stored for subsequent data processing and interpretation.

GPR penetration depth is limited primarily by the conductivity of subsurface materials. High proportions of clay material and/or total dissolved solids within groundwater can severely reduce the effective exploration depth. Although depth penetration can often be increased by reducing GPR antenna frequency, vertical resolution is compromised accordingly. To optimize both penetration depth and horizontal resolution, preliminary testing of acquisition parameters specific to each survey environment is generally required. The correct choice of antenna frequency is paramount. We used two antenna frequencies: 80 MHz and 160 MHz.

An example of a GPR section from another site showing the response of a sinkhole caused by an airshaft is shown in Figure 2-1, below. A sinkhole was caused by an airshaft which had been backfilled but the exact location of the airshaft was unknown. The GPR shows disturbance of the ground near the airshaft and distinguishes between the surrounding undisturbed grounds.

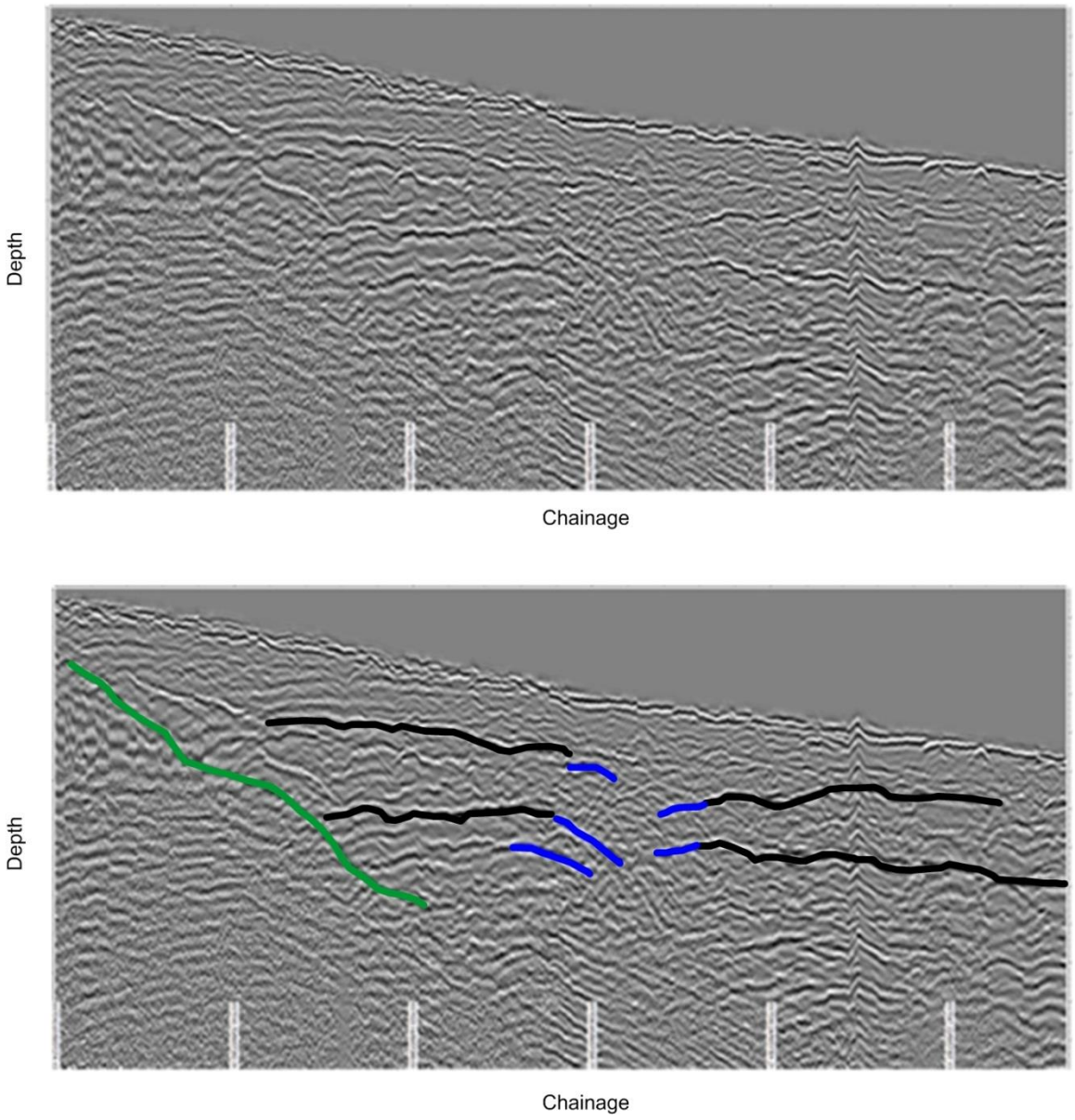


Figure 2-1: GPR section (top panel) and interpreted section (bottom panel) showing underground slumping (blue lines) with disturbed material and undisturbed material (black lines). Reflection from sloping bedrock is indicated with a green line.

2.2 Multichannel Analysis of Surface Waves (MASW)

The MASW survey was collected by towing a geophone land streamer that had 24 geophones with a separation of 5 feet. The signal source was a 20 lb sledgehammer. Recordings were made with a source 5 feet (1 geophone spacing) behind the streamer and stepped forward along the survey line creating a 2D profile.

The MASW method evaluates the elastic properties (stiffness) of the near surface soils(maximum of about 30 m deep, depending on survey parameters) using surface waves which are also known as the ground roll. Upon analysis of the propagation of the surface waves, the variations in the shear wave velocity (Vs) can be calculated below the survey area. The shear wave velocity is generally a direct indicator of the stiffness of the ground and therefore can be useful for use in geotechnical engineering applications.

Computer software is used to analyze the dispersion of the surface waves. Through an inversion process of the raw data, a best fit of the field data is obtained. This best fit prediction is therefore an approximated and averaged value based on the available data. Actual shear wave velocities may vary and may be higher or lower than those depicted on the sections. In general contrasts in the shear wave velocities in the resulting 2D sections will be representative of changes in the soil or rock properties. However the absolute values of those shear velocities should not be used as a direct detection tool based on thresholds and the absolute Vs values may not necessarily agree with other more direct testing methods. Also it should be kept in mind that as with all geophysical methods, lateral and vertical resolution decreases with depth of investigation.

The depth of investigation of MASW is dependent on the sensor array length, frequency content of the source/receivers and shear wave velocity of the soil. It may be less than 30 m in looser sediments where the signal suffers greater attenuation, or where array length is limited by logistical issues, which limits the spatial wavelength of the signal. MASW is also considered less accurate in the top one metre.

Figure 2-2 is a schematic of the basic MASW inversion process. It begins with the field shot record which is used to create a measured dispersion curve. By means of an initial model, it generates a theoretical dispersion curve to fit the data. This iterative process is performed until the RMS error is reduced sufficiently while maintaining a realistic dispersion curve/earth model. The optimal dispersion curve is then converted into the final Vs model. The resulting shear wave data is plotted at the centre of the geophone array, and is referred to as a “1-D” (one-dimensional) MASW sounding. A series of 1D inversions are interpolated to create a 2D section.

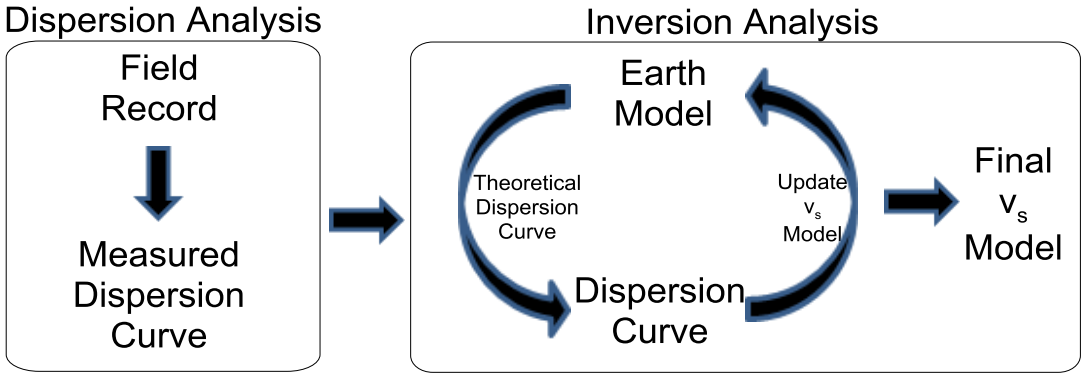


Figure 2-2: Basic MASW inversion process

3.0 RESULTS AND INTERPRETATION

Three lines of 2D MASW data were collected in the survey area as well as one 1D MASW sounding. Based on the inspection of the dispersion curves and the low number of velocity outliers (noisy readings) the MASW data quality was judged to be reliable. The shear wave velocity Vs was calculated to a maximum depth of 30 m, but only the top 15 m are displayed as this is the depth of interest. There is no indication in the data alone of any more or less reliability in the top 15 m from line to line. However it should be noted that data resolution decreases with depth. Ground Penetrating Radar (GPR) was collected in two focus areas as well as along limited areas of the side roads as shown in Figure 1-1. Two frequencies of antennas were used in the survey. The GPR surveys were generally completed using the 160 MHz antennas. One line was collected with both the 160 MHz antennas and the 80 MHz antennas in order to compare the resolution and depth of penetration obtained from the different frequencies. Data from the 160 MHz GPR survey showed useable reflections up to a maximum depth of approximately 6 to 8 m, while those from the 80 MHz survey showed reflections to about 14 m depth.

3.1 GPR 160 MHz antennas compared with 80 MHz antennas

In order to test the difference between 160 MHz and 80 MHz at this site, one line was collected with both antennas. The results of these surveys are shown in Figure 3-1. It can be seen in the upper panel that the 160 MHz antennas produce a more detailed survey, but the penetration depth was limited. The reflections are generally consistent between frequencies. Smaller features are seen and the larger features are more defined in the 160 MHz. The 80 MHz antennas identified many of the same features as the 160 MHz antennas and were able to see approximately 5 m deeper. The deeper reflections are, however, less well defined than those in the upper 10 m.

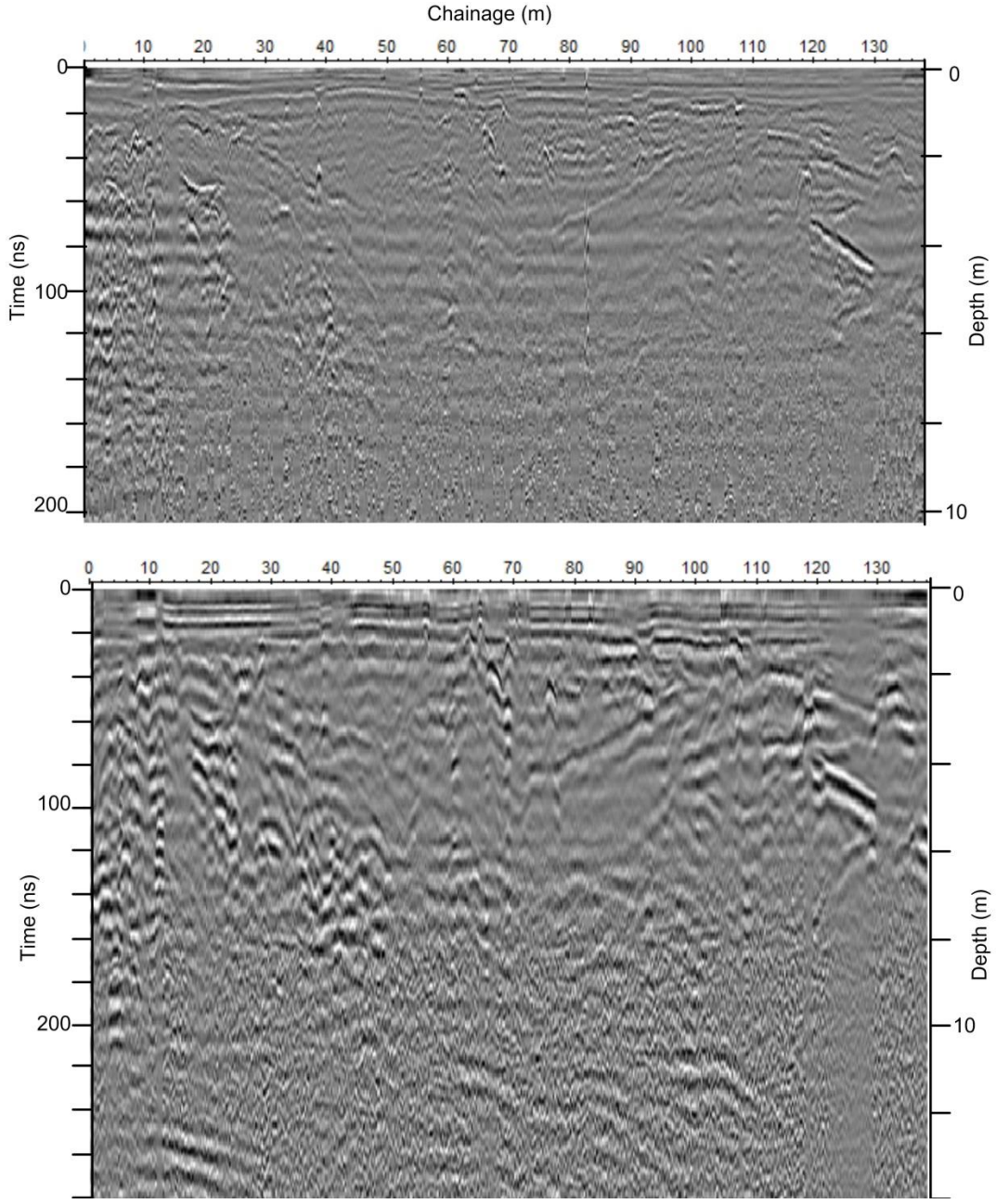


Figure 3-1 Comparison between 160 MHz GPR survey (upper panel) and 80 MHz antenna GPR survey (lower panel)

3.2 Gale Avenue Focus Area

In the Gale Avenue focus area a number of GPR lines were collected as well as two MASW lines. A map of the Gale Avenue Focus Area is shown in Figure 3-2.



Figure 3-2 Site location and survey lines of Gale Avenue Focus Area. Black points and lines indicate GPR collection and blue lines indicate the MASW lines.

3.2.1 Gale Avenue GPR Data

Several GPR lines were specifically collected to coincide with Lines H-H and I-I as identified in geotechnical data from the Thurber drilling investigation April, 2015. The GPR data over Line H-H is shown in Figure 3-3 and the data from Line I-I is shown in Figure 3-4.

Several reflectors can be seen dipping towards each other in Line H-H and are highlighted in yellow in the bottom panel of Figure 3-3. The area in between has been identified with a red oval in the upper panel between chainage (distance along survey line) 60 and 90 m. This area corresponds with a loose zone as identified in Thurber geotechnical data on Line H-H. There is a textural difference in the appearance of the GPR data between chainage 110 and 140 m consisting of a concentrated area of non-coherent, short reflectors (circled in red). This region may correspond with disturbed sediments so we have termed this as a “disturbed zone”. Another explanation could be that the region is composed of fill of variable composition containing cobbles/boulders. Another feature of note is outlined in purple in the upper panel of

Figure 3-3 at chainage 78 m. This discrete bright reflector may be caused by the presence of the void which was identified in Thurber test hole BH15-16.

GPR data collected on Line I-I also has a number of reflectors dipping towards each other as outlined in yellow on the lower panel in Figure 3-4. The reflectors do not appear to be at as steep an angle compared to H-H, and a horizontal reflector is noted (red circle) at a depth of 6 m between chainage 50 and 80 m. A zone of non-coherent reflectors is noted between chainages 118 and 155 m which may be caused by disturbed sediments (red circle). A GPR feature circled in purple in the upper panel of Figure 3-4 at chainage 90 m has the characteristics of void response in the subsurface.

Hyperbolic features called diffractions can be seen in both Figure 3-3 and Figure 3-4. Diffractions are caused by features such as underground utilities or boulders. These diffractions are marked in green in both Figure 3-3 and Figure 3-4.

Several transverse lines were collected between Lots 9 and 21 north and south of the Gale Avenue Focus Area. The easternmost of these lines crosses two of the previously identified sinkholes in Lot 21. Several reflectors can be seen dipping between chainage 0 and 16 m which has been identified with a red oval in the upper panel in Figure 3-5. There is a break in the dipping horizons at chainage 6 m. Within the area of dipping reflectors, there appears to be a textural difference in the GPR data.

Additional GPR lines were collected south of the Gale Avenue Focus Area where features were identified on Lots 20 and 21. The survey location is shown in Figure 3-2. GPR data on Lots 20 and 21 are shown in Figure 3-6.

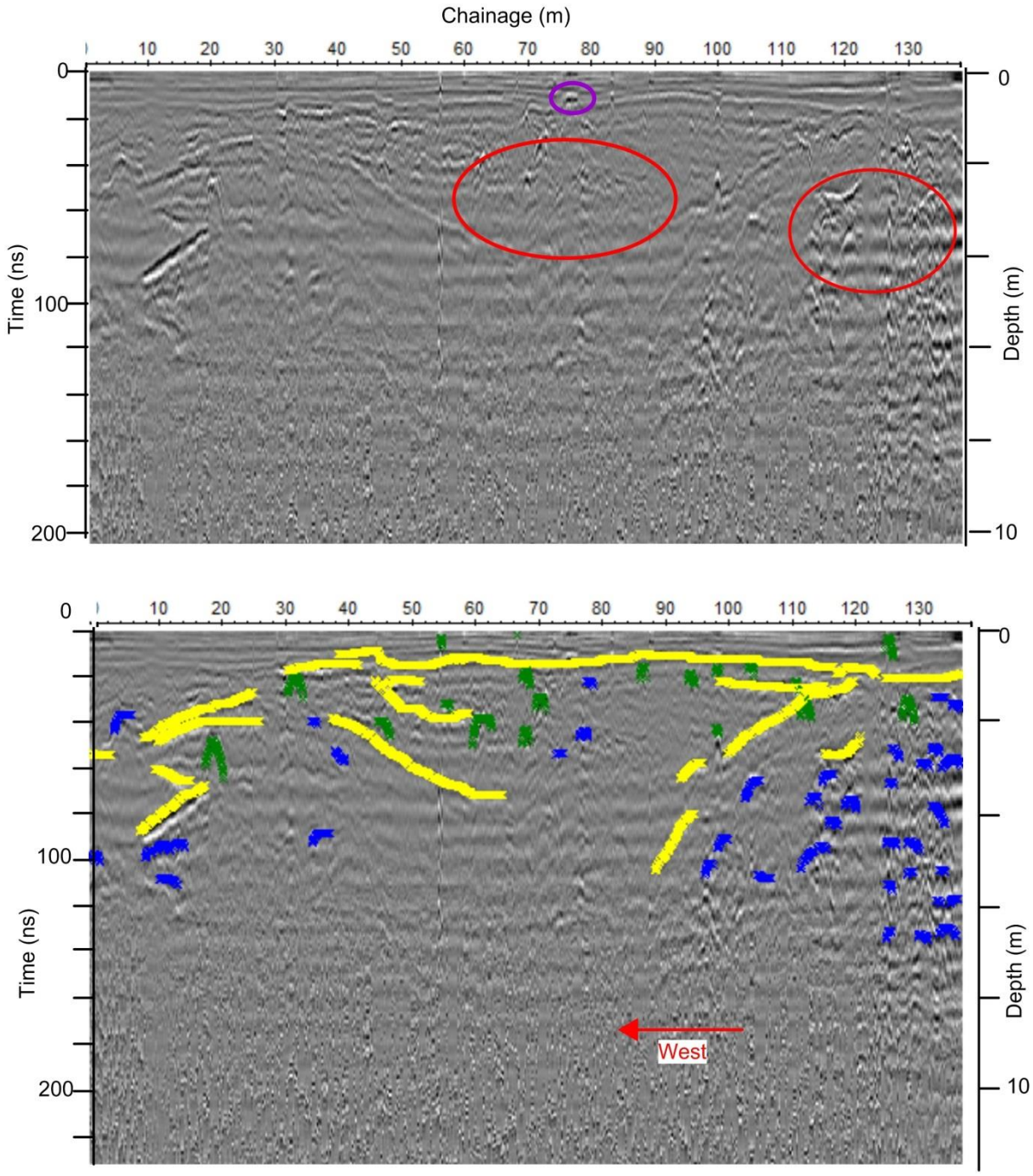


Figure 3-3 GPR line DAT_0111 along Line H-H. Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The purple circle indicates a bright reflector while the red circles indicating areas of interest described above.

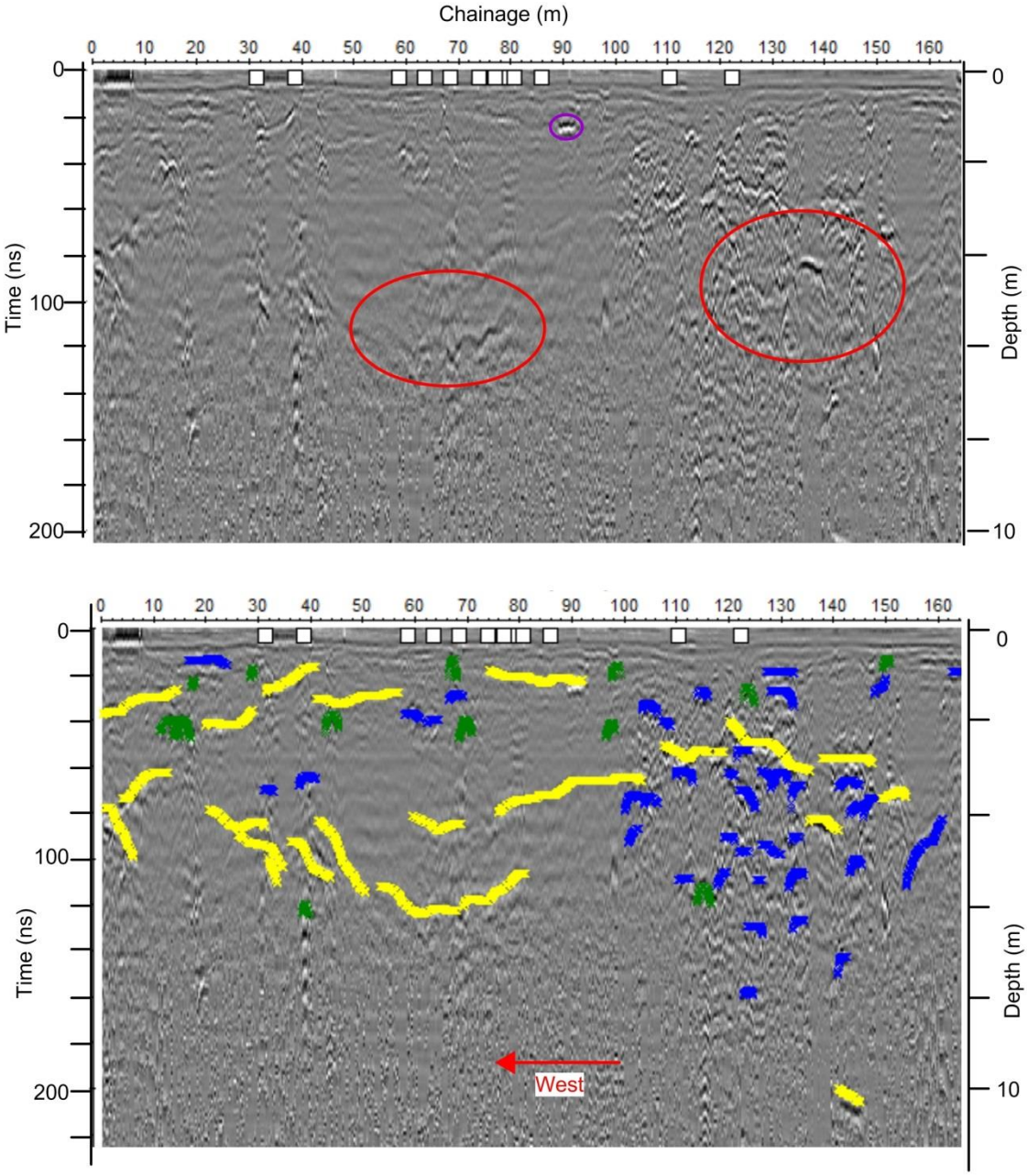


Figure 3-4 GPR Line DAT_0112 over Line I-I. Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The purple circle indicates a bright reflector while the red circles indicate areas of interest described above.

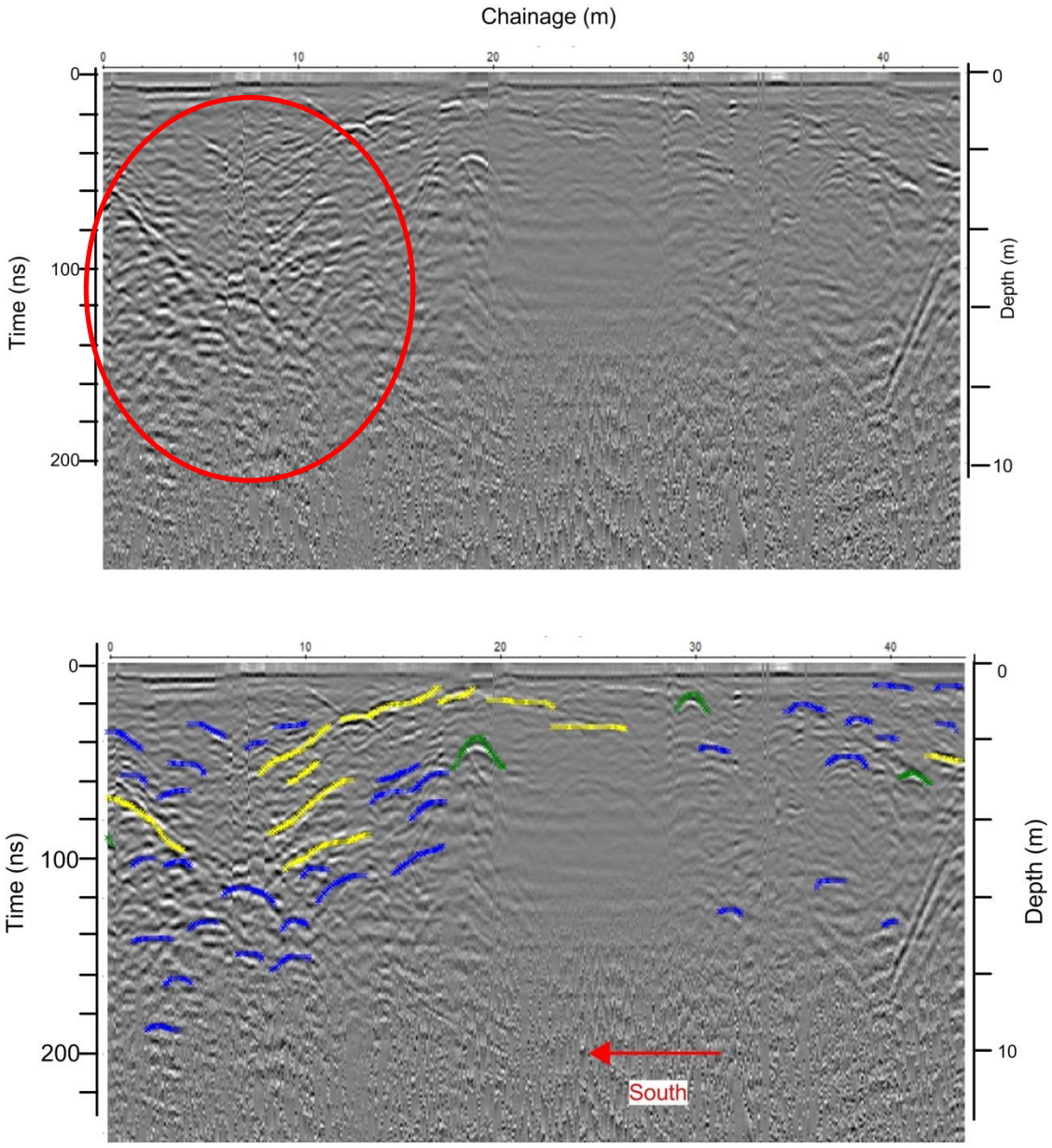


Figure 3-5 GPR Line DAT_0115 transverse line in Gale Avenue Focus Area. Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The red circle indicates an area of interest described above.

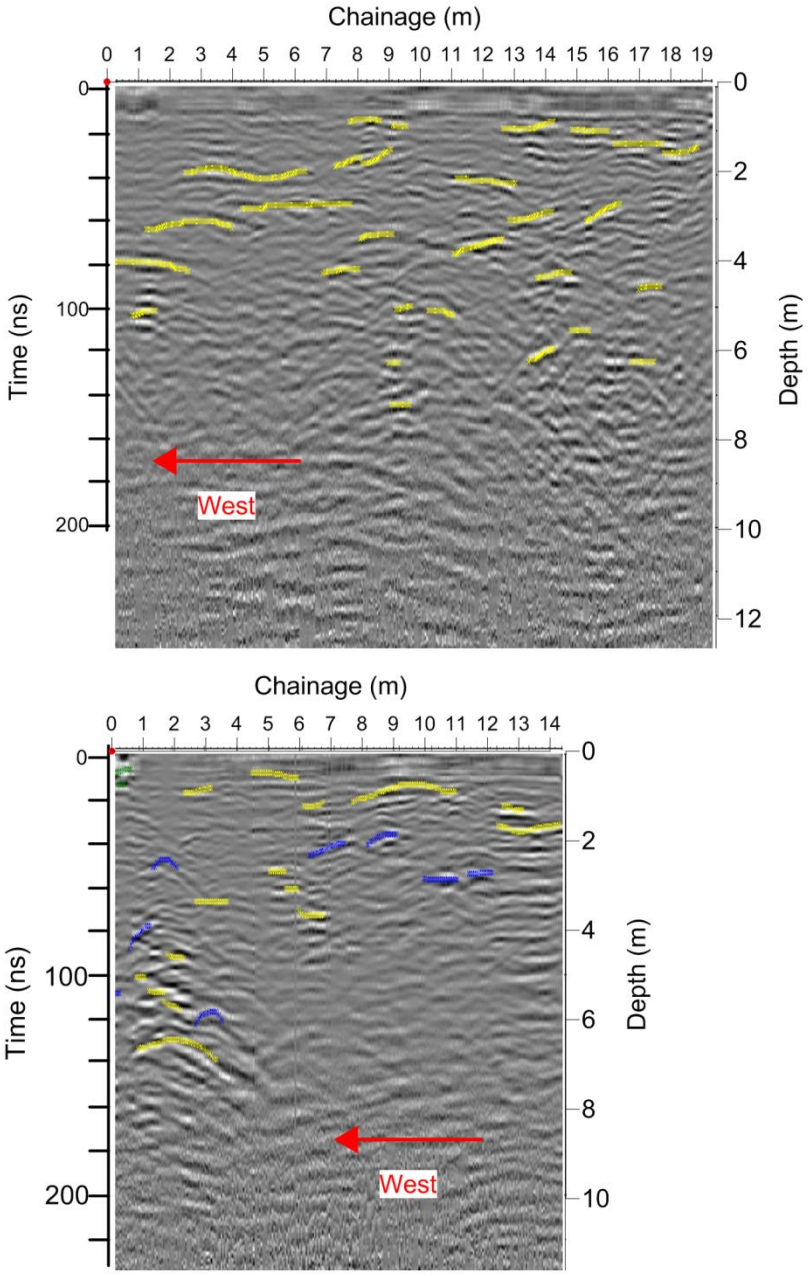


Figure 3-6 GPR Line over Lot 20 (DAT_0161 - top panel) and Lot 21 (DAT_0159 – bottom panel) south of Gale Avenue Focus Area. Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in blue. Green reflection at 0 m chainage on bottom panel is from drain gate.

3.2.2 Gale Avenue MASW

MASW data was collected over both Lines H-H and I-I, with Line H-H collected approximately 1.5 m north of drill lines and test holes and Line I-I collected approximately 0.2 m south of drill lines and test holes. The results of these surveys are shown in Figure 3-7 and Figure 3-8. GPR reflections identified in Section 3.2.1 are overlain on the MASW results. Also overlain is the

approximate location of loose sediments identified in geotechnical drilling investigation results provided by Thurber Engineering.

MASW results from Line H-H identify several low Vs zones. The main low velocity zone occurs between depths of 4 and 8 m. The lowest velocities occur east of chainage 52 m and extend to the edge of the survey. A small low velocity zone can be seen in the upper 4 m on the western edge of the survey

Both 160 MHz and 80 MHz data were collected over Line H-H. The deeper reflections are from the 80 MHz data and appear to correspond with a marked increase in seismic velocity. The low velocity zones coincide with a significant number of short, non-coherent GPR reflections which may be indicative of disturbed sediments. It should be noted that the GPR data beyond the eastern edge of the MASW survey suggest that this low velocity zone may continue to the east. A second low velocity zone occurs centred at chainage 33 m.

There is reasonable correlation with geotechnical data on Line H-H, though the slightly higher (15 m/s) shear wave velocity between 4 and 6 m depth is not seen in the data from Thurber hole TH15-01 which is located 1.5m south of the MASW survey location. The difference in results may be due the distance between the MASW line and hole TH15-01. Another cause for the difference between results may be the difference in the averaging effect of the two methods.

The MASW results from Line I-I show a low velocity zone centred at chainage 53 m between 2 and 6 m depth. Another low velocity zone can be seen at the eastern edge of the survey line between 0 and 6 m depths east of chainage 62 m.

160 MHz GPR data were collected on Line I-I. Reflections identified in the GPR data are overlain on the MASW data in Figure 3-4 . GPR reflections in the low velocity zone on Line I-I are non-coherent and scattered and may be related to disturbed sediments. This zone of non-coherent and scattered reflections extends beyond the eastern edge of the MASW survey which suggests the low velocity zone may also extend to the east.

The loose sediment zone identified in the geotechnical drilling investigation results is overlain on the MASW cross-section. The velocities recorded within this loose zone are low, but not as low as the velocities identified in the eastern portion of the survey and were not lower than beyond this zone where test holes did not encounter loose zones. This suggests that smaller loose zones identified by drilling investigations may not be detectable with the MASW method using these survey parameters. However the GPR did detect anomalies here, which suggests that the combination of methods is more useful than either method alone.

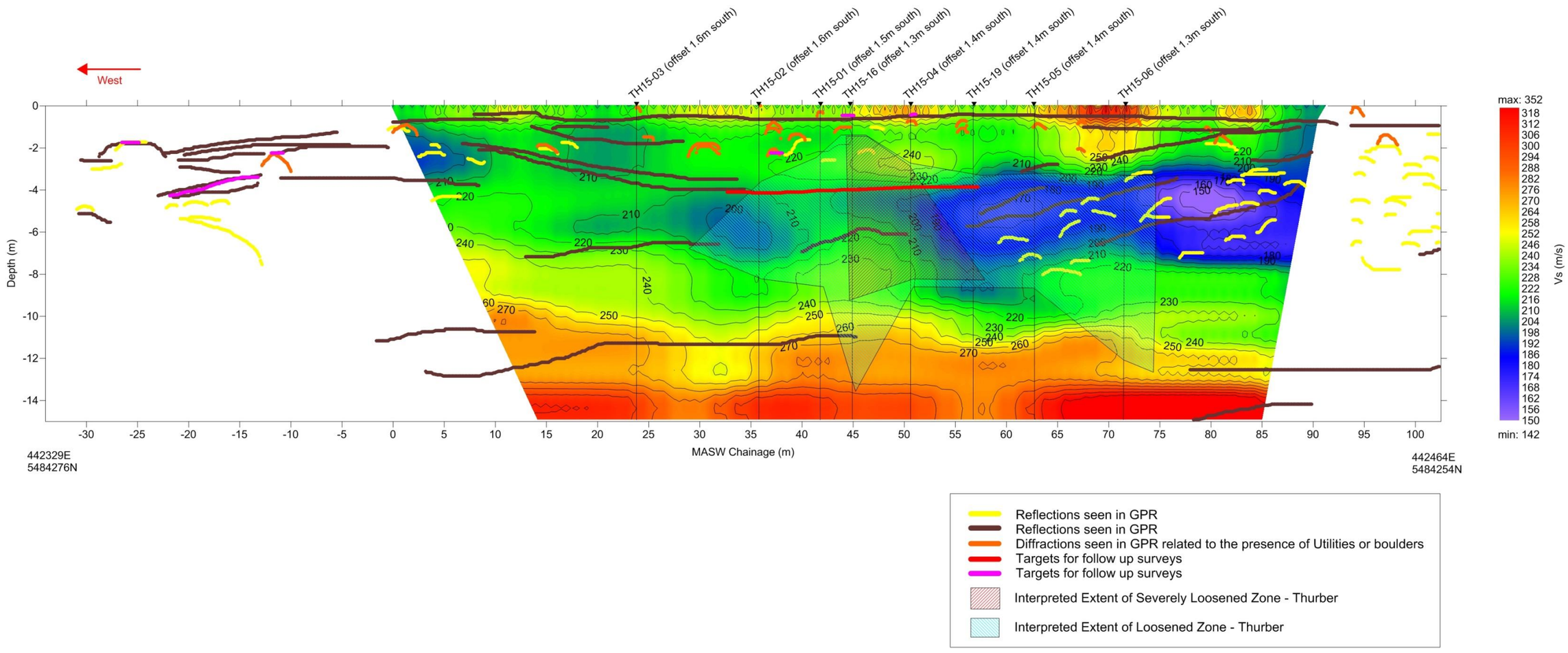


Figure 3-7 Cross-section of data collected over Line H-H. Colour contour of Vs with GPR reflections overlain.

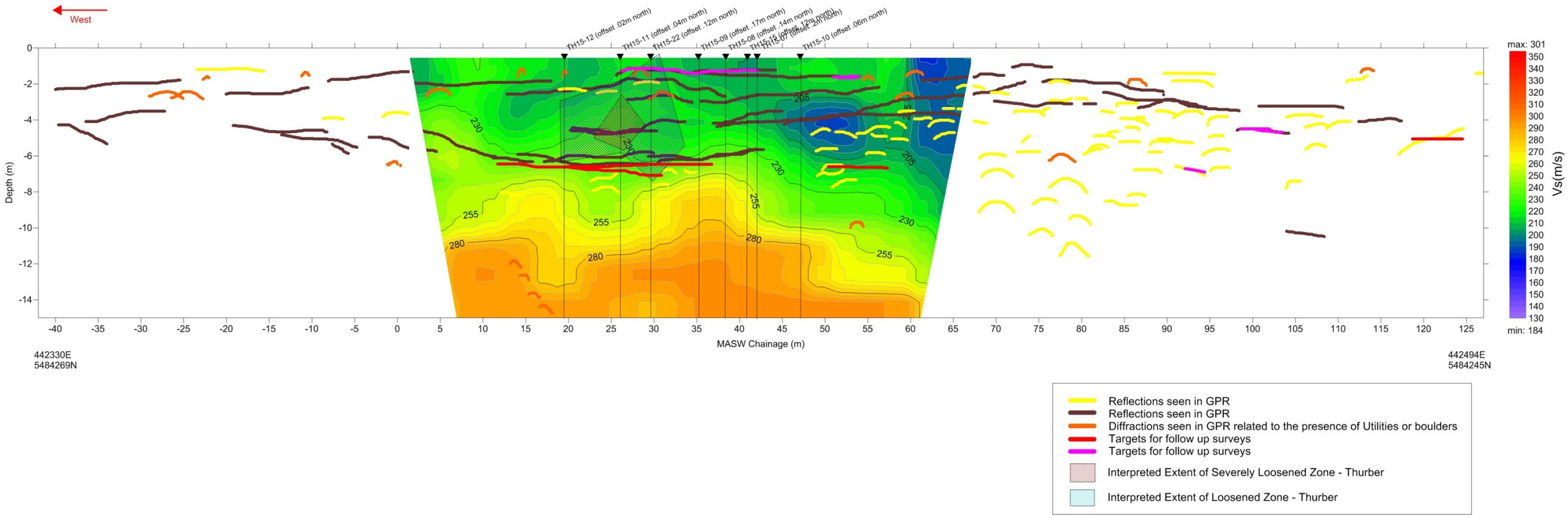


Figure 3-8 Cross-section of data collected over Line I-I. Colour contour of Vs with GPR reflections overlain.

3.3 Seawatch Focus Area

A concentrated grid pattern of GPR data was collected over the area of the 2012 Seawatch Lane sinkhole. In addition, a line of 2D MASW data was collected parallel to Seawatch Lane in a line (termed Line N-N) selected to coincide with an observed depression in the asphalt as directed by Thurber. A single sounding of 1D MASW data was collected over Line M-M. A map of the Seawatch Focus Area is shown in Figure 3-9.

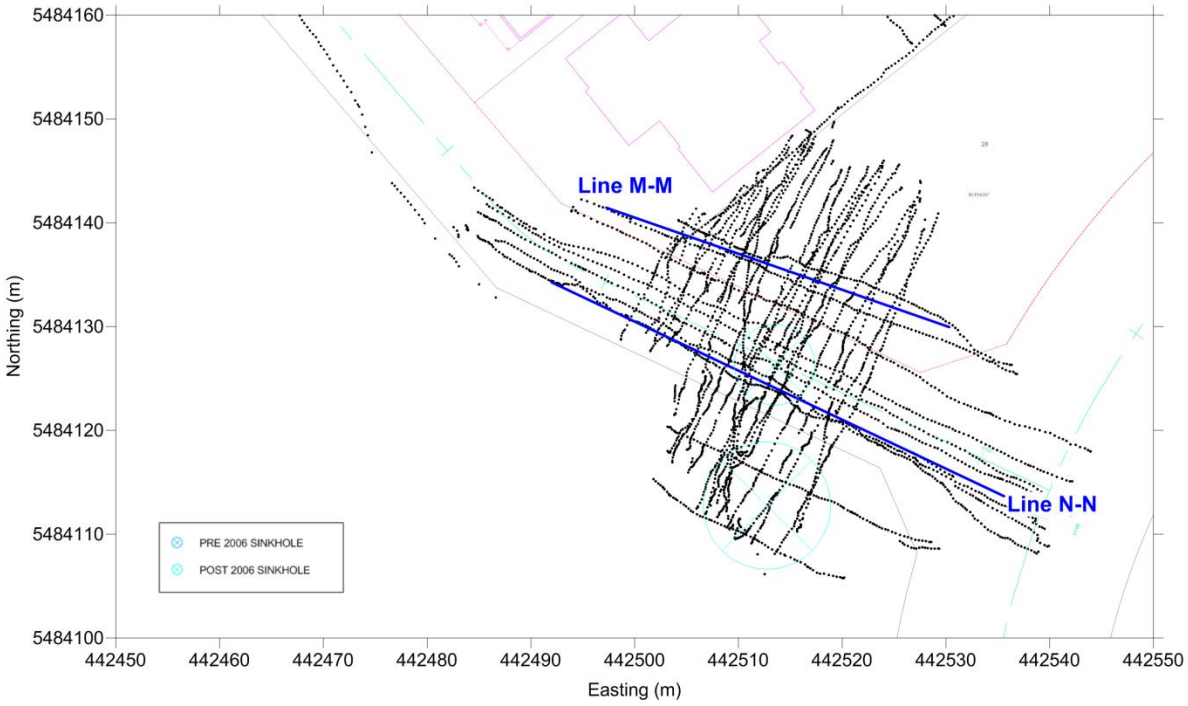


Figure 3-9 Site location and survey lines of Seawatch Focus area. Black points and lines indicate GPR collection and blue lines indicate the MASW lines.

Two GPR lines near the location of MASW Line N-N are shown in Figure 3-10 and Figure 3-11 .

In GPR Line DAT-118, a number of reflections were identified and are outlined in yellow, green and blue in Figure 3-10. The green reflections are diffractions caused either by underground utilities or boulders. One of the reflections has a distinctive depression at the location of a hole observed in the asphalt surface at chainage 32 m. Reflections below and to the east of this point are non-coherent and may be indicative of disturbed sediments. This area is circled in red in the upper panel of Figure 3-10. Another feature of interest can be seen in the GPR section at chainage 5 m. Reflections centred at 5 m chainage at about 2 m depth dip towards each other. The reflection is discontinuous at this point. A similar reflection at about 3 m depth is also discontinuous at this point. This area is circled in red in the upper panel of Figure 3-10. This feature may be indicative of a developing sinkhole. This feature is similar to the signature of the developing sinkhole identified on Gale Avenue North adjacent to Lot 9.

GPR line DAT-120 is offset by approximately 1 m to the north from DAT-118. The results of this survey are shown in Figure 3-11 with reflections identified on the lower panel. There is a reflector dipping to the west identified in yellow in the lower panel. A break in the reflector occurs at chainage 22 to 24 m. Below and to the east of this break is a region of non-coherent reflections which may be indicative of disturbed sediments. This area is circled in red in the upper panel of Figure 3-11. A second region of interest occurs between chainage 4 and 9 m and is also circled in red. A break in a reflector between 1 and 2 m depth can be seen. Diffractions outlined in green below this indicate the presence of a break or edge in the reflecting surface at this depth. This region coincides with a similar feature in GPR line DAT-118 and may be indicative of an developing sinkhole or other disturbance.

The MASW survey on Line N-N is shown in Figure 3-12. Reflections from both GPR line DAT-118 and DAT-120 are shown overlain. A low velocity zone occurs starting at the surface between approximately chainage 5 and 43 m. The zone narrows at a depth of 5m to between chainage 13 m and 31 m. At the time of the survey a small hole in the asphalt was observed at an approximate chainage of 20m, just east of the region where the lowest velocities exist. A number of short non-coherent reflections in the GPR data coincide with the low velocity zone in the MASW section.

The MASW sounding collected over Line M-M is show in in Figure 3-13 . The location of the 1D profile at the centre of the sounding coincides very closely with Thurber test hole TH15-25. The sounding shows a contrasting shear wave velocity with a distinct reduction in velocity centred at 6 m depth. This low velocity zone corresponds with a loose zone in TH15-25.

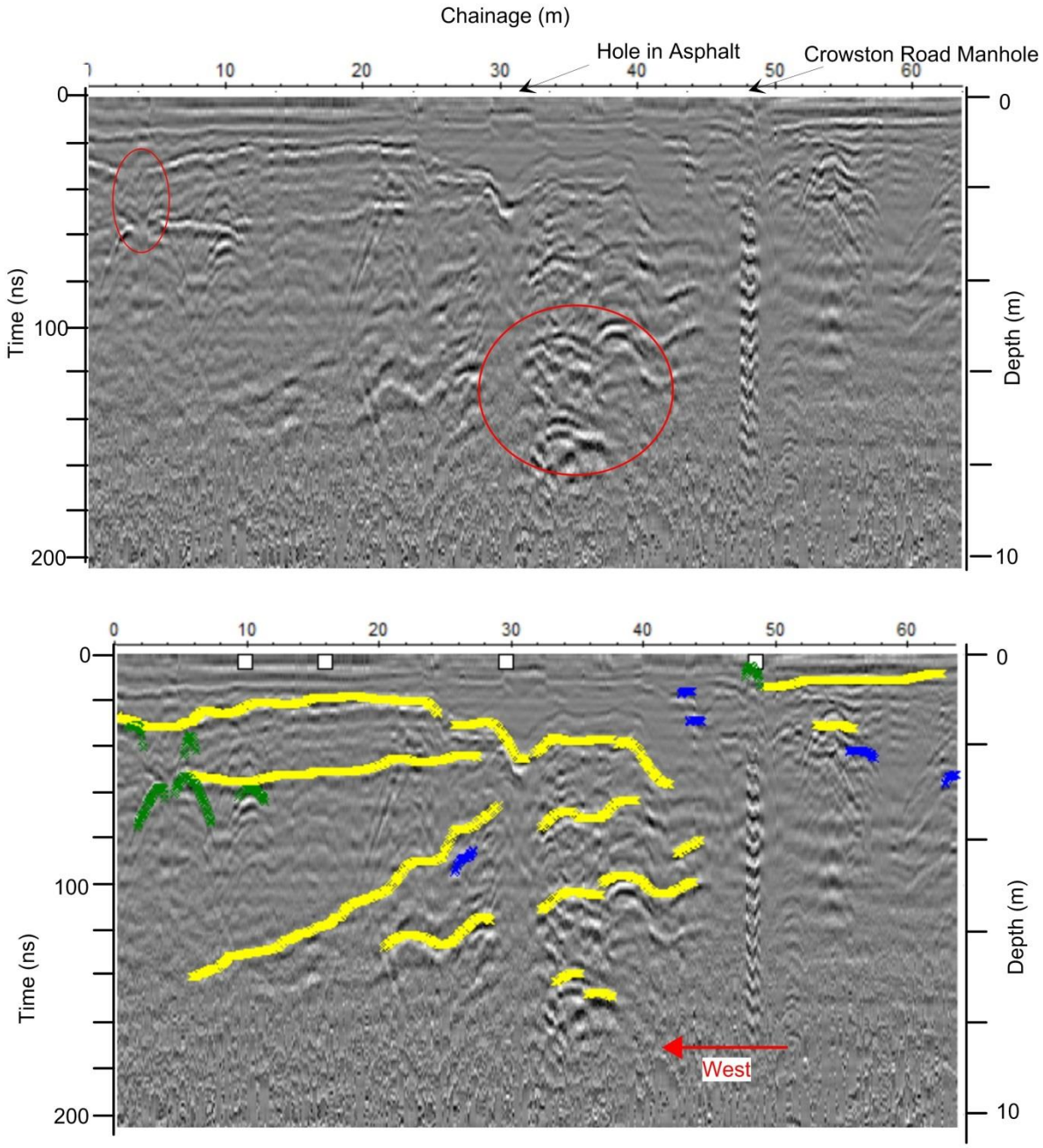


Figure 3-10 GPR line through Line N-N (DAT0118). Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The red circle indicates an area of interest described above.

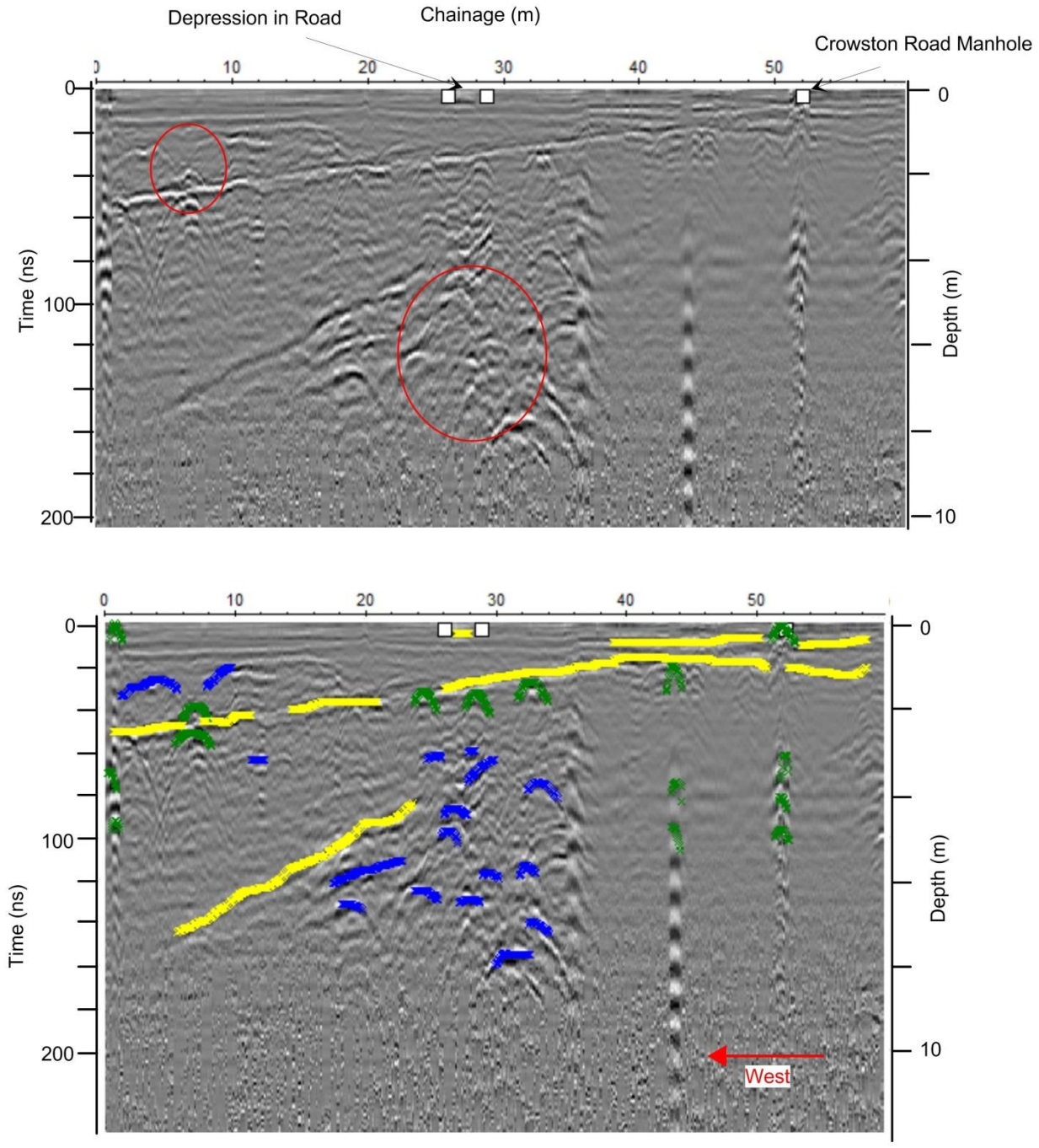


Figure 3-11 GPR line through Line N-N (DAT0120). Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The red circles indicate areas of interest described above.

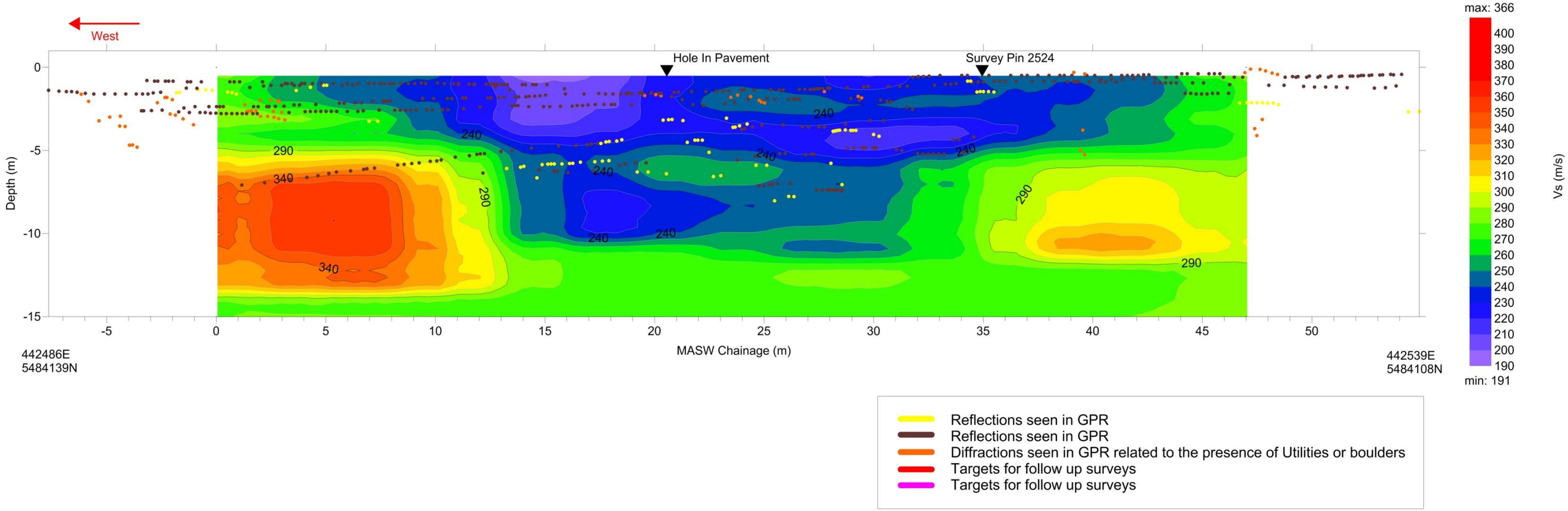


Figure 3-12 MASW line along Line N-N. Colour contour of Vs with GPR reflections overlain.

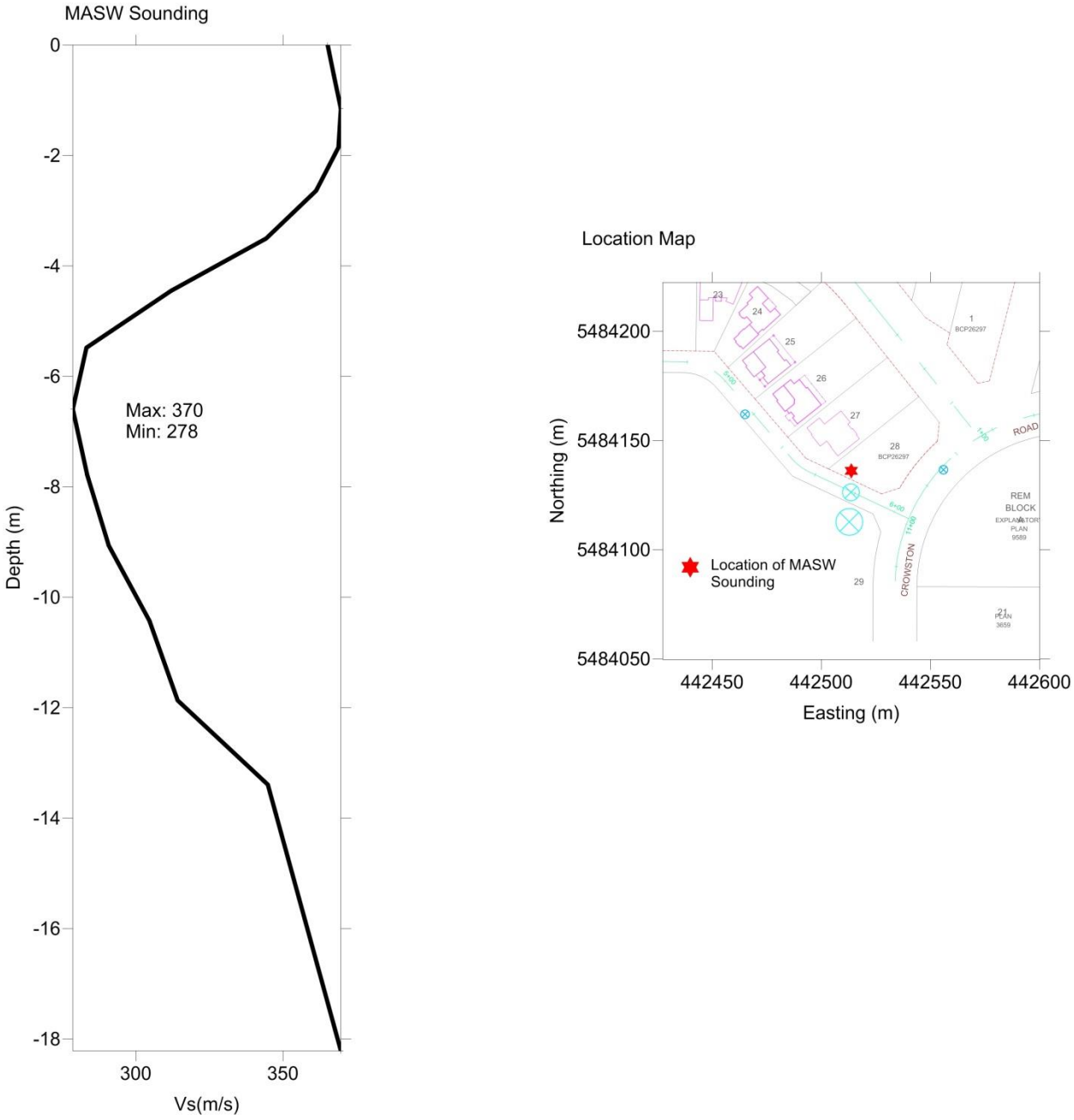


Figure 3-13 MASW Sounding over Line M-M. Location of sounding is identified by orange dot on the location map on the right.

3.4 Reconnaissance GPR Survey

A GPR reconnaissance survey of the lines shown on Figure 1-1 in limited areas of subdivision roads and on several lots in the subdivision was collected to assess the viability of using GPR as a screening tool to identify areas of concern. Full coverage of the roadways and site was not

complete. Further geophysical investigation would be needed. The GPR data over the Lines H-H and I-I on Gale Avenue and Line M-M on Seawatch Lane were used to determine characteristic anomalies and to identify features in the GPR data which might be related to sinkholes or other disturbances.

The result of this survey and analysis is shown in Figure 3-14. All GPR lines including those in the focus areas as well as the reconnaissance lines were analysed to identify GPR reflections and patterns which might indicate target areas potentially requiring follow up investigation. A concentration of features was identified as expected in the focus areas on Seawatch Lane and Gale Avenue. These features within the focus area are circled in green in Figure 3-14. In addition several other areas were identified with an increased concentration of the same types of reflections seen in GPR lines H-H and I-I over known loose zones and sinkholes. These are circled in red in Figure 3-14 and numbered 1 to 4 and can be seen in the GPR cross-sections in Figure 3-15 to Figure 3-18

Tables of identified reflections can be found in the Appendix..

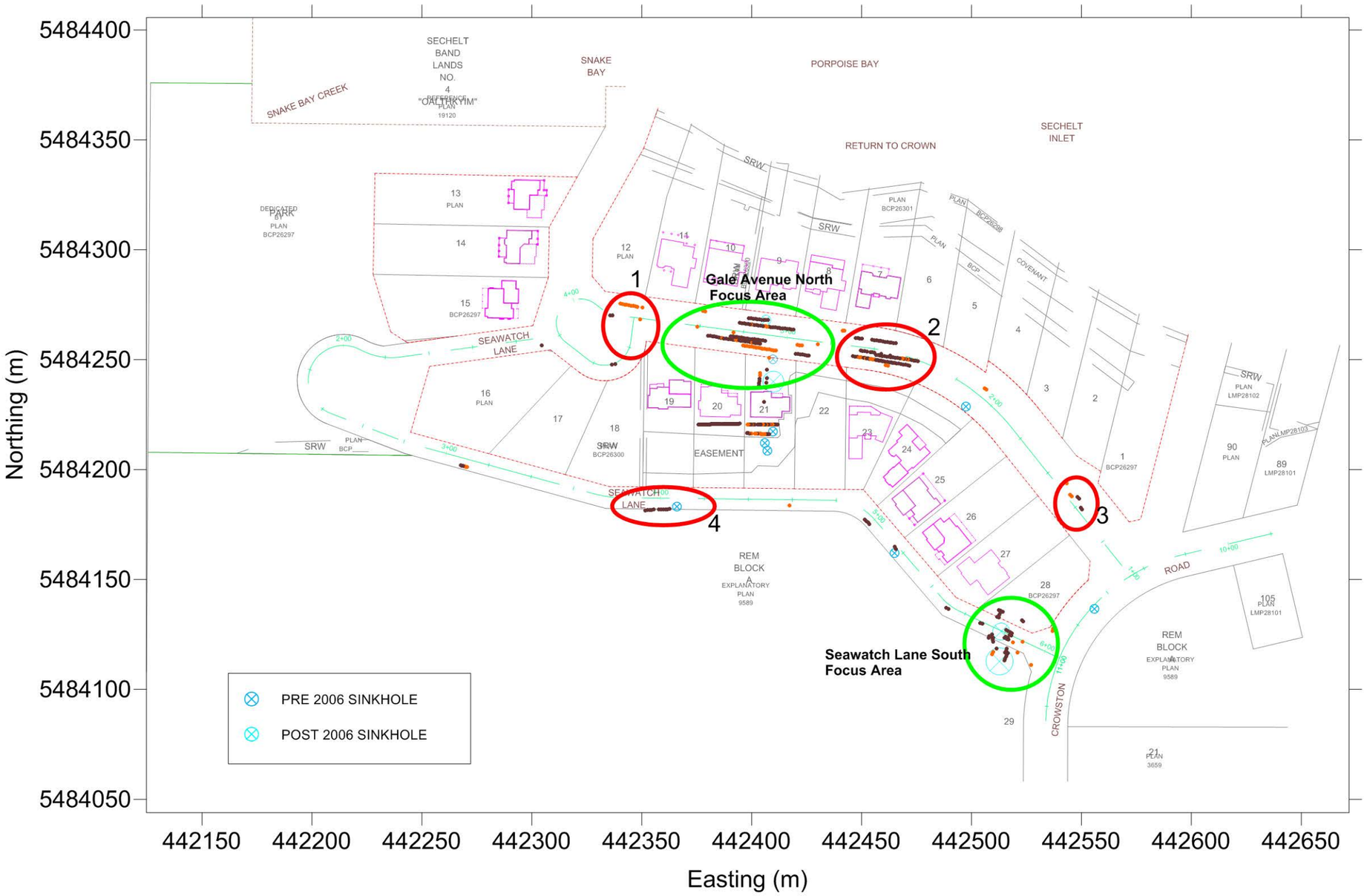


Figure 3-14 Map showing target areas (red circles) for further geophysical and geotechnical study determined from GPR surveys along Seawatch Lane and Gale Avenue. Orange represents general area of disturbance identified in the GPR which may relate to a potential sinkholes. Brown lines identify the location of other features in the GPR survey that may warrant further investigation.

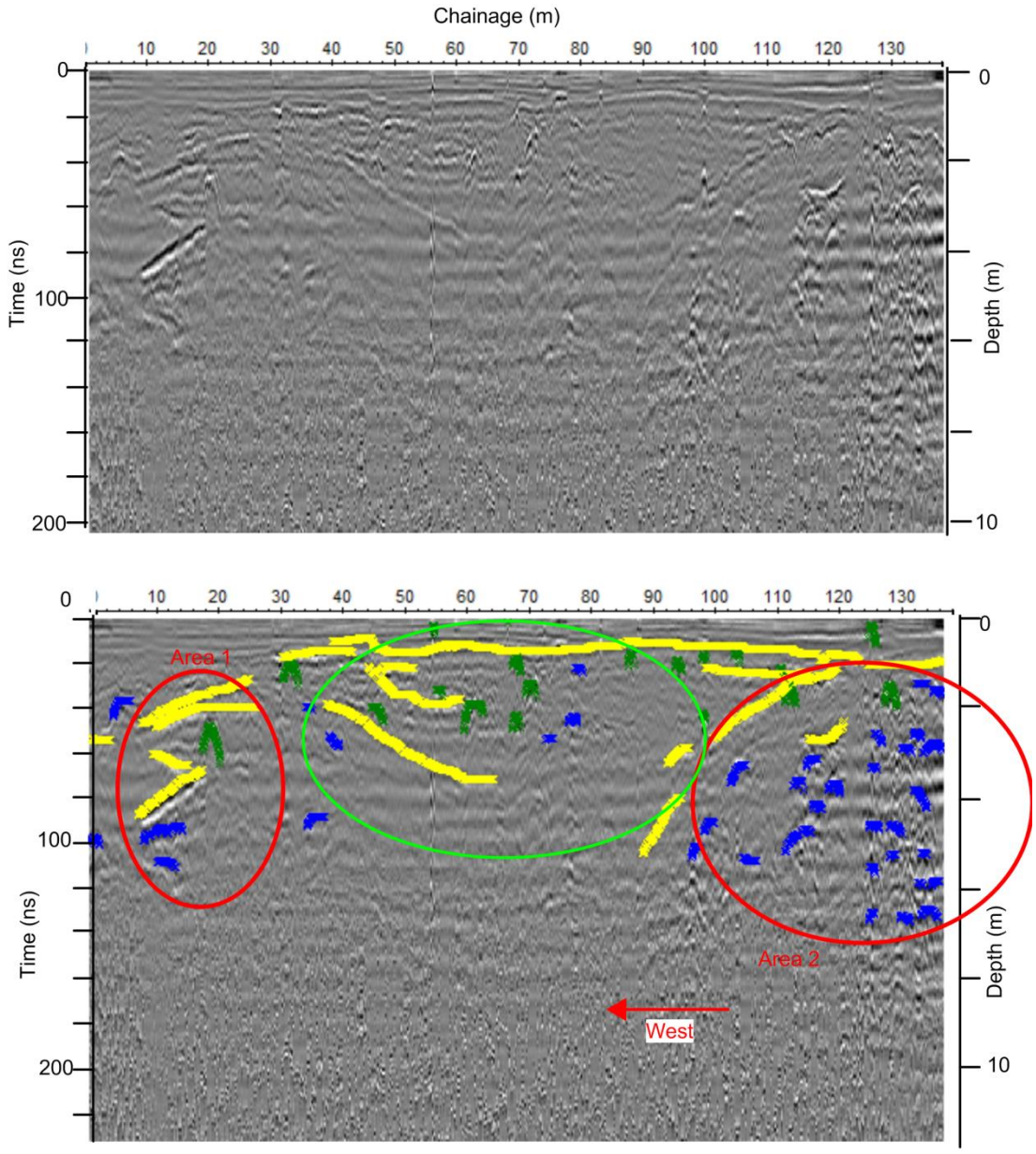


Figure 3-15 GPR line through Area 1 and 2 (DAT0111). Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The red circles indicate Areas 1 and 2 of interest shown in Figure 3-14. Green circle represents approximate location of Gale Avenue Focus Area.

.

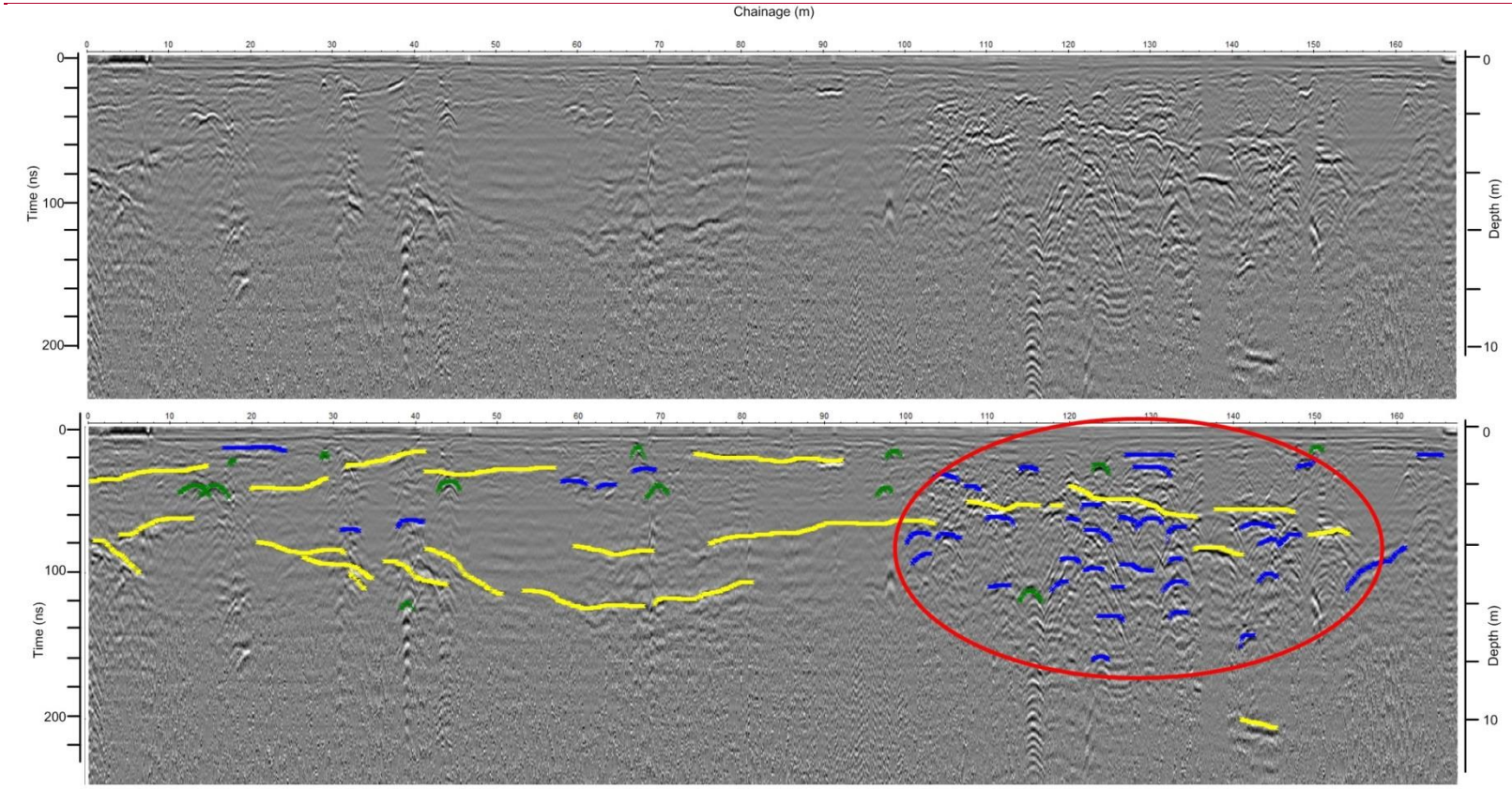


Figure 3-16 GPR line through Area 2 (DAT0112). Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The red circle indicates Area 2 of interest shown in Figure 3-14.

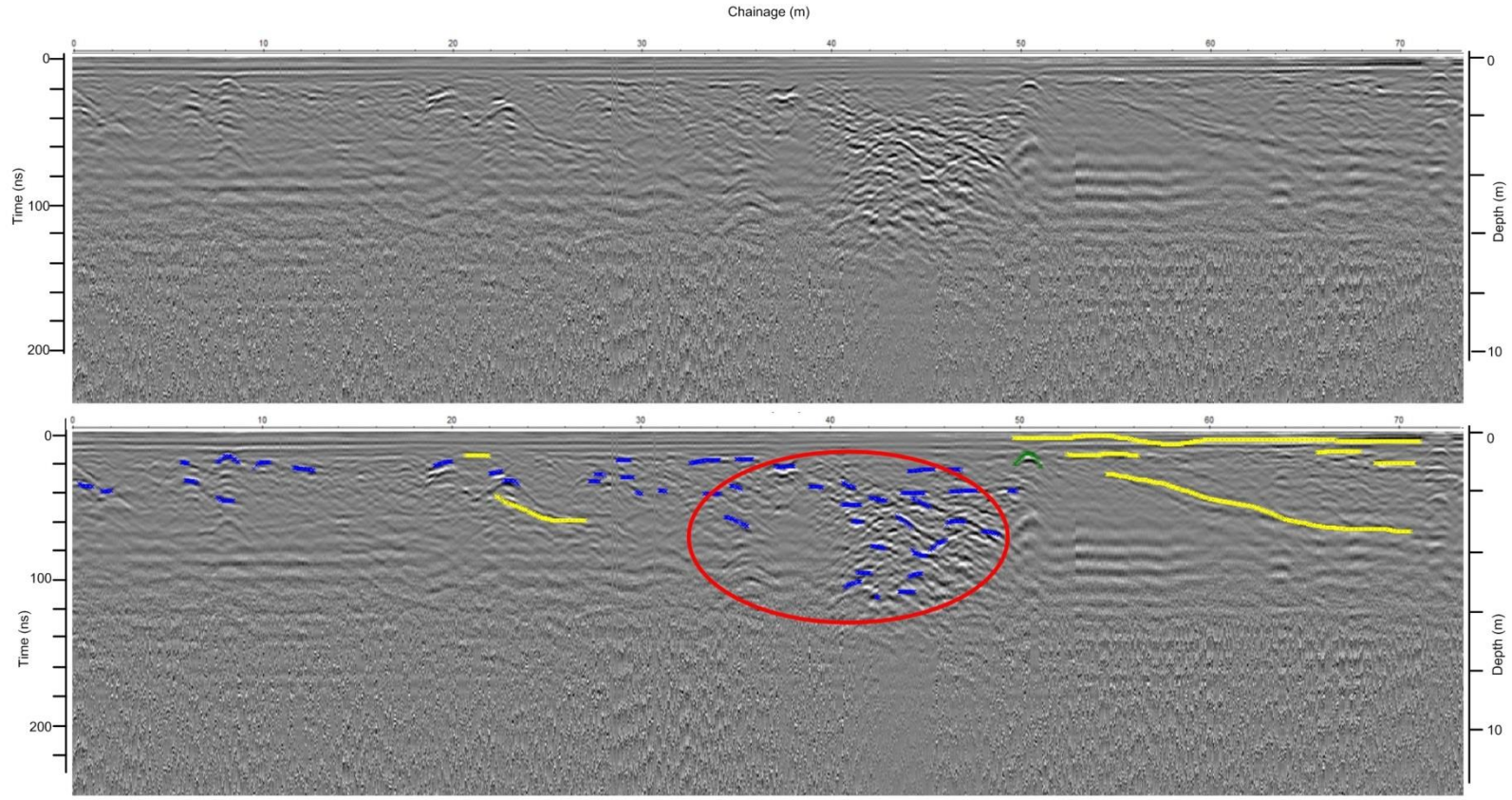


Figure 3-17 GPR line through Area 3 (DAT0154). Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The red circle indicates Area 3 of interest shown in Figure 3-14

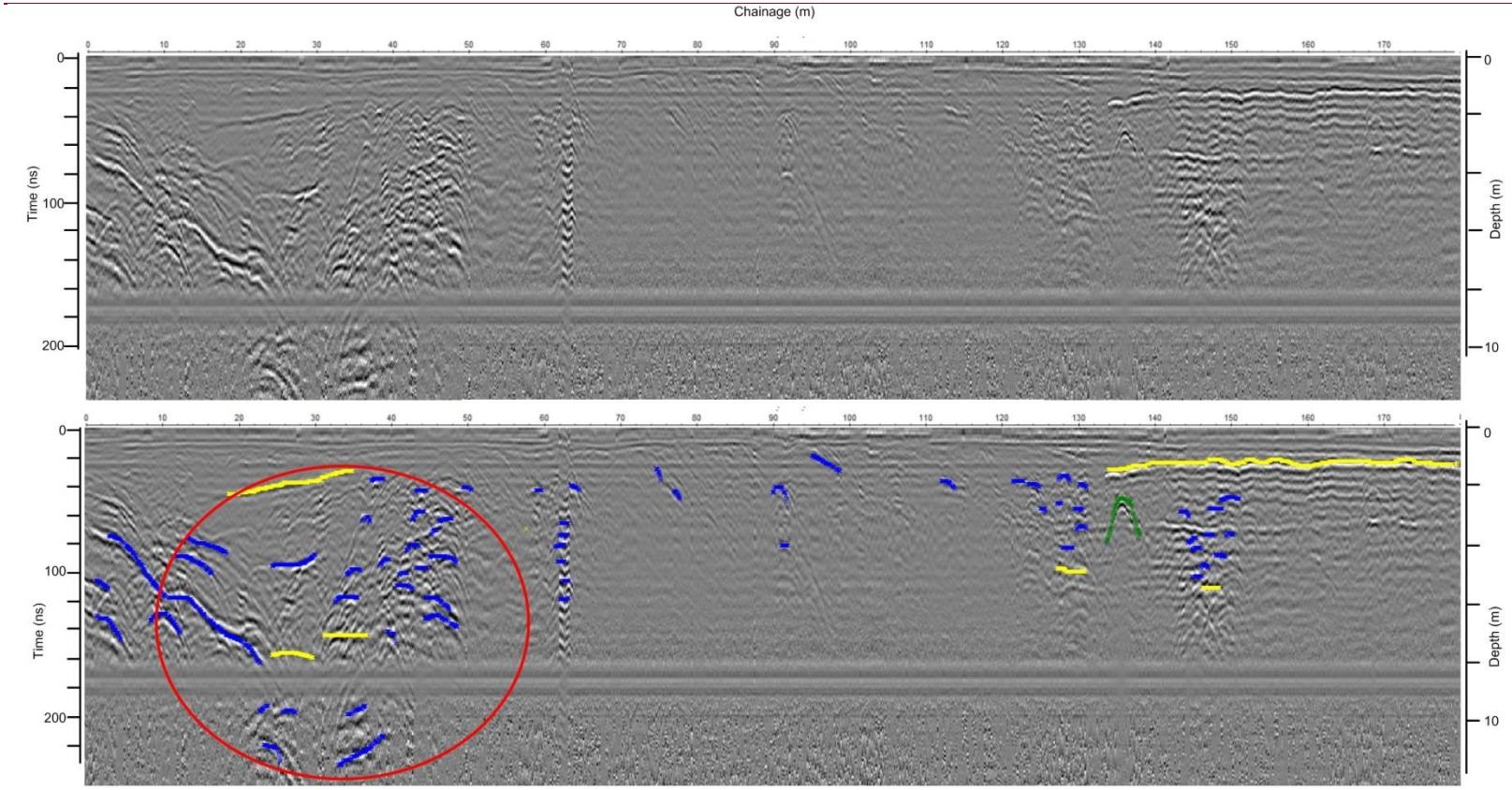


Figure 3-18 GPR line through Area 4 (DAT0147). Long wave-length reflectors are marked in yellow, short wave-length reflectors are marked in blue, and diffractions are marked in green. The red circle indicates Area 4 of interest shown in Figure 3-14

4.0 CONCLUSION AND RECOMMENDATIONS

A combined GPR and MASW survey was conducted in the Shores Phase 1 subdivision in Sechelt, British Columbia. Two focus areas were chosen with known concerns regarding the presence of loose sediments and past or recent sinkholes. GPR data was collected and analysed to determine characteristic reflection patterns over known problem areas. This calibration was used to assess GPR data collected in a reconnaissance survey of the subdivision and a number of target areas potentially requiring further investigations were identified.

MASW data collected over the areas of concern identified lower shear wave velocity zones. These lower velocity zones were in the same general area as the loose sediment zones identified in the Thurber geotechnical investigation of the area.

There are cases where there are GPR anomalies that have not been identified by MASW and other places where the MASW provided useful information on a scale not readily apparent in the GPR. A combination of both techniques has proved more useful than either technique alone.

While GPR has been shown to be an effective tool to identify reflections which may be associated with ground disturbance, it cannot be certain that all disturbed areas will be found. There may be loose sediment areas which do not create the characteristic GPR signals identified in the focus areas of this study. There is also the possibility that zones identified in the GPR survey have similar characteristics to those in the focus areas but do not represent loose sediment areas. High clay content areas may prevent penetration of the GPR signal, thereby masking possible loose sediment zones beneath.

All the areas identified in the analysis of the MASW and GPR data as targets for further investigation should be evaluated by Geotechnical Engineers and subjected to further geophysics and/or drilling investigation where warranted.

Further geophysical studies should be conducted using both GPR and MASW to follow up anomalous areas identified in this investigation. The purpose of the follow up investigation is to identify potential voids or underground slumping by investigating soil stiffness and subsurface soil interfaces. In the rest of the subdivision where there is further sinkhole development risk, GPR is recommended as a reconnaissance tool along with MASW to identify anomalous areas which can be followed up with more detailed GPR and possibly drilling. The 80 MHz and 160 MHz Mala HDR antennae for the GPR should be utilized to ensure the appropriate depth of exploration and resolution in the near surface.

5.0 APPENDIX

Reflection patterns identified in the GPR data are summarized in the following tables. Three types of reflections have been identified. “Short non-coherent” reflections may indicate areas of disturbed sediments. “Bright Reflections” may indicate either a potential void, or a significant change in material property. “Diffractions” are caused by utilities , boulders, or other discrete bodies with a large contrast in material properties. Depths were based on a velocity of .1m/s, based on diffraction analysis. Locally velocities can vary, so depths are to be used as general guidelines only.

5.1 Areas with short non-coherent reflections

Four points in X-Y-Depth are given to identify the general bounds of each region. These should be used as a general guide only.

AnomalyNumber	GPRfile	Easting1	Northing1	Depth1	Easting2	Northing2	Depth2	Easting3	Northing3	Depth3	Easting4	Northing4	Depth4
1-1	111	442467.0	5484257.3	3.7	442466.3	5484257.3	1.0	442458.0	5484258.5	1.1	442456.7	5484258.7	3.7
1-2	111	442451.4	5484259.4	3.1	442451.4	5484259.4	1.9	442445.4	5484260.2	1.9	442444.2	5484260.3	3.1
1-3	113	442476.8	5484249.2	4.5	442476.8	5484249.2	3.4	442461.1	5484251.5	4.3	442460.8	5484251.6	3.3
1-4	113	442407.7	5484258.4	2.8	442407.6	5484258.4	3.9	442390.3	5484260.7	2.8	442389.7	5484260.8	4.2
1-5	114	442418.6	5484253.0	5.5	442418.7	5484252.9	3.7	442427.8	5484251.5	5.6	442428.2	5484251.5	3.3
1-6	115	442410.4	5484259.6	4.7	442410.4	5484259.5	7.1	442409.9	5484254.7	4.7	442409.9	5484254.7	7.4
1-7	118	442540.2	5484111.3	3.7	442540.2	5484111.3	2.0	442536.2	5484113.2	3.7	442536.2	5484113.2	1.8
1-8	118	442520.3	5484120.8	5.3	442520.1	5484120.9	2.0	442514.1	5484124.0	2.1	442513.5	5484124.3	5.5
1-9	118	442489.9	5484136.5	2.7	442489.6	5484136.6	1.6	442487.8	5484137.6	2.8	442487.5	5484137.7	1.7
1-10	120	442518.6	5484122.5	3.7	442518.4	5484122.6	5.8	442514.7	5484124.3	3.7	442514.7	5484124.3	5.8
1-11	121	442519.3	5484123.9	5.6	442519.3	5484123.9	3.1	442514.1	5484126.5	3.5	442513.8	5484126.6	5.6
1-12	122	442516.4	5484126.7	3.0	442516.2	5484126.7	4.7	442513.3	5484128.2	4.7	442513.1	5484128.3	2.9
1-13	133	442520.2	5484114.4	1.4	442520.0	5484114.5	2.7	442515.3	5484116.6	1.4	442515.2	5484116.7	2.7
1-14	135	442507.8	5484113.8	1.5	442507.8	5484114.1	3.0	442509.0	5484117.1	2.9	442509.0	5484117.1	1.4
1-15	136	442510.9	5484118.8	3.7	442510.8	5484118.7	1.6	442508.3	5484113.6	4.2	442508.2	5484113.4	1.5
1-16	146	442523.1	5484121.4	4.2	442523.0	5484121.2	2.4	442521.9	5484119.0	2.4	442521.9	5484118.9	4.4
1-17	147	442454.5	5484174.5	3.2	442454.5	5484174.6	1.8	442448.5	5484180.0	3.4	442447.8	5484180.6	1.9
1-18	147	442357.8	5484182.0	5.0	442356.9	5484182.0	7.7	442351.5	5484181.5	5.0	442350.8	5484181.5	7.7
1-19	151	442339.1	5484248.6	4.8	442338.9	5484248.6	6.0	442335.2	5484247.7	4.8	442334.8	5484247.7	6.1
1-20	151	442304.8	5484256.5	4.5	442304.8	5484256.5	5.7	442301.9	5484256.7	5.9	442301.9	5484256.7	4.4
1-21	152	442396.4	5484261.8	4.8	442396.6	5484261.8	3.9	442405.2	5484260.5	3.8	442405.5	5484260.5	4.8
1-22	152	442443.0	5484255.1	2.5	442445.8	5484254.7	4.6	442456.6	5484253.0	4.7	442457.1	5484252.9	2.5
1-23	153	442546.4	5484189.8	3.0	442547.1	5484189.0	4.5	442549.4	5484186.2	4.4	442549.8	5484185.6	2.9
1-24	154	442552.4	5484179.5	3.3	442551.6	5484180.5	5.4	442548.6	5484184.1	5.4	442547.6	5484185.3	3.0
1-25	156	442406.8	5484268.0	2.7	442406.5	5484268.0	4.7	442400.3	5484268.7	2.8	442400.1	5484268.8	5.0
1-26	158	442403.7	5484241.6	7.7	442403.6	5484241.3	5.8	442403.3	5484238.8	7.8	442403.3	5484238.5	5.8
1-27	163	442514.1	5484132.1	4.6	442514.2	5484132.3	2.5	442515.1	5484134.1	2.5	442515.1	5484134.1	4.7
1-28	165	442507.1	5484122.0	2.6	442507.3	5484122.3	4.1	442508.2	5484124.3	4.3	442508.2	5484124.4	2.5
1-29	168	442517.6	5484145.4	3.8	442517.5	5484145.2	5.8	442516.9	5484144.0	3.7	442516.9	5484144.0	5.8

5.2 Bright Reflections

Two points are given for each reflection these give the approximate endpoints of the “bright” reflection. They should be used as a general guide only. These reflections may indicate a void, or other large contrast in physical properties.

Anomaly Number	GPRfileNumber	Easting1	Northing1	Depth1	Easting2	Northing2	Depth2
2-01	111	442407.0	5484265.1	0.4	442405.3	5484265.3	0.4
2-02	111	442350.9	5484273.6	1.6	442349.5	5484273.9	1.6
2-03	111	442349.2	5484273.9	2.4	442339.6	5484275.6	3.1
2-04	112	442420.3	5484255.0	0.8	442422.9	5484254.6	0.8
2-05	112	442467.0	5484248.1	2.9	442471.0	5484247.5	3.0
2-06	113	442472.0	5484249.9	3.2	442468.0	5484250.6	2.8
2-07	113	442423.1	5484256.4	0.8	442420.6	5484256.7	0.8
2-08	113	442346.8	5484266.3	1.4	442343.5	5484266.8	1.4
2-09	114	442395.7	5484256.5	0.6	442413.0	5484253.8	0.5
2-1	114	442459.9	5484247.5	4.5	442462.6	5484247.2	4.6
2-11	115	442410.5	5484261.1	1.4	442410.5	5484260.4	1.3
2-12	116	5484247.1	442483.2	2.0	5484246.3	442486.0	2.0
2-13	118	442528.0	5484116.9	0.5	442494.3	5484134.2	2.3
2-14	120	442535.3	5484114.8	0.2	442527.8	5484118.3	3.0
2-15	120	442494.6	5484133.5	2.0	442489.0	5484136.1	0.3
2-16	121	442528.6	5484119.5	0.8	442490.2	5484138.0	0.3
2-17	122	442533.5	5484118.1	0.1	442530.4	5484119.7	1.3
2-18	124	442535.1	5484121.4	0.7	442523.5	5484126.7	4.8
2-19	124	442506.7	5484135.4	0.9	442500.9	5484138.1	1.0
2-2	126	442538.1	5484127.0	1.8	442536.8	5484127.6	1.8
2-21	130	442517.5	5484170.2	2.4	442517.2	5484170.6	2.4
2-22	131	442511.3	5484164.6	1.0	442510.8	5484164.2	1.0
2-23	135	442508.3	5484115.3	1.1	442508.4	5484115.6	1.1
2-24	135	442511.8	5484123.1	1.0	442511.9	5484123.5	1.0
2-25	135	442512.3	5484124.3	0.3	442512.6	5484125.0	0.3
2-26	136	442510.6	5484118.5	0.2	442510.4	5484118.1	0.2
2-27	137	442509.8	5484114.6	0.8	442509.9	5484115.0	0.9
2-28	139	442520.9	5484134.0	2.5	442522.0	5484136.2	2.6
2-29	140	442522.6	5484134.8	2.6	442521.9	5484133.4	2.6
2-3	141	442521.5	5484131.0	2.2	442522.2	5484132.4	2.3
2-31	142	442523.4	5484132.5	1.8	442522.3	5484130.5	1.8
2-32	142	442513.8	5484113.6	1.3	442513.6	5484113.2	1.4
2-33	143	442517.7	5484118.9	2.7	442517.9	5484119.3	2.7
2-34	143	442523.2	5484130.2	1.9	442523.6	5484131.0	1.9

2-35	144	442523.3	5484127.7	2.3	442522.8	5484126.6	2.2
2-36	145	442519.7	5484116.8	1.3	442519.9	5484117.2	1.3
2-37	145	442520.1	5484117.6	4.9	442520.5	5484118.5	4.6
2-38	146	442523.5	5484122.1	1.5	442523.3	5484121.7	1.5
2-39	146	442521.9	5484119.1	2.0	442521.6	5484118.3	2.0
2-4	146	442521.1	5484117.2	1.1	442521.0	5484117.0	1.1
2-41	147	442439.0	5484184.4	1.9	442436.6	5484184.8	1.7
2-42	147	442417.8	5484183.7	3.9	442416.4	5484183.7	3.9
2-43	147	442356.7	5484182.0	4.5	442354.1	5484181.7	4.7
2-44	147	442351.2	5484181.5	1.0	442350.7	5484181.5	1.0
2-45	148	442270.6	5484201.2	3.8	442266.9	5484202.1	3.9
2-46	151	442322.6	5484250.7	2.0	442321.4	5484251.3	2.0
2-47	151	442304.9	5484258.7	3.3	442306.3	5484259.6	3.0
2-48	152	442336.0	5484270.2	0.8	442336.6	5484270.1	0.8
2-49	152	442340.8	5484269.6	2.0	442343.5	5484269.2	2.0
2-5	152	442348.9	5484268.4	2.3	442350.6	5484268.2	2.3
2-51	152	442391.6	5484262.5	1.9	442392.3	5484262.4	1.9
2-52	152	442429.8	5484257.0	1.0	442431.1	5484256.8	1.0
2-53	153	442506.3	5484236.8	1.3	442507.2	5484236.0	1.3
2-54	153	442543.1	5484193.9	1.5	442543.5	5484193.4	1.5
2-55	154	442567.3	5484161.5	0.5	442567.0	5484161.9	0.5
2-56	154	442545.6	5484187.7	1.2	442544.9	5484188.5	1.2
2-57	154	442536.2	5484199.4	1.4	442535.8	5484199.9	1.4
2-58	156	442442.7	5484263.1	1.8	442441.1	5484263.3	1.9
2-59	156	442402.9	5484268.4	0.8	442402.4	5484268.5	0.8
2-6	156	442397.1	5484269.2	1.1	442396.7	5484269.3	1.1
2-61	158	442405.7	5484255.5	1.0	442405.5	5484254.7	1.1
2-62	158	442404.0	5484244.3	5.2	442403.7	5484241.9	5.5
2-63	162	442510.5	5484123.2	5.9	442509.9	5484122.0	6.1
2-64	163	442509.4	5484122.3	2.1	442509.8	5484123.3	2.2
2-65	163	442515.0	5484133.9	0.9	442515.5	5484134.7	0.7
2-66	164	442512.7	5484132.3	3.9	442511.7	5484130.2	4.0
2-67	164	442509.7	5484126.0	2.0	442509.3	5484125.1	2.1
2-68	164	442509.2	5484124.9	1.3	442508.9	5484124.2	1.3
2-69	165	442507.9	5484123.6	2.3	442508.1	5484124.2	2.3
2-7	165	442512.3	5484133.3	3.9	442513.0	5484134.7	3.9
2-71	168	442513.1	5484136.4	3.5	442512.7	5484135.5	3.4
2-72	168	442512.1	5484134.3	3.8	442511.6	5484133.3	3.8
2-73	171	442506.9	5484129.4	1.8	442507.0	5484129.8	1.8
2-74	171	442508.5	5484132.6	1.8	442508.9	5484133.3	1.6

2-75	172	442508.0	5484133.6	1.6	442507.6	5484132.9	1.7
2-76	174	442504.2	5484130.5	1.9	442504.1	5484130.2	1.9
2-77	177	442512.9	5484125.3	1.4	442513.0	5484127.3	1.7
2-78	177	442513.0	5484133.7	4.0	442513.1	5484135.6	4.0

5.3 Diffractions

These points correspond to the apex of the diffraction. Diffractions occur in the GPR data over utilities and boulders. While every effort was made to identify the apex of the diffraction, and therefore the depth to the feature of interest, some diffractions included “ringing” making it challenging to pinpoint the exact apex.

AnomalyNumber	GPRdatafile	Easting	Northing	Depth
3-01	112	442344.2	5484266.3	1.3
3-02	112	442346.8	5484265.9	1.3
3-03	112	442360.3	5484264.1	0.5
3-04	112	442374.8	5484261.8	1.2
3-05	112	442398.3	5484258.2	0.5
3-06	111	442434.2	5484261.6	0.6
3-07	111	442429.4	5484262.2	0.6
3-08	111	442429	5484262.2	1.5
3-09	111	442417.7	5484263.8	0.6
3-1	111	442412.4	5484264.4	0.2
3-11	111	442399.4	5484266.1	1.5
3-12	111	442392.7	5484267	1.2
3-13	111	442386.1	5484268	0.2
3-14	113	442482.6	5484248.4	0.6
3-15	113	442466.3	5484250.8	0.2
3-16	113	442446	5484253.5	3.9
3-17	113	442428.9	5484255.7	3.4
3-18	113	442398.2	5484259.6	0.5
3-19	113	442374.9	5484262.5	1.1
3-2	114	442384.3	5484258.2	0.6
3-21	114	442422.8	5484252.3	6.7
3-22	115	442411.5	5484270.2	0.9
3-23	115	442410.8	5484264.2	2.0
3-24	115	442408.3	5484243.2	2.2

3-25	130	442516.3	5484171.6	2.5
3-26	131	442511.2	5484164.6	3.3
3-27	118	442520	5484120.9	4.9
3-28	118	442518.9	5484121.5	4.9
3-29	118	442512.8	5484124.6	2.3
3-3	118	442512	5484125.1	2.2
3-31	120	442518.6	5484122.5	1.4
3-32	120	442517.7	5484122.9	1.4
3-33	120	442517	5484123.3	7.7
3-34	120	442515.4	5484124	7.6
3-35	120	442491.7	5484134.9	1.4
3-36	120	442491.4	5484135	1.4
3-37	121	442530.1	5484118.8	1.4
3-38	121	442529.6	5484119	1.3
3-39	122	442530.6	5484119.5	1.1
3-4	122	442530.3	5484119.7	1.0
3-41	122	442517.7	5484126	2.2
3-42	122	442517.1	5484126.3	2.1
3-43	124	442521.8	5484127.6	1.4
3-44	124	442521.4	5484127.9	1.4
3-45	124	442515.1	5484131.3	5.6
3-46	124	442514.6	5484131.6	5.6
3-47	125	442536.9	5484126.6	1.9
3-48	125	442536.3	5484126.9	1.9
3-49	125	442514.3	5484135.3	4.4
3-5	125	442512.7	5484135.9	4.3
3-51	127	442530.1	5484162.7	0.8
3-52	133	442531.1	5484109.4	0.8
3-53	135	442511.6	5484122.8	1.8
3-54	135	442513.5	5484126.7	1.9
3-55	135	442514.9	5484129.9	1.8
3-56	137	442514.6	5484124.6	1.3
3-57	137	442515.3	5484126	1.8
3-58	137	442516.8	5484129.2	1.8
3-59	138	442522.2	5484138	0.6
3-6	138	442517.4	5484128.5	1.7
3-61	138	442515.1	5484124.2	1.3
3-62	139	442513.6	5484118.5	1.3
3-63	139	442516.4	5484125.2	1.8
3-64	139	442517.1	5484126.5	0.9

3-65	139	442518.1	5484128.4	1.9
3-66	140	442519	5484127.8	1.9
3-67	140	442517.8	5484125.6	0.7
3-68	140	442517.5	5484124.9	1.7
3-69	140	442516.6	5484123.2	1.2
3-7	140	442515.8	5484121.5	0.2
3-71	140	442515.7	5484121.3	0.2
3-72	141	442518.5	5484124.5	1.8
3-73	141	442520	5484127.7	2.1
3-74	143	442519.3	5484122.2	1.2
3-75	143	442521.8	5484127.4	1.1
3-76	144	442521.3	5484123.9	2.1
3-77	144	442520.2	5484121.8	1.7
3-78	145	442521.5	5484120.8	1.2
3-79	145	442524	5484125.9	2.1
3-8	147	442457.1	5484173.5	2.2
3-81	147	442451.6	5484177	1.6
3-82	147	442389.1	5484181.8	0.7
3-83	150	442230.2	5484255.5	0.3
3-84	150	442298.7	5484261.8	0.4
3-85	150	442309.2	5484272.8	4.9
3-86	150	442310.1	5484274.7	3.6
3-87	150	442312.8	5484277.4	5.9
3-88	151	442326.3	5484249.1	1.3
3-89	151	442309.5	5484255.8	3.4
3-9	152	442352.5	5484267.9	0.4
3-91	152	442360.9	5484266.8	0.9
3-92	152	442375.8	5484264.8	2.1
3-93	152	442395.6	5484261.9	0.5
3-94	152	442398.8	5484261.5	0.9
3-95	152	442415	5484259.1	0.9
3-96	152	442429.1	5484257.1	0.8
3-97	152	442436	5484256.1	1.2
3-98	152	442443.4	5484255	1.5
3-99	152	442444.7	5484254.8	1.5
3-1	152	442447.1	5484254.5	2.8
3-101	152	442456.6	5484253	1.3
3-102	153	442517.1	5484225.9	0.3
3-103	153	442569.2	5484162	1.6
3-104	153	442570.3	5484161.1	1.7
3-105	154	442553.5	5484178.1	0.7

3-106	154	442527	5484210.9	0.8
3-107	156	442416.3	5484266.6	1.1
3-108	156	442413.2	5484267.1	1.8
3-109	156	442403.5	5484268.3	1.4
3-11	156	442376.7	5484272.3	2.6
3-111	158	442405.6	5484255.1	2.2
3-112	162	442513.8	5484130.2	1.7
3-113	162	442511.6	5484125.6	1.4
3-114	163	442511	5484126.2	1.4
3-115	163	442511.8	5484127.7	1.7
3-116	165	442506.5	5484120.9	0.6
3-117	165	442509.2	5484126.9	1.5
3-118	165	442509.9	5484128.4	1.7
3-119	165	442511.5	5484131.7	1.7
3-12	168	442514.8	5484140	1.7
3-121	168	442513.3	5484136.9	1.8
3-122	172	442506.3	5484130.1	1.8
3-123	172	442505.8	5484129	1.8
3-124	174	442504.4	5484131	1.9
3-125	174	442503.8	5484129.7	1.9
3-126	175	442502.5	5484129	0.8
3-127	175	442503	5484130.3	1.9
3-128	175	442503.6	5484131.5	1.9
3-129	175	442505.2	5484134.6	1.6

THURBER

APPENDIX 6

Thurber Engineering Ltd. Previous Investigation Test Hole Logs and Geotechnical Laboratory Test Results

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-01**

LOCATION: See Figure 2
N 5484194, E 442292

TOP OF HOLE ELEV: 46.3 m (est.)

METHOD: Solid Stem Auger

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Feb 1, 2013

FILE NO.: 14-214-3

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100 | ELEVATION (m)

COMMENTS

Driller notes drilling conditions typically indicative of dense soils below approximately 1.5 m depth.

Dry conditions when measured Feb 1, 2013.

SOILS DESCRIPTION

Depth (m)	Elevation (m)	Soil Type	Description
0	46	SP-SM	Brown, subangular to subrounded, fine to coarse SAND with traces of silt and gravel (Fill).
1	45	SP-SM	Buff-brown, subangular to subrounded, fine to coarse SAND with traces of silt and gravel.
2	44		Becoming grey/grey-buff with orange streaks below 1.5 m
3	43	SP-SM	
4	42	SP-SM	
5	41		No gravel below 4.5 m
6	40	SP-SM	
7	39	SP-SM	
8	38	SP-SM	
9	37	ML	Firm to stiff, grey SILT with trace to some sand.
10	36	SP-SM	Grey, fine SAND with trace to some silt.
11	35		
12	34	SM/ML	Grey-buff-brown SAND/SILT.
13	33	SM/ML	Stiff, buff grey SILT.
14	32	ML	Stiff to very stiff, grey-buff SILT, with up to 0.2 m thick fine sand interbeds.
15	31	ML	
16	30	ML	Grading to grey, streaked orange, fine sandy SILT below 14.5 m
17	29		
18	28		
19	27		
20			

REMARKS

1. Test hole terminated at required depth.
2. Encountered soils saturated below 12.2 m depth.

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/7/13

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-02**

LOCATION: See Figure 2
N 5484181, E 442372

TOP OF HOLE ELEV: 45.5 m (est.)

METHOD: Mixed Solid / Hollow Stem Auger and CPT

DRILLING CO.: On-Track Drilling /Schwartz Soil Technical

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 28, 2013

FILE NO.: 14-214-3

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	COMMENTS		SOILS DESCRIPTION	ELEVATION (m)
0			Grey, fine to medium SAND with trace gravel.	45
1	CPT conducted from 0.6 to 1.4 m depth prior to auger drilling.	SM	Grey, fine SAND with trace to some silt.	44
2		ML/SM	Grey, silty SAND with trace fine gravel.	43
3			Grey, mottled orange, fine to medium SAND with trace to some silt.	42
4		SM		
		SM		41
5		SM		40
6				39
7		SM		38
8	Driller notes drilling typically indicative of dense / very stiff soils.			37
9		SM	Grey, fine SAND with trace to some silt.	
			Grey, mottled orange, fine SAND with trace silt.	36
10		SM		35
11				
		ML	Stiff, grey, mottled orange, sandy SILT.	34
12			Grey, mottled orange, fine SAND with trace silt.	33
13		ML	Very stiff to stiff, grey, mottled orange, sandy SILT.	
		ML	Very stiff, grey, streaked orange, SILT with trace sand.	32
14		ML	Grey, streaked orange, sandy SILT.	
		ML	Stiff, grey, SILT with trace sand.	31
15		ML/SM	Grey, mottled orange, silty SAND / sandy SILT	30
16			Grey, silty, fine SAND.	
		SM		29
17			Grey, silty SAND / Stiff sandy SILT with trace clay.	
			Firm to stiff, grey SILT with some sand, trace clay. Fine sand lens at 17.7 m.	28
18				
19				27
20				26

REMARKS

1. Test hole terminated at required depth.
2. Groundwater not encountered.

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO.
TH13-03A

LOCATION: See Figure 2
N 5484191, E 442399

TOP OF HOLE ELEV: 45.3 m (est.)

METHOD: Mixed Solid Stem Auger / DCPT

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 31, 2013

FILE NO.: 14-214-3

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0			45
1	Drill out to 7.6 m depth with solid stem auger.		44
2			43
3			42
4			41
5			40
6			39
7			38
8			37
9			36
10			35
11			34
12			33
13		REMARKS 1. Test hole terminated at required depth. 2. 1.5 m east of BH12-09	32
14			31
15			30
16			29
17			28
18			27
19			26
20			

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO.
TH13-03B

LOCATION: See Figure 2
N 5484191, E 442394

TOP OF HOLE ELEV: 45.3 m (est.)

METHOD: Mixed Solid Stem Auger / DCPT

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 31, 2013

FILE NO.: 14-214-3

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

COMMENTS

SOILS DESCRIPTION

DEPTH (m)	ELEVATION (m)	
0	45	Grey, fine to medium SAND with traces of silt and gravel, with occassional wood fragments.
1	44	SM
2	43	SM
3	42	
4	41	
5	40	
6	39	
7	38	
8	37	
9	36	
10	35	
11	34	
12	33	
13	32	
14	31	
15	30	
16	29	
17	28	REMARKS 1. Test hole terminated at required depth. 2. 1.5 m west of BH12-09.
18	27	
19	26	
20		

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-03C**

LOCATION: See Figure 2
N 5484191, E 442401

TOP OF HOLE ELEV: 45.3 m (est.)

METHOD: Mixed Solid Stem Auger / DCPT

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 31, 2013

FILE NO.: 14-214-3

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0		Grey, fine to medium SAND with trace silt and trace to some fine gravel.	45
1	Drilling noted to be likely indicative of compact to loose soils between 0 and 1.7 m depth, and likely indicative of compact to dense soils from 1.7 m to 4.6 m depth.		44
2		Grey, fine SAND with trace silt and trace to some fine gravel.	43
3			42
4			41
5			40
6			39
7	116		38
	171		
8	112		37
9			36
10			35
11			34
12			33
13			32
14	101		31
	143		
15			30
16			29
17			28
18			27
19			26
20			

REMARKS

1. Test hole terminated at required depth.
2. 3 m east of BH12-09.

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-05A**

LOCATION: See Figure 2
N 5484137, E 442517

TOP OF HOLE ELEV: 38.7 m (est.)

METHOD: Mixed Hollow Stem Auger / CPT / SPT

DRILLING CO.: On-Track Drilling /Schwartz Soil Technical

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 29, 2013

FILE NO.: 14-214-3

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	COMMENTS		SOILS DESCRIPTION	ELEVATION (m)
0	CPT conducted from 0.1 to 2.1m depth.			38
1				37
2			Angular, fine to coarse SAND and fine to coarse GRAVEL.	36
3		SM	Very dense, grey SAND with trace silt and trace gravel.	35
4			Silty sandy, angular, fine to coarse GRAVEL.	34
5		SP-SM	Very dense, grey SAND with trace silt and trace gravel. Partial sample recovery.	33
6			REMARKS 1. Auger refusal at 5.0 m depth. 2. Groundwater not encountered.	32
7				31
8				30
9				29
10				28
11				27
12				26
13				25
14				24
15				23
16				22
17				21
18				20
19				19
20				

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-05B**

LOCATION: See Figure 2
N 5484136, E 442516

TOP OF HOLE ELEV: 38.6 m (est.)

METHOD: Mixed Hollow Stem Auger / CPT

DRILLING CO.: On-Track Drilling /Schwartz Soil Technical

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 29, 2013

FILE NO.: 14-214-3

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m) | 10 20 30 40 50 60 70 80 90 100 | ELEVATION (m)

COMMENTS

CPT conducted from 0.7 to 0.9m depth.

SOILS DESCRIPTION

Inferred cobbles and boulders.

REMARKS

1. Auger refusal at 1.2 m depth.
2. Groundwater not encountered.

DEPTH (m)	ELEVATION (m)
0	38
1	37
2	36
3	35
4	34
5	33
6	32
7	31
8	30
9	29
10	28
11	27
12	26
13	25
14	24
15	23
16	22
17	21
18	20
19	19
20	

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 1 of 2

LOG OF TEST HOLE

TEST HOLE NO. **TH13-05C**

LOCATION: See Figure 2
N 5484136, E 442518

TOP OF HOLE ELEV: 38.8 m (est.)

METHOD: Mixed Hollow Stem Auger / CPT / DCPT / SPT

DRILLING CO.: On-Track Drilling /Schwartz Soil Technical

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 29, 2013

FILE NO.: 14-214-3

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading

DEPTH (m)	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
0	CPT conducted from 0.1 to 0.3 m depth.		38
1	Hollow stem auger used to drill out below and between SPTs and CPTs.		
		SM Compact, grey, fine to coarse SAND with trace gravel.	37
2	CPT conducted from 2.05 to 2.25 m depth.		
			36
3		ML/SM Very dense, grey, fine to coarse SAND and SILT with trace gravel.	
4			35
		SM Very dense, grey, fine to coarse SAND with trace silt and trace fine gravel.	34
5		Very stiff to hard, grey SILT.	
			33
6		ML Very dense, buff-grey SILT with trace to some sand.	
7			32
		SM Dense, grey, streaked buff-orange, fine SAND with trace medium to coarse sand.	31
8	CPT conducted from 8.1 to 8.7 m.		
			30
9		SM Dense, grey, fine SAND with trace silt.	
10			29

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 2 of 2

LOG OF TEST HOLE

TEST HOLE NO. **TH13-05C**

LOCATION: See Figure 2
N 5484136, E 442518

TOP OF HOLE ELEV: 38.8 m (est.)

METHOD: Mixed Hollow Stem Auger / CPT / DCPT / SPT

DRILLING CO.: On-Track Drilling /Schwartz Soil Technical

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 29, 2013

FILE NO.: 14-214-3

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m)	10 20 30 40 50 60 70 80 90 100	COMMENTS	SOILS DESCRIPTION	ELEVATION (m)
10				
11			SP-SM Dense, grey, fine SAND with trace to some silt.	28
12				27
13			SP Dense, grey, fine SAND.	26
14		DCPT conducted below 13.7 m.		25
15				24
16				23
17				22
18				21
19				20
20				19

REMARKS

1. Test hole terminated at required depth.
2. Heave noted when setting up for DCPT at 13.7 m. Estimated heave 0.8 m.
3. Ground water at 11.6 m.

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-06**

LOCATION: See Figure 2
N 5484169, E 442522

TOP OF HOLE ELEV: 36.1 m (est.)

METHOD: Mixed Solid Stem Auger / DCPT

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 31, 2013

FILE NO.: 14-214-3

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): ■ GASTECH reading ⊠ PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

COMMENTS	SOILS DESCRIPTION
DCPT at TH13-06A	
Solid stem auger refusal at 3.2 m at location TH13-06A	
Solid stem auger refusal at 5.2 m at TH13-06B and -06C	
DCPT at TH13-06D at 7.9 m (134)	
Solid stem auger drill out	
DCPT at TH13-06D (105)	

REMARKS

1. Test hole terminated at required depth.
2. Four DCPT locations attempted, TH13-06a,b,c, d. TH13-06a is most northwesterly location, -06b, -06c and -06d formed at 1 m intervals southeastward from -06a.
3. Groundwater not encountered.

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-07**

LOCATION: See Figure 2
N 5484216, E 442530

TOP OF HOLE ELEV: 27.8 m (est.)

METHOD: Solid Stem Auger

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 30/31, 2013

FILE NO.: 14-214-3

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%): Disturbed, Undisturbed | WATER LEVEL: Plastic Limit, Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): Peak, Residual, Remolded | GRAIN SIZE (%): Passing #200 sieve, Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

COMMENTS

Solid stem auger drill out to 6.1 m depth. No sampling or logging.

Water level measured Feb 1, 2013

SOILS DESCRIPTION

Depth (m)	Elevation (m)		
0	27		
6	21	GM/SM	Grey SAND with trace to some silt and trace to some gravel.
8	19	ML	Stiff, buff-light brown, sandy SILT with trace of clay and gravel.
9	18		Stiff, buff-light brown, SILT with trace of sand.
10	17	ML	Buff-brown, fine sandy SAND and SILT.
12	16	SM/ML	
20	8		

REMARKS

1. Test hole terminated at required depth.
2. Drilled to 10.7 m depth January 30, 2013. Hole remained open to 7 m and groundwater noted at 5.8 m depth when drilling recommenced on January 31, 2013.

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-08**

LOCATION: See Figure 2
N 5484264, E 442543

TOP OF HOLE ELEV: 10.9 m (est.)

METHOD: Mixed Solid / Hollow Stem Auger / DCPT

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 30, 2013

FILE NO.: 14-214-3

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%) ○ Disturbed ● Undisturbed | WATER LEVEL Plastic Limit – Liquid Limit | SAMPLES ◧ Disturbed ■ Undisturbed ☒ No Recovery | UNDRAINED SHEAR STRENGTH (kPa) ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%) ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm) ■ GASTECH reading ⊠ PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

COMMENTS

Water level measured Feb 1, 2013

	SOILS DESCRIPTION
SM	Compact, buff, fine to coarse SAND with trace silt and trace to some gravel (Fill).
SM/GM	Compact, earth-brown, silty, fine to coarse SAND with some fine to coarse gravel (Fill).
GM/SM	Compact, silty SAND and GRAVEL and fragments of geotextile fabric (Fill).
ML/SM	Loose to compact, buff-earth brown, fine to coarse SAND and fine to coarse GRAVEL with trace silt, occassional organic fragments and dark brown sub 10 mm silt pockets (Fill).
ML	Compact, buff-orange streaked grey, fine SAND with trace silt and trace gravel.
ML	Compact over dense, grey SILT.

REMARKS

1. Test hole terminated at required depth.

GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. **TH13-09**

LOCATION: See Figure 2
N 5484314, E 442419

TOP OF HOLE ELEV: 7.3 m (est.)

METHOD: Mixed Solid / Hollow Stem Auger / DCPT

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: AB

THURBER

CLIENT: District of Sechelt

PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision

DATE: Jan 30, 2013

FILE NO.: 14-214-3

DEPTH (m) | PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed ● Undisturbed | WATER LEVEL: Plastic Limit — Liquid Limit | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ◆ Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading | ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

COMMENTS

Water levels measured Feb 1, 2013 in shallow piezometer (solid) and deep piezometer (outline).

SOILS DESCRIPTION

Depth (m)	Elevation (m)		
0	7	SP-SM	Loose to compact, brown-buff, fine to medium SAND with trace of gravel (Fill).
1	6	SM	Dense over compact, grey, fine SAND with trace to some silt and trace of gravel (Fill).
2	5	GM/SM GP-GM	Loose to compact, buff, sandy GRAVEL with trace to some silt (Fill).
3	4		
4	3	ML	Firm to stiff, grey SILT with trace sand. ...at 3.8 m depth woody, organic fragments ...at 4.0-4.1 m depth fine silty SAND lense ...at 5.3-5.5 m depth with trace sand, gravel absent ...becoming very stiff to hard below 5.8 m depth.
5	2	ML	
6	1		
7	0		
8	-1		
9	-2		
10	-3		
11	-4		
12	-5		
13	-6		
14	-7		
15	-8		
16	-9		
17	-10		
18	-11		
19	-12		
20			

REMARKS

1. Test hole terminated at required depth.

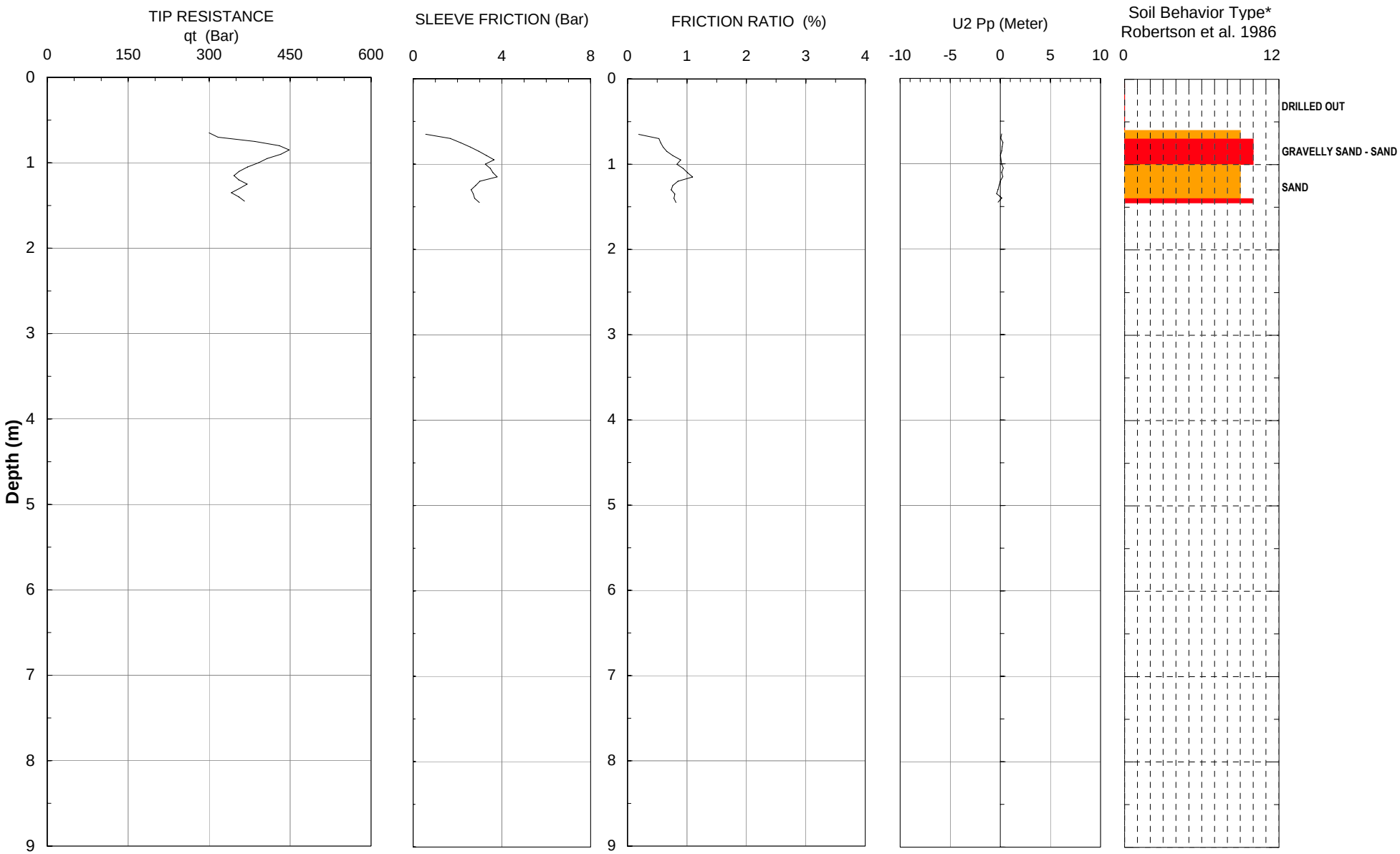
GARN SIZE W ENVELOPE -KM4 14-214-3.GPJ THURBER BC.GDT 4/5/13- THURBER BC.GLB Rev: 2/8/13

THURBER ENGINEERING

Operator: Schwartz Soil Technical
Sounding: CPT13 - 02
Cone Id: DPG1190 10 Ton

Date: January 28, 2013
Site: The Shores, Sechelt
Thurber Project Number: 14 - 214 - 3

Schwartz SOIL TECH



Maximum Depth = 1.45 meters

Depth Increment = 0.05 meters

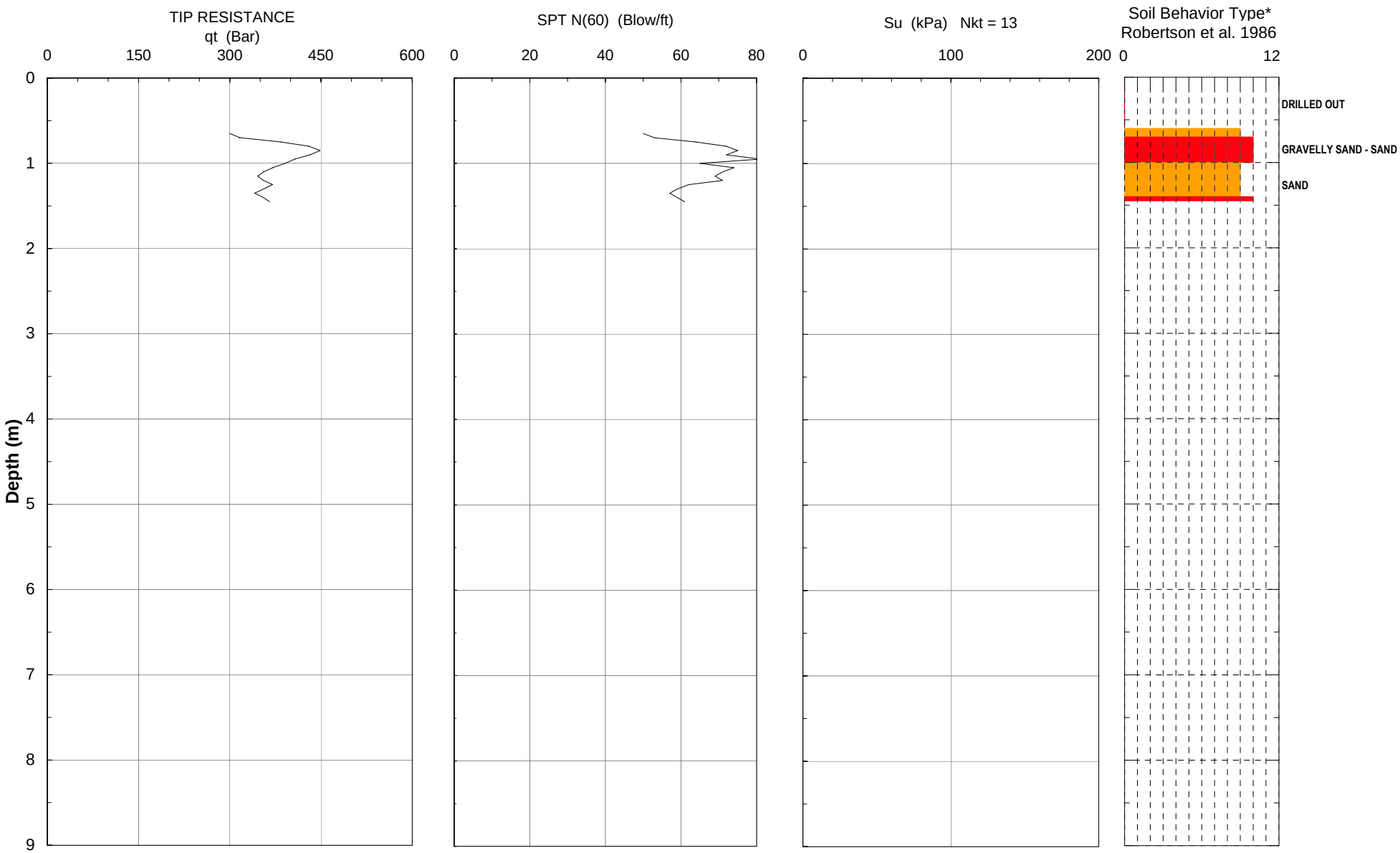
1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

THURBER ENGINEERING

Operator: Schwartz Soil Technical
Sounding: CPT13 - 02
Cone Id: DPG1190 10 Ton

Date: January 28, 2013
Site: The Shores, Sechelt
Thurber Project Number: 14 - 214 - 3

Schwartz SOIL TECH



Maximum Depth = 1.45 meters

Depth Increment = 0.05 meters

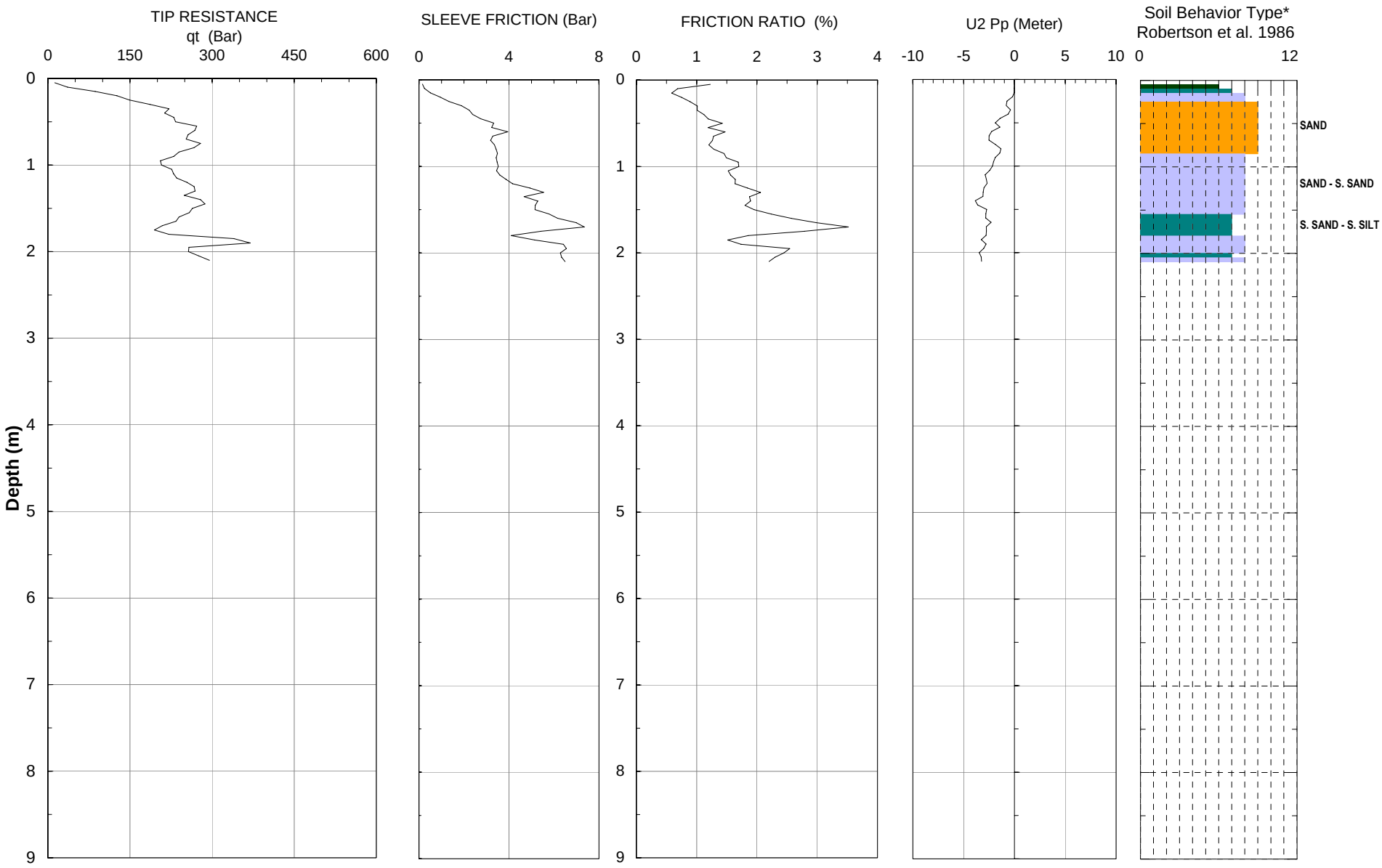
1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

THURBER ENGINEERING

Operator: Schwartz Soil Technical
Sounding: CPT13 - 05A
Cone Id: DPG1190 10 Ton

Date: January 29, 2013
Site: The Shores, Sechelt
Thurber Project Number: 14 - 214 - 3

Schwartz SOIL TECH



Maximum Depth = 2.10 meters

Depth Increment = 0.05 meters

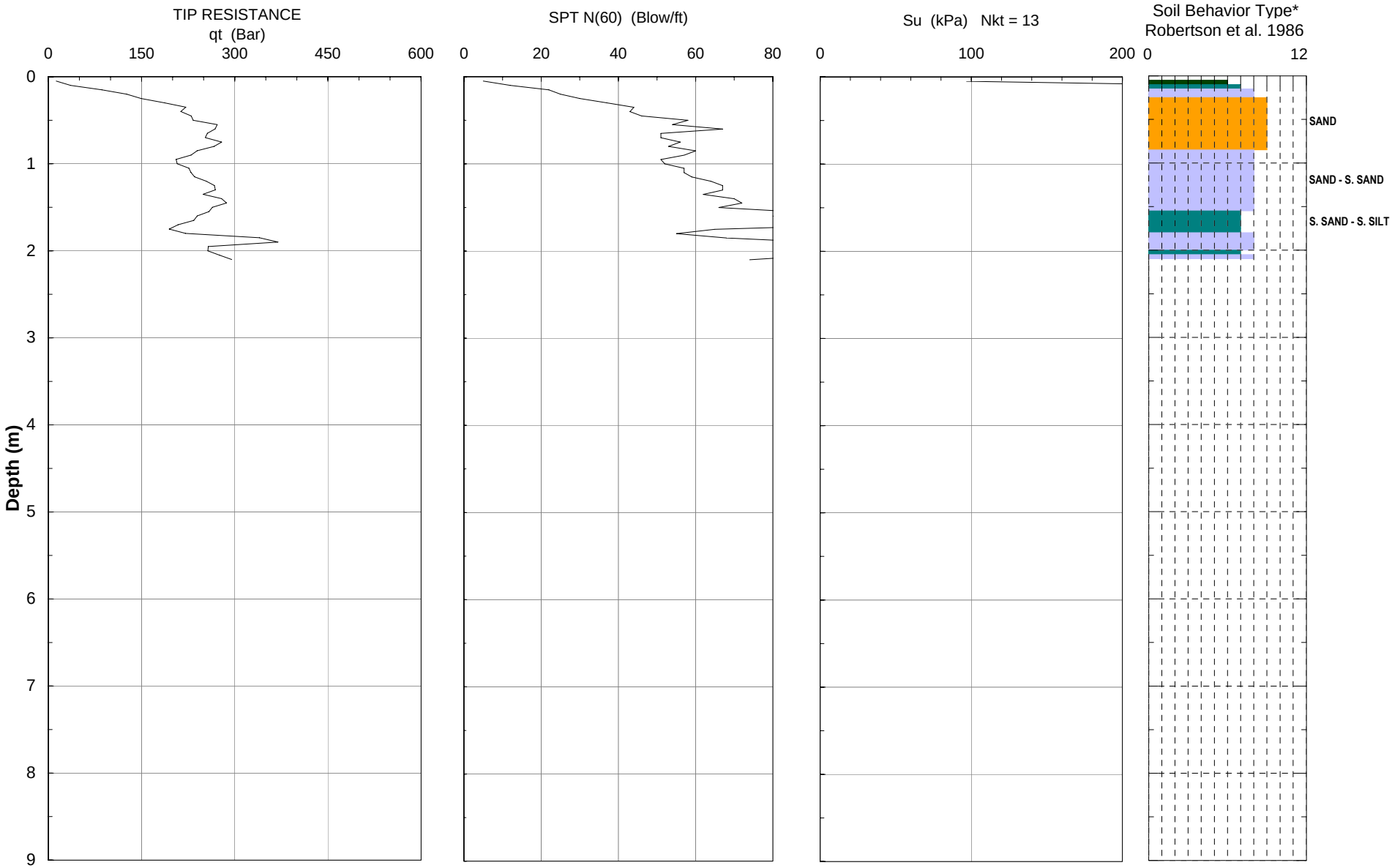
1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

THURBER ENGINEERING

Operator: Schwartz Soil Technical
Sounding: CPT13 - 05A
Cone Id: DPG1190 10 Ton

Date: January 29, 2013
Site: The Shores, Sechelt
Thurber Project Number: 14 - 214 - 3

Schwartz SOIL TECH



Maximum Depth = 2.10 meters

Depth Increment = 0.05 meters

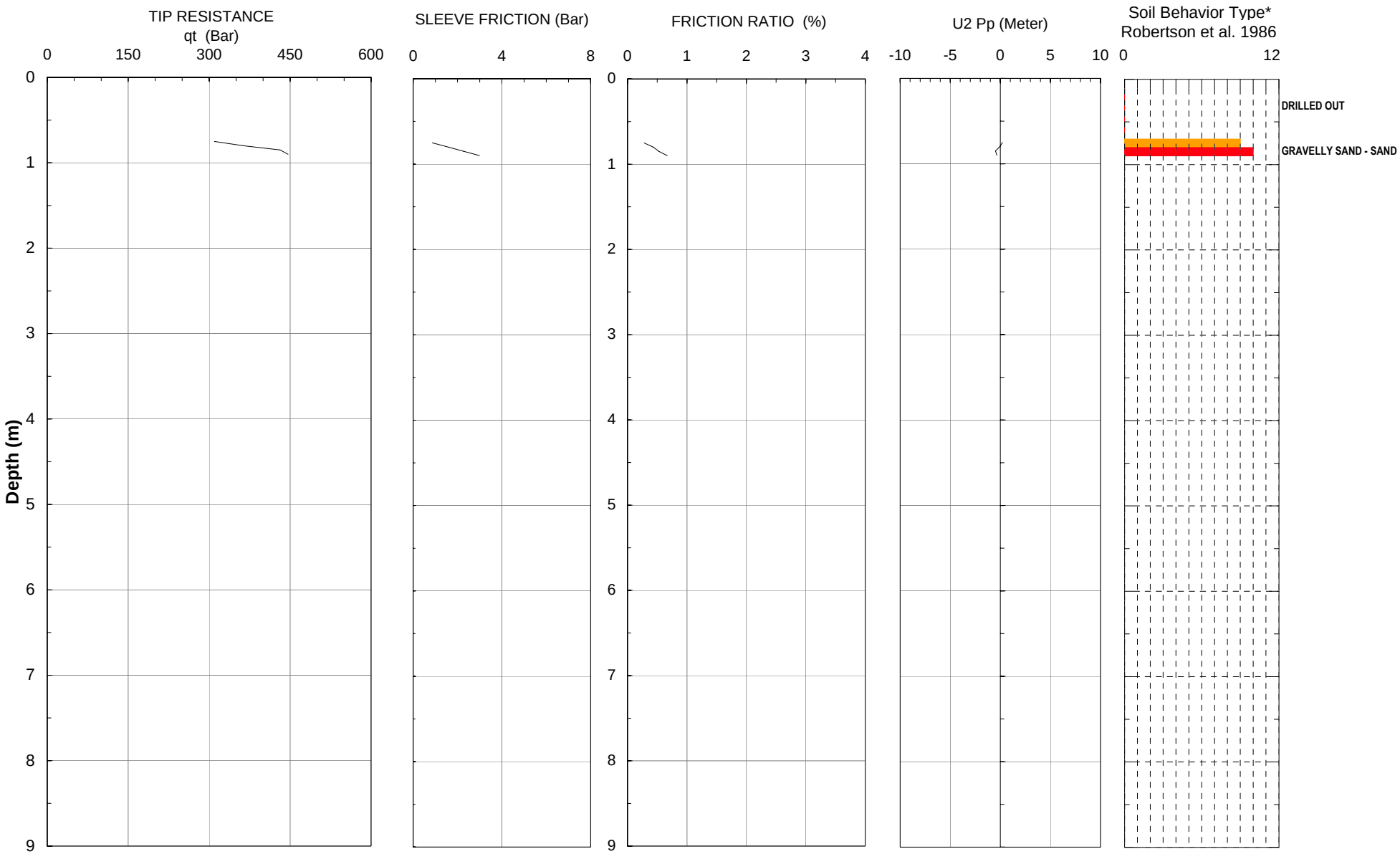
1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

THURBER ENGINEERING

Operator: Schwartz Soil Technical
Sounding: CPT13 - 05B
Cone Id: DPG1190 10 Ton

Date: January 29, 2013
Site: The Shores, Sechelt
Thurber Project Number: 14 - 214 - 3

Schwartz SOIL TECH



Maximum Depth = 0.90 meters

Depth Increment = 0.05 meters

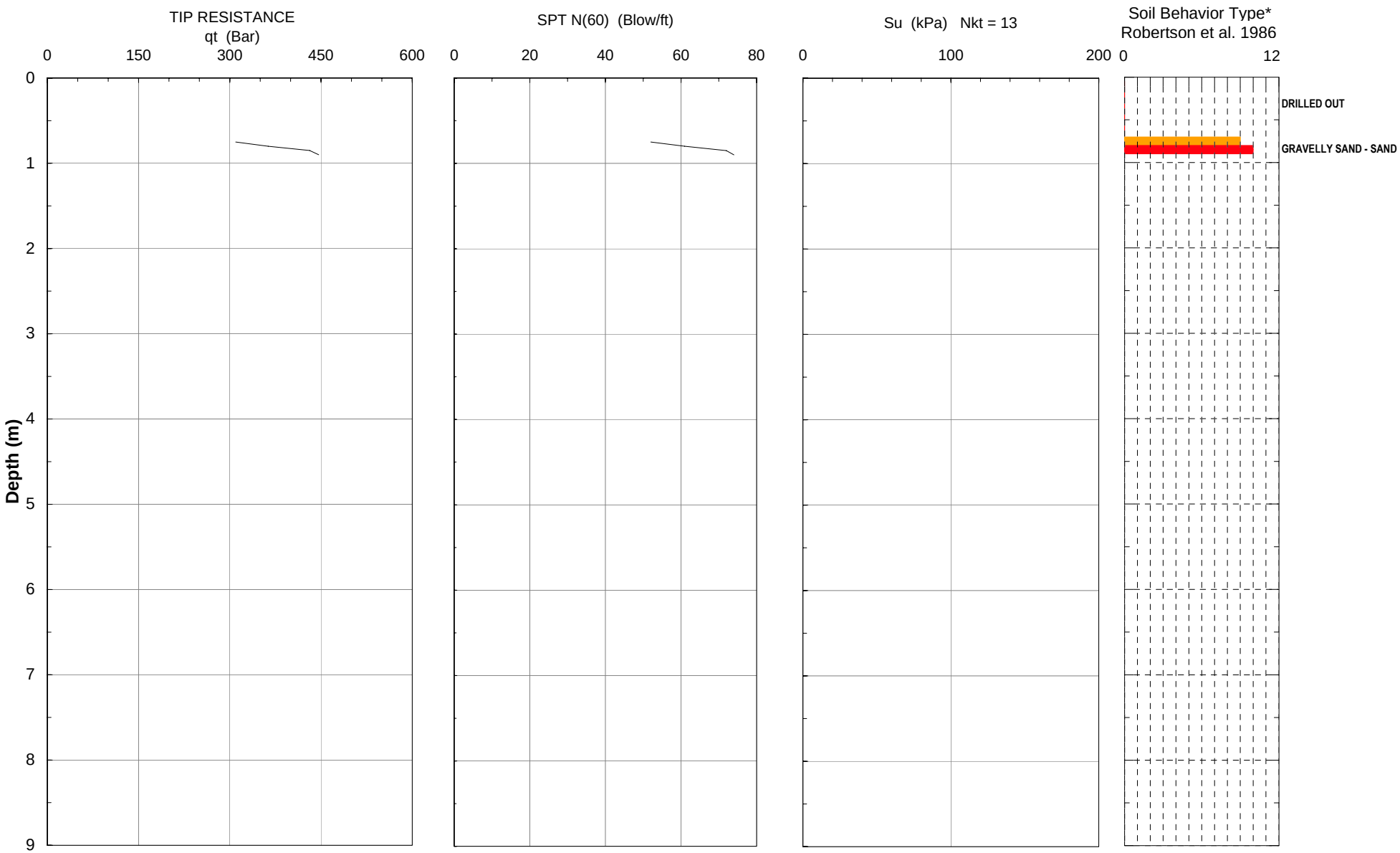
1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

THURBER ENGINEERING

Operator: Schwartz Soil Technical
Sounding: CPT13 - 05B
Cone Id: DPG1190 10 Ton

Date: January 29, 2013
Site: The Shores, Sechelt
Thurber Project Number: 14 - 214 - 3

Schwartz SOIL TECH



Maximum Depth = 0.90 meters

Depth Increment = 0.05 meters

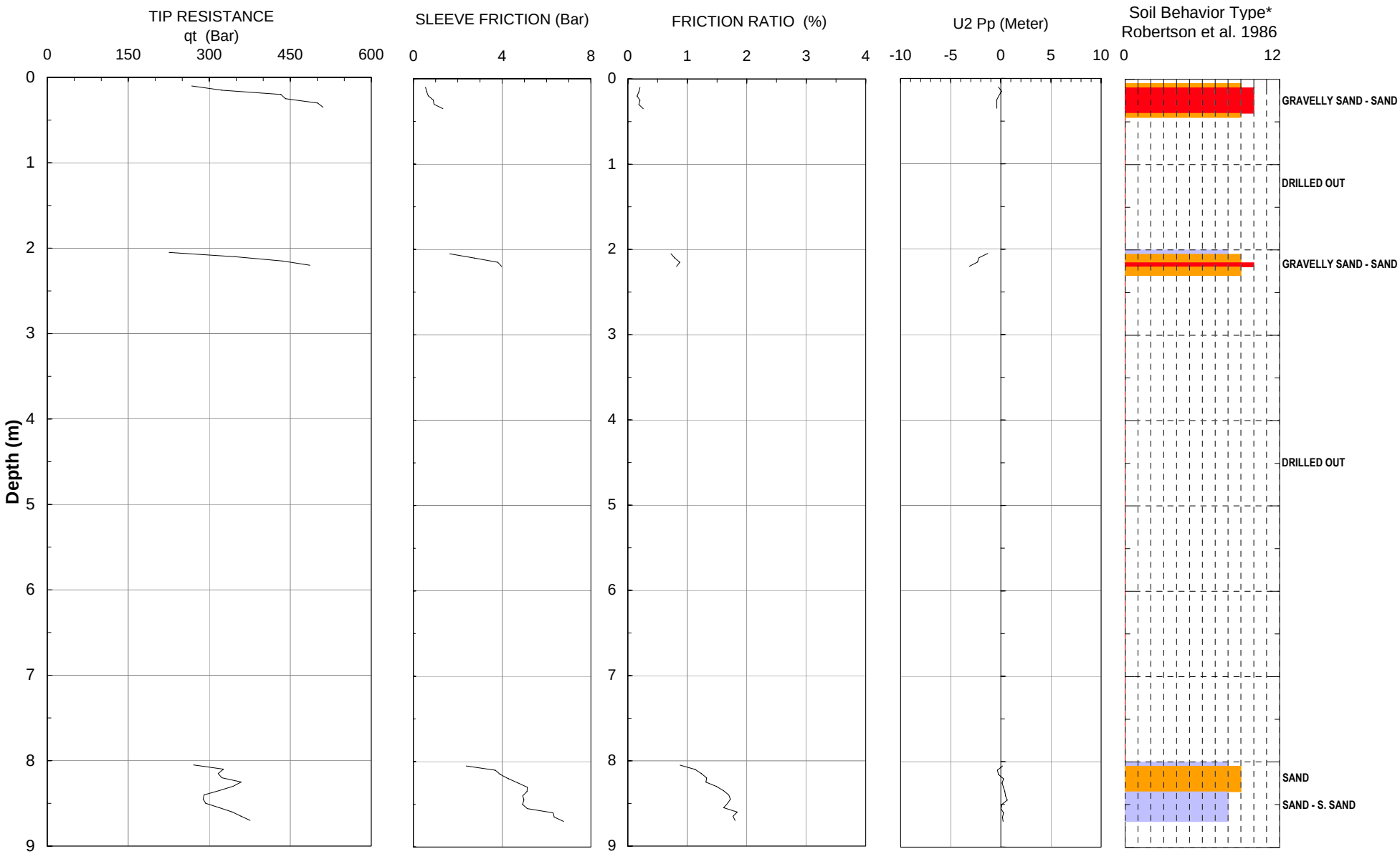
1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

THURBER ENGINEERING

Operator: Schwartz Soil Technical
Sounding: CPT13 - 05C
Cone Id: DPG1190 10 Ton

Date: January 29, 2013
Site: The Shores, Sechelt
Thurber Project Number: 14 - 214 - 3

Schwartz SOIL TECH



Maximum Depth = 8.70 meters

Depth Increment = 0.05 meters

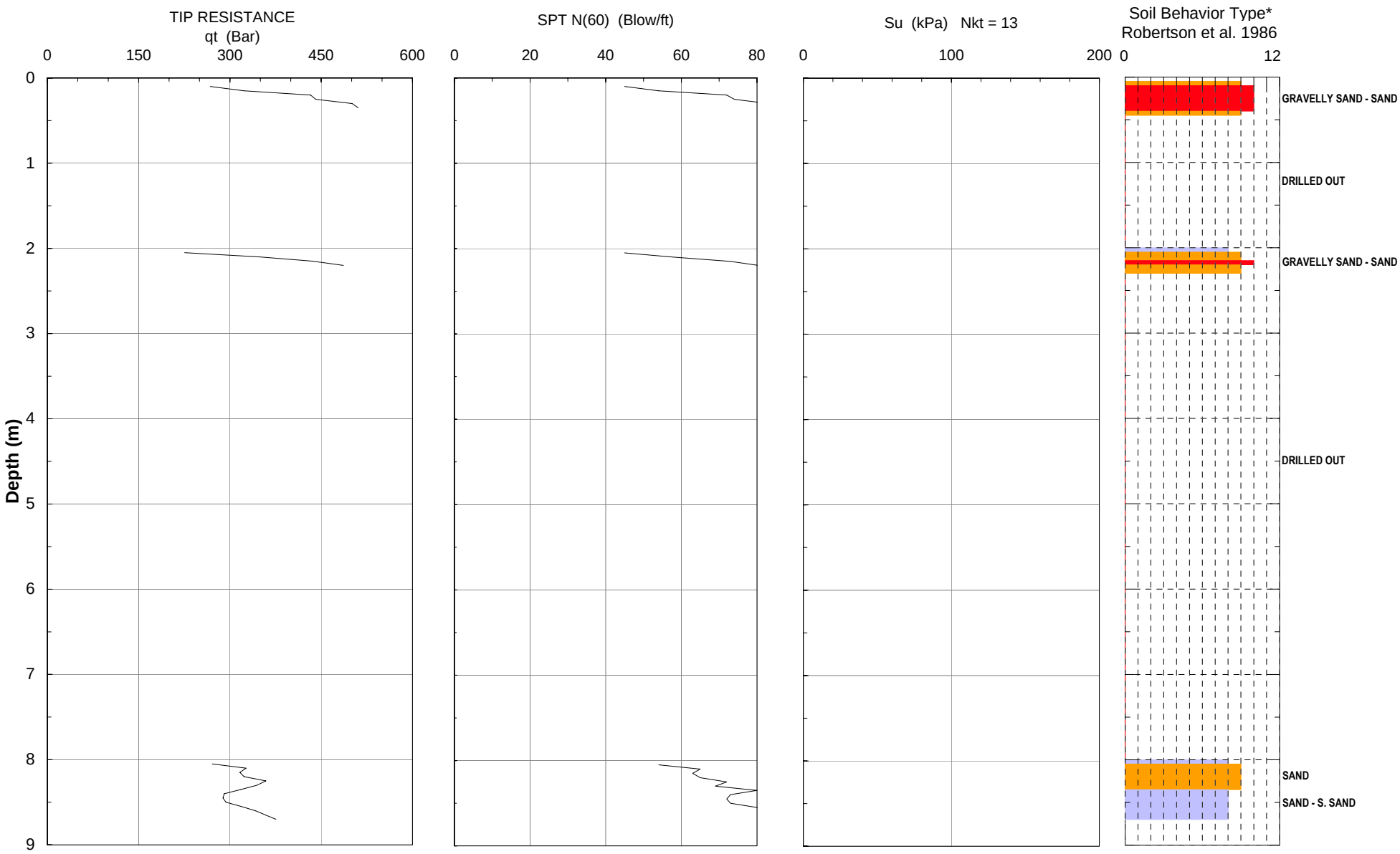
1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

THURBER ENGINEERING

Operator: Schwartz Soil Technical
Sounding: CPT13 - 05C
Cone Id: DPG1190 10 Ton

Date: January 29, 2013
Site: The Shores, Sechelt
Thurber Project Number: 14 - 214 - 3

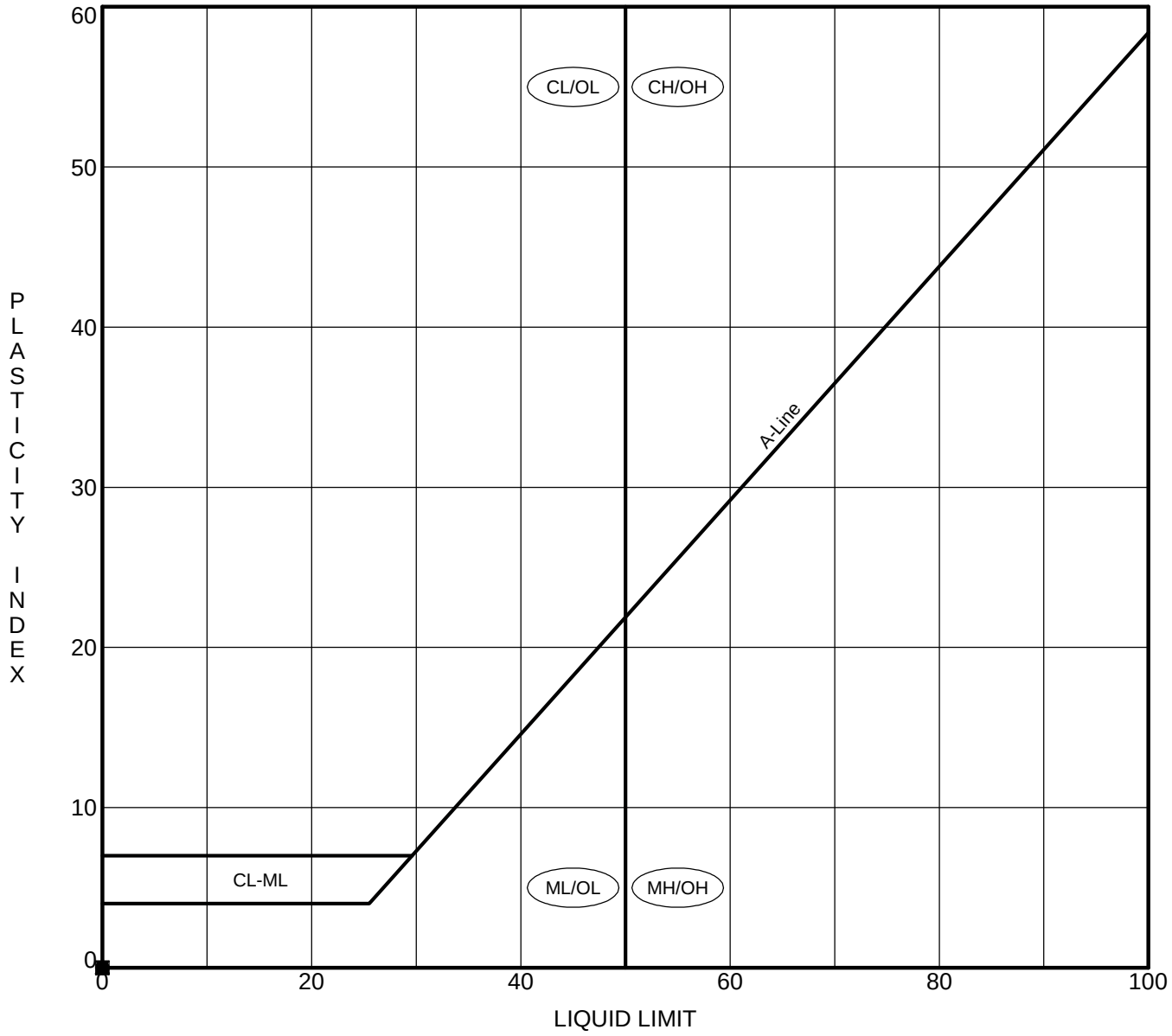
Schwartz SOIL TECH



Maximum Depth = 8.70 meters

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)



	Specimen Identification		LL	PL	PI	MC%	Classification
●	**TH13-07, Sa. 2**	**8.2 m**	**NP**	**NP**	**NP**	**17.6**	**Sandy SILT with traces of gravel and clay (ML).**
⊠	**TH13-08, Sa. 6**	**5.5 m**	**NP**	**NP**	**NP**	**29.2**	**SILT with traces of sand and clay (ML).**
▲	**TH13-09, Sa. 6**	**5.5 m**	**NP**	**NP**	**NP**	**26.3**	**SILT with traces of sand and clay (ML).**

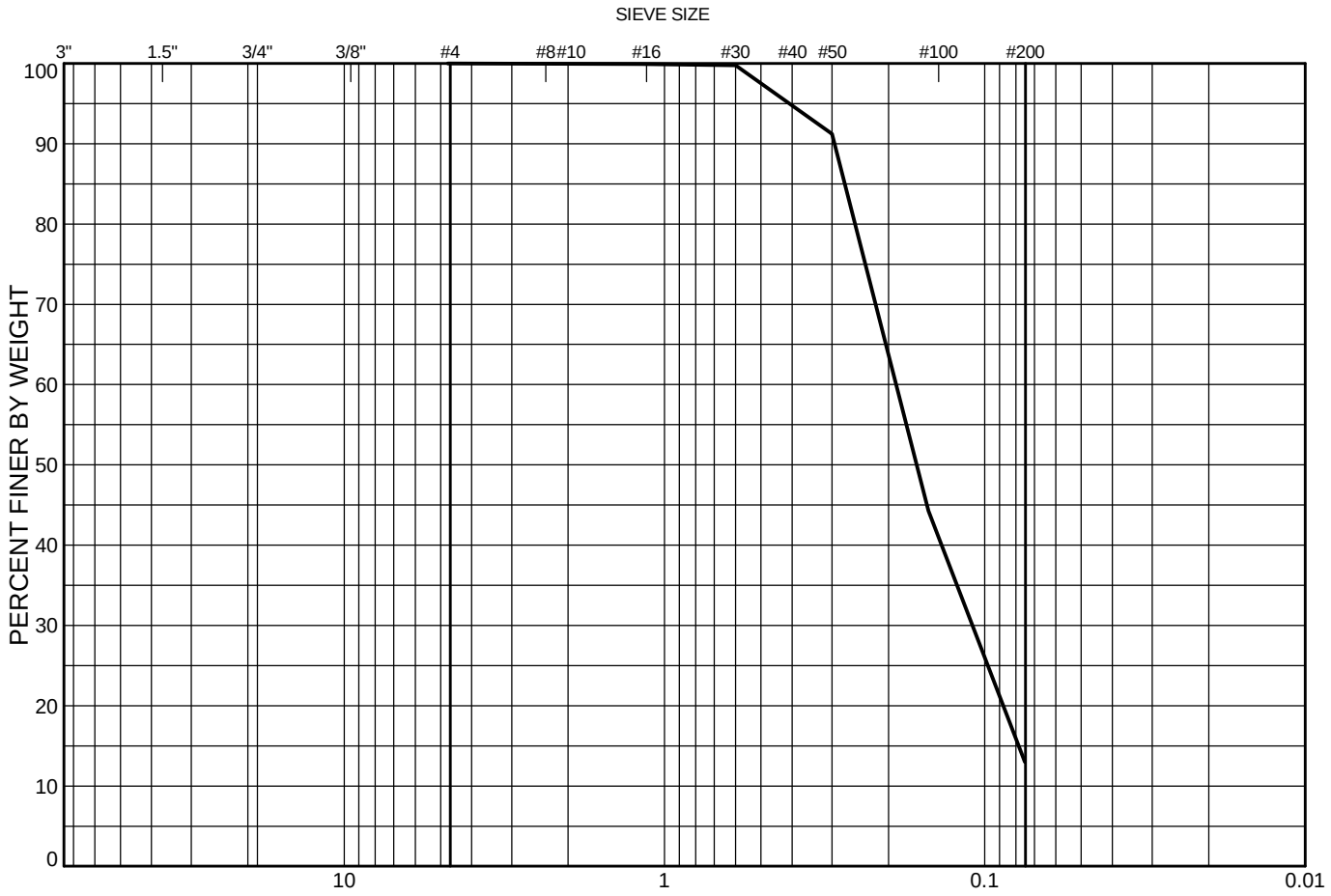
Thurber Engineering Ltd (Vancouver)

Telephone:
Fax:

PLASTICITY CHART

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3

ATTERBERG_LIMITS 14-214-3.GPJ CAN_LAB.GDT 4/4/13- THURBER BC.GLB Rev: 2/8/13



Sample Location: **Sediment Pond**
Sample: 1
Sample Depth: N/A
Date Sampled: February 1, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: February 13, 2013
Tested By: KM/JW
Test Method: ASTM C136 and C117
Specification:

Description:
Comments:

Gravel	**0.0%**
Sand	**87.0%**
Fines	**13.0%**
Moisture Content	**24.4%**

D10	
D30	**0.109**
D60	**0.189**
Cu	
Cc	

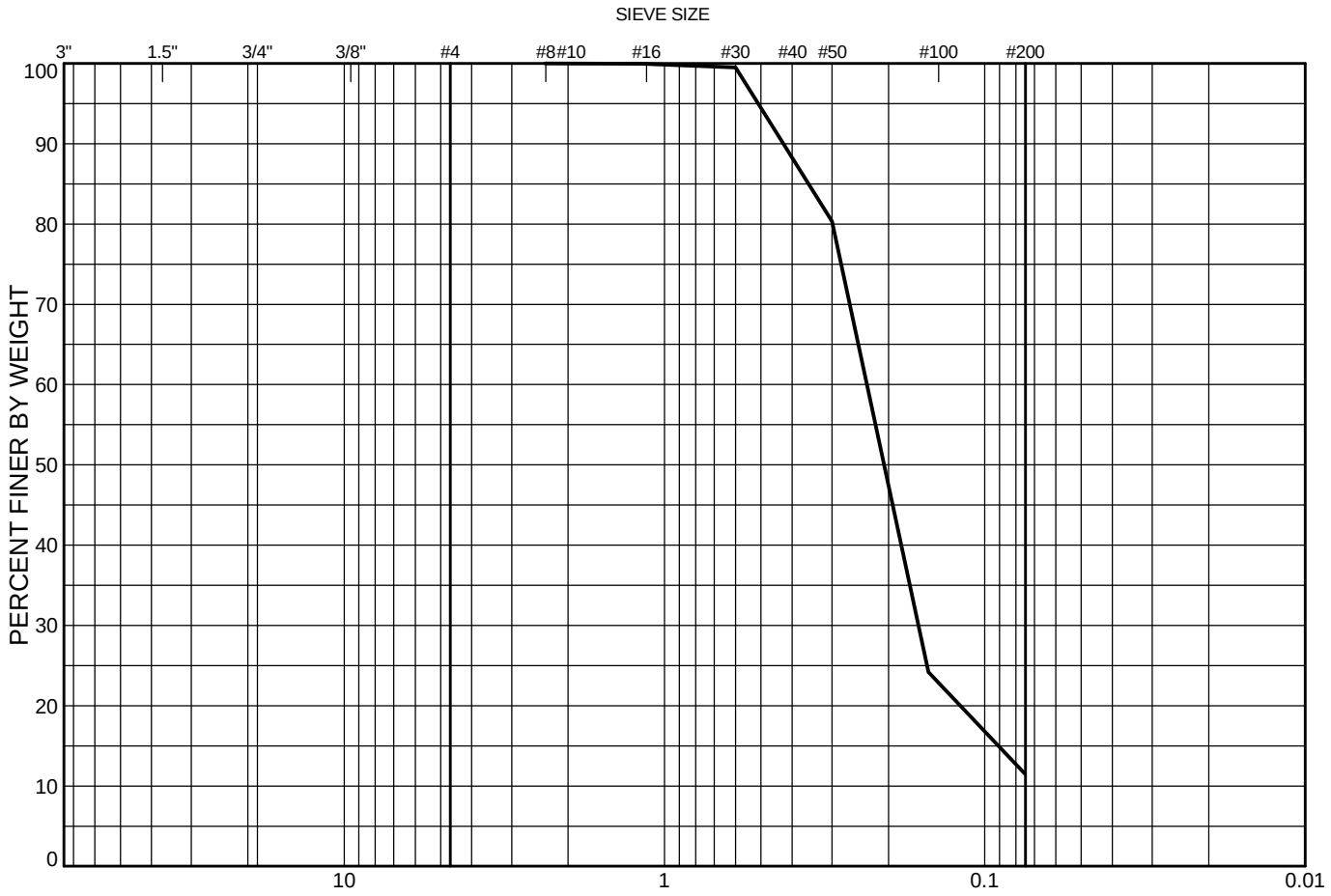
Sieve Size inches	Sieve Size mm	Percent Passing
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	**100.0**
#8	2.36	**100.0**
#16	1.18	**99.9**
#30	0.6	**99.8**
#50	0.3	**91.2**
#100	0.15	**44.3**
#200	0.075	**13.0**

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



Sample Location: **TH13-01**
Sample: 4
Sample Depth: 4.0 m
Date Sampled: February 1, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.0%**
Sand	**88.5%**
Fines	**11.5%**
Moisture Content	**9.8%**

D10	
D30	**0.161**
D60	**0.233**
Cu	**3.38**
Cc	**1.61**

Sieve Size inches	Sieve Size mm	Percent Passing
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	
#8	2.36	**100.0**
#16	1.18	**100.0**
#30	0.6	**99.5**
#50	0.3	**80.3**
#100	0.15	**24.2**
#200	0.075	**11.5**

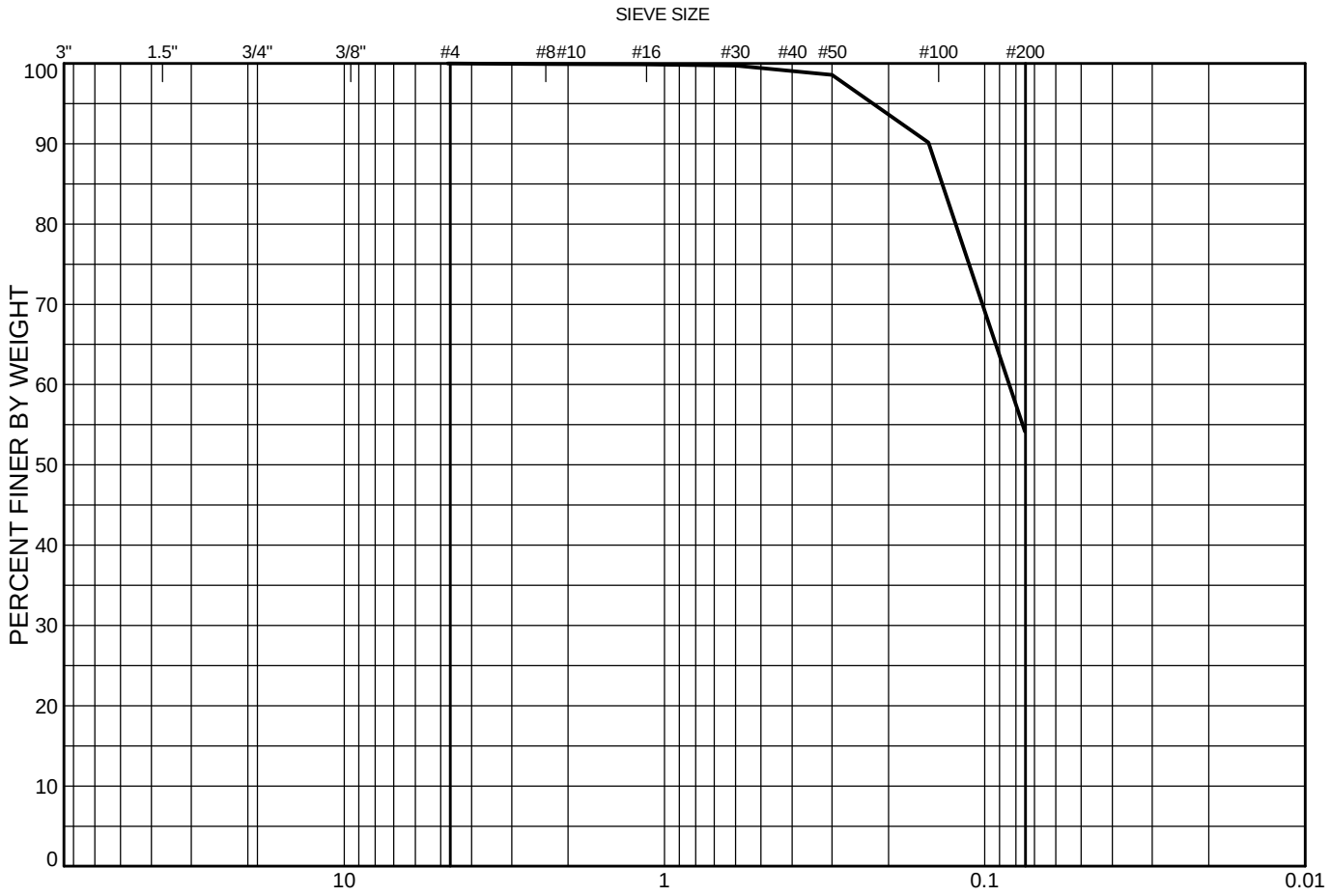
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



Sample Location: **TH13-01**
Sample: 11
Sample Depth: 12.5 m
Date Sampled: February 1, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.0%**
Sand	**45.8%**
Fines	**54.2%**
Moisture Content	**21.8%**

D10	
D30	
D60	**0.084**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	**100.0**
#8	2.36	**99.9**
#16	1.18	**99.9**
#30	0.6	**99.7**
#50	0.3	**98.6**
#100	0.15	**90.1**
#200	0.075	**54.2**

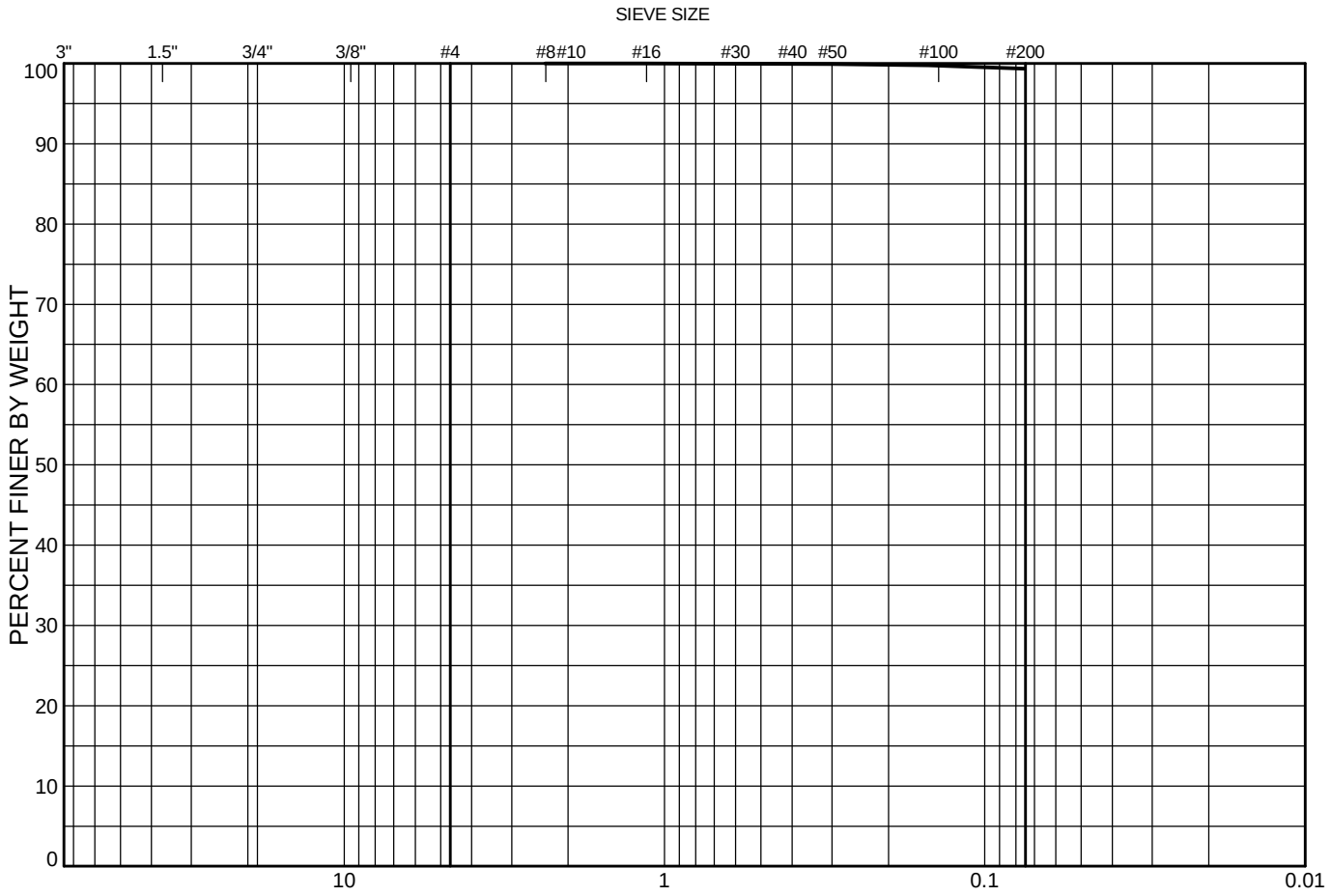
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAIN SIZE IN MILLIMETRES

GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH13-01**
Sample: 12
Sample Depth: 13.4 m
Date Sampled: February 1, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.0%**
Sand	**0.7%**
Fines	**99.3%**
Moisture Content	**27.8%**

D10	
D30	
D60	
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	
#8	2.36	**100.0**
#16	1.18	**100.0**
#30	0.6	**100.0**
#50	0.3	**99.9**
#100	0.15	**99.8**
#200	0.075	**99.3**

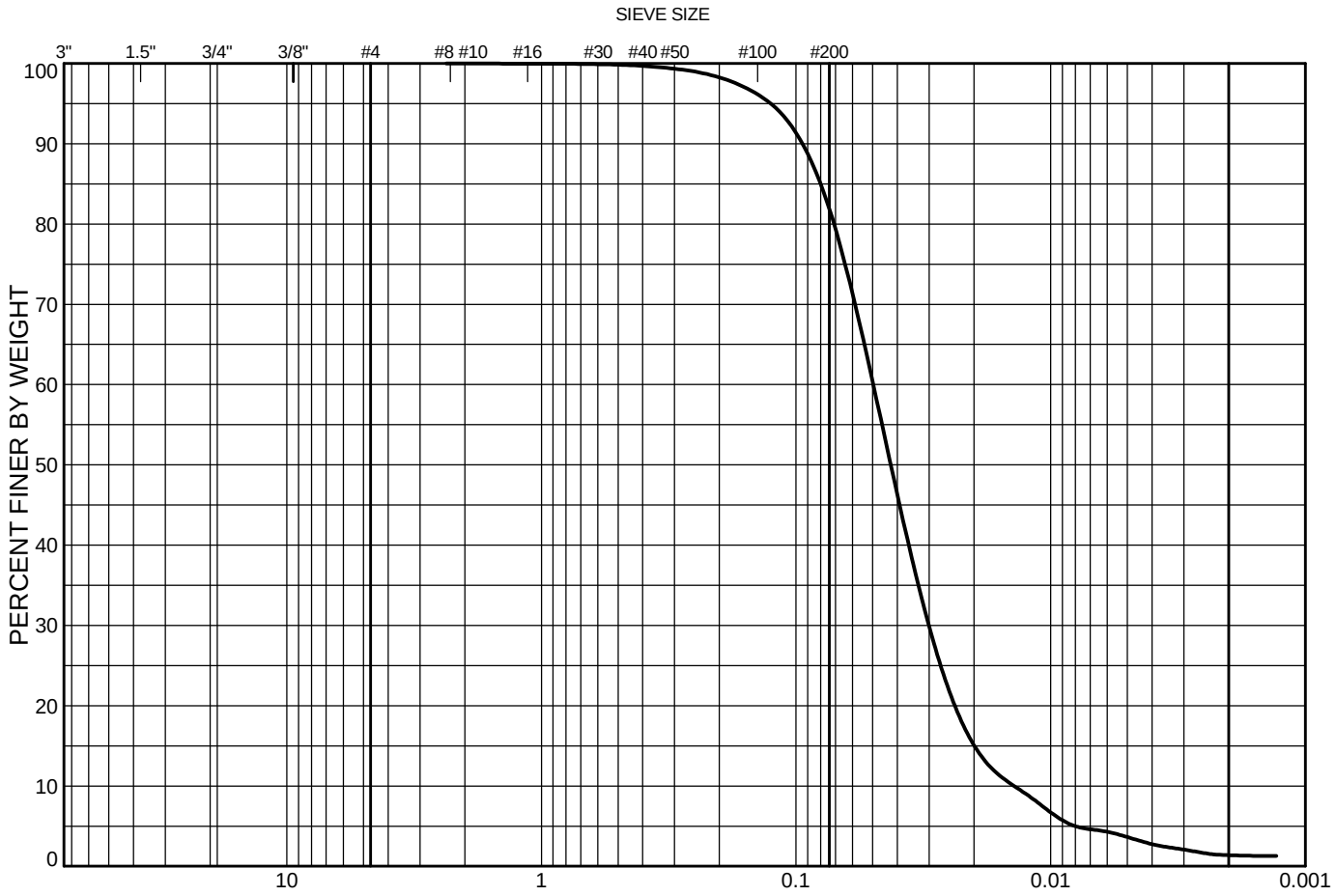
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

Sample Location: **TH13-01**
Sample: 14
Sample Depth: 14.6 m
Date Sampled: February 1, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: February 14, 2013
Tested By: KM
Test Method: ASTM D422 & C136
Specification:

Gravel	**0.0%**
Sand	**17.5%**
Silt	**81.0%**
Clay	**1.4%**
Moisture Content	**24.7%**

LL	
PL	
PI	

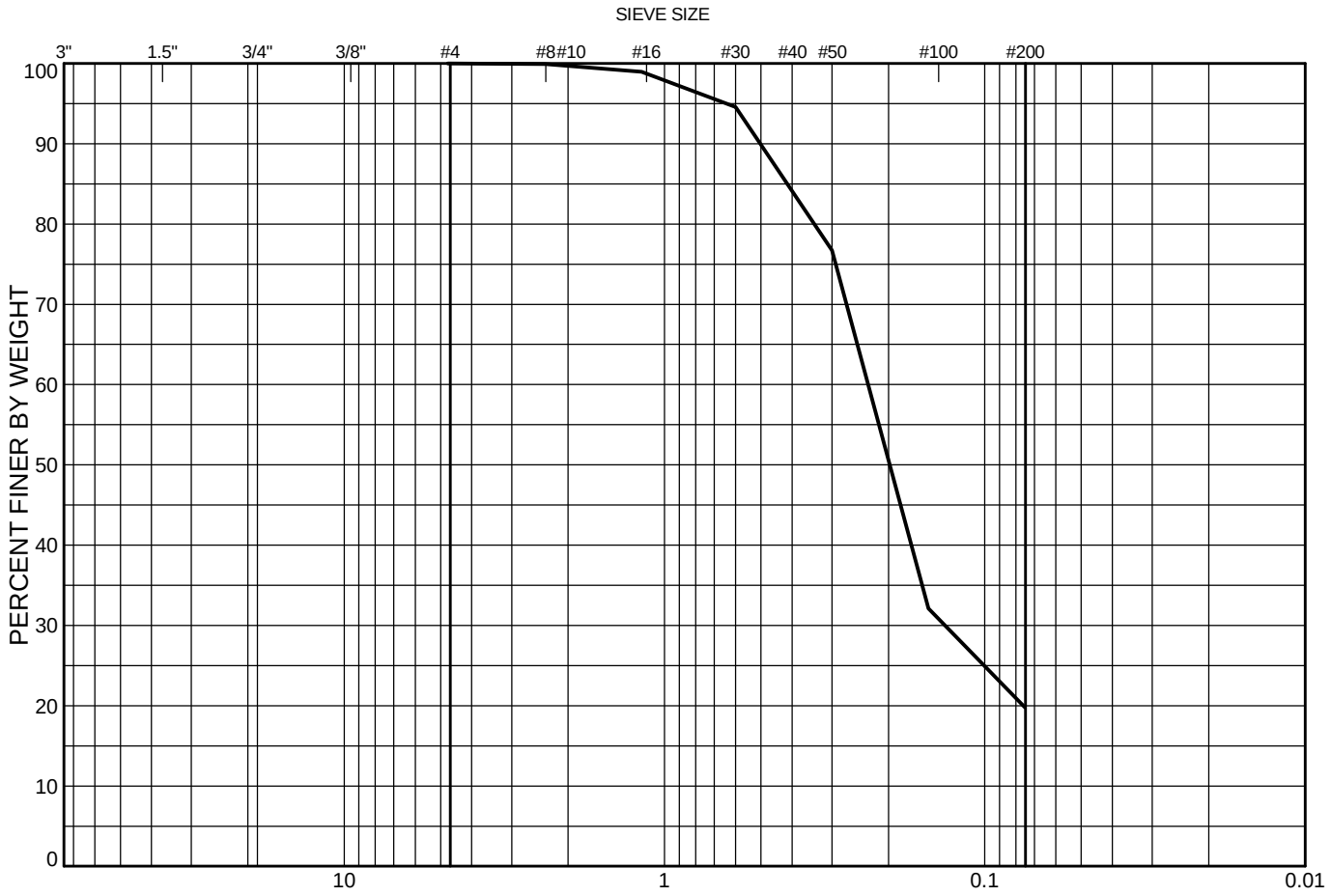
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd (Vancouver)
Telephone:
Fax:

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH13-02**
Sample: 5
Sample Depth: 5.2 m
Date Sampled: January 28, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.0%**
Sand	**80.2%**
Fines	**19.8%**
Moisture Content	**7.0%**

D10	
D30	**0.133**
D60	**0.231**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	**100.0**
#8	2.36	**99.9**
#16	1.18	**99.0**
#30	0.6	**94.6**
#50	0.3	**76.7**
#100	0.15	**32.1**
#200	0.075	**19.8**

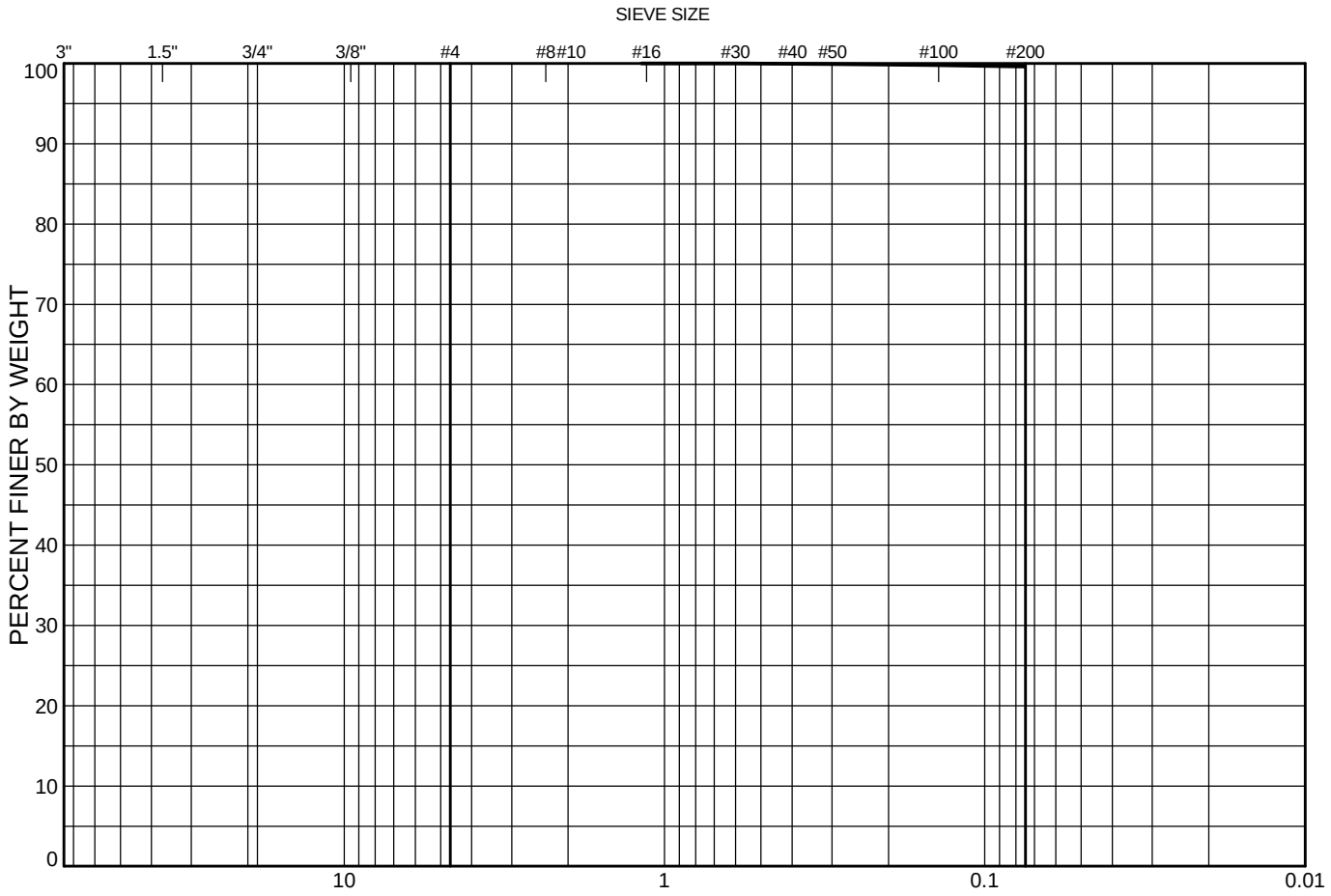
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



Sample Location: **TH13-02**
Sample: 11
Sample Depth: 13.4 m
Date Sampled: January 28, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Description:
Comments:

Gravel	**0.0%**
Sand	**0.4%**
Fines	**99.6%**
Moisture Content	**24.7%**

D10	
D30	
D60	
Cu	
Cc	

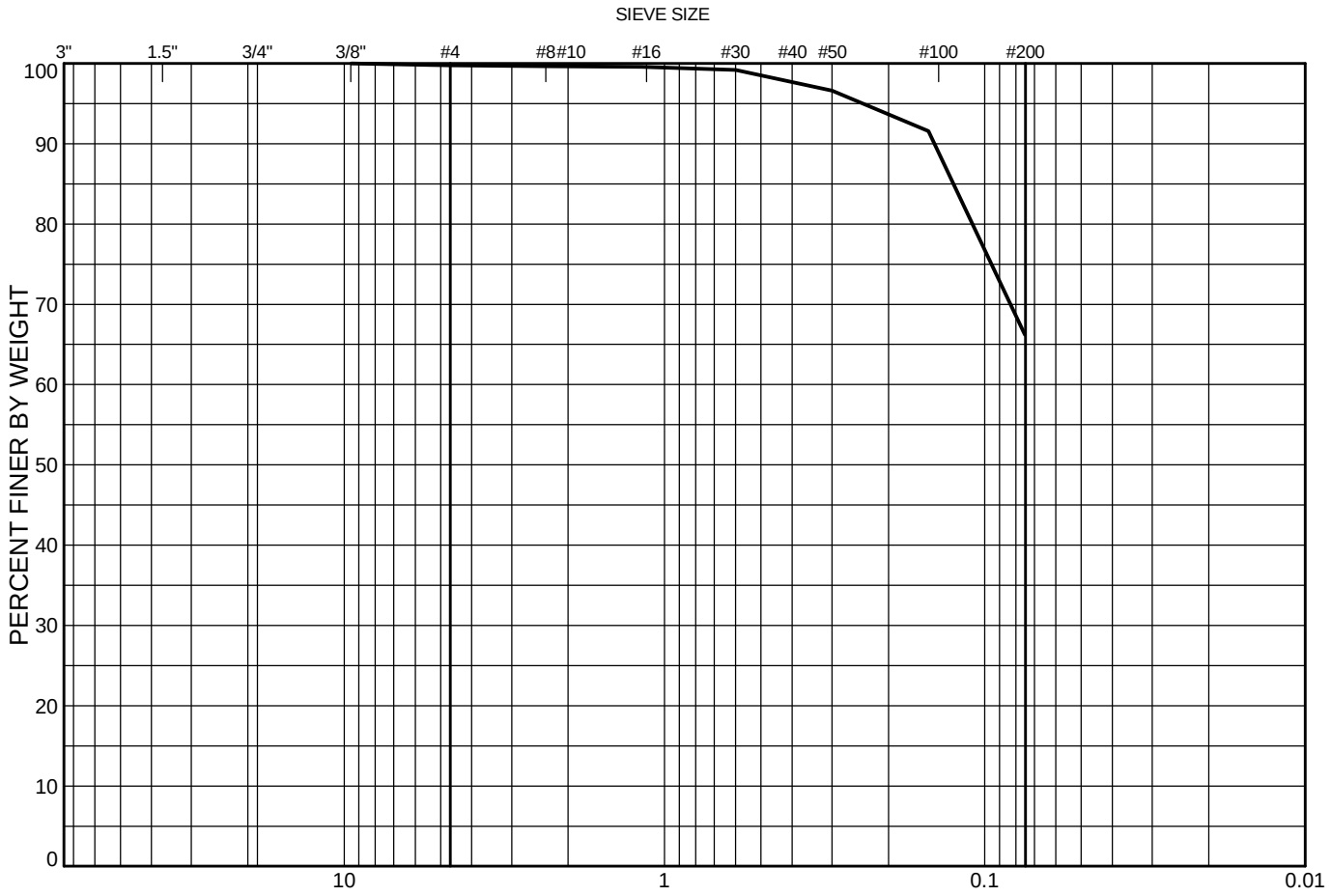
Sieve Size inches	Sieve Size mm	Percent Passing
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	
#8	2.36	
#16	1.18	**100.0**
#30	0.6	**100.0**
#50	0.3	**99.9**
#100	0.15	**99.8**
#200	0.075	**99.6**

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAIN SIZE IN MILLIMETRES

GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH13-02**
Sample: 12
Sample Depth: 13.7 m
Date Sampled: January 28, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.2%**
Sand	**33.6%**
Fines	**66.2%**
Moisture Content	**18.2%**

D10	
D30	
D60	
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	**100.0**
#4	4.75	**99.8**
#8	2.36	**99.7**
#16	1.18	**99.6**
#30	0.6	**99.2**
#50	0.3	**96.6**
#100	0.15	**91.6**
#200	0.075	**66.2**

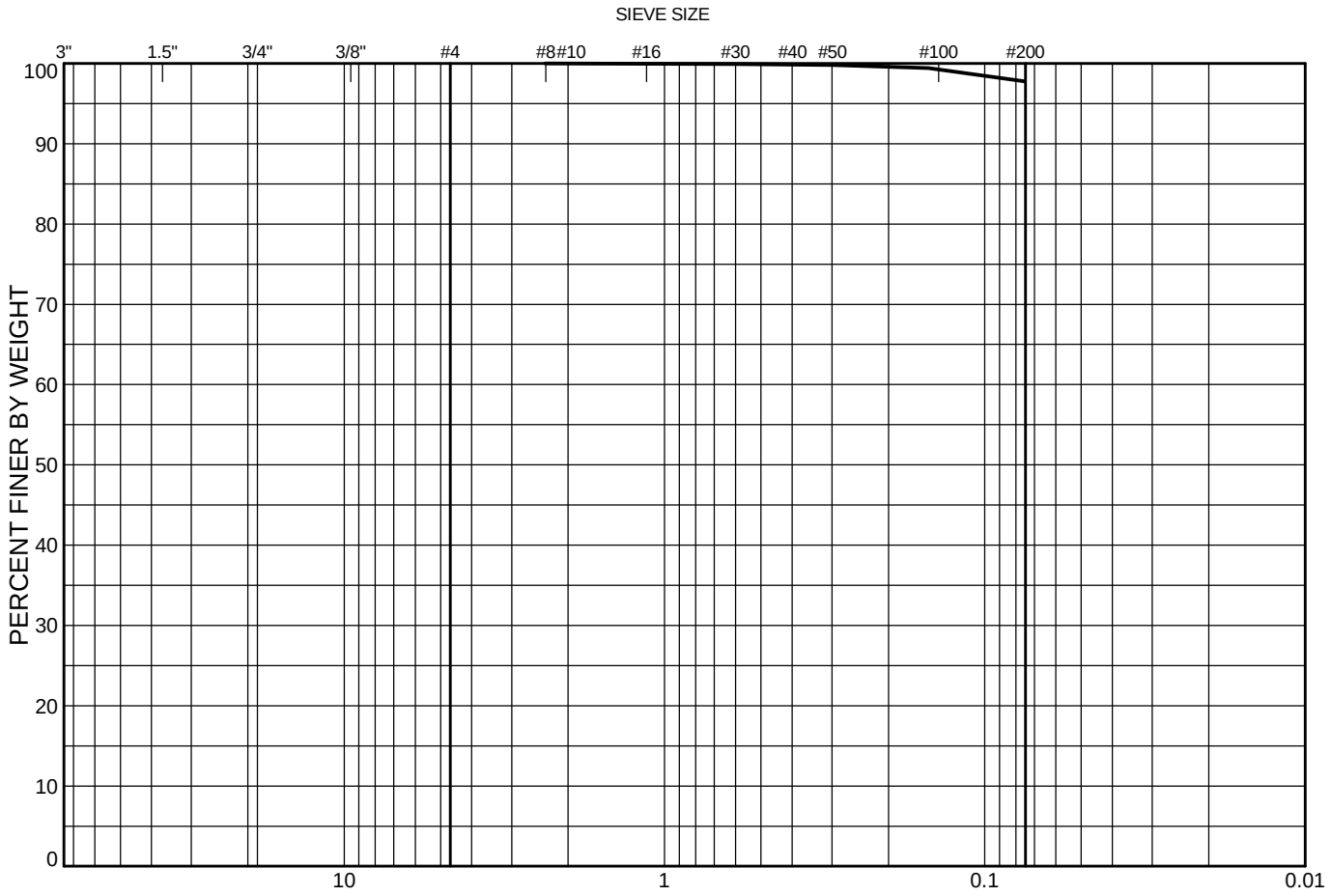
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAIN SIZE IN MILLIMETRES

GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH13-02**
Sample: 13
Sample Depth: 14.3 m
Date Sampled: January 28, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.0%**
Sand	**2.2%**
Fines	**97.8%**
Moisture Content	**29.2%**

D10	
D30	
D60	
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	
#8	2.36	**100.0**
#16	1.18	**100.0**
#30	0.6	**99.9**
#50	0.3	**99.8**
#100	0.15	**99.4**
#200	0.075	**97.8**

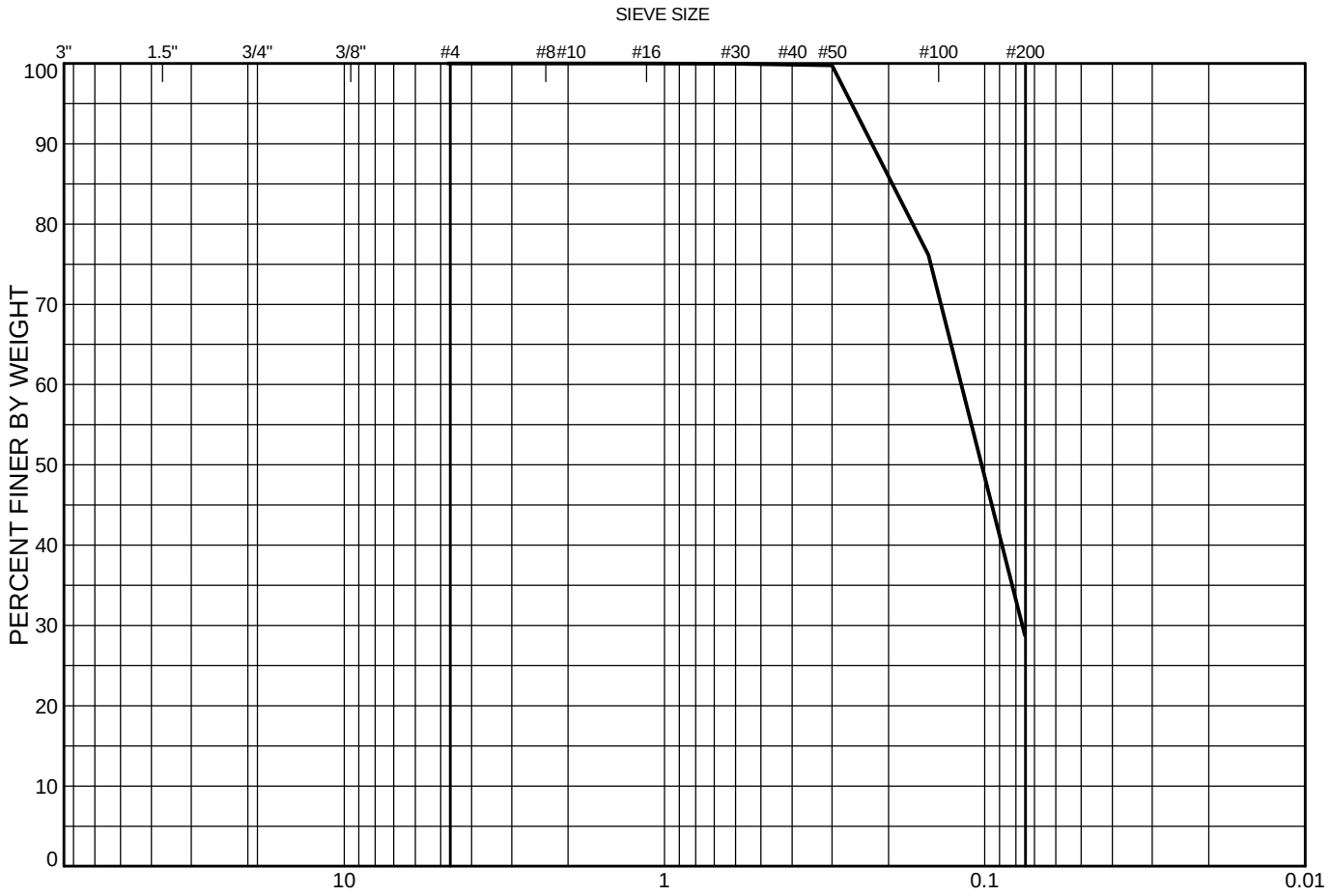
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAIN SIZE IN MILLIMETRES

GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH13-02**
Sample: 15
Sample Depth: 16.2 m
Date Sampled: January 28, 2013
Sampled By: AGB
Date Received: February 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**0.0%**
Sand	**71.2%**
Fines	**28.8%**
Moisture Content	**22.6%**

D10	
D30	**0.076**
D60	**0.118**
Cu	
Cc	

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	**100.0**
#8	2.36	**100.0**
#16	1.18	**100.0**
#30	0.6	**100.0**
#50	0.3	**99.8**
#100	0.15	**76.2**
#200	0.075	**28.8**

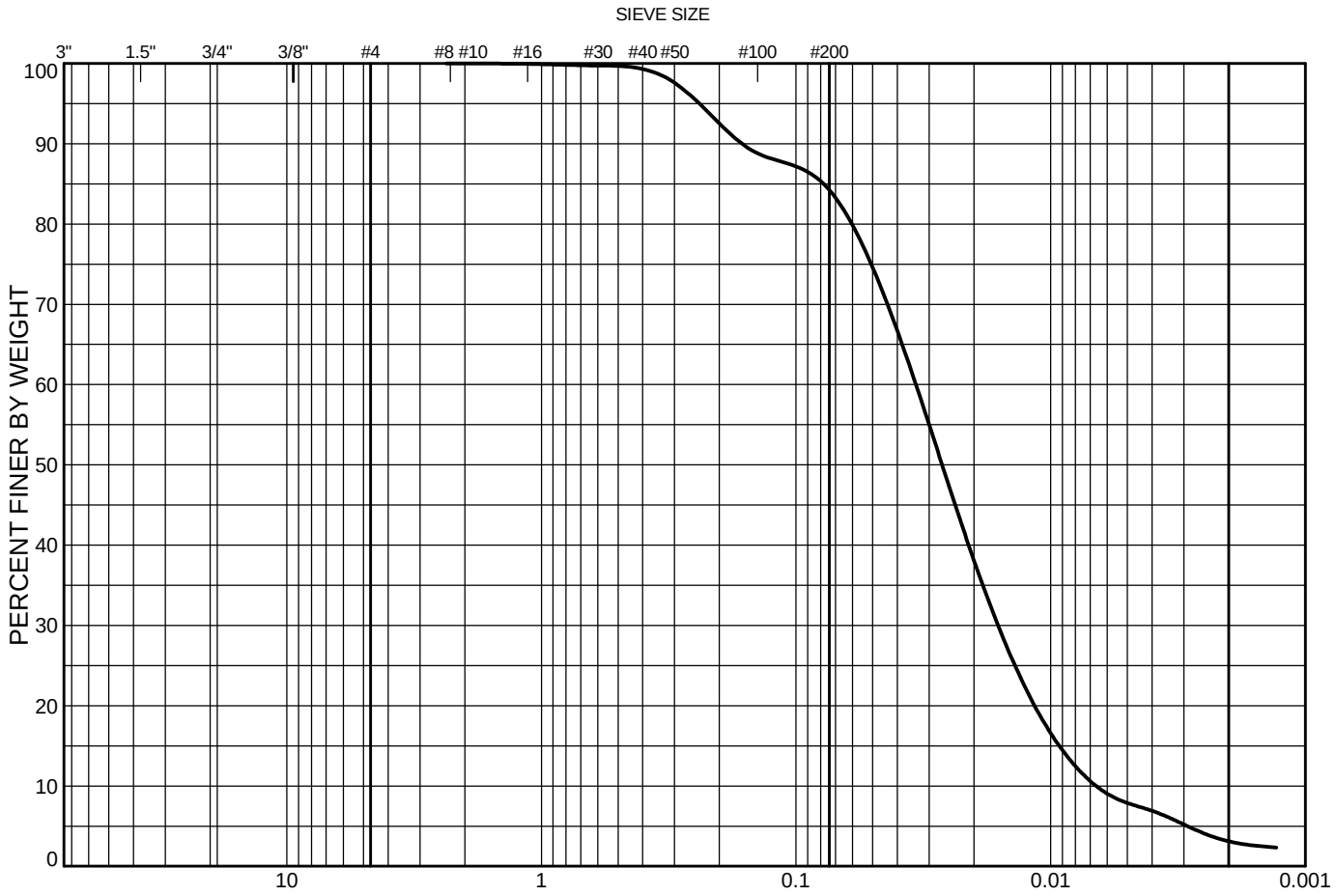
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

Sample Location: **TH13-02**
Sample: 16
Sample Depth: 17.7 m
Date Sampled: January 28, 2013
Sampled By: AGB
Date Received: February 14, 2013
Date Tested: February 7, 2013
Tested By: KM
Test Method: ASTM D422 & C136
Specification:

Gravel	**0.0%**
Sand	**15.5%**
Silt	**81.1%**
Clay	**3.3%**
Moisture Content	**26.2%**

LL	
PL	
PI	

Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd (Vancouver)
Telephone:
Fax:

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



Sample Location: **TH13-05C**
Sample: 2
Sample Depth: 3.0 m
Date Sampled: Jan 29, 2013
Sampled By: AGB
Date Received: Feb 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Description:
Comments:

Gravel	**4.5%**
Sand	**59.3%**
Fines	**36.2%**
Moisture Content	**10.7%**

D10	
D30	
D60	**0.25**
Cu	
Cc	

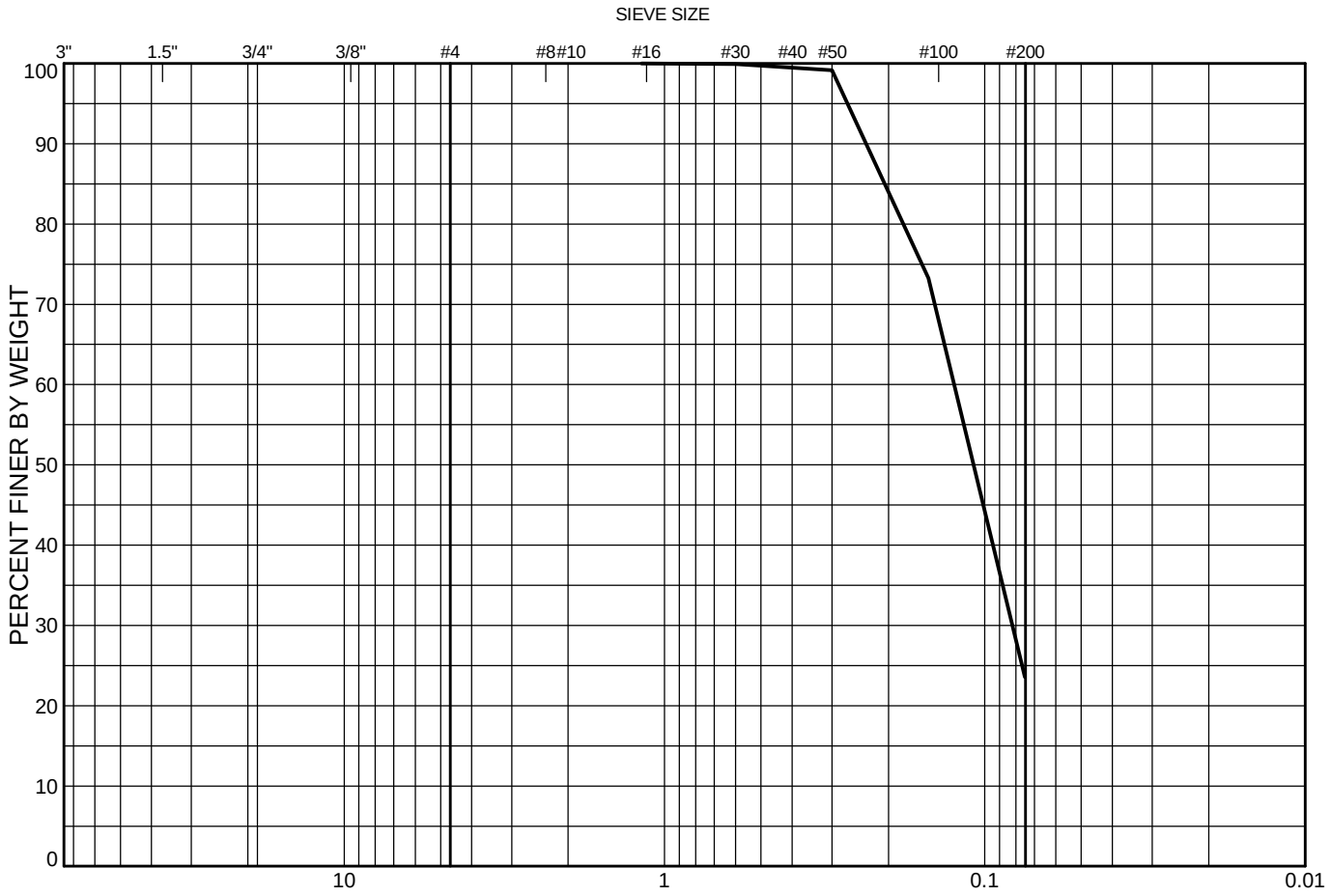
Sieve Size inches	Sieve Size mm	Percent Passing
3	75	
1.5	37.5	
0.75	19	**100.0**
0.375	9.5	**98.2**
#4	4.75	**95.5**
#8	2.36	**91.8**
#16	1.18	**86.8**
#30	0.6	**78.4**
#50	0.3	**64.3**
#100	0.15	**48.0**
#200	0.075	**36.2**

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAIN SIZE IN MILLIMETRES

GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: **TH13-05C**
Sample: 5
Sample Depth: 7.6 m
Date Sampled: Jan 29, 2013
Sampled By: AGB
Date Received: Feb 6, 2013
Date Tested: March 18, 2013
Tested By: KM
Test Method: ASTM C136 and C117
Specification:

Description:
Comments:

Gravel	**0.0%**
Sand	**76.4%**
Fines	**23.6%**
Moisture Content	**13.6%**

D10	
D30	**0.082**
D60	**0.125**
Cu	
Cc	

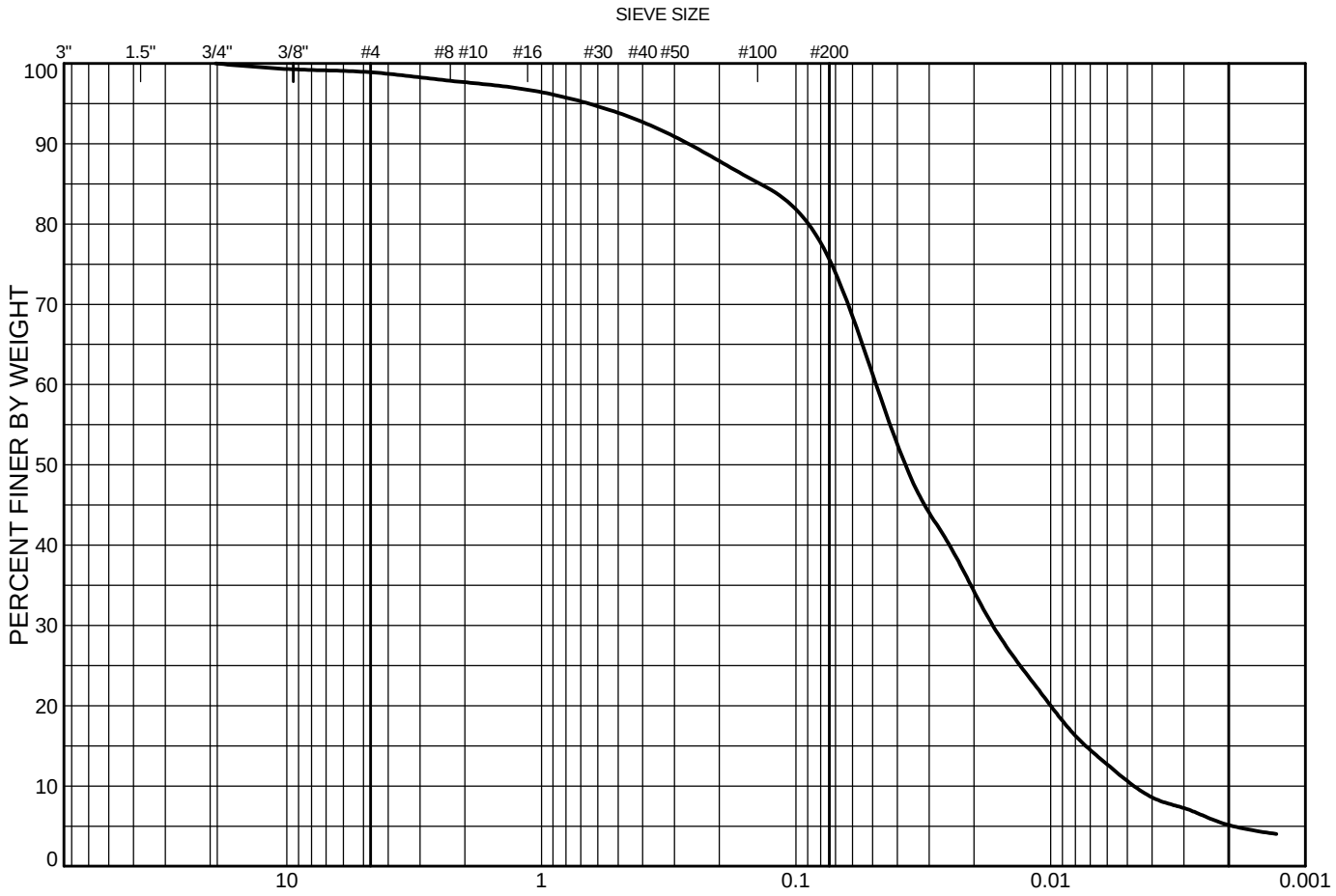
Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	
#8	2.36	
#16	1.18	**100.0**
#30	0.6	**99.9**
#50	0.3	**99.2**
#100	0.15	**73.3**
#200	0.075	**23.6**

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

Sample Location: **TH13-07**
Sample: 2
Sample Depth: 8.2 m
Date Sampled: January 30/31, 2013
Sampled By: AGB
Date Received: February 14, 2013
Date Tested: February 7, 2013
Tested By: KM
Test Method: ASTM D422 & C136
Specification:

Gravel	**1.1%**
Sand	**22.9%**
Silt	**70.6%**
Clay	**5.4%**
Moisture Content	**17.6%**

LL	**0**
PL	**0**
PI	**0**

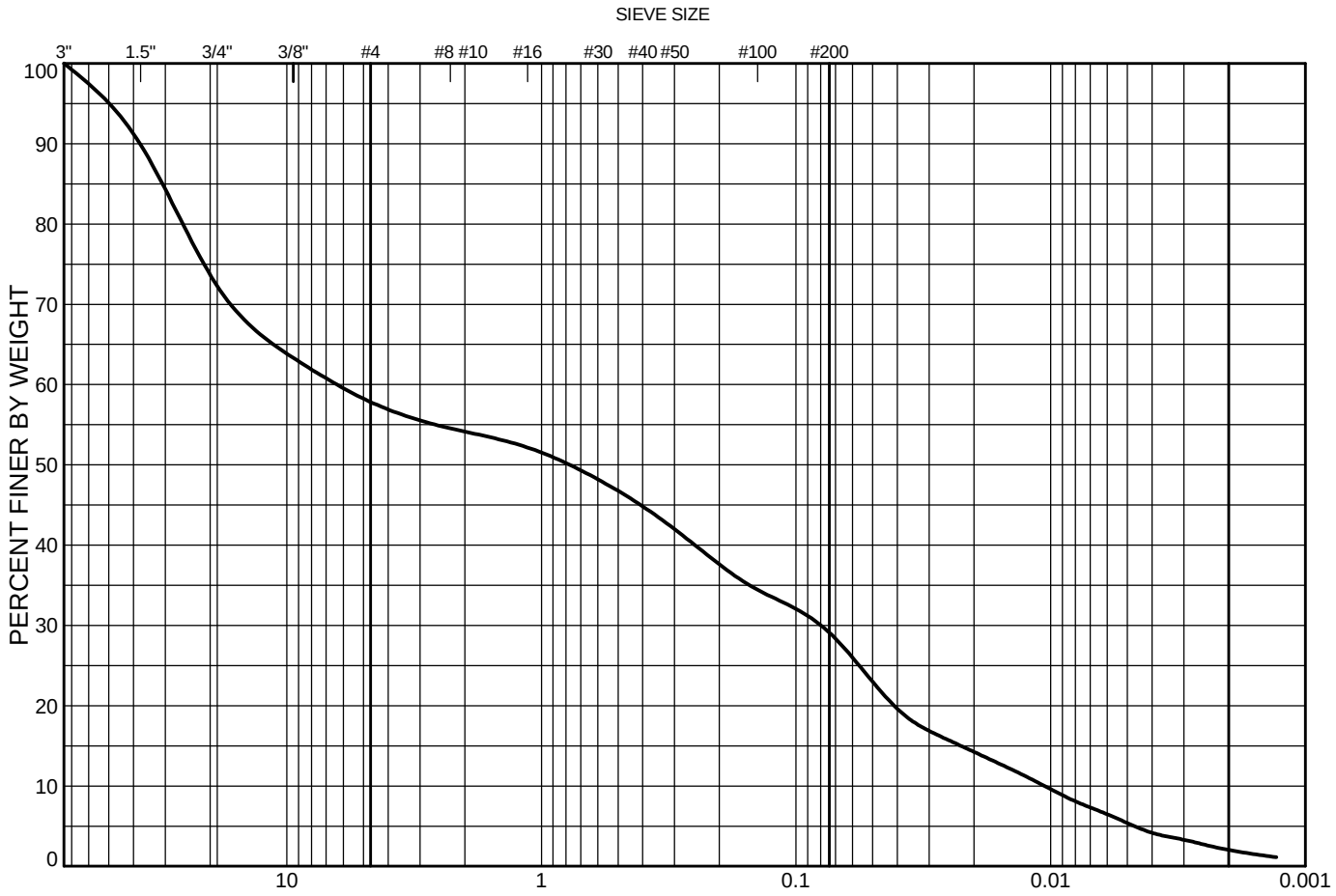
Description: Sandy SILT with traces of gravel and clay (ML).
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd (Vancouver)
Telephone:
Fax:

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

Sample Location: **TH13-08**
Sample: 3
Sample Depth: 2.4 m
Date Sampled: January 30, 2013
Sampled By: AGB
Date Received: February 14, 2013
Date Tested: February 7, 2013
Tested By: KM
Test Method: ASTM D422 & C136
Specification:

Gravel	**42.1%**
Sand	**28.6%**
Silt	**27.2%**
Clay	**2.1%**
Moisture Content	**27.4%**

LL	
PL	
PI	

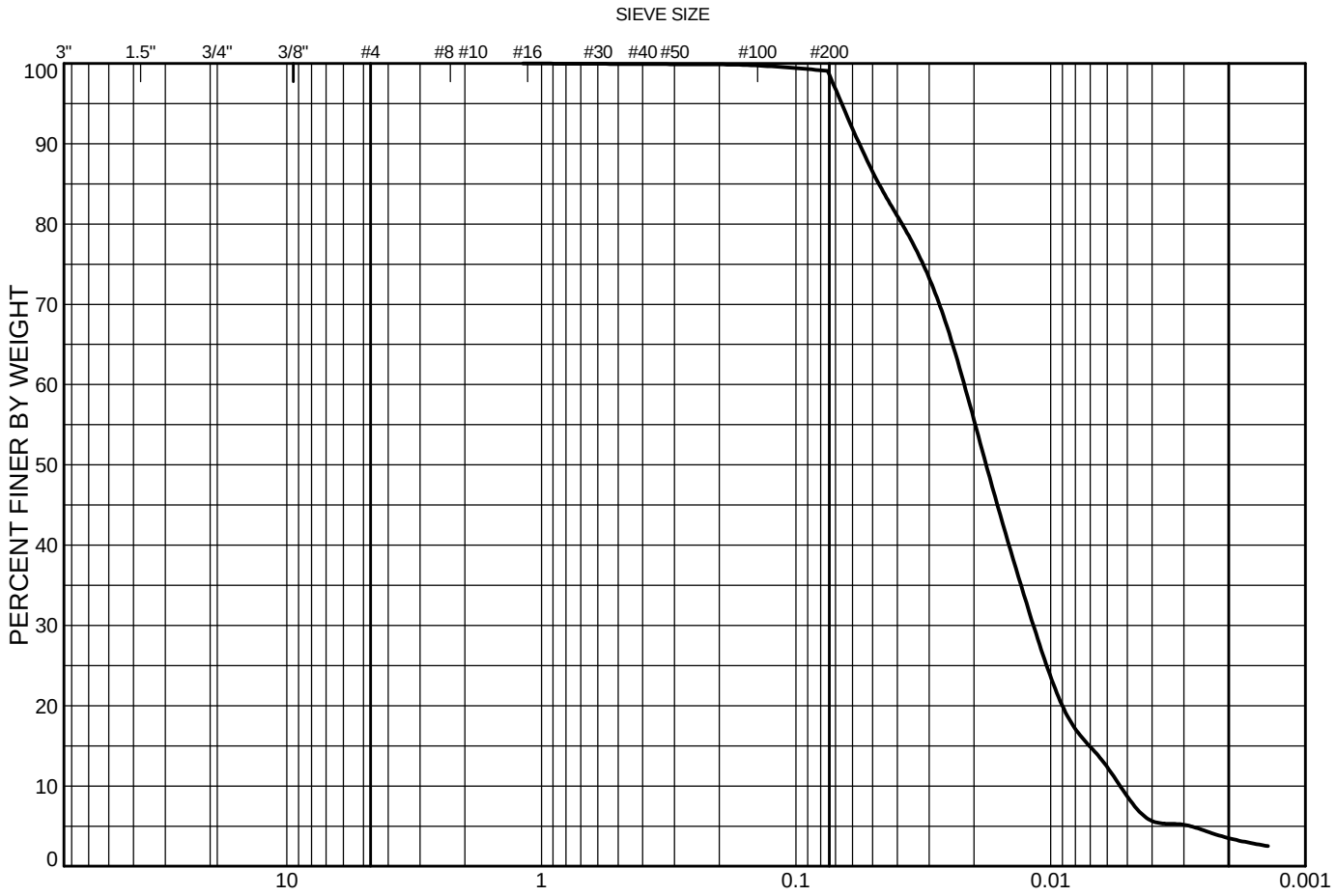
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd (Vancouver)
Telephone:
Fax:

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

Sample Location: **TH13-08**
Sample: 6
Sample Depth: 5.5 m
Date Sampled: January 30, 2013
Sampled By: AGB
Date Received: February 14, 2013
Date Tested: February 7, 2013
Tested By: KM
Test Method: ASTM D422 & C136
Specification:

Gravel	**0.0%**
Sand	**0.9%**
Silt	**95.4%**
Clay	**3.6%**
Moisture Content	**29.2%**

LL	**0**
PL	**0**
PI	**0**

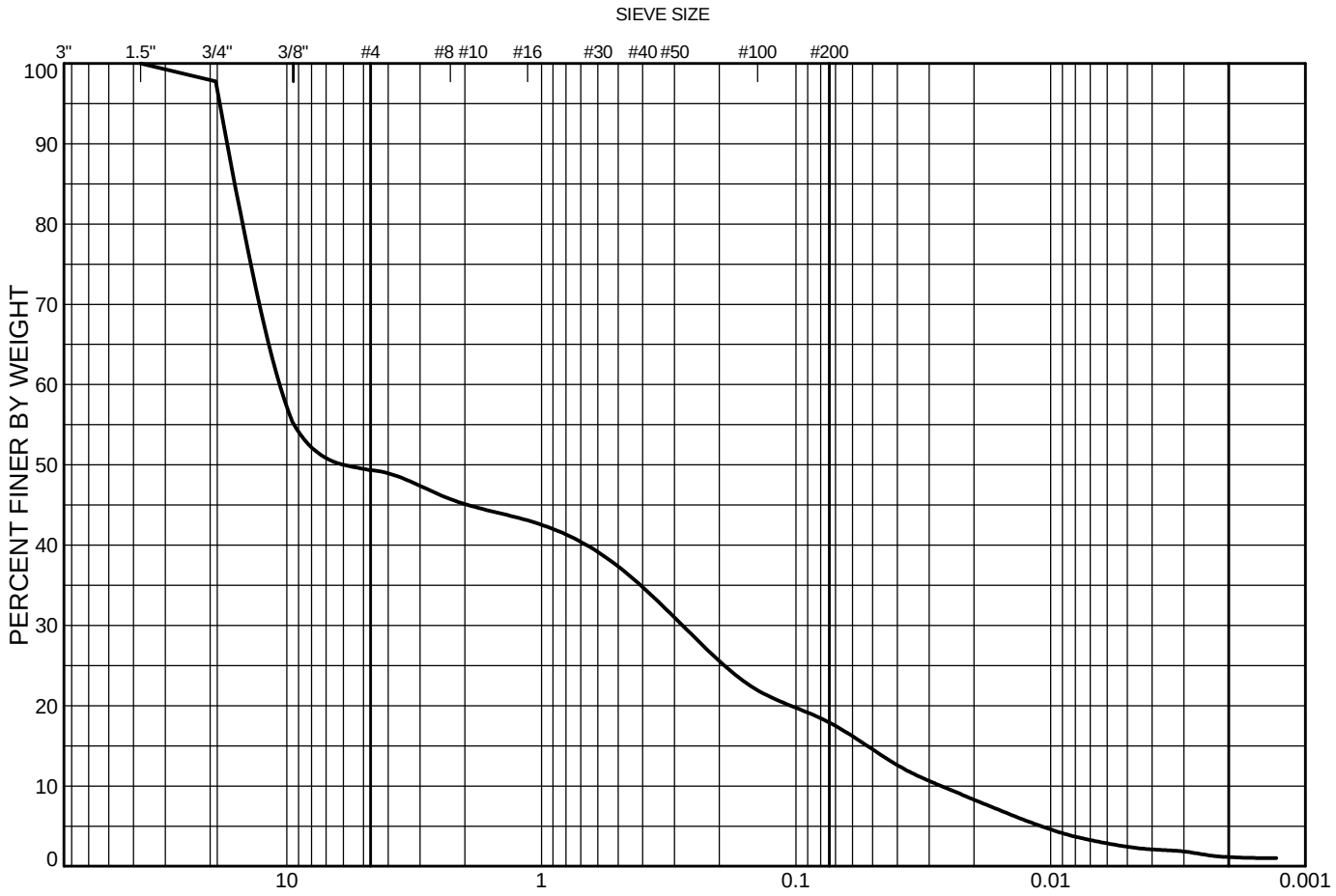
Description: SILT with traces of sand and clay (ML).
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd (Vancouver)
Telephone:
Fax:

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

Sample Location: **TH13-09**
Sample: 4
Sample Depth: 2.4 m
Date Sampled: January 30, 2013
Sampled By: AGB
Date Received: February 146, 2013
Date Tested: February 7, 2013
Tested By: KM
Test Method: ASTM D422 & C136
Specification:

Gravel	**50.7%**
Sand	**31.3%**
Silt	**16.8%**
Clay	**1.2%**
Moisture Content	**9.4%**

LL	
PL	
PI	

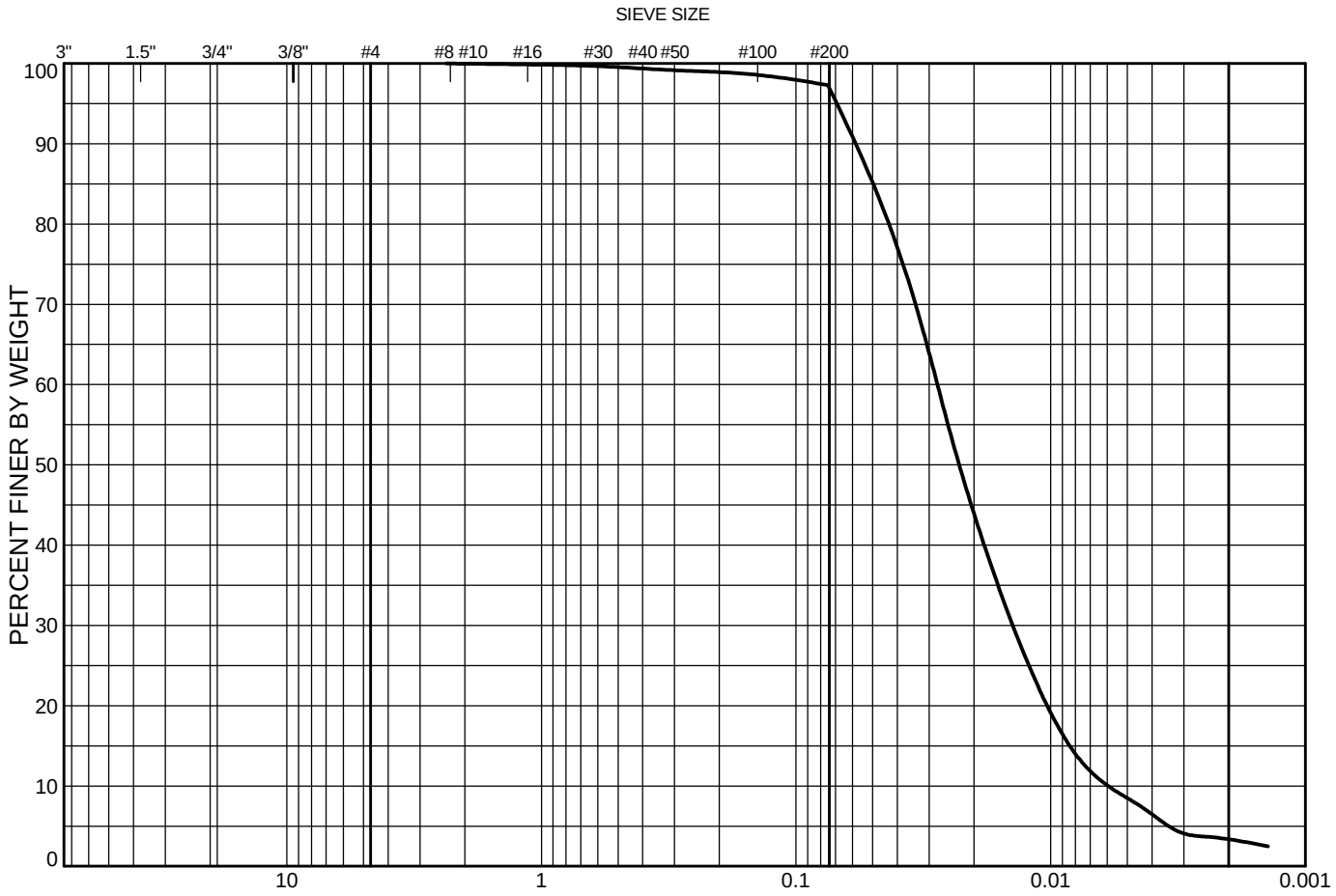
Description:
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd (Vancouver)
Telephone:
Fax:

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

Sample Location: **TH13-09**
Sample: 6
Sample Depth: 5.5 m
Date Sampled: January 30, 2013
Sampled By: AGB
Date Received: February 14, 2013
Date Tested: February 7, 2013
Tested By: KM
Test Method: ASTM D422 & C136
Specification:

Gravel	**0.0%**
Sand	**2.7%**
Silt	**94.0%**
Clay	**3.3%**
Moisture Content	**26.3%**

LL	**0**
PL	**0**
PI	**0**

Description: SILT with traces of sand and clay (ML).
Comments:

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd (Vancouver)
Telephone:
Fax:

GRAIN SIZE DISTRIBUTION

CLIENT: District of Sechelt
PROJECT: The Shores. Phase 1 - Seawatch Lane Subdivision
FILE NO.: 14-214-3

THURBER

APPENDIX 7

Geotechnical Investigation Test Hole Logs and Laboratory Test Results by Others

JACQUES WHITFORD
AND ASSOCIATES LIMITED

TEST PIT RECORD

TP05-01

CLIENT CONCORDIA HOMES LTD. THE SHORES SUBDIVISION — PROJECT No. BCV40527

PROJECT Geotechnical Investigation — DATUM

LOCATION Sechelt, B.C. — ELEVATION

EXCAVATION DATE Feb. 17-05 — CONTRACTOR McCourt Contracting Ltd. — EXCAVATION METHOD Excavator

DEPTH (m)	USC	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLES TYPE	SAMPLES NUMBER	MOISTURE CONTENT (%)
0	TP		Forest Litter (TOPSOIL)			
	GP GM		Yellow brown SILT, SAND, GRAVEL & COBBLES, loose			
1	SP SM		Grey SILT & fine SAND, medium dense	GS	1-1	27
			-seepage at 1.8m			
2			End of Test Pit at 2.1m			
3						

□ Insitu Shear Vane (kPa) ■ Remoulded Shear Vane (kPa)
△ Pocket Penetrometer (kPa)
50kPa 100kPa 150kPa 200kPa
W_P W W_L Moisture Content & Atterberg Limits
● Standard Penetration Test, blows/0.3m
10 20 30 40 50 60 70 80 90

DEPTH (ft): 0 2 4 6 8 10

Sample Type: GS - Grab Sample SPT - Standard Penetration Test
ST - Shelby Tube PT - Piston Tube VT - Shear Vane Test

Piezometer Backfill Type: Bentonite Pea Gravel Drill Cuttings Sand

Logged by: ME/RI
Reviewed by: ME
Date: Feb. 217 - 05

Jacques Whitford
Consulting Engineers
Environmental Scientists
Information Consultants

JACQUES WHITFORD
AND ASSOCIATES LIMITED

TEST PIT RECORD

TP05-02

CLIENT CONCORDIA HOMES LTD. THE SHORES SUBDIVISION — PROJECT No. BCV40527

PROJECT Geotechnical Investigation — DATUM

LOCATION Sechelt, B.C. — ELEVATION

EXCAVATION DATE Feb. 17-05 — CONTRACTOR McCourt Contracting Ltd. — EXCAVATION METHOD Excavator

DEPTH (m)	USC	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLES TYPE	SAMPLES NUMBER	MOISTURE CONTENT (%)
0	TP		Organics, Roots (TOPSOIL)			
	GP		Band of yellow brown medium sandy GRAVEL, loose			
1	SP		Yellow brown medium SAND with gravel,some cobbles, loose to medium dense			
2			-rust stained layer			
	ML		Yellow brown fine sandy SILT, some clay, trace gravel, stiff	GS	2-1	22
3			End of Test Pit at 2.8m			

□ Insitu Shear Vane (kPa) ■ Remoulded Shear Vane (kPa)
△ Pocket Penetrometer (kPa)
50kPa 100kPa 150kPa 200kPa
W_P W W_L Moisture Content & Atterberg Limits
● Standard Penetration Test, blows/0.3m
10 20 30 40 50 60 70 80 90

DEPTH (ft): 0 2 4 6 8 10

Sample Type: GS - Grab Sample SPT - Standard Penetration Test
ST - Shelby Tube PT - Piston Tube VT - Shear Vane Test

Piezometer Backfill Type: Bentonite Pea Gravel Drill Cuttings Sand

Logged by: ME/RI
Reviewed by: ME
Date: Feb. 217 - 05

Jacques Whitford
Consulting Engineers
Environmental Scientists
Information Consultants

JACQUES WHITFORD
AND ASSOCIATES LIMITED

TEST PIT RECORD

TP05-03

CLIENT CONCORDIA HOMES LTD. THE SHORES SUBDIVISION PROJECT No. BCV40527

PROJECT Geotechnical Investigation DATUM

LOCATION Sechelt, B.C. ELEVATION

EXCAVATION DATE Feb. 17-05 CONTRACTOR McCourt Contracting Ltd. EXCAVATION METHOD Excavator

DEPTH (m)	USC SOIL SYMBOL	SOIL DESCRIPTION	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES MOISTURE CONTENT (%)
0	TP	Organics, Roots (TOPSOIL)			
	SM	Rusty Yellow silty medium SAND, trace gravel, loose to medium dense			
1	TL	Yellow brown Glacial TILL (sandy SILT & GRAVEL with cobbles, some boulders), dense to very dense			
2			GS	3-1	12
3		End of Test Pit at 2.4m			

□ Insitu Shear Vane (kPa) ■ Remoulded Shear Vane (kPa)
△ Pocket Penetrometer (kPa)
50kPa 100kPa 150kPa 200kPa
W_P W W_L Moisture Content & Atterberg Limits
● Standard Penetration Test, blows/0.3m
10 20 30 40 50 60 70 80 90

DEPTH (ft): 0 2 4 6 8 10

Sample Type: GS - Grab Sample SPT - Standard Penetration Test
ST - Shelby Tube PT - Piston Tube VT - Shear Vane Test

Piezometer Backfill Type: Bentonite Pea Gravel Drill Cuttings Sand

Logged by: ME/RI
Reviewed by: ME
Date: Feb. 217 - 05

Jacques Whitford
Consulting Engineers
Environmental Scientists
Information Consultants

JACQUES WHITFORD
AND ASSOCIATES LIMITED

TEST PIT RECORD

TP05-04

CLIENT CONCORDIA HOMES LTD. THE SHORES SUBDIVISION — PROJECT No. BCV40527

PROJECT Geotechnical Investigation — DATUM

LOCATION Sechelt, B.C. — ELEVATION

EXCAVATION DATE Feb. 17-05 — CONTRACTOR McCourt Contracting Ltd. — EXCAVATION METHOD Excavator

DEPTH (m)	USC	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLES TYPE	SAMPLES NUMBER	MOISTURE CONTENT (%)
0	TP		Organics, Roots (TOPSOIL)			
	GP GM		Rusty brown silty medium SAND & GRAVEL, some cobbles & roots, loose to medium dense			
1	TL		Yellow brown Glacial TILL (sandy SILT & GRAVEL with cobbles, some boulders), dense to very dense			
2			End of Test Pit at 1.8m			
3						

Insitu Shear Vane (kPa) ☐ Remoulded Shear Vane (kPa) ■
Pocket Penetrometer (kPa) △
50kPa 100kPa 150kPa 200kPa
W_P W W_L Moisture Content & Atterberg Limits
Standard Penetration Test, blows/0.3m ●
10 20 30 40 50 60 70 80 90

DEPTH (ft): 0 2 4 6 8 10

Sample Type: GS - Grab Sample SPT - Standard Penetration Test
ST - Shelby Tube PT - Piston Tube VT - Shear Vane Test

Piezometer Backfill Type: Bentonite Pea Gravel Drill Cuttings Sand

Logged by: ME/RI
Reviewed by: ME
Date: Feb. 217 - 05

Jacques Whitford
Consulting Engineers
Environmental Scientists
Information Consultants

JACQUES WHITFORD
AND ASSOCIATES LIMITED

TEST PIT RECORD

TP05-05

CLIENT CONCORDIA HOMES LTD. THE SHORES SUBDIVISION — PROJECT No. BCV40527

PROJECT Geotechnical Investigation — DATUM

LOCATION Sechelt, B.C. — ELEVATION

EXCAVATION DATE Feb. 17-05 — CONTRACTOR McCourt Contracting Ltd. — EXCAVATION METHOD Excavator

DEPTH (m)	USC SOIL SYMBOL	SOIL DESCRIPTION	SAMPLES TYPE	SAMPLES NUMBER	MOISTURE CONTENT (%)
0	TP	Organics, Roots (TOPSOIL)			
	SP	Rusty brown fine to medium SAND, loose to medium dense			
1	TL	Yellow brown Glacial TILL (sandy SILT & GRAVEL with cobbles, some boulders), dense to very dense			
2		End of Test Pit at 1.5m			
3					

□ Insitu Shear Vane (kPa) ■ Remoulded Shear Vane (kPa)
△ Pocket Penetrometer (kPa)
50kPa 100kPa 150kPa 200kPa
W_P W W_L Moisture Content & Atterberg Limits
● Standard Penetration Test, blows/0.3m
10 20 30 40 50 60 70 80 90

DEPTH (ft): 0 2 4 6 8 10

Sample Type: GS - Grab Sample SPT - Standard Penetration Test
ST - Shelby Tube PT - Piston Tube VT - Shear Vane Test

Piezometer Backfill Type: Bentonite Pea Gravel Drill Cuttings Sand

Logged by: ME/RI
Reviewed by: ME
Date: Feb. 217 - 05

Jacques Whitford
Consulting Engineers
Environmental Scientists
Information Consultants

BORING NUMBER BH12-01

CLIENT Concordia Homes Ltd. **PROJECT NAME** The Shores Seawatch

PROJECT NUMBER SC-0018 **PROJECT LOCATION** Sechelt, B.C.

DATE STARTED 12/9/20 **COMPLETED** 12/9/20 **GROUND ELEVATION** 0 m E.G.S. **HOLE SIZE** 150mm Diam.

DRILLING CONTRACTOR Downrite Drilling Ltd. **GROUND WATER LEVELS:**

DRILLING METHOD Auger: Solid Stem ▽ **AT TIME OF DRILLING** 5.50 m / Elev -5.50 m

LOGGED BY EC **CHECKED BY** ME **AT END OF DRILLING** ---

NOTES BH Locations - See BH Location Plan **AFTER DRILLING** ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m³)	DCPT BLOW COUNT 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80
		FILL, gravelly sand with some silt, grey, medium dense to dense, dry	SURF	GB 01-4				
		FILL, gravelly sand with silt, greyish brown, medium dense to dense, dry to moist		GB 01-9				
		FILL, fine sand with silt, trace gravel, grey, medium dense to dense, dry to moist		GB 01-14				
5		BURIED TOPSOIL, gravelly sand, dark brown to black, loose to medium dense, moist to wet	-5.80	GB 01-18				
		SILTY SAND / SANDY SILT, fine-grained sand, brown, medium dense to dense / stiff to very stiff, moist to wet	-7.60	GB 01-23				
				GB 01-28				
10		SILT, some fine-grained sand, brown, stiff to very stiff, moist to wet of low plasticity		GB 01-34				
		SILTY SAND, fine-grained sand, some silt, brown, medium dense to dense, wet		GB 01-45				

Bottom of hole at 14.60 m.

PRELIMINARY

FLUSH CAP - 8"Ø STEEL
RISER PIPE - 1"Ø PVC
SCREEN - 1"Ø PVC, 5' LN.
.02 " SLOTTED

LEGEND

- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

BORING NUMBER BH12-02

CLIENT Concordia Homes Ltd. **PROJECT NAME** The Shores Seawatch

PROJECT NUMBER SC-0018 **PROJECT LOCATION** Sechelt, B.C.

DATE STARTED 12/9/21 **COMPLETED** 12/9/21 **GROUND ELEVATION** 0 m E.G.S. **HOLE SIZE** 150mm Diam.

DRILLING CONTRACTOR Downrite Drilling Ltd. **GROUND WATER LEVELS:**

DRILLING METHOD Auger: Solid Stem ▽ **AT TIME OF DRILLING** 3.00 m / Elev -3.00 m

LOGGED BY EC **CHECKED BY** ME **AT END OF DRILLING** ---

NOTES BH Locations - See BH Location Plan **AFTER DRILLING** ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m^3)	DCPT BLOW COUNT / PL MC LL / FINES CONTENT (%)
		FILL, gravelly sand, some cobbles, reddish brown, dense, dry	SURF	GB 02-3				20 40 60 80
		SILTY SAND / SANDY SILT, fine grained sand, brown, medium dense to dense / stiff to very stiff, moist to wet. ▽		GB 02-4				PL MC LL
				GB 02-9				20 40 60 80
				GB 02-13				□ FINES CONTENT (%) □
5			-5.20	GB 02-18				20 40 60 80
		SILT, some to trace fine-grained sand, trace clay, grey, stiff to very stiff, wet of low plasticity	-7.00					
				GB 02-28				

Bottom of hole at 9.20 m.

PRELIMINARY

FLUSH CAP - 8"Ø STEEL
RISER PIPE - 1"Ø PVC
SCREEN - 1"Ø PVC, 5' LN.
.02 " SLOTTED

LEGEND

- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

GME BH WITH WELL SC-018-DRILLING_2012.GPJ GINT STD CANADA.GDT 12/10/25

BORING NUMBER BH12-03

CLIENT Concordia Homes Ltd. **PROJECT NAME** The Shores Seawatch

PROJECT NUMBER SC-0018 **PROJECT LOCATION** Sechelt, B.C.

DATE STARTED 12/9/21 **COMPLETED** 12/9/21 **GROUND ELEVATION** 0 m E.G.S. **HOLE SIZE** 150mm Diam.

DRILLING CONTRACTOR Downrite Drilling Ltd. **GROUND WATER LEVELS:**

DRILLING METHOD Auger: Solid Stem ▽ **AT TIME OF DRILLING** 2.10 m / Elev -2.10 m

LOGGED BY EC **CHECKED BY** ME **AT END OF DRILLING** ---

NOTES BH Locations - See BH Location Plan **AFTER DRILLING** ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m³)	DCPT BLOW COUNT / PL MC LL / FINES CONTENT (%)
		FILL, gravelly sand, some silt, some woody debris, dark brown, dense to very dense, moist to wet	SURF	GB 03-4				
		▽ SILTY SAND / SANDY SILT, fine grained sand, brown, loose to medium dense / soft to firm, moist to wet.		GB 03-7				
		SILTY SAND / SANDY SILT, fine grained sand, brown, loose / soft, moist to wet.		GB 03-13				
5		SILTY SAND / SANDY SILT, fine grained sand, brown, medium dense to dense / firm to stiff, moist to wet.	-5.20	GB 03-18				
		SILT, some to trace fine-grained sand, trace clay, grey, stiff to very stiff, wet of low plasticity	-7.00	GB 03-24				
				GB 03-28				

Bottom of hole at 9.20 m.

PRELIMINARY

FLUSH CAP - 8"Ø STEEL
RISER PIPE - 1"Ø PVC
SCREEN - 1"Ø PVC, 5' LN.
.02 " SLOTTED

LEGEND

- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

BORING NUMBER BH12-04

CLIENT Concordia Homes Ltd. **PROJECT NAME** The Shores Seawatch

PROJECT NUMBER SC-0018 **PROJECT LOCATION** Sechelt, B.C.

DATE STARTED 12/9/25 **COMPLETED** 12/9/25 **GROUND ELEVATION** 0 m E.G.S. **HOLE SIZE** 150mm Diam.

DRILLING CONTRACTOR Downrite Drilling Ltd. **GROUND WATER LEVELS:**

DRILLING METHOD Auger: Solid Stem **AT TIME OF DRILLING** ---

LOGGED BY EC **CHECKED BY** ME **AT END OF DRILLING** ---

NOTES BH Locations - See BH Location Plan **AFTER DRILLING** ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m^3)	DCPT BLOW COUNT 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80
		FILL, gravelly sand, some cobbles, brownish-grey, medium dense, dry		GB 04-4				
		FILL, gravelly sand, some silt, grey, medium dense to dense, dry.						
5		*REFUSAL at 6.1m		GB 04-18				

Bottom of hole at 6.10 m.

PRELIMINARY

LEGEND

- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

BORING NUMBER BH12-05

CLIENT Concordia Homes Ltd. **PROJECT NAME** The Shores Seawatch

PROJECT NUMBER SC-0018 **PROJECT LOCATION** Sechelt, B.C.

DATE STARTED 12/9/24 **COMPLETED** 12/9/24 **GROUND ELEVATION** 0 m E.G.S. **HOLE SIZE** 150mm Diam.

DRILLING CONTRACTOR Downrite Drilling Ltd. **GROUND WATER LEVELS:**

DRILLING METHOD Auger: Solid Stem ▽ **AT TIME OF DRILLING** 11.00 m / Elev -11.00 m

LOGGED BY EC **CHECKED BY** ME **AT END OF DRILLING** ---

NOTES BH Locations - See BH Location Plan **AFTER DRILLING** ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m^3)	DCPT BLOW COUNT / FINES CONTENT (%)
		SILTY SAND, some to trace gravel, grey, loose, dry	SURF	GB 05-4				
		medium dense to dense		GB 05-9				
		*Becomes dense with depth		GB 05-13				
		*Grades from dense to very dense, mottled, dry		GB 05-18				
5		SILT, some sand, trace gravel, grey, stiff to very stiff, moist to wet		GB 05-24				
		SAND, fine to medium grained, trace silt, yellowish-grey, medium dense, dry to moist						
10			-10.40					
		▽ *Grades to medium dense to dense with depth *wet *Interbedded with thin seams of coarse-grained sands	-12.20	GB 05-46				
15		SILTY SAND / SANDY SILT, fine grained sand, brown, medium dense to dense / stiff to very stiff, moist to wet. of low plasticity		GB 05-55				
20				GB 05-68				

Bottom of hole at 21.30 m.

PRELIMINARY

FLUSH CAP - 8"Ø STEEL
RISER PIPE - 1"Ø PVC
SCREEN - 1"Ø PVC, 5' LN.
.02 " SLOTTED

LEGEND
- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

BORING NUMBER BH12-06

CLIENT Concordia Homes Ltd. **PROJECT NAME** The Shores Seawatch

PROJECT NUMBER SC-0018 **PROJECT LOCATION** Sechelt, B.C.

DATE STARTED 12/9/20 **COMPLETED** 12/9/20 **GROUND ELEVATION** 0 m E.G.S. **HOLE SIZE** 150mm Diam.

DRILLING CONTRACTOR Downrite Drilling Ltd. **GROUND WATER LEVELS:**

DRILLING METHOD Auger: Solid Stem ▽ **AT TIME OF DRILLING** 10.40 m / Elev -10.40 m

LOGGED BY EC **CHECKED BY** ME **AT END OF DRILLING** ---

NOTES BH Locations - See BH Location Plan **AFTER DRILLING** ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m³)	DCPT BLOW COUNT / PL MC LL / FINES CONTENT (%)
0		FILL, gravelly sand, some silt, brown to grey, medium dense to dense, dry to moist *some woody debris at 6.7m depth.	SURF	GB 06--2				20 40 60 80
5				GB 06-12 GB 06-19 GB 06-23				
10		SILTY SAND / SANDY SILT, fine grained sand, brown, medium dense to dense / firm to stiff, moist to wet. ▽	-10.10	GB 06-29 GB 06-33				
			-11.90	GB 06-39				
15		SILT, some to trace fine-grained sand, trace clay, grey, stiff to very stiff, wet of low plasticity		GB 06-43 GB 06-53 GB 06-58				
20				GB 06-64				
				GB 06-78				

Bottom of hole at 24.40 m.

FLUSH CAP - 8"Ø STEEL
RISER PIPE - 1"Ø PVC
SCREEN - 1"Ø PVC, 5' LN.
.02 " SLOTTED

LEGEND
- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

PRELIMINARY

BORING NUMBER BH12-07

CLIENT Concordia Homes Ltd. **PROJECT NAME** The Shores Seawatch

PROJECT NUMBER SC-0018 **PROJECT LOCATION** Sechelt, B.C.

DATE STARTED 12/9/21 **COMPLETED** 12/9/21 **GROUND ELEVATION** 0 m E.G.S. **HOLE SIZE** 150mm Diam.

DRILLING CONTRACTOR Downrite Drilling Ltd. **GROUND WATER LEVELS:**

DRILLING METHOD Auger: Solid Stem ▽ **AT TIME OF DRILLING** 15.00 m / Elev -15.00 m

LOGGED BY EC **CHECKED BY** ME **AT END OF DRILLING** ---

NOTES BH Locations - See BH Location Plan **AFTER DRILLING** ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m^3)	DCPT BLOW COUNT / PL MC LL / FINES CONTENT (%)
		FILL, gravelly sand, some silt, brown to grey, medium dense to dense, dry to moist	SURF	GB 07-4				
		*some woody debris at 6.7m depth.		GB 07-8				
		SAND, some silt, grey, dense, dry						
5		SILTY SAND / SANDY SILT, fine grained sand, brown, medium dense to dense / firm to stiff, moist to wet.	-5.20	GB 07-17				
			-7.00					
		SILT, some to trace fine-grained sand, trace clay, grey, stiff to very stiff, wet of low plasticity		GB 07-29				
10				GB 07-38				
15	▽			GB 07-48				
				GB 07-58				

Bottom of hole at 18.30 m.

PRELIMINARY

FLUSH CAP - 8"Ø STEEL
RISER PIPE - 1"Ø PVC
SCREEN - 1"Ø PVC, 5' LN.
.02 " SLOTTED

LEGEND

- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

GME BH WITH WELL SC-018-DRILLING_2012.GPJ GINT STD CANADA.GDT 12/10/25

BORING NUMBER BH12-08

CLIENT Concordia Homes Ltd.
PROJECT NAME The Shores Seawatch
PROJECT NUMBER SC-0018
PROJECT LOCATION Sechelt, B.C.
DATE STARTED 12/9/24 **COMPLETED** 12/9/24
GROUND ELEVATION 0 m E.G.S. **HOLE SIZE** 150mm Diam.
DRILLING CONTRACTOR Downrite Drilling Ltd.
GROUND WATER LEVELS:
DRILLING METHOD Auger: Solid Stem
AT TIME OF DRILLING ---
LOGGED BY EC **CHECKED BY** ME
AT END OF DRILLING ---
NOTES BH Locations - See BH Location Plan
AFTER DRILLING ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m^3)	DCPT BLOW COUNT 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80
		FILL, sand, some gravel, some silt, grey, medium dense to dense (at depth), dry	SURF	GB 8B-13				
5		FILL, silty sand, yellowish brown, medium dense to dense, dry to moist						
10		SILTY SAND / SANDY SILT, fine grained sand, brown, medium dense to dense / firm to stiff, moist to wet.		GB 8B-34 / GB 8B-39				
			-13.10					
15		SAND, fine to medium-grained, grey, dense, wet	-14.90	GB 8B-47				

Bottom of hole at 15.20 m.

PRELIMINARY

FLUSH CAP - 8"Ø STEEL
RISER PIPE - 1"Ø PVC
SCREEN - 1"Ø PVC, 5' LN.
.02 " SLOTTED

LEGEND
- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

BORING NUMBER BH12-09

CLIENT Concordia Homes Ltd. **PROJECT NAME** The Shores Seawatch

PROJECT NUMBER SC-0018 **PROJECT LOCATION** Sechelt, B.C.

DATE STARTED 12/9/25 **COMPLETED** 12/9/25 **GROUND ELEVATION** 0 m E.G.S. **HOLE SIZE** 150mm Diam.

DRILLING CONTRACTOR Downrite Drilling Ltd. **GROUND WATER LEVELS:**

DRILLING METHOD Auger: Solid Stem ▽ **AT TIME OF DRILLING** 18.90 m / Elev -18.90 m

LOGGED BY EC **CHECKED BY** ME **AT END OF DRILLING** ---

NOTES BH Locations - See BH Location Plan **AFTER DRILLING** ---

DEPTH (m)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL CONSTRUCTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	POCKET PEN. (kPa)	DRY UNIT WT. (Mg/m³)	DCPT BLOW COUNT 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80
		SAND, fine grained, with gravel, some silt, grey, medium dense to dense, dry to moist	SURF	GB 09-3				
5		*Grades to coarse-grained		GB 09-18				
		*Becomes less dense with depth		GB 09-25				
10				GB 09-35				
		*Loose to medium dense						
		SILTY SAND / SANDY SILT, fine grained sand, brown, medium dense to dense / firm to stiff, moist to wet.		GB 09-47				
15				GB 09-53				
		▽	-18.60	GB 09-62				
20			-20.40					
		SAND, medium to coarse-grained, trace silt, grey, mottled, dense, wet		GB 09-73				

Bottom of hole at 22.90 m.

PRELIMINARY

FLUSH CAP - 8"Ø STEEL
RISER PIPE - 1"Ø PVC
SCREEN - 1"Ø PVC, 5' LN.
.02 " SLOTTED

LEGEND
- BENTONITE
- SAND FILTER PACK
- CUTTINGS / BACKFILL
- SCREEN

PARTICLE SIZE ANALYSIS OF SOILS

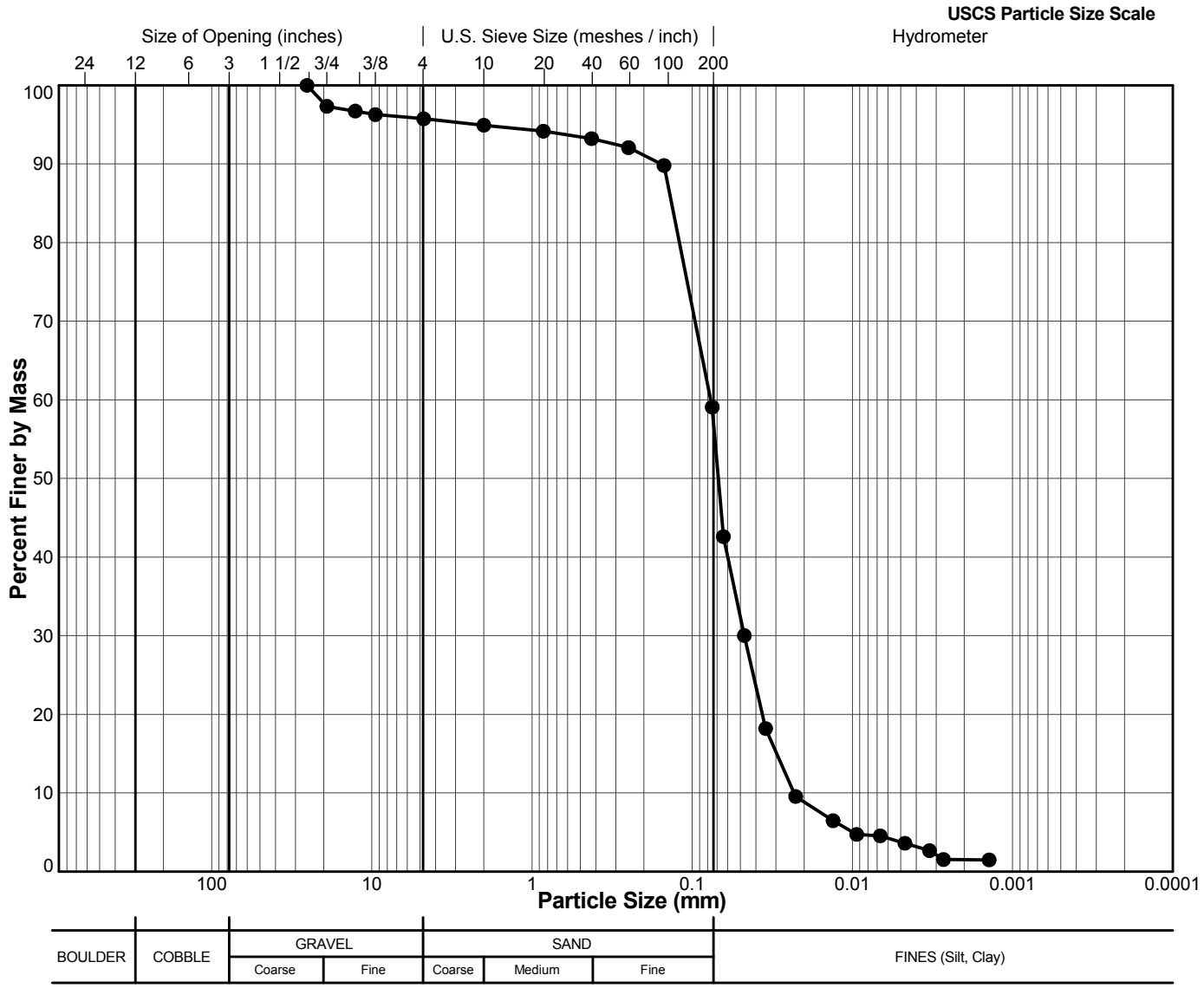
Reference(s)
ASTM D 422-63 (2007)

Client:	Concordia Homes Ltd.	**ID: BH12-01**
Project:	The Shores Seawatch	**Sample No.: 1**
Location:	Geotechnical Investigation	**Depth Interval (m):** 23.00 to 23.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 25.4	**Dispersion Method: Stirring**
Method: Split, Washed	**Dispersion Period (min): 1**

Hydrometer ID: BURNABY - 541360



BM/MM	11/6/2012	LP	11/8/2012
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/08/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

PARTICLE SIZE ANALYSIS OF SOILS

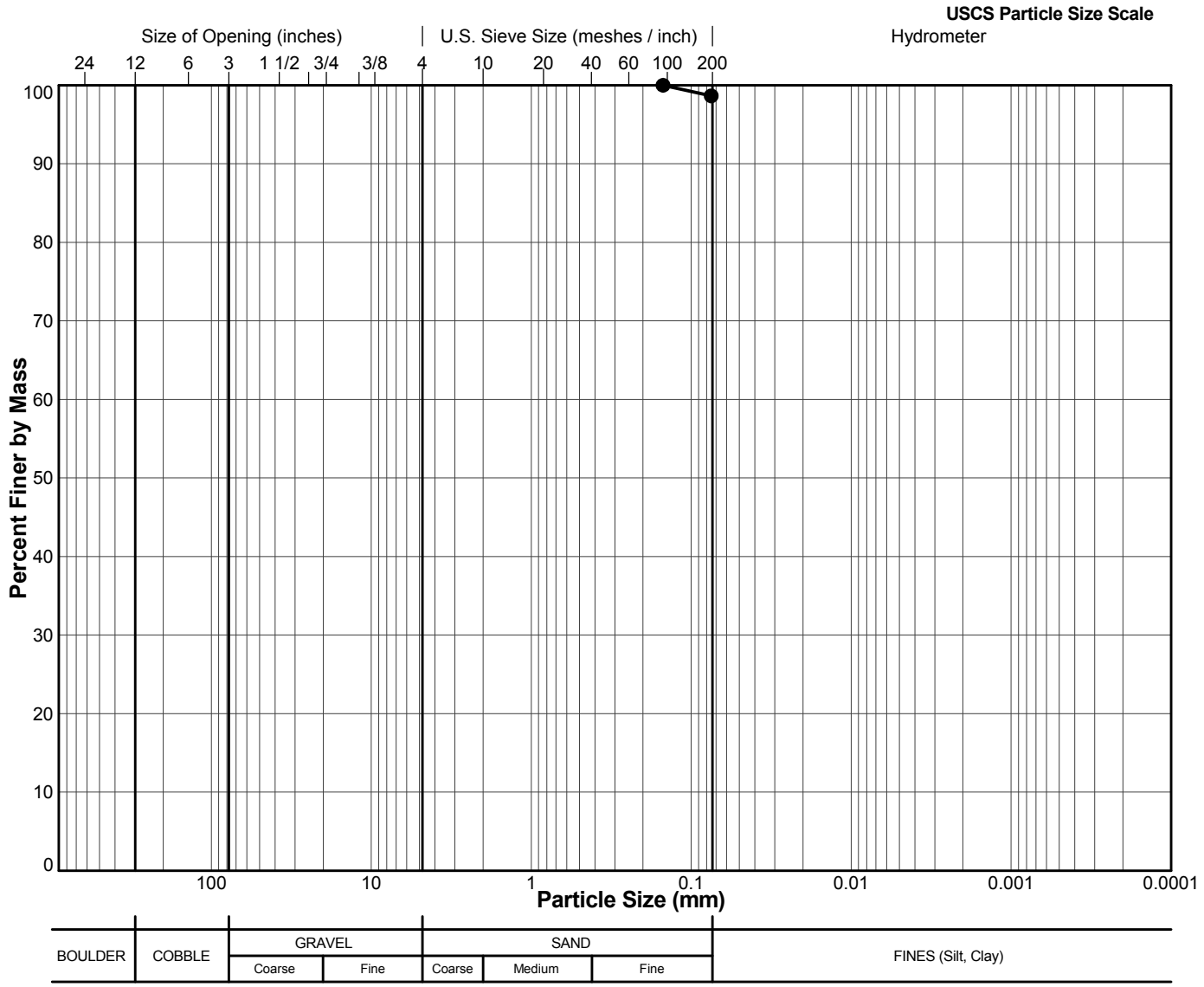
Reference(s)
ASTM D 422-63 (2007)

Client:	Concordia Homes Ltd.	**ID: BH12-01**
Project:	The Shores Seawatch	**Sample No.: 2**
Location:	Geotechnical Investigation	**Depth Interval (m):** 34.00 to 34.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 0.15	

Method: Split, Washed



BM	**10/31/2012**	**LP**	**11/8/2012**
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/09/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM D 422-63 (2007)

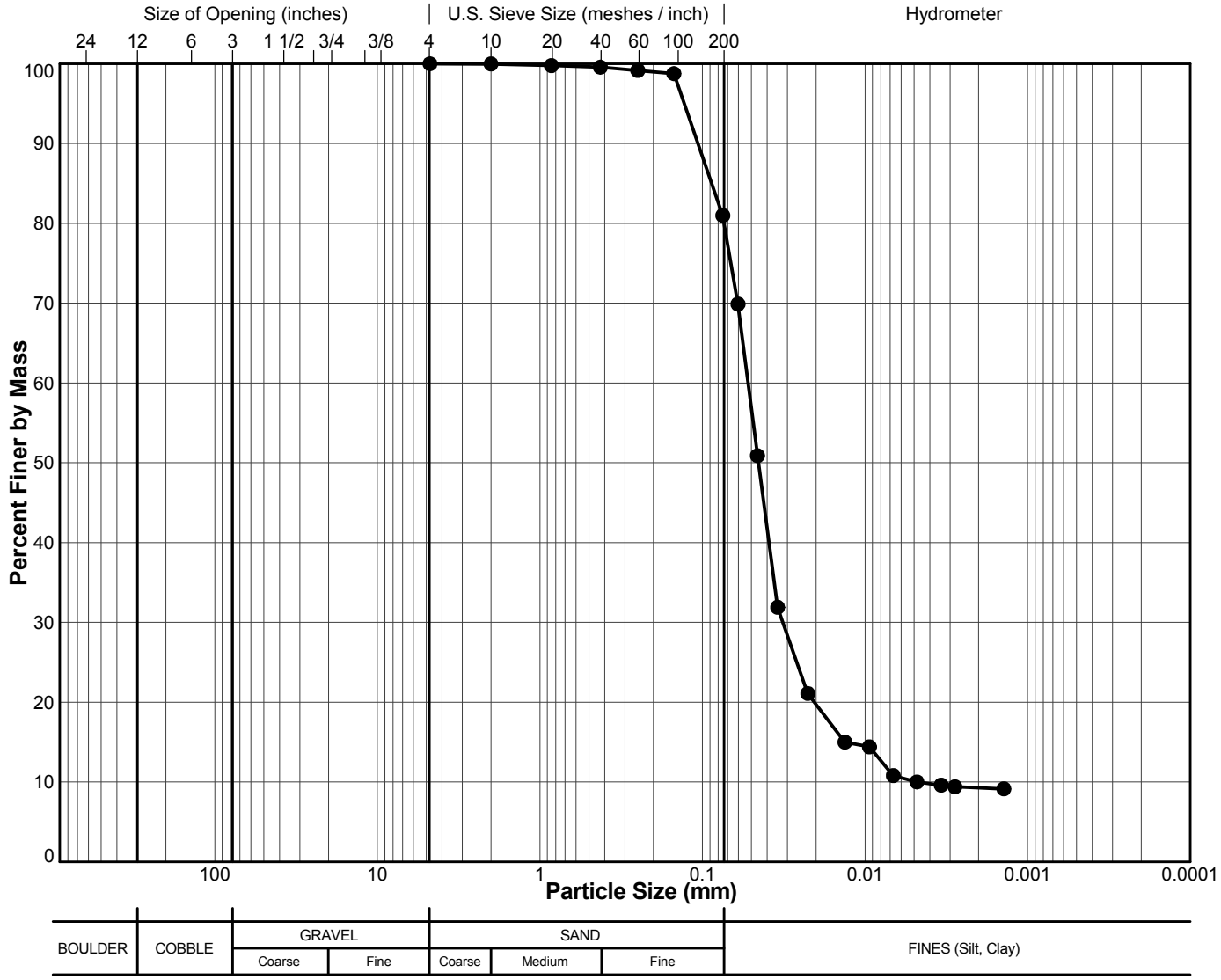
Client:	Concordia Homes Ltd.	**ID: BH12-02**
Project:	The Shores Seawatch	**Sample No.: 2**
Location:	Geotechnical Investigation	**Depth Interval (m):** 9.00 to 9.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 4.75	**Dispersion Method: Stirring**
Method: Split, Washed	**Dispersion Period (min): 1**

Hydrometer ID: BURNABY - 87024

USCS Particle Size Scale



BM/MM	**11/6/2012**	**LP**	**11/8/2012**
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/09/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

PARTICLE SIZE ANALYSIS OF SOILS

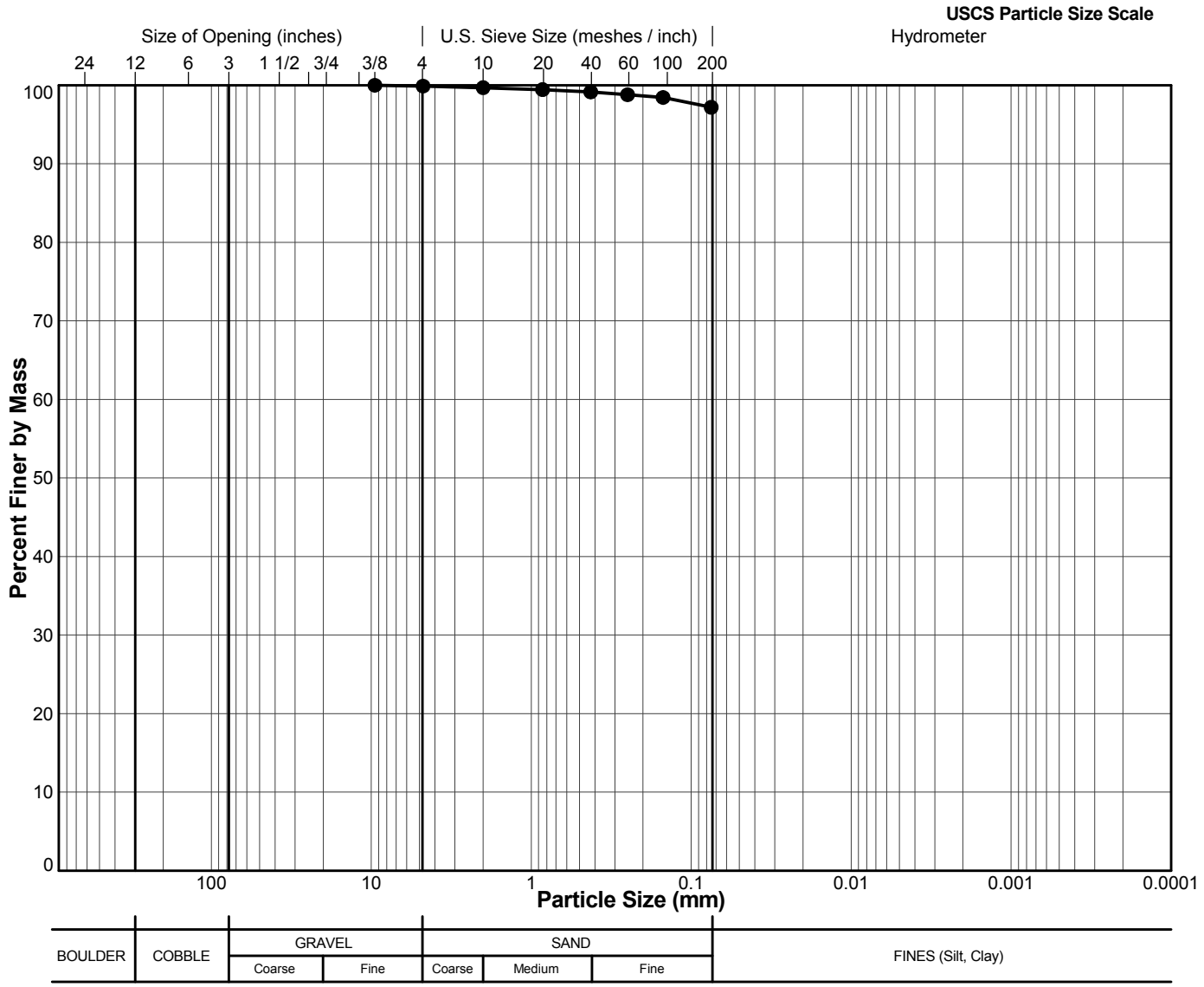
Reference(s)
ASTM D 422-63 (2007)

Client:	Concordia Homes Ltd.	**ID: BH12-03**
Project:	The Shores Seawatch	**Sample No.: 3**
Location:	Geotechnical Investigation	**Depth Interval (m):** 18.00 to 18.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 9.5	

Method: Split, Washed



BM	**10/31/2012**	**LP**	**11/8/2012**
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/09/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

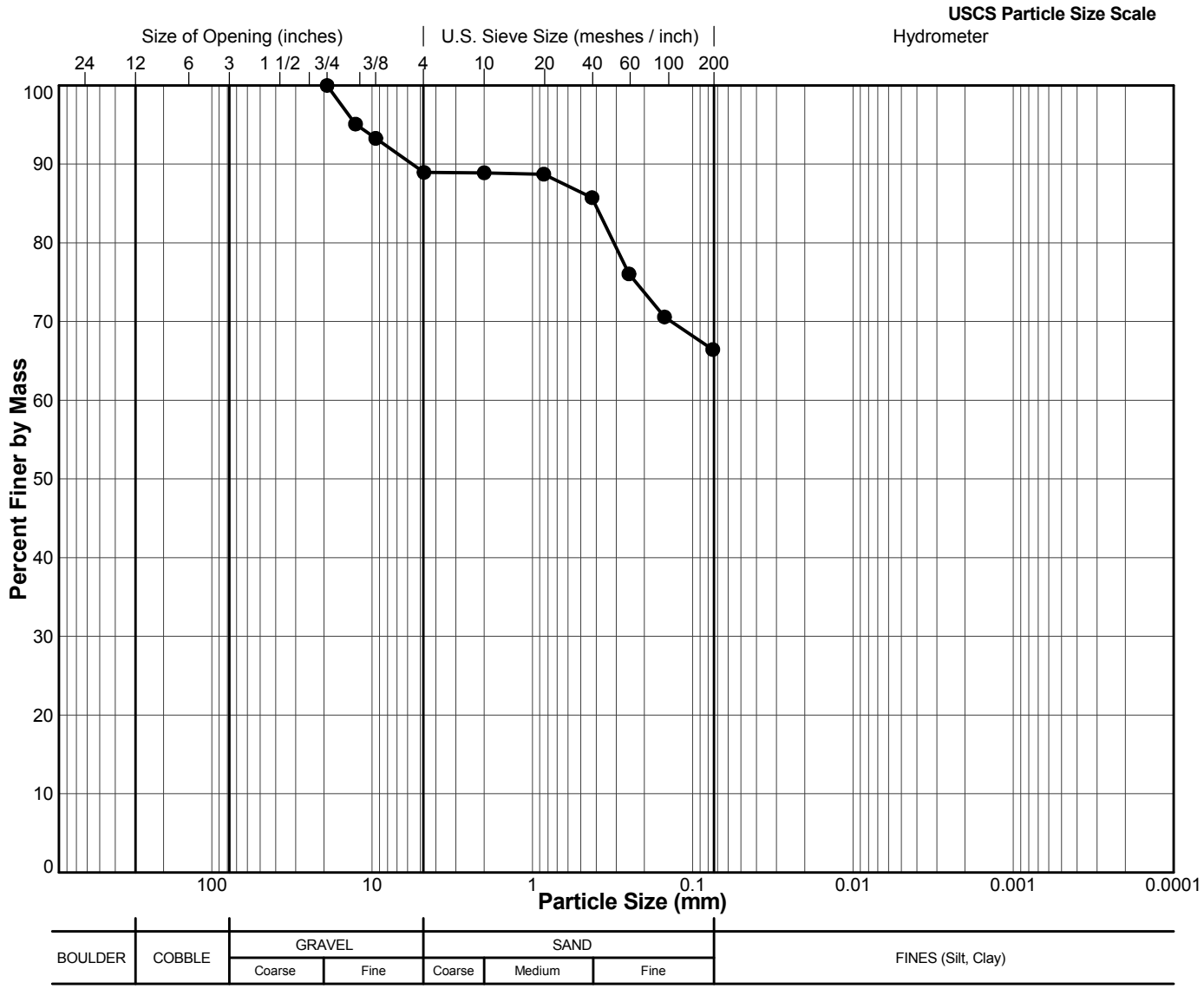
PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM D 422-63 (2007)

Client:	Concordia Homes Ltd.	**ID: BH12-05**
Project:	The Shores Seawatch	**Sample No.: 5**
Location:	Geotechnical Investigation	**Depth Interval (m):** 9.00 to 9.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 19.1	
Method: Split, Washed	



BM	**10/31/2012**	**LP**	**11/8/2012**
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/09/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

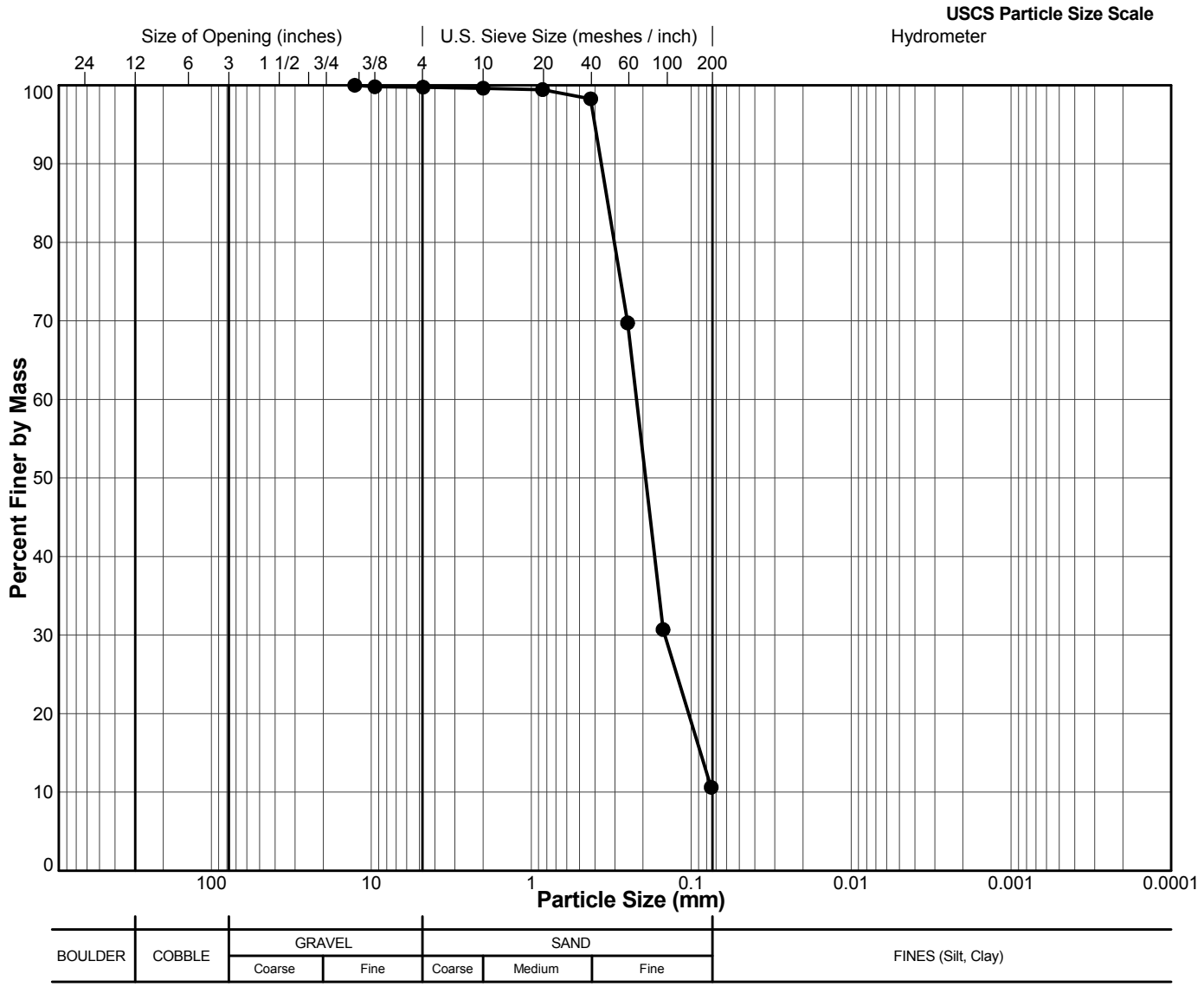
PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM D 422-63 (2007)

Client:	Concordia Homes Ltd.	**ID: BH12-05**
Project:	The Shores Seawatch	**Sample No.: 6**
Location:	Geotechnical Investigation	**Depth Interval (m):** 46.00 to 46.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 12.7	
Method: Split, Washed	



BM	10/31/2012	LP	11/8/2012
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/09/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

PARTICLE SIZE ANALYSIS OF SOILS

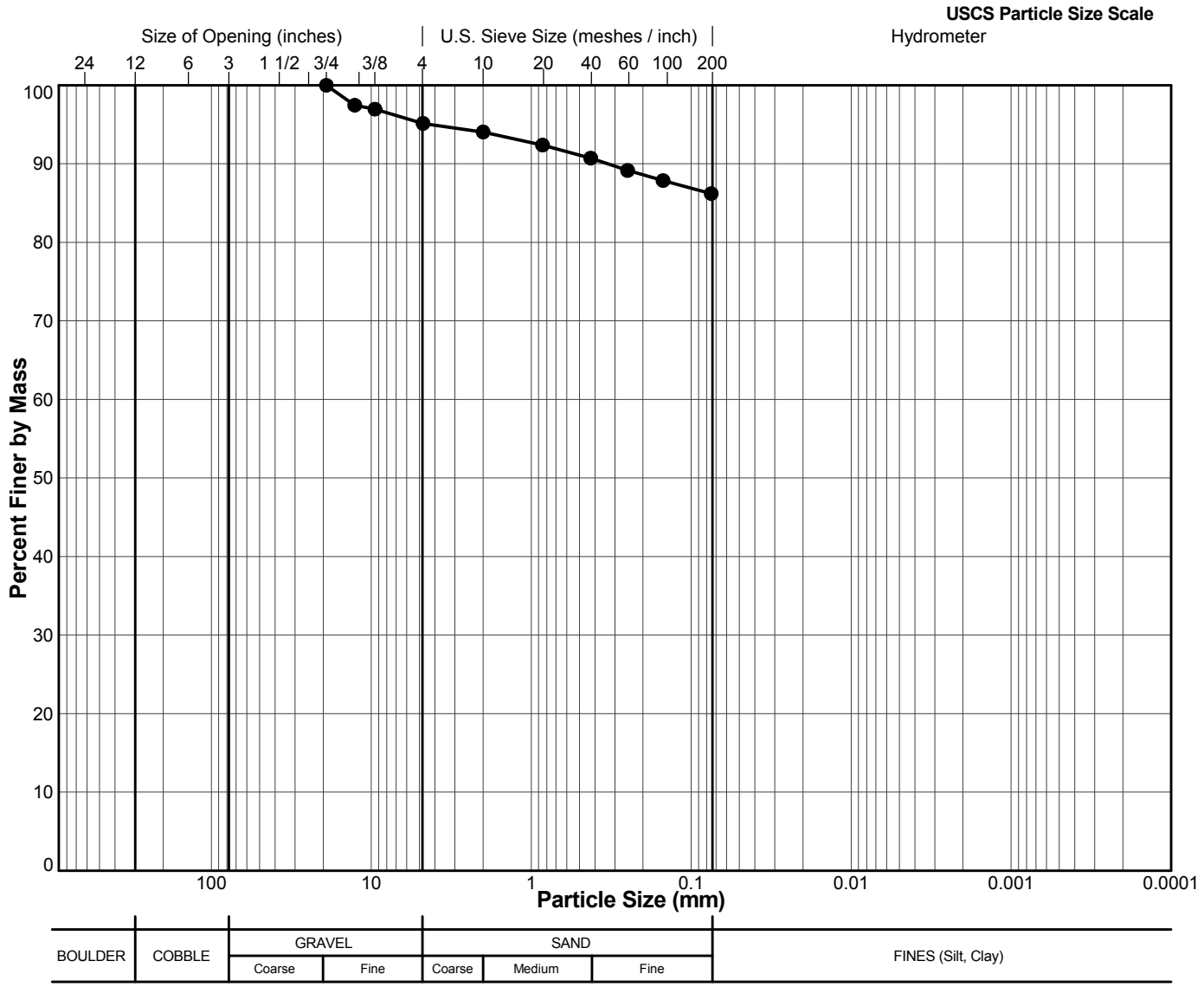
Reference(s)
ASTM D 422-63 (2007)

Client:	Concordia Homes Ltd.	**ID: BH12-06**
Project:	The Shores Seawatch	**Sample No.: 6**
Location:	Geotechnical Investigation	**Depth Interval (m):** 33.00 to 33.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 19.1	

Method: Split, Washed



BM	**10/31/2012**	**LP**	**11/8/2012**
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/09/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

PARTICLE SIZE ANALYSIS OF SOILS

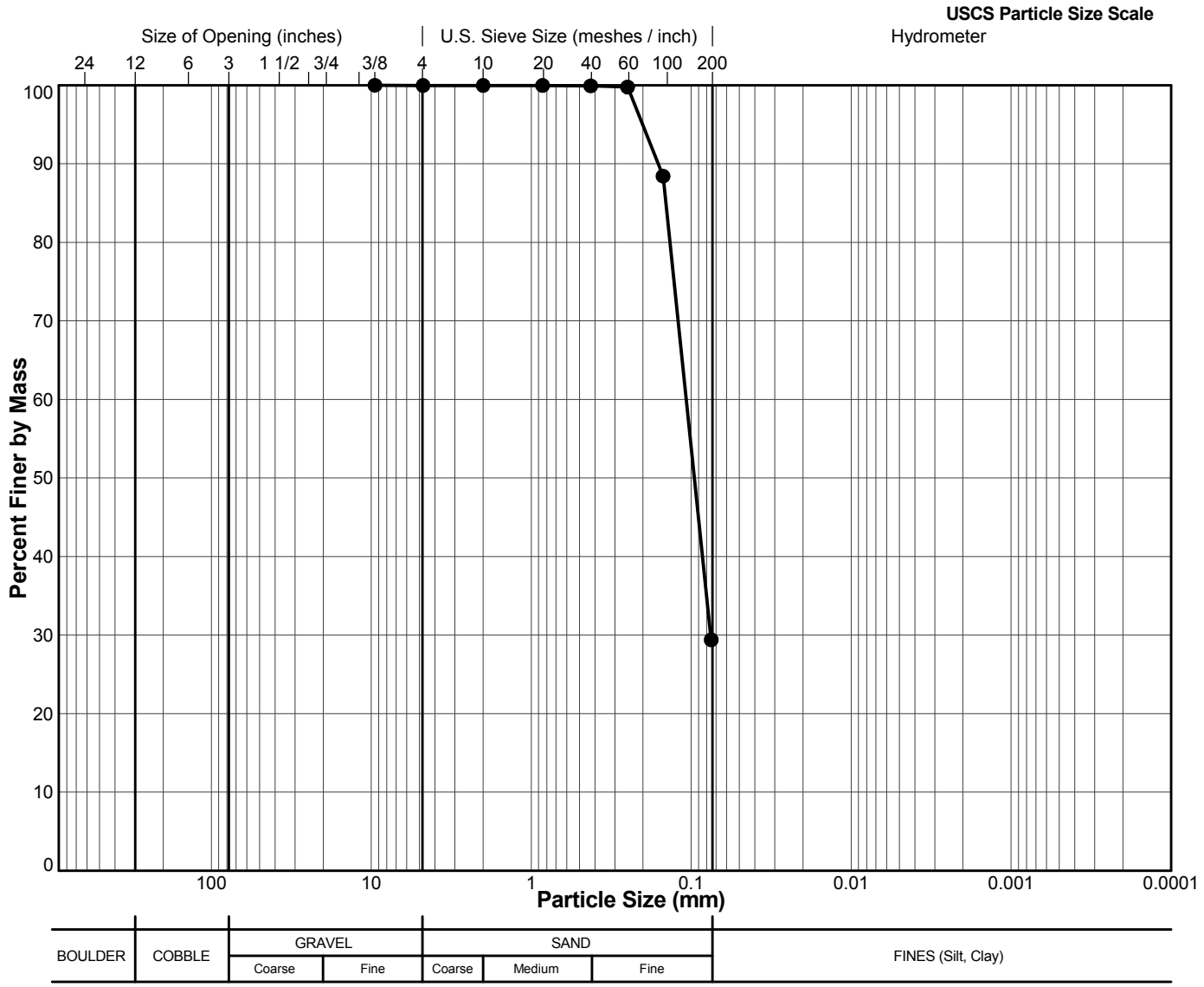
Reference(s)
ASTM D 422-63 (2007)

Client:	Concordia Homes Ltd.	**ID: BH12-07**
Project:	The Shores Seawatch	**Sample No.: 7**
Location:	Geotechnical Investigation	**Depth Interval (m):** 17.00 to 17.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 9.5	

Method: Split, Washed



BM	**10/31/2012**	**LP**	**11/8/2012**
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/09/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

PARTICLE SIZE ANALYSIS OF SOILS

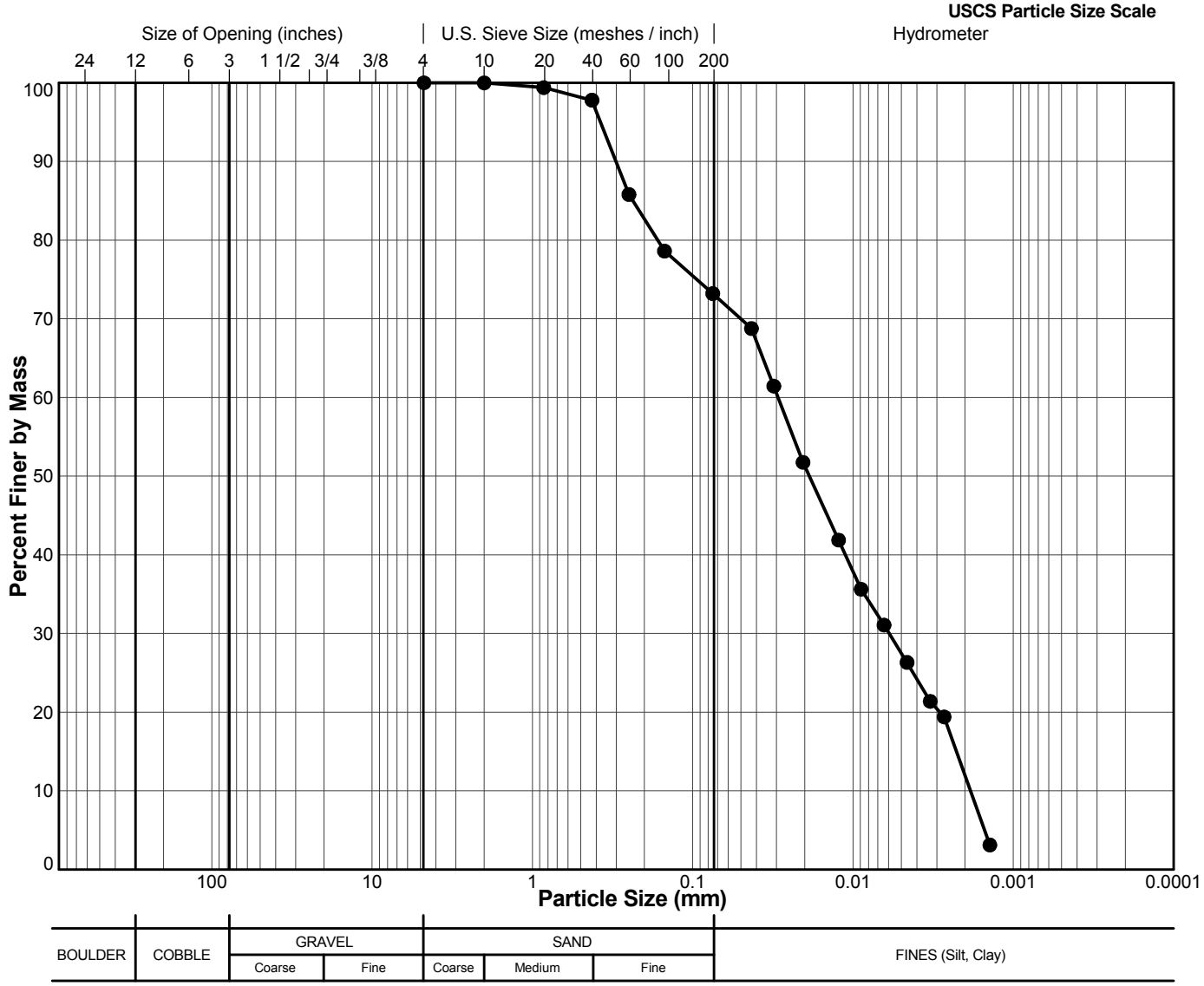
Reference(s)
ASTM D 422-63 (2007)

Client:	Concordia Homes Ltd.	**ID: BH12-09**
Project:	The Shores Seawatch	**Sample No.: 9**
Location:	Geotechnical Investigation	**Depth Interval (m):** 47.00 to 47.00
Project No.:	12-1447-0230	**Lab Schedule No.:** 210

Other Remarks: **N/A**

Specific Gravity (assumed):	**Shape:**
Max. Particle Size Passing (mm): 4.75	**Dispersion Method: Stirring**
Method: Split, Washed	**Dispersion Period (min): 1**
Hydrometer ID: BURNABY - 87024	

USCS Particle Size Scale



BM/MM	11/6/2012	LP	11/8/2012
Tech	Date	Checked	Date

File:N:\BUR-GRAPHICS\PROJECTS\2012\1447\12-1447-0230\GINT\GEOTACTICS-2012.GPJ Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:BC REGION TEMPLATE BETA 2.GDT Library:BC REGION LIBRARY.GLB ebarnes 11/09/12

Golder Associates Ltd.
500 - 4260 Still Creek Drive Burnaby, British Columbia V5C 6C6
Tel: (604) 296 4200 Fax: (604) 298 5253 www.golder.com

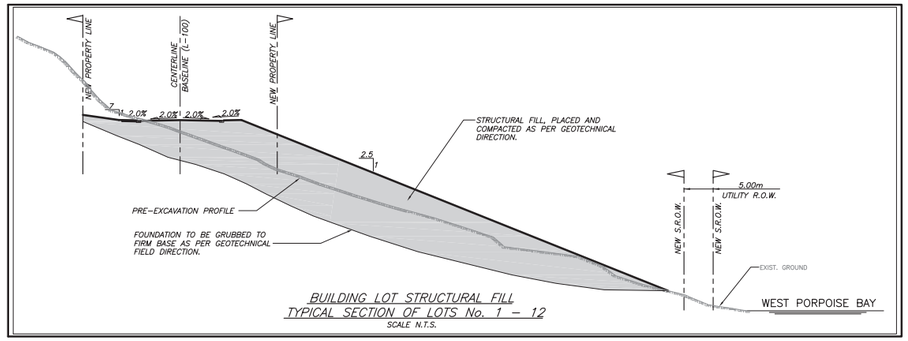
Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

THURBER

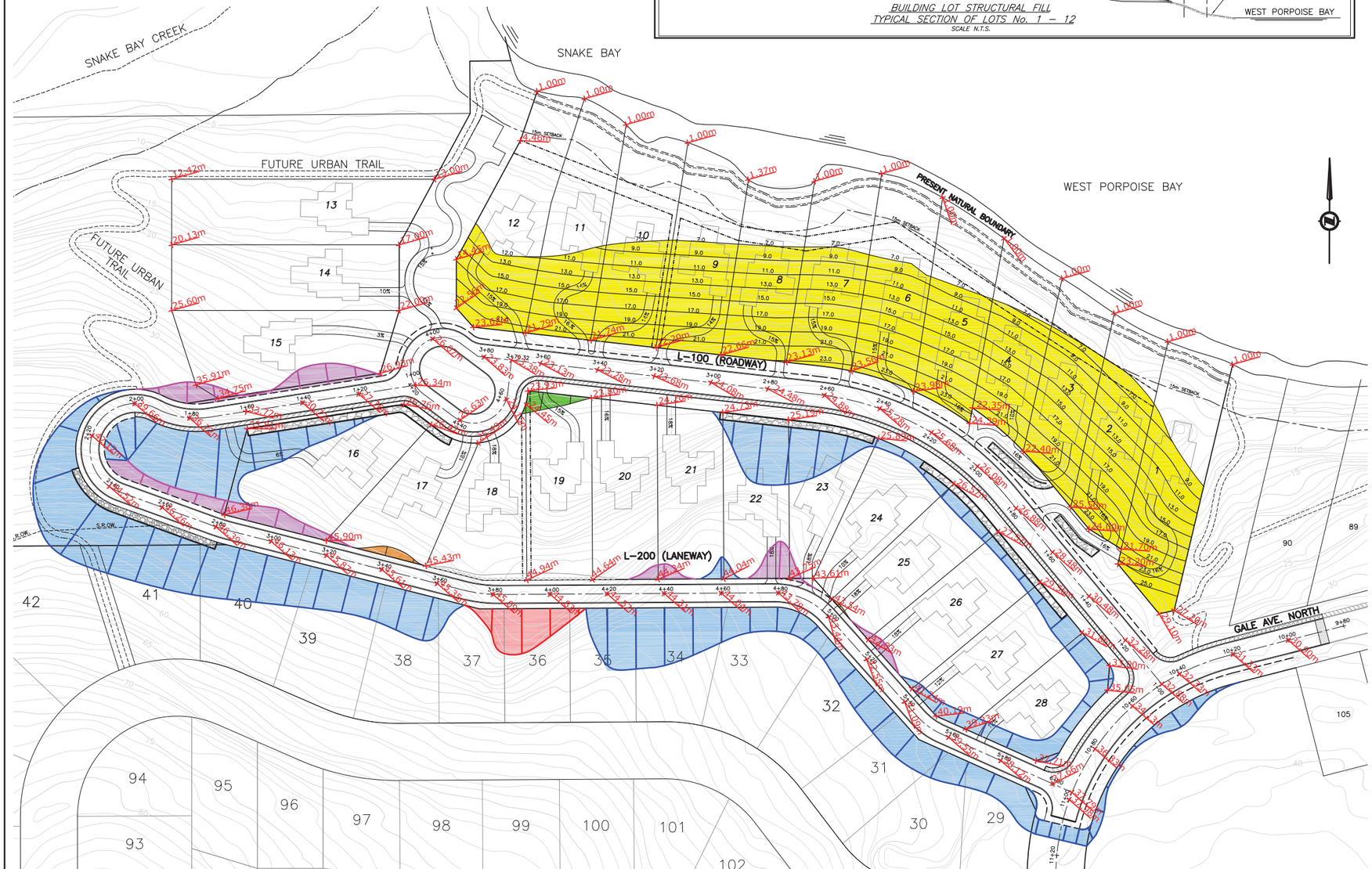
APPENDIX 8

Web Engineering Ltd. As-Built Drawing

NOTE:
ALL CUTS, FILLS, AND RETAINING WALLS TO BE CONSTRUCTED IN ACCORDANCE WITH GEOTECHNICAL RECOMMENDATIONS. SEE GEOTACTICS ENG. LTD. REPORT DATED APRIL 28, 2006.



BUILDING LOT STRUCTURAL FILL
TYPICAL SECTION OF LOTS No. 1 – 12
SCALE N.T.S.



LOT NUMBER	SANITARY SERVICE @ P.L.	STORM SERVICE @ P.L.	M.B.E.
1	6.80 (CAP)	6.80 (CAP)	9.0
2	6.70	6.70	9.0
3	6.30	6.30	8.0
4	5.80	5.80	8.0
5	5.30	5.30	7.0
6	4.80	4.80	7.0
7	4.50	4.50	6.0
8	4.20	4.20	6.0
9	3.80	3.80	6.0
10	3.50	3.50	5.0
11	3.20	3.20	5.0
12	3.20	3.20	5.0
13	11.80	11.80	14.0
14	15.80	15.80	18.0
15	20.80	20.80	23.0
16	25.20	25.20	28.0
17	24.50	24.50	27.0
18	24.10	24.10	26.0
19	22.50	22.50	25.0
20	23.00	23.00	25.0
21	23.10	23.10	25.0
22	24.00	24.00	26.0
23	24.10	24.10	26.0
24	25.30	25.30	27.0
25	25.40	25.40	27.0
26	28.00	28.00	30.0
27	28.70	28.70	30.0
28	31.00	31.00	33.0

LEGEND

- 2.5:1 CUT AREA
- 7:1 CUT AREA
- DAYLIGHT CUT AREA
- DAYLIGHT FILL AREA
- 2.5:1 FILL AREA
- 'ROCK STACKED' WALL
- 'SIERRA' SLOPE WALL

DISCLAIMER:
THIS DRAWING IS FOR INFORMATION ONLY. THE DISTRICT OF SECHELT ACCEPTS NO RESPONSIBILITY AS TO THE ACCURACY OF ANY PLANS OR ELEVATIONS. EXISTING UTILITY LOCATIONS ARE PROVIDED FOR INFORMATION ONLY AND MUST BE VERIFIED BY THE RESPECTIVE UTILITY COMPANY. THE DISTRICT OF SECHELT MAKES NO REPRESENTATION OR WARRANTY EXPRESSED OR IMPLIED, IN FACT OR IN LAW, WITH RESPECT TO THE ACCURACY, COMPLETENESS OR APPROPRIATENESS OF THE DATA CONTAINED OR REFERENCED HEREIN.

ATTACHED TO:

FILE DWG. NUMBER

NO.	REVISIONS	BY	DATE
4	CONSTRUCTION RECORD DRAWING	J.M.	01/12/09
3	PER DISTRICT COMMENTS	J.M.	05/26/06
2	GENERAL REVISION	J.M.	09/02/05
1	GENERAL REVISION TO SECOND SUBMISSION	J.M.	21/09/05

THE LOCATIONS OF EXIST. UNDERGROUND UTILITIES ARE SHOWN IN AN APPROX. WAY ONLY AND HAVE NOT BEEN INDEPENDENTLY VERIFIED BY THE OWNER OR ITS REPRESENTATIVE. THE CONTRACTOR SHALL DETERMINE THE EXACT LOCATION OF ALL EXIST. UTILITIES BEFORE COMMENCING WORK, AND AGREES TO BE FULLY RESPONSIBLE FOR ANY AND ALL DAMAGES WHICH MIGHT BE OCCASIONED BY THE CONTRACTOR'S FAILURE TO EXACTLY LOCATE AND PRESERVE ANY AND ALL UNDERGROUND UTILITIES.

NOTES :
MONUMENT No.:
LOCATION:
COORDINATES:

ELEVATION:
COORDINATE SYSTEM:

APPR–SEAL

DRWN. : J.M.
DSGN. : J.G.
CHKD. : R.P.
DATE : MARCH 2005

WEB ENGINEERING LTD
consulting civil engineers
4173 DAWSON STREET, BURNABY, B.C. tel. 294–8588

CLIENT : CONCORDIA HOMES – PHASE '1'

ROADWORKS
LOT GRADING PLAN
PHASE '1'

SCALE : 1:750
SHEET OF
WEB DRAWING NO.: 1437-G-01
REV. 4
MUNICIPAL NO. :

DESTROY ALL PRINTS BEARING PREVIOUS REVISION NUMBER

THURBER

APPENDIX 9

Excerpt from "Soil Mechanics in Engineering Practice", 3rd Ed., (1996)

by

Karl Terzaghi, Ralph B. Peck, Gholamreza Mesri

Published by John Wiley & Sons, Inc.

SOIL MECHANICS IN ENGINEERING PRACTICE

THIRD EDITION

Karl Terzaghi
Ralph B. Peck
Gholamreza Mesri

WILEY

CHAPTER 11

Dams and Dam Foundations

ARTICLE 57 TYPES OF DAMS AND POTENTIAL MODES OF FAILURE

57.1 Types of Dams and Foundations

Earth and rockfill dams may rest on rock, weathered rock, or soil. High concrete dams are almost invariably founded on rock, but some types of low concrete dams may be established on soil.

The design of an earth or rockfill dam should be adapted to the available construction materials. At most sites both pervious and impervious materials can be obtained. The dam may then be made up of a relatively impervious inner zone or core that retains the water and of outer zones that provide the required stability. Such dams are called *zoned.* The relative quantitites in the different zones are determined chiefly by economic considerations. A dam consisting almost entirely of clay may be provided with a thin filter drain that maintains the downstream portion of the dam in a permanently drained state. On the other hand, a dam made entirely of pervious material must include an impervious membrane. If the dam consists exclusively of rock fill, the membrane sometimes consists of a reinforced concrete slab or a bituminous concrete pavement on the upstream face.

The conditions under which a concrete dam is established on soils are usually encountered in large rivers flowing on alluvial deposits of great depth. The major part or all of such a dam often serves as a spillway containing gates to control the level of the river for power or navigation. The dam consists of rigid units separated from each other by sealed joints that can accommodate moderate differential displacement among the units.

57.2 Causes of Failure

An earth or rockfill dam may fail on account of overtopping, slope failure, spreading or sliding, internal erosion, or subsurface erosion. A concrete dam may fail by sliding or by subsurface erosion, and may be damaged by unequal settlement. Excessive leakage through, beneath, or around a dam of either type does not in itself constitute a failure, but it may have embarrassing financial consequences.

Overtopping of an earth dam, once a major cause of failure, can be avoided by conservative spillway design, attention to the possibility of large rapid landslides into the reservoir, and generous freeboard. Slope failures and failures by spreading or sliding can be avoided by design in accordance with Articles 36 and 48 supplemented during construction by field observations, principally by measurement of porewater pressures. Furthermore, failures of these types are most likely to occur during construction; they cause unanticipated expenditures and delays but they are not catastrophic.

Failures of concrete dams by sliding can be catastrophic because they are apt to occur when the reservoir is full. They are most likely if the dams have been founded on soil or rock containing nearly horizontal weak layers not noticed or not properly evaluated during design. Bedding-plane shear zones have often developed in stratified, alternately strong and weak rocks adjacent to a river during valley cutting, and the strength in such zones may be at the residual value (Article 19.2.3). The strength may be reduced further by pore pressures. Hence, the possibility of such conditions deserves serious consideration.

Catastrophic failures of either concrete or embankment dams can also occur as a result of subsurface erosion. They are likely to occur without any apparent warning, at full reservoir, sometimes many years after the reservoir has been put into operation. The erosion may start at springs fed by seepage and proceed insidiously upstream toward the reservoir, following lines of least resistance along foundation slabs, conduits, or irregularities in the bedrock, or it may develop entirely in the subsoil in a pattern that depends on unknown details of the stratification. When the erosion channel reaches the reservoir it enlarges rapidly; the release of water may destroy the dam and its foundation and devastate the valley downstream. Failure of a dam by subsurface erosion thus ranks among the most serious accidents in civil engineering.

Internal erosion within the body of zoned embankment dams may also have serious consequences. The water-retaining element or core of such dams, usually consisting of clay or other relatively impervious soils, may develop cracks as a result of differential settlements or other causes, may not be sealed tightly against the foundation or abutments, or under the influence of seepage pressures may tend to migrate, particle by particle, into the coarser shell materials intended to support the core. The loss of core material by migration or erosion may result in sinkholes, in weakening and dislocation of the fill material, and sometimes in a breakthrough to the reservoir. If this occurs, the results can be as catastrophic as those of subsurface erosion. To prevent such accidents, filters (Article 14.9) are inserted between the core and the shells and at any other locations where seepage through the dam or its foundation or abutments has the potential to initiate erosion. The design and construction of such filters deserve the greatest care and attention. Unfortunately, the trend toward the use of wide broadly graded filters instead of zoned filters in which each zone is narrowly graded has led to numerous instances of near-failure and expensive remedial work, and to several outright failures. Although various gradation criteria have been developed for broadly graded filters, the practical difficulties of avoiding segregation during placement (Article 59.9) have often nullified the criteria.

Because of the disastrous consequences of failure of a dam by subsurface or internal erosion, the conditions that lead to the erosion and the means for avoiding the danger are described in detail in Articles 58 and 59.

ARTICLE 58 MECHANISMS OF SUBSURFACE EROSION

58.1 Influence of Geologic Factors on Mechanics of Piping

A typical failure caused by piping is illustrated in Fig. 58.1. The dam, of the slab-and-buttress type, rested on a reinforced-concrete base slab provided with an upstream cutoff wall 3 m deep and a downstream cutoff 2 m deep. Failure occurred suddenly by a rush of water beneath the dam. A 16-m gap was left in the subsoil and was bridged over by the structure.

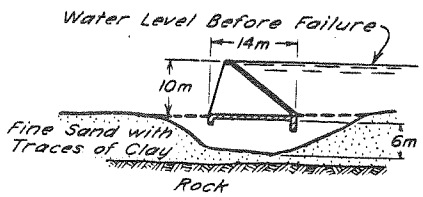


Figure 58.1 Failure of Ashley Dam near Pittsfield, Massachusetts, due to piping (*Eng. News* 1909).

If a dam rests on a perfectly homogeneous, cohesionless subsoil, the factor of safety with respect to piping can be computed as shown in Article 24. The theory presented in that article, in agreement with laboratory tests, leads to the following conclusions: (1) the head h_c at which piping occurs is independent of the grain size of the subsoil, and (2) failure occurs almost instantaneously as soon as the hydraulic head becomes equal to the critical head at which the seepage pressures lift the ground adjacent to the downstream edge of the structure. Piping failures of this kind are referred to as *piping due to heave*.

In reality, most piping failures occur at hydraulic heads h'_c much smaller than the head h_c computed on the basis of theory. They occur from a few to many years after the reservoir is filled for the first time. Moreover, the ratio h'_c/h_c decreases rapidly with decreasing grain size. The conspicuous and almost universal time-lag between application of head and failure indicates that most piping failures are caused by a process that reduces the factor of safety with respect to piping gradually and inconspicuously until the point of failure is reached. The only process that can produce such results is *subsurface erosion*, progressing along a narrow belt toward the reservoir. As will be pointed out in Article 58.2, such a process cannot take place in a homogeneous body of cohesionless sand. In nonhomogeneous material the locations of lines of least resistance against subsurface erosion and the hydraulic gradient required to produce a continuous channel along these lines depend on geologic details that cannot be ascertained by any practicable means.

58.2 Mechanics of Subsurface Erosion

The destruction of dams by either type of piping is usually so complete that the sequence of events can seldom be reconstructed. However, subsurface erosion occurs under other circumstances, such as by careless pumping from an open sump or by natural tapping of a body of ground water through erosion of a river bank. These processes commonly leave evidence that remains open to inspection. Therefore, they constitute the principal sources of our knowledge of the characteristics of subsurface erosion. The following paragraphs contain abstracts of the records of pertinent observations.

Figure 58.2 represents a cross-section through a gently inclined blanket of gravel that rests on a deep bed of very fine uniform loose sand. At *A* a pit was dug for the foundation of a new machine. Although the pit was surrounded by sheet piles that extended to a considerable depth below final grade, the pump discharged a mixture of sand and water. The quantity of sand removed was far in excess of the volume of the pit. Before final grade was reached, the building collapsed. At the same time a sink hole, 1 m deep and 6 m in diameter, appeared at *B*, at a distance 100 m from the pit. Between *A* and *B* the ground surface was intact. Hence, the loss of ground can be

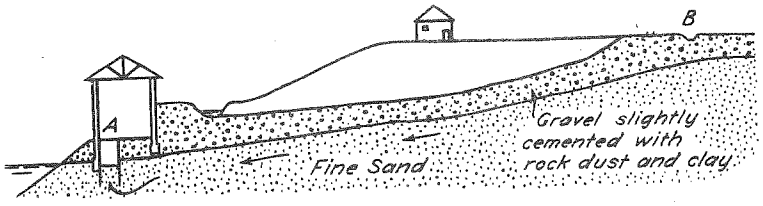


Figure 58.2 Diagram illustrating underground erosion produced by pumping mixture of sand and water from sump *A*. Sinkhole at *B* 100 m from *A*.

accounted for only by the movement of soil particles in a relatively narrow subterranean conduit. It is most likely that the conduit was located immediately below the gravel blanket, because the slightly cemented gravel was capable of forming an unsupported roof.

In the Rhineland pumping was continued for 13 years in a sand pit. The bottom of the pit was located between 5 and 6 m below the original water table. During this period three of the springs that discharged into the sump cut backward and eroded tunnels in the slightly cohesive sand. Each tunnel terminated in a sink hole on the ground surface. The largest tunnel was 1 to 2 m wide and in its length of 50 m had an average grade of only 6%. The sinkhole above the end of this tunnel was 2.5 m deep and 11 m in diameter.

In another instance an open cut was excavated for the construction of a sewer. The excavation passed through fairly stiff clay into fine sand that was drained by pumping from an open sump. While pumping proceeded, a narrow strip of the ground surface subsided about 0.3 m. The formation of the trough started at the sump and gradually proceeded to a distance of about 200 m. The width of the trough increased from a fraction of a meter at the sump to more than 3 m at the farther end.

Although the piping phenomena described in the preceding paragraphs took place in very different soil formations, they had two important features in common. First, the material overlying the eroded soil always possessed at least a trace of cohesion, sufficient to form a roof over the erosion tunnel. Because an unsupported roof cannot be maintained in homogeneous cohesionless sands, such materials are not subject to subsurface erosion unless, of course, they lie beneath an artificial roof such as the base of a concrete dam.

The second feature common to all the examples is that the subsidence of the roof always occurred at a great distance from the discharge end of the tunnel. This fact indicates that the erosive capacity of a spring increases as the length of the tunnel increases. The reason is illustrated by the flow nets in Fig. 58.3. The thin dash curves indicate equipotential lines, or contour lines of the water table, whereas the solid curves represent the flow lines. The dash-dot lines indicate the boundary of the intake area. With increasing length of the tunnel, the number of diverted flow lines increases. Thus, the discharge from the spring becomes greater, and the rate of erosion increases.

Progressive subsurface erosion starting at springs near the toe of a dam also proceeds along lines leading toward the reservoir, as shown in Fig. 58.3. The frequent occurrence of springs at the downstream edge is known to everyone who has had experience with dams. If a spring is powerful enough to start erosion in the first place, the erosion will almost certainly become more serious as time goes on, because the flow from a given spring increases with the length of the eroded tunnel (Fig. 58.3). Finally, the dam will fail by piping.

58.3 Empirical Rules for Estimating Factor of Safety

On account of the frequency and the serious consequences of failures of dams by piping, empirical rules for evaluating the factor of safety against piping were established long before the mechanics of the process were clearly understood. The first rules of this kind (Bligh 1910) were set up after the catastrophic failure in 1898 of the Narora Dam on the Ganges River in India. They were derived from a compilation of case records, and were based on the assumption that the sole cause of piping was erosion along the surface of contact between the soil and the base of the dam. The path that a water particle followed along this surface was called the *line of creep*. If the length L of the line of creep was such that the average hydraulic gradient $i = h/L$ was less than a certain critical value for the foundation material, the dam was believed to be safe. The quantity

$$C_c = \frac{L}{h_{cr}} \tag{58.1}$$

was called the *creep ratio*. The value h_{cr} represented the greatest height to which the water level in the reservoir could rise with reference to tailwater level without producing failure by piping. The available failure records indicated that the ratio C_c increased with increasing fineness of soil from about 4 for gravel to about 18 for fine sand and silt.

The first step in designing a dam on the basis of Eq. 58.1 was to estimate the creep ratio C_c of the subsoil. This was done by means of a table containing the values

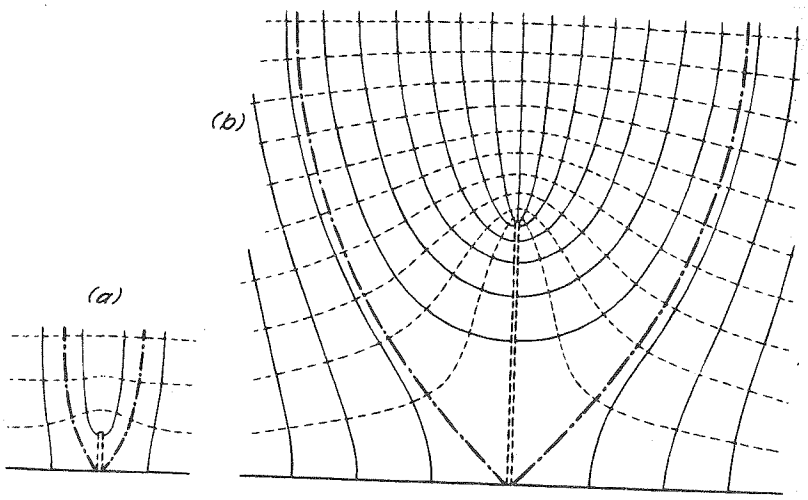


Figure 58.3 Flow nets illustrating increase of intake area of spring as length of erosion tunnel increases: (*a*) incipient state; (*b*) after erosion has proceeded to considerable distance from spring.

of C_c for the principal types of soil. The required length L of the creep line was then obtained by multiplying the creep ratio C_c by the hydraulic head h_{cr} created by the dam. The foundation was laid out in such a manner that the length of the creep line was at least equal to L. For example, the length of the line of creep for the dam shown in Fig. 58.4 is

$$L = t_1 + t_2 + B + t_3 + t_4 = B + \Sigma t$$

and this distance must be at least as great as $C_c h_{cr}$.

During the next 30 years it was gradually recognized that vertical sections of the line of creep contribute more toward reducing the danger of piping than horizontal sections of equal length. The reason for the difference is that the subsoil of dams generally has a sedimentary origin, and sedimentary deposits are always less permeable in the vertical direction than in the horizontal directions (Article 14.8). If k_h and k_v are the coefficients of permeability in the horizontal and vertical directions, respectively, the loss in head per unit of length of vertical sections of the line of creep is roughly equal to the ratio k_h/k_v times that of horizontal sections. The value of the ratio ranges between 2 or 3 and much larger values, in accordance with the details of stratification and the variations of the permeability in the vertical direction.

To take account of the greater efficiency of vertical sections of the line of creep, the original procedure was modified by the assumption that every horizontal section of the line of creep was only one third as effective as a vertical section of the same length. On this assumption, the equation

$$C_w = \frac{\frac{1}{3}B + \Sigma t}{h_{cr}} \qquad (58.2)$$

was obtained. The value C_w is known as the *weighted creep ratio*. Because Eq. 58.2 corresponds approximately to the ratio $k_h/k_v = 3$, it is obvious that it does not take into account the wide range of values that this ratio can have in the field.

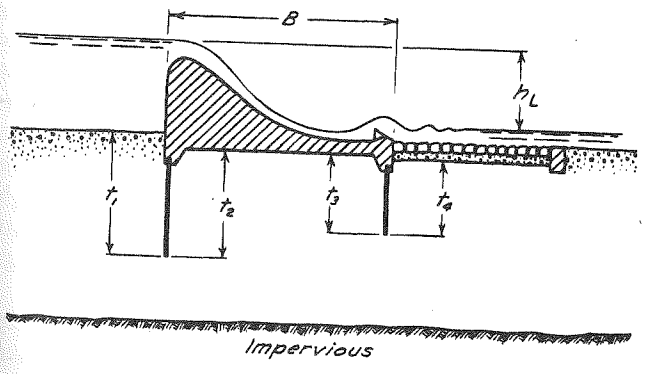


Figure 58.4 Diagram indicating dimensions used for computation of length of line of creep.

Table 58.1 Weighted Creep Values C_w (Eq.58.2)

Very fine sand or silt	8.5
Fine sand	7.0
Medium sand	6.0
Coarse sand	5.0
Fine gravel	4.0
Medium gravel	3.5
Coarse gravel including cobbles	3.0
Boulders with some cobbles and gravel	2.5

From E. W. Lane (1935).

Table 58.1 is an abstract of a list of safe values for C_w, based on a digest of about 280 dam foundations of which 24 had failed (Lane 1935).

The line-of-creep approach to the problem is purely empirical. Like every other procedure based solely on statistical data, it leads to design with an unknown factor of safety. Experience and experiments have shown that the values of C_w (Eq. 58.2) are widely scattered from the statistical average for a given soil. The values of C_w contained in Table 58.1 represent maximum rather than average values, and the values of h_{cr} obtained by means of Eq. 58.2 and Table 58.1 represent the smallest heads at which piping under field conditions has ever occurred. For a single row of sheet piles driven into homogeneous sand the weighted creep ratio C_w at failure by piping through heave would be approximately 0.67 irrespective of the grain size. Yet, under field conditions, dams have failed at creep ratios ranging from 2.5, for boulders with cobbles and gravel, to 8.5 for fine sand and silt. This discrepancy indicates that the real factor of safety against piping by heave of dams designed on the basis of Eq. 58.2 and Table 58.1 is very high. On the other hand, the wide scattering of the values of C_w from the statistical average indicates that, against failure by subsurface erosion, the factor of safety of some existing dams designed by the empirical rules must be excessive; that of others may be barely tolerable; and an unprecedented combination of several unfavorable circumstances may even lead to failure.

58.4 Subsurface Erosion Initiated by Scour

In contrast to subsurface erosion initiated by the progressive removal of material through springs, erosion can also occur when water impinges on or flows against an erodible soil, as through a transverse crack in the core of a dam or through an open joint in a rock abutment against which erodible fill has been placed. If the water carrying the eroded particles can escape downstream, an erosion tunnel can form quickly. The outlet of the erosion tunnel formed shortly before the catastrophic failure of Teton Dam in 1976 is shown in Fig. 58.5. The core material, a wind-blown silt, was placed against open untreated joints in the abutment. During the first filling of the reservoir, water flowing through cracks in the core or through the joints themselves could rapidly remove the eroded material. Only a few hours elapsed between the first appearance of muddy water from springs downstream and the complete destruction of the dam.

58.5 Means for Avoiding Subsurface Erosion

Theory and experience lead to the following conclusions. Most of the piping failures on record have been caused by subsurface erosion involving the progressive removal of materials through springs; this condition invalidates the theory of piping by heave (Article 24.2). The factor of safety with respect to piping by subsurface erosion cannot be evaluated by any practicable means. However, if the removal of subsurface material is reliably prevented, the conditions for the validity of the theory of piping by heave are satisfied and the critical head can be computed. It is, moreover, very much greater than the critical head for subsurface erosion. The means for preventing subsurface erosion depend on the importance of the project and the pattern of stratification of the subsoil.

The foremost requirement is to avoid, by appropriate design of the foundation, local concentrations of flow lines. Such concentrations were, for example, responsible for the failure of Hauser Lake Dam in Montana (Fig. 58.6*a*). The subsoil consisted of 20 m of gravel. The water was retained by a skin of steel plates supported by a steel framework that rested on large footings. The presence of the footings produced a local concentration of flow lines, as shown in the figure. The dam failed in 1908, one year after the first filling (Sizer 1908). Because it did not fail immediately, the cause was undoubtedly subsurface erosion. A second example is shown in Fig. 58.6*b*, which represents a section through a dam across the Elwha River in Washington. The structure rested on gravel and coarse sand underlain by bedrock. While the reservoir was being filled, large springs developed at the downstream toe. To reduce the flow, a row of sheet piles was driven to a depth between 9 and 12 m, at a distance of 2.5 m from the toe. This obstruction caused a concentration of flow lines, as shown in the figure, and subsurface erosion occurred. The dam failed before the sheet-pile wall was completed.

If local concentrations of flow lines are avoided, design on the basis of Eq. 58.2 is acceptable from the point of view of safety but the factor of safety may range from a high value to one close to unity; the real value depends on factors that are unknown. Hence, on important projects, provisions should be made to eliminate the possibility of subsurface erosion by one or more of the following procedures: (1) lowering the piezometric levels beneath the downstream edge of the foundation by means of relief wells; (2) establishing the downstream portion of the foundation on an inverted filter; and (3) observing the terrain downstream from the foundation during the first filling of the reservoir and placing inverted filters over the areas where springs begin to come out of the ground. This procedure was followed, for example, on Vermilion Dam (Terzaghi and Leps 1960). On minor projects such elaborate provisions may not be economically justified, and design based on Eq. 58.2 may be appropriate.

The greatest difficulties associated with preventing piping by subsurface erosion are encountered in sedimentary deposits in which layers of inorganic silt are in direct

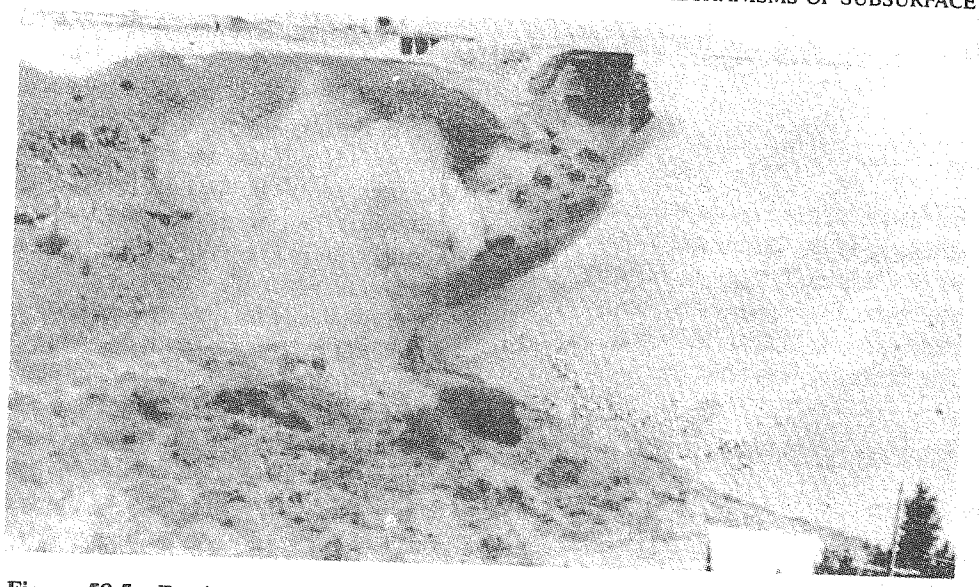


Figure 58.5 Erosion tunnel on downstream face of Teton Dam just before its collapse and failure of dam by piping (United States Bureau of Reclamation photo).

contact with layers of clean coarse sand or gravel. Erosion occurs in the silt and the silt is carried into suspension into the relief wells or toward the springs. If the exit of the sand layer is covered with a filter fine enough to prevent the escape of silt, the filter obstructs the flow of the water out of the sand layer. Such conditions of stratification often exclude the possibility of reliably preventing subsurface erosion by means of filters, and the foundation of even an important structure must be designed on the basis of a conservative interpretation of Eq. 58.2. If relief wells are installed, special precautions must be taken (Article 59.2).

Means to prevent subsurface erosion along cracks through the cores of dams or along core-rock interfaces are described in Article 59.

58.6 Susceptibility of Soils to Erosion

The foregoing discussion has indicated that piping by subsurface erosion, involving grain-by-grain removal of particles, occurs most readily in fine-grained cohesionless materials above which a roof of at least slightly cohesive soils can form. Thus, inorganic silts and very fine sands are potentially troublesome, and protective filters are designed to prevent the migration of these materials. However, some clays may lose their cohesion when exposed to water of a particular chemical composition (Arulanandan et al. 1975), whereupon the particles disaggregate and become susceptible to piping. Such clays are known as *dispersive* (Sherard et al. 1976). The tendency to disperse is not disclosed by the usual index properties. Hence, the presence of dispersive clays is usually investigated by the *pinhole test* wherein water of the expected chemical characteristics is passed through a specimen in which a small hole has been drilled, and the enlargement of the hole is noted under standard conditions. If dispersive clays are likely to participate in subsurface erosion, the protective filters must be designed to retain them. Graded filters will almost surely be required because of

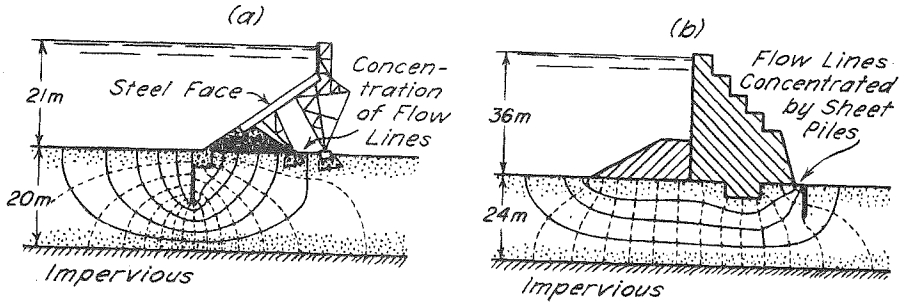


Figure 58.6 Flow nets showing concentration of flow lines responsible for failure by piping of two dams: (*a*) Hauser Lake Dam, Montana; (*b*) Elwha River Dam, Washington.

the fine filter sizes required to satisfy the filter criteria for the clay.

Selected Readings

Descriptions of the failure of three modern dams by subsurface erosion (Baldwin Hills, Teton, and Walter Bouldin) are contained in Chapter 2, Lessons from Notable Events, in *Advanced Dam Engineering for Design, Construction, and Rehabilitation,* (1988). Robert B. Jansen, ed., New York, Van Nostrand Reinhold, pp. 8–59.

ARTICLE 59 EARTH AND ROCKFILL DAMS

59.1 Basis for Design

In designing an earth or rockfill dam, the foundation, abutments, and embankment should be considered as a unit. The entire assemblage must retain the reservoir safely without excessive leakage. In addition, the design must permit diversion of the river during construction and must provide suitable spillway facilities for handling floods. The layout of the project is also influenced by facilities needed for producing power, providing for irrigation, permitting the passage of fish, and satisfying other environmental requirements. Finally, the design should be economical.

Soil mechanics enters into the evaluation of foundation and abutment conditions and of materials for construction; into the estimate and control of seepage through, around, and beneath the embankment; into selection of safe slopes; into methods of placement and control of the embankment materials; into the estimate of deformations and the evaluation of their consequences; and into the means for observing the behavior of the completed works. It may also be concerned with the stability of construction slopes and of the slopes around the reservoir after impoundment. This article deals principally with control of seepage and with the utilization and arrangement of materials to ensure stability and to exclude the possibility of failure by piping or subsurface erosion.

The distinctions among the disciplines of soil mechanics, rock mechanics, and engineering geology become obscure and meaningless at the interface between an embankment dam and foundations or abutments of rock. Findings from the latter disciplines will be invoked where they influence the soil-mechanics aspects of the design.

59.2 Seepage Control

Provisions for seepage control have two independent functions: reduction of the loss of water to an amount compatible with the purpose of the project, and elimination of the possibility of a failure of the structure by piping. Many dams have been in successful service for decades in spite of losses of water amounting to several m^3/s. Therefore, the rational design of measures for reducing seepage should be initiated by an estimate of the largest quantity of water that may escape from the reservoir if no attempt were made to intercept percolation through any but the most conspicuously pervious strata encountered in the borings. In many instances it will be found that the cost of reducing the loss of water further would be far in excess of the value of the additional water that can be retained.

Compliance with the requirement that the loss of water should not exceed a specified amount calls first of all for a knowledge of the coefficients of permeability k_h and k_v of the subsoil. The information is needed even when the feasibility of the project is being studied. Below the water table k_h should be determined by pumping tests, whereas k_v is estimated on the basis of the boring records. The sediments located above the water table should be assigned the highest values compatible with the results of the pumping tests supplemented by the boring records.

The safety of a dam with respect to a failure by piping has no relationship to the amount of water that escapes from the reservoir. Large losses of water may be associated with a high degree of safety against piping. Hence, the means for eliminating the danger of piping require independent consideration. The danger of failure of a dam by piping increases rapidly with increasing values of the hydraulic gradient at which the water percolates through the "impervious" portion of the dam and along the contact between this portion and the natural ground. Piping through the core can be eliminated reliably by adequately designed and constructed transition zones and filters. However, the prevention of piping along the contact between the core and the natural ground requires more than the application of routine procedures. The designer's attention, therefore, must be concentrated on this contact.

59.3 Cutoffs

59.3.1 Efficiency of Cutoffs

If part or all of the base of a dam is located on pervious sediments, water will escape from the reservoir by underseepage. If the loss is estimated to be excessive, it must be reduced by means such as constructed or grouted cutoffs or impervious blankets. If a dam forms part of a high-head power development, it may be economically justifiable to collect the seepage and to pump it back into the reservoir during periods of low demand.

The depth and permeability of the sediments and the loss of water considered tolerable determine whether constructed cutoffs are extended over their full length to impervious materials (complete cutoffs), or are terminated at some depth between the base of the dam and the top of the impervious formation (partial cutoffs). Cutoffs may consist of clay-filled trenches with sloping or vertical sides (Fig. 59.1*a*), of sheet piles, of concrete panel walls