Final Report

John Hendry Park Stormwater Management Plan

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1. Introduction

The City of Vancouver (City) is seeking a Stormwater Management Plan (SWMP) that integrates with the Master Plan for John Hendry (Trout Lake) Park (JHP).

John Hendry Park (27 ha) is located in East Vancouver's Cedar Cottage neighbourhood. Trout Lake (2.5 ha at 28.12 m elevation) is the central feature of the park. This man-made lake is the only accessible freshwater lake in the City of Vancouver. The park attracts approximately 750,000 visitors per year and offers running and biking trails, a swimming beach, an off-leash dog area, and a community centre amongst other amenities. The park is mostly surrounded by single-family houses and duplexes with medium density housing located northwest of the park near the Broadway-Commercial SkyTrain station and southwest of the park in the Commercial-Welwyn area.

The lake and adjacent riparian areas provide aquatic and terrestrial habitat, an off-leash dog area, a swimming area and a recreational beach. Some of the uses of the lake overlap and have competing demands and objectives. The most prominent issue appears to be the required lake water quality (WQ) for swimming versus the use of the lake by birds that contribute to high bacterial counts.

Recently a portion of the combined sewer in Trout Lake's catchment was separated and other near-by sewers were identified for separation, providing a potential source of stormwater to be directed to the lake and new opportunities for improving stormwater quality and enhancing natural habitat for biodiversity in the park and the lake.

The objective of the stormwater management plan is to address:

- increased stormwater flow to Trout Lake;
- surface water quality improvement;
- watercourse creation;
- biodiversity enhancement;
- enhancement of park recreation use including swimming; and
- creation of climate change resilience structure.

The analysis is broken up into the following topics:

- assessing the feasibility of stormwater diversion from the upstream catchment to the park:
  - diverting stormwater through the park (piped diversion); and
  - using the park for management and attenuation of stormwater.
- Conveying urban runoff;
- Conveying runoff from various surfaces/areas in the park;
- improving lake water quality; and
- Stormwater Management Plan and Adaptive Management Plan.

The following sections provide background information, water balance and water quality analysis, and recommendations.

2. Site Description or Existing Conditions

Currently Trout Lake is cut off from most of its original catchment area by combined sewers that drain stormwater away from the park, with only a portion of the stormwater from John Hendry Park flowing into the lake. Most of the impervious area in the park is connected to storm sewers that discharge to a combined GVRD trunk main on E 19th Avenue. Trout Lake drains via two outlets; one located on the east side of the lake and one located on the west side of the lake. The outlets discharge to a combined

GVRD trunk main on E 19th Avenue. There is an overflow route for the lake though a former outfall located in the northwest corner of the lake; however, current water levels are too low (both during dry and the wet season) to utilize this outlet. Capacity of the existing outlet is discussed in more detail in the following sections.

During the summer months park users swim in the lake. To maintain the lake water level and improve water quality to be suitable for swimming, the lake is supplemented with potable water from the City's drinking water supply system during the summer months. As part of the SWMP, options for improving lake operations and reducing reliance on potable water are considered.

Water quality is an on-going concern at the lake especially as human recreational activities take place in and around the lake simultaneously as bird and dog use of the lake. As part of the SWMP, multiple options for improving park surface runoff water quality and lake water quality are evaluated. Options are also evaluated for the management of urban runoff as any diversion of runoff to the lake would require a high level of water quality runoff to maintain or improve water quality at the lake.

City of Vancouver is separating combined sewers upstream and downstream of Trout Lake. In the near future, Trout Lake will serve as a node in a separated storm sewer network; this presents both an opportunity to reconnect the lake to its catchment and to reduce Combined Sewer Overflows (CSOs) by diverting stormwater from catchments upstream of John Hendry Park to the False Creek stormwater catchment. Options for raising the lake water level with stormwater runoff from surrounding catchments and using the park space for management and attenuation of stormwater runoff are considered. City of Vancouver has a proposal for a separated storm sewer from the Trout Lake catchment to False Creek. Any plans for stormwater diversion through the park, should take into account the possibility of discharging stormwater runoff to False Creek.

3. Increasing Stormwater Flow to Trout Lake

The City is currently separating combined sewers surrounding Trout Lake and has proposed diverting separated storm sewer flows from these catchments to the lake. Delivering stormwater to the lake would provide stormwater management and reduce combined sewer overflows (CSOs). CSO reduction would be achieved by diverting stormwater away from the combined GVRD trunk sewer to the False Creek separated stormwater catchment. To determine if this is a viable option for the lake, the following analysis was carried out:

- assessed the feasibility of stormwater diversion from the surrounding neighbourhoods and identified storm sewer catchments that could be diverted (Answered the question "Is it physically possible?");
- developed a list of conveyance and management options;
- determined the capacity of the existing Trout Lake outfall;
- performed water balance analyses for existing and future scenarios at Trout Lake; and
- consulted with the client and took into account the findings of the stakeholder consultation process.

The City has identified three potential catchments that could be diverted to Trout Lake. The total area of the catchments, shown on Figure 3-1, is approximately 40 ha, and the City is in the process of separating the sewers in these catchments. In order to confirm that these areas can be diverted to the lake, inverts of storm sewers in the catchments were compared to the lake invert and possible diversion routes to the lake were identified. Based on review of the topography of the catchments, it is possible to divert most of the 40 ha area to the park via E 18th Avenue.

Once stormwater is diverted to the park, there are many potential options for both water management and conveyance. Options for water management, conveyance, and water quality for the SWMP are listed in Section 3.1, and were developed based on the goals described in Section 1.

3.1 Stormwater Diversion Alternatives

The options for treatment, management and conveyance of stormwater runoff through the park that were considered for the SWMP are listed below. The process for evaluating the options and arriving at the proposed solution is described in the following sections.

Stormwater can be conveyed through the park via pipes or through an open channel and wetlands. It can be diverted to the lake, to the existing GVRD trunk sewer on E 19th Avenue, or to the proposed False Creek storm sewer on E 14th Avenue. A number of different scenarios are presented below.

1. Daylighting to Trout Lake with overflows to existing combined sewer:

   For this option, base flows (up to 6-month storm flows) are directed to the lake via a constructed wetland. A flow diversion prior to the wetland diverts greater than 6-month flows (up to 5-year flows) to the existing combined GVRD trunk sewer on E 19th Avenue. Flows generated by greater than 5-year storms are conveyed by overland flow routes.

2. Daylighting to Trout Lake with overflows to new stormwater trunk sewer:

   For this option, base flows (up to 6-month storm flows) are directed to the lake via a constructed wetland. A flow diversion prior to the wetland diverts greater than 6-month flows (up to 5-year flows) to a new stormwater trunk sewer. The new storm sewer conveys flows from the Trout Lake catchment to False Creek. Flows generated by greater than 5-year storms are conveyed by overland flow routes.

3. Daylighting to wetland with all flows to new stormwater trunk sewer:

   For this option, base flows (up to 6-month storm flows) are directed to and flow through a constructed wetland prior to entering a new stormwater trunk sewer. The new storm sewer conveys flows from the Trout Lake catchment to False Creek. A flow diversion prior to the wetland diverts greater than 6-month flows (up to 5-year flows) directly to the stormwater sewer. Flows generated by greater than 5-year storms are conveyed by overland flow routes.

4. Daylighting to Trout Lake with all flows to existing combined sewer:

   For this option, base flows (up to 6-month storm flows) are directed to and flow through a constructed wetland prior to entering the existing combined GVRD trunk sewer. A flow diversion prior to the wetland diverts greater than 6-month flows (up to 5-year flows) directly to the existing GVRD trunk sewer. Flows generated by greater than 5-year storms are conveyed by overland flow routes.

5. Current Drainage pattern with no daylighting or diversion:

   Continue with the existing drainage pattern.

A water balance model was created to assess the options above to determine the effects of each option on the water level of the lake over a typical year of rain. A water balance analysis accounts for inflows, outflows, and losses from the lake and identifies the potential lake water surface elevation fluctuation in a typical year. The water balance included the existing Trout Lake outfalls, as well as the lake area-elevation curve to show the change in area and elevation of the lake water with additional stormwater run-off being diverted onto the lake.

3.2 Capacity of Existing Trout Lake Outfall

Trout Lake drains via two outlets; one located on the east side of the lake and one located on the west side of the lake. There is an overflow route though the former outfall located in the northwest corner of the lake; however current water levels are too low to utilize this outlet.

The east outlet is in good condition and was surveyed by the City of Vancouver on October 2013 to confirm the inverts and sizes. The outlet consists of a 300 mm pipe with an in lake invert elevation of 28 m and a downstream manhole invert elevation of 28.12 m. This means that the lake water level must be at 28.12 m before the outlet is in use.

The west outlet is in poor condition and was not surveyed. It was assumed that that the outlet was similar to the east outlet, consisting of a 300 mm pipe with an in lake invert elevation of 28 m and a downstream manhole invert elevation of 28.48 m. This means that the lake water level must be at 28.48 m before the outlet is in use.

There is some confusion regarding the status of the northwest outlet. Some reports indicate that the outlet is no longer connected, while some indicate that it is connected to a storm sewer on the E 13th Avenue laneway. For the purposes of this analysis, it was assumed that the outlet was connected to the laneway storm sewer, with an in lake invert elevation of 28.61 m and a downstream manhole invert of 29.66 at the E 13th Avenue laneway. However, the storm sewer on the E 13th Avenue laneway is lower and falls away from this outlet. This means that the lake water level must be at 29.66 m before the outlet is in use and that the E 13th Avenue laneway storm sewer cannot drain to Trout Lake.

3.3 Trout Lake Existing and Potential Water Balance Model

A water balance model was created to examine the effects of potential storm sewer diversion to the lake on the lake water level. The water balance analysis accounts for inflows, outflows, and losses from the lake and identifies the potential lake water surface elevation fluctuation in a typical year. The analysis was carried out for two scenarios: existing pre-diversion scenario and future post-diversion scenario.

A typical year rainfall total for John Hendry Park was estimated to be 1450 mm using the Metro Vancouver Rainfall Isohyetal Map. The typical year rainfall distribution with 15 minute time steps for the Lower Mainland was used to create the rainfall input for the model. Established typical Metro Vancouver evaporation values were used to represent losses from the lake. The existing lake outlet structures, which are described in pervious sections, were used in both the pre-and post-diversion models.

Currently, to improve water quality and maintain lake water levels, the lake is augmented with potable water from a water fountain during the summer months. Typical potable water input to the lake was estimated based on the 2012 data. In 2012, the fountain added a total volume of 206,000 m^3 to the lake between the months of June and November. In the existing scenario of the model, potable water is added to the lake at a constant rate (estimated from 2012 data) between June and October (inclusive). The post-diversion model does not include potable water input.

For the existing model, the area of the drainage catchment was limited to the lake area which was estimated to be 2.8 ha based on air photo representation of the lake; in the exiting model, no additional areas drained to the lake. In the post-diversion model, the drainage catchment was approximately 40 ha and consisted of the lake and the proposed diversion catchment. A runoff coefficient of 1.0 was assigned to the lake and a runoff coefficient of 0.7 was assigned to the reminder of the drainage catchment.

The results of the above water balance model were presented to the client to determine if the water level fluctuations in the lake resulting from the 40 ha diversion were acceptable. The client indicated that the resulting water level fluctuations were too large and that the target lake water level range post diversion is 28.12 m (current lake outlet invert) to 28.42 (30 cm above invert/existing water level). The target water level was selected to minimize the environmental impacts associated with lake level fluctuations.

The target water level was used to determine the size of the diversion catchment. To achieve the target water level, the size of the diversion catchment has to be limited to 15 ha. The proposed diversion catchment is shown on Figure 3-1.

Figure 3-2 shows the result of the post-diversion water balance analysis with a 15 ha diversion catchment. The peak water levels in the post-diversion model are higher than those of the existing conditions, except during the summer months when the lake is augmented with potable water under the existing conditions. Water level fluctuations are much higher in the post-diversion scenario.

The lake does not reach the historic water level seen on drawings (28.85 m) in either the existing or diversion scenario. This indicates that a flow split in the diversion pipe prior to the lake is not needed (from a water quantity perspective), as the lake has the capacity to accept runoff from the entire area. A control structure could be added to the lake outlet to further raise water levels; however, not only is there is a marked improvement over the existing water levels even without a flow control structure at the outlet, but the additional catchment area would have to be reduced to keep the water level fluctuations in the lake to the desired 30 cm range if the outlet was modified.

The current outlet structures can handle the flows from the typical year of rainfall. The additional areas proposed to be diverted currently drain to the same combined sewer to which the lake drains. This means that the existing downstream pipe should be adequately sized to accept the flows from these areas.

3.4 Client Preferences

Throughout the project, multiple meetings were held with the City and the Parks Board to discuss options and preferences. A list of client priorities is included below.

City of Vancouver Parks Board

- maintain swimming at the lake;
- limit the quantity of stormwater diverted to the lake to preserve lake integrity; and
- monitor lake water quality and if water quality is not acceptable initiate further treatment or limit diversion of stormwater to the lake.

City of Vancouver Engineering

- divert stormwater to the False Creek catchment; and
- use the lake for stormwater management.

Client preferences were taken into consideration for developing options and recommendations.

3.5 Water Quantity Findings

In a typical year, the volume of stormwater runoff from the park and the proposed 15 ha tributary catchment is estimated to be 190 ML while the volume of the lake is estimated to be 16 ML (at 28.12 m elevation). The water balance analysis shows that the lake has the capacity to receive runoff from the 15 ha of surrounding catchments identified in Figure 3-1. If the total volume of runoff from this catchment is diverted to the lake, the water in the lake would be diluted over time and replaced with the runoff within a year. Lake water level is expected to fluctuate more than it currently does once stormwater is diverted to the lake.

Taking into account the result of the water balance analysis and the City's and Parks Board's desire to reduce potable water use and maintain lake water levels in the summer, it is recommended that only the typical year runoff (approximately the 6-month, 24-hour rain event) be directed to the lake. Large events should be diverted around Trout Lake and directed to the storm sewer.

4. Water Quality Management

Improving water quality in Trout Lake is one of the main objectives of the SWMP.

Water quality monitoring has been conducted at Trout Lake since 1992 by Vancouver Costal Health due to water quality concerns and recreational swimming at the lake. Since 2012, Vancouver Coastal Health has repeatedly closed the beach to swimming when the indicator bacteria geometric mean levels exceeded 200 cfu/100 mL. The geometric mean indicator bacteria level was greater than 200 cfu/100 mL on 29 of 95 weekly water quality reports since 2010 (30%). 2010 and 2011 were particularly poor years with 27 out of 39 weekly reports exceeding the recommended levels (69%). In contrast there were no exceedances in 2013 and 2014.

Bird populations are considered to be the primary contributors to fecal bacteria in Trout Lake. In 1994, volunteers and parks board staff attempted to determine the contribution of gulls to the fecal coliform contamination in the lake. For two days, gulls were kept away from the lake. Fecal coliform counts were four times lower in the absence of gulls than when gulls were present at the lake. Birds use a raft positioned in the lake to perch on and their feces end up in Trout Lake. Recently, the raft has been covered overnight; the cover being washed each morning on land.

If urban runoff from the 15 ha catchment is diverted to the lake, the urban runoff volume would replace the volume of the lake on a regular basis. The estimated annual runoff volume is12 times the volume of the lake. Typical urban runoff quality in Metro Vancouver is described in Section 4.1. Runoff would require water quality management prior to entering the lake to maintain water quality for swimming.

The selection of the water quality management methods took into consideration other objectives of the SWMP including creation of watercourses, enhancement of biodiversity, resilient infrastructure and enhancing public use of the park.

4.1 Typical Urban Stormwater Quality

Pollutants that can typically be found in urban stormwater runoff consist of sediment, metals, oil and grease, nutrients, bacteria/viruses and others. Estimated mean value of typical pollutant in urban runoff in Metro Vancouver is summarized in Table 4-1 as well as possible water quality targets based on guidelines and best practices.

Table 4-1: Summary of Average Stormwater Pollutant Concentration in Metro Vancouver

Parameter	Estimated Mean Value	Water Quality Targets*
Fecal Coliform	17,700 MPN/100ml[1].	200 MPN/100 ml for primary recreation contact
Total Suspended Solids (TSS)	44 mg/L	40 mg/L

[1] Metro Vancouver (2003), Estimated Urban Runoff Character and Contaminant Loadings in GVRD – Final Report.

Parameter	Estimated Mean Value	Water Quality Targets*
Oil and Grease	3.0 mg/L	15 mg/L
Nitrate	0.64 mg/L	0.5 mg/L
Total Phosphorus	0.14 mg/L	0.05 mg/L
Total Dissolved Phosphorus	0.03 mg/L	0.01 mg/L
*Water quality targets based on email communication with Nick Page on October 25, 2013		

To fully characterize the stormwater and determine the actual E. coli loading and pollutant levels, sampling the storm sewers is recommended.

4.2 Selection of Management Process for Urban Stormwater from the Redirected Catchment

The appropriate level of water quality management required for stormwater runoff depends on the characteristics of runoff, the intended end use of the stormwater, and the quality of the receiving water. In the case of Trout Lake, factors that affect the level of required treatment include:

- health and safety of recreational users;
- lake aesthetics; and
- protection of aquatic life (taking into account eventual discharge to the ocean at the proposed False Creek outfall).

For the protection of surface water quality for aquatic life, the rule of thumb for management of stormwater in the Lower Mainland is to collect and treat the runoff volume from impervious areas for the 6-month, 24-hour precipitation event. Water quality treatment systems should be designed to remove 80% by mass of the inflow Total Suspended Solids for part particle sizes greater than 50 micron.

The proposal for John Hendry Park is to install a flow diversion structure upstream of the wetland process to divert any events larger than the 6-month, 24-hour storm event away from the wetlands. This option would meet the standards of practice while eliminating the disadvantages of bringing major storm events to a surface channel including:

- major events requires a large surface area for management;
- runoff moves too quickly through the system to be effectively managed; and
- potential for damage to the ecosystem.

The following goals of the SWMP were taken into consideration for selection of the management process:

- improving surface water quality;
- creating water courses;
- enhancing biodiversity;
- enhancing park recreation use including swimming; and
- creating a climate change resilient structure.

Water Quality Best Management Practices (BMPs) consist of physical, mechanical/structural and management practices that reduce or prevent water quality degradation. Water quality BMPs that meet multiple objectives of the SWMP are bio-retention facilities including rain gardens, swales, wetlands, and marshes.

In order to achieve the required level of water quality management and ensure proper functioning of bio-retention BMPs, the stormwater management processes includes recommendations for catch basin cleaning in the upstream catchment areas, oil/water and grit/trash separation, solids settlement/settling, water quality testing and potential chemical treatment.

The process is described in Section 4.3 including the rationale for each step.

4.3 Urban Stormwater Quality Management Plan for Diverted Upstream Catchment

A linear approach including a wetland with a sedimentation forebay, is recommended for the diverted urban runoff in the park. The stormwater quantity and quality control elements are described below:

- **Catch basin clean-out** in contributing neighborhood catchment. If stormwater is being diverted to the lake, a catch basin cleanup program in the upstream watershed will significantly reduce the stormwater contaminant loading associated with flushing the contents of the basin (e.g. decaying grass clippings, animal feces, etc.) into the lake.
- **Flow diversion** to divert low flows (up to 6-month, 24-hour precipitation event) into a sequence of Stormwater water quality BMPs and high flows away from the water quality BMPs to a bypass pipe under the park that outlets to E 14th Avenue. Divert flows of up to a 5-year return period in a pipe though park to a new stormwater trunk sewer. This bypass will be piped underground. The bypass pipe is to be located under paths or other such features to limit disturbance to playing fields.
- **Oil/water and grit/trash separation** for gross pollutant and spill containment. This will remove hydrocarbons from the road runoff in the diverted residential catchment and settle out grit and large solids.
- **Sedimentation forebay** to settle out suspended solids.
- **Vegetated linear wetlands and marshes** for filtering suspended solids, and biological uptake of nutrients if the wetland plants are harvested. If the wetland plants are not harvested, the nitrogen and phosphorus extracted by the plants for growth are released to the water again when the plants die and decay in the wetland. Harvested wetlands require a higher amount of maintenance.
- **Open Channel** for the purpose of potential chemical supplemental treatment and water quality monitoring**.** The water quality testing has multiple objectives:
    a. To determine if chemical treatment is required.
    b. To determine where to direct the treated water. If water quality meets specifications, water will be directed to the lake; if not, water will be directed to the bypass pipe.
    c. The channel should be designed in such a way to facilitate the removal of sediments that settle out (e.g. potentially lined, accessible by machine, etc.).
- **Chemical Treatment (Lanthanum Chloride of Phoslock application)**. If water quality analyses determines there is excess phosphorus entering the lake, chemical precipitation using Lanthanum Chloride or Phoslock could be used to remove phosphorus from the stormwater before it enters Trout Lake.

Refer to Figure 4-1 for the proposed stormwater quantity and quality control elements.

Class D Cost Estimates

Class D cost estimates for the key water quality BMPs are included below.

These costs are capital costs and do not included operation and maintenance costs. There will be on-going costs associated with the catch-basin clean out program, wetland harvesting, sedimentation pond maintenance and water quality testing. Sizing is based on preliminary assumptions and available space. Detailed design and costing must be completed prior to future implementation.

Table 4-2: Class D cost estimate for Components.

Stormwater Component	Capital Cost (excludes GST)	Comment
Catch Basin Clean-Out	-	- Municipal operation and maintenance cost.
Flow Control Manhole	$8,750	- 1,350 mm x 5 m concrete manhole. - Based on contractor prices.
Bypass Pipe	$5,140,000	- 875 m of 1200 mm dia. concrete pipe. - Cost includes bonding, engineering and contingency.
Oil/Water and Grit/Trash Separation	$85,700	- Vortechs 9000 (rated for peak flow of 400 L/s). - Cost includes bonding, engineering and contingency.
Sedimentation Forebay	$117,000	- Assumed 1800 m^2 pond on average 1 m deep. - Cost includes bonding, engineering and contingency.
Wetland	$2,640,000	- Assumed 20,000 m^2 of wetlands. - Assumed 6,000 m^2 (of 20,000 m^2) to be pools on average 1 m deep. - Cost includes bonding, engineering and contingency.
Chemical Treatment (Lanthanum Chloride or Phoslock Application)	N.A.	- Cost to be estimated at a future time if necessary.
Trunk Storm Sewer to False Creek	30M +	- Rough estimate from the City of Vancouver. City to determine cost during design phase.

4.4 Park Runoff Water Quality Management

There are several surfaces in the park that generate significant runoff including: parking lots, running/biking paths, and the all-purpose playing field. Runoff from these areas should be directed to the lake either through pipes or open channels. Based on the SWMP goals and client preferences, the recommended method for managing runoff from park surfaces is the use of source controls.

Source controls are often used for runoff volume and flow reduction as well as water quality treatment. Source controls are selected, specified, and sized to maximize water quality treatment. Minimum source control sizes relative to the impervious tributary area are often recommended to keep the pollutant loading to source controls within a range that ensures long term viability of source controls.

These minimum sizes are documented in the *2012 Metro Vancouver Stormwater Control Design Guidelines (SSCDG)* available on Metro Vancouver's website[2].

The recommended source controls are oil and grit separators, rain gardens, absorbent landscaping and pervious pavement. Some specifications for the recommended source controls are included below.

- **Parking Lots:** install rain garden by preference and if this is not possible, install oil/water and grit/trash separation. Rain gardens should be approximately 476 m^2/ ha of impervious area. Rain gardens should have 450 mm of absorbent soil with a 300 mm x 300 mm rock trench with perforated piping to carry overflow to the storm system.
- **Running/Biking Paths**: drain to absorbent landscaping or install pervious paving.
  - **Absorbent landscaping**: Absorbent landscaping should be 300 mm deep. The ratio of absorbent landscaping to the impervious area draining to the source control should not be less than 1.
  - **Pervious pavement:** The ratio of previous pavement area to the impervious area draining to the source control should not be less than 2. Pervious pavements shall have a 450 mm of base gravel depth with 300 mm deep rock trench with perforated piping to carry overflow to the storm system.
- **All Purpose Playing Field:** drain onto the surrounding field, look at alternative materials.
- **Playing Field Fertilizer and Pesticide Management:** monitor the application and effects of fertilizer and pesticide application to the playing fields and adjust application methods and amounts accordingly.

The proposed concepts for park surface areas are shown in Figure 4-2.

Class D Cost Estimate

Since the layout for the park is not finalized, source controls are not sized at this point and the cost estimate is presented per square metre of impervious area by a given source control. The costs are provided for source controls that would meet the criteria presented in the 'Comment' column of Table 4-3.

All costs include bonding and insurance (8% of total cost), engineering (15%), and contingency (20%).

Table 4-3: Class D cost estimate for source controls presented per m^2 of impervious area.

Source Control	Cost/m^2 of Impervious Area*	Comment
Rain Garden	$11	- Rain Garden sized for treatment (not capture) of 90% of average annual runoff volume.
Wetland	$17	- included for reference - sized for available area – to be confirmed on project basis how much treatment it will provide
Absorbent Landscaping	$50	- sized for water quality to treat 90% of the average annual runoff

[2] http://www.metrovancouver.org/about/publications/Publications/01StormwaterSourceControlDesignGuidelinesCover-Intro.pdf

Source Control	Cost/m^2 of Impervious Area*	Comment
(sandy soil with organics)		
Pervious Pavement	$110	- sized for water quality, to treat 90% of the average annual runoff
Mechanical Separation	$88,000 to $126,000 per 1 ha treatment	- Hydrodynamic oil/water separator sized for water quality, to treat 90% of the average annual runoff
*Costs for Source Controls are based on previous KWL projects and construction costing		

4.5 Existing Lake Water Quality

One of the largest driving factors for the SWMP is the existing water quality in Trout Lake. The various functions of the lake and adjacent riparian area, including aquatic and terrestrial habitat, off-leash dog area, and swimming and beach use overlap, resulting in conflicts. The largest of these appears to be the required lake WQ for swimming versus the contribution of fecal material from animals and birds contributing to high bacterial counts.

Vancouver Coastal Health beach water quality monitoring records illustrate the water quality in Trout Lake is significantly poorer during the month of July than in other months of the bathing season. Median E. coli counts exceeded the maximum bathing standard 200 CFU/100 mL in July of 2011, and 2012, resulting in beach closures, and then characteristically dropped off in August allowing the beach to be reopened to swimming. The pattern of having the highest bacteria counts in July is consistent from 2010 through to 2014, although the levels have been markedly lower over the 2013 and 2014 bathing season with no exceedances or closures.

The incidence of high E. coli numbers in July is not likely due to a predisposition for fecal contributions to occur during that month. The higher bacterial counts during the month of July are more likely due to a combination of chronic fecal contamination of the sediments in the lake. Increased bathing activity as the weather improves through Julyis be expected stir up the sediments and consequentially increase bacteria levels in the water column. Eventually the anti-microbial effects of sunlight and other factors reduce the water column bacteria concentrations, and bathing activity diminishes – resulting in a reduction in E. coli levels in the water. Controlling the bacteria concentrations in Trout Lake requires either restricting the sources of fecal contamination to the lake, such as treating the stormwater and runoff entering the lake, or providing water treatment. Potential treatment options were evaluated to determine what treatment options could reduce bacterial levels to acceptable amounts (see Section 4-3).

4.6 Lake Water Quality Management

Several options exist for water quality management for Trout Lake. The following options were considered and discussed with the client and stakeholders:

- no treatment and accepting disruption in swimming use;
- in lake aeration (solar bee, changes to potable water inputs, aeration fountain); and
- water quality curtain to separate swimming area of lake in conjunction with recirculating water treatment for the swimming area (ozone or chlorination).

After presentation of potential options to public and stakeholders the following phased approach to managing water quality within the lake is recommended (referred to as Trout Lake Water Quality Approach) subject to water quality monitoring.

- **Phase 1 - Replace potable water input:** A new potable water input system should replace the existing 'pipe' input and allow the City to adjust how much potable water is added to the lake and location of the inputs. Opportunities for multiple inputs should be considered to help promote circulation of the lake. Inclusion of a fountain or solar bee element in Trout Lake should also be considered to improve oxygen entrainment, natural treatment and lake water exchange/flushing.
- **Phase 2 - Partition and filter the swimming area:** Divide the swimming area from the larger lake system to reduce the volume of water and improving water exchange within the swimming area by applying fresh water, or by recirculating treated lake water, only to the partitioned swimming area. The partition can be created using a subsurface membrane wall suspended from a floating boardwalk, for example, to create visual interest.
- **Phase 3 - Introduce treated stormwater:** Consider treating by filtration and UV disinfection, all or a portion of the stormwater that is discharged to the swimming area.

  Phase 1 is relatively cost efficient and is recommended to be completed as the first step in the WQ program. Development of as associated WQ monitoring program is required to observe the effects of the change. Based on monitoring, Phase 2 should be considered as a second step to improve WQ for swimming. Phase 3 will be more costly to complete and maintain. If Phases 1 and 2 are insufficient to maintain lake water quality for swimming, the Park Board would need to consider what level of investment is appropriate for Trout Lake as part of the City's overall Aquatic Strategy.

5. Stormwater Management Plan

The stormwater management plan is shown on Figures 4-1 and 4-2. The selected plan is adaptive in nature and requires the City to perform water quality monitoring on both the lake and stormwater in order to make decisions about the most sustainable stormwater management approach. Water quantity and quality monitoring at the influent and discharge ends of the wetland will allow the City to determine the treatment characteristics and decide if stormwater runoff from the diverted catchment should be discharged through the lake or continue to be bypassed to the storm sewer.

Water quality monitoring in the lake will allow the City to decide if Phases 2 and 3 of the Trout Lake Water Quality Approach are warranted. An Adaptive Management Plan has been developed to assist the City with the implementation of the Stormwater Management Plan. The Adaptive Management strategies maintain the option of stormwater bypassing the lake open as a last resort, until a reasonable effort has been made to evaluated the benefits and risks of discharging stormwater to the lake in a more 'natural watershed' manner.

5.1 Adaptive Management Plan

With stormwater being diverted to the lake, it is important that management/treatment options be considered and implemented to restrict contaminant loading and meet water quality objectives in the lake. In all cases, we recommend against discharging stormwater directly to the lake without providing for passive and/or active treatment mechanisms to maintain and/or improve water quality within the lake

There are four areas of consideration with respect to meeting water quality objectives within the lake:

1. **Upstream watershed:** the quality of the stormwater entering John Hendry Park from upstream urbanized neighbourhoods.
2. **John Hendry Park water features**: the stormwater management in John Hendry Park between stormwater pipes and the lake. There are many variables in sizing, operations, and effectiveness of potential active and passive stormwater treatment options.
3. **Control and treatment of park runoff:** maximize infiltration for runoff from impervious surfaces within the park as well as enhancing passive treatment prior to discharge to the lake.
4. **Trout Lake treatments:** modifying the location of fresh water inputs to the lake to improve circulation, flushing and overall water quality within the swimming area, separating the swimming area to reduce treatment area and considering treatment options for the swimming area.

Table 5-1 introduces the Adaptive Management Phases for managing water quality in the proposed Trout Lake watershed catchment area.

Table 5-1: Adaptive Management Phases for Trout Lake Water Quality

Component	Phase 1	Phase 2 (Phase 1, +)	Phase 3 (Phase 1 & 2, +)
Upstream Watershed	Seasonal catch basin cleaning program to remove sources of organic contamination, bacteria and nutrients entering the park	Watershed watch public awareness and education program regarding stormwater pollutant management	Sewer cross connection investigation/repair program
John Hendry Park Water Features	Flow control manhole for option of diversion of base flow to water management system or bypass pipe Oil/water separator Sediment forebay and regular cleanout in other features Constructed wetlands with or without seasonally harvested vegetation Series of constructed wetlands with non-harvested wetland vegetation Provision for chemical phosphorus removal (no chemical treatment until Phase 2) Water quality testing Reintroduction of stormwater discharge into Trout Lake to enhance circulation and flushing	Chemical treatment of stormwater, followed by sedimentation, to remove and phosphorus (e.g. Phoslock, Lanthanum chloride, etc.) prior to discharge to the lake.	Divert Stormwater to bypass pipe
Park Runoff Water Quality Management	Enhance natural vegetation around the lake to improve natural water quality treatment Construct rain gardens to increase site runoff infiltration and reduce stormwater flows from the park into the lake and treat parking lot runoff Install pervious pavement	Oil/grit separators Collect and direct runoff to storm sewer	

Component	Phase 1	Phase 2 (Phase 1, +)	Phase 3 (Phase 1 & 2, +)
	Install absorbent landscaping Minimize/control fertilizer use		
Trout Lake Management	Reconfigure the potable water input system to control location and quantity of inputs Add aeration system in form of aeration fountain or solar bee	Partition the swimming area to limit area being managed and limit potential effects of stormwater introduction	Develop a treatment system within the partitioned swimming area

6. Recommendations

Based on the foregoing, it is recommended that the Parks Board and City:

1. Implement Phase 1 of the adaptive management strategy shown in Table 5-1.
2. It is essential that a monitoring program be developed and implemented to determine the benefits derived from the modifications implemented in Phase 1 and the necessity of implementing the next phases of the plan.
3. One of the observations found in this study is the incidence of high E.coli numbers in July. It is felt that these high counts are likely due contaminated sediments being re-suspended due to increased bathing activity as the weather improves through July. The Park Board should undertake a study to confirm the cause of the increased E.coli levels.

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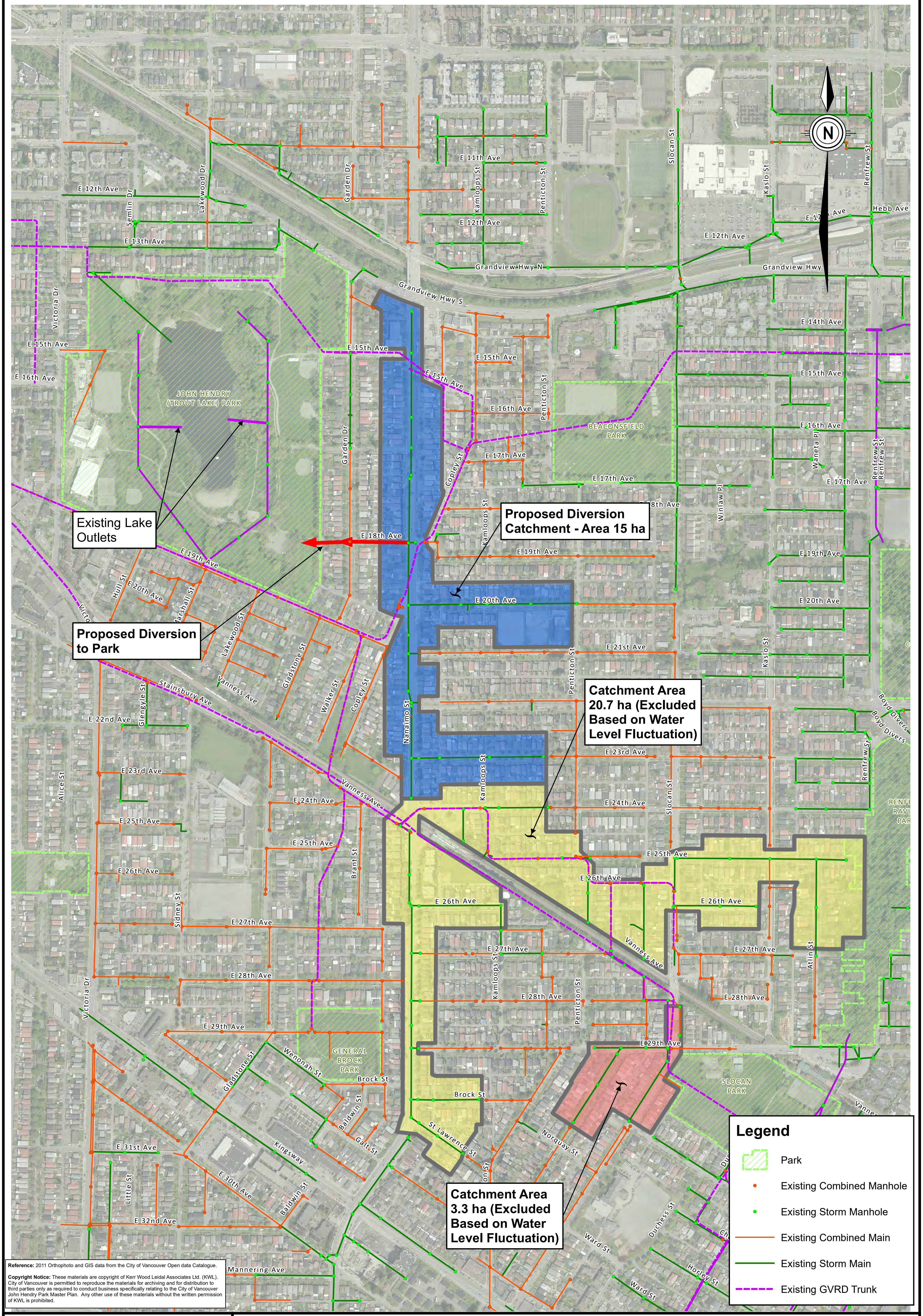
Author: JYoung



Reference: 2011 Orthophoto and GIS data from the City of Vancouver Open data Catalogue.

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City of Vancouver
John Hendry Park Master Plan

Project No.	Date
2023-015	June, 2015

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Study Area

Figure 3-1

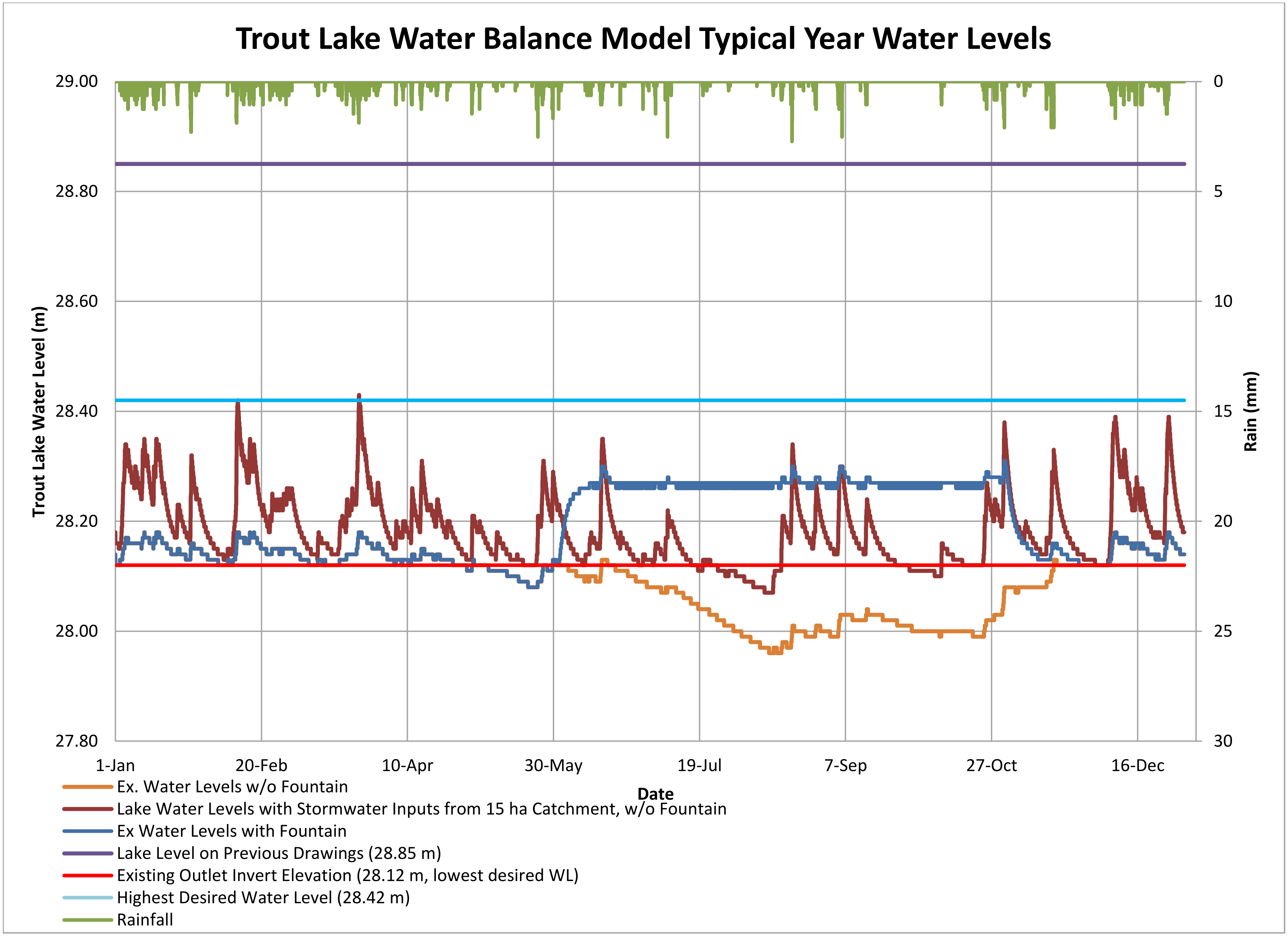

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Figure 3-2

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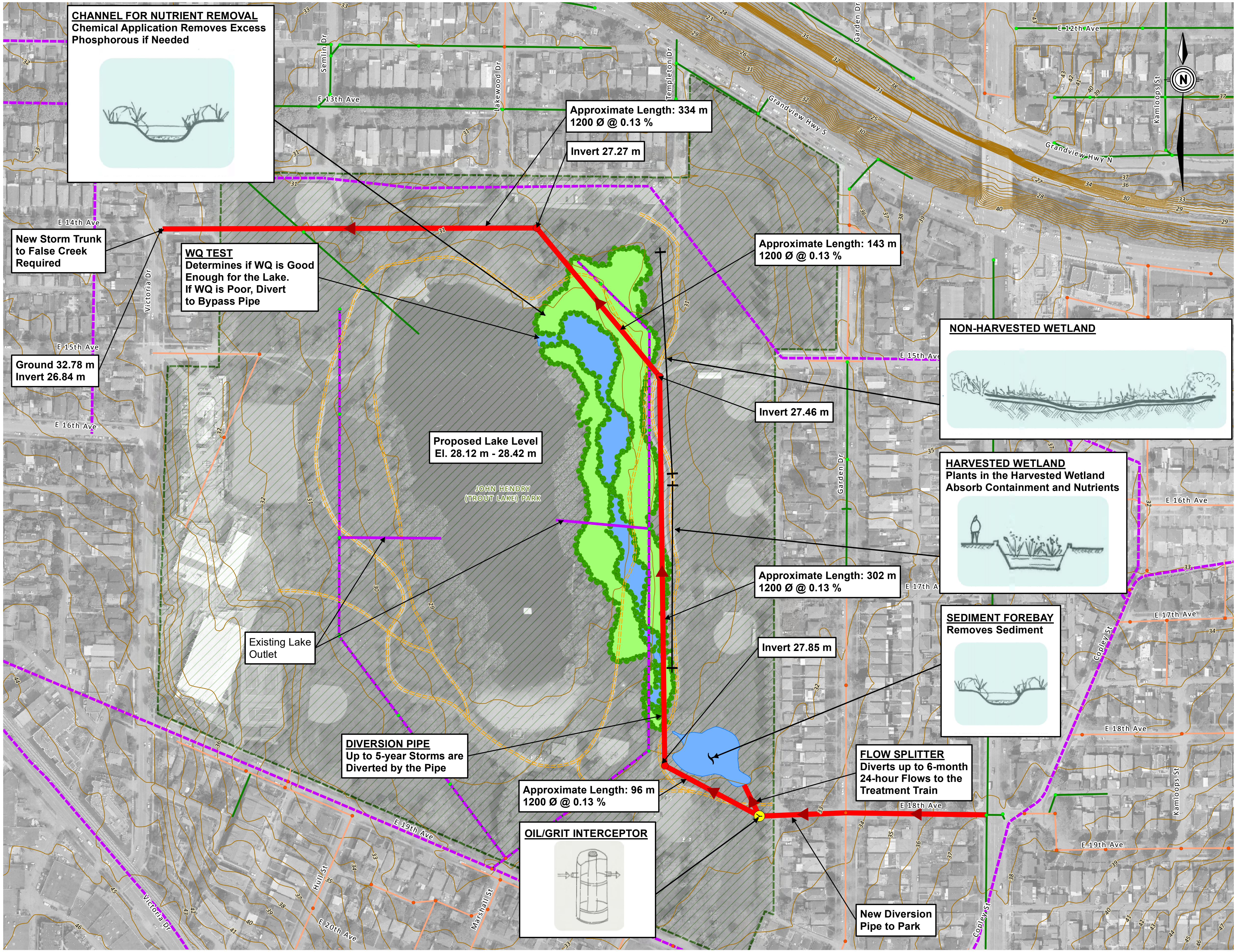

City of Vancouver
John Hendry Park Master Plan

Legend

- Park
- Contours 1m
- Existing Combined Manhole
- Existing Storm Manhole
- Existing Combined Main
- Existing Storm Main
- Existing GVRD Trunk
- Existing Bike and Run Path
- Possible Stormwater Diversion Alignment

Reference: 2011 Orthophoto and GIS data from the City of Vancouver Open data Catalogue.

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Project No.	Date
2023-015	June 2015

John Hendry Park Proposed Wetland and Storm Bypass Pipe

Figure 4-1

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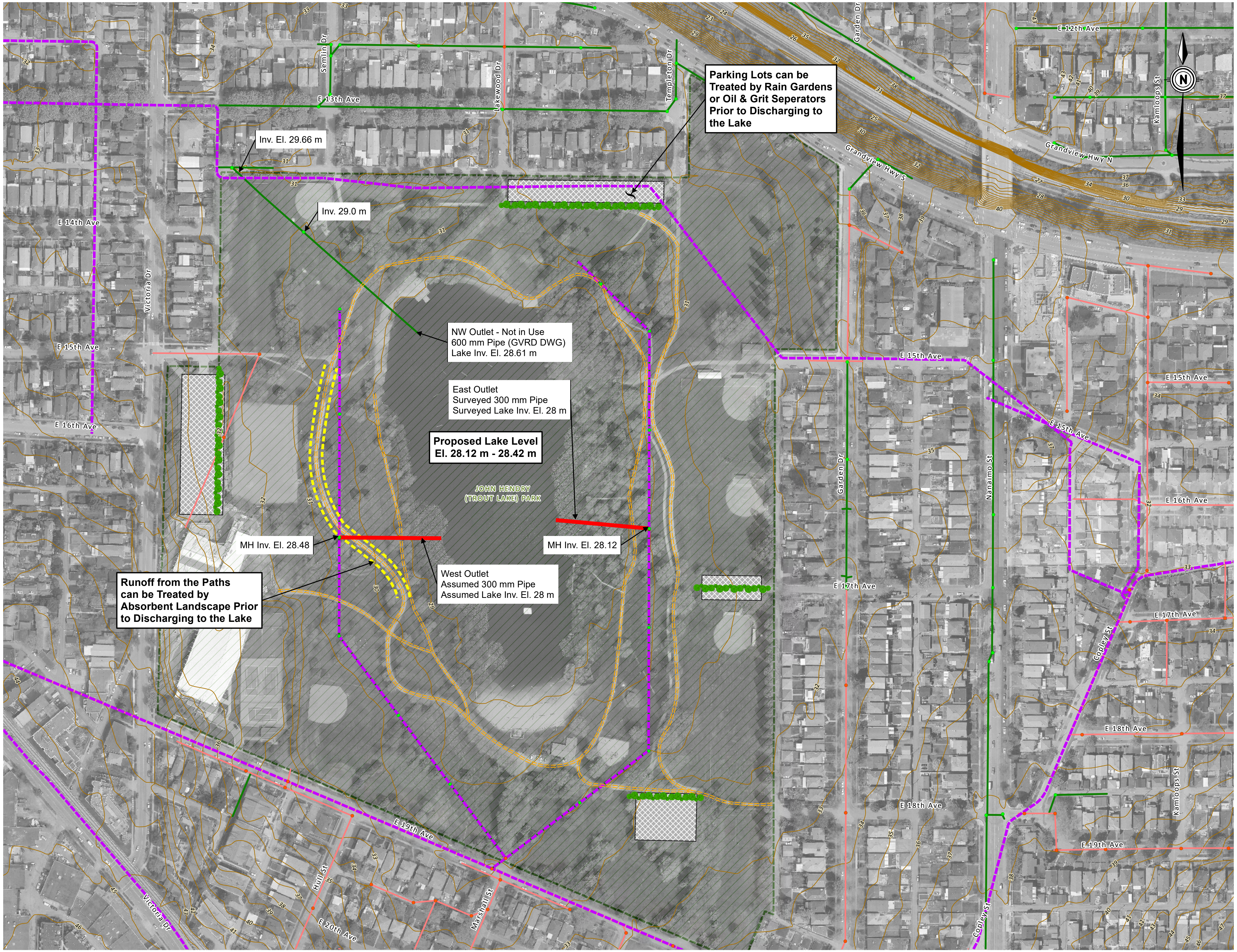
Author: JYoung

City of Vancouver
John Hendry Park Master Plan



Legend

- Park
- Contours 1m
- Existing Parking Lot
- Existing Combined Manhole
- Existing Storm Manhole
- Existing Combined Main
- Existing Storm Main
- Existing GVRD Trunk
- Existing Bike and Run Path
- Absorbent Landscape All Around the Running Trail
- Pond Outlet
- Rain Gardens

Reference: 2011 Orthophoto and GIS data from the City of Vancouver Open data Catalogue.

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Project No.	Date
2023-015	June 2015

John Hendry Park Water Quality Treatment Options for Park Runoff

Figure 4-2

7. Report Submission

Prepared by:

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Revision History

Revision #	Date	Status	Revision	Author
1	December 12, 2014	DRAFT		SMP
2	June 8, 2015	FINAL		JY