DEVELOPMENT PERMIT

NO. **DP- 2019-11**

TO: **Town of Gibsons**

ADDRESS: **P.O. Box 343**
Gibsons, B.C. V0N 1V0
(Permittee)

1) This Development Permit is issued subject to compliance with all of the Bylaws of the Town of Gibsons applicable thereto, except those specifically varied or supplemented by this Permit.

2) The Development Permit applies to those "lands" within the Town of Gibsons described below:

Parcel Identifier: **009-612-084**

Legal Description: **LOTS 1 and 2 BLOCK 1 DISTRICT LOT 686 PLAN 9933**

Civic Address: **749 School Road**

3) These lands are within Development Permit Areas 4 and 9 of the Town of Gibsons Official Community Plan (Bylaw 985, 2005); this permit applies to Development Permit Area No. 9 (Gibsons Aquifer) for the purpose of the protection of the Gibsons Aquifer

4) The purpose of the Permit is to support a drilling program to investigate sub-surface soil conditions and bearing capacity for a multi-unit housing development.

5) The "land" described herein shall be developed strictly in accordance with the terms and conditions and provisions of this Permit, and any plans and specifications attached to this Permit which shall form a part thereof; specifically:

- Geotechnical Report letter titled: *DPA9 Drilling Investigation within Aquifer Boundaries 739/749 School Road, Gibsons, BC*, dated May 19, 2019 and stamped by Ben Davies, P.Eng.

- Plans Titled: *Proposed Drilling Program for 739/749 School Road, Gibsons, BC* by Davies Geotechnical and dated May 21, 2019.

6) All requirements of the permit and plans are to be followed. On site monitoring by the Geotechnical Engineer during construction as outlined in the permit and plans is required.

7) Minor changes to the aforesaid drawings that do not affect the intent of this Development Permit are permitted only with the approval of the Town of Gibsons and Geotechnical Engineer.

8) If the Permittee does not commence the development permitted by this Permit within

twenty four months of the date of this Permit, this Permit shall lapse.

9) Upon completion of the works, a letter from a qualified professional is required to confirm all conditions of this permit were met.

10) This Permit is NOT a Building Permit.

ISSUED THIS 9th DAY OF July, 2019.

Lesley-Anne Staats, MCIP, RPP
Director of Planning

Copy of permit to Davies Geotechnical Inc.

DAVIES GEOTECHNICAL INC.

1520 Cliveden Avenue, Unit 2
Delta, B.C. Canada V3M 6J8

T: 604.395.2300
F: 604.395.2301

www.daviesgeotechnical.com

Foundation Design

Excavation & Shoring Design and Monitoring

Slope Stability

Retaining Wall Design

Earthquake Engineering

Liquefaction Assessment

Storm Water Management Design

Sediment & Erosion Control Design

Design Build

COMMERCIAL

RESIDENTIAL

INFRASTRUCTURE

Date: **May 19, 2019**
Project No: **R030**

Town of Gibsons
474 S Fletcher Road,
Gibsons, BC
V0N1V0

Attn: **Lesley-Ann Staats**
Re: **DPA9 Drilling Investigation Within Aquifer Boundaries**
739/749 School Road, Gibsons, BC

Dear Lesley-Ann:

Davies Geotechnical proposes to complete a geotechnical investigation of the site at 739/749 School Road in the Town of Gibsons, BC.

The purpose of our work is to gather site-specific information regarding soil and groundwater conditions to enable Davies Geotechnical Inc. to provide recommendations regarding the geotechnical aspects of the design and construction of the proposed low-income housing development.

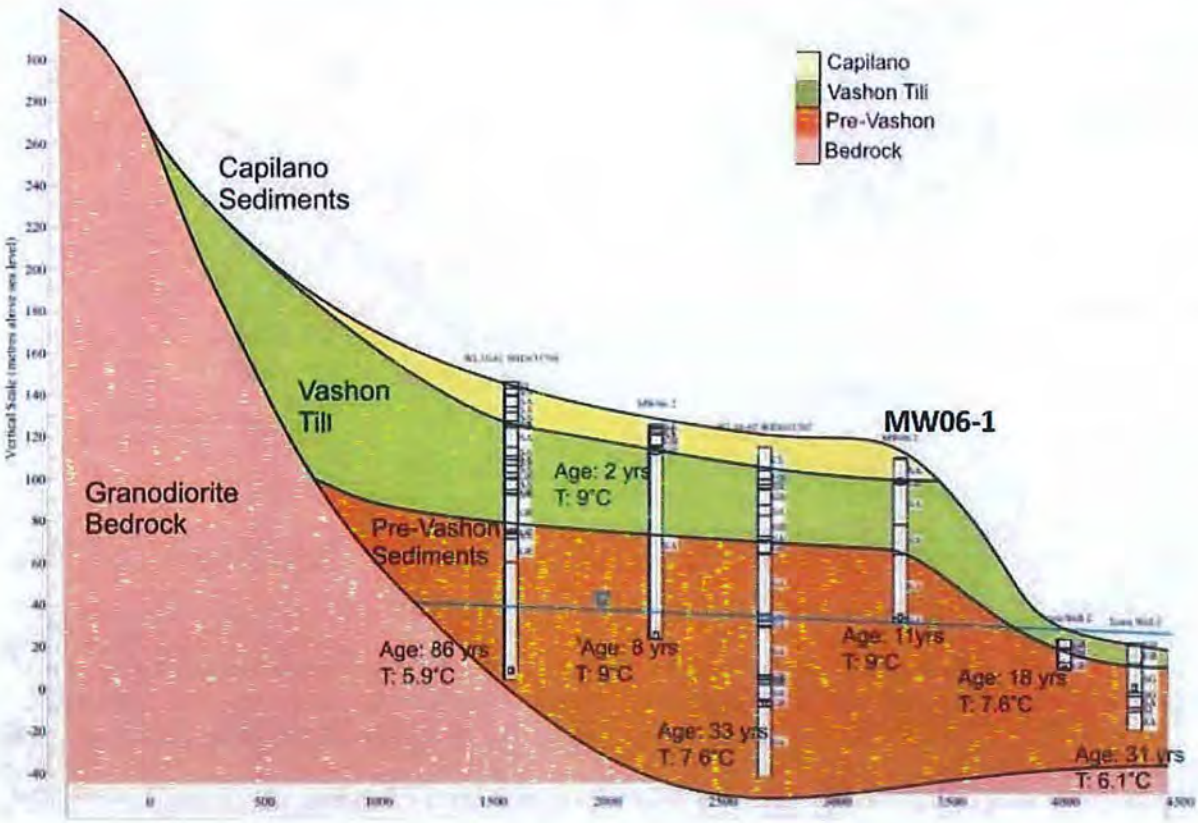
We are aware of the hydrological ground layer considerations that must be accounted for while drilling in the Town of Gibsons which includes, the Pre Vashon (Gibsons) Aquifer, the Vashon Deposited Aquitard, and the Capilano Aquifer.

Drilling in these soil layers increases the risk of ground water contamination, breaching the aquitard, lowering aquifer pressure, and artesian flow.

Davies Geotechnical has reviewed available data regarding the Gibsons aquifer, based on the information found we are able to limit the risks associated with drilling into the Gibsons aquifers.

Our desk study found information from Waterline Resources Inc. which shows the different aquifer layers throughout Gibsons. Our site is within 200 to 300 meters horizontal distance of MW06-1 which was drilled by Piteau Associates Geotechnical and Hydrogeological Consultants in December of 2006 using dual mode air rotary drilling conducted by Field Drilling Contractors Ltd. The hole is located near the proposed site at Spyglass Place with ground elevation of 110 meters above sea level. The drill logs show the following profile:

- Capilano Sediments: 0 – 12 meters below grade
- Vashon till aquitard: 12 – 46 meters below grade
- Pre-Vashon sediments: 46 + meters below grade
- Bedrock estimated at 150 meters below grade



Cross Section of Gibsons Aquifer

We are aware that the Pre-Vashon Gibsons Aquifer in some locations has artesian pressure and if the aquitard is breached surface ground water flow is possible which can deplete water supplies, expose the water supply to contaminants, cause massive damage, and result in sink holes.

To lower the risk of encountering the Vashon Aquitard or Pre-Vashon Aquifer, Davies Geotechnical proposes to drill to a maximum depth of 6 meters below grade. By minimizing the depth of drilling paired with the existing knowledge of the aquitard we believe we can prevent damage to the aquifer or aquitard.

Drilling and Dynamic Cone Penetration Testing (DCPT) will be conducted within the Capilano sediments located above the Vashon Till. The DCPT will involve driving a 0.06-meter diameter blunt tipped cone with a 0.15-meter-long sleeve into the soil using a 63 kg automatic trip hammer free falling 0.76 meters. The number of blows required to drive the cone through every 0.3-meter layer of soil will be recorded and plotted against the results of the auger soil sampling on auger logs.

Soils will be logged by an engineer from Davies Geotechnical Inc. Soil samples considered representative of the soil horizons encountered at the site will be collected at a minimum interval of 1.5 m and returned to our laboratory for further classification. The soil identification and sampling work will be completed by qualified staff from Davies Geotechnical Inc.

Based on past experience, solid stem drilling into Vashon Till deposits is very difficult and often results in refusal of the augers. Based on existing well data we do not anticipate encountering the till like soils. However, if encountered, to prevent damage to the Vashon Till and minimize the risk of loss of ground water pressure or contamination of the lower Pre-Vashon deposits, drilling will be stopped prior to the target 6 meters depth if till-like soils are found or auger drilling encounters hard ground conditions.

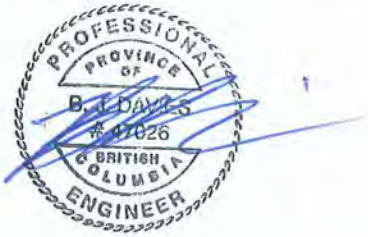
Davies Geotechnical anticipates only encountering the Capilano Sediment deposit aquifer within our investigation which is a perched aquifer over the Pre-Vashon till deposit. See appendix E for Blue Max Drilling credentials for drilling and proposed sealing methods if ground water or artesian flow is encountered. As there are localized confining layers (aquitards) found within this deposit it is still possible to encounter minor artesian flow from the surficial Capilano deposit, due to the sloping nature of the area.

Blue Max Drilling will bring to site all necessary equipment and materials required to seal the holes if artesian flow or ground water is encountered. See appendix E for details.

If artesian flowing water is encountered during the investigation no further holes will be completed and the hole which encountered the water will be sealed and monitored.

Davies Geotechnical will provide drilling logs once the geotechnical report is complete.

Based on our knowledge of the subgrade soils near the site, Davies Geotechnical anticipates low risk to the Gibsons Aquifer using the proposed drilling plan and methods.



DAVIES GEOTECHNICAL INC.
Ben Davies, P.Eng.
BD

604-395-2300
604-395-2301
ben@daviesgeotechnical.com

Proposed Drilling Program for 739/749 School Road, Gibsons, BC

Submitted to: The Town of Gibsons

Date Issued: May 21, 2019

PREPARED BY: Davies Geotechnical Inc.

CC:	Town of Gibsons representative	Dave Newman
	Town's hydrogeology consultant	Simon Wing
	Drilling contractor	Blue Max Drilling
	Barge Contractor (if applicable)	NA
	Other personnel on site (if applicable)	Able1Call

CONTACT LIST

EMERGENCY NUMBERS

Town of Gibsons Representative: Dave Newman, 604-886-2274
Drilling Contractor Owner/Principal: Cole Bertsch, work 778-237-2583, cell 778-995-2583
Ambulance/Hospital **911**

Prime Consultant in Charge

Principal Consultant: Paul Davies, *work 604-395-2300, cell 604-454-7519*
Field Consultant: Ben Davies, *work 604-395-2300, cell 6047547249*

Town Hydrogeology Consultant

Principal Hydrogeologist: Simon Wing
Field Hydrogeologist: Simon Wing

SERVICE COMPANIES

Drilling Contractors: BlueMax Drilling Cole Bertsch, work 778-237-2583, cell 778-995-2583
Grouting/Cement Contractor: BlueMax Drilling Cole Bertsch, work 778-237-2583, cell 778-995-2583
Vacuum Truck: BlueMax Drilling Cole Bertsch, work 778 237-2583, cell 778-995-2583
Waste Removal Contractor: BlueMax Drilling Cole Bertsch, work 778-237-2583, cell 778-995-2583
Utility Locator: Marrietta Ostberg, work 604-536-3603, cell 6048664890

TO BE POSTED ON SITE

1 OVERVIEW

1.1 The purpose of subject the drilling program is to:

- *assess depth to competent soils for proposed buildings footing design*

1.2 As outlined in the Town of Gibsons Development Permit Area Guidelines, the proposed drilling area is underlain by a known artesian aquifer (the Gibson Aquifer) and therefore an increased standard of care is needed to protect the aquifer.

- *The site is located at the corner of School Road and Oshea Road in Gibsons BC, approximately 200 meters north east of well MW06-1. It is located within the area of the Gibsons aquifer. According to the monitoring well logs for MW06-1 by Piteau Associates the water level in the Pre Vashon Gibsons Aquifer is approximately 75 meters below grade. Till soils were found approximately 12 meters below grade. The site is at approximate elevation 96 meters above sea level well above the elevation of measured artesian flow.*

  Davies Geotechnical proposes to complete solid stem auger with dynamic cone penetration testing to 6.0 meters below grade maximum to decrease risk of compromising, the aquitard or aquifer, and to minimize chances of drilling breaching the aquitard and experiencing artesian flow.

1.3 Davies Geotechnical envisage that the following risks would be involved in the proposed drilling program:

We understand that the following risks are possible if an aquitard is breached:

- *Uncontrolled artesian flow if aquitard is breached.*
- *Development of a sink hole if artesian flow is left unattended or site worker are unprepared to mitigate the flow.*
- *Impact on the Town of Gibsons' water wells if the aquifer is breached and left unsealed.*
- *Potential loss of aquifer pressure if the aquifer is breached and not sealed properly.*
- *Environmental concerns with contaminating the aquifer.*

Davies Geotechnical's drilling investigation will stop at 6 meters below grade, the aquitard till is expected to be approximately 12 meters below grade at the subject site, and therefore we do not anticipate artesian flows occurring due to the lower Pre Vashon Gibson aquifer at the subject site however based on passed drilling experience by the drillers, localized confined layers may have perched water artesian flow occur from confined layers within the Capilano Sediments above the till. The risk and consequence of artesian flow is lower at the subject site but still possible and therefore the drillers, Blue Max Drilling, will be prepared with equipment and materials required to seal artesian flow.

1.4 Table 1 summarizes the proposed drilling program with anticipated depth, location, and decommissioning plan. The proposed borehole locations are shown on [*e.g. Figure 1*].

Borehole Name	***Location***	***Planned Depth***	***Decommission Plan***
AH19-01	749 School Road North Corner	4.6 – 6.0 meters below grade	Backfill with bentonite and excavated cuttings if ground water is not encountered. If water is encountered drill down using casing and seal with bentonite or grout.
AH19-02	749 School Road East Corner	4.6 – 6.0 meters below grade	Backfill with bentonite and excavated cuttings if ground water is not encountered. If water is encountered drill down using casing and seal with bentonite or grout.
AH19-03	749 School Road South Corner	4.6 – 6.0 meters below grade	Backfill with bentonite and excavated cuttings if ground water is not encountered. If water is encountered drill down using casing and seal with bentonite or grout.
AH19-04	749 School Road West Corner	4.6 – 6.0 meters below grade	Backfill with bentonite and excavated cuttings if ground water is not encountered. If water is encountered drill down using casing and seal with bentonite or grout.

2 PRE-DRILLING REQUIREMENTS

2.1 The following must be established prior to drilling commencement:

Knowledge and understanding of British Columbia's Groundwater Protection Regulation

Davies Geotechnical understands and has reviewed the Water Sustainability Act Groundwater Protection and Regulation Dated May 3, 2016 that replaced the 2004 edition.

- *(http://www.bclaws.ca/Recon/document/ID/freeside/11_299_2004)*

WorkSafe BC program

- *See attached for Davies Geotechnical H&S documents.*
- *See attached for BlueMax Drilling H&S documents.*
- *Site is located at 749 School Road in Gibsons, closest hospital is Sechelt hospital at* 5544 Sunshine Coast Hwy, Sechelt, BC V0N 3A0, alternatively Gibsons Medical Clinic is located at 211 – 1100 Sunshine Coast Highway, Gibsons, BC, V0N1V7 open 830am to 5 pm mon-sat 9am to 12pm Sundays.
- *Site Specific H and S provided*

Permit Requirements:

- *Gibsons Drilling Permit*
- DPA9 Permit

Driller certification:

- ITA Env-Geo Driller Certification for Blue Max Lead Driller David Rooker

All rig lifting equipment, and overhead equipment must be certified to the Original Equipment Manufacturers Specifications (OEM).

All equipment is certified to Original Equipment Manufacturers Specifications.

Casing handling and running procedures:

Please refer to Blue Max JHA for Auger drilling

Certificate of Insurance and WorkSafe BC letter are attached

COI and WCB Clearance Letter for Blue Max Drilling are included.

Rig specification sheet included.

Additional pre-drilling requirements:

- *Refer to BC MoE Flowing Artesian Wells document included in appendix.*

3 RIG MOVE, RIG UP AND SITE SAFETY

3.1 The following procedures site safety provisions must be followed in mobilizing, set up and operation of the drilling rig:

Drilling contractor to contact prime consultant in charge the day before mobilization to site to confirm site and drill is ready.

Move in and rig up drilling rig and auxiliary equipment on site (or onto the barge if applicable). Prior to initiating drilling, carry out detailed rig inspection and report any unsafe conditions to prime consultant.

Hold a pre-drilling safety meeting with the rig crew and all consultants on site to discuss the Hazardous Operations and drilling program.

Certified driller to be onsite at all times during drilling.

4 GENERAL DRILLING PROCEDURES

4.1 Roles and responsibilities:

- *Prime Field Consultant: to organize utility locating and drilling contractors for investigation date. To review soil samples and collect samples at minimum interval of 1.5 meters.*
- *Driller: to operate drill in safe manner as directed by the prime field consultant.*
- *Drillers helper: to provide assistance to driller during drilling investigation.*
- *Utility Locator: to verify no utility conflicts at proposed drilling locations.*

4.2 Methodology of data and sample collection:

Davies Geotechnical will complete dynamic cone penetration testing (DCPT) and hand collected samples off of the augers.

The DCPT will involve driving a 0.06-meter diameter blunt tipped cone with a 0.15-meter-long sleeve into the soil using a 63 kg automatic trip hammer free falling 0.76 meters. The number of blows required to drive the cone through every 0.3-meter layer of soil will be recorded and plotted against the results of the auger soil sampling on auger logs.

Soils will be logged by an engineer from Davies Geotechnical Inc. Soil samples considered representative of the soil horizons encountered at the site will be collected at a minimum interval of 1.5 m and returned to our laboratory for further classification. The soil identification and sampling work will be completed by qualified staff from Davies Geotechnical Inc.

4.3 Drilling Details

4.3.1 AH19-01 to AH19-04

o *All boreholes to be conducted using solid stem augers to maximum depths of 6.0 meters below grade. Holes to be drilled vertically and logged by the prime field consultant. Drill holes not to exceed 6.0 meters to prevent drilling into or through aquifers or aquitards. Holes will be backfilled with bentonite and excavated cuttings if water is encountered we will drill down using casing and seal with bentonite or grout.*

If the aquifer soil (which is understood to comprise coarse grained sand and/or gravel) and/or artesian pressures or fresh water are encountered, borehole to be abandoned immediately.

o *Refer to BC MoE Flowing Artesian Wells document for guidance.*

o *all required equipment and materials to safely and effectively seal or prevent artesian flows to be provided and brought to site by the drilling contractor to ensure preparedness for aquifer, aquitard, or artesian flows encounters.*

4.3.2 Monitoring Well / Piezometer Installation Details (If Required)

Monitoring or piezometers are not part of the project scope.

4.3.3 Borehole Abandonment Program (Artesian Flowing Well Bore)

- If artesian flow conditions are encountered, hole will be cased with hollow stem auger (approximately 8.25" OD) to the depth where water was encountered (boreholes not anticipated to extend beyond 6m below ground surface).
- Drillers will tremie grout borehole with cement-grout mix from bottom of hole to surface while also retracting hollow stem augers from borehole.
- See additional document entitled "Grouting Specifications-Blue Max Drilling" for grout-mix ratios.
- Allow grout to set overnight (approximately 12 hours) to confirm cement-grout has set and hole has been appropriately sealed before patching top of hole with asphalt or concrete (add more grout-cement mix as needed if any settling occurred while setting overnight).

4.3.4 Borehole Abandonment Program (Non-artesian Flowing Well Bore)

- Boreholes with non-artesian flow conditions will be backfilled with drill cuttings and clean silica sand to surface. If borehole depth is 6m below ground surface or deeper, a 1m (3ft) layer of bentonite (chips) will be added to the hole as a sealant layer to prevent vertical migration of groundwater.
- Boreholes will be capped with either asphalt cold patch or concrete to match existing ground surface.

5 FIELD PACKAGE

The following documents are attached:

- *Proposed borehole/well location plan*
- *Site specific Health and Safety Plan*
- *Davies Geotechnical Health and Safety Plan (https://www.dropbox.com/sh/ev38rib98dguxco/AACE9OoNS_-XQSAAZC0u1MFBa?dl=0)*
- *Drilling Contractor Materials (procedures, rig equipment and operation)*
- *Driller certificates*
- *Development Permit DPA 9*
- *JHA for auger drilling*
- *WCB letter for BlueMax*
- *WCB letter for Davies Geotechnical*
- *Schedule F*
- *Certificate of Insurance Documents for Davies Geotechnical and Bluemax Drilling*
- *BC MoE Flowing Artesian Well Document*
- *Grouting Specifications document included*

Figure 1: GEOTECHNICAL SITE INVESTIGATION

SITE PLAN

Project:	749 School Road, Gibsons, BC
Project No:	R030
Investigation Date:	TBD

BOREHOLE LOCATIONS

Symbol Type:	Sonic Hole Location
Prepared by:	BD
Reviewed by:	BD
Date:	May 6, 2019

DAVIES GEOTECHNICAL INC.
1520 Cliveden Avenue, Unit 2
Delta, B.C. Canada V3M 6J8

BLUE MAX DRILLING – DAILY EQUIPMENT / VEHICLE CHECKLIST & H&S TAILGATE MEETING FORM

Job# R030

Rig# 131

Support# No Support Truck

Location 739/749 School Rd, Gibsons

Date May 16, 2019

Weather Conditions TBD

Client Davies Geotechnical

Client Contact Ben Davies 604 754 7244

First Aid

Nearest Hospital Sechelt - 5544 Sunshine Coast Hwy

Muster Point SW Corner of School Rd and O'Shea Rd

BC One call Y ☑ N ☐ Private Locator Y ☑ N ☐

Private Locator Able 1 Date: TBD

Rig Inspection

	Y	N	N/A		Y	N	N/A		Y	N	N/A
Auger Racks	☑	☐	☐	Fluid Levels	☑	☐	☐	Electrical Func.	☑	☐	☐
Backup Alarm	☑	☐	☐	Hoses	☑	☐	☐	Lug Nuts tight	☑	☐	☐
Brakes	☑	☐	☐	Winch Cables	☑	☐	☐	Wheel Chalks	☑	☐	☐
Doors Close	☑	☐	☐	Headlights	☑	☐	☐	Hand Tools	☑	☐	☐
Drill Head	☑	☐	☐	Marker Lights	☑	☐	☐	Auger/Pipes	☑	☐	☐
E-brake	☑	☐	☐	Rig Mast	☑	☐	☐	Load Secure	☑	☐	☐
Horn	☑	☐	☐	Tire Inflation	☑	☐	☐		☐	☐	☐
Fluid Leaks	☑	☐	☐	Tire Damage	☑	☐	☐		☐	☐	☐

Scope of Work

-4 Augers to 6m + 4 DCPT's to 6m

Electrical Functions:

E Shut Off	☑	☐	☐
Throttle Control	☑	☐	☐
Fan Switches	☑	☐	☐
Mast Lights	☑	☐	☐
Control Panel	☑	☐	☐

Tailgate Items reviewed

	Y	N	N/A		Y	N	N/A	PPE	Y	N	N/A
Emergency Shutoff	☑	☐	☐	Winches/Cable	☑	☐	☐	Hard Hat	☑	☐	☐
Fire Extinguishers	☑	☐	☐	Hoisting	☑	☐	☐	Glasses	☑	☐	☐
First Aid Kit	☑	☐	☐	Rotating Equipment	☑	☐	☐	Steel Toe Boots	☑	☐	☐
Eye Wash	☑	☐	☐	Compressor	☐	☐	☑	Gloves	☑	☐	☐
Spill Kit	☑	☐	☐	Air Hoses	☐	☐	☑	Clothing	☑	☐	☐
Utilities (Above/ below)	☑	☐	☐	Drop Hammer	☑	☐	☐	Ear Plugs	☑	☐	☐
Site Walk Around	☑	☐	☐	Breakout Wrench	☐	☐	☑	Respirators	☐	☐	☑
Contaminated Soil/H_2O	☐	☐	☑		☐	☐	☐	Fit for Work	☑	☐	☐

Signoff

Name	Signature	Date
Ben Davies	[signature]	May 16, 2019
Amanda Tompkins, Blue Max Drilling	Amanda Tompkins	May 16, 2019

BLUE MAX DRILLING – DAILY EQUIPMENT / VEHICLE CHECKLIST & H&S TAILGATE MEETING FORM

Hazard Assessment			
Risk Level Low ,Moderate, High, Extreme (Risk matrix for more detail)	Hazard Identified	Control Method	Date
Low	Overhead Lines	Walk the site before drilling	May 16, 2019
Low	Underground Utilities	BC One Call and Utility Locates preformed prior to drilling	May 16, 2019
Low	Traffic	Parking lot, minimal to no traffic onsite	May 16, 2019
Low	Aquifer	Do not extend drill holes beyond 6m below ground surface, prevent chance of encountering Gibsons Aquifer	May 16, 2019
Moderate	Noise	Ensure all workers onsite wear ear protection and keep pedestrians outside work zone	May 16, 2019

Likelihood	Impact				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	Moderate	High	High	Extreme	Extreme
Likely	Moderate	Moderate	High	High	Extreme
Possible	Low	Moderate	Moderate	High	Extreme
Unlikely	Low	Moderate	Moderate	Moderate	High
Rare	Low	Low	Moderate	Moderate	High

Job Safety Analysis (JSA)		
Task	Hazard (physical, chemical, other)	Preventative Measures
Backing up drill rig	Limited visibility	Use a spotter
Set up rig	Pinch Points	Use proper Blue Max H&S procedures
Drilling in public area	Pedestrians	Block off work zone with delineators and caution tape

Field Level Risk Assessment (FLRA) weather change, task change, no procedure for task, etc		
Task	Hazard (physical, chemical , other)	Preventative Measures
To be determined when onsite		

GROUTING – BLUE MAX DRILLING

1: CEMENT/BENTONITE GROUT (Recommended)

Introducing cement, even a small amount, reduces the expansive properties of the bentonite component once the cement-bentonite grout takes an initial set

This is for Cement (Type 10) + Bentonite Grout pictured here ---------->

Use this mix for Inclinometers or Vibrating Wire Piezometers (OK to change based on client spec)

Use for environmental or geotechnical wells too, if client is ok or asks for it.

Grout Mix for Hard and Medium Soils		
Materials	**Weight**	**Ratio by Weight**
Portland cement	94 lb (1 bag)	1
Water	30 gallons (110 Litres) (Half a Drum)	2.5
Bentonite	+/- 25 lbs. (See Notes Below)	0.3
Mix cement with water first. Then mix in the bentonite. Adjust the amount of bentonite to produce a grout with the consistency of heavy cream. If the grout is too thin, the solids and the water will separate. If the grout is too thick, it will be difficult to pump. The 28 day		

- ➔ Mix cement and water first! Add bentonite as required. Add more bentonite to thicken.
- ➔ Thicker is better than thinner!
- ➔ This mix is more forgiving should the user deviate from the design recipe

Notes:

If you mix cement and water first, the amount of bentonite has to be adjusted. The amount is rarely ever equal to exactly 25 lbs.

If you mix bentonite and water first, the mix usually gets so thick with one bag of cement that it cannot be pumped. There is also a high risk of a flash-set. The cement content must usually be lowered.

If the mix is left too watery, not only do you get shrinkage, but segregation occurs: cement on the bottom, then bentonite and water on top (bleed). This is not acceptable.

2: BENTONITE ONLY (20% SOLIDS) (Not Recommended)

This is for Bentonite Grout ONLY pictured here ---------->
Use this mix for environmental wells or geotechnical standpipes.
Don't use for Inclinometers or Vibrating Wire Piezometers (unless client approves)
Must be High-Solids Bentonite Grout (20% Solids)

Mix:
Bentonite Grout: 50lb Bag
Water: 90 Litres (24 gallons) (Half a Drum)

➔ If the above mix is too thin, add more bentonite!

Notes:
A bentonite grout backfill consisting of just bentonite and water may not be volumetrically stable and introduces uncertainty about locally introduced pore water pressures caused by the hydration process.

Sometimes bentonite only grout never really sets up to anything more than thick paste, not a solid like the chip-seals.

If you can, use chips or pellets rather than just bentonite grout

B61 Truck Rig

AUGER | AIR (ODEX) | MUD | CPT Capable

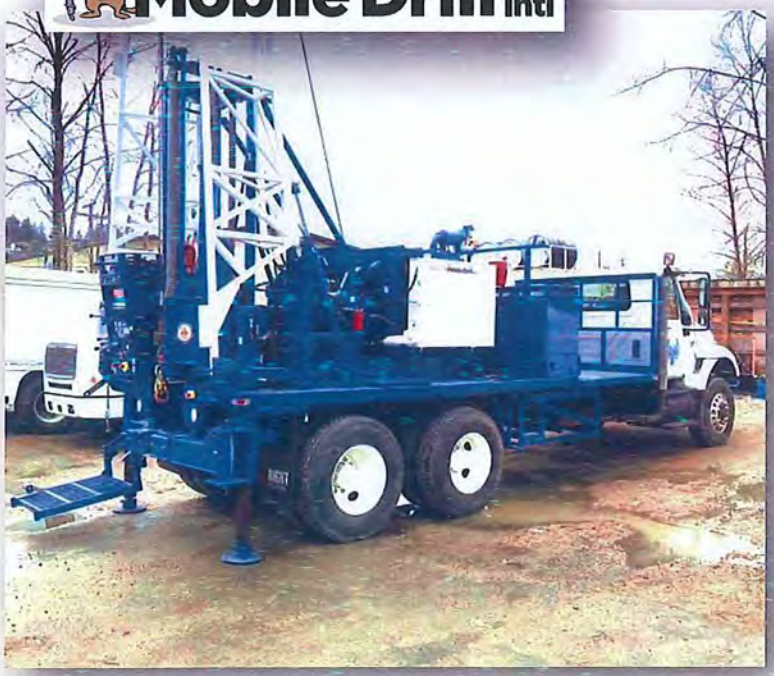
BLUE MAX DRILLING

Offering a wide variety of capabilities, the tandem axle truck mounted Mobile Drill B61 is one of the most powerful environmental/geotechnical drill rigs available. This machine commonly drills through all types of overburden (auger, ODEX, mud rotary) and can perform a variety of installations (monitoring wells, piezometers, inclinometers) and geotechnical tests (CPT, DCPT, SPT).

Rig Specs	Imperial	Metric
Height, Mast Up, Winch Down	13′	3.96m
Height, Mast Down, Winch Up	38′	11.6m
Length	29′	8.85m
Width	8′	2.44m

Drill Depths	Imperial	Metric
Auger, Solid Stem	300′	90m
Auger, Hollow Stem	200′	60m
Air (ODEX), Cased	300′	90m
Air (ODEX), Open Hole	1,500′	450m
Mud Rotary	1,000	300m

Mobile Drill Intl



Additional Features

35,300 lbs of retract force
20,000 foot lbs of rotary torque
Tandem axle truck base
140 lbs SPT Auto Hammer
Winch Line
Full grouting capabilities
Full CPT capabilities
40,000 lb GVW

Locations

Surrey, BC (Head Office)
Vancouver Island, BC
Terrace, BC

www.bluemaxdrilling.com
(778) 237-BLUE (2583)

BLUE MAX DRILLING INC.

YOUR TICKET.

800 8100 Granville Avenue
Richmond, BC V6Y 3T6
Tel 778-328-8700
Fax 778-328-8701

June 28, 2018

David Jonathan Rooker
13727 111 Ave
Surrey BC V3R 2C1

Dear David:

This letter is to confirm your recent successful completion of the trades qualification examination. An endorsed Certificate of Qualification and wallet card are enclosed.

Geotechnical/Environmental Driller
00003-GN-18
2018-JUN-20

In this regard, we are certain that the effort and time spent in acquiring and demonstrating your skill and knowledge will ensure recognition throughout the trade.

We are very pleased to extend our congratulations to you on your achievement in attaining this certification and wish you every success in your future endeavors.

Yours truly,

Gary Herman

Gary Herman, CEO

This is to certify that
DAVID JONATHAN ROOKER
holds a
CERTIFICATE OF QUALIFICATION
in the trade of

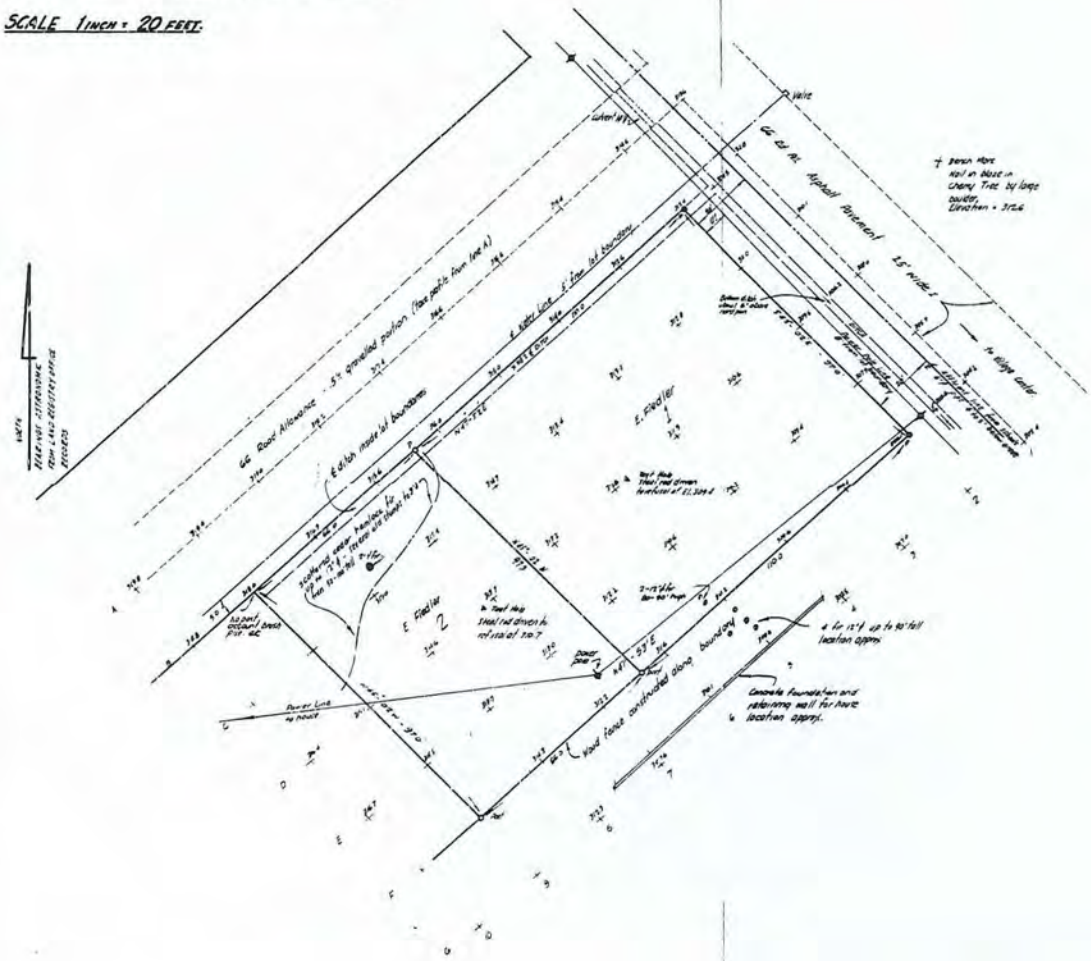
GEOTECHNICAL/ENVIRONMENTAL DRILLER

ita YOUR TICKET. BRITISH COLUMBIA Industry Training Authority CEO

Issue Date: 20/6/2018 | Certificate #: 00003-GN-18

PLAN OF SITE SURVEY OF
LOTS 1 AND 2 BLOCK 15
DISTRICT LOT 686 GR.1
N.W.D. GIBSONS B.C.

SCALE 1 INCH = 20 FEET.



LEGEND

- ⊕ IP, indicates 30" x 1" iron pin
- ○ P indicates white wood post.
- x.x indicates spot elevation.

Datum for elevations approximate Geodetic.

Certified correct 8 February 1989

D.J. Roy
B.C.L.S.

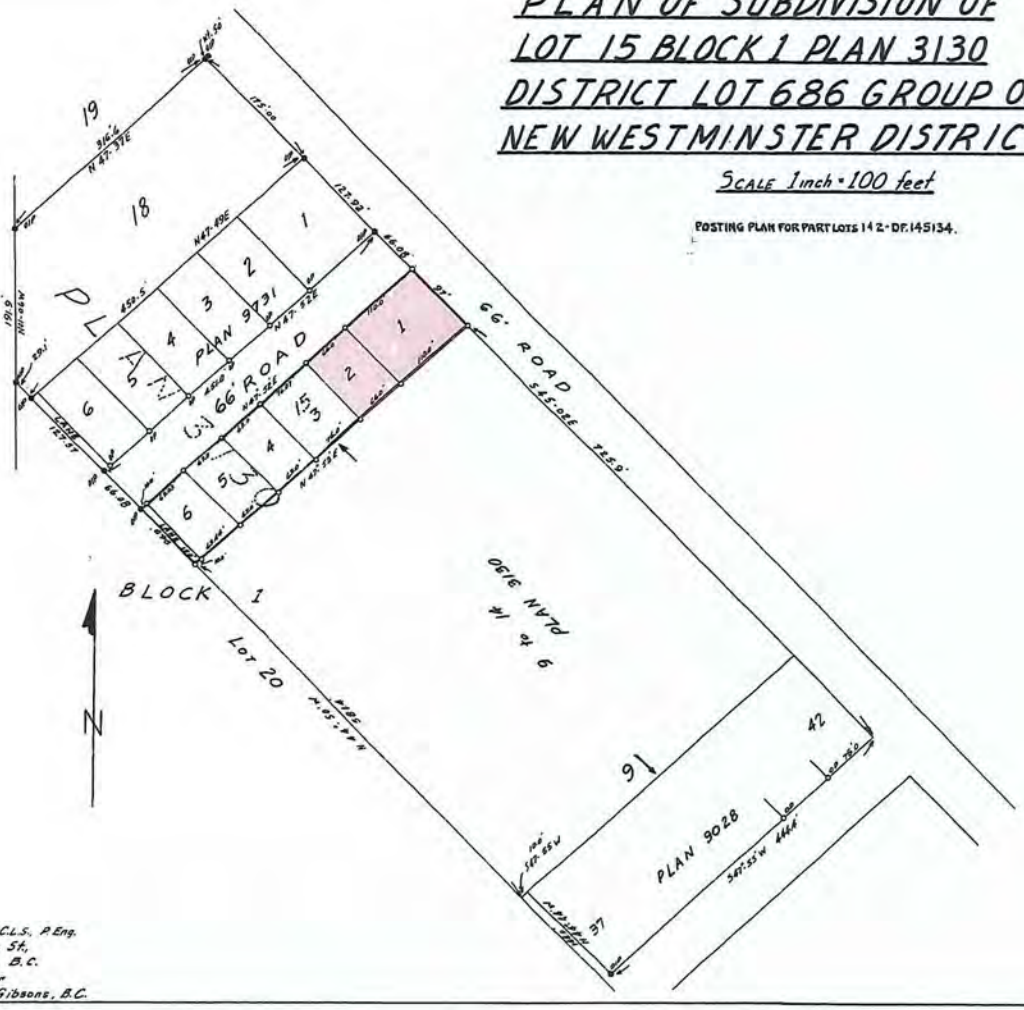
D.J. ROY B.C.L.S. P.ENG
1334 WEST PENDER ST.
VANCOUVER 5, B.C.

YELLOW

PLAN OF SUBDIVISION OF LOT 15 BLOCK 1 PLAN 3130 DISTRICT LOT 686 GROUP ONE NEW WESTMINSTER DISTRICT

SCALE 1 inch = 100 feet

POSTING PLAN FOR PART LOTS 14 2 - DF. 145134.



D. J. Roy B.C.L.S., P.Eng.
1553 Robson St.,
Vancouver 5, B.C.
or
Box 37 - Gibsons, B.C.

PLAN 9933.

Deposited in the Land Registry Office in Vancouver this 4TH day of JUNE 1959.

Registrar

Approved under the Land Registry Act this 15 day of May 1958

Approving Officer

LEGEND

- ○ OP Indicates wood post found.
- ● OIP Indicates iron pin found.
- ○ Indicates wood post set.
- ● IP Indicates iron pin set.

Bearings are Astronomic derived from Plan 9028 with road taken as N 45°42' W

Owner: E. Fiedler
Witness: [illegible]
Owner: _____
Witness: _____

I Douglas J. Roy of West Vancouver a British Columbia Land Surveyor make oath and say that I was present at and did personally superintend the survey represented by this plan and that the plan and survey are correct. The said survey was completed on the 27 day of March 1958

D. J. Roy B.C.L.S.

Sworn before me this 7th day of April 1958

A Notary Public in and for the Province of British Columbia.
J — 33-58

SCRD Maps

Property Report

749 SCHOOL RD

4/3/2018

Folio: 524.00497.000 **PID:** 009-612-084

Address: 749 SCHOOL RD **Jurisdiction:** Gibsons

Lot: 1 **Block:** 1 **Plan:** VAP9933 **District Lot:** 686

2018 Assessed Value: 276900 **Land Value:** 266000 **Improvement Value:** 10900

Approximate Lot Size (BC Assessment): 10454 SQUARE FEET

SCRD Maps

Property Report

4/3/2018

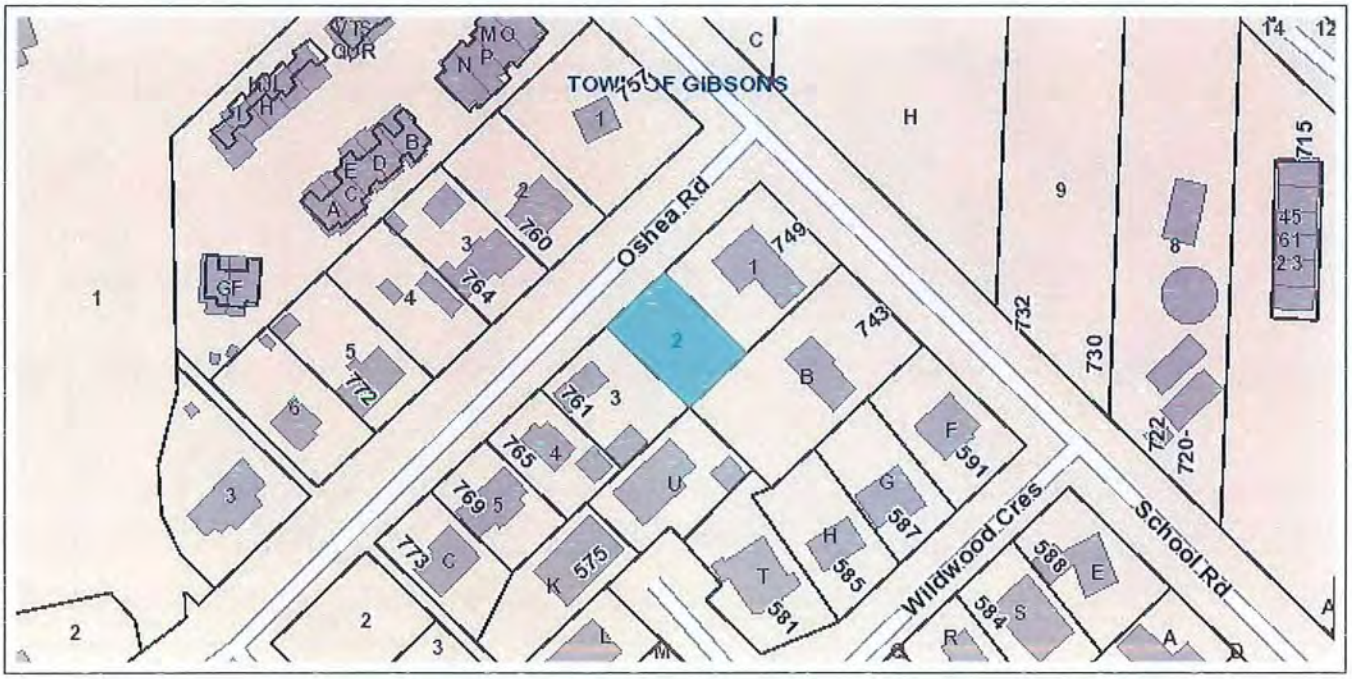
Folio: 524.00498.000 **PID:** 009-612-122

Address: **Jurisdiction:** Gibsons

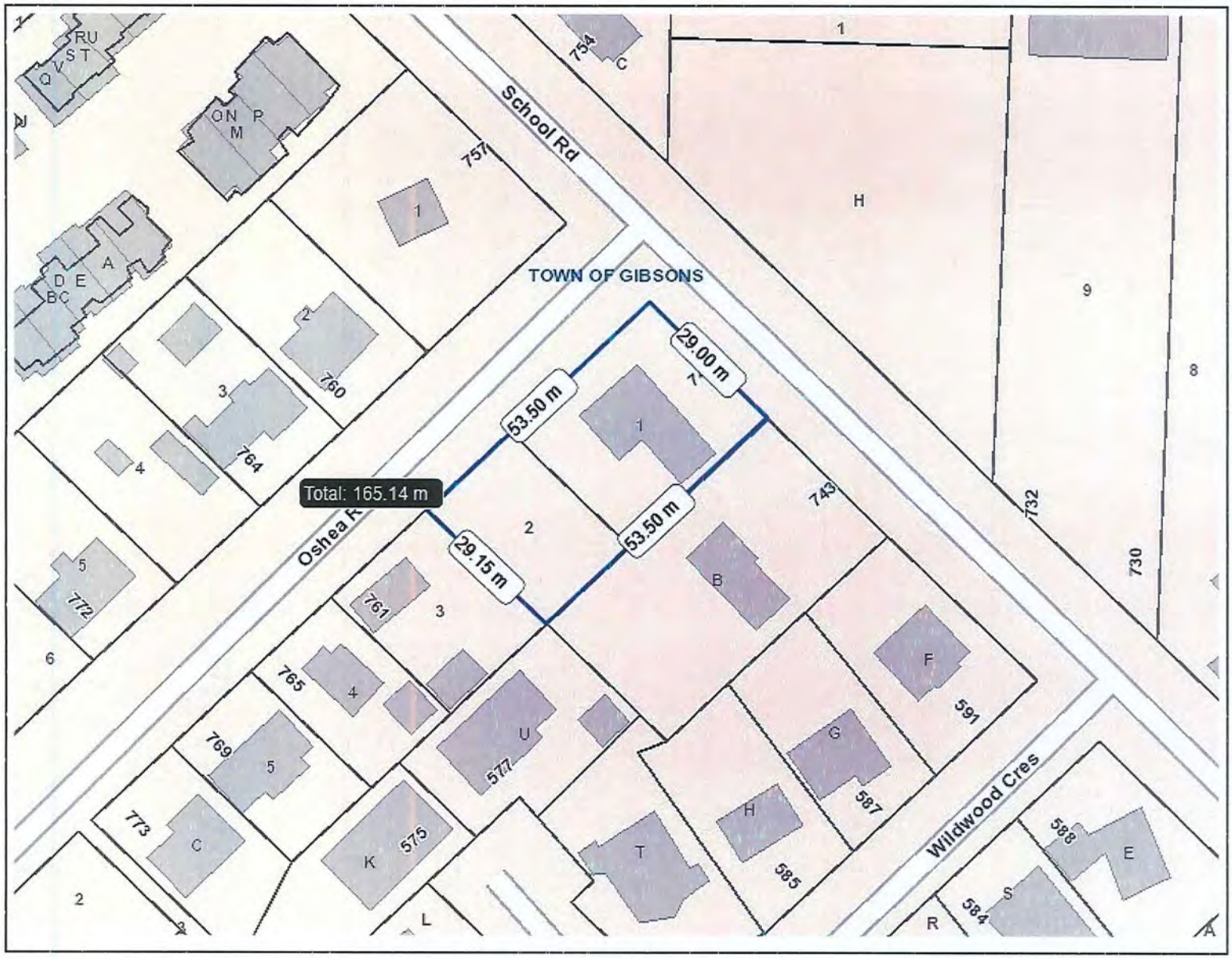
Lot: 2 **Block:** 1 **Plan:** VAP9933 **District Lot:** 686

2018 Assessed Value: 256300 **Land Value:** 256000 **Improvement Value:** 300

Approximate Lot Size (BC Assessment): 6402 SQUARE FEET



Site dimensions



Legend

- Parcel Boundaries
- Jurisdiction
- Golf Courses
- Parks
  - SCRD Park
  - Recreation Site
  - Municipal Park
  - Provincial Park
  - Wharf
  - Cemetery
- Band Lands

78.9 0 39.45 78.9 Meters

This information has been compiled by the Sunshine Coast Regional District (SCRD) using data derived from a number of sources with varying levels of accuracy. The SCRD disclaims all responsibility for the accuracy or completeness of this information.

4/3/2018

1: 1,553

PLAN OF SITE SURVEY OF
LOTS 1 AND 2 BLOCK 15
DISTRICT LOT 686 GP. 1
N.W.D. GIBSONS B.C.

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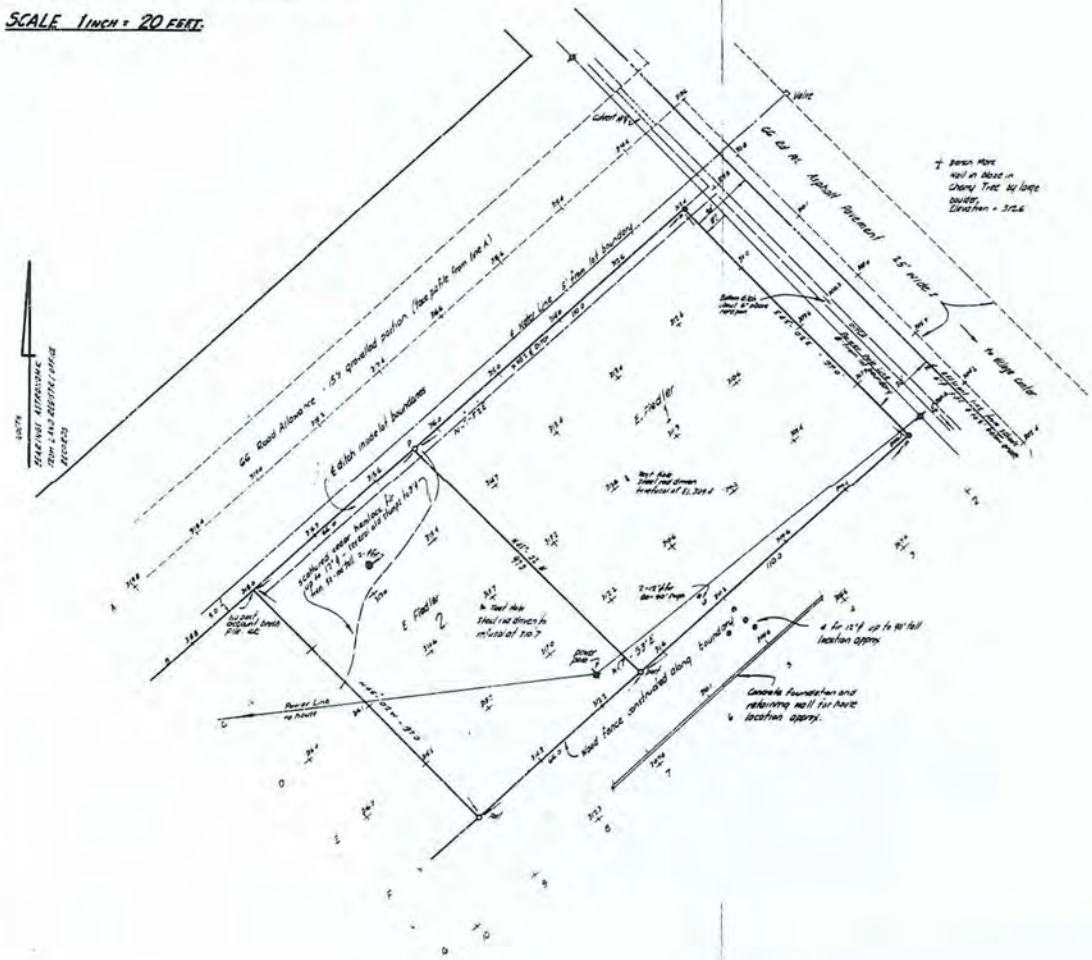

LEGEND

● IB indicates 30" x 1/2" iron pin

○ P indicates white wood post.

204 indicates spot elevation.

Datum for elevations approximate Geodetic.

Certified correct 8 February 1983

D.J. Roy
B.C.L.S.

D.J. ROY B.C.L.S. P.ENG
1334 WEST PENDER ST.
VANCOUVER 5, B.C.

YELLOW

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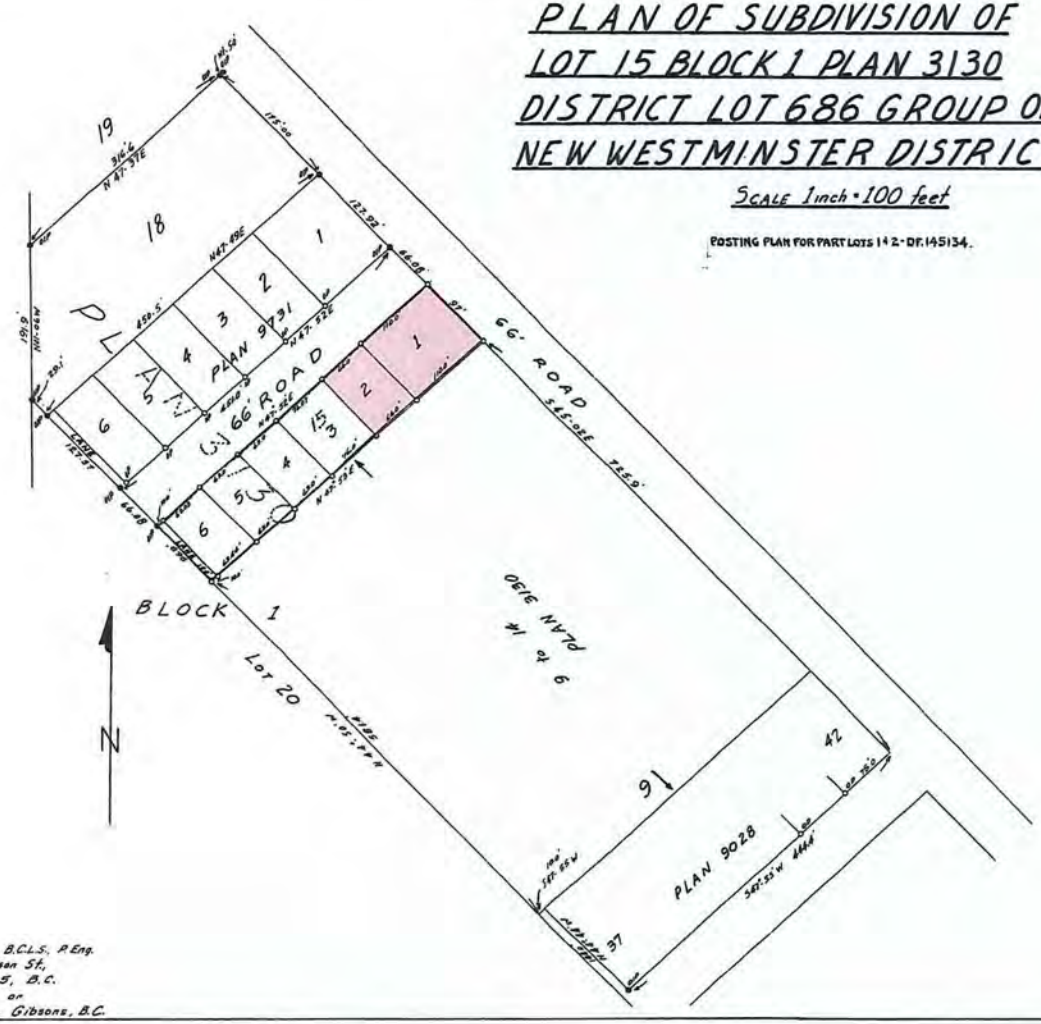
SCALE 1 inch = 100 feet

POSTING PLAN FOR PART LOTS 1 & 2 - DF. 145134.



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1553 Robson St.,
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Registrar

Approved under the Land Registry Act this 15 day of May 1958

Approving Officer

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- ● IP Indicates iron pin set.

Bearings are Astronomic derived from Plan 9028 with road taken as N 45° W

Owner: E. Fiedler
Witness: [illegible]

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D. J. Roy B.C.L.S.

Sworn before me this 7th day of April 1958

A Notary Public in and for the Province of British Columbia.
J-33-58

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4/3/2018

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SCRD Maps

Property Report

4/3/2018

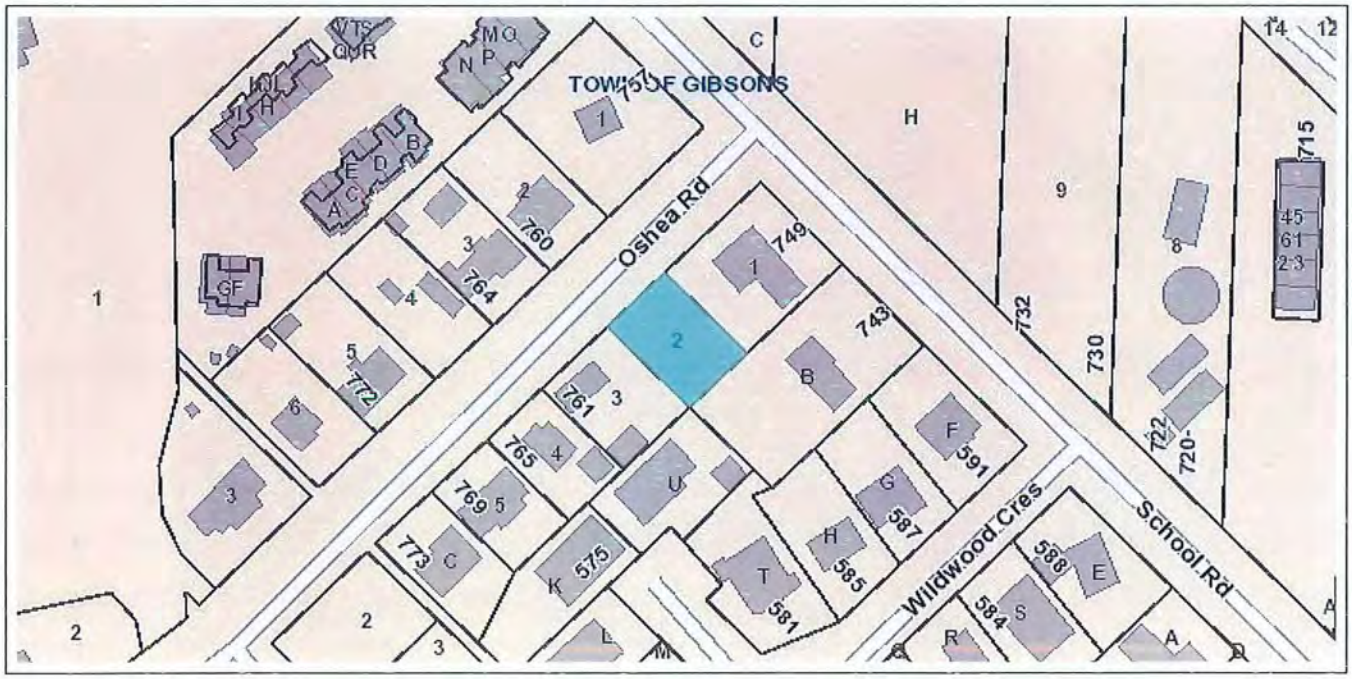
Folio: 524.00498.000 **PID:** 009-612-122

Address: **Jurisdiction:** Gibsons

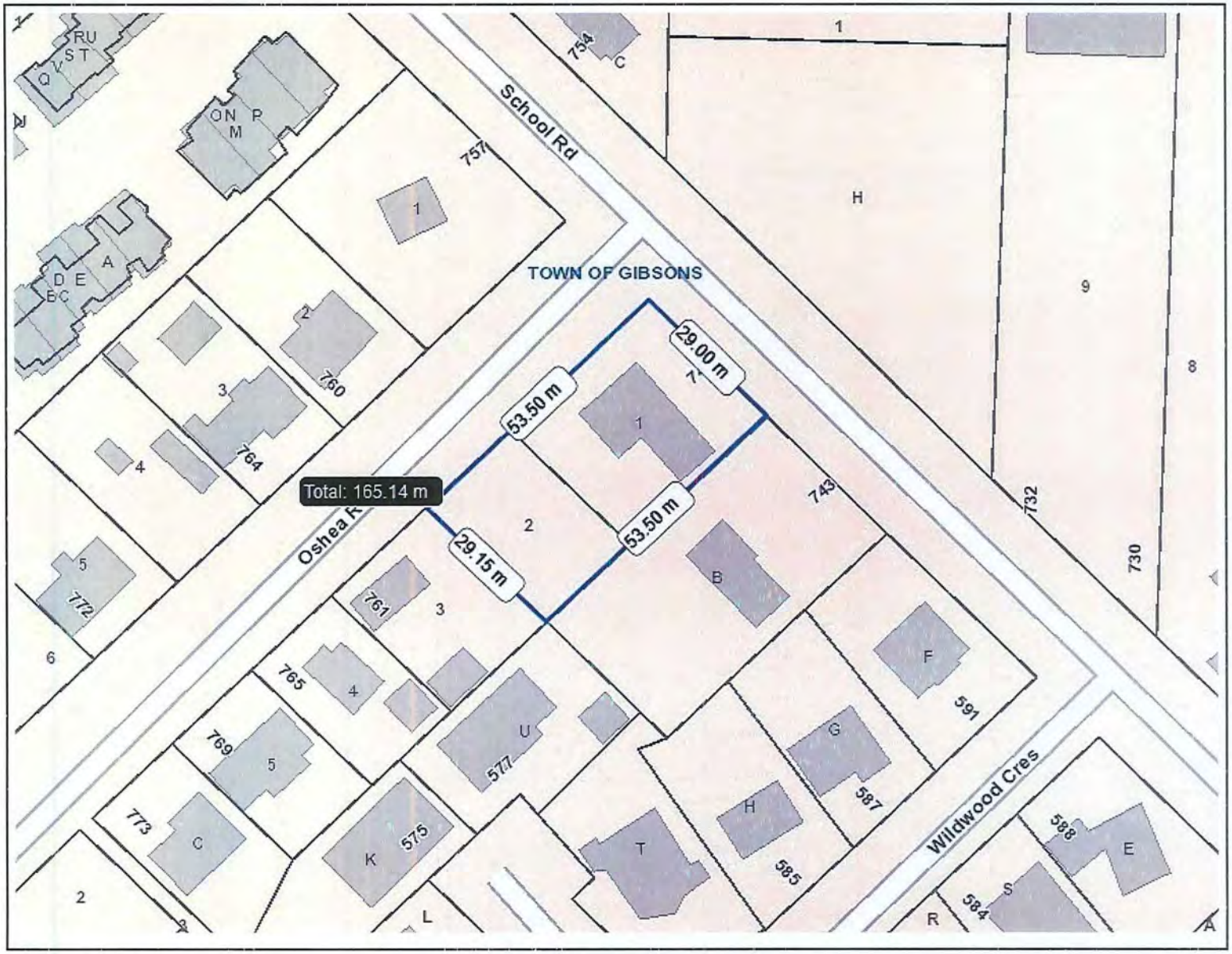
Lot: 2 **Block:** 1 **Plan:** VAP9933 **District Lot:** 686

2018 Assessed Value: 256300 **Land Value:** 256000 **Improvement Value:** 300

Approximate Lot Size (BC Assessment): 6402 SQUARE FEET



Site dimensions



Legend

- Parcel Boundaries
- Jurisdiction
- Golf Courses
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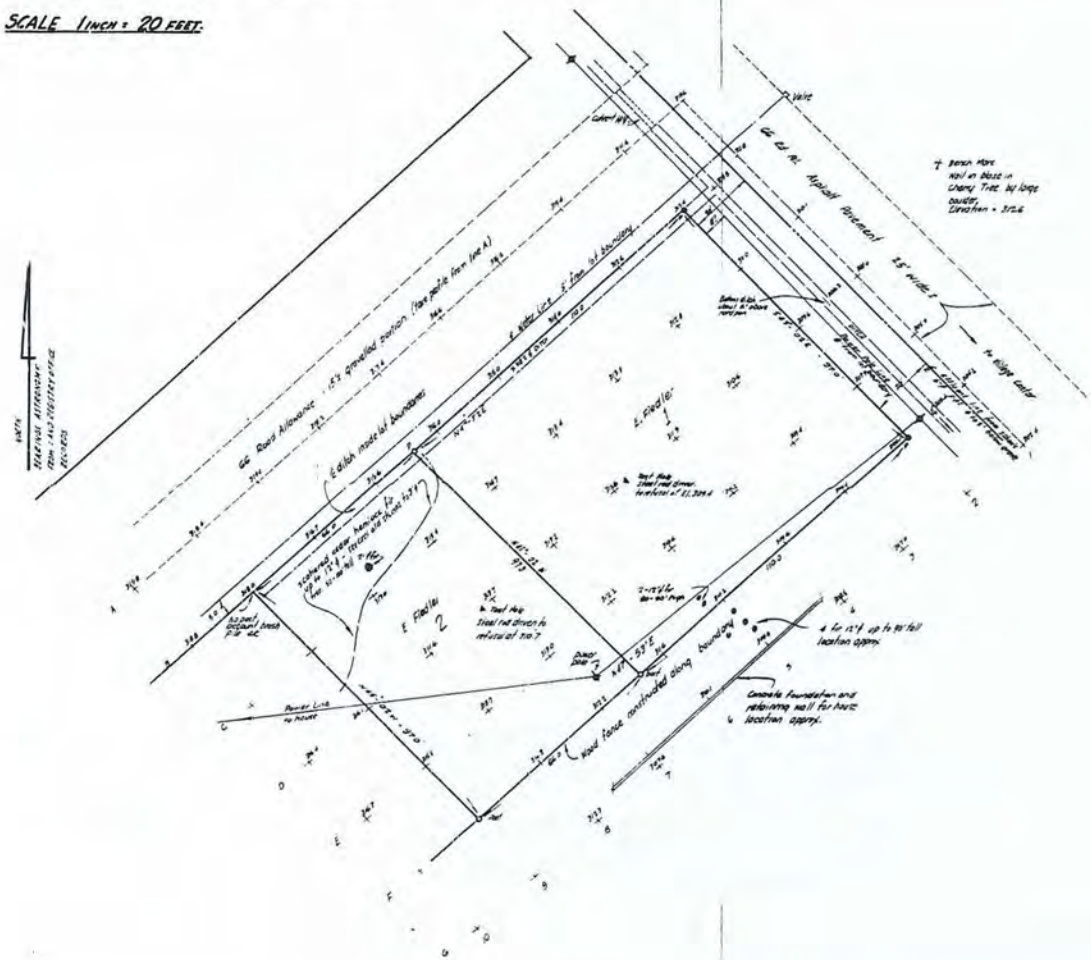

LEGEND

- ⊕ IP indicates 30" x 1" cut iron pin
- ○ P indicates white wood post.
- 3.26 + indicates spot elevation.

Datum for elevations approximate Geodetic.

Certified correct 3 February 1959

D.J. Roy
B.C.L.S.

D.J. ROY B.C.L.S. P.ENG.
1334 WEST PENDER ST.,
VANCOUVER 5, B.C.

YELLOW

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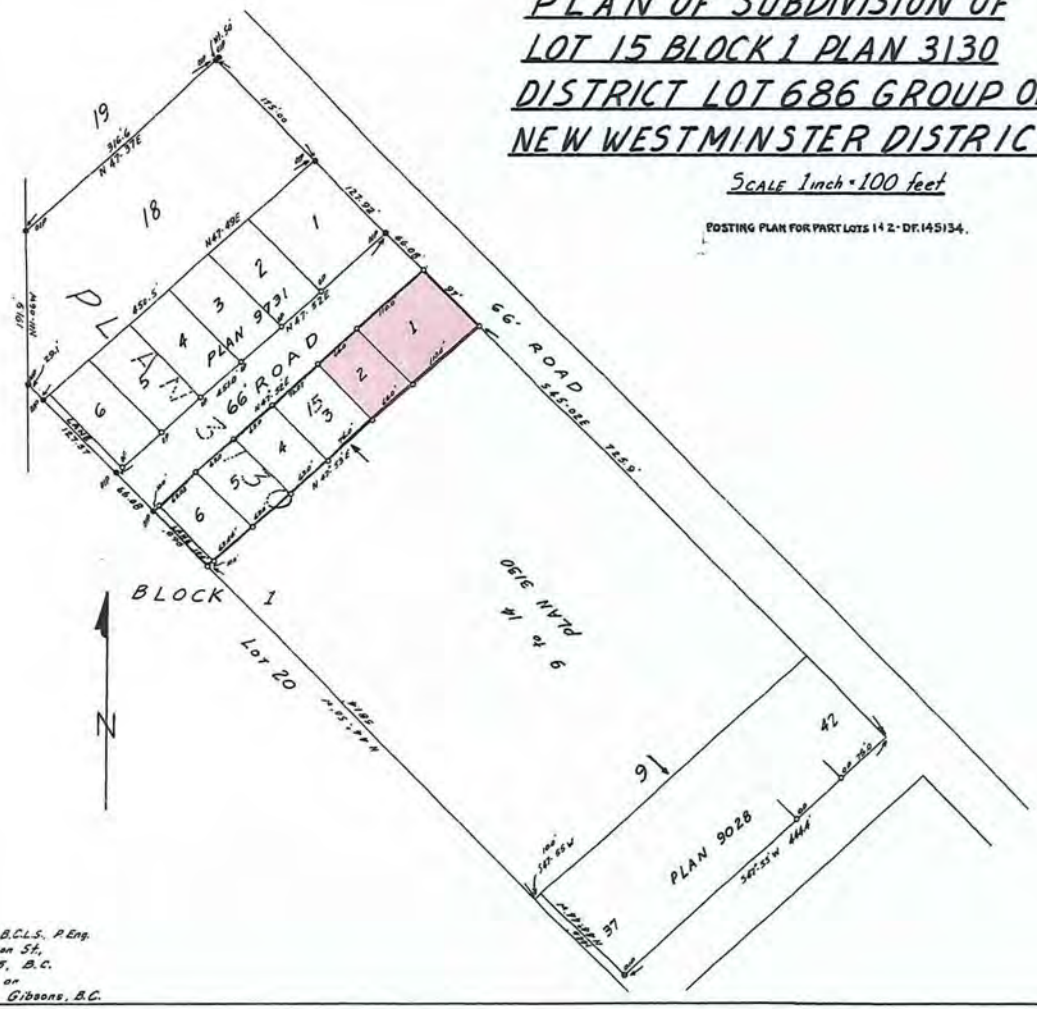

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H. P. Robinson
Registrar

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Robert D. Byrne
Approving Officer

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Witness: [illegible]
Owner: _____
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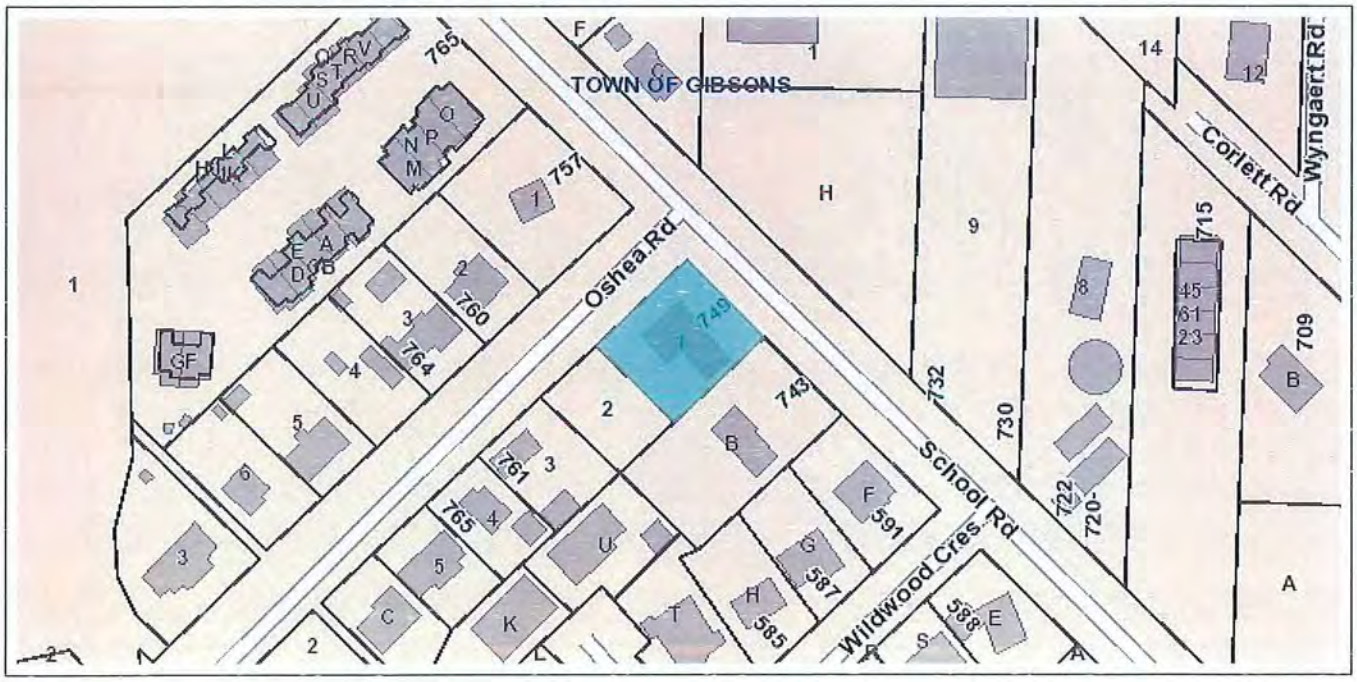

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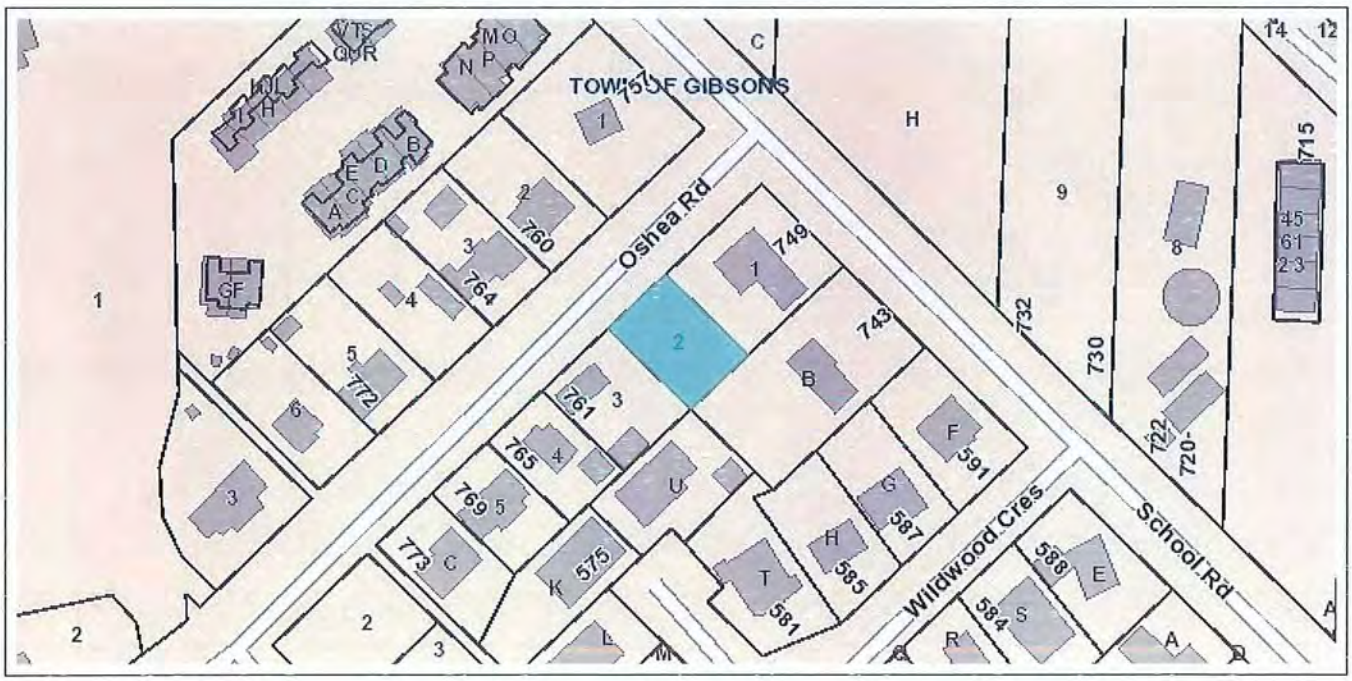
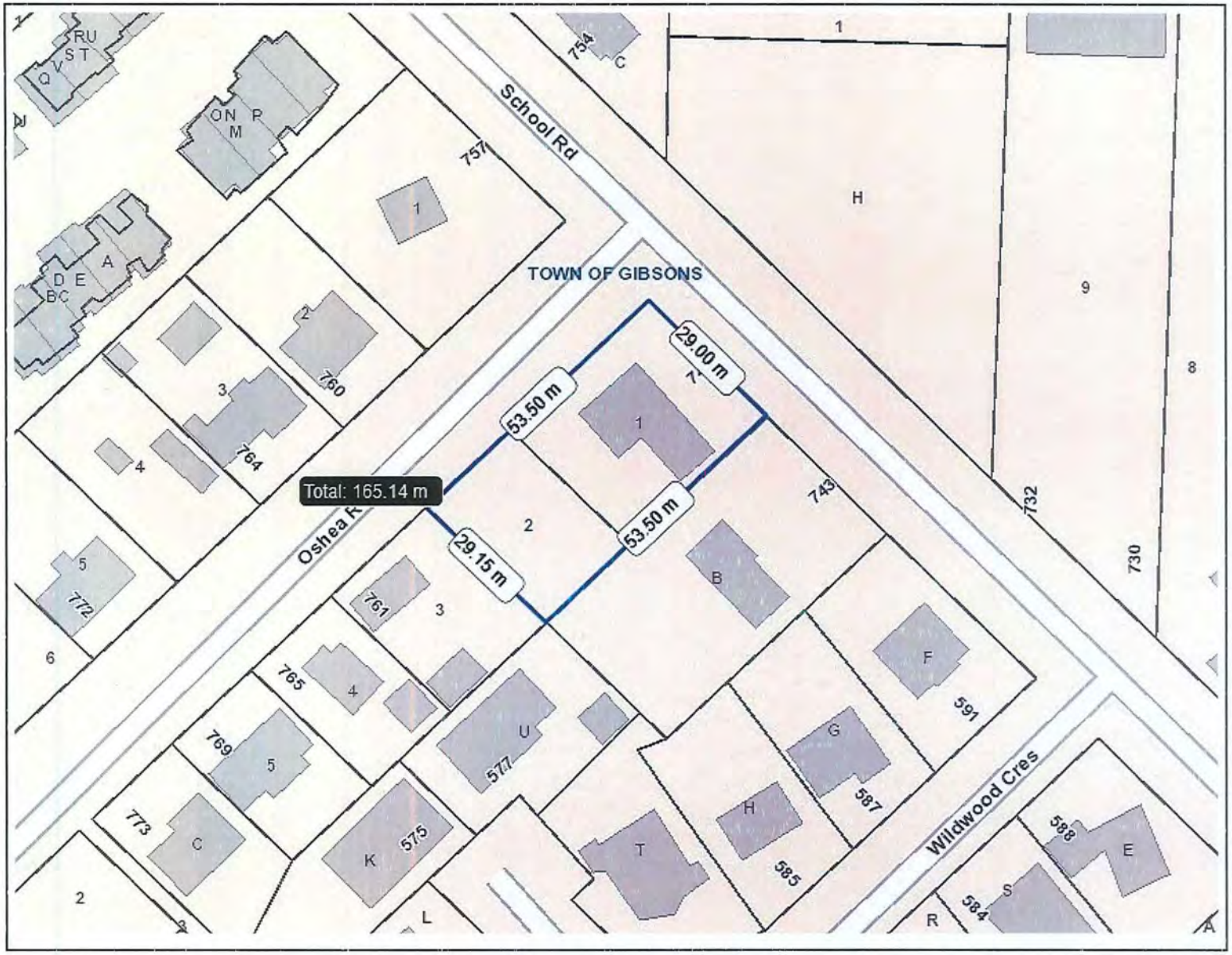


Site dimensions



Legend

- Parcel Boundaries
- Jurisdiction
- Golf Courses
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4/3/2018

1: 1,553

Gibsons Supportive Housing
Planning Study

Gibsons Supportive Housing

O Shea Road, Gibsons, BC

MOBIUS ARCHITECTURE
34720 HIGHWAY 101
SECHELT, BC. V0N3A2
PHONE. 604 885 4390
FAX. 604 885 4312

Gibsons Supportive Housing

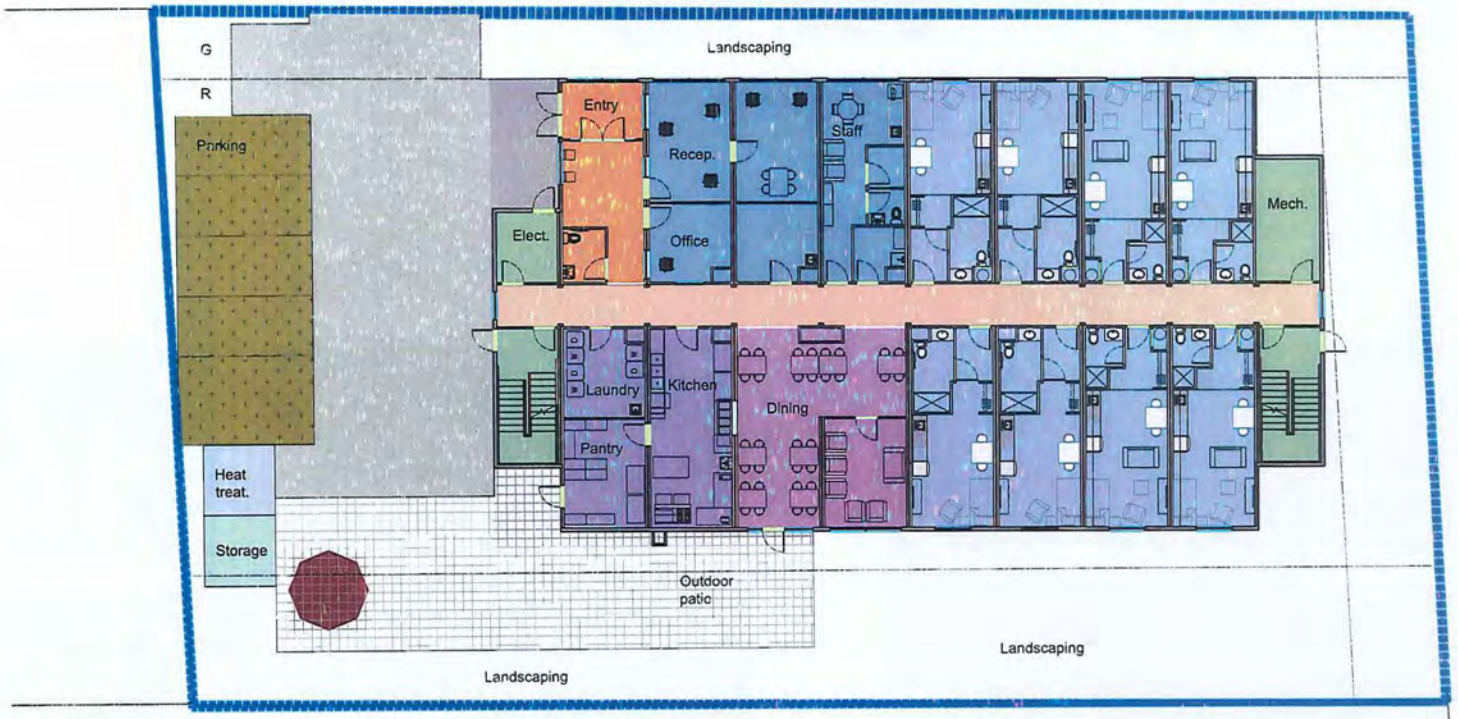
O Shea Road, Gibsons, BC

MOBIUS ARCHITECTURE
34730 HIGHWAY 101
SECHELT, BC V0N3A2
PHONE: 604 885 4240
FAX: 604 885 4312

Aerial Photograph

Project No.:	1905
Date: March 26th, 2019	Scale: 1/16" = 1'-0"
Drawn: PT	
Sheet No.	A 1.0

O Shea Road



School Road

Site Plan/ Ground Floor Plan

Building Summary:

Ground Floor:	650 sm	8 units
Second Floor	650 sm	16 units
Third Floor:	650 sm	16 units
Total Area:	1,950 sm	40 units

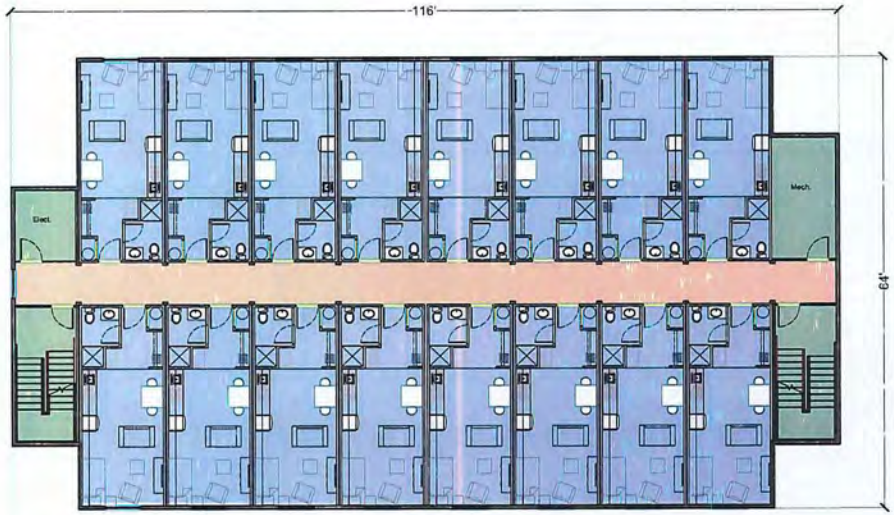
MOBIUS ARCHITECTURE
34720 HIGHWAY 101
SECHELT, BC V0N3A2
PHONE: 604 885 6399
FAX: 604 885 4512

Gibsons Supportive Housing

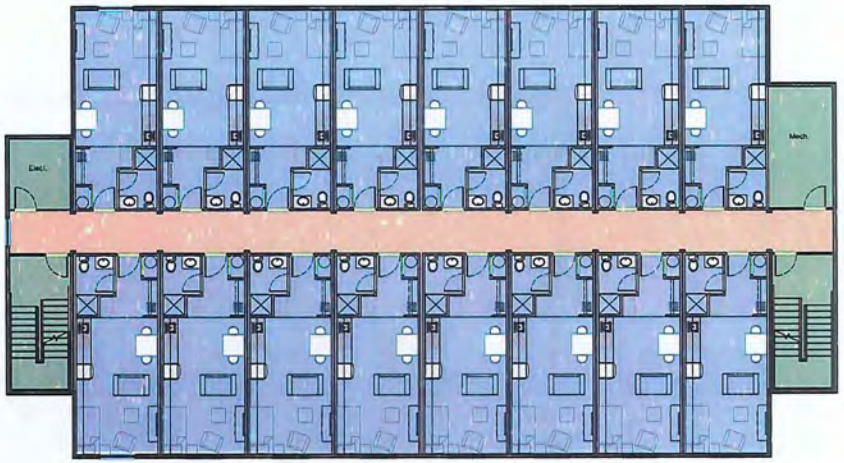
O Shea Road, Gibsons, BC

Planning Concept

Project No.:	1905
Date: March 28th, 2019	Scale: As noted
Drawn: PT	
Sheet No.	A 2.0



Level 2



Level 3

Building Summary:

Ground Floor:	650 sm	8 units
Second Floor	650 sm	16 units
Third Floor:	650 sm	16 units
Total Area:	1,950 sm	40 units

MOBIUS ARCHITECTURE
34720 HIGHWAY 101
SECHELT, BC V0N3A2
PHONE: 604 885 4316
FAX: 604 885 4312

Gibsons Supportive Housing

O SHEA ROAD, GIBSONS, BC

Level 2 and Level 3

Project No.:	1905
Date: March 28th, 2019	Scale: As noted
Drawn: PT	
Sheet No.	A 3.0

View from School Road

View from O' Shea Road

O' Shea Road Elevation

MOBIUS ARCHITECTURE
3-4720 HIGHWAY 101
SECHELT, BC, V0N3A2
PHONE: 604 885 1200
FAX: 604 885 4312

Gibsons Supportive Housing

O SHEA ROAD, GIBSONS, BC

Scheme 1:
Marigold
Cypress
Autumn Red

Colour Scheme 1

Project No.:	1905
Date: March 28th, 2019	Scale: As noted
Drawn: PT	
Sheet No.	A 4.1

View from School Road

View from O' Shea Road

O' Shea Road Elevation

MOBIUS ARCHITECTURE
34729 HIGHWAY 101
SECHELT, BC V0N3A2
PHONE: 604 885 4390
FAX: 604 885 4312

Gibsons Supportive Housing

O SHEA ROAD, GIBSONS, BC

Scheme 2:
Pacific Blue
Savannah Wicker
Sterling Gray

Colour Scheme 2

Project No.:	1905
Date: March 28th, 2019	Scale: As noted
Drawn: PT	
Sheet No.	A 4.2

View from School Road

View from O' Shea Road

O' Shea Road Elevation

MOEJUS ARCHITECTURE
3-4720 HIGHWAY 101
SECHELT, BC V0N3A2
PHONE: 604 885 4390
FAX: 604 885 4312

Gibsons Supportive Housing

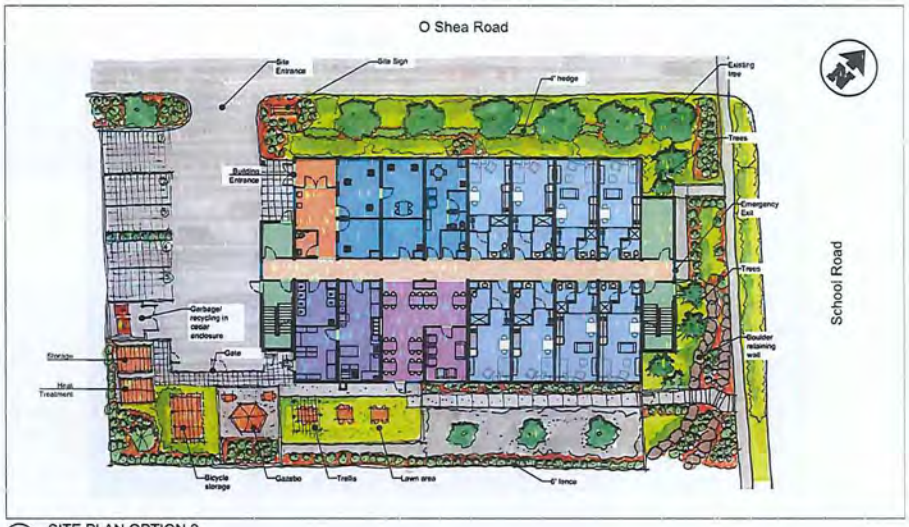
O SHEA ROAD, GIBSONS, BC

Scheme 3:
Midnight Gray
Linen
Olive

Colour Scheme 3

Project No..	1905
Date: March 27th, 2019	Scale: As noted
Drawn: PT	
Sheet No.	A 4.3

1 SITE PLAN OPTION 1
Scale: 1/16" = 1' - 0"



2 SITE PLAN OPTION 2
Scale: 1/16" = 1' - 0"

Steps from School Road with landscape buffer

Steps directly to School Road with trellis

Landscaped buffer School Road with roof

Gibsons Supportive Housing

O Shea Road, Gibsons, BC

MOBIUS ARCHITECTURE
34720 HIGHWAY 101
SECHELT, BC V0N3A2
PHONE: 604 885 4398
FAX: 604 885 4312

Landscaping Options

Project No.:	1905
Date: March 28th, 2019	Scale: As noted
Drawn: PT	
Sheet No.	A 5.0

1. Trellis structure from O Shea Road

2. Entry posts at pedestrian entry

3. Landscaped buffer from O Shea Road

1. Painted aluminum fencing

2. Painted wood fencing

3. Natural cedar fencing

Gibsons Supportive Housing

O Shea Road, Gibsons, BC

MOBIUS ARCHITECTURE
3-4720 HIGHWAY 101
SECHELT, BC, V0N3A2
PHONE: 604 885 4291
FAX: 604 885 4312

Entry and Fence Options

Project No.:	1905
Date: March 28th, 2019	Scale: As noted
Drawn: PT	
Sheet No.	A 6.0

1. Concrete pavers with grassed sitting areas

2. Vegetable gardens

3. Gazebo and sitting areas

1. Fibre cement board lap siding and shingles

2. Fibre cement board panels and metal siding

3. fibre cement board panel siding

MOIRIUS ARCHITECTURE
34720 HIGHWAY 101
SECHELT, BC V0N3A2
PHONE: 604 885 4390
FAX: 604 885 4312

Gibsons Supportive Housing

O Shea Road, Gibsons, BC

Amenity spaces
Material options

Project No.:	1905
Date: March 28th, 2019	Scale: As noted
Drawn: PT	
Sheet No.	A 7.0

WORK SAFE BC
WORKING TO MAKE A DIFFERENCE

Assessment Department
Mailing Address
PO Box 5350
Station Terminal
Vancouver BC V6B 5L5

Location
6951 Westminster Highway
Richmond BC
V7C 1C6
www.worksafebc.com

Clearance Section
Telephone 604 244 6380
Toll Free within Canada
1 888 922 2768
Fax 604 244 6390

Blue Max Drilling Inc.
12247 103A Avenue
SURREY, BC V3V 3G7

May 03, 2019

Person/Business : BLUE MAX DRILLING INC.
Account number : 835234

This letter provides clearance information for the purposes of Section 51 of the *Workers Compensation Act*.

We confirm that the above-referenced firm is active, in good standing, and has met WorkSafeBC's criteria for advance clearance. Accordingly, if the addressee on this letter is the prime contractor, the addressee will not be held liable for the amount of any assessment payable for work undertaken by the above-referenced firm to **July 01, 2019.**

This firm has had continuous coverage with us since October 01, 2009.

Employer Service Centre
Assessment Department

Clearance Reference # : C130927600
CLRAAA

For more information about Section 51 and clearance letters visit WorkSafeBC.com

Please refer to your account number in your correspondence or when contacting the Assessment Department.
To alter this document constitutes fraud.

WORKSAFE BC
WORKING TO MAKE A DIFFERENCE

Assessment Department
Mailing Address
PO Box 5350
Station Terminal
Vancouver BC V6B 5L5

Location
6951 Westminster Highway
Richmond BC
V7C 1C6
www.worksafebc.com

Clearance Section
Telephone 604 244 6380
Toll Free within Canada
1 888 922 2768
Fax 604 244 6390

Town of Gibsons
474 S Fletcher Rd,
GIBSONS, BC V0N 1V0

May 15, 2019

Person/Business : DAVIES GEOTECHNICAL INC
Account number : 669110

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Employer Service Centre
Assessment Department

Clearance Reference # : C130947392
CLRAAA

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Please refer to your account number in your correspondence or when contacting the Assessment Department.

To alter this document constitutes fraud.

Table 1

Subsurface Investigation Summary

Project: 749/School Rd, Gibsons BC 739 **DATE:** 2014-05-15 **Completed by:** Ben Davies

A	*Number (Test Pit, Well, borehole, etc...)*	AH19-01/DCPT	AH19-02	AH19-03
B	*Subsurface Disturbance Type (from Table 2)*	Borehole + DCPT	Borehole + DCPT	Borehole + DCPT
C	*Method of exploration (from Table 3)*	solid stem Augen + DCPT	solid stem augen + DCPT	solid stem augen + DCPT
D	*Northing (m)*			
E	*Easting (m)*			
F	*Ground Elevation (m amsl)*	96m	96m	96m
G	*Proposed testing depth below ground (m)*	6m	6m	6m
H	*Previously Encountered Depth to top of Gibsons Aquitard (ie: Till-Like Soil (m))*	-12m	-12m	-12m
I	*Previously Encountered Depth to top of Gibsons Aquifer (ie: Sand and gravel with Artesian flow (m))*	-46m	-46m	-46m
J	*Distance of existing subsurface information to proposed new intrusive work (m)*	200-300m	200-300m	200-300m
K	*Report Reference for previous work to support new proposed work (Copies of original logs/records should be attached)*	MW06-1 + site Plan + cross section	MW06-1 "	MW06-1 "
L	*Estimated depth offset to top of Gibson Aquitard Row H minus Row I (m, + if above and - if below)*	34m	34m	34m
M	*Estimated depth offset to top of Gibson Aquifer Row L minus Row G (m, + if above and - if below)*	28m	28m	28m
N	*Comment on uncertainty and potential risk to aquifer*	Chance of encountering aquitard (till) or previous deposit/aquifer is low. May encounter capilano aquifer.		
O	*Describe Aquifer Protection measures to be implemented*	-minimal drilling depth -abandonment with bentonite or grout -see driller specifications		

Table 1

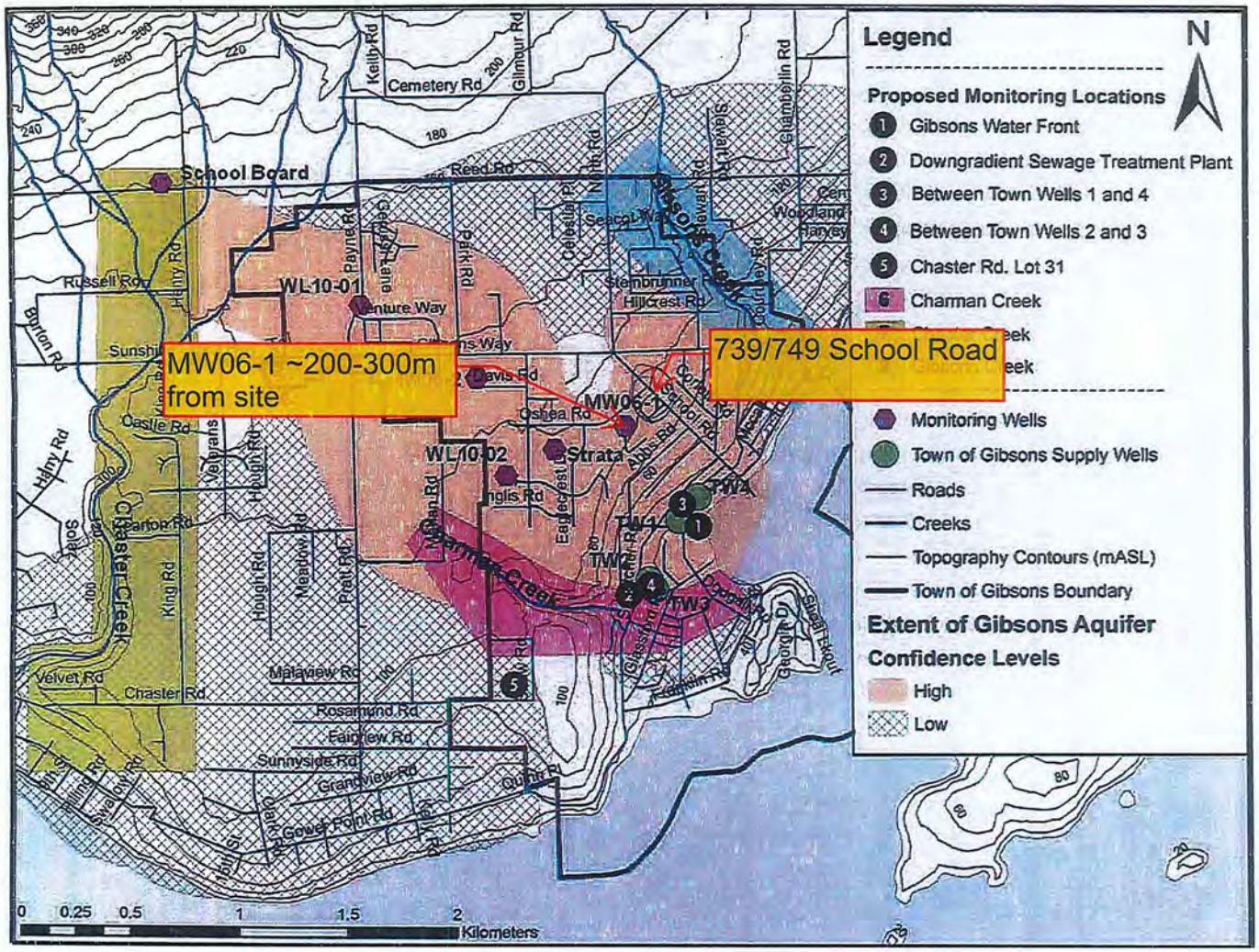
Subsurface Investigation Summary

Project: 749/734 Schedd Rd. Gibsons DATE: 2019-05-15 Completed by: Ben Davies

A	*Number (Test Pit, Well, borehole, etc...)*	AH19-04		
B	*Subsurface Disturbance Type (from Table 2)*	Borehole DCPT		
C	*Method of exploration (from Table 3)*	Solid stem auger + DCPT		
D	*Northing (m)*			
E	*Easting (m)*			
F	*Ground Elevation (m amsl)*	96m		
G	*Proposed testing depth below ground (m)*	6m		
H	*Previously Encountered Depth to top of Gibsons Aquitard (ie: Till-Like Soil (m))*	-12m		
I	*Previously Encountered Depth to top of Gibsons Aquifer (ie: Sand and gravel with Artesian flow (m))*	-46m		
J	*Distance of existing subsurface information to proposed new intrusive work (m)*	200-300m		
K	*Report Reference for previous work to support new proposed work (Copies of original logs/records should be attached)*	MW06-1		
L	*Estimated depth offset to top of Gibson Aquitard Row H minus Row I (m, + if above and - if below)*	34m		
M	*Estimated depth offset to top of Gibson Aquifer Row L minus Row G (m, + if above and - if below)*	28m		
N	*Comment on uncertainty and potential risk to aquifer*	See previous page		
O	*Describe Aquifer Protection measures to be implemented*	See previous page		

Table 2 **Subsurface Disturbance Type**
Borehole
Monitoring Well
Standpipe
Piezometer
water well
Test Pit
Hand Excavation
Pushing or driving (Piles or samplers)
Other

Table 3 **Method of Exploration**
Core
Solid Stem Auger
Hollow Stem Auger
Hand Auger
Rotary with sealed casing
Rotary with no casing
Hydrovac
Backhoe
Drive Point
Cone penetrometer (DCPT or other)
Hand or tube surface sample
Other


Legend
N
Proposed Monitoring Locations
1 Gibsons Water Front
2 Downgradient Sewage Treatment Plant
3 Between Town Wells 1 and 4
4 Between Town Wells 2 and 3
5 Chaster Rd. Lot 31
Charman Creek
Monitoring Wells
Town of Gibsons Supply Wells
Roads
Creeks
Topography Contours (mASL)
Town of Gibsons Boundary
Extent of Gibsons Aquifer
Confidence Levels
High
Low
MW06-1 ~200-300m from site
739/749 School Road
School Board
WL10-01
WL10-02
MW06-1
Strata
TW1
TW2
TW3
TW4
Cemetery Rd
Reed Rd
Russell Rd
Burton Rd
Sunshine Rd
Castle Rd
Henry Rd
Solar Rd
Carlton Rd
King Rd
Velvet Rd
Chaster Rd
Chaster Creek
Charman Creek
Malawey Rd
Rosamund Rd
Fairview Rd
Sunnyside Rd
Grandview Rd
Gower Point Rd
Hough Rd
Meadow Rd
Pratt Rd
Veterans
Davis Rd
Oshea Rd
Inglis Rd
Eaglecrest
Hillcrest Rd
Stembrunner
Seacoast Way
Venture Way
Rayne Rd
Park Rd
Kelly Rd
Gilmour Rd
Chamberlin Rd
Slawalt Rd
Courtney Rd
Quarry Rd
Georgia Dr
Abbs Rd
Gibsons Way
Marine Dr
0 0.25 0.5 1 1.5 2 Kilometers

PITEAU ASSOCIATES

GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

VANCOUVER LIMA

Well Number: MW06-1

Project: Monitoring Well Installation

Location: Spyglass Place

Project Number: 2539

Logged By: Arnd Burgert

Borehole Diameter: 152mm

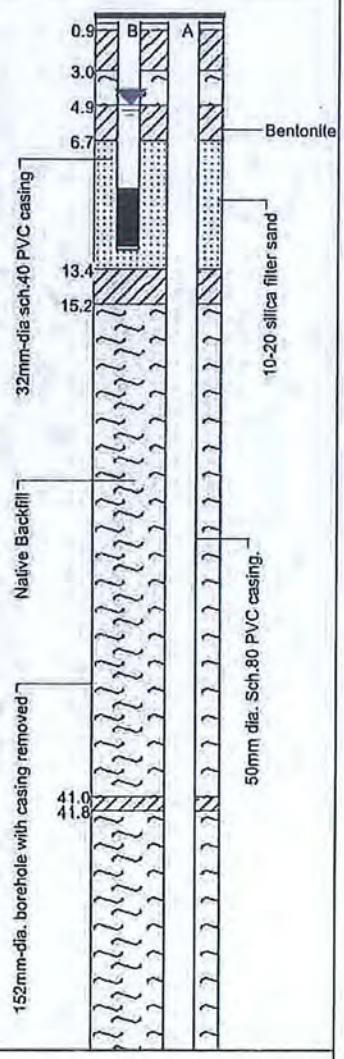
Client: Town of Gibsons

Coordinates: E 462812 N 5472468

Ground Elevation: 110m - asl

Depth Below Ground Surface	Depth (mbGL)	Lithologic Description	Lithology	Remarks
ft / m	0.0	Ground Surface — Asphalt		Steel access cover at grade
		Sand and Silt 0.61m - Gray sand and silt with trace clay. Dry. 3.96m - Gray silt, some clay. Dry. 6.10m - Sandy silt. 6.7m - Silt and sand, trace gravel.		P2 water level Dec. 8, 2006 4.8m-BGS 9.3m-BGS - 12.3m-BGS Machine slotted pvc screen 0.010" openings
	11.3			
	11.9	**Gravel, Silt, and Clay, wet**		
		Sand and Gravel 11.9m-14.0m - Grey sand and gravel. 14.0m-21.3m - Grey sand and gravel. Wet, water. 21.3m-23.8m - Grey sand and gravel. Wet, no water. 23.8m-27.4m - Sand with trace gravel and trace silt. 27.4m-31.7m - Grey sand and gravel, trace of silt. Damp.		
	31.7			
		Sand and Silt 31.7m-32.3m - Light grey very fine sand and silt. Dry. 32.3m-33.5m - Grey sand and silt. Some gravel. Damp. 33.5m-45.7m - Grey sand and silt. Some gravel. Damp.		
	45.7			
		Sand and Gravel 45.7m-47.5m - Grey tan sand and gravel with trace silt. Damp. 47.5m-51.8m - Grey silty sand and gravel. Damp. 51.8m-76.2m - Grey sand and gravel with trace silt.		

Constructed Well



Drilling Contractor: Field Drilling Contractors Ltd.

Drilling Method: Dual Mode Air Rotary

Drilling Started: Dec 4th, 2006

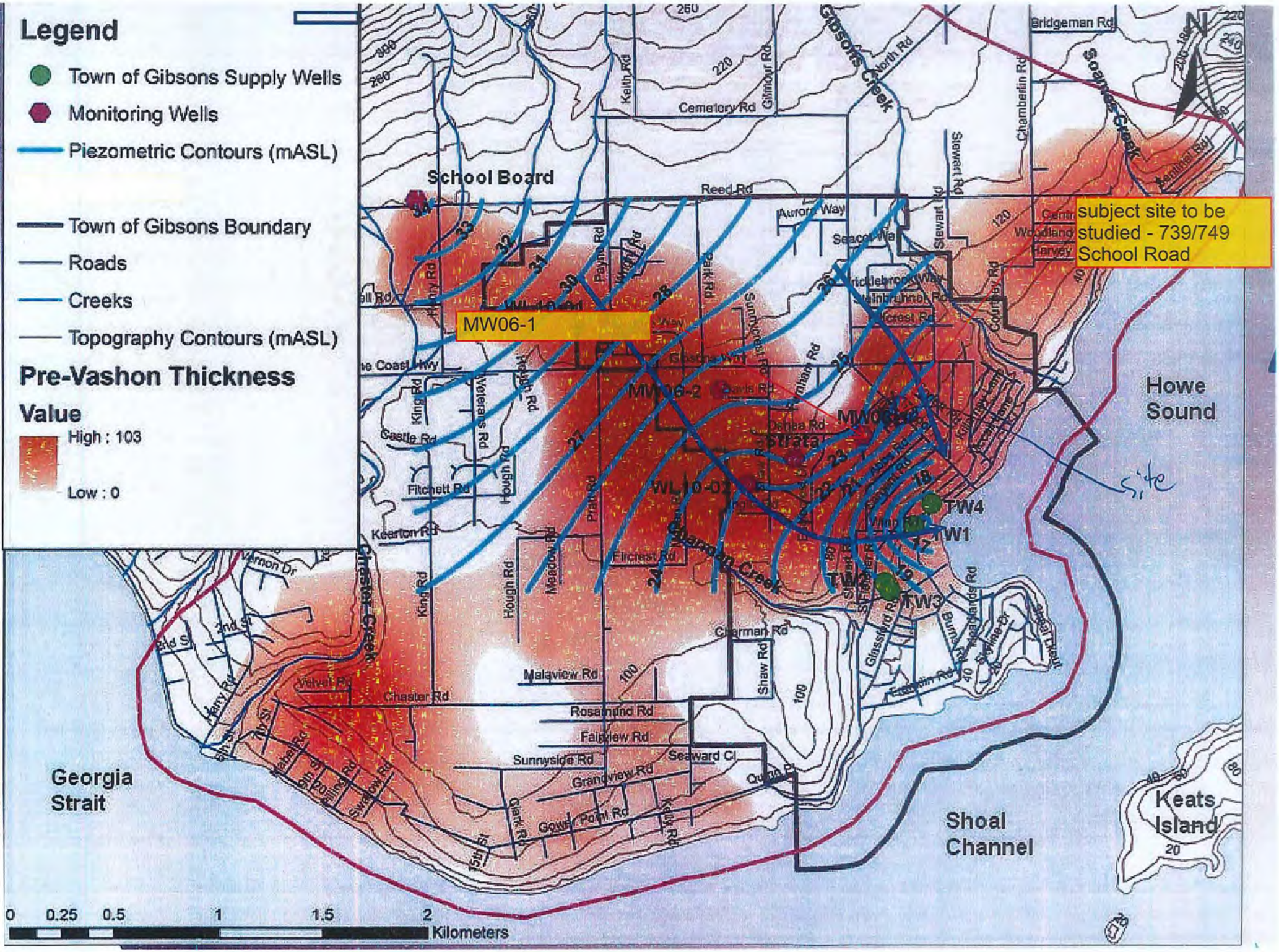
Drilling Ended: Dec 7th, 2006

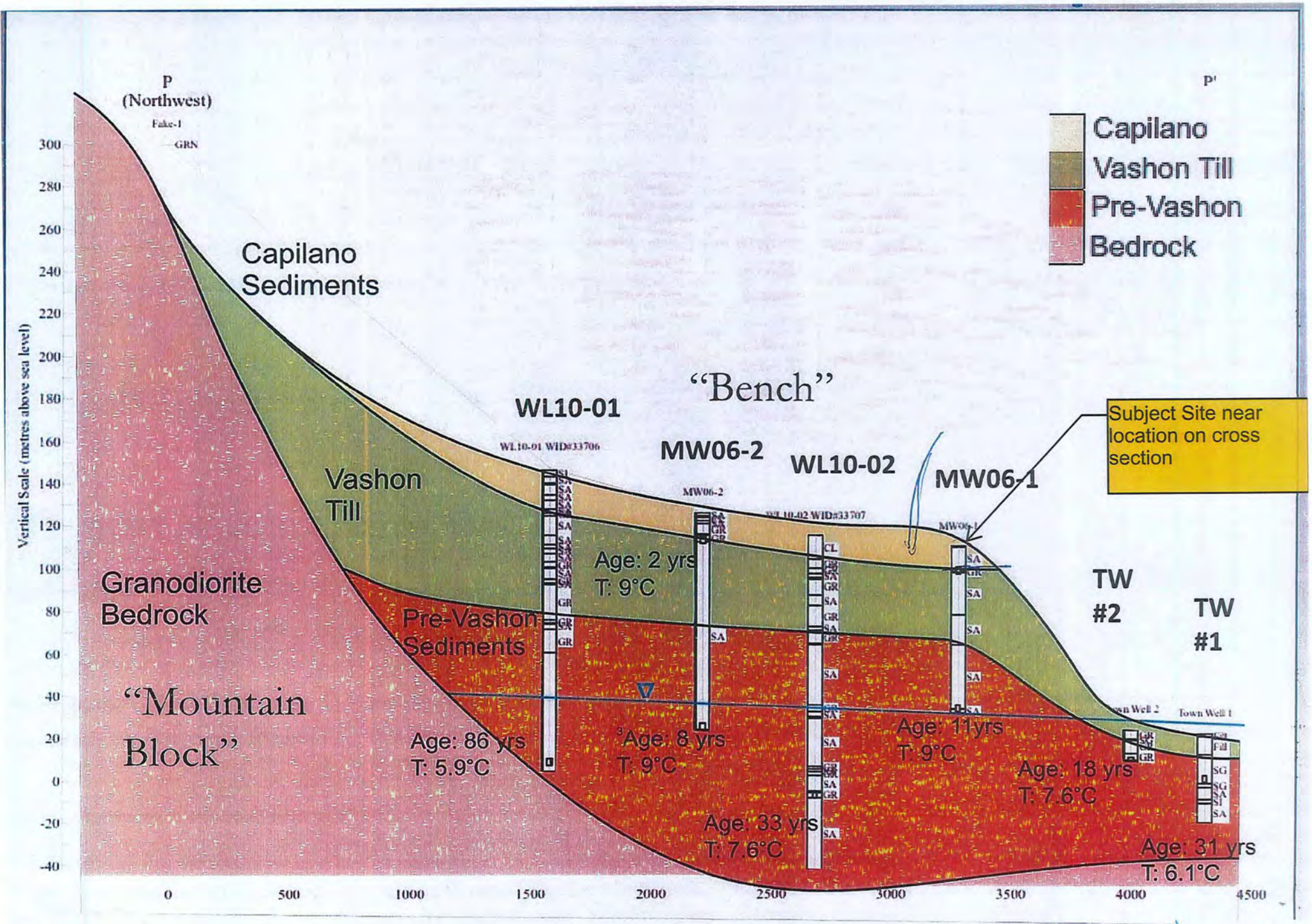
PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS
VANCOUVER LIMA

Well Number: MW06-1
Project: Monitoring Well Installation
Location: Spyglass Place

Depth Below Ground Surface	Depth (mbGL)	Lithologic Description	Lithology	Remarks	Constructed Well
55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75	76			Water Level at 74.7 mGBS (Dec 9, 2006)	66.1, 67.1, 70.4, 71.3, 76.0, 77.9; 10-20 silica filter sand
77	78	**Sand and Silt** Wet grey very fine sand and silt.		74.4m-BGS - 77.4m-BGS Machine slotted PVC screen 0.010" openings	
79, 81, 83, 85, 87, 89, 91, 93, 95, 97, 99, 101, 103, 105					

Drilling Contractor: Field Drilling Contractors Ltd.
Drilling Method: Dual Mode Air Rotary
Drilling Started: Dec 4th, 2006
Drilling Ended: Dec 7th, 2006


Legend
Town of Gibsons Supply Wells
Monitoring Wells
Piezometric Contours (mASL)
Town of Gibsons Boundary
Roads
Creeks
Topography Contours (mASL)
Pre-Vashon Thickness
Value
High : 103
Low : 0
School Board
MW06-1
MW06-2
WL10-01
TW1
TW2
TW3
TW4
subject site to be studied - 739/749 School Road
Site
Howe Sound
Georgia Strait
Shoal Channel
Keats Island
Gibsons Creek
Soames Creek
Chaster Creek
Charman Creek
Reed Rd
Cemetery Rd
Bridgeman Rd
Chamberlin Rd
Stewart Rd
Aurora Way
Seacoast Way
Crest Rd
Gibsons Way
Sunshine Coast Hwy
Gaspe Rd
Shiba Rd
Fitchett Rd
Keartons Rd
Finlayson Rd
Malaview Rd
Rosamund Rd
Fairview Rd
Sunnyside Rd
Seaward Cl
Grandview Rd
Gower Point Rd
Shaw Rd
Glassford Rd
Burns Rd
Franklin Rd
Shoal Trail
Veterans Rd
King Rd
Hough Rd
Meadow Rd
Park Rd
Payne Rd
Keith Rd
Gilmour Rd
Courtney Rd
Harvey Rd
Woodland Rd
Cemetery Rd
Vernon Dr
Velvet Pl
Clark Rd
Kelly Rd
Sandy Rd
Shadow Rd
Castle Rd
Fitchett Rd
0 0.25 0.5 1 1.5 2 Kilometers


P
(Northwest)
P'
Capilano
Vashon Till
Pre-Vashon
Bedrock
Capilano
Sediments
"Bench"
WL10-01
MW06-2
WL10-02
MW06-1
Subject Site near location on cross section
Vashon
Till
Granodiorite
Bedrock
Pre-Vashon
Sediments
"Mountain
Block"
Age: 2 yrs
T: 9°C
Age: 86 yrs
T: 5.9°C
Age: 8 yrs
T: 9°C
Age: 33 yrs
T: 7.6°C
Age: 11yrs
T: 9°C
Age: 18 yrs
T: 7.6°C
Age: 31 yrs
T: 6.1°C
TW
#2
TW
#1
Vertical Scale (metres above sea level)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
0
500
1000
1500
2000
2500
3000
3500
4000
4500

UBC

CSIO

CERTIFICATE OF LIABILITY INSURANCE

This certificate is issued as a matter of information only and confers no rights upon the certificate holder and imposes no liability on the insurer. This certificate does not amend, extend or alter the coverage afforded by the policies below.

1. CERTIFICATE HOLDER - NAME AND MAILING ADDRESS	2. INSURED'S FULL NAME AND MAILING ADDRESS
To Whom It May Concern	Blue Max Drilling Inc.
	12247 103A Ave
POSTAL CODE	Surrey British Columbia POSTAL CODE V3V 3G7

3. DESCRIPTION OF OPERATIONS/LOCATIONS/AUTOMOBILES/SPECIAL ITEMS TO WHICH THIS CERTIFICATE APPLIES (but only with respect to the operations of the Named Insured)

Environmental Drilling Contractor

4. COVERAGES

This is to certify that the policies of insurance listed below have been issued to the insured named above for the policy period indicated notwithstanding any requirements, terms or conditions of any contract or other document with respect to which this certificate may be issued or may pertain. The insurance afforded by the policies described herein is subject to all terms, exclusions and conditions of such policies.

LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS

TYPE OF INSURANCE	INSURANCE COMPANY AND POLICY NUMBER	EFFECTIVE DATE YYYY/MM/DD	EXPIRY DATE YYYY/MM/DD	LIMITS OF LIABILITY (Canadian dollars unless indicated otherwise) COVERAGE	DED.	AMOUNT OF INSURANCE
COMMERCIAL GENERAL LIABILITY	Intact Insurance Company - 5A1198359	2019/04/13	2020/04/13	COMMERCIAL GENERAL LIABILITY BODILY INJURY AND PROPERTY DAMAGE LIABILITY - GENERAL AGGREGATE	$2,500	
☐ CLAIMS MADE OR ☑ OCCURRENCE				- EACH OCCURRENCE		$10,000,000
☑ PRODUCTS AND / OR COMPLETED OPERATIONS				PRODUCTS AND COMPLETED OPERATIONS AGGREGATE		$10,000,000
☐ EMPLOYER'S LIABILITY						
☑ CROSS LIABILITY				☐ PERSONAL INJURY LIABILITY OR ☑ PERSONAL AND ADVERTISING INJURY LIABILITY		$10,000,000
				MEDICAL PAYMENTS		$10,000
☑ TENANTS LEGAL LIABILITY				TENANTS LEGAL LIABILITY	$2,500	$500,000
☐ POLLUTION LIABILITY EXTENSION				POLLUTION LIABILITY EXTENSION		
☑ NON-OWNED AUTOMOBILES ☐ HIRED AUTOMOBILES	Intact Insurance Company - 5A1198359	2019/04/13	2020/04/13	NON OWNED AUTOMOBILE		$10,000,000
AUTOMOBILE LIABILITY				BODILY INJURY AND PROPERTY DAMAGE COMBINED		
☐ DESCRIBED AUTOMOBILES				BODILY INJURY (PER PERSON)		
☐ ALL OWNED AUTOMOBILES				BODILY INJURY (PER ACCIDENT)		
☐ LEASED AUTOMOBILES **				PROPERTY DAMAGE		
** ALL AUTOMOBILES LEASED IN EXCESS OF 30 DAYS WHERE THE INSURED IS REQUIRED TO PROVIDE INSURANCE						
EXCESS LIABILITY				EACH OCCURRENCE		
☐ UMBRELLA FORM				AGGREGATE		
☐						
OTHER LIABILITY (SPECIFY) ☐						
☐						
☐						

5. CANCELLATION

6. BROKERAGE/AGENCY FULL NAME AND MAILING ADDRESS	7. ADDITIONAL INSURED NAME AND MAILING ADDRESS (but only with respect to the operations of the Named Insured)
Metrix Professional Insurance Brokers Inc.	
400 - 555 Burrard Street, Box 275	
Vancouver BC POSTAL CODE V7X 1M8	
BROKER CLIENT ID: BLUEM-2	POSTAL CODE

8. CERTIFICATE AUTHORIZATION

ISSUER Metrix Professional Insurance Brokers Inc.	CONTACT NUMBER(S) TYPE Main NO. (604) 683-5583 TYPE Fax NO. (604) 683-8032
AUTHORIZED REPRESENTATIVE Phil Webb	TYPE NO. TYPE NO.
SIGNATURE OF AUTHORIZED REPRESENTATIVE	DATE April 30, 2019 EMAIL ADDRESS pwebb@mpib.com

CZ

MARSH

Certificate of Insurance

No.: **DAV-2019-1** Dated: **December 21, 2018**

This document supersedes any certificate previously issued under this number

This is to certify that the Policy(ies) of insurance listed below ("Policy" or "Policies") have been issued to the Named Insured identified below for the policy period(s) indicated. This certificate is issued as a matter of information only and confers no rights upon the Certificate Holder named below other than those provided by the Policy(ies).

Notwithstanding any requirement, term, or condition of any contract or any other document with respect to which this certificate may be issued or may pertain, the insurance afforded by the Policy(ies) is subject to all the terms, conditions, and exclusions of such Policy(ies). This certificate does not amend, extend, or alter the coverage afforded by the Policy(ies). Limits shown are intended to address contractual obligations of the Named Insured.

Limits may have been reduced since Policy effective date(s) as a result of a claim or claims.

Certificate Holder:	Named Insured and Address:
Davies Geotechnical Inc. **1520 Cliveden Avenue** **Unit 2** **Delta, BC V3M 6J8**	**Davies Geotechnical Inc.** **1520 Cliveden Avenue** **Unit 2** **Delta, BC V3M 6J8**
To Whom It May Concern	**Paul Davies**

Evidence of Insurance

Type(s) of Insurance	Insurer(s)	Policy Number(s)	Effective/ Expiry Dates	Sums Insured Or Limits of Liability	
PROFESSIONAL LIABILITY • Claims Made Policy	Berkley Insurance Company	BC190126	Jan 05, 2019 to Jan 05, 2020	Each Claim	CDN 2,000,000
				Aggregate	CDN 2,000,000

Notice of cancellation:

The insurer(s) affording coverage under the policies described herein will not notify the certificate holder named herein of the cancellation of such coverage.

Marsh Canada Limited
800 - 550 Burrard Street
Vancouver, BC V6C 2K1
Telephone: (604)-4433533
Fax: -
CertificateRequestsVancouver@marsh.com

Marsh Canada Limited

By: Brad Greening

Brad Greening

Flowing Artesian Wells

Water Stewardship Information Series

BRITISH COLUMBIA
The Best Place on Earth

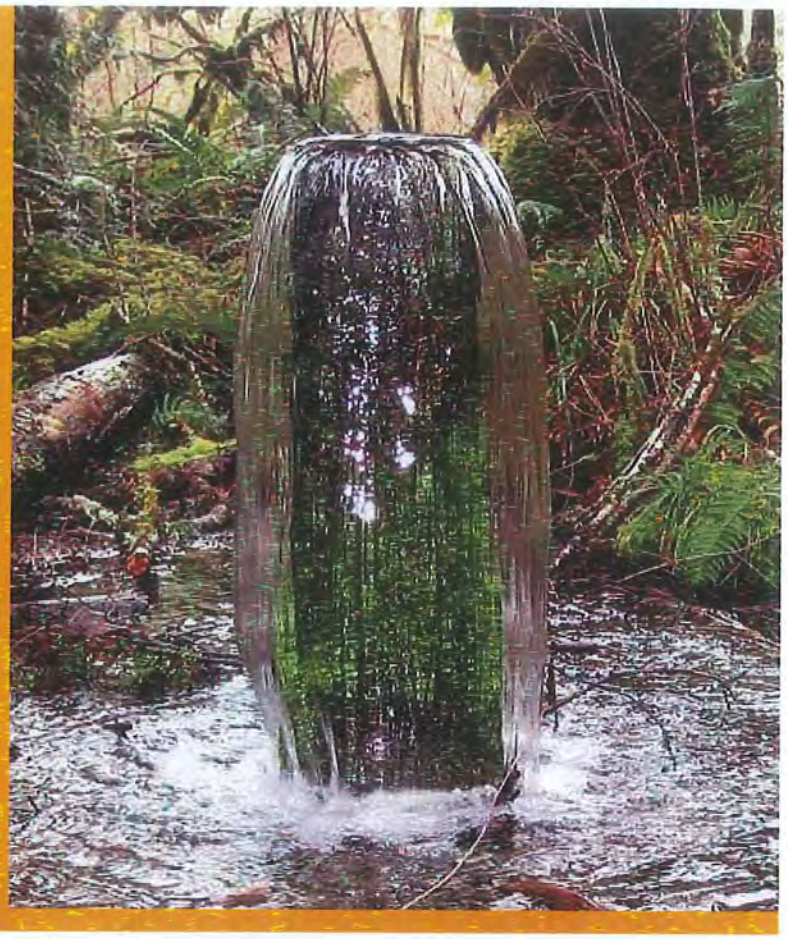


Table of Contents

This booklet contains general information on flowing artesian wells for well drillers, groundwater consultants and well owners in British Columbia. The booklet provides general guidelines on flowing artesian wells and does not replace professional knowledge or experience.

What's the difference between a flowing artesian well and an artesian well?

An **artesian well** is a well that taps into a confined aquifer (see Figure 1). Under artesian pressure, water in the well rises above the top of the aquifer, but does not necessarily reach the land surface. A **flowing artesian well** is one that has been drilled into an aquifer where the pressure within the aquifer forces the groundwater to rise above the land surface naturally without using a pump. Flowing artesian wells can flow on an intermittent or continuous basis and originate from aquifers occurring in either unconsolidated materials such as sand and gravels or bedrock, at depths ranging from a few meters to several thousand meters. All flowing wells are artesian, but not all artesian wells are flowing wells.

Why do wells flow?

Flowing artesian wells can be found in two types of situations:

- the aquifer is confined by impermeable materials (i.e., confined beds where the static water level is above the top of the aquifer and land surface); or
- the aquifer is not confined, but the static water level is above the land surface.

Static water level is the level to which water will naturally rise in a well without pumping. For flowing artesian wells, the groundwater level or static water level can be expressed as a head (e.g., artesian head) and reported as a length (feet or meters above ground level) or pressure (pounds per square inch or psi).

Artesian conditions can be generated by geological and topographical controls (see Figure 1) or by topographical controls alone (Figure 2). In the former, water in an artesian well rises upward due to the pressure confined in the aquifer. Artesian wells are found in inclined confined aquifers sandwiched between layers of rock or overburden that are impervious or have low permeability. Water enters the exposed portion of the aquifer at a high elevation and percolates down through interconnected pore spaces. The water held in these spaces is under pressure (confining pressure or hydrostatic head) due to the high elevation from which it originally came. If a well is drilled from the land surface through the overlying impervious layer, the pressure inside the aquifer will cause the water to rise in the well. In areas where the pressure of the aquifer is great enough, the water rises above ground level resulting in a flowing artesian well.

Hydrostatic head (or confining pressure) is the vertical distance between the water level in the well and the top of the aquifer and is expressed in feet or meters of water or pressure (psi).

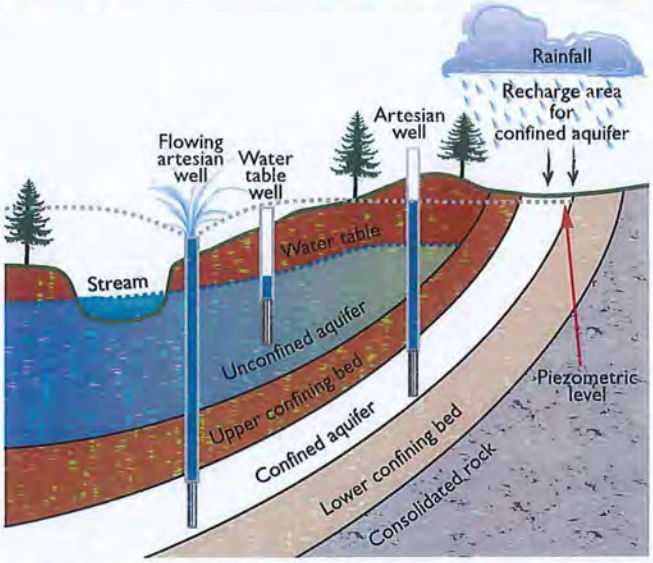


Figure 1. Geological and topographical controls affecting artesian and flowing artesian wells.

Topographical control situations can be found in unconfined aquifers where the well intake is deep enough to intercept a zone where the hydraulic head is higher than the land surface (see Figure 2). This situation typically occurs in groundwater discharge areas at lower elevations near rivers and lakes in valleys surrounded by steep slopes. The pressure of the groundwater typically increases with depth in the discharge areas where the slope of the water's

Hydraulic head is a measurement of the water level or total energy per unit weight above a datum such as sea level. It is commonly measured as water surface elevation in feet or meters.

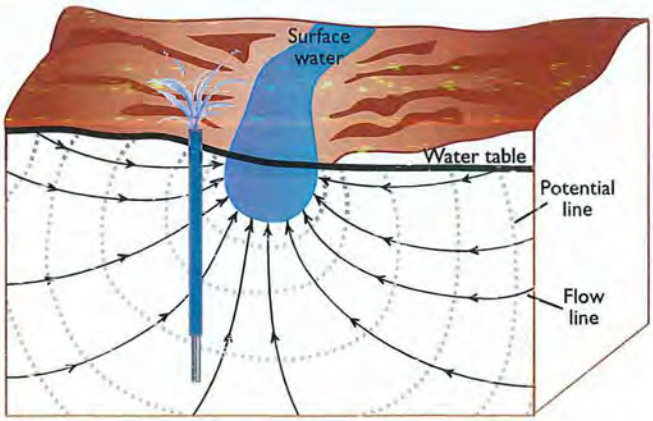


Figure 2. Topographically controlled flowing artesian well.

flow path and its pressure are controlled by the topography. As the groundwater moves along the flow path, it can migrate

deep below ground where it can lie beneath shallow non-artesian groundwater. When a well is drilled into a deeper zone of higher hydraulic head, the groundwater can move upwards inside the well casing to a level that is higher than the levels of the land surface, resulting in a flowing artesian well.

Why is stopping or controlling artesian flow important?

Flow from artesian wells should be controlled to prevent wasting groundwater. For instance, an uncontrolled artesian well flowing at 10 USgpm (55 m^3/day) wastes 14,400 USgallons (55 m^3) every day and 5.25 million USgallons (2.0×10^4 m^3) per year. An uncontrolled flow of 1 USgpm wastes enough water to supply four homes. Wasting water may lower the confining pressure in the aquifer so that the well no longer flows or flows at a reduced rate and affects the yield of neighbouring wells and springs.

Figure 3. Erosion caused by flowing artesian well.

When groundwater breaks out on the outside of the well casing, flooding, damage and/or subsidence and sinkhole formation can occur. Another reason to control flow is to prevent groundwater flowing from an aquifer under artesian pressure into an overlying aquifer(s). If the flowing well breakout is not promptly contained, silt, clay, gravel, sand, and drilling fluids can be carried along with the artesian groundwater to the ground surface and eventually reach surface water. The quality of the surface water and the habitat of aquatic organisms can be impacted.

Flowing artesian wells can also cause erosion (see Figure 3). Flowing water that accumulates into ponds can also contribute to mosquito problems.

How can flowing artesian conditions be determined before drilling?

Before a well is drilled, it is important for the person responsible for drilling the well (qualified well driller or qualified professional[1]) to do a pre-drilling assessment to determine the range of pressures and flows that might be found during drilling, i.e., whether flowing artesian conditions are likely to be encountered.

[1] Qualified professionals who are registered with the Association of Professional Engineers and Geoscientists of British Columbia with competency in hydrogeology or geotechnical engineering.

The pre-drilling assessment should include gathering information about geological conditions, static water levels and any history of flowing artesian wells in the area. This information can be obtained from:

- reviewing available local well construction reports;
- reviewing hydrogeologic information (e.g., maps on the Water Resource Atlas http://www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html showing flowing artesian well coverage (see Figure 4) or reports on Ecocat http://www.env.gov.bc.ca/ecocat/);
- consulting with the Ministry of Environment regional hydrogeologists; and
- consulting with well drillers and professional hydrogeologists or geotechnical engineers with knowledge of the local area.

If this information is not available, the person responsible for drilling the well should consider the proposed well depth in relation to relevant topographic and geologic information about the site (i.e., whether the proposed well is going to be deep in a valley-bottom location). Geophysical logs or an electric survey can also be used to better understand subsurface conditions. When knowledge is limited, a precautionary approach should be taken and planning should assume that flowing artesian conditions will be present.

Figure 4. Map from the BC Water Resource Atlas showing provincial mapped and classified aquifers, contoured elevations and wells (purple dots) that were flowing artesian wells at the time drilling.

What are the provincial regulatory requirements for controlling or stopping artesian flow?

The provincial regulatory requirements for controlling flowing artesian wells are outlined in section 77 of the *Water Act*. If artesian conditions are encountered when constructing or supervising construction of a well, the qualified well driller

or qualified professional must ensure the artesian flow is or will be stopped or controlled and advise the well owner (and the land owner, if applicable) of the steps taken to do so. It is also good practice to advise of any potential hazards associated with uncontrolled flow not being controlled (e.g., erosion, flooding, subsidence) and any associated costs. Agreement on these issues, prior to drilling can help prevent or minimize misunderstandings. For example, some issues can be addressed in a contract. If the qualified well driller or qualified professional fails to stop or control the flow, it is the well owner's responsibility to hire another qualified professional or qualified well driller to ensure that the flow is stopped or controlled. If the ownership of the well is not known, the land owner is responsible to have this done. If the flow cannot be controlled, the person responsible for drilling the well should advise the Ministry of Environment's regional hydrogeologist and must comply with any direction given.

A flowing artesian well must have a securely attached cap to provide access to the well, prevent entry of vermin and contaminants, and to prevent flow escaping from the well.

What does it mean to "control" artesian flow from a well?

A flowing artesian well is considered "under control" when the entire flow is through the production casing to the wellhead and the flow can be stopped indefinitely without leaking on the surface of the ground and with no leakage into any other aquifer penetrated by the well.

Will a flowing artesian well dry up if the flow is stopped or controlled?

Controlling the flow from a flowing artesian well should not stop the flow or dry up the well if the well has been properly constructed. In fact, the opposite is true as waste of artesian water will often eventually cause a decrease in artesian pressure. Controlling the flow from a flowing artesian well prevents unnecessary loss of groundwater from the aquifer upon which other wells rely.

Are there any water quality concerns with flowing artesian wells?

In general, the water quality of flowing artesian wells is excellent. However, some artesian waters may be very poor quality and cause serious damage on the surface or contaminate an overlaying aquifer. In general, water quality can be affected by the depth of the well, i.e., a deeper flowing artesian well may have poorer water quality than a shallower flowing well. Water from bedrock formations, such as deep sandstone formations, may contain concentrations of arsenic that could pose a health concern. Artesian wells with poor quality water should be permanently closed (see page 8).

Are there any other concerns with flowing artesian wells?

Most of the problems associated with flowing artesian wells result from improper discharge controls or improper well construction.

Casing corrosion (see Figure 5) and leakage can occur due to the constant flow of water, particularly if the water is corrosive

Figure 5. Corroded well casing.

or contains fine sand. Where artesian water is known to be corrosive, a smaller diameter flow pipe may be installed in the well. The pipe may be made of corrosion-resistant material or may be periodically replaced when it becomes corroded. Where the casing has been damaged, a slightly smaller diameter casing can be installed inside the old casing using packers if there is an existing surface seal and sealed in place with a cement grout. It is recommended to have the flowing artesian well checked periodically by a qualified well driller to verify the integrity of the well casing and to inspect the well screen, as the well can be difficult to repair once the casing has been corroded or breached. Thin-wall casing should not be used in flowing artesian wells.

Failure of the casing/surface seal during construction or decades after well completion can be costly and may result in the eruption of large volumes of silt, sand, clay or gravel, causing unstable conditions and potential flooding, damage to nearby structures through erosion and subsidence and harm to the habitat of aquatic organisms.

Well screens for flowing artesian wells can yield water with sand or become plugged with sand if the well is not properly developed. This is an issue when a flowing artesian well in a

fine-grained aquifer is shut off and the sand settles and clogs the area in and around the bottom of the casing. The screen size should be coarse enough to prevent pressure build-up in the aquifer and the well should be properly developed. Perforated casings for flowing artesian wells are not recommended. In some areas an unpleasant rotten egg smell (hydrogen sulphide gas) may be present and by reducing or stopping the artesian flow the smell can be brought under control.

What can be done with an existing flowing well?

Trying to stop or control the flow from older flowing wells may result in an uncontrolled discharge of water outside the well casing or at a distance from the well due to the lack of an adequate seal, a defective surface seal or corroded casings. If water does not appear to be flowing outside of the outer casing, then it may be advisable to leave the well alone and not restrict the flow. However, if water appears to be flowing outside the casing and/or the well is causing property or environmental damage, then the well should likely be closed. Alternatively, it may be possible to lower the water levels using a pump but care must be taken to keep the water flowing from the well relatively continuously to avoid additional uncontrolled discharge from occurring.

There are numerous special measures that may be applicable to controlling the flow of an existing flowing artesian well such as using well packers or a bridge to restrict the flow in the confining layer, adding polymers or plasticizers to keep the grout together during placement, using barite to reduce the confining pressure of the water, etc.

Any alteration to an existing flowing well to control the flow needs to be done in compliance with the *Water Act* and Ground Water Protection Regulation and any directions of a Ministry of Environment hydrogeologist. A qualified well driller or qualified professional must be hired. Before any work is done, the well owner should be made aware of the costs and complexities of the work involved with controlling the flowing artesian well, as well as the chances of successfully controlling the flow.

What if the flow is needed, for example, to increase the baseflow of a creek or stream?

In some instances, artesian flow is used to maintain water levels in ponds used for irrigation, fire protection, fish rearing, recreation or wetland enhancement. For existing wells, flow is permissible as long as property is not damaged and streams or aquatic habitats are not negatively impacted. If damage does or may occur, contact the local Ministry of Environment office (see back cover of this booklet).

Are there some general guidelines for constructing a flowing artesian well?

In constructing a well under flowing artesian conditions the potential pressure and flow and the permeability of the formation need to be taken into consideration. A pre-drilling assessment of local conditions may provide this information. If these conditions are known, the following provides general guidance for the design and construction of the well. If this information is not known the well should be designed conservatively for worse case conditions. Flowing artesian wells should not be constructed if the formation conditions are not favourable, i.e., in shallower situations where there is no suitable formation to seal into.

Green Zone (<5 psi)

If the pressure is or will be less than 5 psi (pounds per square inch), flow can usually be controlled by adding additional casing, except where permeability of the formation is extremely high, e.g., medium to coarse gravel. To determine the artesian head use the following conversion factors: 2.31 feet equals 1 psi, and one foot equals 0.3048 meters. For example, for a flowing well with 5 psi, there will be 11.6 ft or 3.5 meters of artesian head, therefore the casing would need to be extended more than 3.5 meters above the ground surface to contain all the artesian head. In general, a 30 per cent bentonite grout can be used for flowing well construction or repair.

Artesian head is the hydraulic pressure created within the confined aquifer that drives the water upward in a well to the piezometric level. The distance from the ground surface to the piezometric level, converted into equivalent pressure (expressed as pounds per square inch, or PSI), is the artesian head.

Yellow Zone (5 to 10 psi)

If the pressure is or will be between 5 and 10 psi, extending the well casing may reduce flow, but extreme care must be taken in highly permeable formations that produce significant volumes of water. Flows of 20 USgpm can potentially occur in this zone and the upward annular velocity resulting from this flow is high enough to begin separating grout mixtures as they are being pumped down. When the pressure is high and the formation highly permeable, it is recommended that an outer surface casing be installed before the permanent casing. The outer casing should end in the confining layer and should not penetrate the underlying artesian aquifer. Cement-type grout should be used.

Red Zone (>10 psi)

If the pressure is or will be greater than 10 psi, static head control or extending the well casing is not usually possible, especially in highly permeable, high-yielding formations. In this category the flow is great enough to make the grout placement very difficult. An outer casing or multiple casings should be installed before the production casing and set to

the confining layer so the production casing can be cemented within the outer casing. Cement or cement plus barite (or other weighting additives) should be used as grouting materials.

What are the key issues to be aware of when drilling a flowing artesian well?

Flowing artesian wells under high pressure and with high flow rates (yellow and red zones) are challenging to construct. Flowing wells that are drilled deep (≥200 feet or ≥60 meters) in unconsolidated deposits or drilled into bedrock are less prone to flow problems and are generally easier to deal with. In bedrock environments (see page 7 for more information on bedrock wells), the competent rock allows for easier installation of the seal (i.e., no casing to wash out or concerns about an eroded annulus).

Drilling a well into a confined aquifer disturbs the overlying geologic confining layer and provides a potential pathway for the upward movement of the pressurized artesian water. Well construction must include restoring any damage to the confining layer. In general, the closer the top of the artesian formation is to the ground surface and the higher the pressure, the more difficult it is to control the flow.

In certain conditions (e.g., soft clay/silt formations), the formation will squeeze back in and set up around the well casing over a period of time. If this condition is likely to occur, it is advisable to let the well flow for a week or two to give the formation a chance to settle in before stopping or controlling the flow. This will result in a seal around the casing at deeper depths than the surface seal.

It is good practice for the qualified well driller to observe the condition of the flowing artesian well head for one or two weeks after construction and check for leakages outside the surface casing or between casings.

Materials and Equipment

One of the key factors to successfully controlling the flow is being prepared with the right tools and materials at the job site. Suggested materials and equipment include:

- drilling mud and additives of sufficient weight to deal with the pressures in the aquifer,
- surface and production casing appropriate to the water quality and geological conditions,
- grouting and sealing materials appropriate to the artesian pressure and anticipated flow,
- tremmie pipes,
- pumps suitable for delivering the grouting and sealing materials,
- well screens with adequate transmitting capacity,
- valves,
- inflatable packers,
- surge block, and
- shale traps.

Drilling Muds

To determine the extra weight of drilling mud needed to counteract the pressures of the artesian aquifer during rotary drilling, the estimated artesian head and the depth to the top of the aquifer is needed. The following formula can be used to estimate the additional weight of drilling mud needed to control the flow during the drilling process:

$$\text{Additional mud weight} = \left(\frac{8.34\ \text{lbs/USgal} \times \text{height of water above ground level (ft)}}{\text{Depth to top of aquifer (ft)}}\right) + 0.4\ \text{lbs/USgal}$$

Where:
One USgallon of water weighs 8.34 pounds
0.4 lbs/USgallon is a safety factor

Example

If the depth to the top of the aquifer is 75 feet and the height of water above ground is estimated to be 10 feet, the additional weight of drilling mud needed would be (8.34 x 10/75) + 0.4 = 1.5 lbs/USgal.

Properly mixed, fresh drilling mud will normally weigh about 9 pounds per US gallon. Drilling mud can be made heavier by adding drilling clay, drilling gel and special solids such as barite. However, some drilling gels are treated with polymers to build viscosity and become difficult to pump before their weight significantly increases. Therefore, some drilling gels have limited ability for control of flows. Mud weights of up to 15 pounds per gallon can be achieved using weighting materials such as powdered barite.

Well Casings

Generally, in areas where flowing artesian conditions are known or suspected, at least one outer surface casing should be installed before installing the permanent/production casing or liner to allow for better control. It is not advisable to pull the surface casing within 20 feet (6 meters) of ground surface. Doing so may disturb the seals and cause water to flow around the surface casing as it is pulled, especially if bentonite is used. There should be at least a 4-inch (10 cm) gap or annulus between the outer surface casing and the production casing to allow for the insertion of a tremmie pipe to pump adequate grout volumes For example, if a 6-inch production casing is needed, a 14-inch outer surface casing would have to be installed to provide a 4-inch annulus.

In areas where the pressure is > 5 psi and the formation is highly permeable, a 4 to 6-inch (10 to 15 cm) annulus between the surface and permanent casing is recommended. Ensuring there is an adequate annulus is especially important where formations are highly permeable and high-density grout mixtures are required to adequately control the artesian flow.

Grouting Mixtures

Use of appropriate grouting material is key to constructing a flowing artesian well. Table 1 is useful for finding the hydrostatic

head pressure (in psi) and for understanding the relationship between drilling fluid or grout density and their ability to successfully control the flow during drilling, plugging, or repair. Table 1 shows that heavy grouts, such as neat cement/bentonite slurry or cement slurry with additives, have a distinct advantage for flowing well work. Mixing neat cement with bentonite is recommended to avoid cracks from occurring.

It is important to allow for sufficient time for the cement or cement grout mixture to set before proceeding with drilling. Use of the appropriate drilling method to minimize impacting the integrity of the seal is also important. In addition, the flowing artesian well should be gradually sealed or shut-in to prevent rupturing the seal(s).

TABLE 1
TOTAL PRESSURE ABOVE TOP OF CONFINED AQUIFER (HYDROSTATIC PRESSURE) FOR FLOWING ARTESIAN WELLS

Depth to Top of Flowing Aquifer (feet)	Artesian Head Above Ground Surface (feet)					
	5	10	15	20	25	30
10	6.5	8.7	10.8	13.0	15.2	17.3
20	10.8	13.0	15.2	17.3	19.5	21.7
30	15.2	17.3	19.5	21.7	23.8	26.0
40	19.5	21.6	23.8	26.0	28.1	30.3
50	23.8	26.0	28.1	30.3	32.5	34.6
75	34.6	36.8	39.0	41.1	43.3	45.5
100	45.5	47.6	50.0	52.0	54.1	56.3
125	56.3	58.4	60.6	62.8	65.0	67.1
150	67.1	69.3	71.4	73.6	75.8	78.0
175	78.0	80.1	82.3	84.4	86.6	88.7
200	88.7	91.0	93.1	95.2	97.4	99.6
225	99.6	101.7	104.0	106.0	108.2	110.4
250	110.4	112.5	115.7	117.0	119.0	121.2

Adapted from the Michigan Department of Environmental Quality, Water Bureau, Lansing, Michigan

Material	Weight	Hydrostatic Pressure
Barite Slurry:	18 - 22 lb/USgal	.96 - 1.1 psi/ft
Neat Cement and Bentonite @ 6 gal water/sack:	15.0 lb/USgal	.78 psi/ft
Bentonite Slurry Grout:	10.4 lb/USgal	.54 psi/ft
Bentonite Slurry Grout:	9.5 lb/USgal	.49 psi/ft

GROUTING MATERIAL SUITABILITY

	Heavy Enough To Overcome Hydrostatic Pressure	Not Heavy Enough To Overcome Hydrostatic Pressure
	Neat Cement @ 15 lb/USgal	All Bentonite Grouts
	Neat Cement @ 15 lb/USgal or Bentonite Grout @ 10.4 lb/USgal	Bentonite Grouts lighter than 10.4 lb/USgal
	All standard grouts have enough weight to overcome hydrostatic pressure of the flow.	

The values in Table 1 correspond to the downhole head pressure (in psi) for different scenarios, e.g., if the depth to the top of the aquifer was 10 feet and the artesian head was 5 feet, the downhole head pressure will be 15 feet or 6.5 psi. To overcome the flow, the downhole grout pressure must be greater than the downhole head pressure.

The following example illustrates how Table 1 can be used to select drilling fluids or grout that are heavy enough to control the flow during drilling.

Example of how to use Table 1

Q. *The top of an artesian aquifer is found at 50 feet and wells in the area have about 15 feet of artesian head. What minimum weight drilling fluid would be needed to overcome the hydrostatic pressure during drilling?*

A. The following steps are used to solve the problem:

Step A: To determine the downhole hydrostatic head pressure look at **Table 1** and find the cell corresponding to depth of top of aquifer (50 ft) and artesian head (15 ft) which is 28.1 psi. This pressure represents the total head above the top of the confined aquifer (e.g., 15 + 50 = 65 ft or 28.1 psi).

Step B: Divide the downhole hydrostatic pressure (28.1 psi) by the depth to the top of the aquifer (50 ft) to determine the downhole grout pressure needed to equalize the flow (28.1 psi/50 ft = 0.56 psi/ft).

Step C: To determine the grout weight divide the downward pressure of the grout (0.56 psi/ft) by 0.052 (a factor to convert lb/USgal to psi/ft of depth). The minimum grout weight needed to control the flow is 10.8 lb/USgal.

Are there specific actions to avoid when flowing artesian conditions are present?

When a large volume, high pressure flow breaks out, the immediate situation can be serious and there is usually a concern to quickly move the drilling rig away from the borehole. Hastily made decisions can get in the way of successful future corrective actions. As up-flowing artesian water typically will erode fine sediments around a solid object that has been placed loosely below ground, the following actions should be avoided:

- dumping field stone or gravel into the annulus around the well casing as this can prevent the installation of grout pipes or a larger casing into the borehole and can collapse PVC well casing;
- pouring ready-mix concrete or bentonite chips into the annulus as it is likely that the concrete or bentonite will solidify above the depth where the flow is originating and

result in a plug that causes the flow to wash out around its perimeter; or

- jamming unopened bags of cement, bentonite chips, lumber, cardboard or other debris into the washed out annulus as these materials are ineffective and complicate further corrective action.

How can flowing artesian wells be constructed in bedrock aquifers?

When constructing an artesian well that is likely to flow in a **bedrock aquifer**, the final or outer well casing should be sealed at least 10 feet (0.3 meters) into competent bedrock. Figure 6 shows one possible method of completing a flowing artesian well in bedrock. Construction techniques and choice of sealant materials need to be determined by the qualified well driller based on site specific conditions, e.g., pressure and flow.

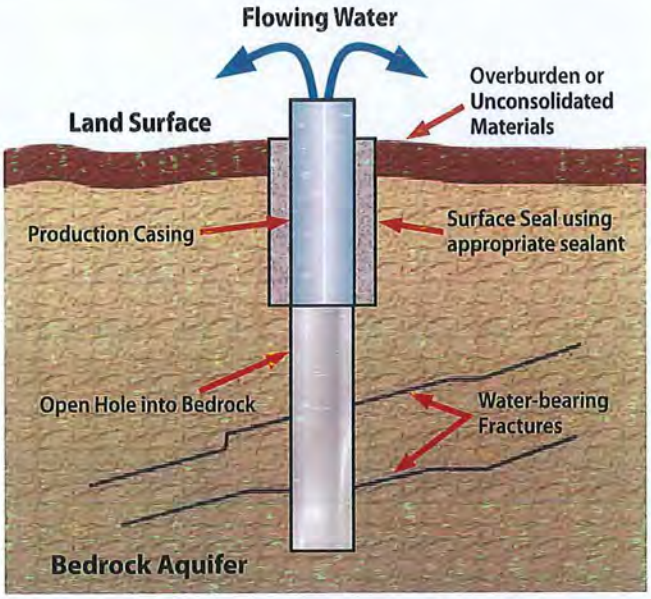


Figure 6. One possible method of completing a flowing artesian well in a bedrock aquifer.

How can flowing artesian wells be constructed in unconsolidated aquifers?

For **confined, unconsolidated aquifers** where flowing artesian conditions are likely, a cased oversized hole should be drilled into the confining layer, to allow a cement, or high solids bentonite seal to be placed between the final production casing and the outer casing (see Figure 7). This can be very complicated and expensive if the pre-drilling assessment indicates the confining layers are more than 100 ft (30 metres) deep. The size of the hole or casings and the depth of the seal must be determined on a site-by-site basis since choices are influenced by local geology and the specific artesian conditions encountered. A careful, conservative approach is recommended.

Figure 7. Bentonite cement grout seal between casings.

When constructing a well into a confined, unconsolidated flowing artesian aquifer, the appropriate sealant material between the outermost well casing and the confining layer must be of a sufficient depth and thickness to contain the flow.

Artesian conditions in **unconfined, unconsolidated aquifers** require special construction techniques such as using heavier drilling mud to counteract the pressure of the aquifer and a temporary surface casing to prevent hole collapse.

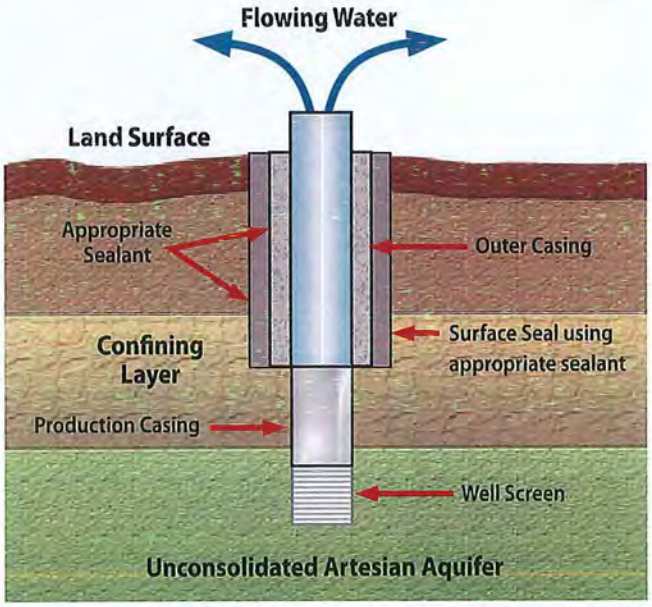


Figure 8. One possible method of completing a flowing artesian well in unconsolidated materials, e.g., sand and gravels.

What should be done if flowing artesian conditions are suddenly encountered?

When unexpected flowing artesian conditions are encountered (i.e., instant flow occurs), a qualified professional, or qualified well driller, should take control of the site and equipment should not be removed from the site until the artesian flow is under control. Contact the owner of the well and the land owner immediately

to report the situation and provide plans to control the flow (see below). Steps to take include:

- control the flow,
- secure the casing or borehole, and
- protect the drill rig.

The flow may be brought under control by:

- increasing the weight of the drilling mud,
- using plugs,
- using a surge-blocking to restrict flow, or
- installing a drillable packer.

The drill pipes can be left in place in cases where the uncontrolled flow occurs in an uncased drill hole, to indicate the exact location of the hole.

If the flowing artesian well is discharging water into a wetland or surface water body, contact the local Ministry of Environment office.

It is important for the well owner (and land owner if applicable) to develop a clear understanding, potentially in the form of a contract, with the drilling contractor on how the well will be repaired and/or the flow stopped or controlled before any work on the well commences to avoid or minimize potential misunderstandings when artesian flow is encountered.

What are the key factors in completing and equipping a flowing artesian well?

Flowing artesian wells, when properly constructed, should be equipped with a device to completely stop or control the artesian flow from the well (see Figure 9). After flow is stopped, there should be no leakage up the annulus between the outermost casing and the borehole. If water does escape, the annulus should be sealed.

Figure 9. Completed high pressure flowing artesian well.

Flowing artesian wells, like all wells, need to be vented. Well caps should be equipped with a two-way vent that allows the well to inhale and exhale air as the water level changes during pumping cycles. The vent will seal the well when the pump is not in use.

Determine the shut-in pressure (see below) and record the measurement on the well construction report. The wellhead should also be designed and equipped to prevent any backflow into the well.

Where freezing conditions may occur, the wellhead of the new flowing artesian well should be covered, insulated and heated, where necessary, to prevent damage of the flow control device leading to an uncontrolled flow situation.

How is the pressure or static water level for a flowing artesian well measured?

It is important to determine and record the hydrostatic pressure of the flowing artesian well for future pre-drilling assessments. There are several ways to measure the hydrostatic pressure or static water level of a flowing artesian well:

1. Extend the well casing, or a smaller diameter pipe through a well seal on the top of the casing, high enough above the ground surface until water no longer flows out the top (without pumping). The water level in the casing extension can then be measured using a water-level sounder. The distance from the piezometric water level in the casing to the ground surface is the artesian head of the aquifer – this can be converted to pressure.

   2.31 feet equals 1 psi or
   0.433 psi equals 1 foot

Example

A static water level of 30 feet is converted to pressure by dividing 30 feet by 2.31 feet/psi = 13 psi.

2. A pressure gauge installed on a well seal at the top of the casing will provide the pressure reading which can be multiplied by 2.31 to find the artesian head at the gauge elevation.

How should flowing artesian wells be closed?

A qualified well driller and/or qualified professional should be hired to close a flowing artesian well and ensure that the well is closed in such a manner that there is no leakage at the surface of the ground (see Figure 10). The driller must be prepared to handle the flow from the well and the discharge of any plugging materials immediately on removal of the flow control device(s). The work site can be dangerous if the flow is not properly diverted. Closing a flowing artesian well is simplified if the flow can be overcome by extending the well casing above the artesian head. Alternatively, insert an inflatable packer or expandable rubber plug at the bottom of the casing. Physically stopping the flow may make things worse, however, which is why the rapid loading of drilling gel is often a better approach.

Another effective approach is lowering the water level by pumping from adjacent wells. A leaking annulus should be sealed (if possible) before proceeding with grouting the production casing.

Pump a high density grout such as neat cement or concrete grout with bentonite through a PVC pipe or drill rod which is lowered to the bottom of the well. The cement mixture is pumped until it reaches the land surface. Pressure grouting with a packer may be required. It may also be good to pull or perforate some of the casing to allow the grout to flow from the casing into the annulus, although this is not critical if the casing is already perforated or corroded.

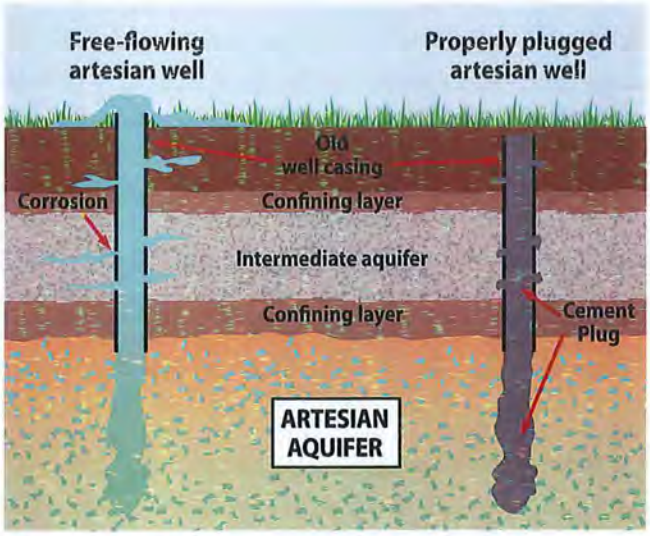


Figure 10. Example of a properly closed flowing artesian well.

How is a flowing artesian well disinfected?

Because of the protected nature of the confined artesian aquifer, flowing wells are generally less prone to bacterial contamination. Furthermore, the positive artesian pressure can minimize entry of surface contaminants into the well. Contamination introduced during the drilling process may be flushed out by the continuous discharge of water.

To disinfect a flowing well using chlorine, a temporary casing extension above the piezometric level or a tight well cap or seal can stop the flow and increase the chlorine contact time. A chlorine solution can also be pumped into the well via the secure well cap and hose connections. Once the casing extension or cap is removed, the well discharge will flush residual chlorine and inactivated bacteria from the well.

If the chlorinated water has a potential to harm the environment (e.g., fish), use an effective neutralizing agent, such as Vitamin C, to inactivate the chlorine. A solution of at least 1 per cent (by weight) of ascorbic acid is the most cost-effective form of Vitamin C. Added to the sump or a stream of chlorinated water, reaction time is nearly instantaneous.

Further Information

A registry of qualified well drillers can be found at: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/applications/well_drillers_reg.pdf.

A listing of groundwater consultants (qualified professionals) can be found at: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/library/consultants.html.

Michigan Department of Environmental Quality, 2005. Flowing well handbook: http://www.michigan.gov/documents/deq/deq-wb-dwehs-wcu-flowwellhandbook_221323_7.pdf.

For further information on whether approvals are needed for discharging flowing artesian well water to surface water bodies, contact the local Ministry of Environment office:

Vancouver Island Region	Nanaimo	250-751-3100
Lower Mainland Region	Surrey	604-582-5200
Thompson and Cariboo Regions	Kamloops	250-371-6200
Kootenay and Okanagan Regions	Nelson	250-354-6333
	Penticton	250-490-8200
Omineca Peace and Skeena Regions	Prince George	250-565-6135

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Environment

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PITEAU ASSOCIATES

GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS
VANCOUVER LIMA

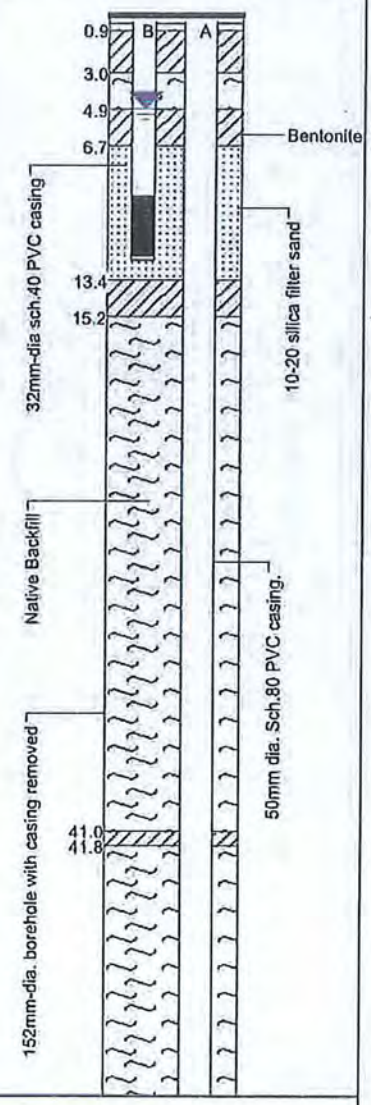
Well Number: MW06-1

Project: Monitoring Well Installation
Location: Spyglass Place
Project Number: 2539
Logged By: Arnd Burgert
Borehole Diameter: 152mm

Client: Town of Gibsons
Coordinates: E 462812 N 5472468
Ground Elevation: 110m - asl

Depth Below Ground Surface (ft / m)	Depth (mbGL)	Lithologic Description	Lithology	Remarks
0 m	0.0	Ground Surface — Asphalt		Steel access cover at grade
		Sand and Silt 0.61m - Gray sand and silt with trace clay. Dry. 3.96m - Gray silt, some clay. Dry. 6.10m - Sandy silt. 6.7m - Silt and sand, trace gravel.		P2 water level Dec. 8, 2006 4.8m-BGS 9.3m-BGS - 12.3m-BGS Machine slotted pvc screen 0.010" openings
	11.3			
	11.9	**Gravel, Silt, and Clay, wet**		
		Sand and Gravel 11.9m-14.0m - Grey sand and gravel. 14.0m-21.3m - Grey sand and gravel. Wet, water. 21.3m-23.8m - Grey sand and gravel. Wet, no water. 23.8m-27.4m - Sand with trace gravel and trace silt. 27.4m-31.7m - Grey sand and gravel, trace of silt. Damp.		
	31.7			
		Sand and Silt 31.7m-32.3m - Light grey very fine sand and silt. Dry. 32.3m-33.5m - Grey sand and silt. Some gravel. Damp. 33.5m-45.7m - Grey sand and silt. Some gravel. Damp.		
	45.7			
		Sand and Gravel 45.7m-47.5m - Grey tan sand and gravel with trace silt. Damp. 47.5m-51.8m - Grey silty sand and gravel. Damp. 51.8m-76.2m - Grey sand and gravel with trace silt.		

Constructed Well



Drilling Contractor: Field Drilling Contractors Ltd.
Drilling Method: Dual Mode Air Rotary
Drilling Started: Dec 4th, 2006
Drilling Ended: Dec 7th, 2006

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS
VANCOUVER LIMA

Well Number: MW06-1
Project: Monitoring Well Installation
Location: Spyglass Place

Depth Below Ground Surface	Depth (mbGL)	Lithologic Description	Lithology	Remarks	Constructed Well
55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75	76			Water Level at 74.7 mGBS (Dec 9, 2006)	66.1, 67.1, 70.4, 71.3, 76.0, 77.9; 10-20 silica filter sand
77	78	**Sand and Silt** Wet grey very fine sand and silt.		74.4m-BGS - 77.4m-BGS Machine slotted PVC screen 0.010" openings	
79, 81, 83, 85, 87, 89, 91, 93, 95, 97, 99, 101, 103, 105					

Drilling Contractor: Field Drilling Contractors Ltd.
Drilling Method: Dual Mode Air Rotary
Drilling Started: Dec 4th, 2006
Drilling Ended: Dec 7th, 2006