KERR WOOD LEIDAL
consulting engineers

PART A:

SITE ASSESSMENT AND BACKGROUND REVIEW

Part A: Site Assessment and Background Review

1. Report Context

The City of Richmond engaged Kerr Wood Leidal Associates Ltd. (KWL) and a team of sub-consultants to prepare a Water and Ecological Resource Management Strategy. This project will support the Garden City Lands Legacy Landscape Plan (the Plan) by developing strategies to protect, restore and enhance important environmental values.

The Plan divides the site into broadly four areas, including remnant bog area, agricultural area, wetland area and community use area. Each land use area represents distinctive needs for surface and sub-surface water management on site.

The objectives of this Water and Ecological Resource Management strategy are:

- To develop methodologies for the protection of the sustainability of the bog including the provision of a buffer;
- To develop methodologies (drainage and irrigation) for enabling agricultural uses on the site; and
- To mitigate impacts of site development and public use on the site's ecological resources and to develop long-term maintenance strategies.

Due to the complex nature of the project, the project team consists of a group of multi-disciplinary specialists. The project work was broken down into the following six phases, each with the following deliverables:

- Phase 1 - Analysis of Current Conditions: Preliminary Site Assessment Report;
- Phase 2 - Hydrogeology Assessment: Draft Seepage Model Results;
- Phase 3 - Water Resource Management: Draft Water Resources Management Plan;
- Phase 4 - Ecological Resource Management: Draft Ecological Resource Management Plan;
- Phase 5 - Operations and Long Term Monitoring: Draft O&M and Long-Term Monitoring Plan; and
- Phase 6 - Final Water and Ecological Resource Management Strategy: Final Strategy.

This report is the deliverable for Phase 6, a preliminary site assessment report that summarizes the existing site conditions and a background literature review.

1.1 Project Background

The Garden City Lands (GCL) is a 136.5 acre parcel owned by the City of Richmond. It is located within and at the eastern edge of Richmond's City Centre at 5555 No. 4 Road. The property boundaries are defined by Alderbridge Way along the north property line, No. 4 Road along the east property line, New Westminster Highway along the south property line, and Garden City Road along the west property line.

The GCL is surrounded on three sides by urban neighbourhoods that are undergoing rapid redevelopment. It is one of four quarter sections that are the remnants of the Lulu Island Bog, the others being the Department of National Defense Lands and the two sections of the city –owned Richmond Nature Park that are bisected by Highway 99. Therefore, the GCL serves as an ecological connection between the natural lands to the east and Lansdowne commercial centre to the west. Over 33,000 people live in the adjacent quarter sections to the site, and the site represents a major addition to urban park area in the City of Richmond.

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The GCL is located within the provincially designated Agricultural Land Reserve (ALR). The Lands are valued for the bog environment that existing on a portion of the site (approximately 70 acres) and also for their potential agricultural capability (approximately 50 acres). The GCL has recently been the subject of a planning and public consultation process that resulted in development of the Garden City Lands Legacy Landscape Plan to develop a green oasis in the City Centre for community wellness, agricultural and ecological conservation purposes.

GCL Legacy Landscape Plan

The Garden City Lands Legacy Landscape Plan is the guiding document for the GCL site development. The work of this project will develop methods to allow the creation and maintenance of the values and facilities that make up the Legacy Landscape Plan. The Legacy Landscape Plan divides the site into multiple sections to support four themes of use in different areas of the site, see Figure 1-1. Broadly, the site is divided into distinct but sometimes intertwined areas including:

- A remnant of the Lulu Island bog to be restored and supported as a viable bog community, including a sphagnum moss 'sanctuary area';
- A naturalized wetland area with stream and year-round open water areas, that could be used to support the hydrology of the bog on the east side of the site and/or supply water for irrigation of the west side of the site;
- An agricultural area for Kwantlen Polytechnic University's Sustainable Agriculture Research and Education Farm as well as community gardening spaces; and
- Community use areas including activity fields and event spaces, the "mound", multi-function buildings and shelters, and water features.

The inherent challenge of the Legacy Landscape Plan is that these areas and uses represent up to four separate sets of needs for water management on the site. These separate surface water, groundwater and drainage needs for the site must be considered individually, as well as in proximity to the other uses, and the conflicts and competing needs reconciled in order to support the whole of the site.

This project, the Water and Ecological Resource Management Strategy, will build on the Legacy Landscape Plan to develop concept-level design options for implementation of the Plan. The team will balance the competing needs to the site and develop practical, feasible methods to achieve the vision for the site.

1.2 Report Organization

This report summarizes the knowledge base of pertinent information available at the start of this project. It looks at the background information and literature available and indicates the basic understanding of the site from the perspective of the several disciplines contributing to this project.

The report is organized in sections according to the expertise reviewing the background information. Each section summarizes the available information, the pertinent conclusions regarding the site, and discusses areas where unknown information will influence or affect the development of options and strategies in this project.

LANDSCAPE ZONES

- The Bog
- The Mound
- The Fields
- The Sanctuary
- The Wetland
- The Community Hub & Farm Centre
- The Edges

Source | From the City of Richmond Garden City Lands Legacy Landscape Plan - May 2014

651-085\501-Drawings\b_Figures\651085_Phase1_Fig1-1.cdr

Project No. 651-085

Date November 2015

Not to Scale

Garden City Lands - Legacy Landscape Plan | April 2014

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Figure 1-1

Part A: Site Assessment and Background Review

2. Site Visit and Survey

2.1 Survey Plan and GIS Data

A site survey plan is shown in Figure 2-1. The plan, dated in January 2015, shows topographic survey points in an approximately 65 m x 35 m grid system all through the site. In addition, the edge of vegetation, abrupt elevation changes (the mound, ditches and swales), and site access path were included in the survey plan.

The City also supplied GIS data sets that contain administrative and utility data such as parcel boundary, address, road, water, sanitary and storm sewer data. The data covered the GCL site and 8 surrounding quarter sections. The only drainage system within the GCL is the south perimeter ditch along Westminster Hwy. The ditch, with a top width of 2.0 m, conveys site runoff westwards to the Garden City Road storm truck and eastwards to the No. 4 Road storm truck. A 900 mm steel culvert is shown along the middle section of the ditch.

2.2 Site Reconnaissance

A site visit was conducted on October 27, 2015. Members of the consulting team were accompanied by City staff from the Parks, Planning and Maintenance Departments. During the site reconnaissance, the GCL appeared to be dry without signs of saturation and surface ponding. Surface growth was freshly mowed to approximately 0.2 to 0.3 m in height. The group walked the site with discussions focusing on the following areas, as summarized in Table 2-1.

Table 2-1: Summary of Site Reconnaissance

Items	Knowledge and Site Observation
Site Maintenance	The current maintenance activity is limited to mowing once per year. Regular mowing has somewhat conserved the bog ecosystem by controlling the growth of tall shrub and tress, as well as reduced invasive exotic weed species.
Site Drainage and Flooding	The site was dry without any signs of saturation and surface ponding. No overland flow path was identified on site at the time. Based on knowledge from the City maintenance department, the western edge of the site (north of the gravel parking lot) experienced flooding a few years ago. Surface ponding elevation approached the edge of Garden City Road. It was believed that a pipe inlet (or multiple inlets) drain the surface runoff into the storm sewer system along Garden City Road. Attempts were made to locate the inlet, but were not successful due to compacted clippings from the recent mowing activities. It is assumed that the outlet pipe, if it exists, would not drain well due to clogging.

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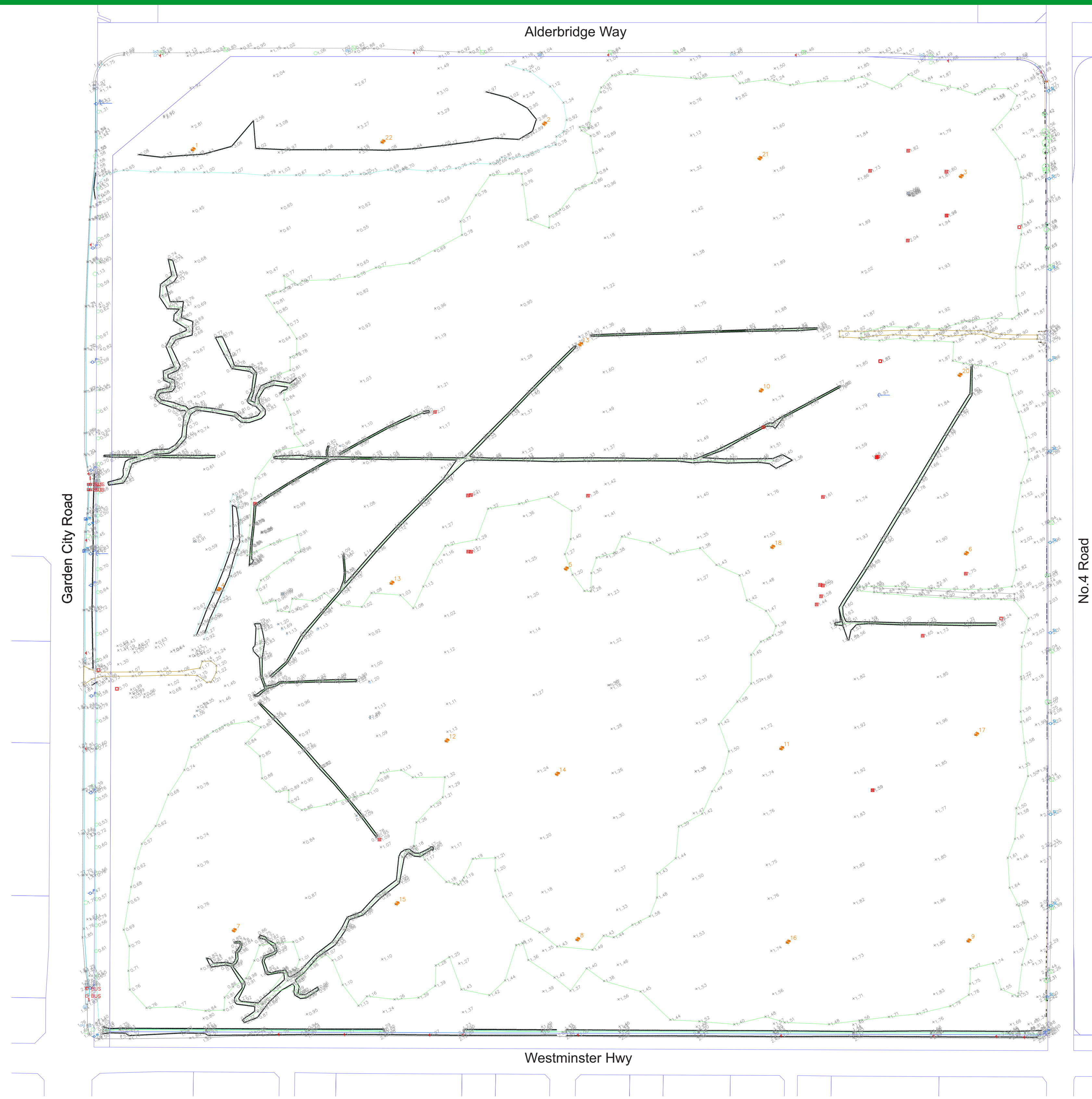
Table 2-1: Summary of Site Reconnaissance (*cont.*)

Items	Knowledge and Site Observation
The mound	The mound area, about 2.5 m above ground elevation, is located along the northwest corner of the GCL. Discussions were focused on the reusability of the mound material for agriculture use. The agricultural consultant questioned the quality of the material as it is thought to be composed of waste from road construction. The City is going to conduct soil testing to better ascertain its composition. Vegetation along the south toe of the mound indicates that this area is a low-lying wet area.
Off Site Inflow	Parks Staff noted that the site received off-site runoff from Alderbridge Way through a possible outlet or abandoned pipe located just east of the mound. However, the site walkover did not find the noted drainage structure. The City Engineering Department will check record drawings to see if any abandoned infrastructure is recorded in the vicinity of this inflow.
Remnant Bog	The eastern part of the site was covered largely by sphagnum peat that resembles a raised bog ecosystem. The centre part of the remnant bog area appeared to be spongy with at least two types of living sphagnum moss.
Wild life and Park Use	The site has a visible diversity of plant communities and wild life habitat. A variety of blueberries, hardhack and sphagnum moss was found, as well as a heron, hawk and a coyote. The site is also used by the public, mainly for dog walking.
Richmond Nature Park	A walk in the Richmond Natural Parks was conducted by KWL staff after the site visit to the GCL site to gain familiarity adjacent remnant areas of the LuLu Island Bog in natural and un-mowed state. The bog portion of the Park is mainly covered by tall shrubs, many of them commercial (non-native) blueberries, approximately 1.5 m to 2.5 m in height. Besides, pine and birch trees are providing stiff competition. Typical bog plants, such as moss and low shrubs were visible but generally overgrown. Wild life such as mole and squirrels were spotted on site.

In summary, the GCL is experiencing a dryer than usual year in 2015. No surface drainage path or infrastructure was located on site. Annual mowing, as a management strategy, has kept the predominance of low growing plants, which preserve the GCL's resemblance to a bog ecosystem. In contrast, the Richmond Nature Park has transitioned into a forest-like ecosystem due to competition from pine, birch trees and tall bushes. Ideally, an additional site visit should be conducted during the wet season to further observe the site drainage patterns.



Source | Survey plan from the City of Richmond.

Project No. 651-085

Date November 2015

Not to Scale

Garden City Lands Site Survey Plan

Figure 2-1

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651-085\501-Drawings\b_Figures\651085_Phase1_Fig2-1.cdr

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3. Hydrogeological Site Assessment

3.1 Available Information

A variety of technical reports and documents were identified that were likely to provide either direct, site-specific information concerning stratigraphic and hydrogeologic conditions underlying the GCL, or information for nearby sites. Documents obtained and reviewed as part of this preliminary assessment are itemized below:

Aerial Orthophotos

- 1922, 1930, 1949, 1954, 1963, 1969, 1980, 1986, 1991, 1997, 2002, 2009

Hydrogeological Assessment Reports

- SNC-Lavalin, 2015, Hydrogeological Investigation, Garden City Lands, Richmond, BC. Project No. 626827.
- SNC-Lavalin, 2013, Vancouver Landfill Hydrogeological Review. Ref: 511867.
- EGSL, 2006, Report on Hydrological Monitoring Program, MK Delta Lands Group Properties and Surrounding Area, Delta, BC. Project No. 06005.
- EGSL, 2010, Ecohydrological Overview of Surrey Bend Park, Surrey, BC. Project No. 01011.
- Golder Associates Ltd., 2004. McLennan Park Detention Pond Groundwater Characterization, Richmond BC. Project No. 03-1411-126

Geotechnical Reports

- Trow Associates, 2008, Preliminary Geotechnical Assessment for Garden City Lands, Richmond, BC. Ref: 071-03105.
- Trow Associates, 2004, Geotechnical Exploration and Report - Proposed Townhouse Development 9180-9220 Westminster Highway, Richmond, BC. Ref: 041-01522.
- GeoPacific, 2014, Geotechnical Investigation Report - Proposed Townhouse Development 9700 & 9740 Alexandra Road, Richmond, BC. Ref: 10913.
- GeoPacific, 2014, Geotechnical Recommendation for Proposed Central at Garden City Commercial/Retail Development (Bldings A-E, L, H) Garden City Road at Alderbridge Way, Richmond, BC. Ref: 12060.
- GeoPacific, 2014, Geotechnical Recommendation for Proposed Central at Garden City Commercial/Retail Development (Bldings East Anchor, J, K, M, N and Green Deck) Garden City Road at Alderbridge Way, Richmond, BC. Ref: 12060.
- GeoPacific, 2009, Geotechnical Investigation Report Proposed 18 Unit Townhouse Development 9460 and 9480 Westminster Highway, Richmond, BC. Ref: 8312.

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Other Reports

- Diamond Head Consulting Ltd, 2013, City of Richmond Garden City Lands Biophysical Inventory and Analysis. Ref: None.
- Agricultural Land Commission, 2009, Exclusion Application – Garden City Lands (Letter and Minutes). Ref: O – 38099
- Schroeter Consulting, 2008, Agricultural Assessment of the GCL Lands, 55 No. 4 Road, Richmond. Ref: 07045.
- Davis, Neil and Klinkenburg, 2008, A Biophysical Inventory and Evaluation of the Lulu Island Bog, Richmond, British Columbia. Publisher: Richmond Nature Park Society.
- Agricultural Land Commission, 2006, Agricultural Capability Assessment (Memo). Ref: O – 36435.
- Lutmerding and Sprout, 1969, Soil Survey of Delta and Richmond Municipalities. Publisher: BC Department of Agriculture, Kelowna.

3.2 Previous Hydrogeology Work

Hydrogeological Investigation, SNC Lavalin, 2015

SNC Lavalin undertook a baseline hydrogeological investigation of the GCL in 2015. Their work included the following activities:

- Established groundwater instrumentation sites (18 piezometers at 10 locations);
  - four nested wells (shallow, intermediate, deep) at 15-01 through 15-04; and
  - six shallow wells completed within peat (15-05 through 15-10).
- Continuous water-level monitoring data obtained at hourly intervals over a period of six months (March to August 2015); data loggers installed in ten wells; and
- Water quality assessment completed in all piezometers. Background water quality was established based on indicator parameters only (i.e., temperature, pH, electrical conductance).

Piezometers 15-01 through 15-06 were drilled using solid and hollow stem augers, which provided samples for logging during drilling. Piezometers 15-07 through 15-10 were installed by hand using a slide hammer device, and no soil or peat samples were acquired for logging. Hydrographs were established documenting water levels within the peat, underlying clayey silt and underlying Fraser River Sand over time. Among observations made, the vertical hydraulic gradients were consistently downward, and water levels dropped over the course of the dry summer months, effectively dewatering the peat over the summer. Water within the peat was characterized as being acidic with relatively low dissolved solids (pH 3.8 to 4.8; electrical conductance less than 100 µS/cm), whereas waters within the underlying Fraser River Sand were near-neutral and minerotrophic (pH 6.3 to 7.0; electrical conductance about 300 µS/cm to 750 µS/cm). Minerotrophic, near neutral pH waters were also encountered in shallow soils nears roads, where peat had likely been removed a part of development.

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Hydrogeological Assessment, McLennan Park, Golder Associates, 2004

In 2004, Golder completed a detailed hydrogeologic assessment of McLennan Park in Richmond to support construction of various water features in the park including a wetland and detention pond. The plans included construction of an on-site well to provide supplemental water to off-set predicted pond losses from the detention pond. The scope of work completed by Golder included:

- One cone penetrometer test (CPT) to develop a detailed stratigraphic profile at the test well site;
- Installation of three monitoring wells at varying distances from the test well site;
- Well development and sampling for a range of test parameters including pH, temperature, and electrical conductance on all wells, and chemical analysis of one well for a range of major ions, nutrients, metals, pesticides, herbicides and fungicides;
- Completion of an eight-inch diameter well within the Fraser River Sand aquifer, with a stainless steel well screen installed at 16.8 m to 18.3 m below ground surface;
- Completion of aquifer pumping tests, including a 3-hour variable rate pumping test followed by a 48-hour constant rate (3.1 L/s, or 50 USgpm) test;
- Water quality sampling from the test well, and
- Long-term water level monitoring using data loggers and manual measurements.

Golder used a computer model (AQTSOLV) using the Theis recovery solution to assess the data from the constant rate pumping test. The assessment indicated that the transmissivity of the aquifer was about 10-2 m2/s whereas the storativity was estimated to be about 2 x 10-3. The estimated long-term yield of the well was estimated to be about 3.1 L/s (50 USgpm), which would create water table drawdowns of at least 0.2 m at a radial distance of several hundred metres from the well. Water quality testing indicated the pumped water met all freshwater aquatic life guidelines with the exception of iron, which was significantly elevated (20.5mg/L vs 0.3mg/L).

Other Bog Monitoring, SNC and EGSL

EGSL undertook a detailed hydrological monitoring program of Burns Bog in Delta in 2006, and built upon the experience gained by SNC and others from monitoring of the City of Vancouver Landfill in Burns Bog. In addition, EGSL conducted an ecohydrological overview of the bog environment in Surrey Bend Park in Surrey, BC in 2010. Data gained from these programs includes information on the hydraulic properties of peat, including properties associated with vertical stratification (i.e., fibrous versus amorphous zones), which will be analogous to that encountered in the GCL. The peat properties provide a reality check for data generated at GCL. Further, the seepage and water balance model conducted for Burns Bog and the City of Vancouver Landfill has elements of seepage, recharge and interception by ditches that is analogous to the effort being undertaken for GCL.

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3.3 Geotechnical Information

Geotechnical Investigation, Trow, 2008

Stratigraphic information, including borehole and cone penetrometer test (CPT) logs, was acquired by Trow Associates Inc. (Trow) in 2008 as part of a preliminary geotechnical assessment of GCL. The Trow study comprised the drilling and logging of soils at 22 locations across the GCL (AH7-1 through AH7-22), based on a nominal 150 m x 150 m grid pattern. Auger-hole depths ranged from 4.4 m to 15 m below grade. Nine CPTs were carried out (CPT07-1 through CPT07-9), with penetration depths ranging from about 30 m to 50 m below surface. Detailed borehole logs were prepared and stratigraphic cross sections were developed based on both visual log descriptions and CPT logs. In summary, the Trow study provides good spatial coverage of subsurface conditions and stratigraphy. A relatively good data set is provided on peat presence and thickness, although specific information on amorphous versus fibrous peat thickness is not provided.

Other Geotechnical Investigations

Relevant stratigraphic information has been made available for five geotechnical investigations of site developments undertaken in the vicinity of the GCL, which allows the seepage model layers to be expanded with greater confidence beyond the boundaries of the GCL. The geotechnical studies were undertaken at the following locations:

- 9280 – 9300 Westminster Highway, Trow Associates Inc. (2004);
  - Located west of GCL; and
  - Scope of work included drilling and logging six auger holes (AH04-1 through AH04-6) to depths of 6 m to 12 m, and four CPTs (CPT04-1 through CPT04-4) to 20 m depth.
- 9460 – 9480 Westminster Highway, GeoPacific Consultants Ltd. (2009);
  - Located immediately south of GCL; and
  - Scope of work included drilling and logging five auger holes (TH09-01 through TH09-05) to depths of 6.0 m to 9.1 m , and three CPTS (CPT09-01 through CPT09-03) to depths up to 30 m.
- Garden City Road at Alderbridge Way, GeoPacific Consultants Ltd. and Jacques Whitford/Stantec (2014); and
  - Located near northwest corner of GCL; and
  - Scope of work included drilling and logging of
    - 15 auger holes by Jacques Whitford (now Stantec) in 2004 (AH04-1 through AH04-15) to depths of 6.1 m to 9.1 m;
    - 28 auger holes by Stantec (AH12-1 through AH12-28) to depths of 6.1 m; and
    - three CPTS (CPT04-1, CPT04-02, CPT07-1 through CPT07-6, CPT 12-1 through CPT12-11) to depths up to 30 m.
- 9700 – 9740 Alexandra Road, GeoPacifc Consultants Ltd. (2014).
  - Located near northeast corner of GCL; and
  - Scope of work included drilling and logging four auger holes (TH12-01 through TH12-04) to depths of 4.6 m, and four CPTS (CPT12-01, CPT12-2, CPT09-04) to depths up to 30 m.

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3.4 Hydrogeologic Understanding of the Garden City Lands

The Garden City Lands Legacy Landscape Plan involves developing strategies to protect, restore and enhance important environmental values. Key to this process is an understanding of current surface water and groundwater interactions, and the development of a predictive capability (i.e., a numeric model) to assess various strategies on achieving desired outcomes. Proposed development will require hydraulic isolation of bog from areas to be used for agriculture. A seepage and water balance model is required for the bog area that will include elements of recharge, seepage, and interception by ditches and underground utilities.

Based on information obtained and reviewed to date, the following items are of relevance to our understanding of hydrogeologic conditions at the GCL:

Hydrostratigraphy

- Native materials underlying the GCL comprise the following from ground surface down:
  - *Peat* – the peat is relatively thin, averaging about 0.6 m in thickness. It is thickest (about 1.4 m) in the eastern part of the site and thins to the west. The upper several centimetres of peat are relatively permeable (perhaps on the order of 10^{-4} m/s) with active plant and moss growth sphagnum), whereas the underlying few centimetres is characterized as amorphous and has a relatively low permeability (inferred to be on the order of 10^{-7} m/s).
  - *Clayey Silt* – this unit is continuous across the GCL and directly underlies the peat. It has a reactively low hydraulic conductivity and acts as a aquitard between the permeable peat unit and underlying Fraser River sand.
  - *Transitional Silt* – In several areas beneath the GCL, the clayey silt transitions into sand. The transitional zone is characterised by silt with thin interbeds of fine sand. The sand layers are unlikely to be laterally extensive and may occur as lenses.
  - *Sand* – beneath the clayey silt or transitional silt is a relatively thick unit composed of fine and fine to medium grained laterally extensive sands. The sand units collectively are referred to as the Fraser River sand aquifer that, beneath the GCL, is on the order of 10 m to 20 m in thickness. The sands extend several tens of kilometres to the east and south, are hydraulically connected to the Fraser River to the north, and extend to the marine environment to the west. The sustained yield from pumping a well installed in this aquifer to the south of GCL near Alberta Street is greater than 3.1 L/s (about 50 USgpm).
  - *Marine Silt* – the sand aquifer is underlain by a continuous layer of silt , inferred to be of marine origin that is laterally extensive an is likely underlain by till. This silt unit behaves as an aquitard, and for purposes of the groundwater model, serves as the base of the model domain.

Water Quality

- Water within the peat was characterized as being acidic with relatively low dissolved solids (pH 3.8 to 4.8; electrical conductance less than 100 µS/cm), whereas waters win the underlying Fraser River Sands were near-neutral and minerotrophic (pH 6.3 to 7.0; electrical conductance about 300 µS/cm to 750 µS/cm). Minerotrophic, near neutral pH waters were also encountered in shallow soils nears roads, where peat had likely been removed a part of development. Based on water quality testing conducted south of the GCL near Alberta Street, groundwater is likely to meet current guidelines and criteria for various organic and inorganic constituents, with the exception of iron, which is highly elevated as noted previously.

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Water Levels and Groundwater Flow Direction

- Water levels in the peat and underlying silt units respond relatively rapidly to rainfall events, whereas water levels in the deeper sand unit are much more attenuated;
- Based on review of historic air photographs and current water level information, the general horizontal flow direction within the peat bog (and underlying sand aquifer) has historically been to the southwest; and
- Vertical flow is downward, from the peat through the silt aquitard and into the sand aquifer. Downward seepage occurs throughout the year. The quantity (i.e., flux) of downward flow is a key parameter to be define in order to assess various development alternatives, and will be assessed through the modeling effort.

The hydrogeology assessment work for this project is focused on resolving data gaps and development of a 3-D finite element model of the hydrogeologic system. It is our understanding that the hydrogeologic work undertaken by SNC in 2015 includes on-going continuous water-level monitoring and hydraulic response tests (i.e., slug tests) at several locations to infer in situ hydraulic conductivity of the major stratigraphic units beneath the GCL. In addition to that work, specific items being addressed include the following:

- Verify the elevation datum used by each of the various consultants at and in the area of the GCL, and consolidate the data following conversion to a common datum (i.e., City of Richmond datum);
- Establish x, y, z coordinates for all borehole, cone penetrometer test (CPT), piezometer and monitoring wells completed at and in the vicinity of the GCL, and locate on a common GIS base map, suitable for presentation purposes and to serve as a base for the 3-D model;
- Compare water elevations in the Fraser Sand Aquifer with those in the Fraser River to the north, to characterize the hydraulic connection and provide data for 3-D model calibration. In particular, the assessment should focus on the effects of spring freshet on water levels and flow, and groundwater flow directions may reverse for several weeks in some areas along the Fraser during such events;
- Prepare at least two local and two regional hydrostratigraphic cross sections through the GCL – one trending North-South and the other East-West. The sections will include information from both on-site and off-site boreholes, and will show relevant peat profiles; and
- Probe the peat thickness, and install shallow small-diameter piezometers within the peat only, in the eastern part of GCL where peat thickness was not recorded by SNC (peat thickness was not recorded at hand-installed piezometers). In conjunction, install small diameter piezometers east of GCL, immediately east of No. 4 Road, and monitor shallow piezometers on either side of the road to establish differences, if any, in horizontal hydraulic gradients. This data will serve to better establish the benefits of hydraulically connecting shallow water beneath No-4 Road via, for example, horizontal drains.

The subsurface seepage model for the site will be calibrated to a summer water table condition (relatively low heads) and to a winter condition (relatively high heads). Once calibrated, scenarios to be assessed may include, the effects of various shallow water table cut-offs (i.e., along a line demarking the agricultural versus peat environments), and the effects of pumping the Fraser River Sand aquifer to maintaining a wetland on site and/or provide water supply for the agricultural lands. The data available from the extraction well to the south of GCL near Alberta Street provide relevant hydraulic parameters to infer the effects of a similar pumping well established at GCL.

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4. Environmental Site Assessment

The GCL property is located on the western edge of the Lulu Island Bog, which also includes the Richmond Nature Park, the Richmond Nature Study Area, and the federal Department of National Defense Lands. Together, these properties (~200 hectares) represent the largest remnant bog ecosystem of what is historically referred to as the Greater Lulu Island Bog. This raised bog ecosystem once covered much of Lulu Island (and Richmond), but has now been greatly reduced due to agriculture, drainage and other human use and development.[1] Information in this section includes a summary assessment of biophysical information for GCL to date, a review of bog and wetland restoration options for the site, and next steps.

4.1 What is a Raised Bog Ecosystem?

Raised bogs are unique ecosystems associated with humid, temperate climates where precipitation exceeds evapotranspiration. They typically form in areas with flat topography and poor drainage and where the water table is at or near the surface for most of the year. The high water table creates anaerobic conditions, which reduces the rate of decomposition and allows partly decayed plant matter (peat) to accumulate over a poorly-drained sediment layer (e.g., clayey-silt).[2] As organic matter accumulates over time, surface vegetation can no longer be fed by mineral rich groundwater and must instead rely primarily on precipitation for moisture. Because rainwater is nutrient poor and acidic, plants adapted to these types of conditions become established. One such plant that predominates in these conditions is *Sphagnum* moss, which is uniquely adapted to nutrient poor, water logged environments and can hold many times its weight in water. Ericaceous and other specialized plants are also able to take hold in these peat-substrate environments. Trees such as lodgepole pine can also persist, although their growth would be severely stunted.

Over time as peat builds up, the bog begins to form a dome (raised) shape, which is typically highest near its centre. The water table builds up and generally follows this domed profile, and water flows out radially from the centre of the bog to the peripheries.[1] Generally, the water table in raised bogs is stable and remains close to the bog surface (i.e., within a few centimetres) 95% of the time. The variable microtopography (e.g., small hummocks and depressions) combined with this stable water table create very small habitat niches for different species of vegetation.[3]

Towards the bog periphery, the depth of peat begins to diminish and vegetation communities begin to change. This is the transition (lagg) zone between the peat dominated bog ecosystem and surrounding mineral soil dominated landscapes. The lagg is the receiving zone where run-off from the bog mixes with groundwater and/or other water sources, resulting in unique hydrological and hydrochemical conditions.[4] Garden City Lands is positioned on the bog margin and shows evidence of both bog and lagg environments.

[1] Davis, Neil and Rose Klinkenberg (editors). 2008. A Biophysical Inventory and Evaluation of the Lulu Island Bog, Richmond, British Columbia. Richmond Nature Park Society, Richmond, British Columbia.
[2] Metro Vancouver. 2007. Burns Bog Ecological Conservancy Management Plan.
[3] Irish Peatland Conservation Council. Retrieved from http://www.ipcc.ie/a-to-z-peatlands/raised-bogs/. Accessed November 12, 2015.
[4] Howie, Sarah A. & Ilja Tromp-van Meerveld. The Essential Role of the Lagg in Raised Bog Function and Restoration: A Review. Wetlands (2011) 31:613–622

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4.2 Previous Environmental Assessment

Biophysical Assessment

Disturbance

The Greater Lulu Island Bog has been degraded significantly from its natural ecological condition. An estimated 95% of the bog has been converted to agriculture or for other land uses. While the Lulu Island Bog (including GCL) represents the most significant remaining relict of this larger ecosystem, it too has been degraded considerably. Construction of drainage ditches, dumping of fill material, conversion to agricultural land, building of trails, introduction of non-native plants, and changes to the natural fire regime have affected ecosystem function.[1] Reduced water levels in the summer are considered the greatest threat to the bog. This has resulted in drier, acidic conditions, which allow succession and the establishment of new vegetation communities.

Soil

Organic peat deposits within Lulu Island Bog are 0.4 to 6 metres thick.[1] GCL is on the bog margin and peat accumulation is lowest, as expected, measuring between 0.4 and 1.2 metres thick.[5] Based on a preliminary interpretation of Trow and SNC Lavalin data, the thickest peat deposits are on the northeast side of the property, and gradually lessen to the south and west. Shallow (thinner) deposits dominate in the bog margins are primarily composed of a mixture of decomposed reeds, sedges, and woody plants overlain by sphagnum moss.[6] As indicated in Section 3.3, the peat unit is underlain by a clayey silt sedimentary unit then a transitional silt/discontinuous sand layer and then a relatively permeable sand unit.[7]

Water

Richmond's humid climate delivers 100-150 mm more precipitation than what is lost through evapotranspiration.[1] However, precipitation varies considerably throughout the year, resulting in seasonal variations in the water balance. Soil fertility test results of GCL soils indicate there is a mix of groundwater and precipitation feeding the site. In particular, available nitrogen levels were found to be higher than would normally be expected in a precipitation-fed bog.[11] This assertion is supported by the 2015 site investigation conducted on GCL. Direct precipitation was considered likely to be the main source of shallow water recharge away from edges and roads, whereas minerotrophic influences were observed on the site periphery and in lower clayey silt layers and sand.[10]

Vegetation

Plant communities on GCL are associated with bog and wetland ecosystems, the latter of which may also be considered the lagg. Significant, regionally rare bog species identified on GCL, closest to the DND lands, include cloudberry (Rubus chamaemorus), bog rosemary (Andromeda polifolia), Chamisso's cotton-grass (Eriophorum chamissonis), and velvet-leaved blueberry (Vaccinium myrtilloides). Other bog-associated plants include Labrador tea (Rhododendron groenlandicum), bog laurel (Kalmia microphylla), bog cranberry (Vaccinium oxycossos) and bog blueberry (Vaccinium uliginosum). Peat moss occurs sporadically on the east side of GCL. Spagnum pacificum, a species

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[5] SNC-Lavalin Inc. 2015. Hydrogeological Investigation of Garden City Lands. Prepared for City of Richmond.
[6] Diamond Head Consulting Ltd. 2013. City of Richmond Garden City Lands Biophysical Inventory and Analysis. Prepared for City of Richmond.

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often associated with disturbed areas or areas with poor soils, is most common. There are minor occurrences of *Sphagnum capillifolium,* which is more frequently associated with raised bog ecosystems.[12]

A variety of introduced and invasive plants are also present, which can compromise ecological function through direct competition with native plants or by changing site conditions. Some examples include Scotch heather (*Calluna vulgaris*) and highbush blueberry (*Vaccinium corymbosum*), both of which are adapted to slightly acidic conditions. While the acidic nature and high water table of healthy bogs can hinder establishment of non-bog plant species (e.g., Himalayan blackberry), disturbances resulting in lower water tables or road construction can do the opposite. [5]

Many bog adapted species, such as cloudberry, are thought to persist in greater numbers on GCL than elsewhere in Lulu Island bog due to reduced competition from introduced plants. In the absence of annual mowing, it is likely that the bog associated plant community on the east side of GCL would gradually evolve to resemble the bog forest communities on DND lands and the Richmond Nature Park. Drainage in DND and RNP has led to conditions suitable for establishment of expansive stands of shore pine (*Pinus contorta* var. *contorta*) and hybrid birch (*Betula*) trees, which dominate the tree canopy, and a dense understory of introduced non-native highbush blueberry. Although these species are present on GCL, regular mowing has controlled their expanse and allowed native bog species to persist. Scotch heather is the most pervasive introduced species on the east side of GCL. This species is adapted to bog conditions, and likely first established on DND lands following relatively recent fire events.[1] Heather has spread quickly in these natural areas and now dominates large portions of the east side of GCL.

Micro-topography is an important influence on plant occurrence in GCL. Plants such as *Sphagnum pacificum* and bog cranberry appear to persist in minor depressions and in larger areas with slightly lower surface elevations (10 cm) than the surrounding landscape. These lower elevation areas may be sufficient to allow these plants to persist, where those on ground slightly more elevated from the water table cannot. In addition to a generally lower water table in the summer, hummocks and slightly elevated ground provides a niche for plants less adapted to saturated conditions to exist. Scotch Heather, which is more adapted to drier heath conditions, is an example.

The west side of GCL is characterized by a transition to plants associated with wetlands or moist conditions, including common rush (*Juncus effusus*), Sitka sedge (*Carex sitchensis*), and reed canarygrass (*Phalarus arundinacea*), an introduced grass. Other dominant plants include hardhack (*Spiraea douglasii*), bracken (*Pteridium aquilinum*), and fireweed (*Chamerion angustifolium*). There are few signs of tree regeneration in the wetter, western portions of the site.[11] The sedge community in this area is expected to persist as long as there are no changes affecting the high water table. Again, annual mowing likely controls spread of some plant species (e.g., Himalayan blackberry), and reduces competition allowing low growing species to persist over time.

4.3 Recent Environmental Information

SNC Lavalin Groundwater Level Monitoring

Site investigations conducted by SNC Lavalin in 2015 determined that the water table is in the peat from March to mid/July, but then drops into the underlying clayey silt from mid-June/July through to August.[12] Data for the September to February period was either not collected or was not available at the time of writing; however, field observations in October indicated that the water table is likely reduced through late summer and early fall. Seasonally low precipitation and increased evapotranspiration in the summer is largely responsible for the lower water table.[10] Drainage ditches may also be factor contributing to reduced water table in the summer.

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Local Bog Restoration Literature Review

Burns Bog in Delta and Camosun Bog in Vancouver offer two examples of bog environments that have been subject to significant study and restoration efforts. Therefore, it is prudent to look to them as important case studies for Garden City Lands and Lulu Island Bog.

Burns Bog is considered to exist at the climatic limits for raised bogs in North America; the water table is 27-39 cm below the lawn microtopographic surface in late summer.[7] The ecological integrity of Burns Bog is threatened by several factors:[2,7]

- changes to hydrology through reduced bog area and excessive drainage (ditching);
- loss of natural lagg (the buffer between bogs and mineral rich waters);
- forest encroachment (loss of peatland leading to drier conditions); and
- climate change (expected longer, drier summers and drought conditions which can affect hydrology).

Activities that lower the water table can cause irreversible damage to functional bog ecosystems. The moisture regime must be sufficient to maintain suitable conditions for *Sphagnum* establishment through spore germination and early growth. Sphagnum grows most actively in the shoulder seasons (Spring and Fall), while going dormant in the summer.[8] However, maintaining moist conditions is also important during the summer drought period, which may be exacerbated by future climate change.[7] A lower water table dries out the peat and encourages establishment of plants adapted to lower moisture regimes and forest encroachment. Trees further reduce water loss by intercepting rainfall and through evapotranspiration.

Restoration strategies for Burns Bog include offsetting water loss through drainage by blocking ditches (leaving evapotranspiration as main output), removing trees, and retaining winter precipitation to make it through the summer drought period. Maintaining and improving storage capacity in the acrotelm is also a critical factor.[7]

Camosun Bog is considerably smaller than Burns Bog, but many of the conditions that affect this ecosystem are similar. Residential development and storm drain installation surrounding the site potentially reduces the catchment area for the bog and increase drainage. Other factors degrading the bog included forest succession due to lower summer water levels and human disturbances including berry picking, garbage and off-leash dog activity.[9]

A key restoration strategy for Camosun Bog was to raise the relative summer water table. Optimal *Sphagnum* establishment occurs where the mean annual water table is approximately 5 cm below the surface, and the water table should not be below 40 cm. The relative water table was lowered in Camosun by removing the top forest layer and some of the underlying peat, thereby lowering the soil surface 10-15 cm.[9] Other restoration and management strategies enacted or recommended at Camosun include:

- transplanting bog species and establishing *Sphagnum* using diaspores;
- removing non-bog associated plants (e.g. salal) and reducing tree cover. Tree removal was not found to affect summer water levels, but could lead to faster recovery times in the fall water table;
- ensuring effects of berms are fully understood prior to implementing, due to potential that berms may raise water levels in some areas and reduce water levels elsewhere;

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[7] Chantler, A. [edt] Water under Pressure. Proceedings of the CWRA Conference Vancouver October 2006. pp 58-70.
[8] Hebda, R. Pers.com. 2015.
[9] Baker, Nadia et al. 2000. Investigation of Options for the Restoration of Camosun Bog, Pacific Spirit Regional Park. University of British Columbia Thesis.

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- blocking ditches (fully or partially) while recognizing need to mitigate flooding and potential for sub-surface drainage;
- avoiding irrigation as method to raise water level due to water conservation and efficacy concerns;
- implementing ecologically sensitive zones to limit public access;
- expanding boardwalks for education and nature appreciation, while managing access;
- continuing water monitoring program (water table levels and soil chemistry) to help evaluate bog condition; and
- investigating potential increases in mosquito populations.[9]

Landscape Legacy Plan Ecological Aspects

The GCL Landscape Legacy Plan focuses on two components of the natural environment ('The Bog' and 'The Wetland'), in addition to a semi-natural area ('The Edge') that should be integrated with the restoration plan due to potential ecological connectivity. The following sections provide a brief summary of relevant literature and issues related to the natural areas and features associated with the Bog, Wetland (i.e., Lagg), and Edge.

Bog

Due to its location on the margins of Lulu Island Bog, there is a strong likelihood that the GCL is representative of both bog and lagg ecosystems and that a transitional plant community exists. The east side of GCL is currently considered a semi-natural bog ecosystem, dominated by introduced Scotch Heather, but also having a diversity of native bog-associated plants, some of which are regionally rare.

There are five conditions that must be met for bog restoration to be considered as a possibility for a site[10]

1) There should be a large area of peat where the drainage does not cut into the mineral substrate;
2) There should be at least 50-100 cm of compressed, humified peat;
3) It should be possible to exclude all sources of nutrient enrichment (air and water borne);
4) There should be a buffer zone between the site and agricultural land; and
5) A source for plant colonization should exist locally.

Garden City Lands meets (or potentially meets) these five conditions.

Wetland (Lagg)

The Legacy Landscape Plan envisions creation of an open water complex in the southwest corner of Garden City Lands. The ecology of this area indicates that it may be considered the transition or lagg zone for the Lulu Island bog. These zones receive water from both the bog and surrounding mineral ground[4], and thus may be considered an important buffer or mixing area. Lagg characteristics include slightly higher pH and nutrient levels than bogs, and fluctuating water table in these zones resulting from high winter runoff and low summer water levels.[4] This results in slightly different plant communities, which is evident in the increased abundance and dominance of hardhack (*Spiraea douglasii*), sitka sedge, bracken fern, rush, and reed canarygrass on the west side of GCL.[11]

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[10] Charman, D. 2002. *Peatlands and environmental change.* Wiley, New York.

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Unfortunately, despite their importance, these lagg systems have received relatively little attention in bog restoration.[4] Therefore, while creation of a marsh (wetland ecosystem) is a primary objective, maintaining representative vegetation components and chemistry gradient in the lagg should also be a focus of restoration efforts.

Treed Perimeter

A landscaped treed perimeter for portions of the GCL is envisioned in the Legacy Landscape Plan. While offering a clear aesthetic value and visual barrier, there are some issues associated with trees and bogs. The acidic, nutrient poor conditions of bogs are not suitable for many tree species. Trees can also affect water balance by intercepting precipitation and through transpiration. Where the water table is reduced through drainage, trees can establish quickly. This is evident on the adjacent DND property and RNP where birch and pine have established in fill areas, along roads and ditches, and elsewhere with reduced water tables. Therefore, landscape tree planting on the periphery of GCL will need to be carefully considered in coordination with natural areas restoration to ensure tree planting is done where it does not pose adverse impact to the survival and restoration of the natural areas. Ecologically suitable trees will be selected for recommended treed areas that will not compromise the ecological integrity of the bog.

4.4 Environmental Understanding of the Garden City Lands

Bog ecosystems are unique and have specific challenges and opportunities associated with them, many of which are based on existing and potential site conditions. Garden City Lands is in a degraded condition and cannot be considered to be ecologically functional, although it does contain regionally rare bog associated species and is potentially a good candidate for restoration. Although there has been considerable research into some aspects of bog ecology and restoration, there are some areas where the knowledge base is limited. One such area pertains to the lagg[7], which characterizes much of GCL.

Detailed topographical information and a comprehensive understanding of the water table (and seasonal fluctuations) on both GCL and DNC lands is required to determine potential for restoration of bog and lagg ecosystems. With this information, modeling can be performed to infer potential increases to the water table that may result from establishment of a berm (as an example of one intervention), and whether this would support active *Sphagnum* growing conditions or if the site is more suited to a semi-modified bog ecosystem. The exact location of the berm may not coincide with that envisioned in the Landscape Legacy Plan.

Due to the different hydrological requirements of bog and lagg ecosystems (e.g., hydrochemical, pH, nutrient availability, stable versus fluctuating water table), and the relatively small size of the site, there is potential that they may have to be managed separately (i.e., isolated from one another) on GCL lands to support ecological integrity.

Another potential challenge is integrating agricultural activity and bog conservation on the same site. Many agricultural activities require drainage, which in large part has been responsible for the significant loss and degradation of bog and other wetland ecosystems. In addition, water requirements for agriculture are often highest during the summer, when bogs are particularly vulnerable to water drawdown. Water quality requirements for agricultural crops and bog ecosystems are sufficiently different that both their water inputs and outputs will have to be separated from one another.

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Off-site considerations must also be included. As a bog ecosystem requires water to be retained on site, seasonal fluctuations in the water table must be addressed. Flooding concerns in surrounding urban areas, which may arise due to limiting drainage and retaining more water in the bog, must be mitigated. In addition, the GCL must not be considered an isolated ecosystem, but rather a part of the Lulu Island Bog which includes DND lands and the Richmond Nature Park. Any proposed changes to the hydrology in GCL should consider potential effects to the greater whole.

Bog restoration typically follows a long-term outlook. The Burns Bog Management Plan has ***a 100 year time horizon***. Future land use changes, adjacent development, and climate change may create conditions that further affect hydrology and bog/lagg ecosystems many years after development of the GCL. For example, if DND lands were at some point considered to be surplus, and subsequently acquired for re-development, there could be significant repercussions to GCL and the Lulu Island Bog. However, if these lands were protected as park there is potential that expanded management could be implemented to improve ecological function of the larger bog.

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5. Agricultural Site Assessment

5.1 Previous Agricultural Work

A number of previous reports and analyses regarding agricultural capability and potential have been completed for the Garden City Lands[11,12,13,14]. These reports note that while the bog may be somewhat debilitated due to previous uses as a rifle range and radio antenna installation array (and associated fill placement), the overwhelming conclusion is that the Garden City Lands are comprised of lands with good to moderately-good agricultural potential. There has been no cultivation on the site historically, however vegetation management in the form of mowing has been conducted by the City of Richmond to control growth height and manage the intrusion of certain types of plants.

Garden City Lands Biophysical Inventory and Analysis

A *Garden City Lands Biophysical Inventory and Analysis*[15] was developed as part an initial phase for the creation of the Garden City Lands Legacy Landscape Plan. This *Biophysical Inventory and Analysis* contained a number of observations and conclusions regarding the agricultural capability and suitability of specific agricultural activities for the site. It built on the previous research and provided a deeper level of analysis regarding the agricultural suitability of the site, including a small number of soil samples that were analyzed for fertility indicators (pH, organic matter, nutrients). CLI classification of agricultural soils were in alignment with the ALC's 2006 report: the assessment noted a mix of Class O3 and Class 3 soils. A small corner of the site was listed as Class 7 (no agricultural capability) due to fill being placed, driveways, and a few naturally-occurring drainage areas. The main limitations to cultivation that were noted were soil structure (peat depth) and high water tables (need for drainage).

5.2 Recent Agricultural Information

Since the Biophysical Assessment (2013) and the Legacy Lands Plan (2014) were produced there has been relatively little progress regarding the agricultural development of the site. No large-scale soils sampling, peat depth analysis, or drainage planning has been conducted. However, Kwantlen Polytechnic University has expressed interest in partnering with the City of Richmond to develop a farm school at the GCL site. As such they have prepared a preliminary proposal for a Sustainable Agriculture Research and Education Farm[16], and have begun collection soil samples for analysis at a later date[17].

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[11] Garden City Lands Exclusion Application and Agricultural Land Commission Decision, 2009.
[12] Agricultural Assessment of the CLC Lands, 555 No. 4 Road, Richmond. Dan Schroeter Consulting Inc., 2008.
[13] Soil Survey of Delta and Richmond Municipalities. Preliminary Report No. 10. H.A. Luttmerding and P.N. Sprout, 1969.
[14] Agricultural Land Commission Agricultural Capability Assessment File #: O-36435. T. Murrie, 1996.
[15] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.
[16] Sustainable Agriculture Research and Education Farm: Preliminary Proposal for the City of Richmond. Kwantlen Polytechnic University, 2013 (revised 2015).
[17] During 2015, KPU collected soil samples from the west side of the GCL site on a 100 m grid line. A total of 60 samples are being stored in the freezer for future physical and chemical analysis (Dr. R. Harbut, personal communication, November 2015).

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Kwantlen Polytechnic Agricultural Plan

Kwantlen Polytechnic University's (KPU) goals for the farm are to provide students with an educational opportunity to learn how to:

- Grow fruit and vegetable crops within a sustainable, ecologically-sound context (there is no mention of livestock, poultry, or egg production in their proposal);
- Develop business, sales, marketing skills;
- Develop problem-solving and research skills;
- Understand the layers of government and associated policies; and
- Incorporate short-term outreach education (workshops, field days) for industry and the public.

The KPU proposal is for a fully operational farm that would include market crops and research, orchard/perennial crops, outbuildings including a barn and tool shed, a composting facility, and cold storage.

The farm would be developed over several years, using a phased approach. For example:

- Year 1: 5 acres (2 acres of market crop production);
- Year 2: Infrastructure installment: high tunnels, irrigation systems, perennial crops; and
- Year 3: Regular farm operations in full effect.

KPU has expressed interest in using a section of the site as an experimental farm to test agricultural best practices for organic (peat) soils.

KPU is also interested in participating in a Project Advisory Committee or Panel to guide the short, medium, and long-term goals of the agricultural development of the Garden City Lands[18].

5.3 Agricultural Understanding of the Garden City Lands

Agricultural Management Conclusions

Soils

The soils of the Garden City Lands are mixture of organic (peat) and mineral sols. These have previously been classified as Terric Mesisols and Rego Gleysols: saline and peaty phase. The main limitations are soil structure problems (mixture of peat and mineral soils) and high water tables (wetness)[19].

The peat layer is found throughout the site and is underlain by fine-textured (silty) mineral subsoils. Previous studies measured this peat depth to be 16 to 39 cm[20], however these results are based on a limited number of samples, and therefore variations likely occur. The rooting depth (typically 0 to 20 cm for most crops) is likely comprised of organic materials in varying stages of decomposition throughout.

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[18] Dr. R. Harbut, personal communication, November 2015.

[19] Agricultural Land Commission Agricultural Capability Assessment File #: O-36435. T. Murrie, 1996.
[20] Agricultural Land Commission Agricultural Capability Assessment File #: O-36435. T. Murrie, 1996.

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Many similar soils exist in the immediate vicinity and have been cultivated. The practice usually involves the removal of the peat layer and development of the mineral layer. If the peat layer is not removed at the GCL site, then the following management steps may need to be followed:

- Ensure that any drainage system installed works in conjunction with the sponginess of peat (to avoid wet surfaces);
- Ensure that the plant's ability to grow a good root system and absorb nutrients is optimized (to neutralize pH); and
- Provide adequate soil aeration (to avoid subsidence and compaction).

Subsidence and compaction, and resulting mixture of organic and mineral soils, is noted as a key potential challenge to the long term cultivation of these soils[21]. The removal of the peat layer would largely eliminate this challenge.

Capability

In 2006, Trevor Murrie, PAg, ALC Staff Agrologist, assessed the property using the Canada Land Inventory (CLI) methodology during a site visit and previous soil reports[22] as a mixture of Class O4WL (O3LW) and 4W (3WN). A follow-up assessment by Upland Agricultural Consulting[23] determined the soils to be a mix of these along with O3WL (O2LW) and 3W (2WN). This can be interpreted as a mixture of organic (peat) and mineral soils with moderate to good agricultural capability. Limitations based on high water tables, soil structure conditions, and potential salinity (to a lesser degree).

The two assessments agreed that while there is no history of cultivation on the site, similar soils nearby the GCL are used extensively for berry and vegetable production and with proper management will produce an excellent diversity of crops. It was noted that special attention will need to be given to soil management if the peat is retained on site.

Suitable Agricultural Activities

Any agricultural use will require some amount of land clearing and the incorporation of some plant vegetation. The following agricultural activities were listed as highly or moderately suitable for the site[24]:

- Root vegetables and green vegetables;
- Corn and grains;
- Blueberries, raspberries, and strawberries;
- Pumpkins, zucchinis, squash;
- Cranberries;
- Field flowers;
- Honey bees;
- Hoop houses (small and medium);
- Poultry (very small scale);
- Farm retail sales and agri-tourism;
- Passive uses (biodiversity conservation, wildlife viewing, parks, recreation);
- Education and research;

[21] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.
[22] Soil Survey of Delta and Richmond Municipalities. Preliminary Report No. 10. H.A. Luttmerding and P.N. Sprout, 1969.
[23] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.
[24] Ibid.

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- Botanical gardens;
- Storing, packing, preparing, or processing foods;
- Large scale compost operations; and
- Production and development of biological products used in Integrated Pest Management programs.

Agricultural Management Unknowns

Several gaps in knowledge remain and need to be filled in order to move agricultural production on the site from conception to reality.

Baseline data on soil fertility

Any agricultural production will require a detailed level of soil fertility analysis. This can be done by collecting samples in a concentrated area (where agricultural production is likely to occur) or across the site in a grid like fashion. The samples should be tested for a full suite of physical and chemical parameters such as pH, EC, nutrients (available and total), CEC, salinity, organic matter, and particle size analysis. This detailed level of analysis is outside the scope of this project. KPU has collected 60 samples that are being stored for future analysis, however they are in need of funds to complete the testing by an external laboratory[25].

Baseline soil data on heavy metals

It is important to check soils for contamination prior to cultivating crops for human consumption. Analysis of heavy metals in soil can provide a relatively cost-effective indicator of toxicity problems. There are many sources of metal contaminants that can accumulate in soils. These include the burning of fossil fuels, use of additives in gasoline, use of insecticides, metal plating, domestic sewage sludge, industrial waste, and air pollution. Based on the GCL's previous use as a rifle range and radio antenna installation array (and associated fill placement), soil toxicity remains a possibility. The greatest human health problems usually arise from Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Lead (Pb), and Zinc (Zn). Cd and As are extremely poisonous to humans; Hg, Pb, and Ni are moderately so; and Boron (B), Cu, Manganese (Mn), and Zn are relatively lower in mammalian toxicity[26].

While it is outside the scope of this project, soil samples should be analyzed in the lab for a suite of trace metals[27] and results should be compared to two commonly-used health and safety guidelines: BC's Organic Matter Recycling Regulation (OMRR) Class A Compost[28] and the Canadian Council of Ministers for the Environment (CCME)'s Canadian Environmental Quality Guidelines (CEQG): Soil Quality Guidelines for Human Health[29]. It may be possible (and cost effective) to use the samples previously collected by KPU and currently being stored to test for both soil fertility and heavy metal parameters at the same time.

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[25] Dr. R. Harbut, personal communication, November 2015
[26] The Nature and Properties of Soils. 11th Ed. 1996. Brady, N.C. and R.R. Weil. Prentice Hall, Upper Saddle River, NJ.
[27] The samples were tested for trace metals using the following techniques: Inductively Coupled Plasma (ICP) for the majority of elements, Hydride Generation Atomic Absorption Spectrometry (HGAAS) for As and Se, and Cold Vapour Atomic Absorption Spectrometry (CVAAS) for Hg.
[28] Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice. Best Management Practices. March 2008. BC Ministry of Environment. http://www2.gov.bc.ca/assets/gov/environment/waste-management/recycling/landappguidelines.pdf
[29] CCME Canadian Environmental Quality Guidelines. Factsheets. http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/index.html

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Detailed data on peat depth

The Biophysical Inventory and Analysis included an initial survey of peat depth across the site based on a survey following a grid pattern[30]. Three linear transects running east to west were established 190 metres apart. Peat depth was measured every 50 metres by either excavating a soil pit or using a metal probe. Depending on the agricultural methods chosen at the time of planting, more detailed information regarding peat depth may be required. It would be beneficial to use these results as a starting point and obtain a more detailed analysis of peat depths within the sections of the site specifically allocated to future agricultural development. Unfortunately, this further analysis is outside the scope of this project.

On site water plans for drainage and irrigation

While it is expected that final plans will involve separating agricultural drainage water from bog water by a dyke, more information will be required to determine appropriate crop-based drainage plans. Data on groundwater depth appears to be largely missing and without it, it will be difficult to complete appropriate agricultural drainage plans for the site. With respect to agricultural drainage, and in particular drain tile spacing, a full drainage assessment based on water table depths measured during the wet seasons is required. We expect a key part of this investigation, the Hydrogeology Assessment, will help to answer some of these questions.

Questions also remain about best sources of irrigation water for crop cultivation on the site. Groundwater could be used as a source, however without more knowledge regarding quantity and quality of this water resource it remains challenging to include groundwater in irrigation plans. Rainwater harvesting could be an option, however many organic certification programs discourage the use of rainwater for certain edible crops due to potential human health concerns. Therefore, without further details regarding groundwater, all irrigation plans associated with agricultural development of the site will need to rely on municipal water sources.

Some of these outstanding questions regarding drainage and irrigation may be answered throughout the course of this project, through the Hydrogeology Assessment and associated modelling. The level of detail provided regarding drainage and irrigation will depend largely on the results of this analysis.

Climate change

It is worth noting that climate change remains an important unknown for agriculture. In particular, changes to the hydrologic and temperature regimes may impact crop selection, irrigation requirements, and potential yields. Throughout this project, efforts will be made to include climate change forecasting and modelling results at every level of analysis.

[30] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013. P73.

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6. Surface Water and Drainage Site Assessment

The GCL site topography is relatively flat with elevation ranging from 1.5 m to 0.6 m. The site gently slopes down from the northeast to the southwest with an average slope of 0.08%. This is with the exception of the mound, which is about 2.5 m above ground level located at the northwest corner of the site. The GCL receives direct precipitation on the site and possibly receives off-site stormwater runoff that inflows to the site along Alderbridge Way. During the wet season, excess site runoff is collected by the south perimeter ditch that drains toward the west to the Garden City Road and toward the east to the No. 4 Road storm sewer system. A series of catch basins are located along the western edge of the site that drains to the west. However, most of the catch basins were fully blocked by grass and sediment.

Historically, surface ponding has been observed at multiple locations. These topographic depression locations, as listed below, are also visible from the orthophoto due to vegetation changes.

- A large pool along the toe of the Mound.
- Multiple locations around the western edge and the southwest corner of the site.
- An area along the entrance from No. 4 Road.

A map showing the historic ponding locations is provided in Figure 6-1.

6.1 Previous Drainage Work

Drainage Modelling of Richmond Stormwater System

The Richmond city-wide MIKE URBAN drainage model was updated by KWL in 2011[31]. The model assessed the effect of the 2041 Official Community Plan land use on the 2010 existing drainage system. In the model, the GCL was divided into two sub-catchments, with the western half contributing to the Garden City Road storm sewer system and the eastern half contributing to the No. 4 Road storm sewer system. Under the 10-year, 24-hour design storm, the model identified surface flooding at all the major nodes located along Alderbridge Way and Garden City Road. As shown in Figures 6-2 and 6-3, the flooding was due to inadequate capacity in the major storm sewer system.

The existing model of the City's storm sewer network is intended to be utilized in this project to assess available off-site stormwater volumes that may be available for on-site uses on the GCL. The model will also be used to assess the impact of development of the GCL for its intended park uses on the existing adjacent storm sewer system, as well as connection options for drainage from the site to the storm sewers. Assessment of whether this flooding can be mitigated by incorporation of stormwater detention and storage in the GCL site will be part of the further work on this project.

In addition, the limitations of the storm sewer network highlighted by the 2011 modelling may pose a problem for drainage design for the GCL for implementation of the Landscape Legacy Plan. The undersized storm sewers on Garden City Road will be unable to accept additional peak runoff flow for the design event from the GCL. While the development of the GCL will not require significant increases in impervious area on the site, there will be additional impervious area and reduced overall permeability on the Western side of the site, relative to the existing condition, as well as reduction in total vegetative

[31] KWL, 2011. Drainage Modelling and Capital Plan for the Proposed 2041 OCP

cover. These will contribute to increase peak runoff from the site. If the undersized pipes will not be upgraded for development of the GCL, then all increases in peak runoff would need to be mitigated on-site. This would be a highly sustainable approach and as the increase in peak runoff is expected to be small relative to the size of the site, this may be possible. This will be investigated as part of later work on this project.

Surface Water and Drainage from the 2013 Biophysical Assessment[32]

The main surface drainage features on the GCL site are drainage ditches, stormwater catch basins, swales and natural depressions. A ditch runs along the south boundary of the site, draining from the middle of the site toward both the west and east with an average slope of 0.2% in either direction. Considerable debris blockage was identified at each end of the ditch outlet. A series of ten stormwater inlets is located along the west boundary of the site. Many of the inlets were noted to be partially or fully blocked by grass and sediment, with pooled water found in adjacent areas.

A system of meandering swales is located on the northwest portion of the site, between Landsdowne Road and the Mound. They are assumed to be remnant channels from pre-settlement times, as Lulu Island grew from the deposition of Fraser River sands and gravels, and water moved across the surface.

At the time of the biophysical inspection, the western half of the site was noticeably wetter than the eastern half. A large area of pooled water was present in the northwest part of the site, extending from near the toe of the Mound reaching southward for about 50 m. Without management, the western half of the site will have excess soil moisture for agriculture use. Poor drainage would damage perennial crops during wet winter months and affect annuals. Therefore, farming practices, as envisioned for the western portion of the GCL, will require site drainage, such as perimeter ditches or mole drains, to remove water from the peat soils.

During the dry summer months, farms require irrigation, which may be able to be obtained from drainage ditches and on-site water storage. Irrigation water taken from pumped wells is not recommended because it is likely to be saline, especially after extended periods of pumping.

On the eastern half of the site, the envisioned peat bog restoration favors high precipitation and restricted drainage. From a bog restoration point of view, the water table should be kept high nearly year round and drainage must be restricted to support the bog and any associated hydrophilic ecosystem components.

A simplified hydrologic analysis using rational method estimated 0.05 m^3/s of surface water flow from the GCL. This value was calculated using a runoff coefficient of 0.1 during a 10-year 24-hour storm event under saturated conditions.

6.2 Recent Drainage Information

Limited recent drainage information is available post the 2011 citywide drainage study. Much of the following is descriptive understanding of the site climate and drainage.

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[32] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.

Part A: Site Assessment and Background Review

Precipitation Data and Climate Change

According to the 1981-2010 climate normal data on the Environment Canada website, the mean annual precipitation at the Vancouver International Airport station (ID 1108447) is 1189 mm (1153 mm of rainfall and 38 cm of snowfall). Rainfall occurs throughout the year, with most occurring from October to March. Most snowfall occurs during November to February. The rainfall intensity frequency data at YVR climate station for various return periods are shown in Table 6-1.

Table 6-1: Local Rainfall Intensity Frequency Data

Return Period (Years)	24-Hour Rainfall Total (mm)
2	51.5
5	65.0
10	73.9
25	85.1
50	93.4
100	101.7

In 2015, GCL experienced an exceptionally dry spring and summer. As shown in Table 6-2, the 2015 monthly precipitation only account for 6% to 58% of the average amount from the Climate Normals. In contrast, the precipitation receive in August 2015 exceeds the average amount by 85%.

Table 6-2: 2015 Precipitation Data

Month	2015 Precipitation (mm)	Climate Normal (1980-2010) Precipitation (mm)	% (2015/Climate Normals)
April	51.4	88.5	58%
May	4.2	65.0	6%
June	11.0	53.8	20%
July	20.8	35.6	58%
August	67.8	36.7	185%

Extreme weather conditions are expected to occur more frequently in the future. Both CGM1 and HADCM2 climate projection models predicted increasing precipitation during winter months and decreasing precipitation in the summer months.[33] Increased winter precipitation suggests increased winter water supply and warmer drier summers suggests increased potential evaporation and transpiration. Development of options for the GCL Water Resource Management Strategy will consider the impacts of changing weather patterns to the site hydrology over time. As bog ecology depends on rainfall for water supply, it will be sensitive to changes in both the timing and amount of precipitation. Agricultural uses of the park and community amenities that incorporate stormwater re-use would also be affected by climate change over time and these considerations will be incorporated to the extent possible. However, climate change predictions are generally based on average annual conditions, and often do not address seasonal rainfall variation or changing storm intensity.

[33]Paul H. Whitfield and Richard J. Hebda, 2006. Restoring the Natural Hydrology of Burns Bog, Delta, BC – The Key to the Bog's Ecological Recovery.

Part A: Site Assessment and Background Review

Site Visit and GIS Data

As noted in Section 2, a site visit was done by the consulting team to walk the site and understand the topography, drainage, and other site characteristics. Information obtained during the site visit, from observations and from City staff, combines with the GIS infrastructure data provided by the City to understand the existing drainage and infrastructure on the site.

Besides direct precipitation, the GCL also receives runoff from offsite. Westminster Highway, along the South side of the site, and Garden City Road, along the West side of the site, are not curbed along the GCL site. Runoff from the adjacent half of both roads flows onto the GCL for collection and drainage into the municipal storm sewer system.

In addition, City staff indicates that there is a source of off-site water that enters the site from the road bank of Alderbridge Way, near the center of the North side of the site. While no visible discharge point was identified in this area during the site visit, there may be an abandoned pipe or other infrastructure that discharges in this location. At this time, the source of the water has not been determined, therefore the volume of water that is discharged here is not known.

Information from staff and GIS data obtained from the City indicates that multiple stormwater system inlets along the West edge of the site are primarily responsible for draining excess surface water from the site. The GIS data indicate that there are inspection chambers, which may also be inlets (this will be confirmed at a later site visit and check with operations staff), located approximately every 20 m along the base of the road bank of Garden City Road. These connect to two storm pipes that run along the edge of the road right-of-way. The storm pipes connect to a storm trunk sewer at Lansdowne Road, which drains toward the West to the Gilbert Road North pump station on the Fraser River.

There is also a storm inlet at the Southeast corner of the site that drains the East half of the ditch along Westminster Highway. In the 2011 modelling report, the catchment for this discharge point includes more than half of the GCL site. This inlet drains to a trunk storm sewer along No. 4 Road that drains to the North, to the No. 4 Road pump station on the Fraser River.

City staff report that the storm inlets (which were un-observable during the site visit) are open pipe inlets and are prone to clogging. Except when inlets are clogged, the existing drainage infrastructure appears to be adequate for draining excess water from the site during normal conditions. Site flooding that encroached upon Garden City Road in the recent past is considered to be due to clogging of the storm inlets along Garden City Road.

The storm sewer pipes along Garden City Road and No. 4 Road are located along the edge of the road adjacent to the GCL. The storm sewer along Alderbridge Way is located in the middle of the road section, and the storm sewer along Westminster Highway runs along the South side of the road, not next to the GCL. These two pipes would be more difficult to connect to for either bringing offsite stormwater to the site or for discharging stormwater from the due to the necessity of crossing part or the entire roadway to connect to the pipe.

Part A: Site Assessment and Background Review

Water Quality Information

Water quality testing of water from the on-site well at Garden City Park was conducted by KWL in January and March 2005. Among the tested parameters (temperature, turbidity, pH, TSS, conductivity, dissolved oxygen, sulphide, ammonia, sulphate, chloride, total hardness, BOD and trace metal), the Al, Cr, Fe and Ti level was above the BC Guidelines for Protection of Aquatic Life. It should be noted that the samples were taken during the excavation of the stormwater pond, and they were a mixture of groundwater and surface water, so are not reliable evidence for the levels in either surface water or groundwater alone.

According to the meeting minutes of the Environment Advisory Committee[34], groundwater monitoring has also been conducted by the City since 2008 at the Southwest corner of the GCL, directly across from the Esso gas station and oil change facility. To date, there is no indication of any contamination at this location. Ongoing monitoring will take place as long as the gas station and oil change facility is there.

Runoff from paved surfaces, particularly roads, carries sediment and other contaminants. The quality of off-site stormwater has not been characterised and will not be as part of this project. This work will need to assume that stormwater runoff from roads and other off-site sources and carries sediment and other contaminants consistent with literature values. Generally, in the urban environment these include significant levels of heavy metals, and may include dissolved nutrients from landscaping management operations or agriculture though the nutrient contaminants vary seasonally[35]. These contaminants will be considered in evaluating the use of road and offsite runoff water on the GCL, such as water supply for wetlands.

6.3 Drainage Understanding of the Garden City Lands

Existing Site Drainage Conclusions

The GCL site receives water from the following sources:

- Precipitation – direct precipitation onto the site;
- Discharge coming from road embankment along Alderbridge Way; and
- Road runoff from adjacent roadways on the South (Westminster Highway) and West (Garden City Road) sides of the site.

There are two general existing flow routes identified across the site. One allows water to drain from the central and east portions of the site toward the South edge of the site. Along the South edge, drainage in the ditch flows from the center toward the East and West to storm sewer system inlets. The Southwest corner of the site appears to drain poorly, as ponding frequently occurs during the wet season. By the early fall timing of the site visit for this project, there was no standing water or wet ground on site. The other flow route generally, drains water across the Northwest quadrant of the site, from the center of the North side of the site to the North half of the West side of the site.

[34] Advisory Committee on the Environment – Garden City Legacy Landscape Plan, April 16, 2014.
[35] Minton, Gary. Stormwater Treatment: Biological, Chemical, and Engineering Principles. 2010.

Part A: Site Assessment and Background Review

Information from staff and GIS data obtained from the City indicates that multiple stormwater system inlets along the West edge of the site are primarily responsible for draining excess surface water from the site. There is also a storm inlet at the Southeast corner of the site that drains the East half of the ditch along Westminster Highway.

City staff report that the storm inlets (which were un-observable during the site visit) are open pipe inlets and are prone to clogging. Except when inlets are clogged, the existing drainage infrastructure appears to be adequate for draining excess water from the site during normal conditions. Site flooding that encroached upon Garden City Road in the recent past is considered to be due to clogging of the storm inlets.

However, the 2011 modelling of the storm system indicates that the storm sewers along Garden City Road and Alderbridge Way are undersized for the 10-year, 24-hour design event. Some flooding in the GCL could be due to limited capacity in the storm sewer system; though the duration of ponding on the site after storms have ended indicates that poor drainage of the site is an issue regardless.

The limited capacity in the storm sewer network on Garden City Road, in particular, may have an impact on the drainage design for development of the site. Without upgrade of the receiving storm sewer pipes, detention on-site of the design rainfall event may be required. The storm sewer pipes will not be able to receive any increase in runoff from the site due to development of the park.

Surface Water Challenges

This project presents a number of challenges for surface water and drainage considerations. Drainage will need to be provided to required elevations both for the bog and natural areas and for the agricultural and community use areas. The levels of drainage for those four uses will be determined as part of the work of this project, but they may all be different elevations and are likely to require separate drainage infrastructure to achieve the different drainage levels.

While drainage may be required to multiple different levels, there will also be a need to retain water on the site to some minimum levels in order to support the bog and wetland natural areas of the Legacy Landscape Plan. This will require careful consideration and balancing of flooding, safety, drainage, and ecological needs.

Drainage may also be challenging due the very low gradients available in this area. The site itself is mostly very flat, and there is minimal gradient from surface drainage from this location to the Fraser River. As drainage conveyance capacity is partly dependent on gradient, the grades are expected to make design of drainage solutions more challenging for this site.

There is also a question whether the site can sustainably supply some or all of the water needs for irrigation and possibly other on-site water uses with storage and re-use of on-site and/or off-site stormwater. The viability of this will be investigated in the course of the Water and Ecological Resource Management Strategy project. Infrastructure to provide storage and re-use of stormwater will also have to be provided with overflow and drainage infrastructure for safe conveyance and discharge of excess flows.

Part A: Site Assessment and Background Review

Existing Site Drainage Unknowns

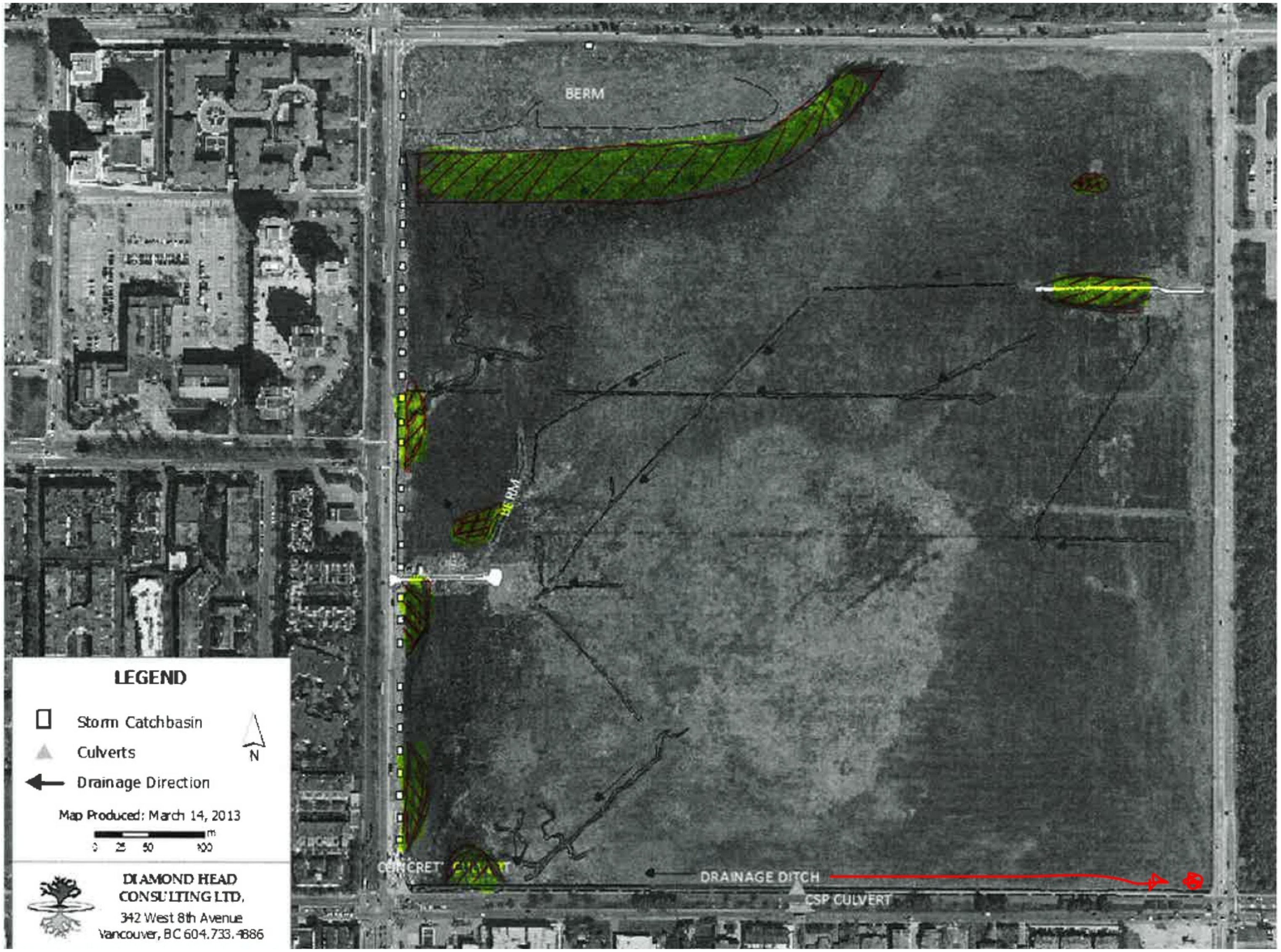
The water quality or water chemistry of the stormwater from on-site as well as from off-site must be considered for use and contribution to the natural areas for the park and for use in irrigation or other on-site water uses. The water chemistry of on-site water has been sampled as part of the Biophysical Assessment, but the off-site stormwater water quality has not been characterised and will not be as part of this project. This work will need to assume that stormwater runoff from roads and other off-site sources carries sediment and other contaminants consistent with literature values.

In addition, the water quality of onsite water that has been in contact with groundwater may be of concern. Groundwater in Richmond is known (see Section 3 of this report) to carry high levels of iron, such that iron staining can occur on surfaces and vegetation that have been in contact with the groundwater. As there may be some existing groundwater contribution to the site[36], as well as there is a possible option developing a groundwater source for on-site irrigation, the possibility of iron contamination is a concern but is not quantifiable at this time.

The source of water that enters the site along South side of Alderbridge Way is currently unknown and may not be able to be identified with certainty. The affects the stormwater management options and design as the volume of water will be difficult to estimate for storage or conveyance on GCL.

[36] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.

City of Richmond



Ponded Water

Source | from Diamond Head Consulting Ltd.

Project No. 651-085

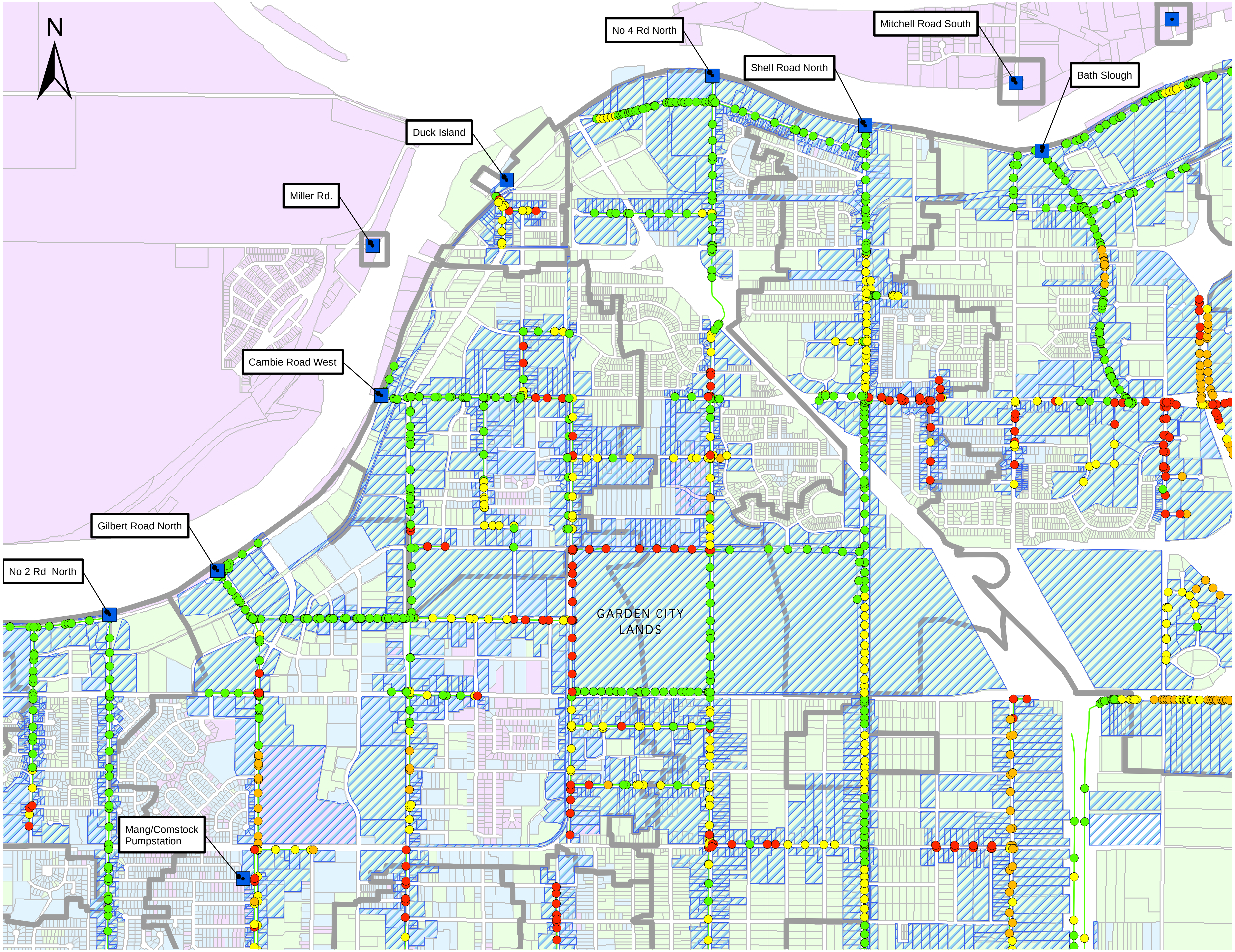
Date November 2015

Not to Scale

KERR WOOD LEIDAL consulting engineers

Garden City Lands Ponded Water

Figure 6-1



Richmond

Garden City Lands Water and Ecological Resource Management Plan

Legend

Catchment Boundary

Pump Station

Parcel Elevation (m)

< 0.5

0.5 - 1.0

> 1.0

Max Water Levels (Min El)

Surface Flooding

Surface Flooding (No IC)

Inadequate Freeboard (< 0.45 m)

Acceptable

Lots Adjacent to Major System

Note:
Parcel elevations based on lowest inspection chamber elevation where available and DEM elsewhere. Inspection chamber elevations and DEM as provided by the City of Richmond, February 2011. DEM reported accuracy is 0.6 m ±.

Peak water levels compared to minimum parcel elevations.

Model results of existing infrastructure without improvements.

Pump stations on along western dyke.

KERR WOOD LEIDAL
consulting engineers

500 0 500 (m)

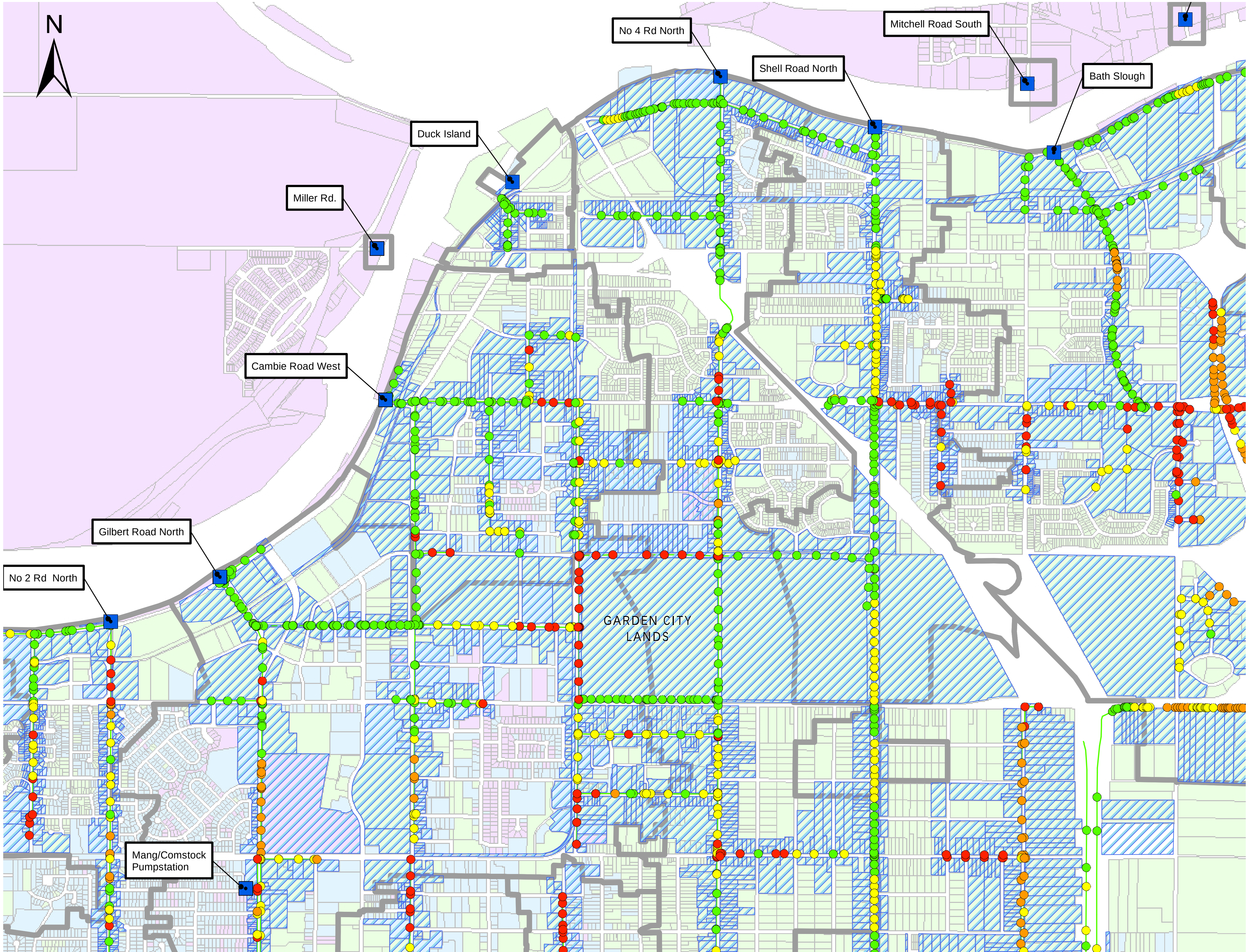
1:20,000

Project No.	Date
651-085	November 2015

Major System Flooding 2041 OCP Condition Without Improvements 10-Year, 24 Hour Free Outfall

Figure 6-2

Path: O:\0600-0699\651-085\430-GIS\MXD-Rp\Phase1\651085_Phase1_Fig6-2.mxd Date Saved: 24/11/2015 11:42:58 AM
Author: JLau



Richmond

Garden City Lands Water and Ecological Resource Management Plan

Legend

Catchment Boundary

Pump Station

Parcel Elevation (m)

< 0.5

0.5 - 1.0

> 1.0

Max Water Levels (Min El)

Surface Flooding

Surface Flooding (No IC)

Inadequate Freeboard (< 0.45 m)

Acceptable

Lots Adjacent to Major System

Note:
Parcel elevations based on lowest inspection chamber elevation where available and DEM elsewhere. Inspection chamber elevations and DEM as provided by the City of Richmond, February 2011. DEM reported accuracy is 0.6 m ±.

Peak water levels compared to minimum parcel elevations.

Model results of existing infrastructure without improvements.

KERR WOOD LEIDAL
consulting engineers

500 0 500 (m)

1:20,000

Project No.	Date
651-085	November 2015

Major System Flooding 2041 OCP Condition Without Improvements 10-Year, 24 Hour Constant 2 m Outfall

Figure 6-3

Path: O:\0600-0699\651-085\430-GIS\MXD-Rp\Phase1\651085_Phase1_Fig6-3.mxd Date Saved: 24/11/2015 11:40:42 AM
Author: JLau

Part A: Site Assessment and Background Review

7. Site Assessment Conclusions

The conclusions from the preliminary site assessment are summarized below.

7.1 Site Groundwater Management Conclusions

Based on information obtained and reviewed to date, the following items are of relevance to our understanding of hydrogeologic conditions at the GCL:

Hydrostratigraphy

- Native materials underlying the GCL comprise the following from ground surface down:
  - *Peat* – the peat is relatively thin, averaging about 0.6 m in thickness. It is thickest (about 1.4 m) in the eastern part of the site and thins to the west. The upper several centimetres of peat are relatively permeable (perhaps on the order of 10^{-4} m/s) with active plant and moss growth sphagnum), whereas the underlying few centimetres is characterized as amorphous and has a relatively low permeability (inferred to be on the order of 10^{-7} m/s).
  - *Clayey Silt* – this unit is continuous across the GCL and directly underlies the peat. It has a reactively low hydraulic conductivity and acts as an aquitard between the permeable peat unit and underlying Fraser River sand.
  - *Transitional Silt* – In several areas beneath the GCL, the clayey silt transitions into sand. The transitional zone is characterised by silt with thin interbeds of fine sand. The sand layers are unlikely to be laterally extensive and may occur as lenses.
  - *Sand* – beneath the clayey silt or transitional silt is a relatively thick unit composed of fine and fine to medium-grained laterally extensive sands. The sand units collectively are referred to as the Fraser River sand aquifer that, beneath the GCL, is on the order of 10 m to 20 m in thickness. The sands extend several tens of kilometres to the east and south, are hydraulically connected to the Fraser River to the north, and extend to the marine environment to the west. The sustained yield from pumping a well installed in this aquifer to the south of GCL near Alberta Street is greater than 3.1 L/s (about 50 USgpm).
  - *Marine Silt* – the sand aquifer is underlain by a continuous layer of silt, inferred to be of marine origin that is laterally extensive and is likely underlain by till. This silt unit behaves as an aquitard, and for purposes of the groundwater model, serves as the base of the model domain.

Water Quality

- Water within the peat was characterized as being acidic with relatively low dissolved solids (pH 3.8 to 4.8; electrical conductance less than 100 µS/cm), whereas waters win the underlying Fraser River Sands were near neutral and minerotrophic (pH 6.3 to 7.0; electrical conductance about 300 µS/cm to 750 µS/cm). Minerotrophic, near neutral pH waters were also encountered in shallow soils nears roads, where peat had likely been removed a part of development. Based on water quality testing conducted south of the GCL near Alberta Street, groundwater is likely to meet current guidelines and criteria for various organic and inorganic constituents, with the exception of iron, which is highly elevated as noted previously.

Part A: Site Assessment and Background Review

Water Levels and Groundwater Flow Direction

- Water levels in the peat and underlying silt units respond relatively rapidly to rainfall events, whereas water levels in the deeper sand unit are much more attenuated;
- Based on review of historic air photographs and current water level information, the general horizontal flow direction within the peat bog (and underlying sand aquifer) has historically been to the southwest; and
- Vertical flow is downward, from the peat through the silt aquitard and into the sand aquifer. Downward seepage occurs throughout the year. The quantity (i.e., flux) of downward flow is a key parameter to be define in order to assess various development alternatives, and will be assessed through the modeling effort.

Work currently underway is focused on resolving data gaps and supporting development of a 3-D finite element model of the hydrogeologic system.

7.2 Site Environmental Management Conclusions

Due to its location on the margins of Lulu Island Bog, there is a strong likelihood that the GCL is representative of both bog and lagg ecosystems and that a transitional plant community exists. The east side of GCL is currently considered a semi-natural bog ecosystem, dominated by introduced Scotch Heather, but also having a diversity of native bog-associated plants, some of which are regionally rare.

There are five conditions that must be met for bog restoration to be considered as a possibility for a site[37]

1. There should be a large area of peat where the drainage does not cut into the mineral substrate;
2. There should be at least 50-100 cm of compressed, humified peat;
3. It should be possible to exclude all sources of nutrient enrichment (air and water borne);
4. There should be a buffer zone between the site and agricultural land; and
5. A source for plant colonization should exist locally.

Garden City Lands meets (or potentially meets) these five conditions for restoration of the bog on the Eastern portion of the site.

The Legacy Landscape Plan envisions creation of an open water complex in the southwest corner of Garden City Lands. The ecology of this area indicates that it may be considered the transition or lagg zone for the Lulu Island bog. These lagg systems have received relatively little attention in bog restoration, therefore, while creation of a marsh (wetland ecosystem) is a primary objective, maintaining representative vegetation components and chemistry gradient in the lagg should also be a focus of restoration efforts.

The acidic, nutrient poor conditions of bogs are not suitable for many tree species and trees can also affect water balance by intercepting precipitation and through transpiration of groundwater. Therefore, landscape tree planting on the periphery of GCL will need to be carefully considered in coordination with natural areas restoration.

[37] Charman, D. 2002. *Peatlands and environmental change.* Wiley, New York.

Part A: Site Assessment and Background Review

Management considerations for bog restoration on the GCL site include:

- Creating hydrological conditions sufficient to support active *Sphagnum* growth and prevent peat from drying out during summer months, thereby encouraging establishment of plants more suited to these conditions;
- Management control of invasive plants which are outcompeting native bog species;
- Isolating bog and lagg ecosystems due to their different hydrological and hydrochemical requirements;
- Isolating hydrological inputs and outputs separately in the agriculture zone and wetland zone;
- Ensuring any management action taken on GCL does not negatively affected the greater Lulu Island bog ecosystem (DND lands and RNP), and that potential future changes in adjacent land use will not compromise restoration efforts on the GCL site;
- Potential impacts of climate change (e.g. longer, drier summers) are appropriately considered in water balance models for the site to ensure wetland requirements can be met over the long-term; and
- Restoration of the bog and lagg ecosystem will require a long-term vision and adaptive management to achieve objectives. For comparison, the Burns Bog Management Plan has a 100 year outlook.

7.3 Site Agricultural Management Conclusions

The Garden City Lands offer a wealth of opportunity for a diverse range of agricultural activities. The breadth and scope of farming that will occur will depend on how the following factors are managed:

- The cultivation of the organic (peat) and mineral soils;
- The sophistication of drainage incorporated into the water management plan;
- The source of water for irrigation (quality and quantity of water available); and
- The operation of the site itself (either solely by the City of Richmond, in partnership with KPU, or through land use agreements with other individuals and/or agencies).

There are no serious limitations to farming the Garden City Lands and those that do exist (e.g., high water tables, organic soil layers) can be overcome with minimal to moderate levels of amendments and modifications to the site.

7.4 Site Drainage Management Conclusions

The GCL site receives water from the following sources:

- Precipitation – direct precipitation onto the site;
- Discharge coming from road embankment along Alderbridge Way and
- Road runoff from adjacent roadways on the South (Westminster Highway) and West (Garden City Road) sides of the site.

Part A: Site Assessment and Background Review

There are two general existing flow routes identified across the site. One allows water to drain from the central and east portions of the site toward the South edge of the site. Along the South edge, drainage in the ditch flows from the center toward the East and West to storm sewer system inlets. The Southwest corner of the site remains wet with standing water on site through the winter season. The other flow route generally drains water across the Northwest quadrant of the site, from the center of the North side of the site to the North half of the West side of the site.

There are multiple stormwater system inlets along the West edge of the site are primarily responsible for draining excess surface water from the site. There is also a storm inlet at the Southeast corner of the site that drains the East half of the ditch along Westminster Highway. The existing storm inlets are thought to be open pipes (unconfirmed at this time) and are prone to clogging.

This project presents a number of challenges for surface water and drainage considerations, including:

- Drainage will need to be provided to required elevations both for the bog and natural areas and for the agricultural and community use areas.
- There will be a need to retain water on the site to some minimum levels in order to support the bog and wetland natural areas of the Legacy Landscape Plan.
- Drainage may also be challenging due the very low gradients available in this area.
- There is a question whether the site can sustainably supply some or all of the water needs for on-site water uses with storage and re-use of on-site and/or off-site stormwater.

Among the unknown information that will affect the development and selection of water management options for the site, the water quality of off-site stormwater will be assumed based on typical values.

The source of water that enters the site along South side of Alderbridge Way is currently unknown and the volume of water will be difficult to estimate for storage or conveyance on GCL.

Storm system modelling indicates that existing storm sewer pipes on Garden City Road and Alderbridge Way are undersized for the design storm event. The limited capacity in the storm sewer network on Garden City Road, in particular, may have an impact on the drainage design for development of the site. Without upgrade of the receiving storm sewer pipes, detention on-site of the design rainfall event may be required. The storm sewer pipes will not be able to receive any increase in runoff from the site due to development of the park.