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NORTH VANCOUVER DISTRICT

Maplewood Lands Environmental and Hydrogeological Assessment Report

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Executive Summary

The District of North Vancouver's official community plan identifies the Maplewood Village Centre as one fo four key centres for community growth. The Maplewood area comprises Maplewood Village, the light industrial lands south of Dollarton Highway and the District Lands and Maplewood North Lands. Maplewood Village East, District Lands and Maplewood North Lands comprised the Study Area for this report and are referred to here as the Maplewood Lands.

This environmental and hydrogeological assessment report identifies the important environmentally sensitive features and hydrological characteristics of the area and identifies the potential constraints and possibilities in the development of these lands. Key environmental features examined included vegetation and wildlife habitat, wildlife corridors, streamside and wetland setbacks, steep slopes and surface and ground water hydrology. Sensitive environmental features included steep escarpment slopes, watercourses that are fish-bearing or potentially fish-bearing, remnant forested areas that have been identified as provincially designated ecosystems at risk, and wetland and wildlife habitat including important riparian and mature forests, located in the Study Area, which provide foraging and nesting habitat to wildlife and resident and migratory bird species.

In the absence of environmentally sensitive development and environmental impact mitigation, potential direct environmental impacts of development include permanent loss of wildlife habitat, loss of surface water resources to fish bearing habitat, and loss of wetlands and wetland habitat. Potential permanent impacts of development of the Study Area can be mitigated by avoidance of building on those areas in which impacts to terrestrial and aquatic resources would be high and/or difficult to replace in the form of compensation for loss of habitat.

The escarpment slopes are a source of surface water seeps feeding watercourses and wetlands. These slopes also provide vegetative cover for wildlife and have been identified as unstable in areas. Recommendations include: 1) maintaining forested vegetation on those steep slopes to provide for slope stability and continuity of forested habitat for wildlife access and 2) the use of appropriate buffers or setbacks from development at the base or top of slope. Development restrictions the Study Area include 1) maintaining riparian setbacks along watercourses that are important sources of water for the wetlands and for downstream aquatic habitat in the Maplewood Conservation Area and 2) retaining wetlands, such as W1 and W2, which provide important habitat for wildlife and fish and are difficult to replace through development of compensatory habitat that would be required under the provincial *Water Sustainability Act* and the federal *Fisheries Act.*

Retention and protection of wetlands W1 and W2 and their associated permanent and ephemeral sources of water are recommended to maintain water resources to the habitat downstream in the MCA. These wetlands and riparian areas provide natural corridors of vegetation cover for the movement of wildlife from through the area to and from the MCA. Other ephemeral watercourses may be reconfigured and consolidated, with approvals obtained under the *Water Sustainability Act*, to provide additional water resources to increase the ecological functioning of the retained watercourses and wetlands. Fish habitat enhancements may be possible within the Study area with the removal of fish passage barriers to improve access from the MCA. Augmentation (through the use of pumps and wells) of water flow and enhancement of habitat will increase the ecological function of the wetlands and watercourses.

Development may occur in areas of lower environmental sensitivity where potential impacts to water resources and wildlife habitat can be minimized on site and without impacting adjacent habitats.

Indirect impacts of development within the Study Area include the potential for disturbance of nesting birds protected under legislation as follows: a) birds and their nests protected under the *Migratory Birds Convention Act* and b) birds and their nests protected under the provincial *Wildlife Act* Section 34. While the nests and nest trees of some bird species are protected all year round, most mitigations include avoidance of noise disturbance of actively breeding birds. Noise disturbance can be mitigated through application of best management practices such as placing buffers around trees with active nests, scheduling construction outside of the bird breeding season near active nests, and avoidance of damage to trees containing nests protected under these two Acts.

The hydrogeological conditions, surficial geology and groundwater occurrences in the Study Area were also investigated. Potential impacts of development within the Study Area on groundwater conditions of surrounding sites such as Hogan's Pools Park and the Maplewood Conservation Area (MCA) were assessed. The assessment involved a review of previous reporting and historical information, monitoring well construction and ground water level monitoring over one year. Salient findings of the hydrogeological study included determination of the character of sediments underlying Hogan's Pools Park. These appear to be hydraulically separated from sediments at the Study Area by a layer of dense till. Development within the Study Area is not likely to impact groundwater conditions at Hogan's Pools Park. Sediments underlying much of the Maplewood North Lands consist of dense till and development there is unlikely to have a strong impact on groundwater conditions on site or in the MCA. Conversely, sediments covering most of the Maplewood Village East area are permeable, and while there is the potential for development to impact groundwater conditions on site and in the MCA, the impacts can be easily mitigated by incorporating storm water infiltration features within the development. Avoidance of deep building foundations in the Maplewood Village East area where the soils are permeable and the ground water elevations close to the surface is recommended.

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Acronyms Used

BIEAP	Burrard Inlet Environmental Action Program	QEP	Qualified Environmental Professional
CDC	Conservation Data Center	RAR	Riparian Areas Regulation
CHWdm	Coastal Western Hemlock dry maritime	SARA	Species at Risk Act
DNV	District of North Vancouver	SEI	Sensitive Ecosystem Inventory
DPA	Development Permit Area	TEM	Terrestrial Ecosystem Mapping
EA	Environmental Assessment	WBT	Wild Bird Trust
MBCA	Migratory Birds Convention Act	VRI	Vegetation Resource Inventory

1. Introduction

McElhanney Consulting Services Ltd. (McElhanney) was retained by the District of North Vancouver (DNV or the District) to provide an environmental and hydrogeological assessment to inform the District's conceptual land use planning for the Maplewood Lands (the Study Area). The location of the Study Area within the District is indicated with a gold star in *Figure 1*. Piteau and Associates provided hydrogeotechnical expertise.

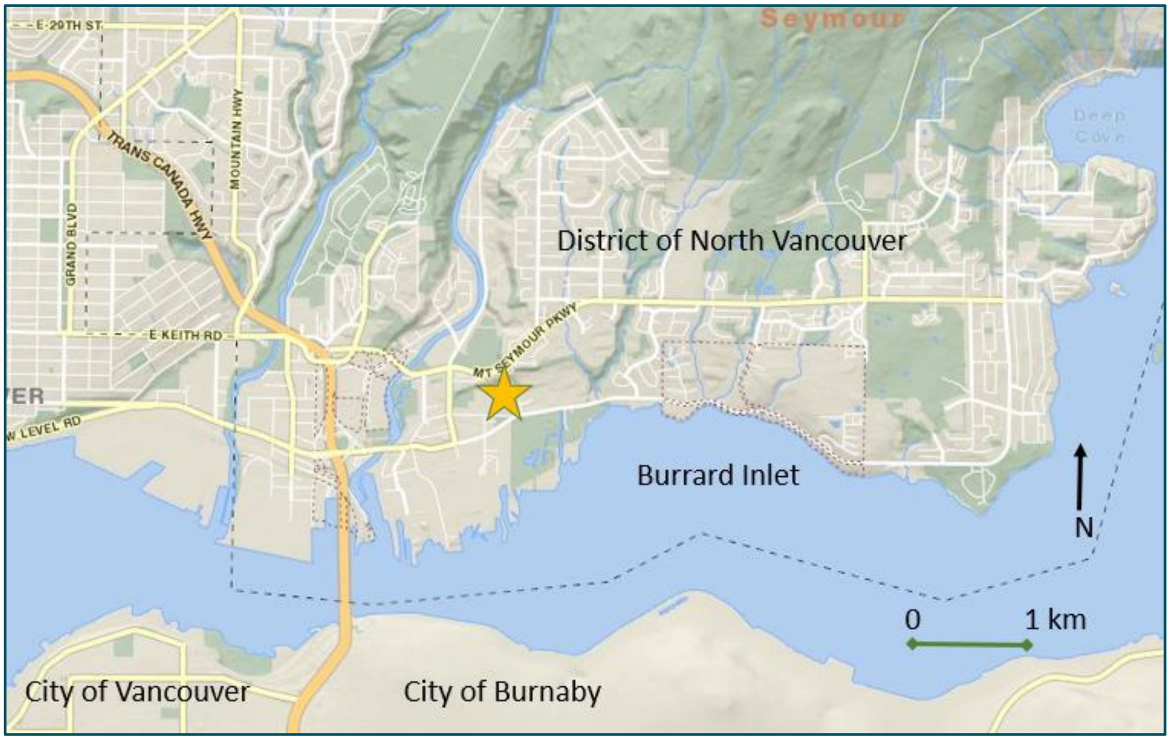

Figure 1. Location of Study Area in the District of North Vancouver, BC

The Study Area is comprised of those areas of land designated as Maplewood Village East, District Lands and the Maplewood North Lands (*Figure 2*). The Study Area is a relatively undeveloped portion of the Maplewood Area. A school (former International College) lies at the centre of this undeveloped area. Riverside Drive and McCartney Creek ravine mark the west and east boundaries of the study area, respectively. An escarpment roughly marks the northern boundary while Dollarton Highway borders the south side of the study Area.

The Study Area is bordered by several large parks and greenspaces including the Maplewood Conservation Area (MCA) to the south, Windridge Park to the north and east and Hogan's Pools Park to the northwest *(Figure 1)*. These protected green spaces provide important wildlife habitat connecting mountain and shoreline areas. The Study Area lies directly north of the MCA , a protected wildlife habitat area. The District and the Vancouver Port Authority set aside the MCA due to its regional ecological value as an important bird sanctuary, particularly for migratory birds (BIEAP 2002). Historically, some of the lands within the Study Area have been disturbed by past industrial or other activities. Previous land use and activities area discussed in the Section 3.1 of this report.

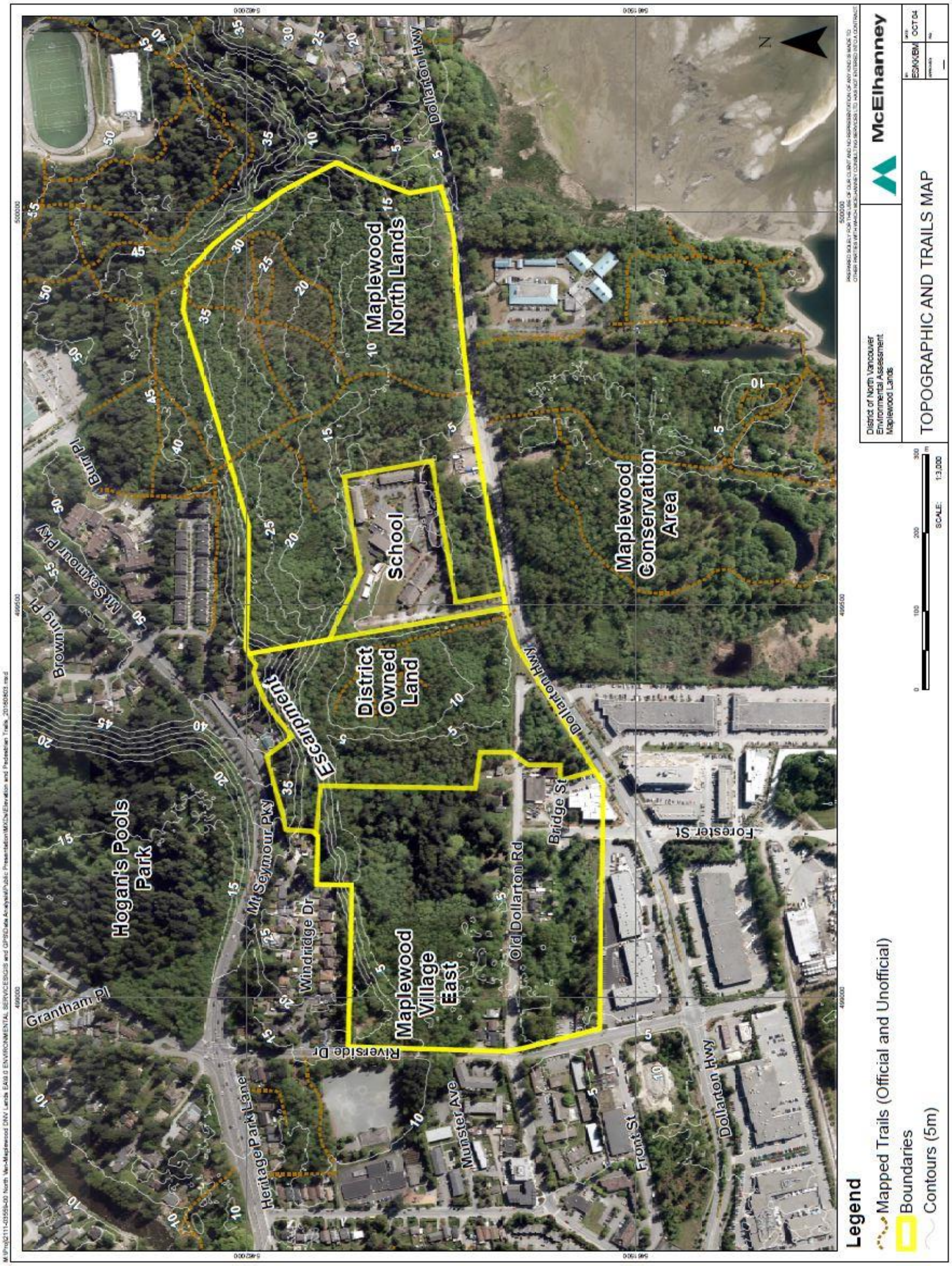

Figure 2. Location of the Maplewood Study Area (gold outlined (map modified from DNV GeoMap 2016).

The goals of the environmental and hydrological studies were to:

- Identify environmental resources in the Study Area highlighting areas to be conserved with respect to environmental values,
- Identify and assess the hydrogeological conditions underlying the Study Area
- Assess resource values and sensitivity in the Study Area
- Recommend sensitive environmental areas requiring protection or that are not developable
- Identify areas suitable for development in the Study Area
- Recommend mitigations and best practices for development to minimize environmental impacts and retain ecological functions.

Previous environmentally related studies have reviewed the Maplewood Area. The information in these reports and collection of supplemental field assessment information were intended to identify and confirm environmentally sensitive features at the Study Area and provide guidance in the early land use planning stages in order to mitigate environmental impacts of potential development.

The results of the current environmental and hydrological field studies are presented under Section 3, environmental sensitivities and potential impacts on environmental and hydrological resources are presented in Section 4 and 7 and recommendations for development provided in Section 8.

2. Assessment Methods

2.1. Environmental Assessment

This Environmental Assessment (EA) was comprised of a desktop database study, review of previous environmental reporting and supplemental field studies to complete an analysis of possible impacts of potential development on the Study Area and to inform land use planning.

The desktop study was comprised of reviews of previous studies, the gathering of local knowledge from stewardship groups, and obtaining information from the government databases for environmental data was conducted prior to field investigations. Field investigations were conducted to confirm and expand on the known data for the Study Area and are ongoing to assess seasonal changes.

Specific environmental resources investigated included:

- Location of watercourses, wetlands and other surface water flow.
- Terrestrial vegetation resources.
- Terrestrial wildlife and wildlife habitat features including wildlife trees and wildlife corridors for birds, mammals- and amphibians.
- Presence of habitat of endangered, threatened or vulnerable species provincially or federally designated.

2.1.1. Literature Review

A comprehensive literature review included a review of the following environmental and hydrological studies reports prepared for the District (and others) between 1991 and 2015.

- Biophysical Assessment Maplewood North Property, Dollarton Highway, North Vancouver, BC (2015a), prepared by Keystone Environmental
- Biophysical Assessment (Draft #1) Maplewood North Property, Dollarton Highway, North Vancouver, BC (2014), prepared by Keystone Environmental
- Maplewood Environmental Strategy, Dillon Consulting (2012)
- Forest Ecosystem Mapping and a Framework for Ecosystem-Based Management (2009), BA Blackwell and Associates (Andrew and Green)
- A Bioinventory and Environmental Impact Assessment of a Proposed Trail along Park St., North Vancouver (2007), Keystone Wildlife Research Ltd.
- Geotechnical Assessment, Dollarton Highway Realignment, Preliminary Design Stage (1999), AGRA Earth and Environmental
- Environmental Evaluation Hogan's Pools (1993), Triton Environmental Consultants Ltd.
- Environmental Assessment of the Maplewood Area and Proposed Maplewood Business Park (1992), Tera Planning Limited
- Environmental Science Centre and Wildlife Conservation Area Maplewood South Environmental Screening Report (1992), Public works Canada, Architecture and Engineering
- Preliminary Geotechnical / Hydrologic Assessment of the Proposed Maplewood Business Park (1991), Hardy BBT Limited

2.1.2. Stakeholder Workshop

Personnel from the Wild Bird Trust (WBT), who manage public education programs and provide operation and maintenance for the Maplewood Conservation Area were engaged in discussions to determine their organizations concerns and needs associated with the planning and potential impacts of development in the Study Area. A stakeholder meeting was held on June 29, 2016 with representatives from the following organizations:

- North Vancouver Arts Council
- Maplewood Farm
- Advisory Committee on Disability Issues)
- Parks and Natural Environment Committee
- Wild Bird Trust
- Save Our Shores
- North Shore Mountain Biking Association
- Transportation Consultation Committee and HUB
- North Shore Streamkeepers
- Parkgate Community Services Society
- North Shore Black Bear Society
- Nature Vancouver

Environmental and hydrological sensitivities of the local area were among the topics discussed and stakeholder concerns were summarized in the DNV Maplewood Area Plan Summary of Engagement -Phase 1; Maplewood

Stakeholder Engagement (DNV 2016a). Conservation and protection of wetlands and watercourses were items of interest which have been incorporated in the environmental protection and mitigations recommended in this report.

2.1.3. Soils and Terrain

Surficial geology maps for the North Vancouver area published by the Geological Survey of Canada (Canada 1960, Bednarksi 2014) were reviewed. Soil coring for ground water level monitoring also provided information on the characteristics of the surficial soils and their derivation.

2.1.4. Vegetation

Vegetation assessments were conducted by field observation. Dominant species in the canopy and understory were noted. Ecosystems were identified through observations of vegetation assemblages throughout the Study Area during the site visit. Provincial vegetation resource inventory (VRI) mapping and other provincial resources listed below were used to supplement data analysis. Wetland vegetation and classified according to the biogeoclimatic and vegetation determined based on potential climax species and soil moisture regimes as identified in Green and Klinka (1994). Wetland classification was conducted according to MacKenzie and Moran (Ministry of Forests (MOF) 2004).

Vegetation Resources

The ecological databases reviewed in the assessment of vegetation resources included the following:

- Biogeoclimatic Ecosystem Classification Subzone / Variant Map for the Chilliwack Forest District (Coast Forest Region) (MOFR 2008),
- A Guide to Site Identification and Interpretations for the Vancouver Forest Region. Land Management Handbook Number 28, British Columbia Ministry of Forests (Green and Klinka 1994),
- VRI Forest Vegetation Composite Polygons (MFLNRO 2016)
- BC Conservation Data Centre (CDC 2016a) iMapBC 2 database of provincially listed plant species including information from the federal *Species at Risk Act* (Canada 2002) and the Committee on the Status of Endangered Wildlife in Canada [COSEWIC],
- BC Species and Ecosystems Explorer (CDC 2016b),
- E-Flora BC: Electronic Atlas of the Plants of British Columbia (E-Flora BC 2015),
- Non-native invasive plant species (as listed in the *Weed Control Act* (BC 1996a),
- Field Guide to Noxious and Other Selected Weeds of British Columbia (Cranston *et al.* 2014),
- Provincially-listed ecological communities at risk (as defined in the BC Species and Ecosystem Explorer) (CDC 2016b).

The BC Conservation Data Center (CDC 2015b), iMapBC 2.0 (2016) and the BC Species and Ecosystems Explorer (CDC 2015a) databases were queried for known at risk ecological communities, vascular plant and non-vascular plant species associated with the Coastal Western Hemlock dry maritime (CWHdm) biogeoclimatic zone. The 'Field Manual for Describing Terrestrial Ecosystems' (MELP 1998) assisted in confirming vegetation assemblages on site. Invasive plant species were also noted.

Listed Species / Ecosystem Designations

The CDC compiles and maintains information on wildlife and plant populations in BC. As part of this system, the CDC assigns a provincial rank or listing that ascribes to each species a 'red', 'blue' or 'yellow' designation based on its population status within BC (CDC 2015a,b). The rankings, described below, highlight the wildlife and plant species as well as natural plant communities that are at risk:

- Red – any indigenous species, subspecies or ecological community that is extirpated (X), endangered (E), or threatened (T) in BC.
- Blue – any indigenous species, subspecies or ecological community considered to be vulnerable or of special concern in BC. Blue-listed elements are at risk, but are not extirpated, endangered, or threatened.
- Yellow – any indigenous species, subspecies or ecological communities that are apparently secure and not at risk.

These designations were used in this report to indicate the status of species and ecosystems observed relative to the provincial and federal listings of species at risk.

2.1.5. Terrestrial Wildlife Resources

A desktop literature review was completed to describe wildlife habitat conditions in terms of habitat suitability, wildlife movement, and/or level of disturbance. The web based databases considered in the assessment of wildlife use of the area and wildlife habitat include the following:

- CDC database of provincially listed wildlife species (CDC 2015a, b), as well as species listed under the federal *Species at Risk Act* (Canada 2002) and COSEWIC.
- BC Species and Ecosystems Explorer (CDC 2015a).
- E-Fauna BC: Electronic Atlas of the Wildlife of British Columbia (E-Fauna BC 2015).

The Study Area was reviewed for evidence of wildlife including nests, scat, tracks and burrows during field visits for listed and common species. Wildlife and wildlife habitat was assessed for listed mammals, amphibians, reptiles, and terrestrial birds. Species occurance in this area was determined utilizating procedures outlined in Resources Inventory Standards Committee (RISC) biodiversity inventory methods for presence detection (MELP 1998b). Inventory Methods for Raptors (SRM 2001), Inventory Methods for Owl Surveys (MOE 2006), Inventory Methods for Pond-breeding Amphibians and Painted Turtle (MELP 1998c), and Inventory methods for Forest and Grassland Songbirds (MELP 1999) were reviewed. Modified inventory methodologies were employed to assist in determining presence and habitat use of the site by these various animal groups. Call-playback methods were utilized to detect raptors. Songbirds were identified by their song or by visual identification as encountered along transects. Amphibians were surveyed by nocturnal song and by scraping of upland forest debris adjacent ot wetlands. Presence / not detected surveys were conducted to ground-truth potential or known occurrances and to supplement findings of previous studies.

Field procedures included the following:

- The Study Area was reviewed for evidence of wildlife including nests, scat, tracks and burrows during the site visit by visual sweeps along transects. Wildlife and wildlife habitat was assessed for mammals, amphibians, fish, reptiles, and birds and listed species at risk.
- Surveys took place at different times during the active breeding season and at different times of day to account for diurnal variation in wildlife activity.

- Locations of wildlife trees, active dens, nests, or wildlife houses identified during the field assessment were georeferenced

Wildlife habitat conditions were assessed in terms of habitat suitability, wildlife movement, and/or level of disturbance. Observations were completed in a way as to not elicit a response from an individual or alter wildlife behavior.

Seasonal sampling was undertaken to capture seasonal variation in site use. Field work was conducted in March for watercourse delineation and raptor inventory during their active breeding season and in June and July to capture other bird activity on the site and potential amphibian and small mammal use of the site.

Field studies were conducted with respect to seasonal timing anticipated to provide the greatest likelihood of observations. Wildlife and vegetation studies were conducted during the breeding season for birds from the beginning of March to the end of August (MOE 2014). The first field study was conducted on May 5, 2016 providing early morning call-play back for local owls and for a Cooper's Hawk (*Accipiter cooperii*) known to have been in the area in previous years. Wildlife observations were conducted between dawn and 9 am in the morning when wildlife tend to be most active.

Identification guides were utilized to identify animal scat, markings and remains. Identification of bear tracks and scat, deer tracks and droppings were accomplished through a review of published web information and photos (Cabrera 2016).

Species at Risk

Database queries for the known provincially mapped locations for species at risk were conducted to determine if known species at risk were located within the Study Area (iMapBC 2016).

The BC Species and Ecosystems Explorer database was accessed to determine vertebrate and invertebrate at risk species in the Study Area. Habitat preferences were noted for each listed species within the database for the Coastal Mountain Hemlock zone, Metro Vancouver Region (CDC 2015 a,b, E-Fauna BC 2015, E-Flora 2015). During the field investigations, the Study Area was assessed for the presence of habitat for regionally identified federally and provincially listed species at risk.

2.1.6. Watercourses and Wetlands

A review of iMapBC 2.0 (2016) and District Geoweb (DNV 2016b) was conducted to determine known mapped drainages and potential water features in the Study Area. Keystone (2014, 2015a) had conducted field surveys within the Maplewood North Land sites for watercourses and wetlands. These watercourses and wetlands were confirmed and identified during site visits.

Watercourses were identified by channel scour, indications of rafted vegetative material and observed water flow. Wetlands were determined by indicator vegetation and soil characteristics. Wetlands include a broad range of ecosystem types from permanently flooded with open water to forested sites with wet soils. Wetlands were identified at the Study Area as areas that are inundated with surface or groundwater at such a frequency and duration that they support vegetation adapted to saturated soil conditions (MOF 2004). Wetlands retain their wetland characteristics even during dry periods of the summer when there may be no water present. Wetlands were identified by the following characteristics: 1) presence of gleying or mottling (determined by augering soil cores to look for prominent grey colour or mottles within 30 cm of the surface in sandy soils (MacKenzie and

Moran 2004)), presence of characteristic wetland vegetation (such as rushes and sedges), and the presence of water. Wetland areas can dry up during the summer and still maintain characteristics. Man made watercourse were mapped as ditches as they are usually straight, of even depth and width, and often border roadways or fencelines.

The provincial Riparian Areas Regulation (*RAR*) was enacted to protect the integrity of watercourses, water quality and the stream conditions that support fish life processes. Streamside protection and environment areas (SPEA), establish riparian setbacks from development to facilitate the protection of the water quality and riparian conditions that support fish life processes. Watercourses, wetlands and ditches that convey water to fish habitat were surveyed in the Study Area and the riparian assessment methodology was applied. The province enables each municipality, under the *Municipal Act,* to adopt development policy and bylaws that meet or beat the protective setbacks from watercourses required under the provincial regulation. The District's OCP Schedule B: Streamside Protection DPA requires a minimum of 15 m streamside protection buffer (setback) though application of the provincial regulations may have prescribed a lesser setback. Determination of fish passage barriers were determined by observations of connections to fish bearing waters, barriers to passage such as blocked culverts, and physical stream characteristics.

2.2. Hydrogeological Assessment

In assessing the hydrogeology and groundwater conditions in the Study Area, numerous investigative techniques were used. Methodologies for each are described in this section.

2.2.1. Literature Review

Previous reports containing information pertaining to geology or groundwater conditions in or around the Study Area were reviewed (see Section 2.1.1) including:

- Hardy BBT Limited, 1991. Preliminary Geotechnical / Hydrogeologic Assessment, Proposed Maplewood Business Park, Dollarton Highway / Riverside Drive, North Vancouver, B.C. Report prepared for DNV, February 28.
- Keystone Environmental, 2015b. Report of Findings – Phase II Environmental Site Assessment Maplewood North, even Numbers Block 2400 – 2500 Dollarton Highway, North Vancouver, BC. Report to Darwin Properties (Canada) Ltd. September 9.
- Agra Earth & Environmental Limited, 1999. Geotechnical Assessment Dollarton Highway Realignment Phase 1 and 2 Preliminary Design Stage North Vancouver. Report to Intercad Services Ltd. March 8.

Other sources of information included topographic maps and geology maps of the local area. Information about subsurface conditions was obtained from construction logs for water wells that were historically drilled near the Study area. These well logs were obtained from the BC Ministry of Environment, and the locations of these nearby wells are shown on *Figure 3*, identified by their respective Well Tag Numbers.

2.2.2. Field Investigations and Data Collection

Two field visits to the Study Area and surrounds were completed by a Piteau hydrogeologist to order to reconnoiter the area and map features pertinent to groundwater and surficial geology.

Subsurface sediments were investigated by drilling six boreholes at the locations mapped in *Figure 3*. The boreholes were drilled on April 20 and 21, 2016 using a track-mounted environmental drilling rig equipped with a sonic drillhead. This type of drilling applies a high-frequency vibration combined with downward hydraulic pressure to advance a rotating casing. A continuous core of the intersected sediments was collected within an inner core tube for retrieval to the ground surface. Logs showing well construction and sediments encountered are included in *Appendix A*. Samples of the sediments recovered from the boreholes were collected, and grain size analyses were completed with selected samples. The results of the grain size analyses are included in *Appendix B*, and these were used to estimate hydraulic properties of the sediments.

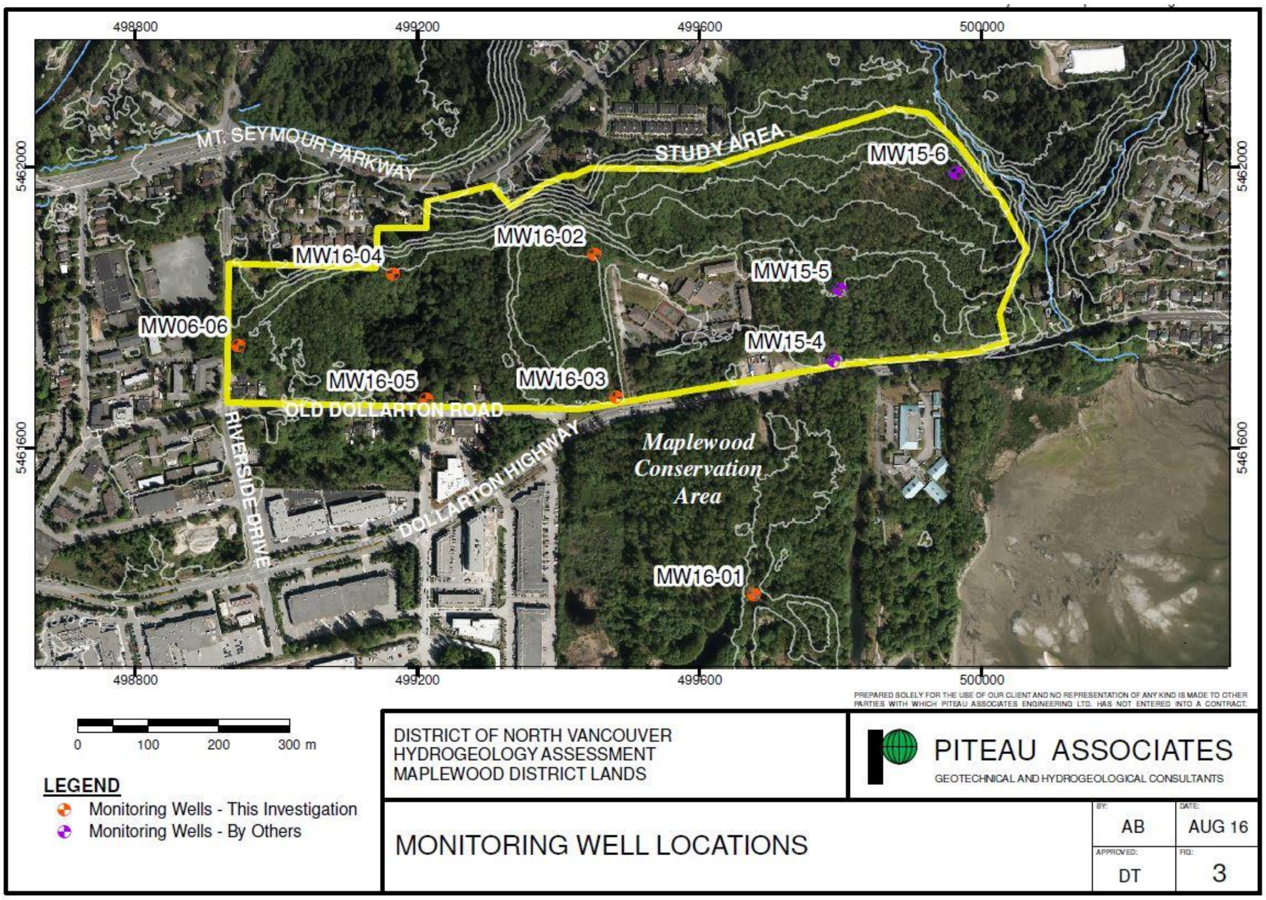

Figure 3. Location of water level monitoring wells throughout the Study Area.

To facilitate measurement of the depth to the water table, the boreholes were converted to monitoring wells by installing standpipes consisting of 2” diameter PVC with slotted lower sections. Washed silica sand was installed around the screened sections and bentonite chips were introduced from the surface to form seals above the sand filters. The monitoring wells were covered with flush-mount well caps seated in concrete at ground surface. The elevation of the top of each flush-mount well cap was surveyed using a surveyor’s total station. Elevations were also obtained for three existing monitoring wells.

Manual water level measurements were made using a water level sounding tape, using surveyed well cap as the datum point. These measurements were augmented by deploying transducer-dataloggers in selected wells. The dataloggers were programmed to measure water levels at an hourly interval. The three wells previously installed under a different study, located in the Maplewood North Lands area, were included in the monitoring program.

2.2.3. Data Analysis

Water level measurement data were collated and the results used to prepare two types of mapping: a) maps of lines showing equal depths to groundwater are presented to show how deep the groundwater occurs with respect to the ground surface and b) maps showing groundwater elevations feature contour lines that connect points of equal groundwater elevation (equipotential lines).

Six time-series hydrographs were prepared to illustrate vertical rises and falls of the water table in each of the monitoring wells. In these, differences in water level response can be used to interpret hydraulic characteristics of the sediments. The data were also integrated with observations from the reconnaissance and the literature review to prepare a water balance. This study accounts for surface water and groundwater passing through the Study Area, to estimate potential impacts that may result from physical changes to the land as the Study Area is developed.

2.3. Timing of Studies

2.3.1. Environmental Studies

Field studies were conducted on several dates with respect to seasonal timing anticipated to provide the greatest likelihood of species observations. General observations were made of the relative canopy and understory composition (type and general abundance), along with other observations including but was not limited to watercourses and wetlands, wildlife trees, bird and raptor nests, and wildlife and their habitat.

Watercourse and wetland identification and survey were conducted on March 10, 11 and 14th, 2016, prior to canopy overstory canopy closure, following each drainage using an RTK GPS unit run by a professional surveyor. A Qualified Environmental Professional (QEP) made notes on riparian and watercourse characteristics.

Wildlife and vegetation studies were begun during the bird breeding season. The first field study was conducted on May 5, 2016 providing early morning call-play back for local owls and for a Cooper's Hawk known to have been in the area in previous years. Wildlife observations were conducted early mornings. Site visits also occurred on May 26 and July 29, 2016.

2.3.2. Hydrological Studies

Groundwater level monitoring will continue for a full year to account for potential variation associated with changing seasons. The monitoring wells were installed April 20, 2016. Data from the data loggers are collected quarterly.

3. Description of Existing Environment

3.1. Land Use and Terrain

The Study Area was bounded on the north and east by steep slopes due to the presence of an escarpment (locally known as the Windridge Escarpment). A review of historical aerial photographs indicated that within the Maplewood North Lands, below the escarpment, much of the local topography of the Study Area landscape was altered by past gravel pit mining. The Maplewood Area was logged in the 1920's and gravel extraction from the Maplewood North Lands area (once called Dollarton Pit) began in 1929 and continued to the early 1970's. Once gravel extraction was completed, much of the pit was regraded with undifferentiated fill (described in surficial geology section). A landfill was located on the District owned lands (*Figure 2*).

The Study Area is mostly undeveloped land but is located in an urban environment. The center of the Study Area has been developed for school grounds (formerly International College). The upper portions of the escarpment have been designated for use as a Municipal Park (Windridge Park) with numerous trails existing along the ridge and down its steep slopes (*Figure 2*).

3.2. Vegetation

3.2.1. Species Assemblage

Individual plant species observed throughout the Study Area during the May and July 2016 site visits are presented in *Table 1*. Most of these species are dominant native species in the canopy and understory. Invasive species found in the Study Area are presented in *Table 2*.

Black cottonwood (*Populus trichocarpa*) was the most common tree species on site. It is a pioneer species (a species first to establish on disturbed moist sites) and an indicator of high light availability and moist to very moist well aerated soil conditions and its dominance in the forest canopy across the Study Area is an indicator of the high moisture availability in the area. While red alder (*Alnus rubra*) is also a pioneer species on disturbed moist sites, it has a relatively short life of 70 to 80 years compared to black cottonwood which has a minimum longevity of 200 years (Niemiec *et al.* 1995).

Table 1. Notable native plant species observed during the site visit

Common Name	Scientific Name	Type of Plant
Grand fir	*Abies grandis*	Conifer tree
Sitka spruce	*Picea sitchensis*	Conifer tree
Douglas Fir	*Pseudotsuga menziesii*	Conifer tree
Western red cedar	*Thuja plicata*	Conifer tree
Western hemlock	*Tsuga heterophylla*	Conifer tree
Vine Maple	*Acer circinatum*	Deciduous tree
Big leaf maple	*Acer macrophyllum*	Deciduous tree
Red alder	*Alnus rubra*	Deciduous tree
Black cottonwood	*Populus trichocarpa*	Deciduous tree
Bitter cherry	*Prunus emarinata*	Deciduous tree
Red-osier dogwood	*Cornus stolonifera*	Shrub
Salal	*Gaultheria shallon*	Shrub
Dull Oregon-grape	*Mahonia nervosa*	Shrub
Indian plum	*Oemleria cerasiformis*	Shrub

Common Name	Scientific Name	Type of Plant
Thimbleberry	*Rubus parviflorus*	Shrub
Salmonberry	*Rubus spectabilis*	Shrub
Trailing blackberry	*Rubus ursinus*	Shrub
Willow species	*Salix spp*	Shrub
Red elderberry	*Sambucus racemosa*	Shrub
European mountain-ash	*Sorbus aucuparia*	Shrub
Common snowberry	*Symphoricarpos albus*	Shrub
Red huckleberry	*Vaccinium parvifolium*	Shrub
Skunk cabbage	*Lysichiton americanus*	Herbaceous
Horsetail	*Equisetum arvense*	Herbaceous
Sweet scented bedstraw	*Galium trifolium*	Herbaceous
Tall blue lettuce	*Lactuca biennis*	Herbaceous
Common rush	*Juncus effusus*	Herbaceous
False Lily of the Valley	*Maianthemum dilatatum*	Herbaceous
False Solomon's seal	*Maianthemum stellatum*	Herbaceous
Reed canarygrass	*Phalaris arundinacea*	Herbaceous
Creeping buttercup	*Ranunculus repens*	Herbaceous
Black gooseberry	*Ribes divaricatum*	Herbaceous
Soft-stemmed bulrush	*Schoenoplectus tabernaemontani*	Herbaceous
Hardhack (Douglas spirea)	*Spiraea douglasii*	Herbaceous
Foam flower	*Tiarella trifoliata*	Herbaceous
Piggyback plant	*Tolmiea menziesii*	Herbaceous
Cattail	*Typha latifolia*	Herbaceous
Lady fern	*Athyrium filis- femina*	Fern
Deer fern	*Blechnum spicant*	Fern
Sword fern	*Polystichum munitum*	Fern
Bracken fern	*Pteridium aquilinum*	Fern
Fowl bluegrass	*Poa palustris*	Grass
Step moss	*Hylocomium splendens*	Moss
Flat moss	*Plagiothecium undulatum*	Moss
Red-stemmed feather moss	*Pleurozium schreberi*	Moss
Lanky moss	*Rhytidadelphus loreus*	Moss
Contorted pogonatum moss	*Pogonatum contortum*	Moss

Historical disturbances associated with forest clearing, gravel extraction and other anthropogenic activities have contributed to the presence and continued stand development of invasive plant species.

Table 2. Invasive plant species observed in the Study Area

Common	Scientific Name	Type of Plant
English holly	*Ilex aquifolium*	Shrub
English ivy	*Hedera helix*	Herbaceous
Himalayan	*Rubus armeniacus*	Shrub
Japanese	*Fallopia japonica*	Shrub
Periwinkle	*Vinca major*	Herbaceous
Reed	*Phalaris arundinaceae*	Grass

Japanese knotweed has been declared a noxious weed under the provincial *Weed Control Act* (2011). The Act imposes a duty on land owners to control noxious weeds on their property.

3.2.2. Plant Species at Risk

The CDC database was reviewed for occurrences of plant species at risk in the Study Area (CDC 2015a). The provincial database does not list plant species at risk for the Study Area. No provincially or federally listed plant species at risk were observed within the Study Area during field reviews.

3.2.3. Ecosystems

The Study Area lies in the Coastal Western Hemlock dry maritime (CWHdm) biogeoclimatic zone. Logging, landslides, gravel extraction activities, ATV recreation and various other sources of soil and vegetation disturbance over decades have contributed to the development of differently aged forest types within the Study Area. These forests have been mapped using terrestrial ecosystem modelling (TEM) by Andrew and Green (2009) and evaluated for the presence of sensitive ecosystems by Meidinger *et al*. (2012). A descriptive mapping for the forest vegetation found in the Study Area is presented in *Figure 4.*

Much of the Maplewood North Lands and the District Owned Lands have been disturbed and now comprise an early-stage forest ecosystem dominated by black cottonwood, red alder, bigleaf maple and sparsely vegetated in the mid canopy by coniferous species such as western redcedar. Sensitive Ecosystem Inventory (SEI) mapping conducted by Meidinger *et al.* 2012 for this Study Area indicated that much of the forest was comprised of a young stand less than 50 years old and was considered a non-sensitive ecosystem.

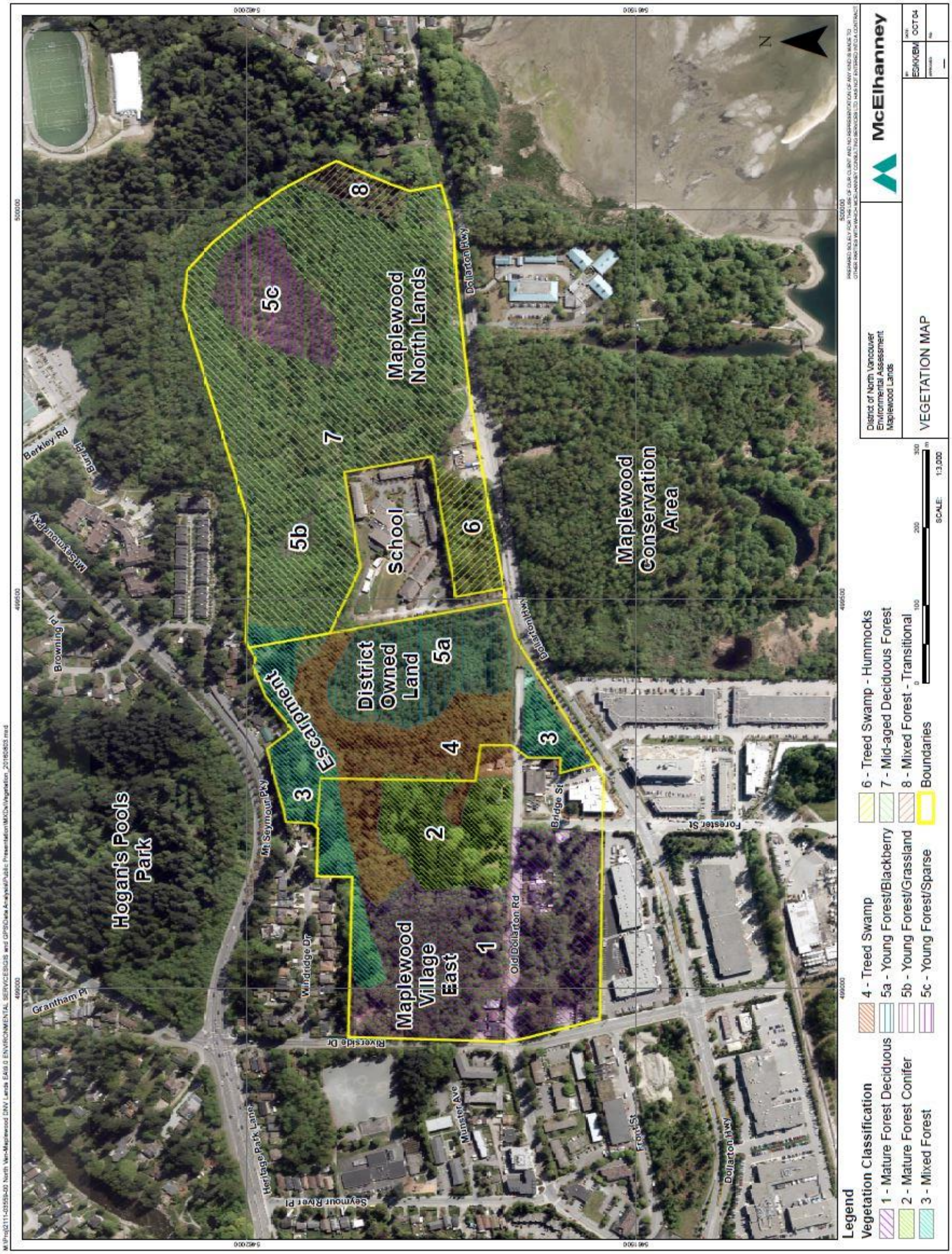

Figure 4 Vegetation map: Forest types in the Study Area.

The following are descriptions of the forest types classified and outlined in *Figure 4*.

Area 1 (Mixed forest deciduous) was comprised of a mature deciduous overstory of black cottonwood and bigleaf Maple in the overstory, western red cedar and western hemlock in the lower and mid canopy and a healthy understory of patches of salmonberry or sword fern or false lily of the valley. This area was mapped by Andrew and Green (2009) as a blue listed ecosystem CWHdm/07 Western redcedar/three-leaved foamflower though the climax status of this forested area is not yet expressed in the current vegetation.

Area 2 (Mature forest conifer) was comprised of a very moist mature conifer forest dominated by a stand of primarily western red cedar with a swordfern understory adjacent to a wetland. This mature forest area exhibited the vegetative characteristics of two provincially red-listed ecosystems: exhibited the characteristics of the red-listed ecosystems CWHdm/05 (western redcedar / sword fern) and CWHdm/13 (western redcedar / salmonberry ecosystem) (see Section 3.2.4).

Area 3 (Mixed forest) occur mostly along the escarpment slopes. These drier steep slopes of the escarpment comprise a mature mixed forest of western hemlock and Douglas fir mixed with mature trees of bigleaf maple and black cottonwood with an understory shrub and herb layer that help to stabilize the soils on the slope. This area was mapped by Andrew and Green (2009) as a blue listed ecosystem CWHdm/07 Western redcedar/three-leaved foamflower though the climax status of this forested area is not yet expressed in the current vegetation. There is also a small area of moist mixed cottonwood and western redcedar forest along Dollarton highway that has been set aside by the District as parkland. This small area is heavily impacted by invasive plants such as Himalayan blackberry.

Area 4 was a treed swamp fed with water from seeps of the escarpment. Willows (Salix sp.) and cottonwood dominate the canopy, and various shrub species typical of wetland areas such as red-osier dogwood, salmonberry, skunk cabbage, and horsetail.

Areas 5 a, b, c (Young forest) area of more recent disturbance characterized by a young stand of black cottonwood and some red alder. The understory of 5a (on District landfill) was mostly comprised of Himalayan blackberry with some saplings of western hemlock. This area was mapped by Andrew and Green (2009) as a blue listed ecosystem CWHdm/07 Western redcedar/three-leaved foamflower though the climax status of this forested area (upon which the ecosystem classification is based) is not yet expressed in the current vegetation. Area 5b was a very young stand of black cottonwood with an understory of fowl bluegrass in an understory gradually filling in with blackberry and salmonberry. Area 5c was a maturing black cottonwood forest with occasional saplings to mid canopy conifer species of western hemlock and western red cedar in the understory. The understory was fairly open except in areas of wet soils where hard hack and common reed dominate. Individuals of various invasive species could be seen throughout the area including Scotch broom, English holly and Japanese knotweed.

Area 6 was a wetland area (treed swamp) with many hummocks (raised portion of ground drier than surrounding depressions) that support mature mixed forest vegetation such as Sitka spruce, western hemlock, and western red cedar as well as wetland indicator species of willows, red-osier dogwood and hard hack.

Area 7 (Mid-aged deciduous forest) was a deciduous forest that has developed after gravel extraction operations had seized. A predominantly black cottonwood and big leaf maple forest has developed from the disturbed soils. Salmonberry and Indian plum are common throughout the shrub layer. Occasion saplings of western hemlock and western red cedar are found mid-canopy.

Area 8 was transitional mixed conifer – deciduous forest contiguous with the riparian area of lower McCartney Creek. Vegetation species included a variety of tree and shrub species such as cottonwood, big leaf maple, red alder, red elderberry and salmonberry. This mixed forest was dominated by mature conifers included western hemlock with lesser amounts of grand fir, western red cedar, Sitka spruce and big leaf maple. Understory vegetation was dominated by a mix of sword fern and bracken fern. Other species of note were trailing blackberry, salmonberry, dull Oregon-grape and snowberry.

Of these forest types, the forest assemblages of species that have developed to maturity can be evaluated as ecosystems and classified based on the Ministry of Forests Biogeoclimatic Ecosystem Classification (BEC) system. This classification system is helpful in providing descriptive dominant vegetation and site characteristics. The Province uses this system to identify ecosystems at risk in the province.

3.2.4. Ecosystems at Risk

Some ecosystems found in the CWHdm biogeoclimatic zone have been provincially blue and red-listed as ecosystems at risk. Though small in area, some remnants of these sensitive terrestrial ecosystems were mapped by Andrew and Green (2009) in this Study Area. Our site reviews found evidence of these ecosystems though we did not formally identify or map them. The ecosystems at risk within the Study Area are included in *Table 3*.

Table 3. Ecosystems at Risk – Forest ecosystems (CWHdm) observed in the Study Area.*

Scientific Name	English Name	Site Series as per BEC	BC List	Ecosystem Group	Description
Thuja plicata / Polystichum munitum Very Dry Maritime	western redcedar / sword fern	CWHdm / 05	Red	Terrestrial - Forest: Coniferous - mesic	Slightly dry to fresh / nutrient rich site
Tsuga heterophylla - Thuja plicata / Blechnum spicant	western hemlock - western redcedar / deer fern	CWHdm / 06	Red	Terrestrial - Forest: Coniferous - moist / wet	Moist to very moist / nutrient poor to medium sites
Thuja plicata / Tiarella trifoliata Dry maritime	Western redcedar / three-leaved foamflower Dry maritime	CWHdm / 07	Blue	Terrestrial - Forest: Coniferous - moist / wet	Moist to very moist / nutrient rich sites
Populus trichocarpa - Alnus rubra / Rubus spectabilis	black cottonwood - red alder / salmonberry	CWHdm / 09	Blue	Terrestrial - Flood: Terrestrial - Forest: Broadleaf – moist / wet	Moist to wet, nutrient rich sites
Thuja plicata / Rubus spectabilis	western redcedar / salmonberry	CWHdm / 13	Red	Terrestrial - Forest: Coniferous - moist / wet	Sites with strongly fluctuating water tables.

**CDC. 2016. BC Species and Ecosystems Explorer. B.C. MOE Victoria, B.C. Available: http //a100.gov.bc.ca/pub/eswp/ (accessed July 28, 2016)*
*** Biogeoclimatic Ecosystem Classification (BEC) (Green and Klinka 1994)*
**** Andrew and Green (2009), describes soil moisture and nutrients.*

Throughout the District, Andrew and Green (2009) had mapped ecosystem site series (listed in *Table 3*) as per the BEC system as follows: 425.1 ha of CWHdm / 05, and 13.1 ha of CWHdm / 06, 218 ha of CWHdm / 07 and 8.9 ha of CWHdm / 09. Within the Study Area we also identified areas adjacent to or transitional to a wetland (W2) that exhibited the characteristics of the red-listed ecosystems CWHdm/05 and CWHdm/13 in Area 2: Mature Conifer Forest of *Figure 4*. Andrew and Green (2009) had also mapped the site series CWHdm/07 in the Study Area though the climax vegetation that would represent this ecosystem had not yet developed here. Though the ecosystems listed in *Table 3* are provincially blue and red-listed as threatened or vulnerable ecosystems, these ecosystems are not protected under provincial legislation but are designated as sensitive ecological areas.

3.3. Terrestrial Wildlife Resources

The Study Area, though located within an urban environment, is connected to greenways, parklands and natural riparian corridors which promote wildlife use and passage. The adjacent Blueridge Creek and McCartney Creek ravines provide a natural corridor for many mammals, birds, fish and other animal species access from shoreline to upstream habitats. Observations of wildlife during the field review for this project were restricted to observable evidence of habitat use or modification. Wildlife trees were defined as trees that had visible signs of nesting or foraging activity located within or very close to the Study Area. Wildlife observations are mapped on *Figure 5.*

3.3.1. Mammals

Larger mammals typically present in North Vancouver area include black-tailed deer (*Odocoileus hemionus)*, black bear (*Ursus americanus*), and cougar (*Puma concolor*) (Green and Klinka 1994). Scat provided evidence of the presence of black bear within Wetland 2 (W2) and Wetland 4 (W4) (See Section 3.6). A check of the list of species observed in the MCA, on the regularly updated post board of the Wild Bird Trust, indicated that a black bear had been seen in the area on June 24, 2016. Other scat observed included that of deer and coyote (*Canus latrans*). Footprint traces of deer and raccoon (*Procyon lotor*) were commonly seen in the mud of the wetlands at the study site. No other observations were made of mammals during the field review for this project.

3.3.2. Birds

Bird nesting and foraging activity was observed throughout the Study Area. Field observations included identification of bird calls, observations of bird nests, presence of bird droppings at tree perches, pecking and foraging activity on trees, and observations of flying and foraging within the Study Area. Most birds observed were common to woodlands and forested areas. A raptor kill was observed in the North Lands area. During the nesting season several active nests were observed. Bird calls, nests and other bird observations are mapped on *Figure 6.*

A pair of Mallard ducks (*Anas platyrhynchos*), were observed on several occasions swimming in the watercourse fed by seeps on the District owned lands.

Numerous passerines were observed during the field review nesting and foraging. Most commonly heard and observed during site visits were the American Robin (*Turdus migratorius*), Northern Flicker (*Colaptes auratus*), Swainson's Thrush (*Catharus ustulatus*), Pacific Wren (*Troglodytes pacificus*), Spotted Towhee (*Pipilo maculatus*) and the Black-capped Chickadee (*Poecile atricapillus*). Osprey (*Pandion haliaetus*), Bald Eagle (*Haliaeetus leucocephalus*) and Turkey Vulture (*Cathartes aura*) were observed flying overhead. A feather of a northern harrier (*Circus cyaneus*) was found within the Study Area though the WBT lists this raptor as rare in the area.

Several other birds observed during the field visits and those known to frequent the area are listed in *Table 4* below. None of these species are provinicially listed species at risk.

Table 4. Other bird species common to woodlands and forests observed in the Maplewood Area, April through July 2016

Common Name	Scientific Name
Great horned owl	*Bubo virginianus*
Brown creeper	*Certhia americana*
Evening grosbeak	*Coccothraustes vespertinus*
Rock pigeon	*Columba livia*
Northwestern crow	*Corvus caurinus*
Common raven	*Corvus corax*
Stellar's jay	*Cyanocitta stelleri*
Common yellowthroat	*Geothlypis trichas*
Pileated woodpecker	*Hylatomus pileatus*
Varied thrush	*Ixoreus naevius*
Dark-eyed junco	*Junco hyemalis*
California gull	*Larus californicus*
Hairy woodpecker	*Leuconotopicus villosus*
Song sparrow	*Melospiza melodia*
Downy woodpecker	*Picoides pubescens*
Bushtit	*Psaltriparus minimus*
Black throated gray warbler	*Setophaga nigrescens*
Red-breasted sapsucker	*Sphyrapicus ruber*
American goldfinch	*Spinus tristis*
Barred owl	*Strix varia*
Bewick's wren	*Thryomanes bewickii*
Golden-crowned sparrow	*Zonotrichia atricapilla*

3.3.3. Wildlife Trees

Many wildlife trees were observed throughout the Study Area. Most wildlife trees showed signs of woodpecker, sapsucker, or Northern Flicker foraging activities. Several trees contained American robins actively nesting. A few wildlife trees had large enough holes that might accommodate a Northern Flicker nest but no such activity was observed around these holes.

3.3.4. Wildlife Species at Risk

The CDC database was reviewed for occurrences of wildlife species at risk in the Study Area (CDC 2015a). The provincial database does not report wildlife species at risk for the Study Area. No federally listed wildlife species at risk were observed within the Study Area during field reviews. However, one individual of the provincially blue-listed Northern Red-legged Frog was observed in the area of watercourse CR7 (see *Figures 5 and 6*) .

A broader search was completed using the CDC BC Species and Ecosystem Explorer (CDC 2015a, b) for species at risk in the Coastal Western Hemlock biogeoclimatic zone of Metro Vancouver area that utilized forested, riparian and wetland habitat. Provincially listed wildlife species that may potentially utilize habitats within Study Area, based on the presence of suitable habitat conditions are listed in *Table 5*. These species were not observed within the Study Area during the site visit and likelihood is based on habitat subtype availability on-site. However, the Maplewood Lands may provide suitable habitat to listed species in the region as suggested in previous studies (Dillon 2015).

Table 5. Provincially listed wildlife species at risk potentially occurring in the Study Area based on habitat conditions.

Common Name	Latin Name	Class of Animal	Likelihood of presence in Study Area
Red Listed Species (extirpated, endangered or threatened):			
Johnson's Hairstreak	*Callophrys johnsoni*	Insect	Low
Western Painted Turtle - Pacific Coast Population	*Chrysemys picta pop. 1*	Turtle	Low
Keen's Myotis	*Myotis keenii*	Mammal	Low
Pacific Water Shrew	*Sorex bendirii*	Mammal	Moderate
Southern Red-backed Vole (occidentalis ssp).	*Myodes gapperi occidentalis*	Mammal	Moderate
Blue Listed Species (Special Concern):			
Black Gloss	*Zonitoides nitidus*	Insect	High
Monarch	*Danaus plexippus*	Insect	Low
Northern Red-legged Frog	*Rana aurora*	Amphibian	High (Observed)
Pacific Sideband	*Monadenia fidelis*	Snail	Moderate
Pacific Tailed Frog	*Ascaphus truei*	Amphibian	Low
Scarletback Taildropper	*Prophysaon vanattae*	Insect	Moderate
Townsend's Big-eared Bat	*Corynorhinus townsendii*	Mammal	Moderate
Trowbridge's Shrew	*Sorex trowbridgii*	Mammal	Moderate
Western Pine Elfin, sheltonensis subspecies	*Callophrys eryphon sheltonensis*	Insect	Low

Common Name	Latin Name	Class of Animal	Likelihood of presence in Study Area
Western Thorn	*Carychium occidentale*	Insect	Moderate
Western Toad	*Anaxyrus boreas*	Amphibian	Moderate

Protected Nests Under *Wildlife Act* 34b

Bald eagle and Osprey are among the species for which their nests are protected all year round under the provincial *Wildlife Act 34b* (BC 1996b). These species are known to nest nearby in the MCA.

3.3.5. Other Species

Incidental sightings of the common garter snake (*Thamophis sirtalis*) and invertebrates such as grovesnail (*Cepaea nemoralis*) and chocolate Arion (*Arion rufus*) were recorded and mapped. Amphibian species were surveyed for their presence around the wetland areas. While there appeared an abundance of chorus frog (*Pseudacris regilla*) across Dollarton Highway at the MCA, no chorus frog were heard or observed around the wetlands on the northside of the highway. As mentioned in the wildlife species at risk section of this report, one individual of Northern Red-legged frog was observed near CR7.

3.4. Wildlife Connective Corridors

The MCA provides a variety of marine shoreline, fresh and salt water marsh and wooded upland habitats for a variety of birds, as well as other wildlife. The MCA and adjacent parks and green spaces such as the McCartney Creek / Blueridge Creek ravine and Windridge Park act as corridors allowing for the movement of wildlife through the area. Potential wildlife corridors that were observed and are recommended for retention are mapped in *Figure 5.*

3.5. Aquatic Species

An incidental observation was made of one coho fry (*Oncorhynchus kisutch*) (*Figure 5.*) within the watercourse (CR7 on *Figure 6*) adjacent to the escarpment.

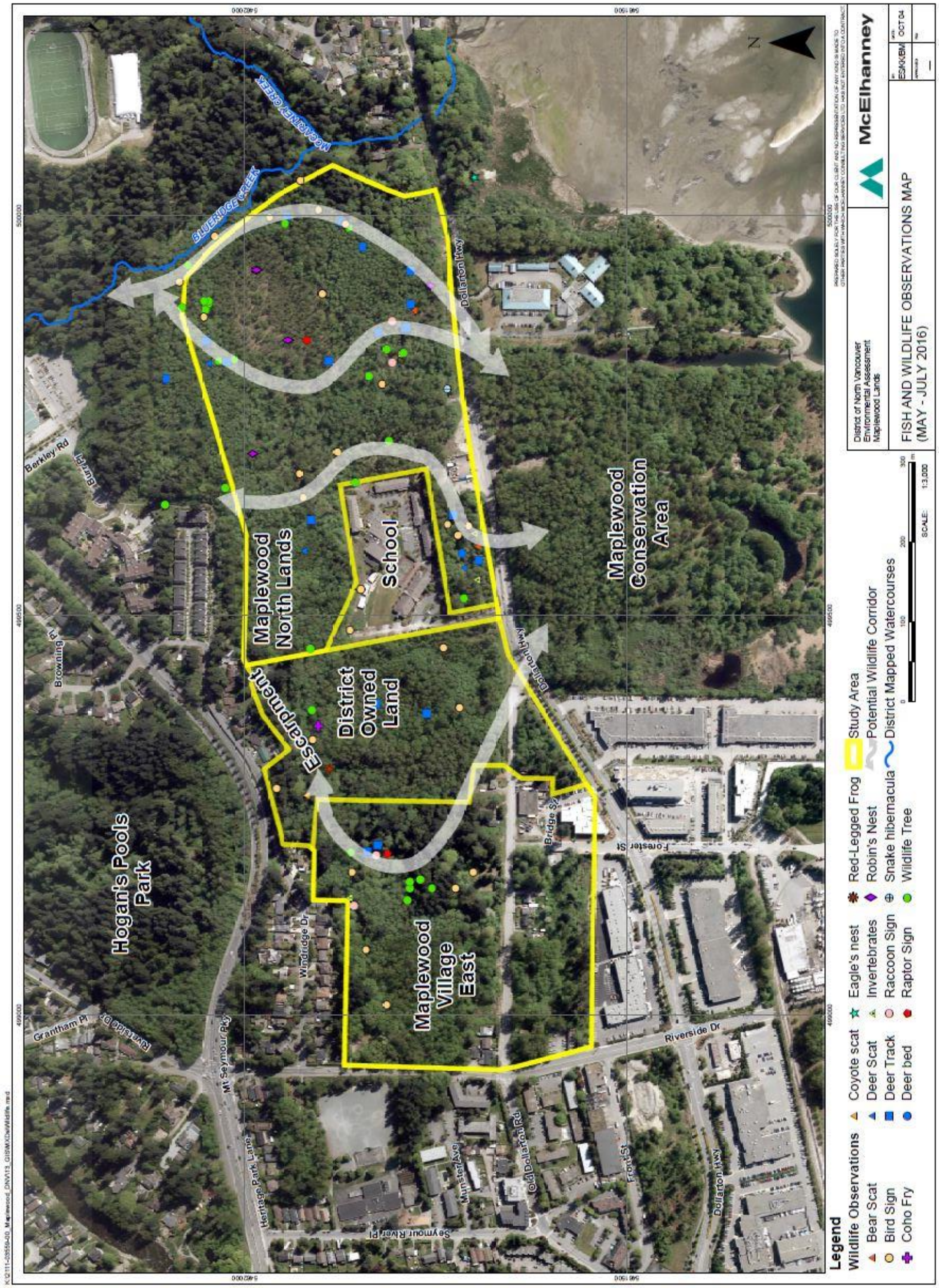

Figure 5. Fish and wildlife observations May to July 2016 around the Study Area.

3.6. Watercourses and Wetlands

The impermeable till layer that underlies much of the Maplewood Northlands contributes to higher surface runoff than in the Maplewood Village East area where the surface soils are most permeable. This is discussed in detail in the Section 3.7.2 on Surficial Geology. Past land use as a gravel quarry has also impacted the Maplewood Northlands hydrology and altered the natural drainage patterns. Field observations of channels and drainages throughout the Study Area are of developing watercourses and wetlands that follow pathways associated with old roads, paths, bulldozer and equipment marks and man-made alterations to the topography of the site (*Photo 1*). These watercourses and wetlands were located and characterized.

Photo 1. Wetland 4 (remnant of a gravel pit road) conveys water from Watercourses CR1, CR2, CR3 and CR4 to fish bearing habitat on the southside of Dollarton Highway during the winter and is an active wildlife corridor other times of the year.

Previous studies noted that stormwater drainage ditches collect water from some of the land area on the north side of Dollarton Highway and pass water through culverts to the south side of the highway to flow west towards the Park Street Marsh in the MCA. An assessment of water flows towards the Park Street marsh (Keystone 2007) determined that there was not enough water flow to the marsh during dry periods in the summer months to maintain marsh integrity. As a result a water supply well was developed to artificially supply fresh water to the marsh through the summer months (Keystone 2007). This well was observed in use by MCA in 2016.

Field surveys for wetlands and watercourses in our 2016 survey on the Maplewood North Lands yielded several more watercourses than originally identified in previous environmental assessment reports written in 1992, 2014 and 2015. The watercourses within the Maplewood North Lands were ephemeral, resulting from the gradual collection of upslope overland flow during rainfall events, particularly in winter, and lack of soil permeability to water.

Natural seeps were expected at the base of the slope of the escarpment on the north side of the Study Area, however only one seep was observed to be permanent. This seep was located directly north of the fill site on the District owned lands (*Figure 6*). The Hardy geotechnical report (Hardy 1991) identified this seep which was observed to be flowing during visits to the Study Area. This seep is considered a permanent source of water providing water to watercourses and wetlands downstream.

General watercourse and wetland characteristics are outlined in *Tables 6 and 7.* Blueridge and McCartney Creek ravines immediately east of the Study Area tend to maintain flows most of the year to the Burrard Inlet. An estimate of base flow in McCartney Creek is 23 m^3 / s in winter and 0.16 m^3 / s in summer (Tera 1992).

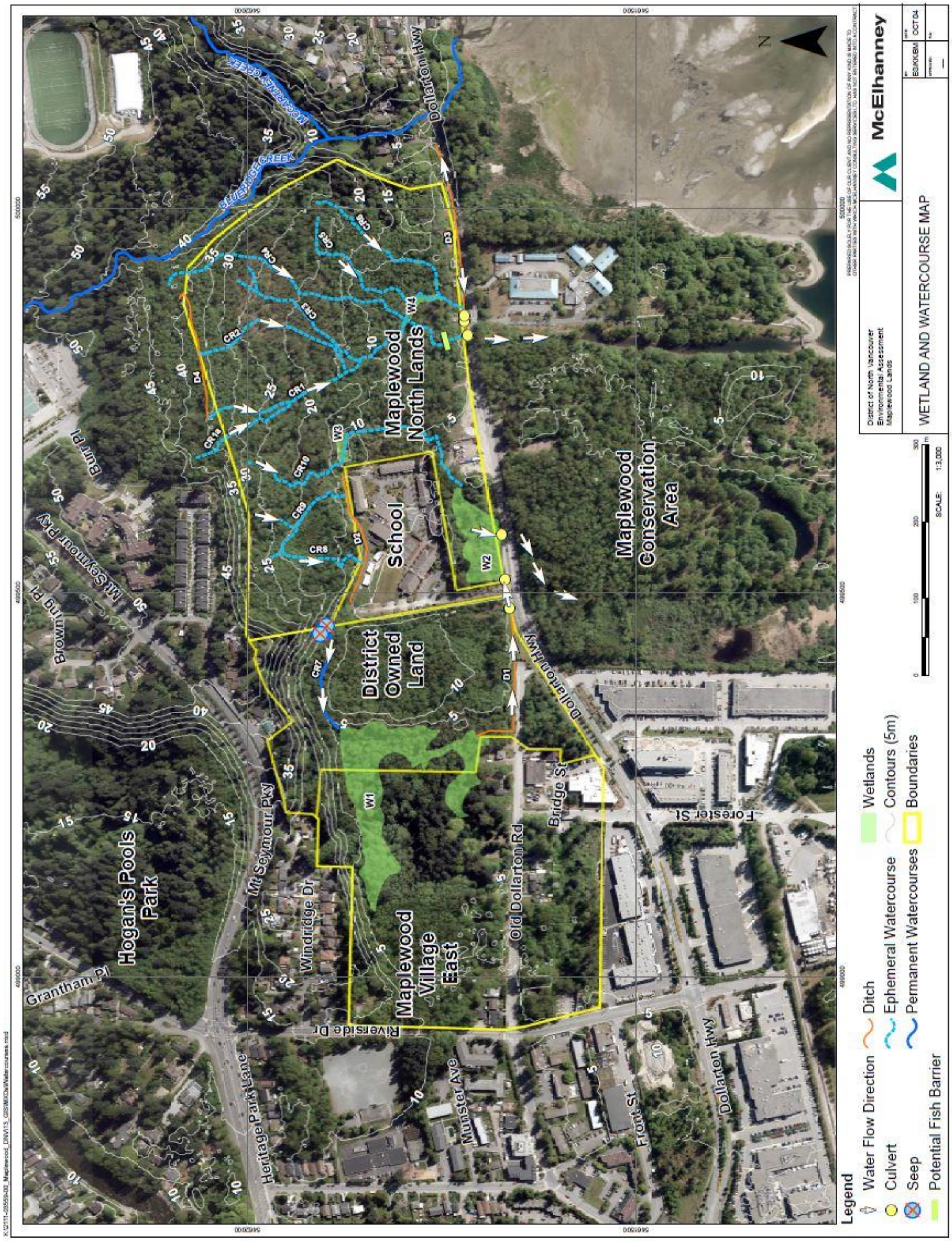

Figure 6. Watercourses, Wetlands, and Ditches identified throughout the Maplewood Lands. Directional arrows are provided to indicate water flow direction.

Table 6. Watercourses identified and their characteristics as mapped in Figure 6

Watercourse/ Ditch Identification Number	Channel Type	Average Channel Width (bank full width (m))	Average Channel Depth (m)	Slope	Watercourse bed composition	Watercourse Connections
CR1	Step Pool (in ravine)	1.0	1.12	Variable 2 to 11 %	Pebble / Cobble	Ephemeral watercourse starts from cross slope ditch (D4) at top of the escarpment. Enters portion of Wetland 4 then flows to Dollarton Highway Ditch culverted to Barge Inlet. Potentially fish-bearing with the removal of barriers and habitat enhancement.
CR1a	Step Pool (in ravine)	1.55	0.7	12 %	Pebble / Cobble	Ephemeral tributary to ephemeral watercourse (CR 1) from base of escarpment
CR2	Step Pool	0.5	0.2	20%	Pebble	Ephemeral tributary with a vEery narrow channel starting as an erosional channel from an old quarry road and entering into watercourse (CR1).
CR3	Step-Pool	1.0	0.4	8 %	Gravel	Ephemeral tributary to watercourse (CR 1)
CR4	Step-pool / Cascade Pool / Riffle pool	0.35	0.20	Slope varies between 24% at near top of slope, 9.2% mid slope, and 2.8% at the lower slope. Average: 12%	Pebbles. gravel with some silt and organics	Ephemeral watercourse enters Wetland 4 (W4) flows to Dollarton Ditch (D3)
CR5	Cascade pool / Step pool	1.15	.2	1 to 8 %	Pebbles. gravel with some silt and organics	Ephemeral watercourse enters Wetland 4 (W4) and flows to Dollarton Ditch (D3)
CR6	Riffle pool	0.5	0.2	2 to 8%	Small gravels	Ephemeral and relatively undefined watercourse in places following gravel pit scars from equipment, marked by wet ground, presence of hardhack and other indicators of moist soils, development of a deep organic horizon in the soil and presence of rafted material.

Watercourse/ Ditch Identification Number	Channel Type	Average Channel Width (bank full width (m))	Average Channel Depth (m)	Slope	Watercourse bed composition	Watercourse Connections
CR7	Riffle Pool	3 to 4 m	0.3 to 1.0	1 to 2%	Silt	Permanent watercourse derived from a seep and influenced by placement of fill. Enters on the northside of wetland 1 (W1). Fish were found here.
CR8	Partial shallow channelization / Step pool	1.2	0.05-0.15	5 to 25%	Pebbles and small gravels	Ephemeral watercourse starts at the base of escarpment and flows along scars of gravel pit activity, flows to ditch (D2)
CR9	Partial channelization / Step pool	Variable 1 to 3 m	0.1 to 0.2	5 to 10%	Pebbles and small gravels / organic accumulations along flatter slopes	Ephemeral watercourse starts at base of escarpment and flows along scars of gravel pit activity, flows to ditch (D2)
CR10	Step-pool / Riffle-pool	0.87	0.17	Slopes above W2: 13% Slopes below W2: 2.5%	Pebbles, gravel with some silt and organics	Ephemeral watercourse enters wetland (W2) flows into wetland (W1) and continues into the wetland culvert to Dollarton Ditch (D1)
D1	Channelized	2.0 to 2.5	0.5	2	Silt	Ditch leaves wetland (W1) along Old Dollarton Highway as a constructed ditch and conveys flow from the wetland through culverts to W2
D2	Channelized	0.5 to 1.0	0.2 to 0.4	2- 5 %	Silt	Ditch follows asphalt path north of the school and enters stormwater system
D3	Channelized	1.0	0.5	1 to 2%	Grass / Silt	Collects stream water and overland flow from the broad slope of the Maplewood North Lands along Dollarton Highway and flows from this ditch are culverted to discharge into the Barge Inlet
D4	Channelized	2.0	1.0 to 1.5	1 to 2 %	Small gravels / Silts	Ditch created on the north side of an old gravel pit roadway which follows the north property line of the Study Area

Table 7. Characteristics of wetlands observed in the Study Area.

Wetland Number	Type	Area (m^2)	Topographic position Elevation (m)	Description
1	Treed Swamp	14,825 m^2	5 m (base of escarpment)	Water source from seep from the escarpment area along watercourse CR7 (permanent due to seep source of water)
2	Treed Swamp	4,885 m^2	< 5 m (near flats)	Water source from W1 through culverts along Dollarton Highway and from ephemeral watercourse CR10
3	Rush and Horsetail Wetland	424 m^2	9 m to 14 m (base of upland slope)	Potentially man made wetland which is naturalizing, water source from ephemeral watercourse CR10
4	Rush Wetland	403 m^2	5 to 7 m (lower slope)	Developing in a topographic flat, this developing wetland receives ephemeral water from CR1, CR2, CR3, and CR4 and floods in the winter

The source of surface water and the size of the wetlands found in the Study Area is described in *Table 7*. W1 and W2 appeared relatively undisturbed in historical aerial photography and seem to have been part of the landscape for many decades. W2 receives ephemeral flow from CR10 and is becoming a naturalized feature within the Study Area. W3 appears to be a manmade feature, rectangular in nature and may have been created during the construction of the Metro Vancouver Sewer line. W4 appears to have been developed from an old gravel road scar during the time that the area was a gravel quarry. However, W4 is now naturalized and receives water upslope from watercourse CR1, CR2, CR3 and CR4 before they dry up in the spring and summer. During the rainy season W4 conveys water to the Dollarton Highway ditch which conveys water through a culvert to the Barge Inlet.

CR1 is connected by a culvert under Dollarton Highway to fish bearing tidal waters. There is currently a barrier to fish movement from this culvert upslope due to depositional fill along the northside of the highway which has become a berm. Also, a few meters upslope of the highway there is another culvert (for an access road) that is partially buried and conveys CR1 from upslope.

A Coho fry was found in CR7. CR7 lies north of W1 and provides water to W1. For a fish to be found at CR7, the route of fish passage must have been through the Park Street Marsh through the culvert under Dollarton Highway into W2, through the culverts and ditches of Old Dollarton Highway into and through W1 to CR7. In the summer most of this route is entirely dry except within the immediate vicinity of the seep and CR7. This suggests that winter time water levels are substantial enough to allow fish passage along this route. However, the apparent seasonal drying and low volume of water from the permanent seep that is the source of CR7, in late spring through summer, may leave fish stranded in remaining pools.

3.7. Groundwater Hydrology

3.7.1. Geomorphology

Geomorphology is the study of the shape of the land surface and the five main geomorphological units (land features) occurring in the vicinity of the Study Area are described in this section, and their locations are depicted by shaded polygons on *Figure 7.* Relating the land features to surficial geology and groundwater occurrences helps interpret how groundwater moves through an area. The mapping was completed by a combination of field observations made during site visits and topographic maps.

Escarpment

The western two-thirds of the northern margin of the Study Area features a steep escarpment, depicted on *Figure 7* as a tan-coloured strip. The topographic gradient is about 60%, with an elevation drop of up to 35m.

Broad Slope (mostly in the area of the Maplewood North Lands)

In the eastern portion of the Study Area, the escarpment gives way to a broad slope with a gentle (10%) gradient to the south. A large part of the slope area is a former gravel pit.

Plain (Maplewood Village East area)

The west side of the Study Area consists of a broad plain having a low (<5%) topographic gradient.

Closed Landfill (District owned lands)

The central portion of the plain is occupied by a closed landfill that rises about 9m above the plain. It is mapped on *Figure 7* as a pink polygon near the centre of the Study Area. The sides of the landfill are steep (about 50 to 70% gradient) while the top surface has gentle slopes.

Blueridge Creek Valley

Blueridge Creek flows along a valley outside the eastern Study Area boundary before converging with McCartney Creek. The valley is steeply incised into the sediments, in places up to 8m below the surrounding topography.

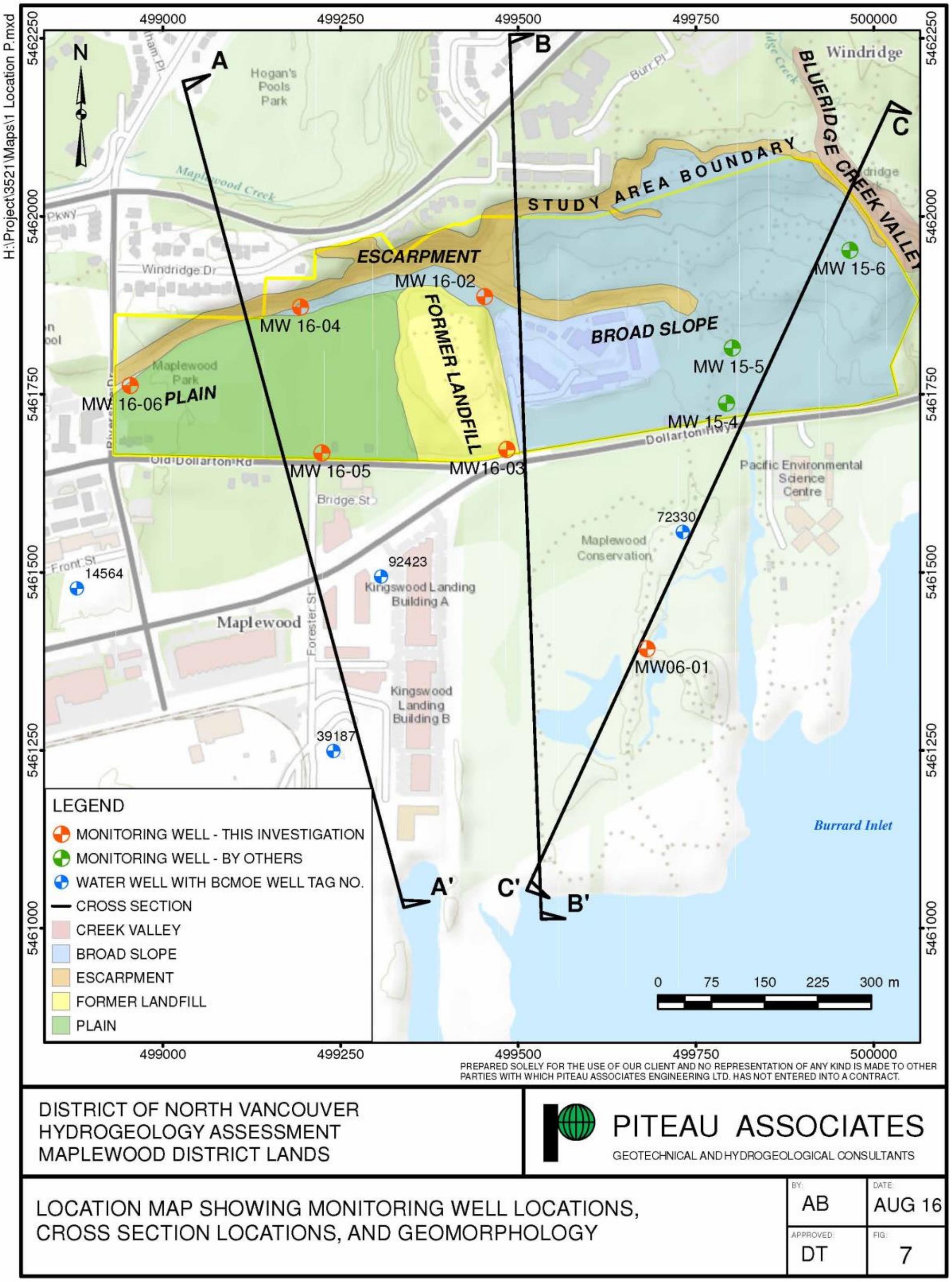

Figure 7. Location map of geomorphological units within the Study Area and location of cross sectional lines for subsurface water depth analysis

3.7.2. Surficial Geology

Surficial geology of North Vancouver was mapped by the Geological Survey of Canada (Canada 1960m, Bednarksi 2014) and is presented in *Figure 8.* The Study Area is underlain by thick terraced deposits of sand and gravel belonging to the Capilano Sediment lithogic group that were deposited by glacial rivers (deltaic outwash and glacial till) during glaciation (Armstrong and Brown 1957). These have been redistributed by postglacial rivers, forming deposits belonging to the Salish Sediment group. River-deposited sand and gravel are permeable, meaning that groundwater can seep through rapidly. These sediments form today's aquifers. The Salish Sediments also include layers of silty sand and gravel that have been compressed beneath the continental ice sheet. The dense, silty material is called till and groundwater can only seep through it slowly.

Photo 2. Coarse sand and gravel encountered in the borehole at MW16-06.

Soils derived from these deposits are characterized by medium sand to cobble gravels up to 15 m thick deposited by proglacial streams and commonly underlain by silt to silt clay loam. The area is also designated as a known area of landslides (Armstrong and Hicock 1976). The soil stratigraphy of the area is primarily derived from these glacial deposits of sand, gravel and silts.

Subsurface investigations by Piteau and others (Hardy, 1991; Keystone 2015b, Agra 1999) have confirmed the presence of loose coarse sand and gravel sediments beneath the plain in the western portion of the Study Area to a depth of more than 10m (*Photo 2*). Occasional interbeds of dense silty sand and gravel (glacial till) or silty sediment are present, but since these constitute a minor component of the sediments, groundwater seepage beneath the plain is generally rapid.

Photo 3. Dense till layer north of the Study Area observed in the Blueridge Creek ravine.

Surficial sediments in the broad slope area consist of dense till, and as a result groundwater seepage in this area is slow.

The upland area lying northeast of the Study Area consists of thick till deposits (Salish) and glacio-marine sediments (Capilano) consisting of sand and silt strata. Till is exposed in the incised Blueridge Creek valley immediately east of the Study Area (*Photo 3*).

A former landfill was situated in the central portion of the Study Area, identified on *Figure 8* as the pink polygon labeled "AN U". A 1991 assessment (Hardy, 1991) of the subsurface in the landfill indicated the presence of compact sandy soils with roots, stumps, logs, slabs of concrete and asphalt, construction or vegetation debris, organic soil, metal, gravel, cobble, and boulders.

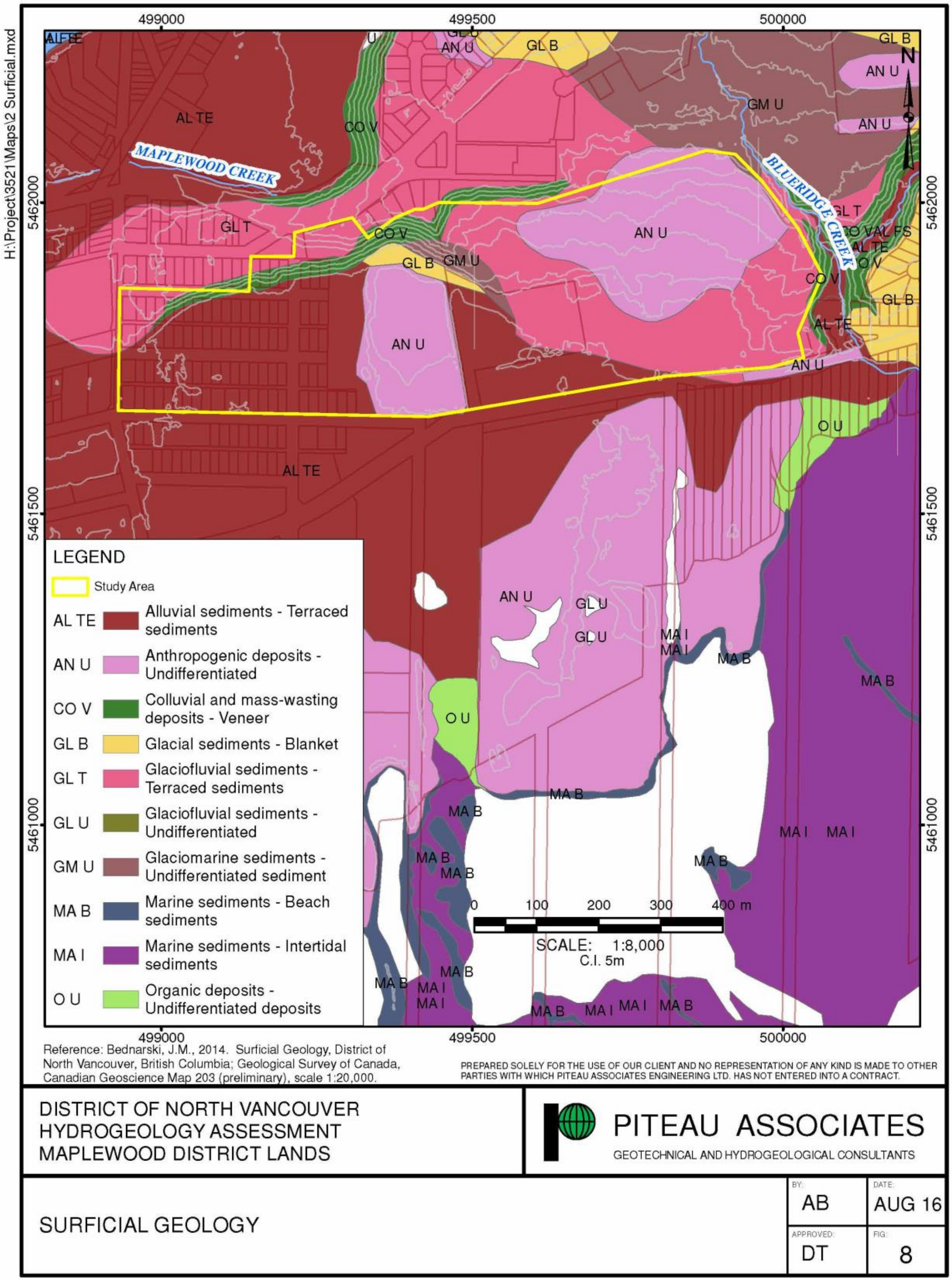

Figure 8. Surficial geology of the Study Area. (from Bednarski 2014).

An historic context to the surficial geology is presented on *Figure 9.* This figure shows the surficial geology map superimposed on a nautical chart from 1930. A gravel pit is shown on the historic chart, with a dredged barge channel accessing tidewater south of the pit. A small area west of the barge channel was identified as "Sand Dump" in 1930. Since then the filled area has expanded to a 21 Ha portion of the historic intertidal area west of the barge channel.

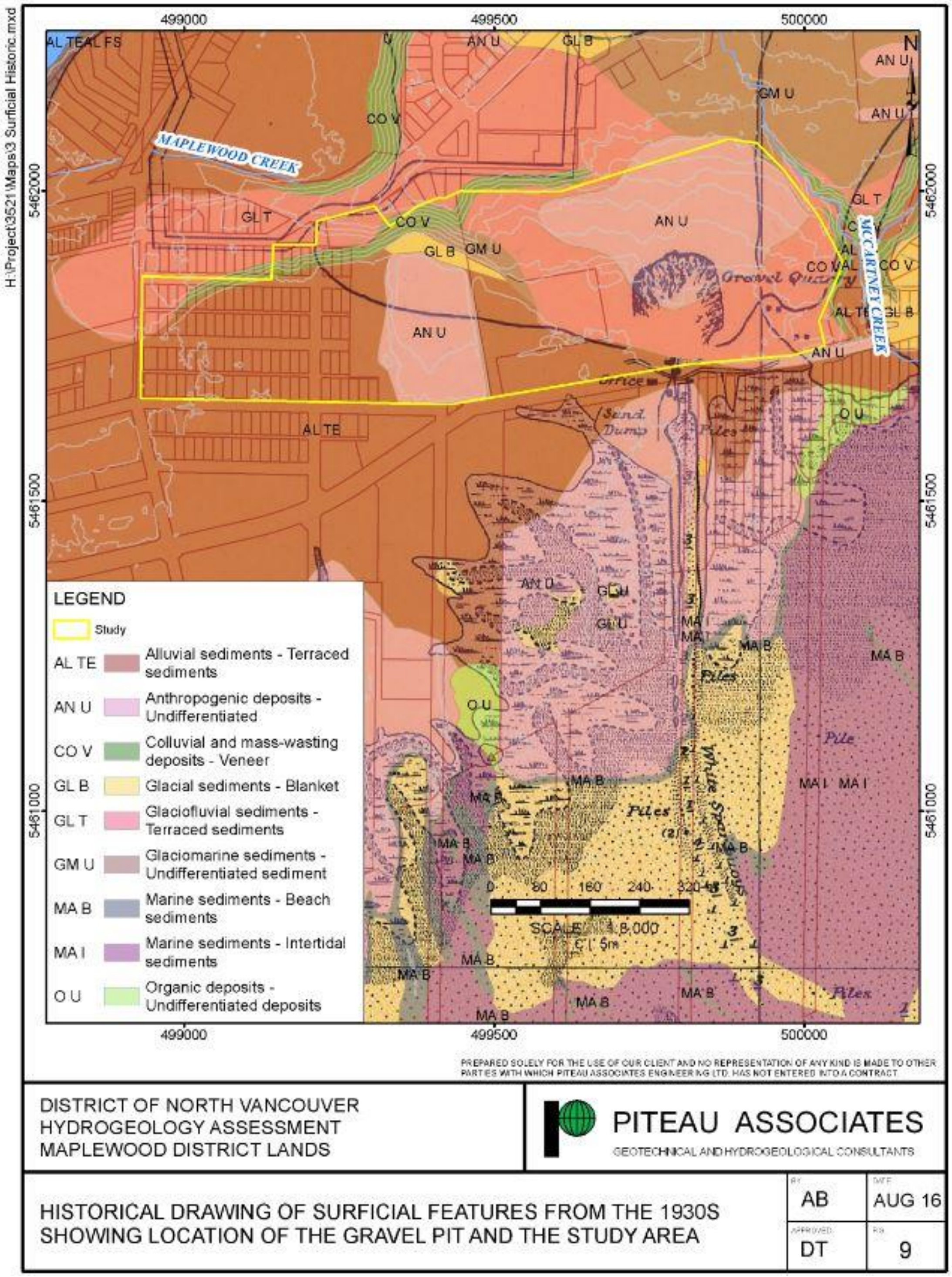

Figure 9. Historical drawing of surficial features from the 1930's showing the location of the gravel pit and the Study Area.

3.7.3. Hydrological Connectivity

One of the Districts' objectives for the EA was to identify locations that will likely be sensitive to development at the Study Area. Of particular concern were local areas known to host wildlife and/or provide freshwater aquatic habitat. This study included an assessment of the hydraulic connectivity between the Study Area and nearby Hogan's Pools and the MCA as analyzed from the following hydrostratigraphic cross-sections.

Hydrostratigraphic cross-sections show the depth of the surface geology across the landscape. Cross sections are used to illustrate subsurface conditions, including the spatial relationships of sediments beneath the ground surface. Rather than a vertical map view, cross sections provide a horizontal view toward imaginary section lines. The three cross-section lines in black shown on *Figure 7* are diagramed on *Figures 10* and *11* with the ends of each cross-section line labeled by capital letters, for example A-A'.

Section A-A' on *Figure 10* shows sand and gravel deposits, in places cobbly, covering the western portion of the Study Area to a depth of about 22 m. Lenses of dense glacial till are present within sediments beneath portions of the Study Area, but the sand and gravel is present beneath. Hogan's Pools Park is near the left side of section A-A', underlain by till.

Section B-B' on *Figure 10* shows the steep escarpment along the northern Study Area boundary (the left side of the red line marked "STUDY AREA"). Glacial till and marine sediments are present in the escarpment, and a layer of till covers underlying sand and gravel in the Study Area.

Section C-C' shows dense till underlying the broad slope in the western portion of the Study Area to a depth of over 8m at MW15-6 (*Figure 11*). Buried peat deposits are present in the central portion of the cross section.

Hogan's Pools Park

Hogan's Pools Park is situated north of Mt. Seymour Parkway, near the northern end of cross section A-A' on *Figure 10*. It is a groundwater discharge area that supports a network of wetlands forming the headwaters of Maplewood Creek (Triton 1993). Most of the stream flows are sourced from groundwater, particularly in late summer. After a long interval with little precipitation, the stream flow is sourced entirely from groundwater discharging in seeps or springs issuing from permeable sand and gravel deposits. This is called a stream's baseflow, which for some streams is sensitive to competing groundwater users.

Triton (1993) tested sediments in ten auger test holes, and infer the sediments beneath Hogan's Pools Park to include a layer of dense, till at a shallow depth. This till layer is restrictive to downward groundwater seepage (impermeable), allowing groundwater perched on this layer to maintain its elevation until it discharges in springs to support the baseflow in the watercourses and pools. This till layers also prevents water from ponds and stream channels from rapidly seeping down into the sediments. As depicted on section A-A' (*Figure 10*), the till layer presents a hydraulic barrier between Hogan's Pools Park and the Study Area, allowing water to remain in the pools year-round at a much higher elevation than groundwater within the Study Area.

Maplewood Conservation Area (MCA)

The MCA lies south of Dollarton Highway, along the southern portion of cross section B-B' (*Figure 10*). The MCA includes ponds and bird habitat managed by the Wild Bird Trust of British Columbia. A water well ("72330" on *Figure 7*) is operated seasonally to augment the flow of surface water in watercourses and ponds at the MCA. Beneath the filled areas, surficial geology appears contiguous in the Study Area with the surficial geology at the MCA.

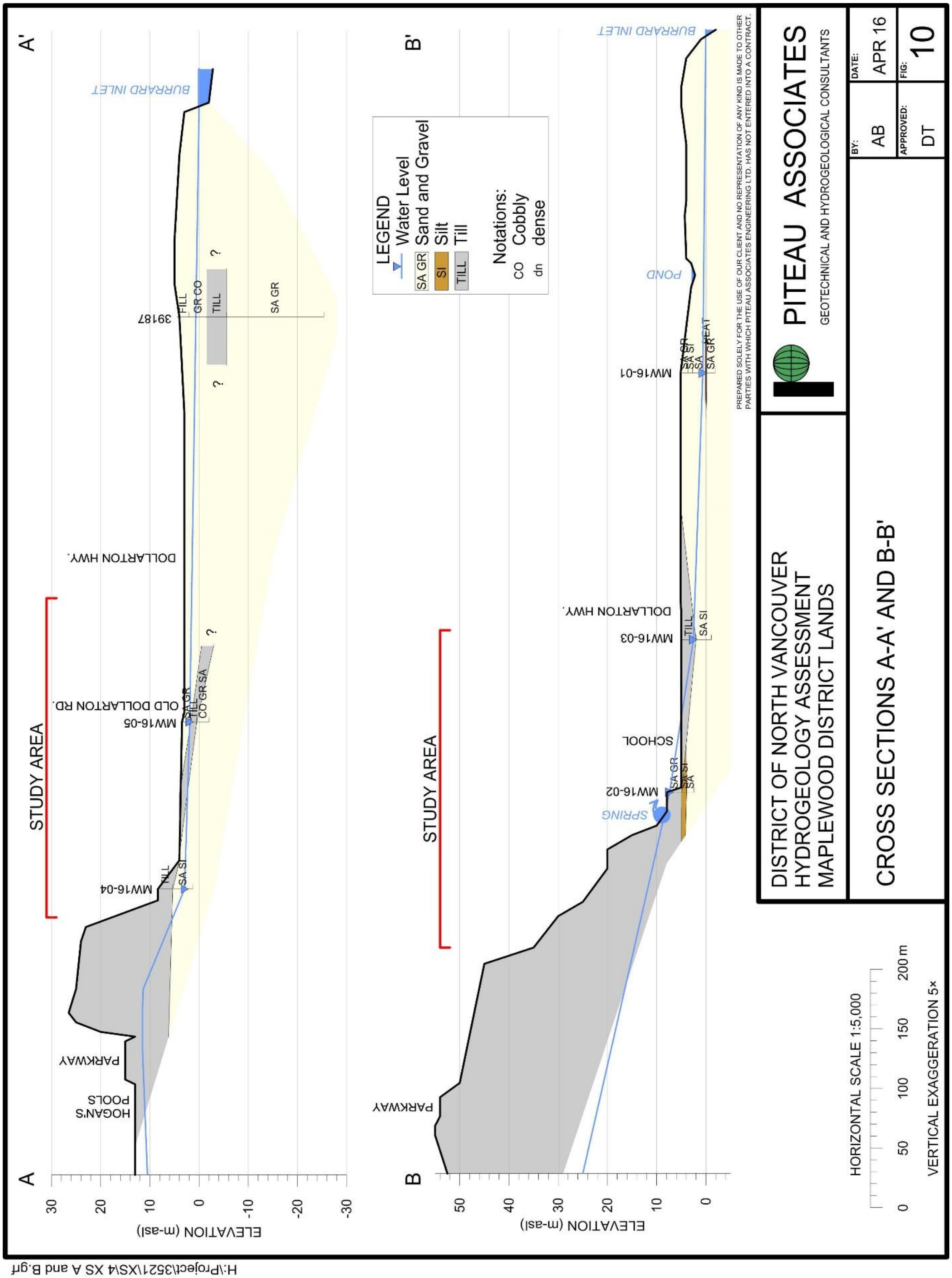

Figure 10. Hydrostratigraphic cross-sections showing subsurface features for lines A-A' and B-B' located on Figure 7.

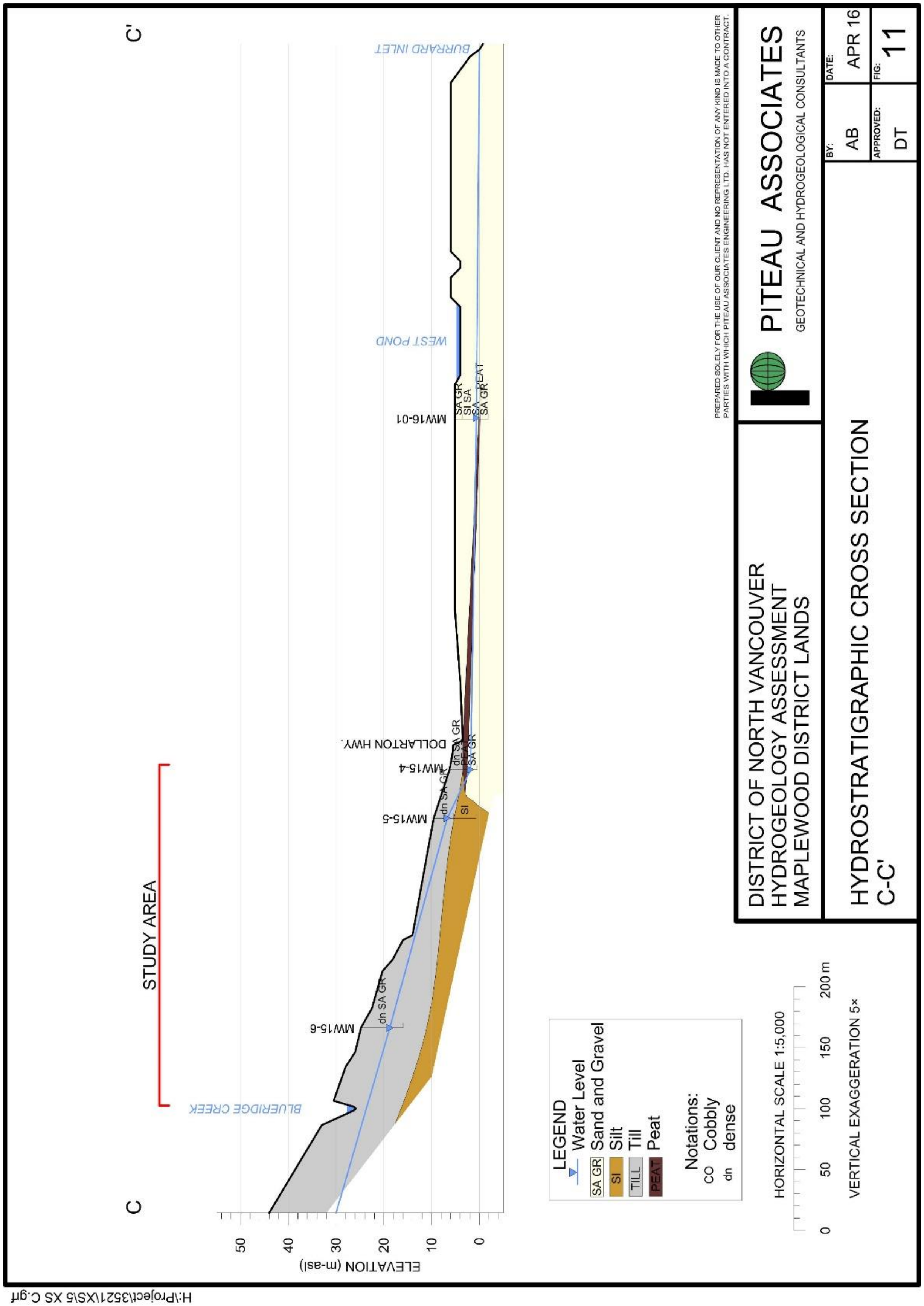

Figure 11. Hydrostratigraphic cross-sections showing subsurface features for line C-C' located on Figure 7.

Blueridge Creek

As depicted on section C-C' (*Figure 11*), sediments exposed in the Blueridge Creek valley include dense till that is restrictive to downward seepage. Where groundwater perched on the till daylights (seeps) in the valley, it contributes to the stream flow.

3.7.4. Groundwater Resources and Hydrogeology

Aquifer Mapping and Water Wells

Aquifer mapping by the BC Ministry of Environment (MOE) (Kreye *et al.* 1998) indicates that Aquifer 67 (Seymour River / Lynn Creek Aquifer) lies immediately west of the Study Area. The aquifer is not mapped beneath the Study Area because no wells were present from which to obtain information. The aquifer likely extends east beneath the plain in the western portion of the Study Area. Well logs indicate that the aquifer extends to a depth of 23m in places outside the Study Area.

Locations of water wells are shown by blue symbols on *Figure 8*, identified by their respective MOE Well Tag Numbers. Driller's estimated yield estimates for these wells range from 1 to 19 L / s (15 to 300 USgpm).

Sediments beneath the broad slope in the eastern portion of the Study Area comprise dense glacial till having low permeability. These have been explored to a depth of 8.8m in MW15-6. It is not known whether a sand / gravel aquifer is present at greater depths.

Sources of recharge to saturated sediments at the Study Area include precipitation (rain and melting snow), and seepage from up-gradient lithologic units to the north.

Water Table Mapping

Data from the monitoring wells were used to map subsurface sediments and measure the depth to groundwater on April 26 and August 4, 2016. The water level data are summarized in *Table 8.* Relative locations of surficial geology formations and groundwater occurrences at the Study Area are depicted in the cross sections for April 26 and August 4, 2016 on *Figures 10* and *11*, respectively.

Depth to the water table is presented in *Figures 12* and *13* with equal depths to ground water connected by contour lines (equipotential lines). These maps are useful for planning as they identify zones in which the water table is near surface. The water table is shallowest within the 1m contour north and west of the former landfill. Near MW16-02, groundwater flows to the ground surface as a series of springs along the base of the escarpment. The depth to water rapidly increases northward, as the topography of the escarpment rises more steeply than the water table. This relatively steep gradient is indicated by the close spacing of the contour lines. Comparison of *Figures 12* and *13* show an increase in the depth to water of about 0.3m to 0.5m across the Study Area.

Table 8.Monitoring well information and water level measurements

Monitoring Well ID	UTM East	UTM North	Top of Casing Elevation (m-asl) [1]	Depth to bottom (m-btoc)[3]	Date of Data Collection	Depth to Water (m-btoc)	Water Elevation (m-asl)
MW16-01	499681	5461393	5.13	5.95	26-Apr-2016	4.50	0.63
					4-Aug-2016	3.93	1.20
MW16-02	499452	5461887	7.92	4.99	26-Apr-2016	0.55	7.38
					4-Aug-2016	0.78	7.14
MW16-03	499483	5461672	5.02	5.17	26-Apr-2016	2.48	2.54
					4-Aug-2016	3.19	1.83
MW16-04	499193	5461872	8.35	7.08	26-Apr-2016	5.41	2.94
					4-Aug-2016	6.05	2.30
MW16-05	499223	5461668	3.47	5.25	26-Apr-2016	1.57	1.90
					4-Aug-2016	2.02	1.46
MW16-06	498954	5461762	5.96	5.64	26-Apr-2016	3.36	2.60
					4-Aug-2016	3.90	2.06
MW15-4	499792	5461737	6.24	5.79	26-Apr-2016	4.39	1.85
					4-Aug-2016	4.12	2.12
MW15-5	499801	5461815	9.58	4.27	26-Apr-2016	2.84	6.74
					4-Aug-2016	3.79	5.79
MW15-6	499967	5461952	24.78	7.91	26-Apr-2016	6.02	18.76
					4-Aug-2016	6.47	18.31

Notes:

[1] From total station survey by McElhanney (m-asl - metres above sea level).

[2] m-btoc – metres below top of casing

Equipotential lines for April 26 and August 4, 2016 are presented on *Figures 14* and *15.* These show the water levels converted to elevations and the contours of the water table. These maps are useful for interpreting the direction of groundwater seepage, which is always perpendicular to the equipotential lines (from high to low elevation).

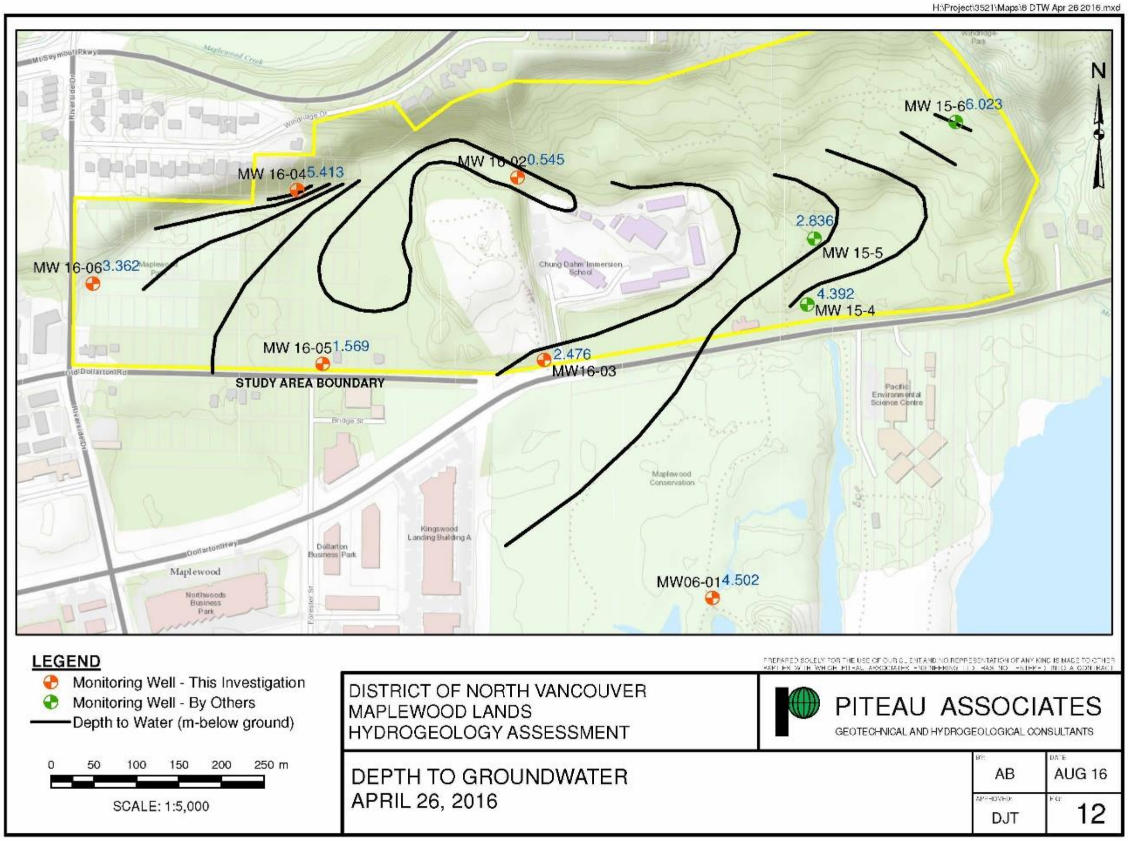

Figure 12. Black lines indicate equal depths to ground water derived from monitoring well data taken on April 26, 2016.

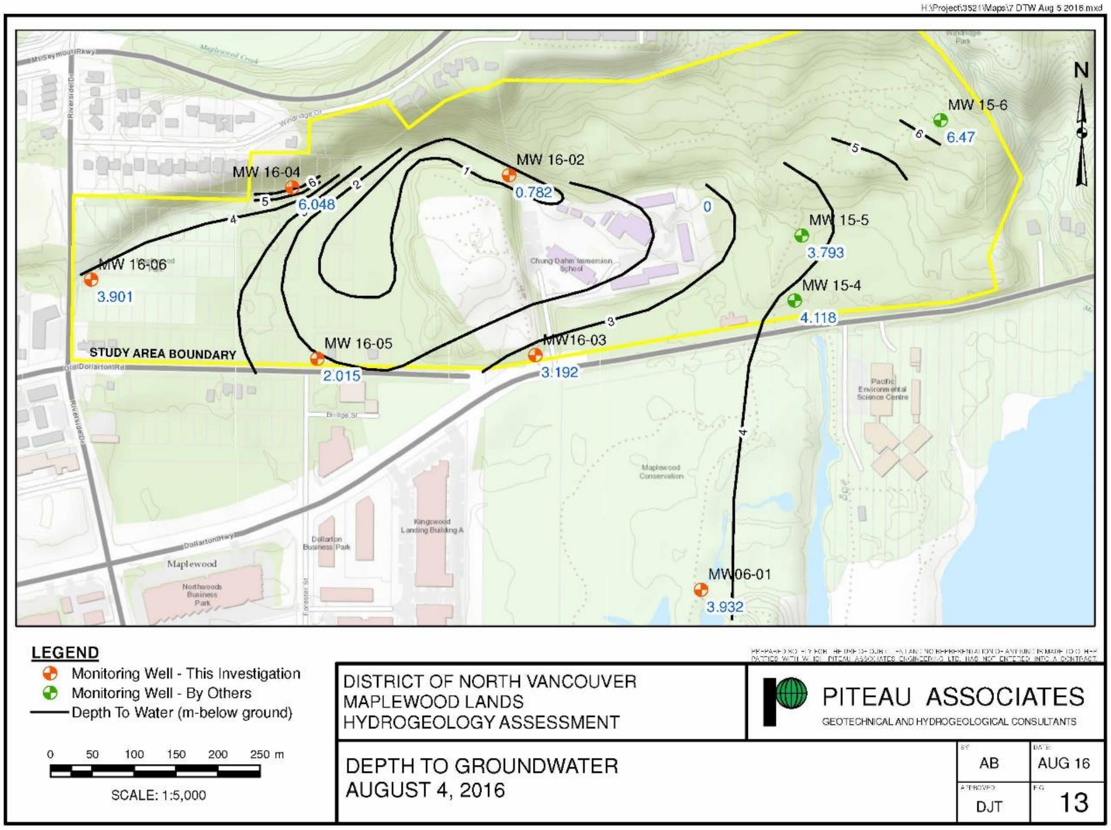

Figure 13. Black lines indicate equal depths to ground water derived from monitoring well data taken on August 4, 2016.

The interpreted groundwater seepage direction is generally toward the south and southwest. Comparison of the April and August equipotential maps (*Figures 14* and *15*) shows that equipotential lines have migrated northward during that interval. The corresponding drop in water table elevation is between 0.2 and 1.0m across the Study Area.

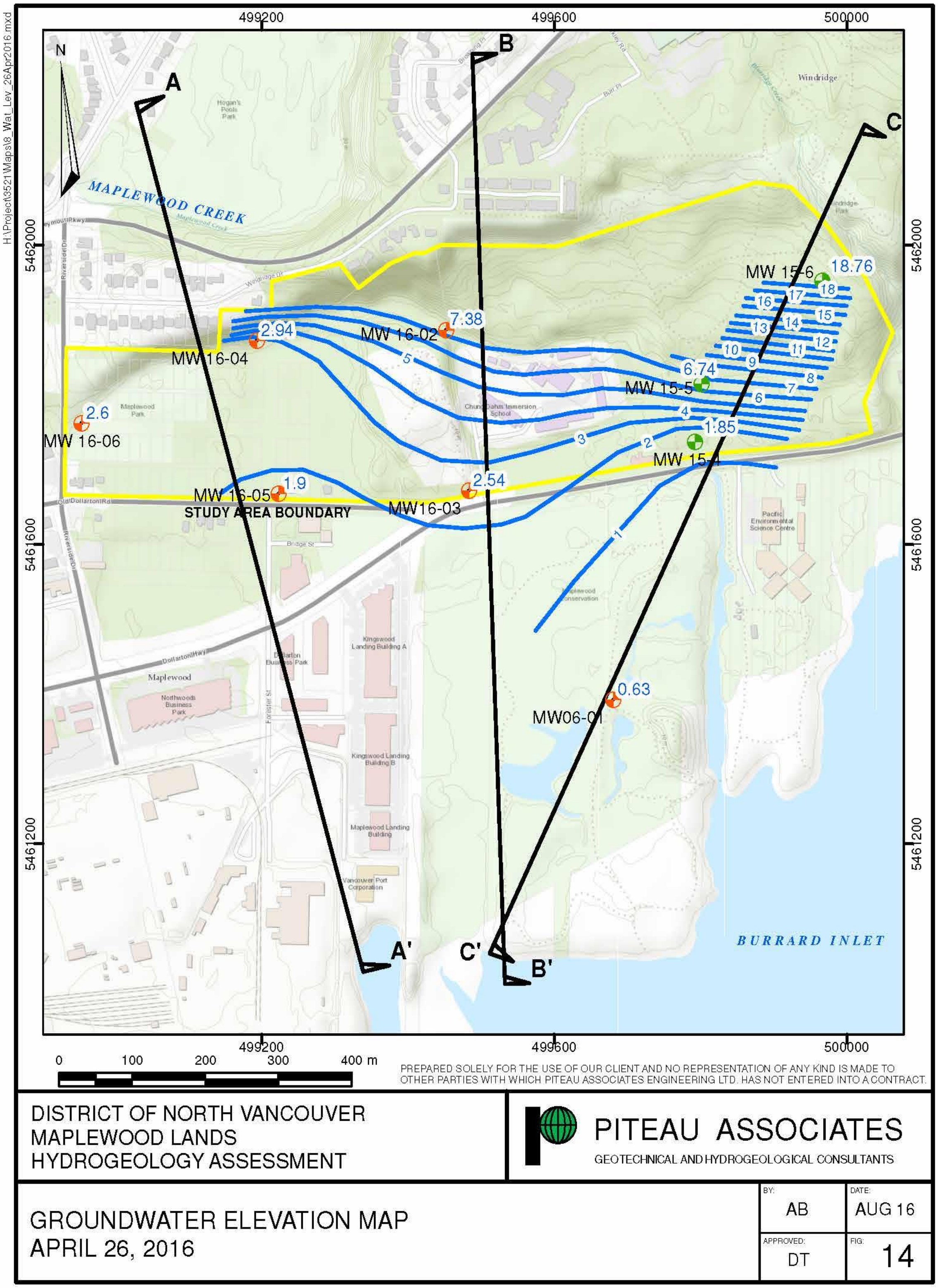

Figure 14. Ground water elevations mapped for April 26, 2016.

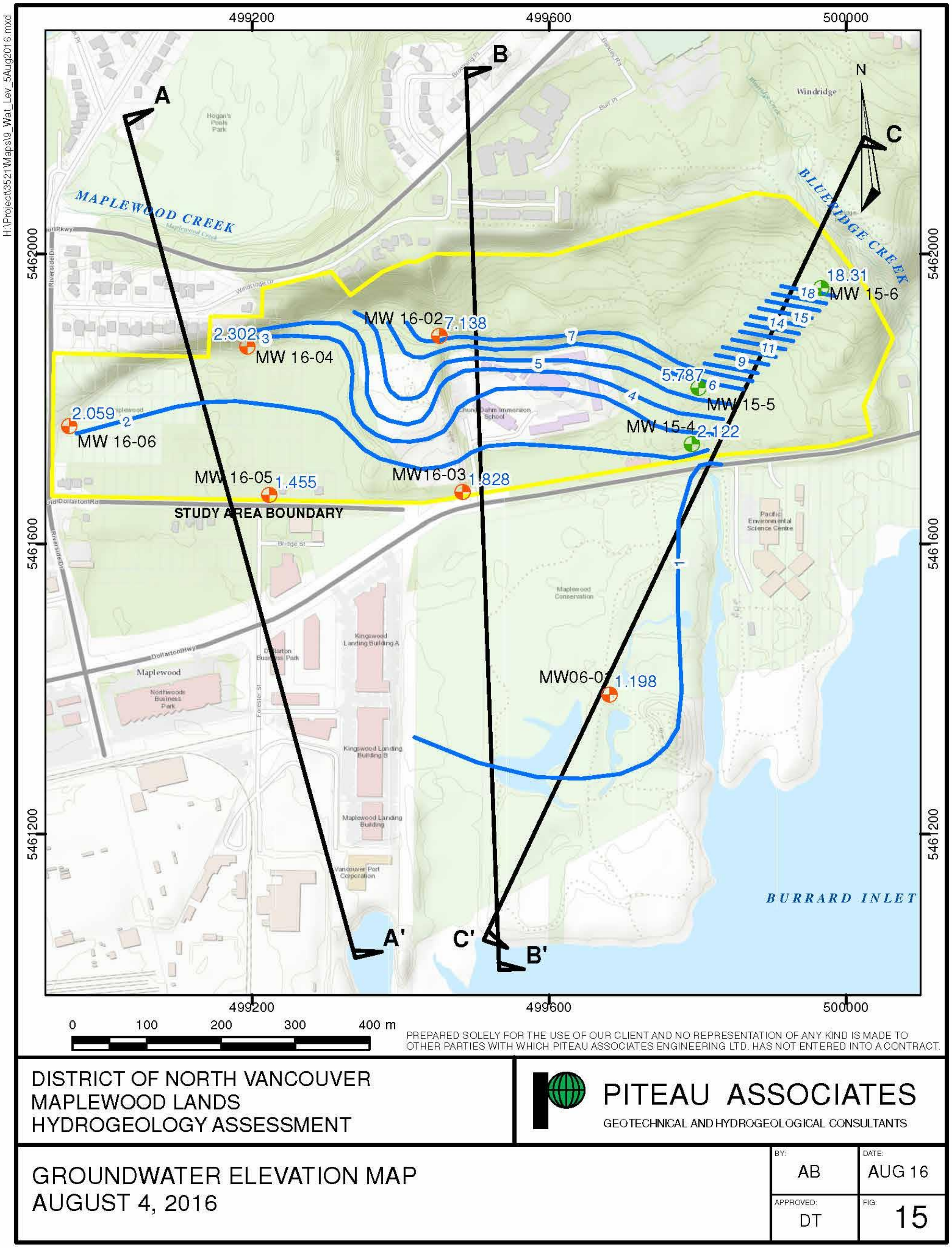

Figure 15. Ground water elevations mapped for August 4, 2016

The ground water levels also appear as blue lines on the cross sections on *Figures 10 and 11.* On the cross sections the depths to water and hydraulic gradients can be visualized. For example, beneath the plain (right side of Section A-A' on *Figure 10*) where gravelly sediments have a high hydraulic conductivity, the corresponding hydraulic gradient is low. Conversely, in till with a low hydraulic gradient (left side of Section A-A'), higher gradients are maintained. The symbol marked "SPRING" on Section B-B' (*Figure 10*) denotes an area where the water table intersects the ground surface, and groundwater seeps to the surface.

3.7.5. Groundwater Levels

Transducer-data loggers were deployed in six monitoring wells at the Study Area to measure and record water table levels at hourly intervals. The data are presented as a series of hydrographs in *Figures 16* and *17*.

The water level response to precipitation and tidal events provides some indication of aquifer permeability and confinement. For example, the screened section of MW15-6 is within dense till, and in the corresponding hydrograph (*Figure 16*), precipitation events do not correspond to water level variations. This indicates that the till unit acts as a confining layer, hydraulically separating the ground surface from saturated sediments at depth. In the current state (undeveloped), the infiltration rate into these sediments is low.

Conversely, the water level in MW16-03 (*Figure 17*) responds rapidly to precipitation events, confirming that no confining till cover is present in this area. MW16-03 is completed in gravely sediments that appear to form part of Aquifer 67. Rainfall in this area can readily seep into the soil (infiltrate) to replenish groundwater stores in the aquifer.

In MW16-03 a rapid water level rise of 0.4m occurred in response to a 0.06m rainfall on May 28 and-29, 2016. Assuming all the precipitation infiltrated into the ground, a 0.4m water level rise would require an unrealistically low sediment porosity of 0.15. Porosity is a measure of the void space between sediment grains, and a normal range is 0.2 to 0.3. Accordingly, it can be interpreted that rain water was concentrated in this area, possibly having been transported along the Dollarton Highway ditch system, or running off low-permeability sediments covering the old landfill. This should be taken into account when selecting areas for stormwater infiltration.

MW16-01 is situated in the MCA and its screen is completed in gravely sediments presumed to be the southeast extension of a nearby provincially mapped aquifer (Aquifer 67). Tidal influence is obvious in the water level record for this monitoring well. The lag time in tidal swings between Burrard Inlet and MW16-01 is 80 minutes. This relatively short lag time indicates high sediment permeability.

The hydrograph for MW16-06 (*Figure 17*), at the northwestern corner of Maplewood Village East, shows a dampened response to precipitation events, indicating that the 0.7m thick silty zone encountered above the aquifer in this borehole is sufficiently extensive to attenuate the response from the rainfall event.

3.7.6. Aquifer Hydraulics

The generally coarse sediments (sand and gravel) encountered in boreholes in the plain (in and around Maplewood Village East) of the Study Area indicate that relatively rapid groundwater seepage rates can be expected. Grain size analyses completed with samples of sediment collected from borehole cuttings are included as Appendix B. The samples were collected from depths between 2.4 and 8.2m below ground level, and hydraulic conductivity (K) values for these sediments were estimated using the Hazen formula. The geometric mean for the nine K values was 9×10^{-2} m / s, which is consistent with a coarse, permeable and free draining material.

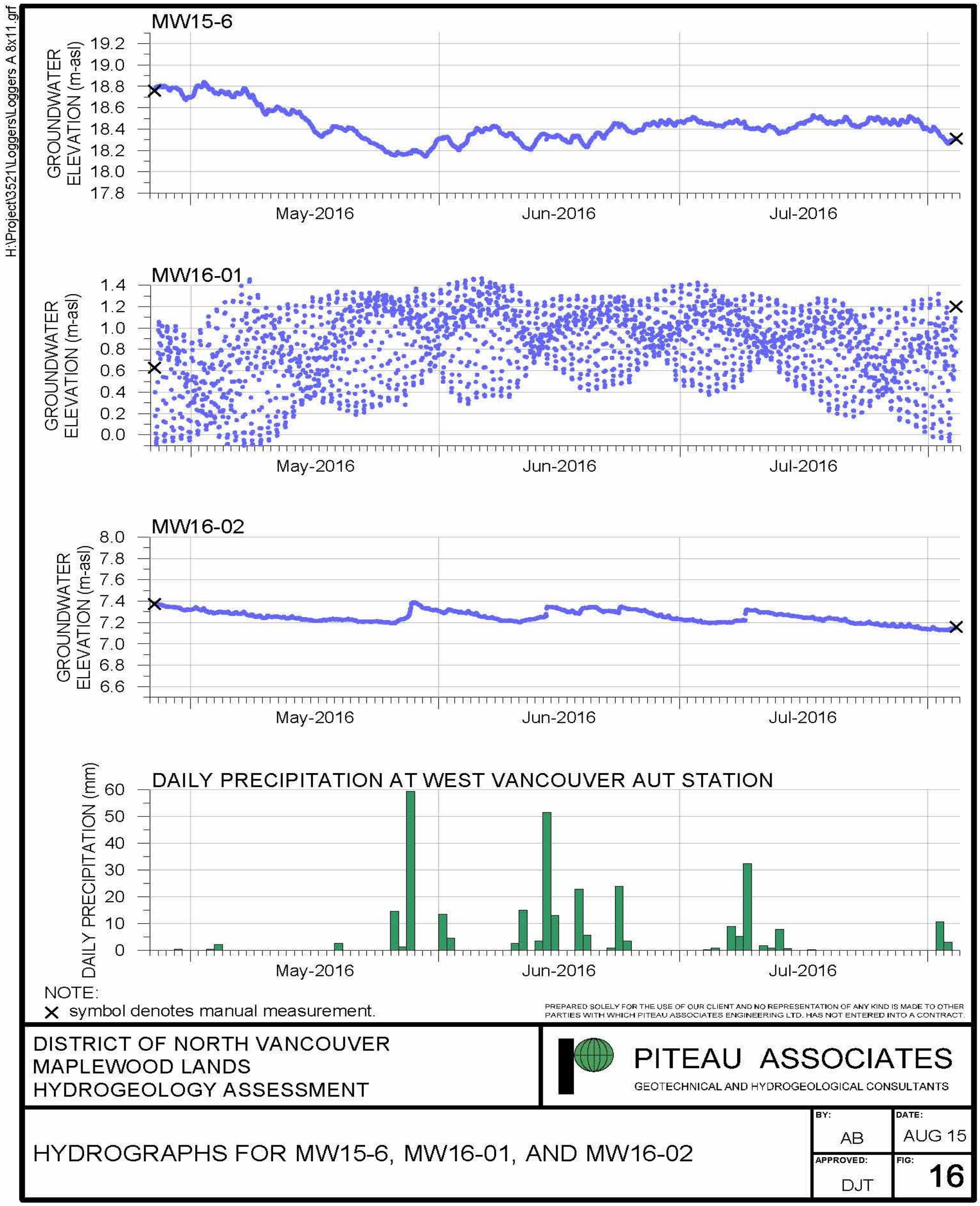

Figure 16. Hydrograph data (water levels) for three monitoring wells located in the MCA and northward in and around the District owned lands.

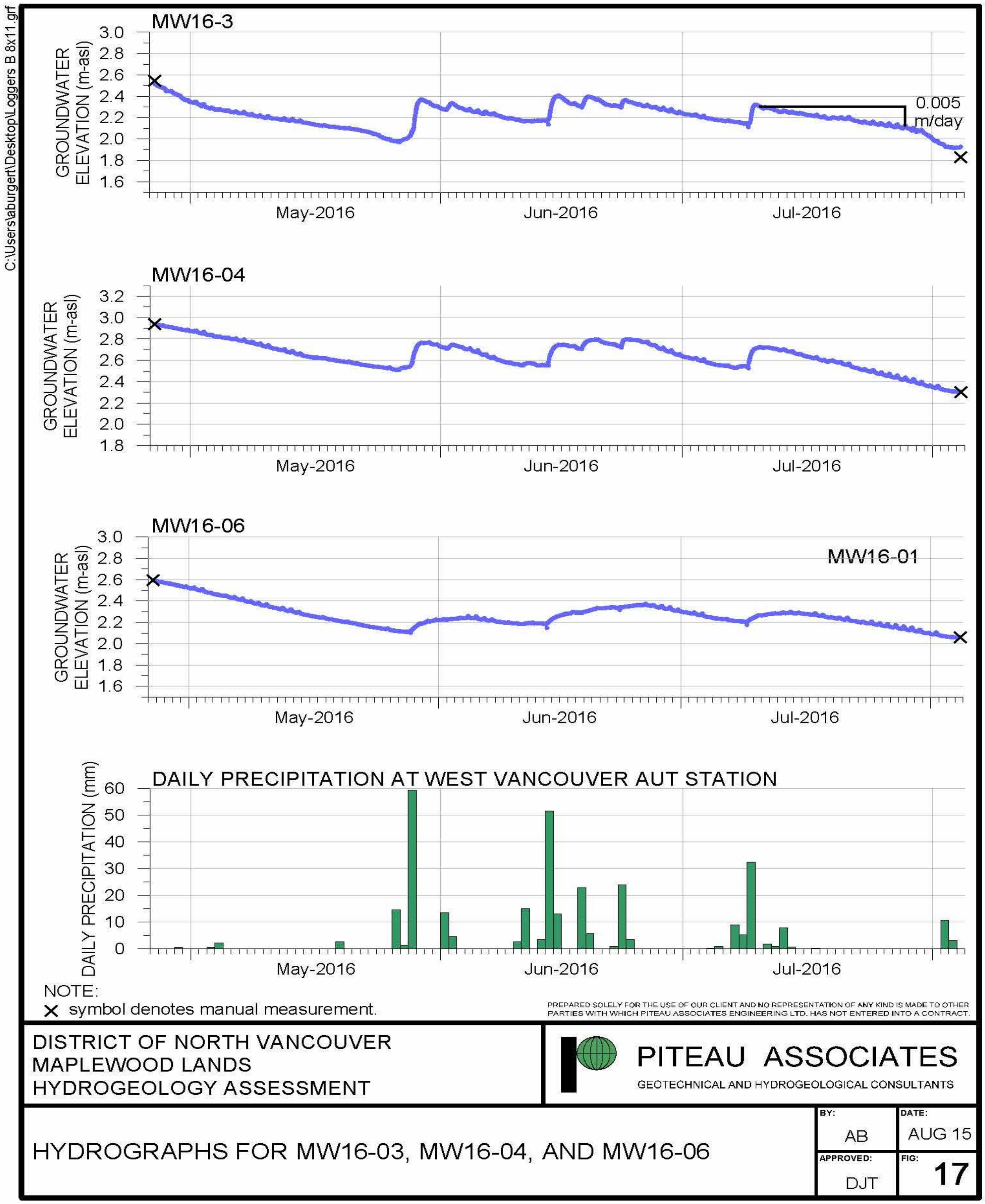

Figure 17. Hydrograph data (water levels) for three monitoring wells located in and around the west side of the Study Area in the Maplewood Village East.

3.7.7. Groundwater Flow Modelling

The rate at which groundwater seeps through sediments is controlled by the hydraulic gradient and hydraulic conductivity. The hydraulic gradient is the ratio of the difference in water table elevation to the distance between two points. If the water table is very flat, this means the gradient is low. Hydraulic conductivity is a measure of how easily water can seep through sediments. Sand and gravel have high hydraulic conductivity, whereas silt and clay have low hydraulic conductivity. For a given hydraulic gradient, more water will seep through sediments having a high hydraulic conductivity than through sediments with a low hydraulic conductivity.

Groundwater generally seeps toward the Study Area from the upland to the north. The higher hydraulic gradient in sediments north of the Study Area results from the presence of glacial till and marine deposits, both having relatively low hydraulic conductivities, within upland sediments. In sediments beneath the plain in the western portion of the Study Area, the hydraulic conductivity is very high, allowing seepage from upgradient sediments to be accommodated, even at a lower hydraulic gradient.

Groundwater seeping south from the Study Area passes beneath the MCA. This seepage from north to south represents an important source of recharge to the aquifer underlying the MCA. The aquifer, in turn, is the water source for the MCA augmentation well.

At the base of the slope near MW16-02, groundwater discharging from a series of seeps and springs feeds small watercourses. During the summer months, the watercourse draining west of the landfill has no surface outlet, indicating that the water not consumed by evapotranspiration is re-infiltrated into sandy sediments in the flat area south of the escarpment.

The largest source of recharge to the aquifer underlying the Study Area is seepage from upgradient sediments north of the Study Area. A secondary source of recharge is precipitation. The hydrographs in *Figures 10* and *11* indicate that across the plain in the western portion of the Study Area (Maplewood Village East area), infiltration is rapid. Conversely, infiltration rates in the broad slope area in the eastern part of the Study Area (Maplewood North Lands) are low.

3.7.8. Water Balance

A water balance that accounts for groundwater and surface water flows passing through the Study Area is presented as *Tables 10 and 11 in Appendix C. Table 10* models the fate of precipitation at the Study Area, accounting for soil moisture and losses through evapotranspiration and runoff. *Table 11* incorporates these results, in addition to seepage through the aquifer and monthly storage within it.

An estimate of the seasonal water level fluctuation was required to estimate monthly volumes of groundwater moving into and out of storage in the aquifer. This was obtained from the water level trend, which indicated the rate of water level recession at MW16-03 during July was 0.0050 m / day. This rate of decline extrapolated for a 120-day interval is 0.60m, and this was used to calibrate the seasonal storage factor in the water balance.

The balance indicates groundwater is continuously seeping beneath the Study Area at a rate ranging from about 62 L / s (985 USgpm) to 137 L / s (2180 USgpm). This flow seeps under Dollarton Highway and south to discharge into Burrard Inlet.

4. Environmentally Sensitive Resources

A variety of environmentally valuable resources were assessed in this EA including, but not limited, to vegetation, ecosystems, wildlife and habitat, sources of water and presence of watercourses, and fish habitat. Environmentally sensitive features have special attributes worthy of retention or special management attention to protect their value. Criteria considered in the identification of potentially environmentally sensitive features mapped for the Study Area in *Figure 18* included: 1) disturbance regime of the biotic communities observed including minimally disturbed areas and/or areas with diversity for a specific habitat type. These biotic communities may contain elements of conservation concern including species at risk and/or ecosystems at risk, wetlands or riparian areas; 2) ecological functioning needed to maintain a healthy ecosystem including provision of habitat, biodiversity, water supply, or corridor for wildlife within the system, 3) habitat or ecosystem providing representative habitat for wildlife of recognized significance and 4) presence of wetlands and watercourses including key areas that contribute to water quality, water quantity, and biological connectivity (MOE 2014).

The environmentally sensitive features map presented here (*Figure 18*) incorporates the above mentioned considerations together with the District's development permit quidelines and environmental protection legislation. The District has DPA guidelines for locating development away from a) habitat for species at risk, b) mature stands of trees, c) raptor's nesting sites, d) wetlands, and e) wildlife corridors.

Sensitive features found within the Study Area and discussed below include: steep forested slopes, wetlands, watercourses and riparian areas, mature forested ecosystems- at- risk, and wildlife habitat and raptors nests within 100 m of the Study Area.

Steep Slopes of the Escarpment

- The escarpment provides water seeps that flow to wetlands and provide wildlife habitat. We recommend the use of appropriate buffers from development at the base or top of slope (20 m as per the OCP or more as directed by a geotechnical expert) and maintaining forested vegetation on those steep slopes to provide stability and continuity of forested habitat for wildlife access.

Vegetation Resources/ Forest Ecosystems

- Area 2 on the vegetation mapping (*Figure 4*) comprises a mature forest with the features of two provincially red-listed ecosystems at risk. This area is designated as a non-developable area due to its unique nature in the landscape, its immediate connectivity to wetlands (W1) and watercourses (CR7) and use as wildlife habitat and corridor and is designated as an ESA feature (*Figure 18*). No buffer has been placed on this forest ecosystem on the ESA mapping but it is bordered on three sides by other buffered sensitive features (steep slopes, wetlands, and watercourses).

Terrestrial Wildlife Resources

- Suitable habitat was observed for a variety of wildlife adapted to urban forests. Evidence of the presence of black-tailed deer, black bear and smaller animals such as raccoons left evidence of tracks in the wetlands within the Study Area.
- The forested and riparian areas provide nesting and foraging habitat for numerous bird species both resident and migratory.

- Bald Eagles and Osprey nest along the shores of the MCA. An known eagles' nest lies within 100 m of the Maplewood North Lands outside of the Study Area.
- Wildlife trees were observed throughout the area including nest trees and trees with obvious foraging marks.
- Provincially listed wildlife species may potentially utilize the Study Area due to the presence of suitable habitat conditions.
- Wildlife habitat connectivity (corridors) exist as the Study Area is bordered by several large greenspaces including the MCA, Windridge Park and the Blueridge Creek/ McCartney Creek ravine to the north and east and Hogan's Pool Park to the north west. These protected green spaces provide wildlife habitat and creation of greenways or habitat corridors along riparian areas within the Study Area, as recommended in *Figure 5*, will facilitate habitat linkage from the coastline to the mountains.

Water/Aquatic Resources and Habitat

- W1 and W2 are not readily replaceable as fish and wildlife habitat and are designated in this study as non-developable areas (*Figure 18*).
- An apparent permanent seep coming from the escarpment provides water to CR7 and W1. This escarpment provides a water source for downstream systems and the riparian area of CR7 and the wetland are a natural wildlife corridor. This riparian corridor has as 15 m protective buffer on both sides as per the OCP DPA guidelines.
- Habitat for salmonids was found for W1 and W2. CR1 is expected to provide habitat for salmonids but culvert passage may be blocked or partially blocked. Access and habitat improvements would be required to provide improved habitat functionality particularly with respect to blocked culverts.
- Consolidation and reconfiguration of existing drainages to enhance seasonal flows into retained watercourses CR1 and CR10.
- Listed wildlife species, such as the Northern Red-legged Frog, may potentially utilize the wetlands, watercourse and other suitable habitat within the Study Area.

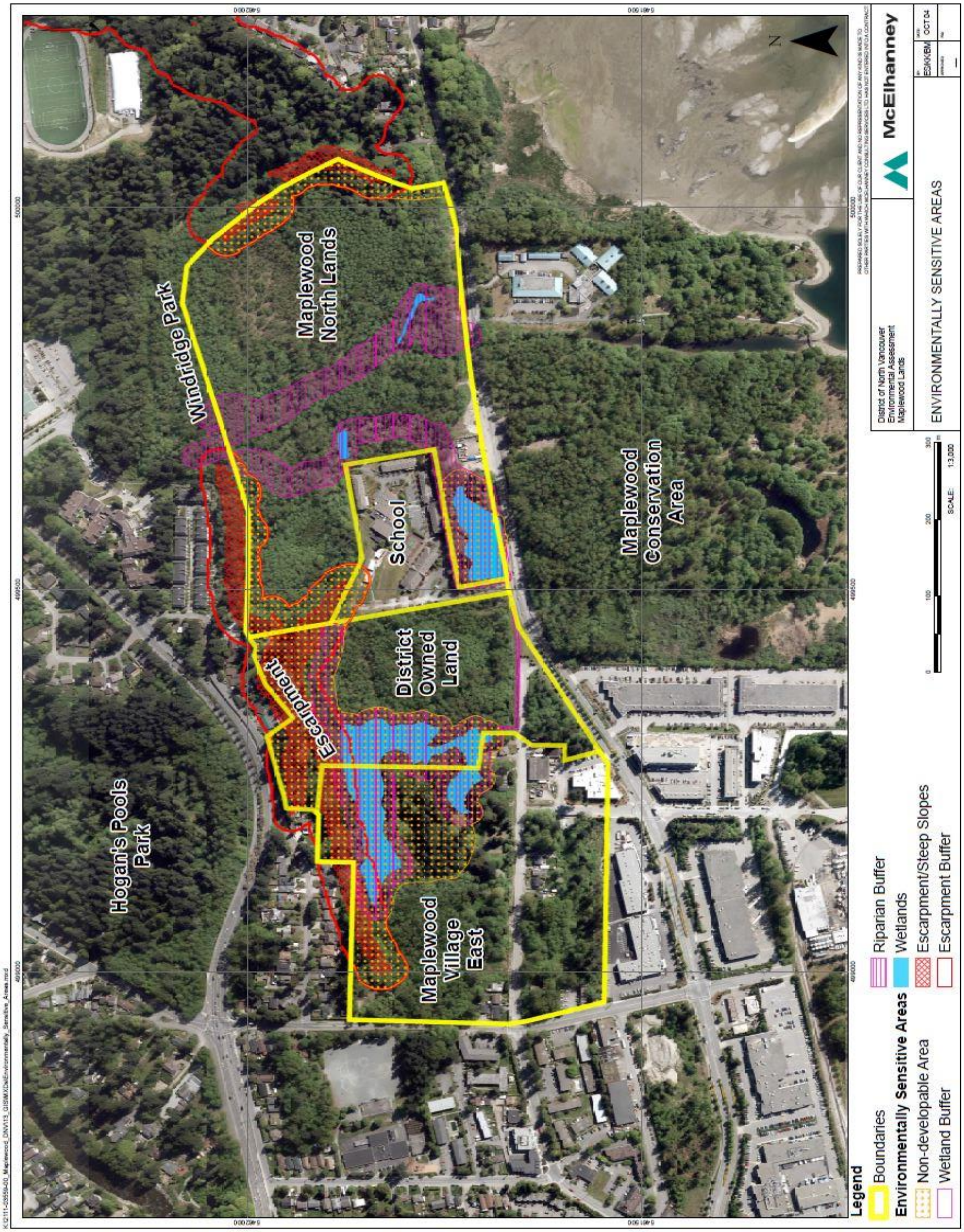

Figure 18. Environmentally sensitive features include wetlands, riparian areas, steep slopes and mature forest (ecosystem at risk).

5. Regulatory Considerations for Development

Several environmental statutes, regulations, and bylaws were reviewed for applicability in order to determine potential environmental protections that may be applicable to this Study Area and its future development. These are discussed and referenced with respect to potential impacts of development and mitigations.These include the following:

5.1.1. Federal

- The federal *Migratory Birds Convention Act* (MBCA) (Canada 1994) protects migratory birds and their nests during the bird breeding season. This Act prohibits the disturbance, destruction, or possession of migratory birds, their nests, or eggs. In addition, migratory bird habitat is protected under the MBCA which prohibits the deposit of oil, oily waters, or other substances harmful to migratory birds in any areas that they frequent.
- The federal *Fisheries Act* (Canada 1985, amended 2013) protects fish and fish habitat. The *Fisheries Act* and supporting policies aim to protect and manage fish habitats that support freshwater and marine fisheries associated with commercial, recreational or Aboriginal fisheries. The *Fisheries Act* regulates activities that affect fish or fish habitat including permanent alteration or destruction of habitat and deposition of deleterious substances into fish-bearing waters. Recent amendments to the *Fisheries Act* in 2012 shifted Fisheries and Oceans Canada's (DFO) emphasis from a broad-based protection of fish habitat to one that prevents serious harm to fish that are part of a fishery or to fish that support such a fishery. If a project cannot avoid serious harm to fish through mitigation measures, a DFO authorization is required. A DFO project review request can be submitted to the agency for determination if the project is deemed to require an authorization under Paragraph 35(2)(b) of the *Fisheries Act*. Under Paragraph 35(2)(b) of the *Fisheries Act*, the Minister of Fisheries and Oceans Canada may issue an authorization with terms and conditions in relation to a proposed work, undertaking or activity that may result in serious harm to fish. Habitat offsetting (development of new habitat) or compensation would be required to obtain a DFO authorization for such a project.
- The federal *Species at Risk Act* (Canada 2002) protects wildlife and wildlife habitat listed as threatened or endangered on federal lands. Federal lands are subject to the protection of species listed under Schedule 1 of SARA as extirpated, endangered or threatened (Canada 2002). It is an offence to kill, harm, harass, capture or take an individual, and that species has legal protection related to the species' residence and critical habitat as specified in *SARA*.

5.1.2. Provincial

- The provincial *Wildlife Act* (BC 1996a), Section 34, protects birds and their nests during the bird breeding season as well as the nests, nest trees and eggs of certain species of raptors all year. The provincial *Wildlife Act* Designation and Exemption Regulation (BC 2014), which indicates exemptions from permitting required under the *Wildlife Act* for nuisance wildlife.
- The provincial *Water Sustainability Act* (BC 2015), which governs works in or about a stream, surface water use, and diversions of water
- The *BC Weed Control Act* and Weed Control Regulations which requires control of designated noxious plants (MOA 2013).
- The provincial *Riparian Area Regulation* B.C. Reg. 376 / 2004 (Section 12 of the *Fish Protection Act)*, establishes protective riparian areas or streamside protection areas to support fish life processes. The province requires local governments to protect streamside areas from development activities through adherence to the provincial requirements, at a minimum, at a local level.

5.1.3. Municipal

- *District of North Vancouver OCP* (DNV 2014) guides planning and decision making for development within the District. As a municipal bylaw, it establishes policy and requirements concerning protection of the natural environment which is outlined in the OCP Schedule B Development Permit Areas. The DNV OCP outlines development permit areas for hazard lands and areas of environmental sensitivity such as streamside protection. The DNV OCP Schedule B policy concerning development around steep slopes is to avoid building a minimum of 20m setback from the base of a steep slope (>36% slope) (DNV 2014). On a site by site basis a geotechnical engineer's evaluation of a development setback beyond the minimum 20m from the toe of slope is required.

  Schedule B also provides guidelines that apply towards the protection of the natural environment DPA which locates development away from wildlife species at risk habitat, mature stands of trees, raptor nesting sites, wetlands, and wildlife corridors. The Streamside Protection DPA, which regulates development activities in and near watercourse to protect the aquatic environment, requires a 10m, 15m or 30 m streamside protected area from top of bank of a watercourse. For this study, a minimum 15m streamside protection buffer (setback) from the top of bank of retained watercourses is recommended.

All development plans must be compliant to municipal, provincial and federal legislation for the protection of the environment. Approvals, permits and authorizations must be obtained to for potential impacts to or modification to environmental resources that are protected under this legislation.

6. Potential Impacts of Development

6.1. On Environmental and Biological Resources

Potential impacts of development on environmental features include:

- Loss of contributions of the escarpment to water resources and wildlife habitat
- Loss of surface water flow to wetlands and fish habitat
- Loss of potential fish rearing habitat
- Loss of remnant forest (ecosystem at risk) that is important wildlife habitat (species at risk)
- Potential to spread invasive plant species existing on site.

6.2. On Hydrological Resources

Potential impacts on stream flows and aquifer recharge that could result from the proposed development include:

- Alteration of the groundwater flow regime;
- Impacts on water quality by urban stormwater being discharged to local watercourses;
- Increased stream peak flows resulting from surface hardening;
- Lower aquifer water levels and reduced stream base flows due to diversion of water that would have recharged aquifers.

7. Environmental and Hydrogeological Considerations for Development

The developable areas of the ESA map (*Figure 18*) are the unmarked areas of the map after applying protective buffers (or setbacks) to the identified ESA's that may be expected under provincial legislation or as District development permit requirements (DNV 2014). Though these areas may be identified as developable in this report, they contain vegetation, water and wildlife habitat resources requiring permits and approvals from regulatory agencies in order to be modified or otherwise altered or removed. Proposed or planned development must take into account risks associated with proximity to steep slopes (potential for landslide), the surface drainage and groundwater characteristics, and the wildlife and fish habitat that was present in the Study Area.

7.1. Environmental Considerations

7.1.1. Surface Water Resources

All of the watercourses within the Study Area were ephemeral (with the exception of CR7 which is fed from a groundwater seep). Important groundwater and drainage features within the Study Area include the seepage site and the drainage channels which have become ephemeral watercourses. These features convey water flow to marshes and fish bearing habitat in the MCA, particularly in the winter wet period. Water quality and quantity of water leaving the Study Area to this sensitive habitat must be maintained or improved. The quality of water entering fish bearing habitat is regulated under the federal *Fisheries Act* and the provincial *Water Sustainability Act.*

Development setbacks to protect watercourses and their riparian areas from development are recommended for CR7, CR10 and CR1 and for the wetlands, W1 and W2. The District's OCP Schedule B: Streamside Protection DPA requires a minimum streamside protection buffer which, for this study, was determined to be 15m from the top of bank on either side of a watercourse. These buffers from development are included on *Figure 18* as riparian buffers for the Study Area. Under the *Water Sustainability Act* approvals can be obtained from the Ministry of Forest, Lands, and Natural Resource Operations (FLNRO) to divert or move watercourses, particularly with respect to stormwater management around development. Habitat offsets or compensated area can be developed under the approvals and conditions set by FLNRO and DFO (if fish habitat is impacted). Watercourses and riparian buffer areas can be crossed by roads using culverts or bridges with approval from FLNRO.

As fresh water and fresh water habitat are under the jurisdiction of the Province, alterations to watercourses (diversion, piping) and wetlands (infill, diversion, rehabilitation) requires approvals from FLNRO and the Ministry of Environment. As wetlands provide habitat for variety of species of mammals, birds, amphibians and invertebrates, approvals to alter or infill (with compensation for lost habitat) may be obtained through applications to the Ministry of Environment and the Fish and Wildlife branch of FLNRO.

7.1.2. Fish and Wildlife Resources

Impacts to wildlife and wildlife habitat are legislated under the provincial *Wildlife Act* and the federal *Species at Risk Act (SARA).* No legislation exists to protect wildlife trees or wildlife habitat for unlisted species except as outlined in these Acts.

Numerous nests of bird species were found within the Study Area but none were observed on site that were protected under the *Wildlife Act Section 34b* provision for the year-round protection of nests of specific species such as the Bald Eagle and the Osprey. However, a Bald Eagle nest was located within 100 m of the Study Area that may require development buffers as outlined in the 'Develop with Care' guidelines (MOE 2014). Also, while unmarked areas on *Figure 18* are areas of low environmental sensitivity, it is possible that a situation may occur, such as a Bald Eagle building a nest within the Study Area, that could alter the developable area boundaries in the future. A breeding and migratory bird survey is recommended in advance of tree clearing or development of the area to avoid conflict with *Wildlife Act Section 34* or birds listed under the *MBCA*. It is further recommended that tree clearing or noisy construction activities be conducted outside the bird breeding window typically September 1 to February 29 of any year (MOE 2014). A qualified environmental professional may be engaged to conduct the surveys and prepare nest management and monitoring plans to mitigate potential risks.

Wetland 1 (W1), CR7 (a water resource and fish habitat) and the forested ecosystem-at-risk adjacent to it are natural environmental features that are to be protected under the DNV's Natural Environment DPA, Streamside Protection DPA, and under the *Fisheries Act* and the provincial *Water Sustainability Act, as* these habitats are connected or adjacent to fish habitat and provincial species at risk habitat (Northern Red-legged frog).

7.2. Hydrogeological Considerations

7.2.1. Alteration of the Groundwater Flow Regime

Residential and commercial developments present the potential to alter local groundwater flow regimes, and Hogan's Pools Park and MCA have been identified by the District as areas in which impacts from development are to be prevented. Impacts could occur if excavations below the water table involve long-term dewatering of saturated sediments to lower the water table, or if a large amount of stormwater is diverted from infiltrating into the ground. Provided that these conditions do not occur, the risk of development of the Study Area to impact groundwater conditions at Hogan's Pools Park and MCA is low.

In summary:

- Sediments at Hogan's Pools Park appear to be hydraulically separated from sediments at the Maplewood Study Area by a layer of dense till. Development of the Study Area is not likely to impact groundwater conditions at Hogan's Pools Park.
- Sediments at the MCA appear to be contiguous with sediments at the Study Area. Groundwater seeps southward from the Study Area to replenish groundwater supplies at the MCA. Development of the Study Area has the potential to impact groundwater conditions at MCA by hardening of surfaces in the western portion (Maplewood Village East) of the Study Area. This can be mitigated by incorporating design elements for stormwater infiltration.

7.2.2. Impacts on Water Quality

Runoff from residential and commercial developments has the potential to impact downstream water quality either by introducing pollutants, decreasing opportunities for passive attenuation, or both. Pollutants that can be introduced in a residential setting include suspended solids, petroleum from automobiles, and bacteria from animal waste. Natural attenuation of these contaminants can be decreased because hardened surfaces such as asphalt and sidewalks offer fewer opportunities for processes such as bacterial biodegradation, adsorption, and physical straining.

Water quality impacts from the proposed Maplewood development can be mitigated through the use of design elements such as rain gardens, bio-swales, filter strips, and vegetated retention ponds.

7.2.3. Increased Watercourse Peak Flows

Peak watercourse flows generated during rain events can increase as land is developed because runoff from hardened surfaces reaches an outfall more rapidly than runoff from undeveloped land. The peak runoff flow from undeveloped land is attenuated by the vegetated surface and by water percolating into the ground. In contrast, runoff from hardened surfaces reaches an outfall very rapidly unless engineered structures are placed along its path to delay the flow.

Attenuating watercourse flows would require the use of engineered structures to infiltrate as much rain water as possible into the ground. Since the ground consists of sand and gravel deposits, the infiltrative capacity in the Maplewood Village East area will likely be very high. Design elements such as infiltration trenches, soakaway pits, bio-swales, and filter strips will be effective provided that a sufficient thickness of unsaturated granular material is present to accommodate water table mounding. Till-covered areas in the Maplewood North Lands will not be suitable for stormwater infiltration, and detention ponds may be required to provide temporal storage for storm runoff.

7.2.4. Lower Aquifer Water Levels and Reduced Watercourse Base Flows

During the summer when precipitation rates are low, watercourses rely on groundwater discharging from aquifers as springs or seeps to sustain their flow. At the Study Area, groundwater discharges support fish habitat in local wetlands and watercourses. Residential and commercial developments have the potential to impact groundwater levels and discharge rates by diverting water that would have percolated down to replenish the aquifers that are the sources for the seeps and springs.

Mitigating impacts on watercourse flows and aquifer levels as the Study Area is developed will mean avoiding the use of conventional storm drain pipes to convey rain water off the Study Area. Rain water should instead be infiltrated into the ground at every opportunity where where it would be practicable based on sediment types and groundwater levels. For example, features like infiltration trenches, soakaway pits, bio-swales, and filter strips would likely be effective in portions of Maplewood Village East. Flows are most readily absorbed when distributed among numerous infiltration features distributed over a large area, rather than concentrated in a few large features. Infiltration features should be sized to accommodate most typical rainfall events, with only peak events clipped and discharged to a storm drain to prevent flooding.

While the sediments underlying the Maplewood Village East area are generally permeable, some areas are subject to a seasonal water table near ground surface. If these areas are to be developed, placement of granular fill will be required to provide unsaturated thickness for rain water infiltration. Infiltrating substantial amounts of stormwater through the till in the eastern portion of the Study Area will not be feasible, but since infiltration rates are low in the current (undeveloped) condition, no significant impact on infiltration rates is anticipated as the eastern area is developed.

7.2.5. Potential for Watercourse Flow Augmentation

Watercourse within the Study Area receive a portion of their flows from groundwater sources. After long intervals with little precipitation, such as late summer, water flow is supplied by springs and seepages along the banks and bed of the watercourses. In some municipalities, aquatic habitat for fish has been improved by augmenting the water flow during low-flow times. Groundwater sources are valuable for this purpose because groundwater temperature fluctuates less than surface water temperature, so springs provide a source of cool water to help regulate stream temperatures on hot days.

Hydrostratigraphic conditions at the Study Area present several options for augmenting flow to surface water watercourses. The maps showing the depth to the water table (Figures 10 and 11) can be used for planning augmentation features.

Diverting groundwater at a rate of up to 3 L / s (50 USgpm) for watercourse augmentation is not likely to impact recharge to the aquifer beneath the MCA, since the estimated seepage rate through the aquifer is an order of magnitude larger, and since a portion of the flow may reinfiltrate into the aquifer lower in the watercourse channel. Accordingly, groundwater can be used to augment stream flows at rates of up to 3 L/s without dedicated structures to reinfiltrate this flow.

To augment flows in watercourses, groundwater could be pumped from wells drilled in the aquifer. Existing wells south of the Study Area have driller's yield estimates of up to 19 L / s (300 USgpm), and productive wells could likely be constructed in the aquifer at the Study Area.

It may be possible to obtain a water source that supplies water without pumping by developing the spring near MW16-02. This could be accomplished by capturing the seepage in a French drain with a single outlet pipe.

Excavating beds of existing wetlands below the water table would result in their retaining water year-round.

8. Summary of Recommendations

The following are a summary of recommendations concerning the protection of environmentally sensitive features within the Study Area and potential development considerations:

8.1. Environmental

- Retain W1 and W2 and the watercourses that supply them. Provide protective riparian buffers which will also act as wildlife corridors connecting the MCA with upslope forest habitat. The connecting ditches also provide for fish passage and should be maintained for fish passage.
- Retain CR1 and the associated wetland (W4) and provide improved fish access and develop rearing habitat for salmonids.
- Reconfigure and consolidate ephemeral drainages within the Maplewood North Lands to improve retained watercourses such as CR1 and CR10 to a higher level of ecological function
- Enhance the vegetative character of the riparian area of retained watercourses
- Retain mature conifer forest at Maplewood Village East as it appears comprise a provincially listed ecosystem at risk and has high value as wildlife habitat

- Buffer the steep slopes of the escarpment from development and retain the forest on these slopes for greenway and wildlife habitat connectivity.
- Manage surface and groundwater resources with low impact stormwater management techniques and avoidance of deep building foundations which may require water management that could impact the ground water resource, particularly within the Maplewood Village East area.
- Ensure compliance to *Wildlife Act 34* and the *Migratory Birds Convention Act* by avoiding disturbance of breeding birds during development activities.

Buffer areas for the protection of environmental features should include measures to restrict human access or use so that they maintain some ecological functionality for wildlife.

8.2. Hydrogeological

The broad slope area occupies much of the Maplewood North Lands. Dense till present in this area has low permeability and allows little infiltration of precipitation. As a result, in its current (undeveloped) state, rainfall infiltration rates into sediments in this area are low. Accordingly, development of the till-covered slope area is not likely to impact groundwater conditions. The potential to infiltrate stormwater in this area is also low.

We anticipate that the feasibility of stormwater infiltration will be limited in areas having a shallow water table unless granular fill is placed. Construction of buildings with foundations penetrating the water table should be avoided.

The opposite is true of sediments underlying the plain in the Maplewood Village East area, where the potential to infiltrate stormwater appears to be high provided that a sufficient thickness of unsaturated granular sediment is present to accommodate mounding. Mounding occurs as the water table rises in response to water infiltrating from the surface. Modification of the ground surface, such as placement of low-permeability fill, could result in reduced infiltration rates.

The presence of coarse, permeable and free draining material in the Maplewood Village East area has several implications that may be pertinent to designing features within the development, for example:

- water features involving impounded water above the water table, such as for decorative ponds, will need to be lined to prevent water from rapidly seeping out;
- construction that relies on conventional perimeter drains for dewatering will not be suitable below the seasonal high water table, as the resulting groundwater inflows would be very large;
- stormwater can be rapidly discharged through constructed infiltration features provided that a sufficient thickness of unsaturated granular material is present.

Construction of buildings with foundations penetrating the water table should be avoided. We anticipate that the feasibility of stormwater infiltration will be limited in areas having a shallow water table unless granular fill is placed. However, provided that a sufficient thickness of unsaturated granular sediment is present to accommodate mounding the potential to infiltrate stormwater appears to be high. Mounding occurs as the water table rises in response to water infiltrating from the surface. Modification of the ground surface, such as placement of low-permeability fill, could result in reduced infiltration rates.

<u>In Summary</u>

- Sediments beneath the broad slope occupying much of the Maplewood North Lands consist of dense till to a depth of more than 8m. The till limits infiltration of water, and development in this portion of the Study Area is unlikely to strongly affect groundwater conditions. Detention ponds may be required to provide temporal storage for runoff from hard surfaces.

- Sediments beneath the plain occupying much of the Maplewood Village East area consist of permeable sand and gravel. Hardening of surfaces in this area is likely to impact the volume of water infiltrating into the ground unless this is mitigated through the use of design elements for infiltrating stormwater and recharging ground water.
- Impacts to water quality, stream peak flows, stream baseflows, and aquifer water levels can be mitigated by incorporating design elements for infiltrating stormwater in the proposed development. Features include infiltration trenches, soakaway pits, bio-swales, filter strips, rain gardens, bio-swales, vegetated retention ponds, and detention ponds.
- In drained excavations penetrating the water table in the western portion of the Study Area (Maplewood Village East), substantial inflows of groundwater can be expected.
- Opportunities for stream flow augmentation include well construction or spring development. Wetlands could be reconfigured to retain water year-round by deepening them.

9. Conclusions

The environmental assessment found that the Study Area provided terrestrial and water habitat and resources for local and migratory birds as well as habitat for a variety of other animals. Also, the Study Area was a source of water, conveying surface water flows during the winter rainy season to the MCA, and contained watercourses that may be enhanced to provide improved winter rearing habitat for salmonids. The watercourse, CR1 and the wetlands, W1 and W2, and their upslope water sources (CR7 and CR10) were considered highly sensitive riparian and fish and wildlife habitat that must be retained and undeveloped. These areas also provide green corridors for wildlife movement to and from the MCA to upslope forests. The mature conifer forest adjacent to W1 is comprised of sensitive red-listed ecosystems at risk and important habitat for wildlife, including species at risk. Other environmentally sensitive features included the forested and steep escarpment slopes that are protected under the Steep Slope development permit guidelines of the District's OCP.

Potential direct environmental impacts of development include permanent loss of wildlife habitat, loss of surface water resources to fish bearing habitat, and loss of wetlands and wetland habitat. Permanent impacts of development of the Study Area can be mitigated by avoidance of building on those areas in which impacts to terrestrial and aquatic resources would be high and/or difficult to replace as compensation for loss of habitat. The escarpment slopes are a source of surface water seeps feeding watercourses and wetlands, provide wildlife habitat and are known to be unstable in areas. Recommendations include maintaining forested vegetation on those steep slopes to provide stability and continuity of forested habitat for wildlife access. Appropriate buffers (setbacks for development) from the top or base of steep slopes are outlined in the OCP or may be modified a the recommendation of a geotechnical expert.

Water resources such as watercourses and wetlands have legislated protections by the Province. Other development restrictions include 1) riparian buffers or setbacks along watercourses that are important sources of water for the wetlands and for downstream aquatic habitat in the Maplewood Conservation Area and 2) retention of wetlands, W1 and W2, which provide important habitat for wildlife and fish and are difficult to replace through development of compensatory habitat that would be required by regulatory agencies under the provincial *Water Sustainability Act* and the federal *Fisheries Act.*

Watercourses and wetlands to be retained for fish and wildlife habitat can be protected from the impacts of development by appropriately sized riparian buffers. Indirect impacts of development within the Study Area include the potential for disturbance of breeding/nesting birds protected under legislation as follows: a) birds and their nests protected under the *Migratory Birds Convention Act* and b) birds and their nests protected under the provincial *Wildlife Act* Section 34. Impacts can be mitigated through construction scheduling outside of the bird breeding window and/or environmental monitoring of active nests during the breeding season to observe and report that birds are not being disturbed during this critical period. If there is evidence of disturbance, the work causing the disturbance would need halt until the active nest had fledged (young had left the nest).

In the hydrogeological assessment, surficial geology and groundwater occurrences in the Study Area were investigated and potential impacts of development were assessed. Salient findings include the determination of the character of sediments underlying Hogan's Pools Park. These sediments appear to be hydraulically separated from sediments at the Maplewood Study Area by a layer of dense till. Development within the Study Area is not likely to impact groundwater conditions at Hogan's Pools Park.

Sediments underlying much of the Maplewood North Lands consist of dense till and development there is unlikely to have a strong impact on groundwater conditions on site or in the Maplewood Conservation Area. Conversely, sediments covering most of the Maplewood Village East area are permeable, and while there is the potential for development there to impact groundwater conditions, the impacts can be easily mitigated by incorporating storm water infiltration features within the development. Avoidance of deep building foundations in the Maplewood Village East area where the soils are permeable and the ground water elevations close to the surface is recommended.

Areas recommended for development contain environmental features such as water resources and wildlife habitat. Water quality and quantity impacts to downstream habitats can be minimized in the developable area through incorporation of low impact stormwater management techniques and without impacting quantity or quality of surface water flow to downslope habitats nor impact natural groundwater conditions.

Retention and protection of wetlands W1 and W2 and their associated permanent and ephemeral sources of water are recommended to maintain water resources to the habitat downstream in the MCA. These wetlands and riparian areas will provide natural corridors of vegetation cover for the movement of wildlife from through the area to and from the MCA. Other ephemeral watercourses may be reconfigured and consolidated, with approvals obtained under the *Water Sustainability Act*, to provide additional water resources to increase the ecological functioning of the retained watercourses and wetlands. Fish habitat enhancements may be possible within the Study area with the removal of fish passage barriers to improve access from the MCA. Augmentation (through the use of pumps and wells) of water flow and enhancement of habitat will increase the ecological function of the wetlands and watercourses.

10. Limitations

This investigation has been conducted using a standard of care consistent with that expected of scientific and engineering professionals undertaking similar work under similar conditions in B.C. No warranty is expressed or implied.

This report is prepared for the sole use of the District of North Vancouver. Any use, interpretation, or reliance on this information by any third party, is at the sole risk of that party, and Piteau and McElhanney accept no liability for such unauthorized use.

11. Closure

The information presented in this report is for use by the District of North Vancouver and their representatives as part of their land use planning. The objective of this assessment was to document inventory findings, identify environmentally sensitive areas and make recommendations to avoid and mitigate potential impacts from development.

We trust this report provides the information you require at this time. Please do not hesitate to call the undersigned with questions or concerns.

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Appendix A: Hydrogeological Study – Monitoring Well Drill Logs

MONITORING WELL ID: MW15-1

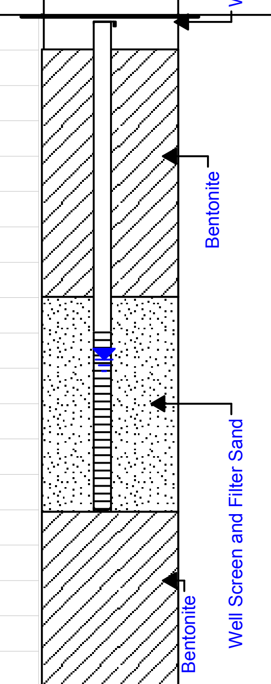
Keystone Environmental

Well Type: Groundwater Monitoring Well
Project Location: Maplewoods North, North Vancouver, BC
Drilling Contractor: Mud Bay Drilling Co. Ltd.
Drilling Equipment/Method: Sonic
Well Location: west of former buildings

Project Name/No.: 12325
Client: Darwin Properties (Canada) Ltd.
Engineer/Geologist: FOM
Drill Date: July 30, 2015
Page: 1 of 1

Depth (ft)	Depth (m)	Soil / Sediment Description	Sample Type	% Recovery	Sample Analyzed	Sample ID	Headspace (PID) ppm
0	0	Ground Surface					
0–1.5	0–0.15	***ROADBASE*** Roadbase					
1.5–9	0.15–2.75	***SAND and GRAVEL*** Brown-Grey medium to coarse-grained Sand and Gravel. Some cobbles. Dense, dry. Fine-grained sand content increasing with depth.	■	100	N	MW15-1 (0.5)	1.4
			■	100	N	MW15-1 (1.0)	2.2
			■	100	N	MW15-1 (2.0)	0.7
9–14	2.75–4.2	***SILTY SAND*** Dark brown, fine to medium grained Silty Sand. Dense and moist to wet. Saturated at 3 mbg. Some rootlets at 3.5 mbg.	■	100	N	MW15-1 (2.9)	2.1
			■	100	Y	MW15-1 (3.2) and MW15-A	3.7
							3.2
14–19	4.2–5.8	***SAND and GRAVEL*** Brown Sand and Gravel with cobbles. Wet and dense. Colour switchs to grey at 5.2 mbg.	■	100	N	MW15-1 (4.2)	
			■	100	N	MW15-1 (5.2)	2.1
19	5.8	End of Hole					

Headspace (PID) scale: 0, 500, 1000, 1500, 2000 ppm



Date of Water Level: August 4, 2015
Water Level (from TOC): 2.960 m

Well-Borehole Diameter: 15 cm
Well Casing Diameter: 5 cm
Well Casing Material: PVC
Well Screen Slot Size: 0.025 cm

Depth of Well (TOC): 4.068 m

MONITORING WELL ID: MW15-2/SV15-2

Keystone Environmental

Well Type: Groundwater and Soil Vapour Monitoring Well
Project Location: Maplewoods North, North Vancouver, BC
Drilling Contractor: Mud Bay Drilling Co. Ltd.
Drilling Equipment/Method: Sonic
Well Location: south of former buildings

Project Name/No.: 12325
Client: Darwin Properties (Canada) Ltd.
Engineer/Geologist: FOM
Drill Date: July 30, 2015

Depth (ft)	Depth (m)	Soil / Sediment Description	Sample Type	% Recovery	Sample Analyzed	Sample ID	Headspace (PID) ppm	Remarks
0	0	Ground Surface						Well Cover
0–1		***ROADBASE*** Roadbase						
1–14	0.3–4.2	***SAND and GRAVEL*** Brown-Grey medium to coarse Sand and Gravel. Some cobbles. Some silt. Dense, dry. Silt and moisture content increasing with depth. Wet at 3.7 mbg.	■	100	N	MW15-2 (0.5)	0.0	Bentonite
			■	100	N	MW15-2 (1.4)	0.0	Soil Vapour Screen and Sand
			■	100	Y	MW15-2 (2.2)	13.7	Bentonite
			■	100	N	MW15-2 (3.2) and MW15-B	3.2	Well Screen and Filter Sand
14–15	4.2–4.6	***SILTY SAND*** Grey fine to medium grained Silty Sand. Dense and wet.	■	100	N	MW15-2 (4.2)	3.3	
15–17	4.6–5.2	***PEAT*** Dark-brown Peat. High fibre content. Damp.	■	100	N	MW15-2 (4.9)	3.7	
17–19	5.2–5.8	***SAND and GRAVEL*** Brown to grey Sand and Gravel with cobbles and some silt. Moist to wet.	■	100	N	MW15-2 (5.4)	2.1	Bentonite
		End of Hole						

Headspace (PID) scale: 0, 500, 1000, 1500, 2000 ppm

Date of Water Level: August 4, 2015
Water Level (from TOC): 3.01 m

Well-Borehole Diameter: 15 cm
Well Casing Diameter: 5 cm
Well Casing Material: PVC
Well Screen Slot Size: 0.025 cm

Depth of Well (TOC): 4.23 m

MONITORING WELL ID: MW15-3

Well Type: Groundwater Monitoring Well
Project Location: Maplewoods North, North Vancouver, BC
Drilling Contractor: Mud Bay Drilling Co. Ltd.
Drilling Equipment/Method: Sonic
Well Location: east of former buildings

Keystone Environmental

Project Name/No.: 12325
Client: Darwin Properties (Canada) Ltd.
Engineer/Geologist: FOM
Drill Date: July 30, 2015
Page: 1 of 1

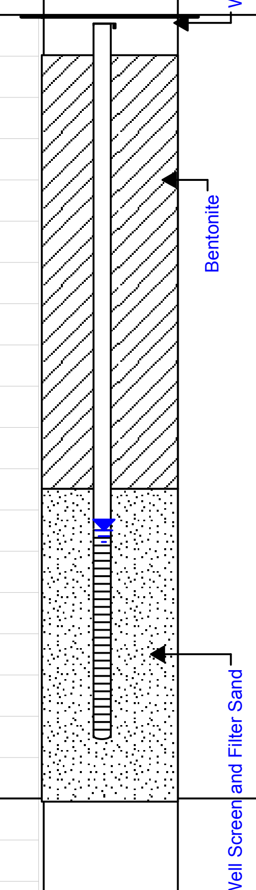
Ground Surface

Depth (m)	Soil / Sediment Description
0 – ~0.3	***ROADBASE*** Roadbase
~0.3 – ~1.8	***SAND and GRAVEL*** Brown-Grey medium to coarse Sand and Gravel. Some cobbles. Dense, dry. Boulder at approximately 1.5 mbg. Fine-grained sand content increasing with depth.
~1.8 – ~2.1	***GRAVEL*** Well-sorted gravel.
~2.1 – ~3.0	***SAND and GRAVEL*** Brown Sand and Gravel with cobbles. Dry to moist and dense.
~3.0 – ~3.7	***PEAT*** Dark Brown Peat. Moist to wet. Cedar-like wood fragments and odour. Low recovery, not enought to sample.
~3.7 – ~5.8	***SAND and GRAVEL*** Brown-Grey medium to coarse-grained Sand and Gravel. Some cobbles. Dense, dry. Boulder at approximately 1.5 mbg. Fine-grained sand content increasing with depth.

End of Hole

% Recovery	Sample Analyzed	Sample ID	Headspace (PID) ppm
100	N	MW15-3 (0.5) and MW15-C	2.6
100	N	MW15-3 (1.3)	3.3
100	N	MW15-3 (2.0)	8.0
100	N	MW15-3 (2.9)	5.2
100	Y	MW15-3 (3.8)	19.1
100	N	MW15-3 (4.6)	1.7
100	N	MW15-3 (5.4)	0.5

Well Construction / Remarks



Date of Water Level: August 4, 2015
Water Level (from TOC): 3.81 m

Well-Borehole Diameter: 15 cm
Well Casing Diameter: 5 cm
Well Casing Material: PVC
Well Screen Slot Size: 0.025 cm

Depth of Well (TOC): 5.44 m

MONITORING WELL ID: MW15-4/SV15-4

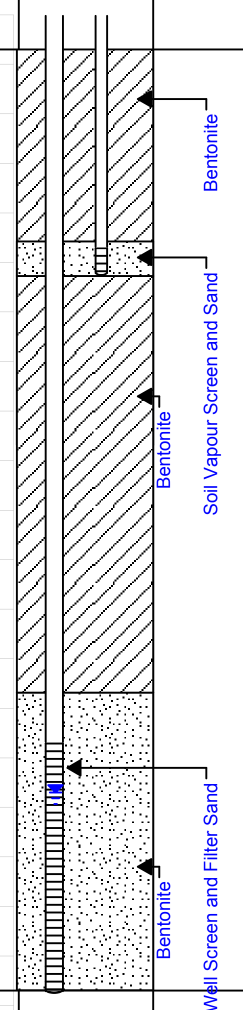
Keystone Environmental

Well Type: Groundwater and Soil Vapour Monitoring Well
Project Location: Maplewoods North, North Vancouver, BC
Drilling Contractor: Mud Bay Drilling Co. Ltd.
Drilling Equipment/Method: Sonic
Well Location: former potential ASTs area

Project Name/No.: 12325
Client: Darwin Properties (Canada) Ltd.
Engineer/Geologist: FOM
Drill Date: July 31, 2015

Depth (ft/m)	Soil / Sediment Description	% Recovery	Sample Analyzed	Sample ID	Headspace (PID) ppm
0	Ground Surface				
0–1.3 ft	***TOPSOIL*** Topsoil				
1.3–9 ft	***SAND and GRAVEL*** Brown-Grey medium to coarse Sand and Gravel. Some cobbles. Some silt. Dense, dry.	100	Y	MW15-4 (0.5)	37.3
		100	N	MW15-4 (1.0)	1.0
		100	N	MW15-4 (2.0)	6.4
9–12 ft	***PEAT*** Dark-brown Peat. High fibre content. Damp.	100	N	MW15-4 (3.0) and MW15-B	1.5
12–19 ft	***SAND and GRAVEL*** Brown-Grey medium to coarse-grained Sand and Gravel. Some cobbles. Some silt. Dense, dry.	100	N	MW15-4 (3.9)	0.0
		100	N	MW15-4 (4.1)	0.0
		100	N	MW15-4 (4.5)	0.0
		100	N	MW15-4 (5.0)	0.0
		100	N	MW15-4 (5.5)	0.0
19 ft	End of Hole				

Headspace (PID) scale: 0, 500, 1000, 1500, 2000 ppm



Date of Water Level: August 4, 2015
Water Level (from TOC): 4.91 m

Well-Borehole Diameter: 15 cm
Well Casing Diameter: 5 cm
Well Casing Material: PVC
Well Screen Slot Size: 0.025 cm

Depth of Well (TOC): 6.50 m

MONITORING WELL ID: MW15-5/SV15-5

Keystone Environmental

Well Type: Groundwater and Soil Vapour Monitoring Well

Project Location: Maplewoods North, North Vancouver, BC

Drilling Contractor: Mud Bay Drilling Co. Ltd.

Drilling Equipment/Method: Sonic

Well Location: central portion of the Site

Project Name/No.: 12325

Client: Darwin Properties (Canada) Ltd.

Engineer/Geologist: FOM

Drill Date: July 31, 2015

Page: 1 of 1

Depth (ft/m) | Symbol | Soil / Sediment Description | Sample Type | % Recovery | Sample Analyzed | Sample ID | Headspace (PID) ppm (0, 500, 1000, 1500, 2000) | Well Construction | Remarks

Ground Surface

TOPSOIL
Topsoil

SAND and GRAVEL
Brown-Grey medium to coarse Sand and Gravel. Some cobbles. Some silt. Dense, dry.

Boulders at 1.5 mbg and 2.5 mbg.

Colour changes to grey at 3.0 mbg.

Wet at 4.0 mbg.

SANDY SILT
Grey Sandy Silt with gravel. Very stiff and moist to dry.

Silt content increasing with depth.

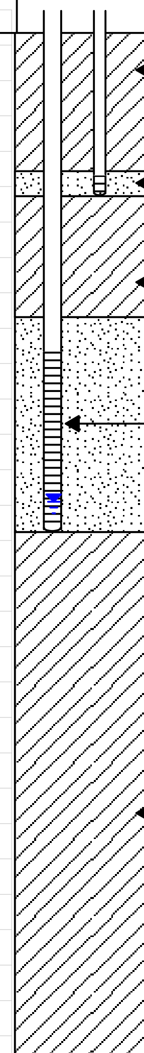
Moist at 6.0 mbg.

Decreasing moisture content with depth.

Increasing density with depth.

End of Hole

% Recovery	Sample Analyzed	Sample ID	Headspace (PID) ppm
100	N	MW15-5 (0.4)	3.3
100	Y	MW15-5 (0.8)	4.0
100	N	MW15-5 (1.1)	0.0
100	N	MW15-5 (1.5)	0.0
100	N	MW15-5 (2.0)	0.9
100	N	MW15-5 (2.2) and MW15-D	0.3
100	N	MW15-5 (2.5)	0.0
100	N	MW15-5 (3.0)	0.0
100	N	MW15-5 (4.0)	0.1
100	N	MW15- 5 (5.0)	0.6
100	N	MW15-5 (6.0)	0.0
100	N	MW15-5 (7.0)	1.1
100	N	MW15-5 (8.0)	0.0



Remarks: Bentonite; Soil Vapour Screen and Sand; Bentonite; Well Screen and Filter Sand; Bentonite

Date of Water Level: August 4, 2015
Water Level (from TOC): 5.0 m

Well-Borehole Diameter: 15 cm
Well Casing Diameter: 5 cm
Well Casing Material: PVC
Well Screen Slot Size: 0.025 cm

Depth of Well (TOC): 5.1 m

MONITORING WELL ID: MW15-6/SV15-6

Keystone Environmental

Well Type: Groundwater and Soil Vapour Monitoring Well
Project Location: Maplewoods North, North Vancouver, BC
Project Name/No.: 12325
Drilling Contractor: Mud Bay Drilling Co. Ltd.
Client: Darwin Properties (Canada) Ltd.
Drilling Equipment/Method: Sonic
Engineer/Geologist: FOM
Well Location: northeast portion of the Site
Drill Date: July 31, 2015
Page: 1 of 1

Depth (ft/m) | Symbol | Soil / Sediment Description | Sample Type | % Recovery | Sample Analyzed | Sample ID | Headspace (PID) ppm (0, 500, 1000, 1500, 2000) | Well Construction | Remarks

Ground Surface

TOPSOIL
Topsoil

SILTY SAND and GRAVEL (TILL)
Grey Silty medium to coarse-grained Sand and Gravel. Some cobbles. Dense, dry.

Moist at 4.0 mbg.

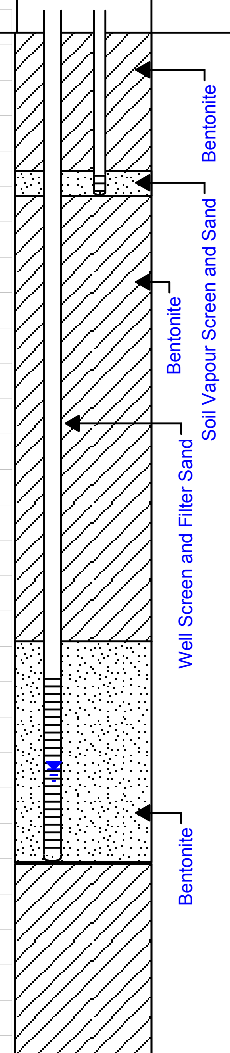
Cobbles content decreasing with depth.

Wet at 6.0 mbg.

Moist to dry at 6.9 mbg.

End of Hole

% Recovery	Sample Analyzed	Sample ID	Headspace (PID) ppm
100	N	MW15-6 (0.5)	0.0
100	N	MW15-6 (1.0)	3.0
100	N	MW15-6 (2.0)	2.2
100	N	MW15-6 (3.0)	1.8
100	N	MW15-6 (4.0)	2.9
100	N	MW15-6 (5.0)	1.2
100	N	MW15-6 (6.0)	1.8
100	N	MW15-6 (7.0)	0.8
100	N	MW15-6 (8.0)	1.4



Date of Water Level: August 4, 2015
Water Level (from TOC): 7.035 m

Well-Borehole Diameter: 15 cm
Well Casing Diameter: 5 cm
Well Casing Material: PVC
Well Screen Slot Size: 0.025 cm

Depth of Well (TOC): 7.940 m

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

Drillhole Number: MW16-01

Client: McElhanney/District of North Vancouver

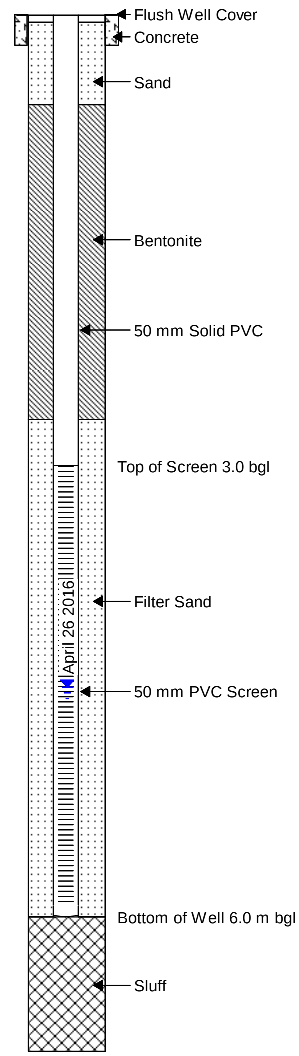
Project: Hydrogeology Assessment
Location: Maplewood District Lands, North Vancouver
Project Number: 3521
Logged By: Rob Bulger
Borehole Diameter: 15 cm (6")

Elevation (maSL)	Lithologic Description	Depth (mbg)	Sample ID
0.0	Ground Surface	0.0	
-0.5	**Gravely Sand** Brown, moist	0.5	
-0.9	**Gravely Sand** Grey, moist	0.9	
-1.4	**Silt and Sand** Grey, moist, some gravel	1.4	
-1.5	**Sand** Dark grey, moist, some gravel, some silt	1.5	
-2.4	**Silt** Light, grey, dry, stiff,trace sand, trace gravel	2.4	
-2.7	**Sand and Silt** Grey, moist	2.7	
-3.5	**Gravely Sand** Grey, moist	3.5	
-3.8	**Silt** Grey, wet	3.8	
-5.0	**Sand** Grey, wet, fine to med grained	5.0	13-15
-5.3	**Peat** Dark brown, wet	5.3	
-6.4	**Sand** Grey, wet, some gravel, trace cobbles	6.4	19-20
-7.0	**Gravely Sand** Grey, wet, trace cobbles	7.0	
	End of Hole		

Depth Below Ground Surface: ft 0, 5, 10, 15, 20, 25; m 0, 5

Remarks

Constructed Well



Drilling Contractor: Omega Drilling
Drilling Method: Sonic
Drilling Started: April 20 2016
Drilling Ended: April 20 2016

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

Client: McElhanney/District of North Vancouver

Drillhole Number: MW16-02

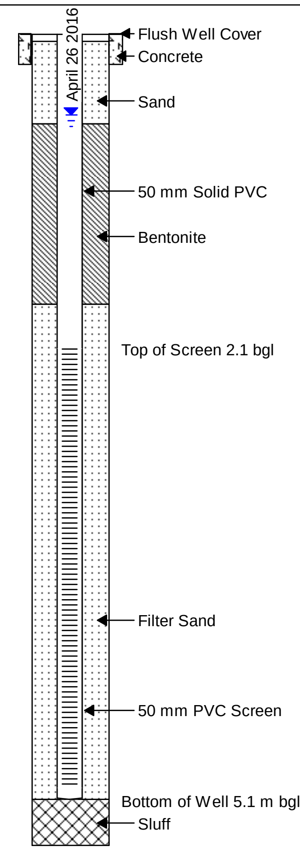
Project: Hydrogeology Assessment
Location: Maplewood District Lands, North Vancouver
Project Number: 3521
Logged By: Rob Bulger
Borehole Diameter: 15 cm (6")

Elevation (maSL)	Lithologic Description	Depth (mbg)	Sample ID
0.0	Ground Surface	0.0	
-0.9	**Gravel and Sand** Dark brown, moist	0.9	
-1.2	**Sand** Light brown, moist, some gravel	1.2	
-1.5	**Silty Sand** Light grey, moist	1.5	
-3.0	**Sand and Gravel** Dark brown, moist	3.0	
-4.0	**Sand and Silt** Dark brown, wet	4.0	10-12
-4.6	**Sand** Light brown, wet, some silt, trace gravel	4.6	
-5.5	**Sand** Light brown, wet, some gravel, some silt	5.5	16-17
	End of Hole		

Depth Below Ground Surface: ft 0, 5, 10, 15, 20, 25; m 0, 5

Remarks

Constructed Well



Drilling Contractor: Omega Drilling
Drilling Method: Sonic
Drilling Started: April 20 2016
Drilling Ended: April 20 2016

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

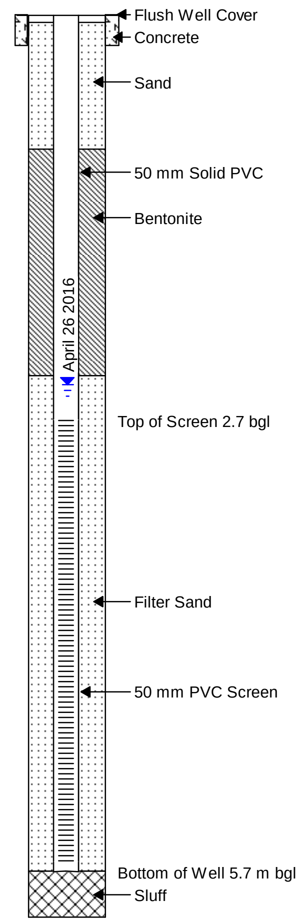
Client: McElhanney/District of North Vancouver

Drillhole Number: MW16-03

Project: Hydrogeology Assessment
Location: Maplewood District Lands, North Vancouver
Project Number: 3521
Logged By: Rob Bulger
Borehole Diameter: 15 cm (6")

Depth Below Ground Surface (ft / m)	Elevation (maSL)	Lithologic Description	Depth (mbg)	Lithology	Sample ID	Remarks
0 / 0	0.0	Ground Surface	0.0			
		Asphalt				
	-0.5	**Gravely Sand** Dark grey, moist, dense	0.5			
	-0.6	**Sand** Light grey, moist, some gravel	0.6			
	-1.2	**Sand, Silt and Gravel** Dark grey, moist, dense (Till)	1.2			
5	-1.5	**Sand and Gravel** Grey brown, dry, some, silt (Till)	1.5			
		Sand, Silt and Gravel Dark grey brown, moist (Till)				
	-2.6	**No Recovery**	2.6			
10						
15	-4.6	**Sand and Silt** Grey, wet, trace gravel	4.6			
/ 5	-4.9	**Silt** Grey, wet, some sand	4.9		17-19	
20	-6.1	End of Hole	6.1			
25						

Constructed Well



Drilling Contractor: Omega Drilling
Drilling Method: Sonic
Drilling Started: April 20 2016
Drilling Ended: April 20 2016

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

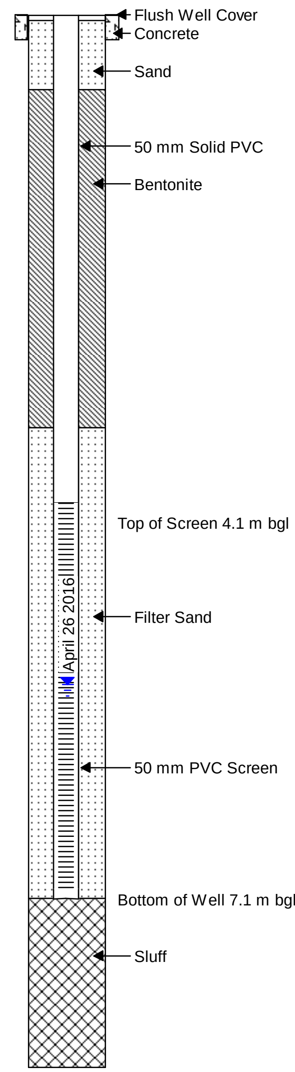
Client: McElhanney/District of North Vancouver

Drillhole Number: MW16-04

Project: Hydrogeology Assessment
Location: Maplewood District Lands, North Vancouver
Project Number: 3521
Logged By: Rob Bulger
Borehole Diameter: 10 cm (4")

Depth Below Ground Surface (ft)	Depth Below Ground Surface (m)	Elevation (maSL)	Lithologic Description	Depth (mbg)	Sample ID	Remarks
0	0	0.0	Ground Surface	0.0		
		-0.5	**Sand and Gravel** Dark brown, moist	0.5		
5		-1.5	**Cobbles and Boulders** Grey moist	1.5		
10		-3.0	**Sand and Gravel** Brown, moist	3.0		
15		-4.9	**Gravely Sand** Grey brown, moist, dense, some silt	4.9		
	5	-5.5	**Sand Gravel and Silt** Dark grey brown, moist	5.5		
		-5.8	**Silt and Sand** Grey brown, moist, some some gravel, trace cobbles, dense	5.8		
20		-7.3	**Sand** Grey brown, wet, some silt, some gravel	7.3	20-22	
25		-8.5	**Sand and Gravel** Grey, wet, trace cobbles	8.5	25-27	
30			End of Hole			

Constructed Well



Drilling Contractor: Omega Drilling
Drilling Method: Sonic
Drilling Started: April 21 2016
Drilling Ended: April 21 2016

PITEAU ASSOCIATES

GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

Client: McElhanney/District of North Vancouver

Drillhole Number: MW16-05

Project: Hydrogeology Assessment

Location: Maplewood District Lands, North Vancouver

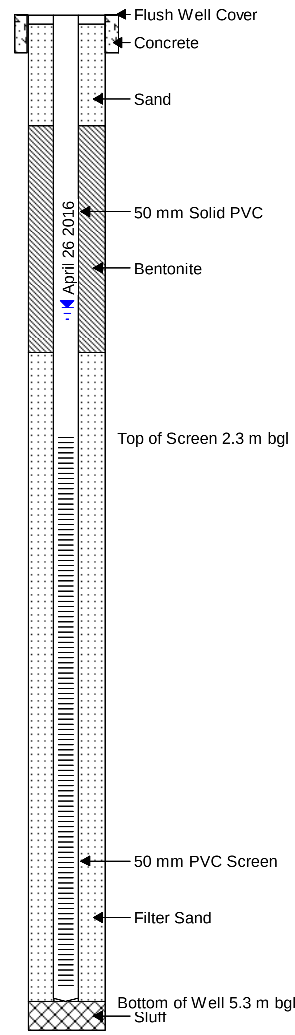
Project Number: 3521

Logged By: Rob Bulger

Borehole Diameter: 15 cm (6")

Depth Below Ground Surface (ft / m)	Elevation (maSL)	Lithologic Description	Depth (mbg)	Lithology	Sample ID	Remarks
0 / 0	0.0	Ground Surface	0.0			
	-0.3	**Organic Rich Soil** Dark brown, moist	0.3			
	-0.9	**Gravely Sand** Grey brown moist	0.9			
5	-1.5	**Gravely Sand** Grey, moist, some silt	1.5			
	-1.8	**Sand Gravel and Silt** Dark brown, moist	1.8			
10	-3.0	**Sand and Gravel** Grey dense, moist becoming wet @ 2.4 m, trace cobbles	3.0			
15	-4.6	**Gravel and Cobbles** Grey brown, wet, some sand	4.6		12-14	
/ 5	-5.5	**Gravely Sand** Grey, wet, trace cobbles	5.5		15-17	
20		End of Hole				

Constructed Well



Drilling Contractor: Omega Drilling

Drilling Method: Sonic

Drilling Started: April 21 2016

Drilling Ended: April 21 2016

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

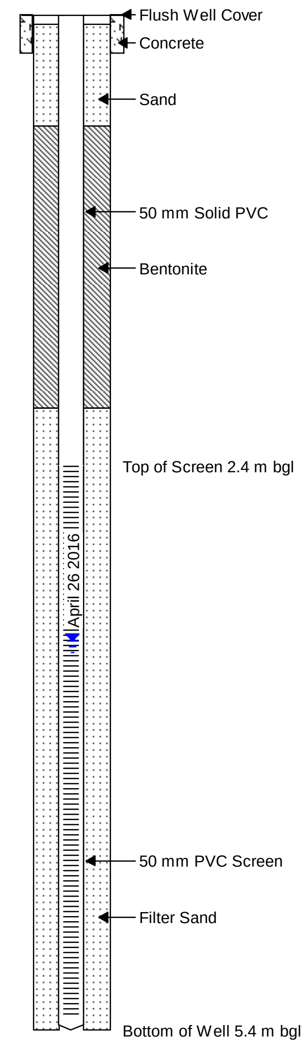
Client: McElhanney/District of North Vancouver

Drillhole Number: MW16-06

Project: Hydrogeology Assessment
Location: Maplewood District Lands, North Vancouver
Project Number: 3521
Logged By: Rob Bulger
Borehole Diameter: 15 cm (6")

Depth Below Ground Surface (ft / m)	Elevation (maSL)	Lithologic Description	Depth (mbg)	Lithology	Sample ID	Remarks
0 ft / 0 m	0.0	Ground Surface	0.0			
	-1.2	**Sand and Gravel** Grey moist (road base fill)	1.2			
5 ft	-2.3	**Sand and Gravel** Light brown, moist, some cobbles	2.3			
	-3.0	**Sand and Silt** grey brown moist, some cobbles	3.0		8-10	
10 ft / 15 ft / 5 m	-5.5	**Gravely Sand** Grey, wet	5.5		16-18	
20 ft		End of Hole				

Constructed Well



Drilling Contractor: Omega Drilling
Drilling Method: Sonic
Drilling Started: April 21 2016
Drilling Ended: April 21 2016

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 14564 Owner: CANADIAN OCCIDENTAL Address: 100 AMHERST AVENUE Area: NORTH VANCOUVER WELL LOCATION: NEW WESTMINSTER Land District District Lot: 193 Plan: 40923 Lot: A Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 83): 092G035222 Well: 2 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Licence General Status: UNLICENSED Well Use: Abandoned Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 12.0 inches Casing drive shoe: Well Depth: 68 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches	Construction Date: 1955-09-15 00:00:00 Driller: International Water Supply Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 300 (Driller's Estimate) U.S. Gallons per Minute Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 9 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag:

Well Cap Type:

Bedrock Depth: feet

Lithology Info Flag:

File Info Flag:

Sieve Info Flag:

Screen Info Flag:

Site Info Details:

Other Info Flag:

Other Info Details:

Material:

Method:

Depth (ft):

Thickness (in):

WELL CLOSURE INFORMATION:

Reason For Closure:

Method of Closure:

Closure Sealant Material:

Closure Backfill Material:

Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	null	null	null

GENERAL REMARKS:
TEST HOLE #3

LITHOLOGY INFORMATION:

From 0 to 4 Ft. Silty sand

From 4 to 11 Ft. Boulders and gravel

From 11 to 20 Ft. Silty sand and gravel

From 20 to 35 Ft. Clean sand and gravel

From 35 to 40 Ft. Mostly sand

From 40 to 68 Ft. Coarse sand and gravel

- Return to Main
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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 39187 Owner: STERLING PULP Address: 100 FORESTER STREET Area: NORTH VANCOUVER WELL LOCATION: NEW WESTMINSTER Land District District Lot: 611 Plan: 9510 Lot: 3 Township: Section: Range: Indian Reserve: Meridian: Block: X Quarter: Island: BCGS Number (NAD 83): 092G035222 Well: 1 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Licence General Status: UNLICENSED Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 8.0 inches Casing drive shoe: Well Depth: 98 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag:	Construction Date: 1978-01-24 00:00:00 Driller: Pacific Water Wells Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 200 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 14 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft):

File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	null	null	null

GENERAL REMARKS:
REC. PUMP RATE 200 GPM, REC. PUMP SETTING 70'

LITHOLOGY INFORMATION:

From 0 to 8 Ft. Fill

From 8 to 15 Ft. Gravel and boulders

From 15 to 20 Ft. Gravel and cobbles

From 20 to 23 Ft. Grey silty till

From 23 to 24 Ft. Log

From 24 to 25 Ft. Grey silty till

From 25 to 26 Ft. Boulder

From 26 to 31 Ft. Gravel

From 31 to 33 Ft. Boulder

From 33 to 98 Ft. Sand and gravel

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- Return to Search Criteria

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 72330 Owner: WBT WILD BIRD TRUST Address: 2645 DOLLARTON HIGHWAY Area: NORTH VANCOUVER WELL LOCATION: NEW WESTMINSTER Group 1 Land District District Lot: 469 Plan: Lot: Township: Section: Range: Indian Reserve: Meridian: Block: 4 Quarter: Island: BCGS Number (NAD 83): 092G035222 Well: 8 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Licence General Status: UNLICENSED Well Use: Observation Well Number: Observation Well Status: Construction Method: Diameter: 0.0 inches	Construction Date: 1996-02-12 00:00:00 Driller: Field Drilling Contractors Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Development Method: Pump Test Info Flag: Y Artesian Flow: Artesian Pressure (ft): Static Level: 17 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: N Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name:

Casing drive shoe:	
Well Depth: 74 feet	SURFACE SEAL:
Elevation: 0 feet (ASL)	Flag: N
Final Casing Stick Up: inches	Material:
Well Cap Type:	Method:
Bedrock Depth: feet	Depth (ft):
Lithology Info Flag: N	Thickness (in):
File Info Flag: N	
Sieve Info Flag: N	WELL CLOSURE INFORMATION:
Screen Info Flag: N	Reason For Closure:
	Method of Closure:
Site Info Details:	Closure Sealant Material:
Other Info Flag:	Closure Backfill Material:
Other Info Details:	Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
CASING 1.5 TO 61.0, PUMP TEST RATE 50 GPM,

LITHOLOGY INFORMATION:

From 0 to 4 Ft. COARSE GRAVEL

From 4 to 18 Ft. BROWN SAND DAMP

From 70 to 74 Ft. GREY SILTS

From 50 to 70 Ft. COARSE SAND & GRAVEL CLEANER

From 18 to 50 Ft. COARSE SAND & GRAVEL DIRTY

- Return to Main
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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 92423 Owner: FALLIS Address: Area: WELL LOCATION: KOOTENAY Land District District Lot: 377 Plan: X15 Lot: 12 Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 83): 092G035222 Well: 7 Class of Well: Water supply Subclass of Well: Domestic Orientation of Well: Vertical Status of Well: New Licence General Status: UNLICENSED Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Diameter: inches Casing drive shoe: Y Well Depth: 180 feet Elevation: feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: N File Info Flag: N Sieve Info Flag: N Screen Info Flag: N Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 2001-11-25 00:00:00 Driller: J. R. Drilling Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 15 (Driller's Estimate) U.S. Gallons p Development Method: Air lifting Pump Test Info Flag: N Artesian Flow: Artesian Pressure (ft): Static Level: 52 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: N Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: N Material: Method: Depth (ft): Thickness (in): Liner from To: feet WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type

Casing from	to feet	Diameter
0	180	6

GENERAL REMARKS:
MEASUREMENTS FROM TOP OF CASING. PITLESS UNIT: WELDED. WATER QUALITY & QUANTITY NOT GUARANTEED BY CONTRACTOR. RECOMMENDED PUMPING RATE: 1-5 USGPM. PUMPI

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LITHOLOGY INFORMATION:

From     0 to    50 Ft.

From    50 to    70 Ft.       brown

From    70 to   176 Ft.       blue

From   176 to   180 Ft.
```

- Return to Main
- Return to Search Options
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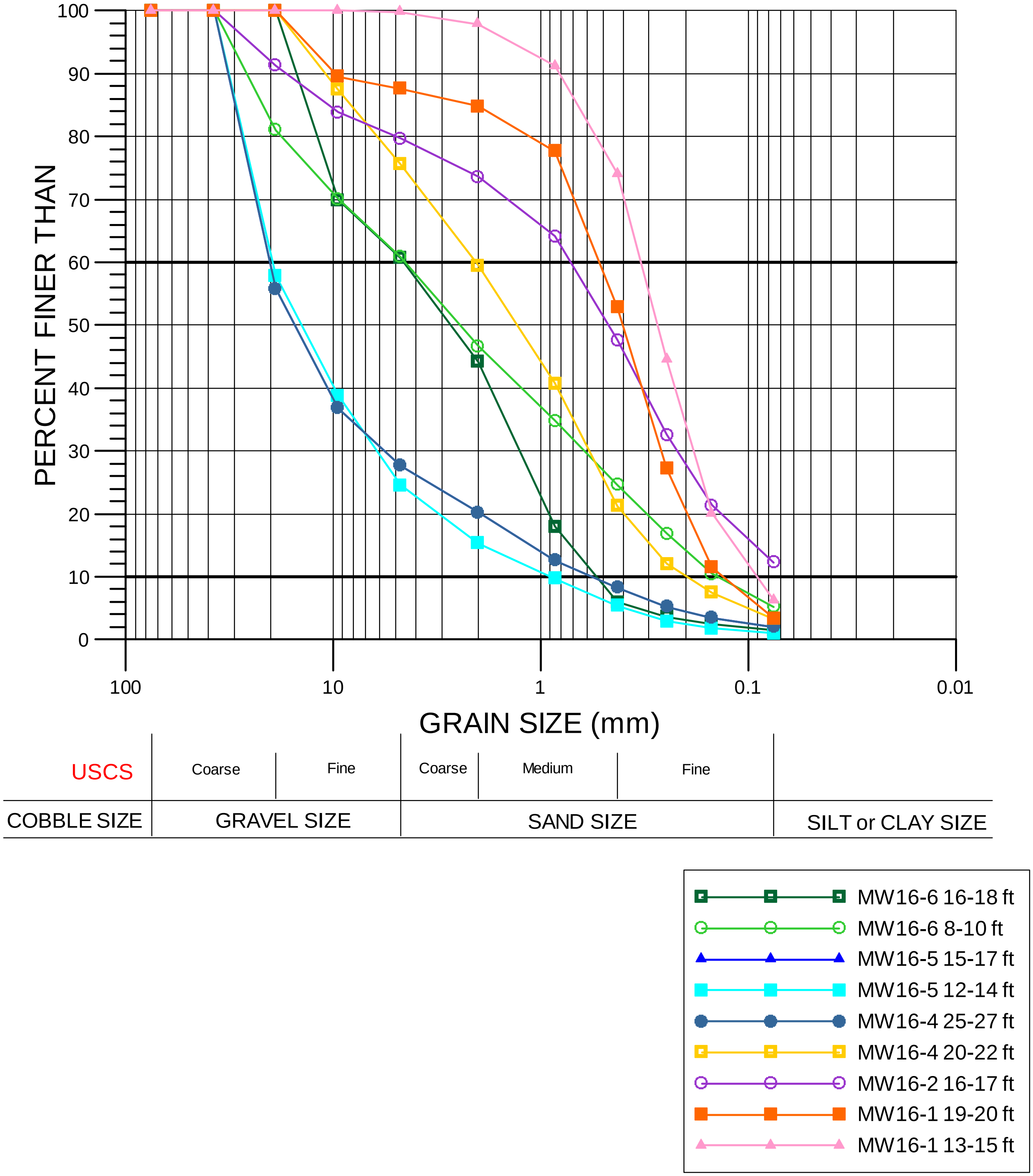
Appendix B: Hydrogeological Study - Grain Size Analysis

H:\Project\3521\Sieve Analysis\3521 SIEVE TESTS 2.grf



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DISTRICT OF NORTH VANCOUVER
HYDROGEOLOGY ASSESSMENT
MAPLEWOOD DISTRICT LANDS

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

GRAIN SIZE ANALYSES RESULTS

BY:	DATE:
RB	APR 15
APPROVED:	FIG:
	B1

Appendix C: Hydrogeological Study -

Table 9 Estimated Monthly Recharge Summary

Table 10 Monthly Water Balance

Table 9 Estimated Monthly Recharge Summary for Maplewood Study Area

CLIMA E VARIABLES	MON H NI S	AN	EB	MAR	APR	MA	N	L	A G	SEP	OC	NOV	DEC	O AL	ANN AL	MEAN MON HL	L L/s/km²	LOW L/s
Average Monthly Precipitation (1)	mm	255	168	167	136	103	83	53	55	77	189	290	230	1806	107	150	57	18
Average Monthly Temperature (2)	°C	3.8	5.2	6.6	8.4	12.6	15.4	16.2	17.3	14.9	10.7	6.1	3.7	-	-	10	-	-
Calculated Potential Evapotranspiration (3,4)	mm	12	19	29	44	77	102	105	103	76	45	21	11	642	36	54	20	7
Potential Infiltration, Runoff or Storage	mm	244	148	138	92	27	-19	-52	-48	1	144	270	219	1282	71	97	41	13
SOIL WA ER BALANCE																		
Assumed Water Holding Capacity (5)	mm	250	250	250	250	250	250	250	250	250	250	250	250	-	-	-	-	-
Water in Storage in Soil	mm	250	250	250	250	250	231	179	131	132	250	250	250	-	-	-	-	-
Remaining Water for Infiltration and/or Runoff	mm	244	148	138	92	27	0	0	0	0	26	270	219	1,164	64	97	37	12
Assumed Runoff Coefficient (6)	-	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	-	-	-	-	-
Loss due to Surface Runoff	mm	37	22	21	14	4	0	0	0	0	4	40	33	175	10	15	6	2
Remaining Water for Infiltration	mm	207	126	117	78	23	0	0	0	0	22	229	186	989.1	54.8	82.4	31.4	10.1

NO ES:

1) Average monthly precipitation recorded at Environment Canada N Vancouver 2nd Narrows Station (1981-2010).
2) Average monthly temperature data for Environment Canada West Vancouver Aut Station (2000-2015).
3) Potential evapotranspiration for months with negative mean temperatures are assigned a value of 0.0.
4) Monthly evapotranspiration calculated using the Thornthwaite method and average monthly temperature data.
5) Assumed typical soil water holding capacity for soils in the groundwater recharge areas = 250 mm
6) Assumed surface water runoff coefficient; expressed as a fraction of the remaining water, after storage and evapotranspiration = 0.66
7) Area of the Study Area = 0.32 km^2

Table 10 Monthly Water Balance for Maplewood Study Area

	LOWS EN ERING HE S D AREA (L/s)				GRO NDWA ER S ORAGE		LOWS LEAVING HE S D AREA (L/s)		
	IN IL RA ION ROM PRECIPI A ION ON S D AREA OO PRIN	INP ROM PGRADIEN GRO NDWA ER SEEPAGE	S R ACE R NO EN ERING S D AREA	O AL IN LOW GRO NDWA ER S R ACE WA ER	IN O S ORAGE WI HIN S D AREA (L/s)	IN S ORAGE (m3)	GRO NDWA ER LOW LEAVING S D AREA	S R ACE R NO O O S D AREA	NE O LOW GRO NDWA ER S R ACE WA ER
MEAN ANN AL LOWS (L/s)									
TOTAL MEAN ANNUAL DISCHARGE	18	0	3.4	22	0	-	100	0.9	100
AN AR LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	25	78	6.9	110	94	3451099	78	4.4	82
EBR AR LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	17	115	4.6	136	57	3589162	115	2.1	117
MARCH LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	14	134	4.3	152	53	3731092	134	1.8	136
APRIL LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	10	134	3.2	147	46	3851092	134	0.7	135
MA LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	3	134	1.6	138	-112	3551167	137	-0.9	137
NE LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	0	118	1.0	119	-112	3260917	122	-1.5	121
L LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	0	103	1.0	104	-112	2960992	106	-1.5	105
A G S LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	0	86	1.0	87	-112	2661067	90	-1.5	88
SEP EMBER LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	0	68	1.0	69	0	2661067	68	-1.5	66
OC OBER LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	3	62	1.6	66	10	2688073	62	-0.9	61
NOVEMBER LOWS (L/s)									
TOTAL MONTHLY DISCHARGE	29	72	7.5	109	104	2956938	72	5.0	77
DECEMBER LOW (L/s)									
TOTAL MONTHLY DISCHARGE	22	77	6.3	106	84	3182800	77	3.8	81