VANCOUVER
PARKS & RECREATION

STANLEY PARK
STORMWATER MANAGEMENT PLAN

FINAL REPORT
AUGUST 1999

kwl

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August 11 1999

Mr. Steve Wong
Vancouver Board of Parks and Recreation
2099 Beach Ave.
Vancouver, B.C. V6G 1Z4

Dear Mr. Wong:

Re: **STANLEY PARK STORMWATER MANAGEMENT PLAN**
Submission of Final Report
Our File: 714.001

Enclosed are three copies of the finalized version of the *Stanley Park Stormwater Management Plan* report for your records. The report documents the work program, including the workshop process, and develops the preferred option as determined in the workshop into a predesign appropriate for costing and discussions with approving and funding agencies. Your comments from review of the draft are addressed herein. We will also provide an electronic version of the report (in Adobe Acrobat format) for your use within approximately one week.

The estimated cost of the recommended stormwater treatment concept (engineered wetland) is $699,000. This is primarily the cost of the wetland, as most other costs are incorporated into the changes to the Causeway Drainage Plan that you have already requested of the BCTFA. The cost is a result of the objective to treat the Causeway discharge to the highest degree possible and the need to locate the facility in such a way as not to require forest clearing or garden removal. These objectives essentially demand that an engineered wetland-type facility be constructed within the confines of Lost Lagoon.

Also presented in the report is what we believe to be an adequate level of treatment for discharge to Lost Lagoon. This would require a wet pond facility, also located in Lost Lagoon, estimated to cost in the range of $420,000. However, the drawback (in addition to lower degree of stormwater treatment) is that a wet pond would not provide any significant habitat or aesthetic bonuses to the proposed site.

Of greatest importance at this time is to ensure that the BCTFA implements the recommended changes to the Causeway Drainage Plan (recommendations 1-4, and 10) as construction on the Causeway has begun. To this end, we would be pleased to assist the Board of Parks in an advisory role with respect to review of design drawings (see recommendation 6).

Continued...

It would also be prudent at this time to assemble an application to the Vancouver Port Authority (see page 6-20), and to initiate public consultation with known interest groups. In both of these regards, it is important to describe the improvements in water quality, habitat enhancement, and interpretive benefits that will stem from the project.

The project team wishes to express our great interest in continuing to assist the Board of Parks and Recreation with the project application, public participation, and detailed design of stormwater management facilities. Thank you for the opportunity to work on this challenging and intriguing assignment.

Yours truly,
KERR WOOD LEIDAL ASSOCIATES LTD.

J. Alex Wood, P.Eng.
Project Manager

Enclosure

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PROJECT NO. 714.001

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

STATEMENT OF LIMITATIONS

This report has been prepared by Kerr Wood Leidal Associates Limited (KWL) for the sole and exclusive benefit of our client, The City of Vancouver Board of Parks and Recreation. It represents KWL's best professional judgement based on the knowledge and information available at the time of completion. No third party is entitled to rely on any of the information, conclusions, data, opinions, or any other material contained in this report.

Services performed in the production of this report have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practicing under similar conditions. No other warranty, express or implied, is made.

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EXECUTIVE SUMMARY

As part of the Lions Gate Bridge rehabilitation project, the British Columbia Transportation Finance Authority (BCTFA) is rehabilitating the Stanley Park Causeway which runs from the western end of Georgia Street through Stanley Park to the bridge. Roadway upgrades include improvement of Causeway drainage, which has historically been poor both in terms of surface runoff management and control of groundwater underneath the roadway. The drainage upgrades include construction of a storm sewer system that will concentrate roadway runoff at two points, rather than distributing it along the roadside. In granting the BCTFA permission to rehabilitate the Stanley Park Causeway, the City of Vancouver Board of Parks and Recreation required that facilities to manage and treat the concentrated stormwater discharge be included.

NEED FOR STORMWATER MANAGEMENT PLAN

During design of the Causeway drainage upgrades, the Board of Parks outlined a general scheme for stormwater discharge and treatment that was integrated into the design drawings. In June of 1999, the Board commissioned this Stormwater Management Plan to further refine the scheme for stormwater management and treatment. A workshop-approach to the plan was adopted in order to complete it in as timely a manner as possible, as the construction work on the Causeway upgrades was to commence at the beginning of July.

STORMWATER MANAGEMENT WORKSHOP

On June 30th, five Board of Parks staff and six members of the consultant team met to discuss the alternatives for stormwater treatment and target the preferred option.

STORMWATER MANAGEMENT PLAN

Based on the workshop outcome, this report documents the development of the recommended Stormwater Management Plan that integrates the Causeway drainage upgrades with the Board of Parks' objectives for stormwater management. The Plan calls for:

- discharge of all pavement surface runoff to Lost Lagoon (none to Beaver Lake);
- treatment of runoff with an engineered wetland located in the northeast corner of Lost Lagoon;
- discharge of new sub-surface groundwater drains to Prospect Creek / Beaver Lake; and
- spill interceptors in two locations.

The total cost outside of the contract currently let by the BCTFA for road rehabilitation is estimated at $699,000. This is primarily the cost of constructing the engineered wetland.

IMPLEMENTATION

The recommendations in Section 7 provide the basis for the Board of Parks and Recreation to proceed with implementation of the Stormwater Management Plan. Of particular note is the need to proceed with detailed design of the Causeway discharge storm sewer line as soon as possible, to facilitate the ongoing Causeway construction. Once this component is properly designed, the remainder of the investigations and design can proceed as funding and schedules allow.

1. INTRODUCTION

1.1 BACKGROUND

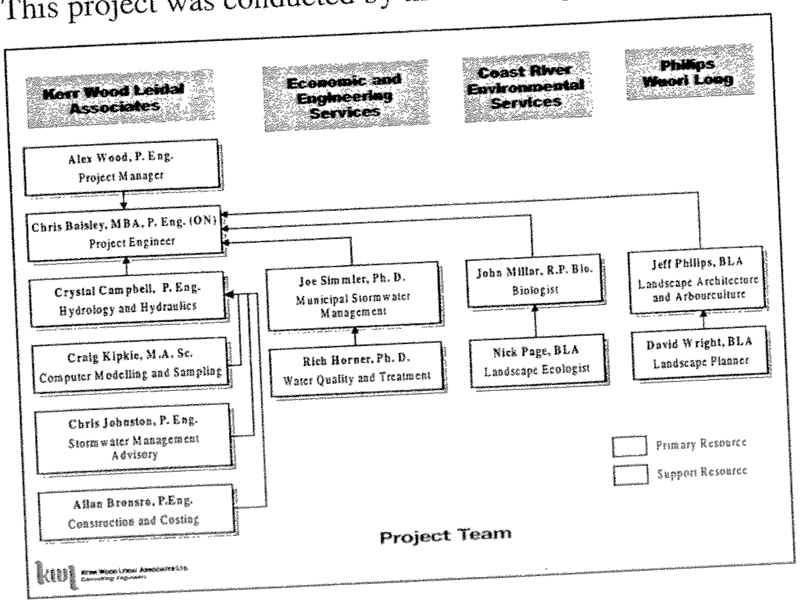
As part of the Lions Gate Bridge project, the British Columbia Transportation Financing Authority (BCTFA) is rehabilitating the Stanley Park Causeway from the Park Drive overpass near Lost Lagoon through the full width of the park to the Bridge itself. The work commenced in July 1999, and includes the following:

- Surface rehabilitation;
- Improved sidewalks; and
- Improved road drainage.

Where storm drainage is discharged from the rehabilitated Causeway, it will be concentrated and conveyed through Park lands to water bodies within the Park. Recognizing that roadway runoff contains contaminants and can cause erosion problems if uncontrolled, the Parks Board has commissioned this stormwater plan to manage the road runoff in areas outside of the Causeway right-of-way.

1.2 PROJECT TEAM

This project was conducted by the following team:



This report was authored primarily by Chris Baisley, MBA, P.Eng. (ON), with assistance and input from all team members.

1.3 ACKNOWLEDGEMENTS

The project team wishes to acknowledge the input of the following staff of the Board of Parks and Recreation:

- Steve Wong, Park Development Co-ordinator (Project Manager)
- Eric Meagher, Supervisor of Stanley District Works
- Kate Davis-Johnson, Manager of Park Development
- Brian Quinn, Park Foreman
- Bill Stephen, Assistant Arborist

In addition, the cooperation of the BCTFA and their consultant team in providing information and assistance is acknowledged:

- Garry Dawson, Manager, Project Technical Services (BCTFA)
- David Chang, Manager, Planning and Construction (BCTFA)
- Mehran Avini, Project Engineer (N.D. Lea Consultants)
- Scott Hanna, Manager of Environmental and Planning Services (Acres International)

1.4 FORMAT OF REPORT

The Board of Parks selected a workshop-based work program, and this report is structured accordingly. The workshop based program was selected with the objective of completing the project as quickly and efficiently as possible. This was necessary because of the pressing schedule for Causeway construction.

The work program focussed very quickly on the optimal stormwater management solution by intensively applying the knowledge and expertise of the project team (including Board of Parks staff) in a workshop setting. This report therefore focuses on the development of the recommended plan, and does not investigate all of the possible alternatives that were discarded through the workshop process.

Documentation of the study process is provided through appendices which contain the memorandums developed as the project unfolded.

1.5 LIMITATIONS OF CONCEPT DESIGN

The Causeway drainage works have been designed by others, and have been reviewed by KWL only to the extent of determining their impact on the Park and as the basis for making configuration changes. No formal review of the hydrologic, hydraulic, or detailed design elements of the proposed works has been undertaken. The work by KWL is conceptual in nature, and some elements must be refined in detailed design of the recommended facilities.

2. RECEIVING WATER SENSITIVITIES AND VALUES

2.1 Introduction

There are three receiving waters that conceivably could be impacted by the drainage upgrades on the Causeway. This Section describes the values and sensitivities of each, as these form the basis for development of the Stormwater Management Plan.

2.2 Beaver Lake

Beaver Lake is a wetland feature that supports a wide variety of aquatic species, is surrounded by forest, and is accessible to the public by walking trails only. It is separated from Pipeline Road and the Causeway by significant swaths of forested area, and is considered a reasonably natural area.

Beaver Lake from the eastern shore

The Lake (and Prospect Creek, its main inlet) is supported through dry periods with supplemental water from the City water supply. In its natural state, it is expected that the Prospect Creek and Beaver Creek would be dry in the summer, and that the Lake levels would drop significantly.

The Lake currently supports resident cutthroat and salmonid outplants. The Board of Parks' goal for Beaver Lake is to improve conditions, with the possible goal of encouraging a future run of wild salmon on Beaver Creek (the Lake's outlet creek).

Given the current environmental value of the Lake, and the Board's goals to improve conditions, Beaver Lake is rated as having a high sensitivity to changes in water quality.

The high sensitivity dictates a high degree of protection from any detrimental impacts that causeway drainage improvements may have.

The current Causeway Drainage Plan[1] calls for discharge of road surface drainage to Beaver Lake at a point just south of the Pedestrian/Equestrian overpass. This point was selected partially at the request of the Board of Parks, who wish to enhance the volume of water flowing through Beaver Lake (see section 2.5).

2.3 PROSPECT CREEK

Prospect Creek is Beaver Lake's largest tributary creek. The Prospect Creek / Beaver Creek system is supplemented in the summer with City water in the headwaters of Prospect Creek. The Creek supports a resident cutthroat trout population between Beaver Lake and the Causeway. As part of the Beaver Lake system, the objective is to protect, and preferably enhance, the environmental values of the Creek.

The current Causeway Drainage Plan calls for discharge of ditch subdrains (not roadway surface runoff) to Prospect Creek where the creek crosses under the Causeway, and via a small existing tributary to the Creek about halfway between the Causeway crossing and Beaver Lake.

2.4 LOST LAGOON

Lost Lagoon supports a resident carp population and a large number of waterfowl. However, it is primarily perceived as an aesthetic water feature, located adjacent to developed areas with heavy public access through trails and roads.

Originally, Stanley Park was an island, and Lost Lagoon a saltwater passage between Vancouver and the parklands. The western end is now cut off from the Burrard Inlet, and the eastern end protected from saltwater ingress and changing tides by a flap gate at Coal Harbour. It has been mentioned that the Board of Parks may one day opt to revert the Lagoon to a saltwater system by allowing ingress of saltwater from Coal Harbour, and ceasing to supplement the Lagoon with City water.

An investigation into the tides a Coal Harbour reveals that even if the Lagoon were allowed to revert, water levels will have to be controlled by tide gates to ensure that various park facilities such as walkways and lawns are not inundated at high tides[2].

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[1] The 'Causeway Drainage Plan' is described in Section 3, and refers to the roadway drainage system proposed as part of the 1999 Causeway upgrading project by the BCTFA.

[2] The high tide elevation is approximately 1.9 m, which is higher than many of the Park facilities surrounding Lost Lagoon.

The Lagoon supports a range of aquatic species that are tolerant to changing salinity and water quality conditions. Therefore, there is greater risk-tolerance at Lost Lagoon than at Beaver Lake. The objective for Lost Lagoon is to maintain water quality and not allow it to worsen as a result of drainage improvements on the Causeway.

Lost Lagoon looking NE towards the Causeway

The current Causeway Drainage Plan calls for discharge of road surface drainage to Lost Lagoon at its northeast corner. This point was selected partially at the request of the Board of Parks, who wish to enhance the volume of water flowing through the Lagoon (see section 2.5).

2.5 FLOW AUGMENTATION

Prospect Creek, Beaver Lake, and Lost Lagoon are all augmented by the City water supply to maintain water levels during the dry season. This has been the basis for the stated objective of the Board of Parks to use Causeway runoff to supplement the flow to Beaver Lake and Lost Lagoon.

As will be described in the next Section, the volume of runoff from the road surface is a very small portion of the total water input into the hydrologic regime, and will not have a measurable impact on water levels or flow-through in either water body. In other words, regardless of the form of the Stormwater Management Plan, flow augmentation (with either the City water supply or some other external source) at existing levels will remain a requirement if current water levels are to be maintained.

2.6 SUMMARY

There are two water body systems that are subject to potential impacts from the Causeway drainage improvements:

- Beaver Lake (including Prospect Creek); and
- Lost Lagoon.

The differing sensitivities and environmental values of each water body suggest that different stormwater management techniques may be appropriate in each case.

3. CAUSEWAY DRAINAGE PLAN

3.1 INTRODUCTION

Within this report, the plan for Causeway drainage as detailed on the N.D. Lea Consultants drawings[1] is referred to as the *Causeway Drainage Plan*. Additional works outside of the Causeway working right-of-way and developed as part of this project are referred to as the *Stormwater Management Plan*.

This Section describes the Causeway Drainage Plan (CDP) and its potential impacts on the water bodies in the Park. The CDP is the starting point for development of the Stormwater Management Plan, as the essential elements of the CDP have been approved for construction by the Board of Parks.

The most northerly section of the Causeway Drainage Plan (the Bridgehead Storm Sewer System that discharges towards the First Narrows) is not relevant to this report and is discussed no further.

3.2 CDP ELEMENTS

The Causeway Drainage Plan includes the following drainage elements:

- Catchbasins to collect stormwater runoff at regular intervals along the road surface;
- Storm sewer conveying collected stormwater in a southerly direction;
- Ditch subdrains on the east and west sides, connected (draining) to the storm sewer in some cases, and to roadway cross culverts in other cases;
- Two discharge points, one at Lost Lagoon and one at the Pedestrian/Equestrian overpass, each equipped with oil/water separators; and
- Upsized roadway cross-culverts to replace existing culverts.

The Causeway is currently drained by catchbasins which discharge to ditches on either side of the roadway, rather than to a central storm sewer.

3.3 DISCHARGE POINTS

The two discharge points at the pedestrian/equestrian overpass (to Beaver Lake) and Lost Lagoon have been selected based partly on the desire of the Parks Board to augment flow in both water bodies. The stormwater system discharging to Beaver Lake is designated as the *Upper Stormwater System*. The remainder of the Causeway Drainage Plan is the *Lower Stormwater System*.

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[1] N.D. Lea Consultants Ltd., *Highway 99 Lions Gate Project, Revision B, Dec 23 1998*. The reader should consult these drawings for detailed information on the CDP.

3.4 OIL/WATER SEPARATORS

The oil/water separators are currently specified as Stormceptor Model #3000 for the Beaver Lake System and Stormceptor Model #4000 for the Lost Lagoon System. Stormceptors are precast manhole devices that are designed to remove oil and suspended solids during low flows, and bypass higher peak flows that would otherwise flush out contaminants that have been removed. Such facilities cannot remove emulsified (small-droplet) oil, and are therefore considered effective for spill control, but are not considered effective as 'treatment' devices.

3.5 DITCH SUBDRAINS

Ditch subdrains are proposed to remove groundwater (sourced from both the side ditches and the west side forest slope) that has historically flowed underneath the Causeway and surfaced between the roadway slabs.

Since water intercepted by the new subdrains will be fully comprised of shallow groundwater that has been filtered by the forest vegetation and soils, they represent a new source of clean and temperature-moderated water that could be of beneficial use in either receiving water body.

UPPER STORMWATER SYSTEM

The ditch subdrains within the Upper Stormwater System discharge at three points as follows:

- To Prospect Creek at its main culvert crossing of the Causeway;
- To a small tributary to Prospect Creek approximately halfway between the main culvert and the pedestrian/equestrian overpass; and
- To a marshy area just south of the pedestrian/equestrian overpass, at the storm sewer system discharge point. There is no obvious overland watercourse connection to Beaver Lake from this point, although it is relatively certain that water discharged here will travel through the soils and partially surface in Beaver Lake.

The subdrain discharge points can be referenced on the N.D. Lea construction drawings approximately at stationing 85+60, 87+60, and 90+00.

LOWER STORMWATER SYSTEM

The ditch subdrains within the Lower Stormwater System discharge to the storm sewer system, rather than to surface watercourses. Intercepted groundwater is therefore combined with surface runoff, and discharged to Lost Lagoon.

3.6 Role of Wetlands and Marshes in CDP

The Causeway Drainage Plan 'ends' at the discharge points of each oil/water separator. However, it is important to note that the concept of additional treatment of stormwater discharge using 'filtration marsh' methods[1] has been discussed by the Board of Parks. The idea is included in the discussion attendant to the Board decision in favour of allowing Causeway rehabilitation as follows:

> *Causeway drainage will be redesigned to feed both Beaver Lake and Lost Lagoon. This will include oil separators and filtration marshes at both water bodies. These two environmental measures are considered integral to the project.* [2]

While the Stormwater Management Plan does not necessarily have to take the form described above, it must at least meet the objectives that the Board of Parks had in mind when developing the decision.

3.7 Impacts of Causeway Drainage Plan

The potential impacts (both beneficial and detrimental) of the CDP are described within each of the two stormwater systems.

Upper Stormwater System

Roadway Runoff

The Causeway Drainage Plan will concentrate road runoff at two points, rather than dispersing runoff along the full length as happens currently. At Beaver Lake, it is proposed that road runoff will be discharged and filtered through the natural soil strata before eventually reaching the Lake.

While this would likely serve to treat potentially contaminated stormwater runoff to a high degree, it utilizes a natural, uncontrolled, and un-engineered system as the primary treatment mechanism. Therefore, there is a risk of contaminating the soils and potentially the groundwater in an unspecified area.

There is the additional concern associated with concentrating peak roadway flows at a single point in the forest. The likely impacts include erosion of the forest floor, raising of the local groundwater table (a detriment to trees), and loading of sediment to Beaver Lake (if the erosion establishes an overland flow path).

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[1] The wet pond and wetland stormwater treatment alternatives described in Section 4 correspond to the idea of 'filtration marshes'

[2] July 20 1998 Board of Parks and Recreation Recommendation

In addition, the plan requires that a deliberate decision be made to discharge potentially contaminated roadway runoff to Beaver Lake. Because no spill control or stormwater treatment has 100 percent effectiveness and reliability, such a decision could be criticized in light of the sensitivity and value of the water body as described in Section 2.

Since the road and sidewalk surface makes up only about 1 percent of the total area tributary to Beaver Lake, and since the CDP does not bring any additional drainage area into the system, the beneficial impact of diverting water more directly to the lake via the storm sewer system is insignificant.

Ditch Subdrains

The first two discharge points are expected to provide a net benefit to Prospect Creek and Beaver Lake by diverting groundwater that currently moves underneath the Causeway directly to surface watercourses. The subdrains get the water into the watercourses further upstream, improving fish habitat and reducing losses through evapotranspiration and subsurface diversions that may occur if the water remained in the ground and exit at points downstream.

Some of the water intercepted by the ditch subdrains currently travels through the causeway embankment to the forest on the east side. Diversion of some of this water to Prospect Creek will help in drying out the soils on the east side earlier during the dry season and possibly to a greater degree, which is considered a benefit to the health of existing trees in this area. Once this area becomes dryer, planted or naturally reproduced trees will grow without stress related to water logged root systems. Mid to long term benefits could be a more diversified and healthy mixed forest with a longer potential life span.

Since the overall volume of groundwater reaching Beaver Lake via Prospect Creek is expected to increase as a result of the CDP, the ditch subdrains are considered an enhancement. It is *not* likely that significant additional volume will be available during the dry season however, so augmentation will still be required.

The only potential detrimental impact of the CDP ditch subdrains in the upper system is a depletion of the groundwater table to the west of the Causeway slightly earlier in the dry season each year. This could conceivably create the need to augment flows to Prospect Creek earlier in the year also. However, since the ditch subdrains are deeper than the roadside ditches currently in place, this effect could be offset by the greater depth of capture. It is not possible to add 'new' water to the system through the design of Causeway drainage works, so the perennial nature of the watershed must be accepted unless an external source can be found.

Lower Stormwater System

Roadway Runoff

The roadway runoff from the Lower Stormwater System is proposed for discharge to the Lagoon in its northeast corner, adjacent to the Park Drive underpass. Without treatment, the storm sewer discharge could negatively impact water quality in the Lagoon. No energy dissipation structure is proposed at the point of discharge.

Even though no spill control or stormwater treatment has 100 percent effectiveness and reliability, the greater risk-tolerance and more modest goals for Lost Lagoon make it a better candidate for stormwater discharge than Beaver Lake.

Based on a simple comparison of the paved causeway area to the area of Lost Lagoon, the beneficial volumetric impacts of diverting Causeway runoff to Lost Lagoon are minor.

Ditch Subdrains

The ditch subdrains will contribute a minor additional clean groundwater flow to Lost Lagoon, offering a very minor net benefit to volumes and water quality.

Although the CDP has some impacts that require mitigation through the Stormwater Management Plan, it should be noted that the opportunity to create the Stormwater Management Plan and its attendant facilities has arisen *because* of the Causeway rehabilitation. The existing drainage situation on the Causeway has some significant negative features, including the lack of spill control and the inadvertent use of natural forest floor areas as stormwater filtration facilities.

3.8 Summary of Recommended Changes to Causeway Drainage Plan

During the course of this project, various changes to the Causeway Drainage Plan have been recommended in order for the BCTFA to investigate and incorporate those changes in a timely manner with respect to the construction schedule, and to ensure flexibility for development of the Stormwater Management Plan.

Appendix A is a compilation of the memorandums by which these recommendations have been made. The recommendations are listed here, and described elsewhere in this report:

- Connection of the upper storm sewer to the lower storm sewer;
- Elimination of the Beaver Lake discharge point;

- Upsizing of the lower storm sewer to accept all discharge from the upper storm sewer;
- Installation of the upper Stormceptor on-line with the storm sewer;
- Connection of the southmost ditch subdrains outlets to both the storm sewer and a surface watercourse;
- Possible relocation of the lower Stormceptor within the Causeway embankment;

As can be noted in Appendix A, some interim recommendations were made and then retracted as the field investigations and the project progressed.

4. HYDROLOGY AND WATER QUALITY

4.1 Introduction

In order to size stormwater treatment and management facilities, the volume and flow rates of stormwater must be determined. This Section describes the hydrologic modelling and water quality assessment that provide the foundation for facility selection and sizing.

4.2 Basis for Water Quality Treatment Hydrograph

The Stanley Park area receives approximately 1500 mm of rain per year. The distribution of that rainfall varies from month to month and from storm to storm. Each storm event is unique in its pattern of rainfall intensity, total duration, and total volume. This can present some considerable challenges in engineering analysis for stormwater facilities.

Event and Continuous Analysis

There are two fundamental analysis methodologies for investigating the performance of stormwater facilities: continuous methods, and event methods. Continuous methods involve simulating many years of system performance (based on rainfall records), followed by a statistical analysis of the synthetic stormwater flow records that result.

Event methods simulate the system performance for a small number (generally one) storm event only. The storm event is either a historical storm that actually occurred, or a synthetic storm based on a statistical analysis of rainfall patterns.

Continuous methods are expensive, time consuming, and complex. Event methods are simple, but sometimes overly so. For this project, a hybrid of continuous and event methods has been used, to take advantage of the benefits of each.

Water Quality Design Storm

Over each hydrologic year, many storm events occur. Most are minor events that go almost unnoticed in a wet climate such as Vancouver's. Only occasionally does a severe event occur. The crux of this is that the vast majority of roadway runoff occurs during minor events with very low peak rates of runoff flow.

It follows that if a stormwater treatment facility can effectively contain and treat the minor events (and bypass the severe events), then most of the year's roadway runoff can be treated with a facility of reasonable size. This has been proven with continuous simulations done by KWL and in the literature, and will be illustrated later in this chapter.

In order to size stormwater treatment facilities quickly and economically, event methods must be used. Based on studies of continuous simulation results, it has been determined that if a facility can treat the storm event with a six-month return period[1], the majority of the year's runoff can be treated.

For wet climates with long duration rainfall such as Vancouver, it is necessary to use a long duration six-month storm event to ensure that any facilities designed based on the design storm can function during the rainy season.

To develop facility sizes for the Stanley Park Stormwater Management Plan, a 24-hour, six-month design storm based on the Environment Canada Atmospheric Environment Service Vancouver Harbour urban design storm was used[2]. The design storm has 46 mm of rain in 24-hours, and is henceforth referred to as the Water Quality Design Storm.

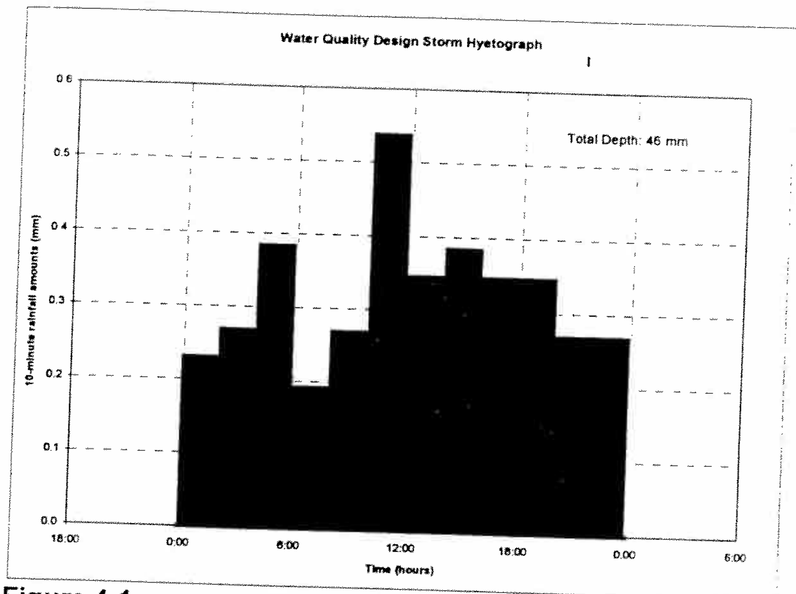

Figure 4-1
Water Quality Design Storm Hyetograph

The design storm is used as input to a hydrologic model to simulate the performance of the storm sewer system and estimate the pattern and volume of water entering stormwater management facilities.

[1] The six-month return period storm is that which would occur, on average, once every six months.

[2] The differences between design storms are usually in the spatial distribution (ie. rainfall pattern). This is of minor importance in this case, because the design storm is used primarily to develop the total *volume* of runoff, which depends on the total amount of rain, and not the pattern in which it falls.

4.3 HYDROLOGIC MODELLING

In order to develop the water quality design hydrographs[1], a hydrologic model (XP-SWMM) of the proposed Causeway storm sewer was assembled. The storm sewer design calculation sheets provided by N.D. Lea were used as the basis for the model, so that the model's base is an exact replication of the Rational Method[2] model used for storm sewer sizing.

XP-SWMM is a powerful hydrologic and hydraulic model used in storm sewer, sanitary sewer, and creek modelling. The computation engine is based on the U.S. Environmental Protection Agency's SWMM model.

Things to note about the model are:

- The tributary area is 100 percent impervious (paved); and
- Subdrains connected to the storm sewer (in the lower system) were not modelled.

The subdrains were not included because of the comparatively slow response of flow through the soils as compared to flow from the paved surfaces, and because of the considerable uncertainty associated with attempting to model such a phenomenon. The subdrains would contribute baseflow for several days after a design event, but would have a relatively insignificant effect while the event is occurring.

Instead of attempting to model this minor process, the uncertainly associated with the subdrains connected to the storm sewers is accounted for by adding a 'safety factor' to the total volume of stormwater facilities designed.

4.4 WATER QUALITY DESIGN HYDROGRAPHS

Water quality design hydrographs have been developed at three points in the stormwater system as follows:

- For the Upper Stormwater System
- For the Lower Stormwater System
- For the combined system (Upper System discharges into the Lower System).

These allow the sizes of stormwater management facilities to be estimated for various stormwater management options. Figure 4-2 illustrates the third hydrograph, while Appendix B contains all three.

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[1] A hydrograph is the pattern of stormwater flow over time.

[2] N.D. Lea used the 'Rational Method' for design of the Causeway storm sewer. While appropriate for peak-flow based design, this method does not provide stormwater volume information.

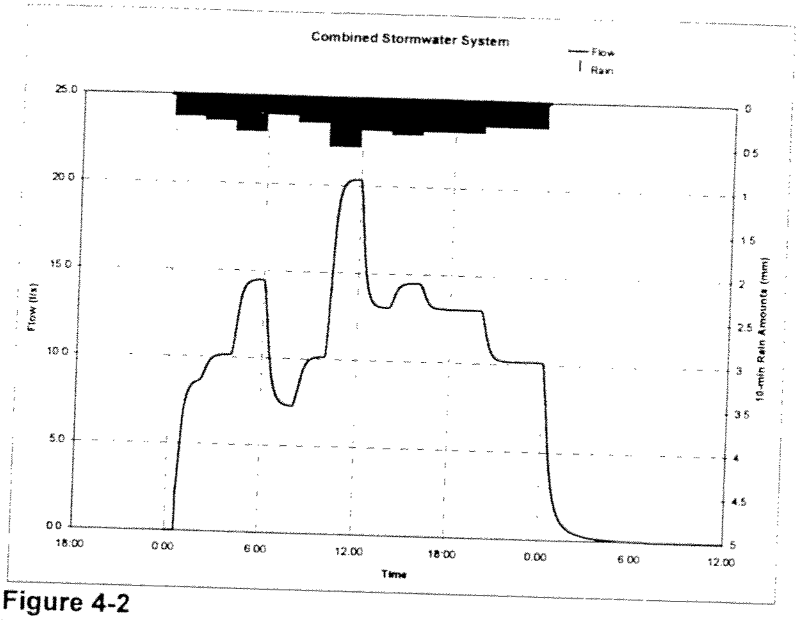


Figure 4-2
Water Quality Design Storm Hydrograph

Each hydrograph has two key features of interest:

- Total volume of runoff; and
- Peak rate of runoff.

The volumes and peak flows at each point are summarized as follows:

	Upper	Lower	Combined
Peak Flow (l/s)	8	13	21
Total Volume (m^3)	376	646	1022

Table 4-1
Water Quality Hydrograph Characteristics

These are the starting point for sizing of stormwater treatment facilities.

RELATIONSHIP TO STORM SEWER DESIGN FLOWS

The storm sewer design flows are much higher than the peak flows of the water quality design storms. This is because the Causeway storm sewer is designed to collect and convey peak runoff rates from the 25-year and 100-year return period storm events. The difference in the peak flow capacity of the storm sewer system and the stormwater treatment facilities requires that peak flows greater than the six-month return period flow be diverted *around* stormwater treatment facilities. The peak flows shown in the table above are the treatment rate that would be applicable for stormwater treatment facilities in each case. These flows are defined as the high flow *diversion rates*, above which all flow is diverted.

4.5 CONFIRMATION OF DIVERSION RATES

To confirm that the diversion rates shown above are appropriate, a hybrid continuous simulation was run using a typical year[1] of rainfall. The XP-SWMM model was run to simulate a full year of typical Causeway storm sewer performance. The results are shown on Figure 4-3.

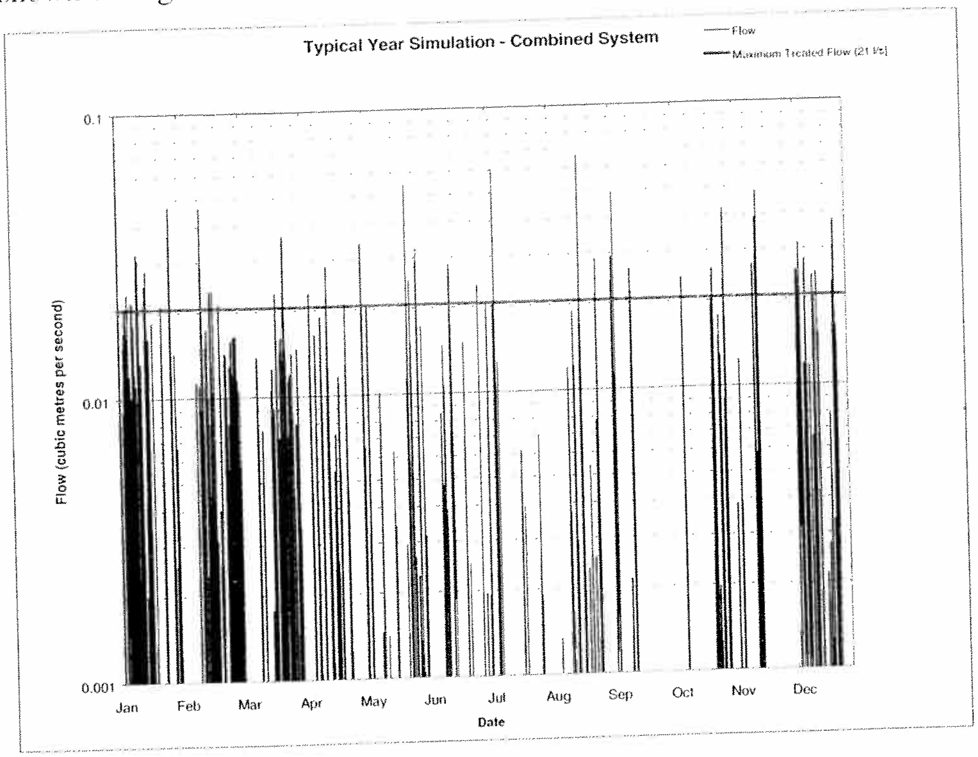


Figure 4-3
Typical Year Simulation for Combined System

The red line indicates the high flow diversion rate. Flows greater than this would be bypassed around the stormwater treatment facility, while flows below would enter the facility for treatment. It can be seen that the majority of the yearly runoff (at least 92.5 percent) is treated.

This analysis confirms that the event methodology and the design storm used in estimating the water quality design hydrographs is sound, and that facilities based on the hydrographs will typically treat the overwhelming majority of roadway runoff each year.

[1] The 'typical year' has an average total rainfall, distributed between the months in an average pattern, with an average distribution of storms of different magnitudes. The data used is from the North Vancouver District City Hall, for which KWL has completed the typical year analysis previously. Since the North Vancouver station receives, on average, more rainfall than Vancouver Harbour, the analysis within is conservative: that is, the percentage of annual rainfall bypassed around a treatment facility in Stanley Park will be *less* than what is noted in the text. The corollary is that the percentage of yearly runoff treated will be slightly *more* than what the analysis indicates.

4.6 CAUSEWAY RUNOFF QUALITY

AMBIENT RUNOFF QUALITY

Runoff from the causeway will contain contaminants primarily sourced from motor vehicle operation. Atmospheric deposition and some organic matter sourced from the surrounding trees will also be present.

It has been reported that receiving water ecology may be affected immediately adjacent to highways carrying greater than 30,000 vehicles per day[1]. At 60,000 vehicles per day, it is clear that proper management of stormwater runoff from the Causeway is necessary if the desired protection of Beaver Lake and Lost Lagoon is to be achieved.

Contaminants expected to be found in Causeway runoff include:

- Sand, grit, and other sediments;
- Metals (partially associated with particulates, and partially in dissolved form);
- Low levels of oil, grease, and fuels (perhaps surprisingly, also associated with particulates); and
- Low levels of nutrients from organic matter.

De-icing salts are not used often, and their use will decline further once the roadway drainage is improved and the ice hazard reduced.

In general, stormwater treatment facilities for Causeway runoff should therefore be able to remove:

- Particulate matter (through settling); and
- Dissolved contaminants (through adsorption onto soil particles and through bacterial processes associated with plant matter).

SPILLS

While the risk of occurrence of a spill on the Causeway is high due to the high traffic count, the anticipated volume of any spilled material is small. As no heavy trucks are permitted on the Lion's Gate Bridge, hazardous cargoes such as fuels and chemicals are not present. The greatest spill risk is that attributable to a fully fuelled transit bus. Most spills will be small volumes from vehicle fuel tanks.

[1] B.C. Research Corporation, *Urban Runoff Quality Control Guidelines for the Province of British Columbia*, 1992

4.7 STORMWATER TREATMENT FACILITY SIZING

Appendix C contains a description of various stormwater treatment alternatives. Using the water quality design hydrographs, minimum facility sizes and footprints have been developed for several types of stormwater treatment facilities. These were presented as the basis for discussion at the Stormwater Management Workshop. The Workshop is the subject of the next Section of this report.

4.8 WATER LEVELS IN LOST LAGOON

Lost Lagoon outlets through a 900 mm (36 inch) overflow pipe to Coal Harbour. Although no quantitative data is available on water levels, discussions with Board of Parks staff have revealed a qualitative understanding of how the system works.

A flap gate located at the overflow outlet allows Lost Lagoon to drain during low tides and prevents sea water from entering during high tides (although a flap gate deterioration has occurred in the past causing the Lagoon to become brackish for a time).

There is also a manual gate located at the inlet of the overflow pipe consisting of aluminum stop boards. The stop boards are adjusted to control Lagoon water levels. The gate is adjusted approximately every 2 to 3 months based on visual inspections of the water level. Typically the gate is fully closed during the dry summer months to prevent any flow from leaving the Lagoon, and opened to varying degrees in the winter. The water level as surveyed by KWL in July 1999 was 0.60 m.

5. STORMWATER MANAGEMENT WORKSHOP

5.1 INTRODUCTION

The Stormwater Management Workshop was conducted to speed up development of the Stormwater Management Plan and make the project more cost-effective. By gathering all related expertise together for one afternoon, it was possible to eliminate several stormwater alternatives and focus the project team on development of the preferred option without a lengthy process of analysis, documentation, and review.

Pre-engineering and field inspection was completed prior to the workshop to ensure that the workshop participants would have the information required to make decisions during the course of the afternoon. The outcome of the workshop was a clear direction for the project team in developing the recommended stormwater management option.

5.2 WORKSHOP DOCUMENTATION

Appendix D contains the workshop agenda package and the follow-up workshop summary memorandum. The agenda is summarized as follows:

- Review of Workshop Objectives
- Review Causeway Drainage Plan
- Water Quality Objectives
- Potential Stormwater Management Alternatives and Sites
  - Beaver Lake (Upper) Stormwater System
  - Lost Lagoon (Lower) Stormwater System
- Development of Stormwater Management Option

The reader is encouraged to review these materials, which document the discussions and consensus on each agenda item. Of particular interest are likely the two figures that accompany the workshop agenda, as they illustrate the various alternatives considered for stormwater management.

5.3 RESULTS OF WORKSHOP – STORMWATER MANAGEMENT OPTION

The end result of the workshop was development of the preferred stormwater management option that was to be investigated and proven out by the project team. The following text is taken from the Workshop Summary in Appendix D, and forms the basis for the remaining Sections in this report.

Based on the foregoing discussions, the overall Stormwater Management Plan will consist of the following components:

- *A single storm sewer system running from the north and discharging to Lost Lagoon only;*
- *Spill control at two points to maximize spill capture; near the Pedestrian/Equestrian bridge, and at Lost Lagoon (using already-specified Stormceptors);*
- *In the Beaver Lake watershed, ditch subdrains connected to existing natural watercourses to encourage groundwater conveyance to Beaver Lake;*
- *In the Lost Lagoon watershed, a combination of ditch subdrains connected to the storm sewer, and ditch subdrains connected to existing surface watercourses; and*
- *A single stormwater treatment facility located at and discharging to Lost Lagoon.*

The treatment process chain will include the Stormceptor pre-treatment followed by one or a combination of the following:

- *An underground sedimentation facility in the Causeway embankment for additional pre-treatment;*
- *A 'pond-marsh' located in the northeast corner of Lost Lagoon;*
- *A 'pond-marsh' with sedimentation forebay, located in the northeast corner of Lost Lagoon;*
- *A wetland located in the northeast corner of Lost Lagoon; or*
- *A wetland with sedimentation forebay, located in the northeast corner of Lost Lagoon.*

The stormwater treatment facilities will be sized as a minimum for the 'water quality design storm', which is a 24-hour duration event with a return period of six months. Flows greater than the water quality design storm will be bypassed around the treatment facility, as is standard practice. In this way, on a yearly volumetric basis, the majority of stormwater entering the Lagoon will be treated prior to discharge.

The rationale for treatment at Lost Lagoon is to do the best that is possible given the constraints of the site. Wetland treatment is required to remove the ambient levels of hydrocarbons and dissolved contaminants, and sedimentation is required to remove sediment and sediment-bound contaminants.

6. STORMWATER MANAGEMENT PLAN

6.1 INTRODUCTION

Based on the stormwater management option as arrived at during the stormwater management workshop, this Section documents the analysis completed in resolving the alternative approaches and presents the recommended Stormwater Management Plan.

The recommended plan comprises the following components:

- One continuous storm sewer serving both the 'upper' and 'lower' areas of the Causeway, discharging to Lost Lagoon.
- Stormceptor oil/grit separators for spill control;
- A combination of ditch subdrain discharge to existing watercourses and to the storm sewer;
- A flow diversion structure at Lost Lagoon; and
- An engineered wetland including sedimentation forebay and flow augmentation structure.

The overall concept for stormwater management is shown on Figure 6-1. The recommended treatment process is a wetland with sedimentation forebay, rather than an underground sedimentation chamber. Figure 6-2 (in a pocket at the end of this Section) is the concept plan for stormwater treatment that shows the works proposed in the vicinity of Lost Lagoon. The recommendations for changes to the Causeway Drainage Plan are addressed in Appendix A, and are being handled through communication with the BCTFA in parallel with the study process.

6.2 SELECTION OF TREATMENT PROCESS

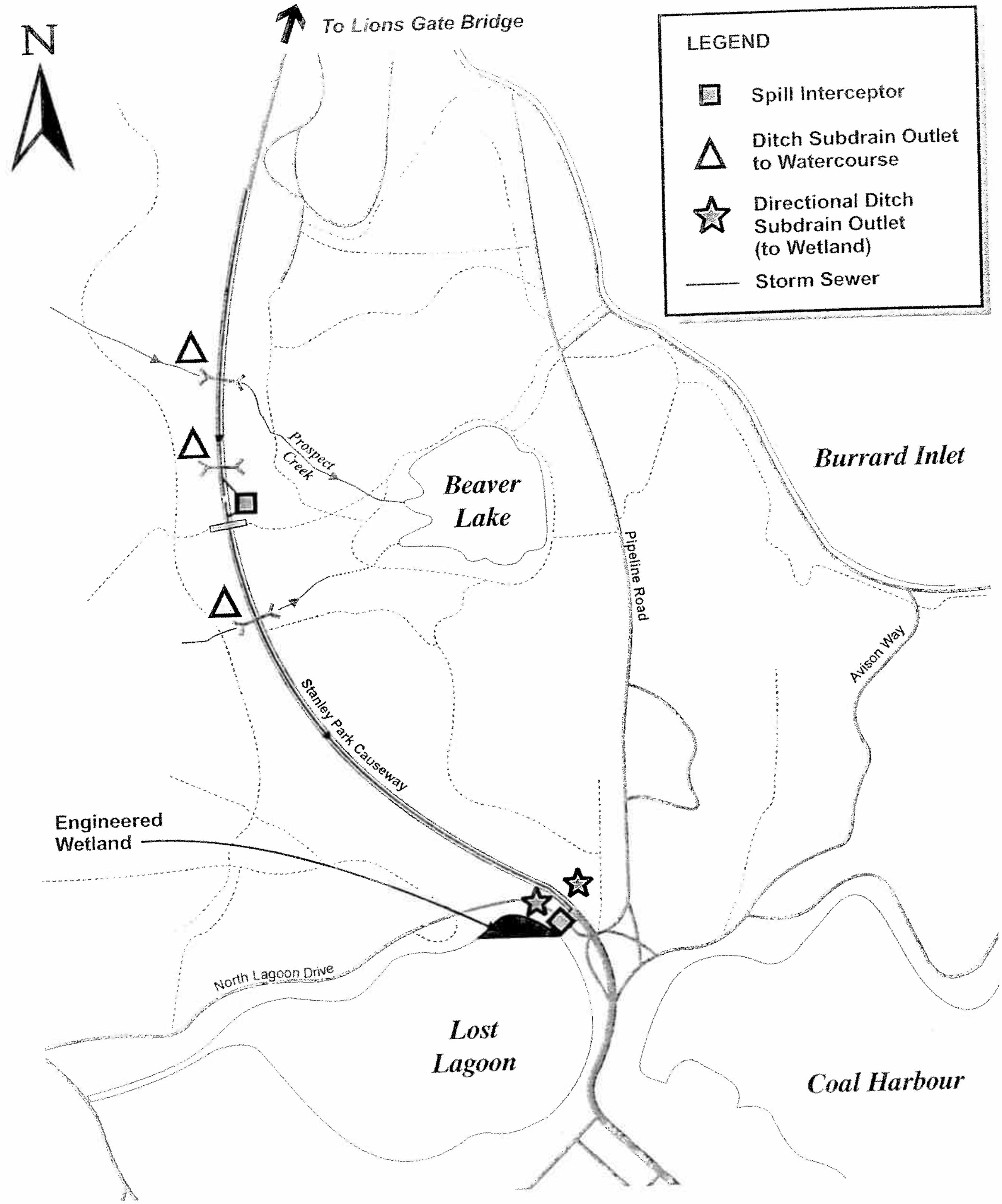
The alternatives considered for stormwater treatment included various combinations of:

- Underground sedimentation chamber;
- Pond-marsh with sedimentation forebay;
- Pond-marsh without sedimentation forebay;
- Wetland with sedimentation forebay;
- Wetland without sedimentation forebay.

The recommended option is a wetland with sedimentation forebay.

PARTICLE SETTLING

Referring to Section 4.6, settling of particles is important for removal of contaminants such as metals and oils, as well as for clarification to improve aesthetic qualities and aquatic habitat. The alternatives for settling are an underground chamber located in the



Stormwater Management Plan Schematic

N.T.S.

Figure 6-1

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Alternative	Suitability[1]	Treatment Processes	Comment	Lagoon Area Req'd
Wetland w/ Forebay	**Recommended**	Settling Extended settling Adsorption Biological	Best treatment	Most
Wetland w/ Pre-Sedimentation Chamber (Stormceptor)[3]	Not Recommended	Settling Less extended settling Adsorption Biological	Wetland should have forebay to prevent siltation	Marginally less
Wet Pond / Marsh Combination	For Consideration	Settling Extended settling Adsorption Biological	Less plant/soil contact	60% of wetland
Wet Pond	For Consideration[2]	Settling Extended Settling	No plant/soil contact	30% of wetland
Underground Settling Vault (alt. for wet pond)	Not recommended	Settling Extended Settling	Impractical size and cost	none
Pre-Sedimentation only (Stormceptor)	Not recommended	Settling	Settling only	none

Notes
1 Suitability is determined with respect to the Workshop goals of providing the best possible stormwater treatment.
2 While a wet pond does not have plant/soil contact, its extended settling capability provides significantly greater total contaminant removals than short-term settling such as in a pre-settling chamber.
3 With respect to treatment facility design, the Stormceptors can be considered a pre-treatment / pre-settling facility.

Table 6-1
Alternative Treatment Processes

embankment between the Causeway and Lost Lagoon, or a sedimentation forebay integrated into a wetland or pond-marsh facility.

It has been determined that the benefits of an underground settling chamber are heavily outweighed by the disadvantages of:

- Capital cost;
- Recommended frequency of maintenance (2 - 4 times per year in some jurisdictions);
- Relative difficulty of inspection;
- Reported difficulty of maintenance; and
- Poor industry experience with chamber-settling for stormwater.

Although the chamber appears an attractive option in that it would be completely concealed underground and could be maintained in a less visible manner (ie. with a vacuum truck parked on North Lagoon Drive), expert consensus is that even when designed according to proven settling theory, such chambers simply do not perform as well as the forebay alternative. As such, a chamber of reasonable size (ie. affordable and site-able) does not meet the objective[1] of treating stormwater to the best possible degree before discharge to Lost Lagoon.

While maintenance of a forebay is a more involved procedure, a forebay can be designed such that it requires maintenance very infrequently. The forebay sized and shown on Figure 6-2 is based on design guidelines for promoting structural diversity and visual appeal throughout the entire wetland facility, which overrides the minimum size required by settling theory.

The forebay is predicted (using settling theory and typical stormwater sediment concentrations) to require maintenance only once every 10-plus years. The point of this analysis is not to guarantee such performance, but to indicate the relative order of magnitude of maintenance interval that can be expected.

It should also be noted that while it is difficult to estimate the removal efficiency of the proposed Stormceptor at Lost Lagoon for the water quality design hydrograph, it could provide up to 50 percent removal of settleable particles[2]. The settling capability of the Stormceptor will be of definite benefit, but it is difficult to quantify.

ADSORPTION AND BIOLOGICAL TREATMENT

Removal of contaminants that are not associated with particles cannot be achieved with gross settling. The primary function of the recommended wetland is to provide an area of contact between stormwater and soil and plant material to facilitate adsorption of very

[1] as articulated in the Stormwater Management Workshop (see Appendix D)

[2] based on settling theory, the Lost Lagoon Stormceptor an be expected to remove approximately 50 percent of particles at the peak flow of the water quality design storm

fine particulates and dissolved constituents (such as metals and nutrients). The movement of stormwater through the planted areas also promotes additional (extended) settling.

While wetlands are the most promising of all end-of-pipe stormwater management technologies for water quality enhancement, they also have considerable side benefits in creation of terrestrial, aquatic, and aviary habitat.

Wetlands and pond-marshes are slightly different types of facilities. The pond-marsh has less planted area. The wetland is considered a superior choice, with greater plant and soil contact. Since sufficient area for a wetland is available, and since the side-benefits of aesthetic appeal and habitat augmentation are in harmony with the park setting, a wetland facility is recommended.

ALTERNATIVE TREATMENT PROCESSES

In the event that a wetland facility is not feasible for any reason, alternative treatment processes are required to meet the Stormwater Management Plan's objective of treating stormwater to the best degree possible prior to discharge to the Lagoon.

An extended settling chamber of sufficient size (ie. to fully contain the water quality design hydrograph) is too large to fit on the Causeway embankment site, and would be an extremely expensive cast-in-place concrete structure. A wet pond would have to be constructed within the Lagoon, but would require approximately one third the area of a wetland. The disadvantage of both of these types of facility is that they cannot provide the absorption and biological removal processes of the wetland.

If the use of Lagoon space must be less than that required for a full wetland, the overall footprint could be reduced by about 40 percent with a combination wet pond – marsh facility. This type of facility is a compromise in size and cost, with less wetland area for plant and soil contact. The alternatives are summarized in Table 6-1.

The wetland treatment offers the most aesthetic and habitat enhancement of the first four alternatives in addition to being the preferred type of treatment facility.

TREATMENT FACILITY SIZING

The recommended stormwater treatment facility has been sized to accommodate the water quality design hydrograph as described in Section 4, for the combined Upper and Lower stormwater systems. In addition, a 25 percent factor of safety is added to account for uncertainties associated with the water quality design hydrograph with respect to ditch subdrain flow[1] and to ensure conservatism in design. The high flow diversion around the facility must hold peak flow to the facility at approximately 21 litres per second.

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[1] see Section 4.3

6.3 Functional Narrative

The functional narrative explains the purpose of each component of the Stormwater Management Plan, including the recommendations that have been made regarding changes to the Causeway Drainage Plan.

Single Storm Sewer System

The sensitivity of Beaver Lake to the threat of spills and ambient Causeway runoff quality is respected by not discharging any roadway surface runoff towards the Lake. This requires a single storm sewer system that discharges to Lost Lagoon.

Stormceptor Oil/Grit Separators

Stormceptors are required to provide control of spills on the causeway. Two locations are recommended, one online with the storm sewer at approximately the location of pedestrian/equestrian overpass, and one just upstream of the recommended stormwater treatment facility. The upper Stormceptor (model #3000) is desirable in providing an upper control point for spill management, and to enhance spill control by halving the maximum distance that spilled materials may travel before being contained. This reduces the degree of emulsification of spilled material with stormwater, which improves removal efficiency.

Ditch Subdrains

Ditch subdrains are an integral part of the improvement of roadway drainage on the Causeway. In the Upper Stormwater System, discharging the clean and cool groundwater intercepted by the subdrains to Prospect Creek and a small tributary of Prospect Creek is considered an enhancement to both the Creek, Beaver Lake, and in the long term the forest complex between the Causeway and Prospect Creek.

In the Lower Stormwater System, the majority of the ditch subdrains are connected to the storm sewer. This means that the intercepted groundwater will provide a sewer baseflow that will constantly replenish the wetland with a trickle of cool, clean water. This will have no measurable negative impact in the wet season, and is considered a benefit to the wetland in the dry season, as baseflow is required to sustain the wetland when rainfall is scarce.

The southernmost sections of ditch subdrains are to be constructed so that they discharge both to the storm sewer, and to an existing surface watercourse that drains into the recommended wetland area. This allows flexibility in providing baseflow to the wetland at two different points: the first point into the forebay, and the second point directly into the wetland itself. For reference, the points of storm sewer connection are at Manholes 51-2 and 51-5, as shown on the N.D. Lea design drawings.

WETLAND DIVERSION

The diversion structure located between the lower Stormceptor and the wetland inlet is required to divert high peak flows around the wetland directly to Lost Lagoon. As described in Section 4, this allows almost all of the yearly road runoff to be treated without requiring an uneconomically sized treatment facility. The diversion structure must also allow for bypass of all stormwater flow around the wetland, in order to prevent water from entering during maintenance periods. An energy dissipator at the outlet point should be provided to prevent scour of the Lagoon bottom during major peak flow events.

ENGINEERED WETLAND

The recommended engineered wetland has several separate components, the function of which is described in the following sub-sections

Sedimentation Forebay

The purpose of the forebay is to promote settling of particles to remove grit and particle-bound contaminants. This is the first part of the treatment process chain.

Marsh Terraces

Marsh terraces are shallow wetland areas populated by a range of wetland plantings. Their purpose is to allow sustained contact between stormwater and soil and plant matter, to promote extended settling, adsorption, and biological removal processes. Different depths of terrace are required to promote a diversity of plant and biotic life, which in turn increases the numbers of pollutant removal processes.

Deep Pools

Deep pools and low flow channels also contribute to diversity of plant and biotic life, increase the plant/water surface edge length, and are aesthetic features to enhance the natural look of the engineered wetland.

Outlet Structure

The wetland outlet structure is located at the opposite end of the wetland from the inlet structure (forebay). This promotes a long residence time in the facility and eliminates short-circuiting of under-treated stormwater to the outlet. The outlet is an overflow-type, ensuring that the water level in the marsh remains constant. When a rain event occurs, the incoming water gently displaces the standing water in the wetland through the outlet.

Baseflow Inlets

Baseflow sourced from surface watercourses and ditch subdrains is available to the wetland through the main forebay inlet and via an existing watercourse that discharges to the wetland on the north edge. Baseflow during non-rain periods helps sustain plant life through drought seasons.

Augmentation Structure

The purpose of the flow augmentation structure is to provide a means of moving Lagoon water into the forebay of the wetland in the event that supplemental water is required in a drought year.

SUMMARY

The Stormwater Management Plan addresses the means of discharge and treatment required to meet the Board of Parks' objectives for each water body. All roadway surface runoff is carried to Lost Lagoon, where it is treated prior to discharge. Ditch subdrains within the Upper system enhance the conveyance of clean groundwater to Prospect Creek and Beaver Lake. Ditch subdrains in the Lower system provide baseflow to the treatment wetland at two points. Spill containment is provided both midway along the storm sewer, and at the bottom of the system.

6.4 DESCRIPTION OF STORMWATER TREATMENT SITE

GENERAL

Based on the desire to afford the greatest degree of protection to Beaver Lake, all flow is to be conveyed from the Causeway for discharge at Lost Lagoon. The area affected by storm sewer discharge is the west embankment of the Causeway between the road and Lost Lagoon. North Lagoon Drive and several walking paths bisect the area.

Proposed Stormwater Treatment Site
Lower area within Lagoon

Proposed Stormwater Treatment Site
Upper area on boulevard

Since it is not possible to disturb natural treed areas or large areas of garden landscaping, the only reasonable site for location of a sizable wetland facility is within the Lagoon itself. A small bay located in the northeast corner presents a good opportunity in terms of the area available and its location with respect to the point of Causeway drainage discharge.

It is also worth noting that the proposed wetland site in Lost Lagoon was, in the 1930s after the Causeway was constructed, a vegetated marshland rather than an open water bay[1]. Further background on Lost Lagoon is included in Appendix E.

EXISTING PLANT SPECIES

Existing trees in the areas of the Stormwater Treatment Site include healthy stands of mature Western Red Cedar, Douglas Fir, Red Alder, Bigleaf Maple, and Larch. There are no major trees immediately adjacent to the water edge and any potential construction. Red Alder adjacent to the existing water edge are also healthy and should be retained and protected during any construction.

At the east end of the proposed site there are recently planted, (within the last 5 years), Weeping Nootka Falsecypress. If necessary these trees can be relocated and replanted.

A few of these trees are in decline but short to midterm health prospects for these trees is good. No Hazard Tree Assessment has been made concerning these trees.

A narrow band of aquatic and riparian vegetation extends along the shoreline of the potential marsh creation site. Hooker's willow, Pacific Willow and Salmonberry all occur in the immediate riparian margin of the lagoon. Aquatic vegetation includes Cattail, Pacific Water-Parsley, Sedges and yellow-flag Iris. Patches of non-native and invasive plants do occur along the lagoon margin near the site and include Himalayan Blackberry, Purple Loosestrife and Morning Glory. Invasive species should be removed and replaced with appropriate native species.

The native aquatic/riparian plant community appears relatively well-established and healthy. This plant community and the habitat values it provides should be maintained or expanded at the site.

Freshwater marsh development at the site should focus on expanding the available habitat diversity and productivity as well as providing final treatment to stormwater runoff entering Lost Lagoon.

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1 George Clifford Carl, *A Biological Survey of Lost Lagoon*, Master of Arts Thesis, University of British Columbia Department of Zoology, 1932

CRITICAL ANIMAL AND PLANT HABITAT

Edges of Cattail, yellowflag Iris, Sedges, and other riparian plantings adjacent to Lost Lagoon offer a unique quality of habitat in Stanley Park that is immediately adjacent to the granular pedestrian path.

This lake margin community also provides valuable food and nutrient input as well as cover for fish and a variety of aquatic invertebrates that inhabit the lake. Fish species recently documented in the lake are carp, (Cyprinius carpio), brown bullhead, (Ictalurus nebulosus), and Threespine Stickleback, (Gasterosteus aculeatus).

It is evident that Lost Lagoon provides habitat values for aquatic insects, introduced fish, waterfowl, wildlife and vegetation. Based on field review of the site and current understanding of the Lost Lagoon ecosystem, it is our view that a freshwater marsh constructed with care at the northeastern margin of the lagoon could benefit the local ecosystem through improvement of water quality and increased habitat diversity at the site. It is also important to note that the creation of a stormwater treatment marsh that extends into the lake would not preclude any number of possible future ecological or aesthetic enhancements of the lagoon.

SUN AND SHADE

The proposed Stormwater Treatment site has full southern exposure. Red Alder trees at the existing water edge provides shade on the granular pedestrian walk and the wood viewing deck. The remainder of the walk and the proposed site have full sun exposure.

The sun exposure is ideal for maintaining plant life within a stormwater treatment facility such as a wetland or pond / marsh facility.

SLOPES

The existing granular path is generally level and there is a rather quick slope down to the water of Lost Lagoon between .75 to 1.2 metres below the elevation of the walk. At some places the water is within .5 metre of the edge of the walk. At the east end of the proposed site, the existing lawn area slopes steeply up to Lost Lagoon Drive and then steeply up to the Causeway. The slopes in the lawn areas are between 2.5:1 and 4:1.

PEDESTRIAN CIRCULATION

People using Stanley Park trail maps use both the upper asphalt walk adjacent to Lost Lagoon Drive and the lower granular walk along Lost Lagoon. The granular walk is between 2.2 and 2.75 metres wide. No bicycles or inline skaters are allowed on the lower granular walk but joggers have been seen moving in both a westerly and an easterly direction. Small numbers of pedestrians were observed mid-week but higher numbers typically use the area on warm weekends.

VEHICULAR CIRCULATION

This is a confusing area for both vehicles and pedestrians. Traffic was light on the day observed, but when heavier it can be hard to understand, both as a driver and as a pedestrian. Paths and sidewalks disappear, paths and trails are poorly labelled, paths crossing the road, minimal parking available, car traffic and buses moving along Lost Lagoon Drive all contribute to a confusing system. A dedicated bus lane eliminates parking at the eastern end of Lost Lagoon Drive and traffic was observed to move at a fast rate, making it uncomfortable, as a pedestrian, to walk along the upper asphalt walk, which is not separated from the roadway by a median strip.

Opportunities may arise to improve the pedestrian and vehicular circulation during construction of stormwater management facilities. Improvements in particular to signage and trail marking should be considered. Given the high visibility and intensive use of the area, it is important that any above-ground stormwater management facilities, at the very least, do not detract from the enjoyable atmosphere of the site. Enhancements to the aesthetic and interpretive value of the area are welcome, as the benefits will be shared by a great number of park uses, both local residents and tourists.

6.5 LANDSCAPE DESIGN GUIDELINES

The following sub-sections detail the proposed landscape design guidelines that should be implemented in detailed design to ensure that the new facility blends harmoniously with the existing Park features while improving the interpretative and aesthetic features of the area. Figure 6-3 is a concept plan for landscape design.

EXISTING PEDESTRIAN EDGE

Clarify the existing circulation patterns by insuring trail signage clearly indicates appropriate trail use, directions and destinations. Connect the existing boardwalk lookout and proposed additional lookouts to the existing pedestrian circulation system. Incorporate interpretive signage with the boardwalk lookout design.

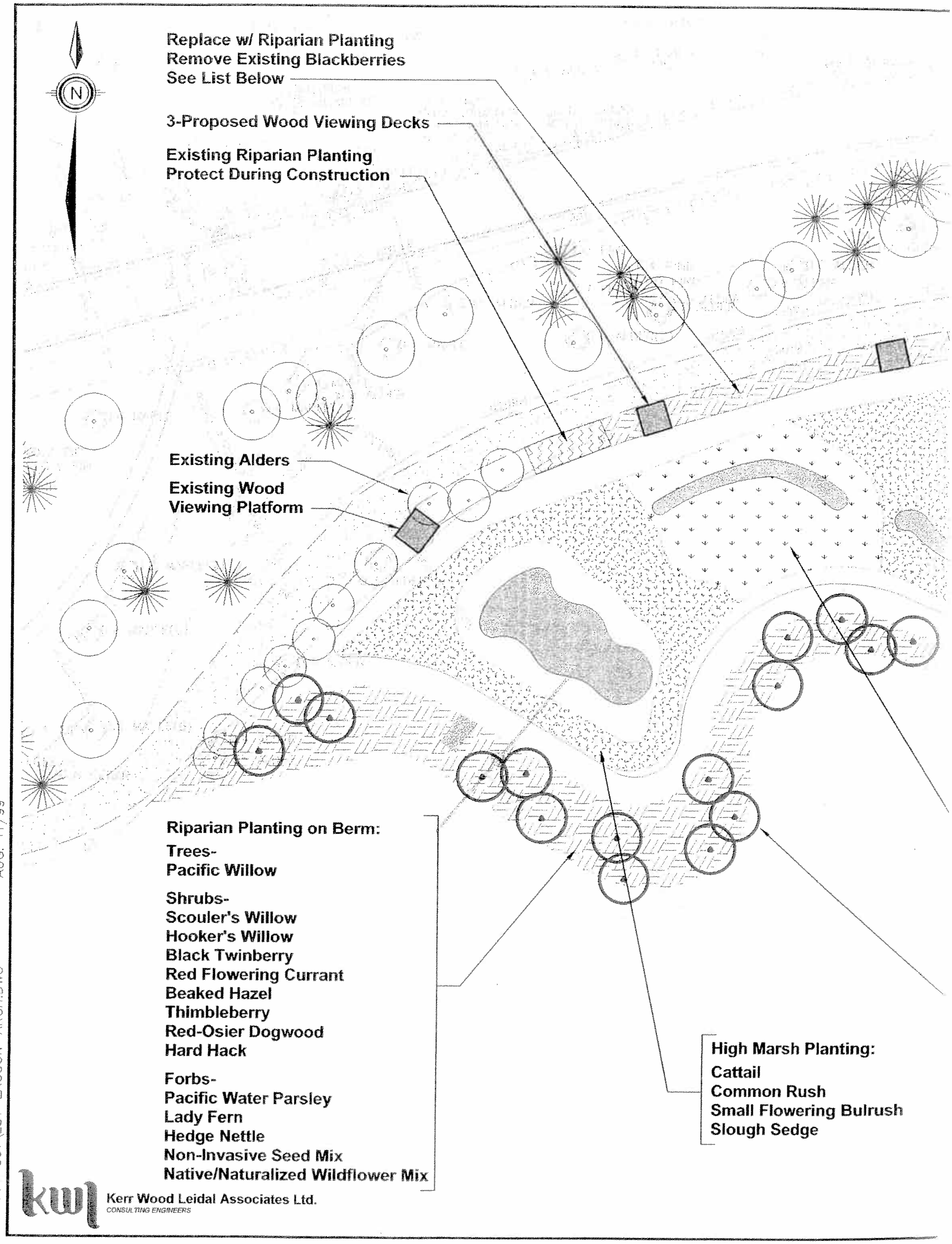
Incorporate barrier planting to insure that there is no direct pedestrian access to the marsh from the pedestrian path system except at the boardwalk lookouts.

BERM EDGE

The width of the outer berm edge is 3.5 metres with the exception of the westerly end which varies from 5.0 metres to 9.0 metres. The variation in berm width is designed to allow for a more diverse mix of plant material species and plant material scale. The depth of growing medium required to accommodate the plant material proposed varies from 300 mm deep for shrubs, forbs, and high marsh plants to 600 mm deep for trees. Growing medium placement specifications should be coordinated with engineers berm construction details.

	Botanical Name	Common Name
Trees	Salix lasiandra	Pacific Willow
Shrubs	Salix scouleriana	Scouler's Willow
	Salix hookeriana	Hooker's Willow
	Lonicera involucrata	Black Twinberry
	Ribes sanguineum	Red Flowering Currant
	Corylus cornuta	Beaked hazel
	Rubus parviflorus	Thimbleberry
	Spiraea douglasii	Hardhack
Forbs	Oenanthe sarmentosa	Pacific Water Parsley
	Athyrium filix-femina	Lady Fern
	Stachys cooleyae	Hedge Nettle
	Non-invasive seed mix (low on fall rye unless needed for sediment control; no canary reed grass)	
	Native/naturalized wildflower mix: lupin, daisy sp., columbine, foxglove etc.	
	Planting in patches rather than interplanting	
High Marsh	Typha latifolia	Cattail
	Juncus effusus	Common Rush
	Scirpus microcarpus	Small Flowered Bulrush
	Carex obnuta	Slough Sedge
Low Marsh	Scirpus microcarpus	Small Flowered Bulrush, dominant in low marshes
	Carex utriculata	Beaked Sedge, cattail would also do well but would tend to dominate
	Alisma plantago-aquatica	Water-plantain, small amount near pond/ deep water channel
	Lysichiton americanum	Skunk Cabbage

Table 6-2
Landscape Design Guidelines – Plant Species



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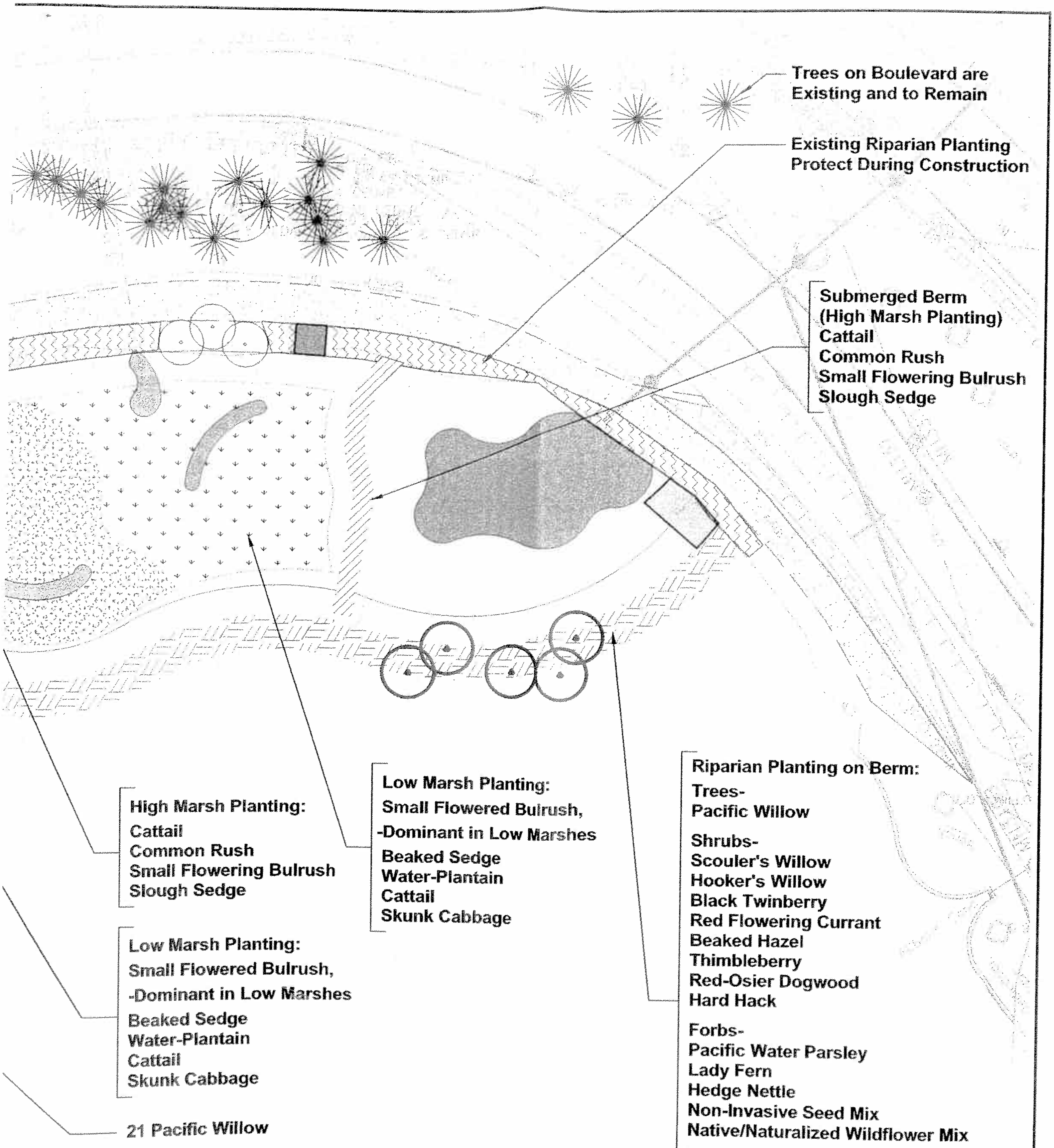

Lost Lagoon
Stormwater Treatment
Landscape Design Concept

Figure 6-3

FOREBAY

Small truck access to the forebay is required to facilitate periodic maintenance including the removal of sediment that will accumulate on the forebay bottom. The vehicle access point should incorporate a perforated, waffle-like structural system which allows the marsh edge planting to grow through it. The density of plant material should be such that the mature vegetation completely disguises the vehicle access. Periodic vehicle access will require cutting back the existing marsh edge vegetation at a designated vehicle access point.

PLANT MATERIAL

The selection of plant material to vegetate the marsh and berm should be restricted to native plant material which is indigenous to riparian, high marsh and low marsh growing conditions. The design intent is to recreate the natural character of a British Columbia wetland marsh. The selection of individual species should be such that there is a seamless transition from the existing riparian edge to the proposed area of re-vegetation. Table 6-2 outlines plant species appropriate for planting in each component of the stormwater treatment site.

Planting design should consider the need for visual access to the marsh and Lost Lagoon beyond while preventing any physical access to the marsh edge. This can be accommodated through the selection of plant species which are suitable for barrier planting. Protection of young, tender, newly planted material during the initial growing season should be considered in light of the large numbers of water fowl which inhabit and feed along the edges of Lost Lagoon.

The only plant removal on the existing bank will include the sections of Himalayan Blackberry which have overgrown the desirable native species. Once cleared these areas should be replanted with native species appropriate to their location.

6.6 SCHEDULE OF WORKS

This section provides a general description of the key structural components of the Lost Lagoon Treatment Concept Plan as illustrated in Figure 6-2. Design criteria are summarized in Table 6-3.

SPILL INTERCEPTORS (STORMCEPTORS)

Two Stormceptors, specified by N.D. Lea, form part of the Stormwater Management Plan, one located on-line near Beaver Lake (STC 3000) and another on-line at Lost Lagoon (STC 4000). N.D. Lea is currently assessing the feasibility of locating the STC 3000 within their existing design. If it is not possible to locate this Stormceptor near Beaver Lake, a bigger Stormceptor (STC 5000) should be installed at Lost Lagoon instead of the STC 4000.

Component	Design Criteria
Diversion Structure	▪ Split flow as follows: Up to 21 lps (6-month peak flow) to wetland Over 21 lps (up to 100-year peak flow) to Lost Lagoon ▪ Adjustable overflow weir and sluice gate
Wetland General	▪ Permanent pool volume 1,022 m^3 * 1.25 (factor of safety) = 1,280 m^3 ▪ Peak flow 21 lps ▪ 5:1 to 12:1 side slopes ▪ 5:1 length/width ratio ▪ Ensure depth diversity, approximate target depth allocations: Deep pool areas (forebay, deep pools, outlet pool) – 15% to 40% of total area Low and high marshes areas - 50% to 80% of total area ▪ Irregular inundated area - 5% of total area
Outside Berm	▪ 3.5 m minimum crest width ▪ Low-permeability zone to minimize leakage ▪ 5:1 side slopes ▪ 0.5 m freeboard above permanent pool elevation ▪ Berm topped with 300 mm to 600 mm of planting soil
Sedimentation Forebay	▪ Inlet pipe / structure ▪ Deep pool – maximum depth 1.8 m ▪ No emergent vegetation ▪ Hard surfaced bottom ▪ 5:1 side slopes minimum ▪ Maintenance access 5 m wide ▪ Level spreader 2 m wide berm with interlocking stone with openings for vegetation
Marsh Terraces	▪ Low marsh 0.15 m to 0.30 m water depth ▪ High marsh 0 m to 0.15 m water depth ▪ 300 mm to 600 mm of topsoil layer ▪ Appropriate marsh vegetation
Deep Pools Outlet Pool	▪ Maximum depth 1.8 m ▪ No emergent vegetation
Outlet Structure	▪ Capacity to discharge maximum inflow (from diversion and baseflow) ▪ Isolation valve to close outlet ▪ No drain possible because of Lagoon water levels ▪ Emergency spillway to discharge 1.0 m^3/s

Table 6-3
Schedule of Works

WETLAND DIVERSION

A diversion structure is required to direct low flows (up to and including the peak of the Water Quality Design Event) of 21 l/s into the wetland and bypass higher flows around the wetland to discharge directly to Lost Lagoon. The structure should be located downstream of the Lost Lagoon Stormceptor, adjacent to North Lagoon Drive to allow for maintenance access. This requires that the Stormceptor be located up-slope from the currently-proposed location[1].

The primary design considerations are hydraulic efficiency, flow flexibility for possible adjustments in the future, and ease of maintenance. For the purposes of pre-design and costing, a preliminary diversion structure has been developed as shown on Figure 6-2.

A large manhole chamber (1500 mm) could serve as the diversion structure with an adjustable height weir that would divert low flows toward the wetland. High flows would overtop the weir, bypassing the wetland and discharging to Lost Lagoon. The low flow pipe would be fitted with a sluice gate. Both the weir and gate are adjustable to allow for fine tuning of the operating flow rates in the future. The gate can also be completely closed in order to isolate the forebay for maintenance, and to isolate the entire wetland area for construction and 'green-up'.

The gate opening would be relatively small. Although most of the litter will be removed in the upstream Stormceptor, the small gate opening could be susceptible to clogging under certain conditions. Inspection and maintenance of the diversion chamber is therefore required.

The high flow bypass pipe should be designed to convey the 100-year peak flow event of 650 lps (100-year return period flow estimated by N.D. Lea). An energy dissipater at the outlet point should also be constructed to prevent scour of the Lagoon bottom during high flows.

ENGINEERED WETLAND

Engineered wetlands are designed based on hydrologic demands, treatment needs, and aesthetics. The key design criteria for treatment is structural and biological complexity. This creates a variety of habitats and adds to the natural appearance of the engineered facility. Structural complexity is incorporated into the wetland concept in the following ways:

Wetland Shape

The wetland shape is consistent with the Lagoon foreshore with added articulations for diversity and interest. The enveloping berm varies in top width from 3.5 m to 9 m to create structural complexity and provide an elongated island

[1] See the BCTFA construction drawings, MH 51-6

to support nesting, breeding and refuge to desired birds and wildlife. The side slopes are gradually sloped at 5:1 (horizontal : vertical) to mimic natural wetlands and allow for plantings. The overall shape is relatively long and narrow, maximizing the distance between the inlet and outlet to prevent short-circuiting and maintain a long residence time in the facility. A length/width ratio of approximately 5:1 is provided, allowing for extended settling to occur throughout.

The shape is also cost-effective, in that it maximizes the use of the existing shoreline for wetland containment.

Depths and Wetland Zones

A variety of water depths are incorporated into the wetland design to provide diversity in structure and treatment processes. The forebay, outlet pool and deep pools throughout the marsh area range in depth between approximately 1.0 m to 1.8 m. There will be no emergent vegetation in these zones and they will appear as open water areas.

The marsh is divided into 'high' and 'low' marshes ranging in depth from 0 to 0.3 m. For the purposes of the pre-design, the high marshes are shown at 0.15 m depth and the low marshes at 0.3 m and are shown in zone strips. During detailed design additional variety in the marsh depths and layouts could be incorporated. The marsh areas represent the majority of the submergent plantings. Different depths of terraces promote a diversity of plant and biotic life, which in turn increases the numbers of pollutant removal processes.

Deep water zones provide habitat for invertebrates and amphibians, the higher marsh areas offer feeding grounds for birds, and the elevated berm sections can provide various nesting opportunities.

Vegetation Zones, Canopy, and Plant Species

The plant mix, outlined in Section 6.5, is chosen to achieve the following: nutrient uptake, filtration of stormwater, maximization of flow path, prevention of sediment re-suspension, reduction of flow velocities, promotion of safety around the perimeter and enhancement of the aesthetics of the wetland concept.

Wetland Operation

Low flows, up to 21 l/s, will enter the wetland through the forebay. The forebay is a deep water zone that promotes the settling of fine particles to remove silt and particle-bound contaminants, and reduces incoming velocities. The flow then overtops a vegetated berm which distributes the flow evenly onto the shallow marsh area. Sheet flow is maximized through the marsh to allow sustained contact between stormwater and soil and plant matter, in order to promote extended settling, adsorption, and biological removal processes. Finally the flow

reaches a deep outlet pool and is discharged to Lost Lagoon. The wetland is designed to avoid large fluctuations in water level. When a rain event occurs, the incoming water gently displaces the standing water in the wetland through the outlet. Therefore, outflow approximately equals inflow at all times.

WETLAND BASEFLOW AUGMENTATION

Wetlands require a minimum baseflow to sustain the permanent pool and nourish the plantings. Based on a preliminary water balance calculation[1] the high marsh area is expected to experience approximately one month in the dry during the typical year if no baseflow is provided. Marsh plants can generally withstand and recover from up to two months of drought, therefore on average the wetland is not expected to require baseflow agumentation to survive the summer.

However, baseflow from surface watercourses and ditch subdrains will enter the wetland through the main forebay inlet and via an existing watercourse that discharges to the wetland on the north edge. While the quantity of baseflow from these sources cannot be quantified at this time, it is certain that these sources will provide dry-weather augmentation and therefore help sustain the wetland plants in times of drought.

At this pre-design stage, an allowance has been made for a small pump station to provide flow-augmentation during exceptional drought periods. Water can be pumped from the Lagoon to supplement moisture in the wetland provided that the lagoon water is not brackish. In addition, by closing the outlet to hold additional volume at the start of the summer, wetland water levels could be maintained longer into the dry season.

A more detailed water balance analysis should be undertaken as part of detailed design to evaluate the need for a flow augmentation pump station. This should include consideration of the baseflow available from ditch subdrains, probable Lagoon water levels, and geotechnical estimates of dyke leakage. The flow in the existing small watercourse should be monitored in August and September of 1999 to provide input to the detailed design process.

LOST LAGOON WATER LEVELS

The water level fluctuation in Lost Lagoon is integral to the design of the wetland. For the purposes of conceptualizing the wetland operation and layout, a fluctuating water level of El. 0.60 m to El. 0.90 m was assumed based on KWL and N.D. Lea survey information.

It should be noted that the possibility of seawater intrusion into the Lagoon exists, and brackish water can be harmful to the wetland plants. The operation of lagoon water levels therefore takes on added importance in ensuring lagoon water level do not enter the

[1] the calculation approximates inputs to the wetland from roadway runoff in the typical rainfall year, and subtracts water losses by berm seepage and evapotranspiration. See section 4.5 for a discussion of the typical year.

wetland unintentionally. A water balance should be undertaken for Lost Lagoon to document fluctuating water levels, 100-year inflows and outflows and an outlet profile, and develop a better understanding of lagoon operation. From this, operational guidelines could be developed. Lost Lagoon water levels should not be allowed to overtop the wetland berm emergency spill at El. 1.25. Additional detail will be required as input to detailed design.

Additional Investigations Required For Detailed Design

The following investigations should be addressed as part of detailed design:

Geotechnical

- Determine a soil profile under the proposed berm;
- Estimate seepage through berm under various Lagoon level conditions;
- Evaluate depths of sediment;
- Characterize the nature of the sediment, particularly any contamination (metals, hydrocarbons) that can affect lagoon water quality if exposed; and
- Assess the seismic stability of berm given the possibly weak foundation.

Hydrologic

- Develop a comprehensive water balance and operation plan for Lost Lagoon.
- Complete a detailed water balance for the wetland and to determine the need for flow-augmentation.
- Determine overland flow area tributary to wetland to ensure proper sizing of emergency spillway.
- Attempt to quantify wetland baseflow input (monitor ditch flow in late summer of 1999).

Construction

- Develop an overall runoff and water control plan for construction. This would include operational plan for water levels in Lost Lagoon, including lowest practical water level allowable.

Maintenance

- Develop an Operations and Maintenance manual for the wetland facility, including diversion structure, forebay, outlet, and augmentation.

Environmental

- Confirm construction window (waterfowl concerns).
- Develop fish and other wildlife salvage plan.
- Develop construction monitoring plan.
- Input into engineering drawings for habitat enhancement.

Component	Class 'C' Cost
Diversion Structure & Downstream Sewers	$29,300
Site Preparation	$42,300
Outer Berm	$165,000
Forebay	$39,050
High and Low Marshes	$57,600
Outlet Pool & Structures	$28,600
Landscaping	$105,500
Subtotal	**$467,350**
General Requirements @ 4%	$18,700
Contingency @ 25%	$121,500
Engineering @ 15%	$91,100
Total (Excluding GST)	**$699,000**

Table 6-4
Lost Lagoon Stormwater Treatment Wetland Cost Estimate

Alternative	Level of Treatment	Estimated Cost
Wetland with Forebay (Recommended)	Settling Extended Settling Adsorption and Biological Treatment	$699,000
Wet Pond / Marsh Combination	Settling Extended Settling Some Adsorption and Biological Treatment	$559,000
Wet Pond	Settling Extended Settling	$419,000

Table 6-5
Summary Cost Estimates for Stormwater Treatment Alternatives

Architectural

- Develop landscape design, including planting, viewing platforms, interpretive signage.
- Input into engineering drawings for landscape design.

DURATION OF DESIGN PROCESS

It is expected that the detailed design process could take in the range of six months to one year, depending on the resources devoted to the project. The time is required to complete the geotechnical, sediment, and survey investigations that are required prior to design. Once all background information is compiled and analyzed, actual detailed design is expected to take approximately two months, plus time for client review of construction drawings.

6.7 COST ESTIMATES

The capital cost estimate for the components of the Lost Lagoon Stormwater Treatment Plan itemized in the Schedule of Works is summarized on Table 6-4, and detailed in Appendix F. Considerable construction and incidental costs arise from the relatively difficult construction environment in Lost Lagoon, and the need for traffic, safety, and environmental controls. Specific construction issues are discussed in Section 6.8.

BASIS FOR COST ESTIMATES

The unit prices reflect KWL's recent experience with similar work, and therefore represent the best prediction of actual 1999 costs as of the date prepared. Actual (tendered) costs would depend on such things as market conditions generally, the time of year, contractors' work loads, any perceived risk exposure associated with the work, and unknown conditions.

Recently, construction prices have been stagnant, as demonstrated by experience in the Lower Mainland and elsewhere. The Infrastructure Program in 1995 abated in 1996, resulting in sharp price drops. Prices have remained steady since, and we expect prices to remain steady into 2000, partly because of reduced provincial funding to municipalities. Prices for certain types of work may drop.

The cost estimates are based on:

- preliminary quantity take-offs from the Figure 6-2;
- typical unit costs;
- estimates of materials, labour and equipment rental costs;
- assumptions about geotechnical conditions; and
- allowances for unknown conditions.

These preliminary cost estimates have been undertaken without the benefit of geotechnical information about the lagoon bottom and are therefore subject to adjustment during the detailed design stage.

The estimates are Class C indicative estimates, prepared with limited site information and based on probable conditions affecting the projects. They represent the summation of all identifiable project component costs, and are intended for program planning, and for obtaining approval in principle.

ALLOWANCES

The following allowances have been added to the base cost estimates:

- General requirements (mobilization, demobilization, bonding and insurance) at 4 percent;
- Contingency of 25 percent to cover uncertainty in the estimated prices; and
- Engineering costs at 15 percent.

When comparing with other options not covered herein, it should be ensured that cost comparisons are done on equivalent bases. For example, the costs for the City's overhead are not included.

COSTS FOR ALTERNATIVE TREATMENT PROCESSES

Relative cost estimates for the stormwater treatment alternatives marked as either recommended or worth considering on Table 6-1 are presented in Table 6-5. As these alternatives are not part of the recommended Plan, the costs have been estimated on a pro-rata basis relative to the wetland alternative.

Even though the wet pond / marsh combination and wet pond alternatives use somewhat less area than the recommended wetland alternative, the costs are not directly proportional to the surface area of the alternative. This is because the dominant component cost of construction is the outer berm, which does not decrease in size proportionally with a reduction in area. It should be noted that the concept design is relatively 'berm-efficient', as it maximizes the use of the existing shoreline for containment of the wetland by isolating an existing bay that provides containment on three sides.

POTENTIAL FOR COST REDUCTION

Reducing the capital cost of stormwater treatment could be achieved by:

- Relaxing the hydrologic design criteria (ie. duration of water quality design storm); or
- Reducing the treatment effectiveness (ie. selecting a less effective treatment process).

Significant cost reduction would require a compromise on both criteria, such as using a wet pond based on 12-hour design event. Neither of these is recommended for meeting the stormwater treatment objectives as stated in the workshop. However, it remains that the water discharged from the recommended wetland will likely be of higher quality than that in the Lagoon, so some reduction in treatment efficiency is a rational consideration. As a *minimum*, extended settling through use of a wet pond is recommended in order to remove fine particulate matter that would otherwise settle out in an uncontrolled manner in Lost Lagoon.

While working within Lost Lagoon introduces some additional construction costs, it should be noted that there is no alternative site for a water treatment facility of adequate size to treat roadway runoff from the Lower or Combined Stormwater Systems. The use of two separate sites as originally proposed would do little, if anything, to lower total costs, because one facility would still be required in Lost Lagoon.

SUMMARY

The capital costs are related to the complexities of construction at the available treatment site in the Lagoon. In order to significantly reduce the cost of stormwater treatment, any treatment facility would have to be located outside of the Lagoon boundaries. This would require the use of areas that are currently either landscaped gardens, or naturally forested. As stated in the Workshop meeting, neither of these are deemed acceptable by the Board of Parks.

6.8 CONSTRUCTION CONSIDERATIONS

Important issues relative to the sequence of construction for an engineered wetland are discussed in this Section.

CAUSEWAY DISCHARGE STORM SEWER

The storm sewer section between the Causeway and Lost Lagoon (including the Lower Stormceptor, wetland diversion structure, and high flow diversion pipe) can be designed and constructed independently of the engineered wetland. This may be required to facilitate the ongoing construction on the Causeway.

LOST LAGOON WATER LEVEL

The water level in Lost Lagoon should be lowered to facilitate construction. The lowest water level will not be dictated by the elevation of the lake outlet (El. –0.48), but by environmental considerations. Lowering the water level too low will expose parts of the Lagoon bed with possible consequences to benthic lifeforms. Dissolved oxygen levels and water temperatures should be monitored to ensure the health of resident species during this operation. The fountain should be operated during construction to provide aeration.

BERM CONSTRUCTION

The wetland construction area cannot practically be isolated from the Lagoon. Methods such as berming or sheet-piling would be impractical, excessively costly, and have negative environmental impacts. The preferred method is to hang a floating silt curtain to envelop the construction area, and construct the berm within the sectioned area. Every precaution must be taken to prevent siltation of the lake. The curtain must be continually monitored during construction.

Once the curtain is installed, the fish inside the enclosure must be salvaged.

It is proposed to construct the outer berm in order to isolate the wetland area for completion. The outer berm construction is the most critical step from the point of view of the lake water quality. The most practical and cost-effective method of completing the berm is to advance a shot-rock base, dumping rock off the face, and displacing the bottom sediments with the rock. This is considered appropriate[1] as long as the sediments are not too thick, and the stability of the berm has been checked. Sediment-control will be critical during this phase, but once the initial rock starter-berm is complete, it will act to safeguard the lake from the construction activities within.

An alternative is to remove the bottom sediments by dredging prior to berm construction. This alternative has several major drawbacks:

- The dredging operation would likely stir up far more sediment than rock-dumping, with consequences for water quality. This issue is of much more concern if the bottom sediments are contaminated.
- The sediments would likely have to be dewatered to a certain extent by means of stockpiling prior to trucking off-site, and therefore require double-handling at substantial cost. The stockpiles would be unsightly and could produce undesirable odours. As of this writing, a destination for the dredged material cannot be determined (because of its possible contamination).
- The additional costs of stockpiling, trucking, and disposal fees are likely to be in the hundreds of thousands of dollars, although they cannot be quantified at this time.

Figure 6-2 shows a conceptual cross-section of the outer berm. The berm will consist of several zones, each serving a specific purpose. The first zone is a shot-rock base advanced by dumping rock off the face as it is advanced, displacing the bottom sediments in the process. This base serves several purposes:

(i) it provides construction access during construction, and minimizes or eliminates equipment operation in the lagoon;
(ii) it provides a stable base for the rest of the berm; and

[1] KWL has experience in the design and construction of such berms for hatchery projects

(iii) it isolates the inner part of the wetland so that construction will not cause additional siltation in the lake.

The shot-rock material would be well-graded, with coarse rocks (300-500mm) providing a stable matrix, and finer fractions serving to reduce the permeability and minimize the void spaces.

The wetland-side zone would be composed of pit-run silty sand and gravel having a substantial fines (silt) content in order to minimize seepage losses through the embankment (see below). Depending on the final design and the gradations selected, an intermediate filter zone may also be required in order to prevent the fines from the upstream zone from migrating into the voids of the shot-rock.

The entire berm above the water line will be planted for erosion-protection, and topsoil will be placed on the inside (marsh-side) face for planting of riparian plants.

For pre-design purposes, the side slopes are shown at 5:1 (11 degrees), but slopes as steep as 3:1 (18 degrees) should be considered at the design stage in order to reduce costs and reduce the area disturbed by the berm.

As noted, a geotechnical investigation will be required at the detail design stage to determine the site conditions and finalize the cross section.

Design for Low Permeability

A critical design criterion for the outer berm will be control of seepage out of the wetland. At this time the magnitudes of the available dry-weather baseflows (from ground- and surface-water interception) are not known, but the overall leakage rate from the impoundment must be minimized. A careful design and selection of embankment materials should be undertaken during detailed design.

Construction of an impervious membrane (whether of clay, geomembrane or a combination) has several drawbacks. It would considerably complicate the construction, as well as increasing the costs. Moreover, the long-term performance of a membrane is in doubt because of the nature of the created wetland: the membrane could be exposed to damage from root penetration and burrowing by animals.

Another safeguard against drying-up of the wetland is a flow-augmentation system that would allow water from Lost Lagoon (or other source) to be pumped to the marsh during droughts, as described conceptually in Section 6.6. The cost estimates include a nominal allowance for such a system. Note that water from Lost Lagoon could not be conveyed to the wetland during times when it is brackish.

CONSTRUCTION OF POOLS AND MARSHES

Once the outer berm is constructed, additional cross-dykes can be built inside with relative ease. The forebay, outlet pool, and marsh areas can be constructed sequentially, and the construction areas dewatered as required. A water control plan would have to be developed to deal with both site runoff and seepage through the berm. During construction, the Wetland Bypass would be set to divert all storm sewer flow to Lost Lagoon, with nominal treatment (pre-settling) by the online Stormceptor(s).

SOURCES OF MATERIALS

Appreciable quantities of rock will be required. For costing purposes it is assumed that rock would be barged to False Creek from quarries on the Pitt River or elsewhere, and trucked from False Creek to Stanley Park. Other soil and gravel materials for construction could be sourced in a similar way.

MONITORING

Environmental and water quality monitoring will be required during the construction period. A vehicle and pedestrian traffic control and safety plan would be required that considers the park setting, tourists, fencing, dust control, noise control, and limited hours of work (daytime).

PERMITS AND APPROVALS

The Vancouver Port Authority (VPA) is the owner of the lands affected by the proposed wetland project, which are leased to the City of Vancouver for use as Park facilities. Before works can commence, application must be made to the VPA for their internal environmental review and possible referral to outside agencies. If the application to an outside agency such as the Burrard Environmental Review Committee (BERC) is deemed necessary by VPA, the application would be made by VPA as the lead agency.

The involvement of other approving agencies such as the Ministry of Environment (MOE) or Department of Fisheries and Oceans (DFO) would be dependant on the decision of the VPA as to the type of review process and notification that is required for the project.

If involved, the DFO is expected to have little interest in the project as there are no anadromous salmonids present in Lost Lagoon. The MOE may be interested in the impact on birds and wildlife, to which the wetland is expected to provide a net benefit through the recreation of additional land-water margin and habitat complexity.

In addition to formal application to the VPA, notification of the public should be considered integral to moving forward with the proposed wetland facility. Targeting of known interest groups may be the most time and resource efficient means of gathering

sufficient input to satisfy the Board of Parks, but a more comprehensive program could be triggered depending on the type of review deemed necessary by the VPA.

The duration of the approval process will depend significantly on the comprehensiveness of the review process determined by the VPA. If an in-house review only is required, the review may be completed within two or three months. If a full environmental assessment is required, approvals could easily take over one year.

Given that the approval process may range from a simple in-house assessment of the VPA, or a full-blown environmental assessment, it is in the Board of Parks' best interest to activate as short a process as possible. This is best done by making an initial application that is complete and that highlights the stormwater treatment and habitat enhancement benefits of the plan.

Construction Duration and Timing

Based on the concept plan, it is expected that construction could take in the order of four months from initial mobilization of crews and equipment through site cleanup and initial planting.

It is important that construction activities do not conflict with periods of sensitivity in waterfowl habitat. In general, November to March is the most important period for overwintering and seasonal use of the lagoon by waterfowl. Construction in the summer months, from June to September, is expected to be the preferred construction window. Planting of marshland vegetation can be done in the fall if required.

6.9 Spill Control Plan

A spill control plan must be developed to allow all concerned agencies to respond appropriately to ensure that spills do not have detrimental impacts on the wetland facility and receiving waters. Agencies involved may include:

- BCTFA;
- BC Ministry of Transportation and Highways (and/or contractor);
- Transit Authorities;
- Police;
- Fire Department; and
- Board of Parks maintenance department.

As owner and operator of the Causeway, the lead agency for the Spill Response Plan should be the Ministry of Transportation and Highways (MOTH).

The primary components of a spill response plan are:

- Monitoring (MOTH, Police, Parks);

Component	Frequency of Routine Inspection	Frequency of Maintenance
Catchbasins	Yearly After / during known spills	
Storm Sewers		
Subdrains		
Stormceptors	Monthly After / during known spills	
Wetland Diversion	Monthly	
High Flow Bypass Outlet	Yearly	
Outer Berm	Yearly	
Sedimentation Forebay	Yearly After / during known spills	
Wetland Inlet	Yearly	
Wetland Outlet	Yearly	
Flow-augmentation Pump	Monthly	

Table 6-6
Elements of a Maintenance Plan

- Reporting (MOTH, Police, Parks, Fire Department);
- Event Assessment (Fire Department, Parks);
- Control (Fire Department, MOTH, Parks)
- Impact Assessment (Parks).

With two recommended points of spill containment, the Stormwater Management Plan allows for development of a relatively simple spill response plan. During a spill event, the first point of interception (ie. upper or lower oil/grit separator) should be identified and monitored.

If necessary (such as during a severe rainfall event or the unlikely event of a high volume spill), a vacuum truck can be dispatched immediately to the control point to remove contaminants as they enter. For most routine spills, the remaining interception capacity[1] and proper operation of the Stormceptor need only be confirmed.

Excess loading of the wetland with spilled contaminants should be avoided. The wetland forebay should be monitored if it is suspected that spilled material may be making it past the spill containment devices. The forebay should be cleared of spilled material before it reaches the wetland portion of the facility.

Development of the spill response plan will require multi-agency coordination, and is best perhaps facilitated through the BCTFA's maintenance agreement with the Board of Parks and Recreation.

6.10 MAINTENANCE PLAN

Inspection and maintenance of all the stormwater management facilities (especially spill control interceptors) is required for them to operate as designed. Table 6-6 outlines the elements of a maintenance plan, with some suggested frequencies of inspection. The detailed frequencies and maintenance activities for Causeway Drainage Plan elements are to be developed by the BCTFA, presumably in accordance with MOTH standards, while the wetland detailed design will develop corresponding information for the appropriate components. In addition to routine inspections, it is expected that routine MOTH patrols will identify catchbasin blockages or other situations that may require immediate inspection and maintenance.

6.11 STORMWATER QUALITY MONITORING

By selecting the best available technology for treatment (wetland), the Board of Parks is doing the most that can be done to improve roadway runoff quality prior to discharge to

[1] Stormceptor oil/grit separators have viewing ports and dipstick-type elements to allow for simple and rapid assessment of the remaining interception capacity. Regular inspections may be all that is necessary to ensure that spill containment capacity is always maintained.

Alternative	Level of Treatment	Estimated Cost	Additional Benefits
Wetland with Forebay	▪ Settling ▪ Extended Settling ▪ Adsorption and Biological Treatment	$699,000	▪ Aquatic, terrestrial, and aviary habitat enhancement ▪ Aesthetic and interpretive enhancement
Wet Pond / Marsh Combination	▪ Settling ▪ Extended Settling ▪ ***Less*** Adsorption and Biological Treatment *Smaller wetland area reduces soil and plant contact.*	$559,000	▪ Aquatic, terrestrial, and aviary habitat enhancement ▪ Aesthetic and interpretive enhancement *Smaller wetland area offers less overall enhancement than wetland alternative.*
Wet Pond	▪ Settling ▪ Extended Settling	$419,000	▪ Minor habitat enhancement through creation of containment berm *Wet pond would visually appear as a bermed-off section of Lagoon. There is no wetland area.*

Table 6-7
Decision Support for Selection of Treatment Facility at Lost Lagoon

Lost Lagoon. Water quality monitoring would be of little benefit in operation of the wetland, because it is a passive facility.

It would be of greater benefit to keep records of the maintenance and performance history of the spill interceptors and wetland forebay, in order to determine removal rates and develop possible improvements over time. Statistically significant stormwater quality monitoring can be very expensive, with little direct payoff.

However, given the facility's high-profile location and easy access, there may be research and academic organizations interested in studying the wetland. This should be encouraged, in the interests of advancing the science of stormwater treatment and linking the Park with environmental protection initiatives.

Approving agencies may desire water quality monitoring as part of their permitting process, in which case their specific requirements for monitoring may have to be met.

6.12 SUMMARY

This Section presents a considerable amount of detail regarding the implementation of the recommended stormwater treatment alternative (wetland). For clarity, the three treatment technologies for consideration, their estimated costs, and relative benefits of each are summarized on Table 6-7 to allow the Board of Parks and Recreation to focus on the broad decision of which version of the Stormwater Management Plan to carry forward.

The least-preferred treatment (wet pond) would provide a level of treatment commensurate with the current water quality in Lost Lagoon. The extended settling capability of such a facility would protect the Lagoon from sedimentation and a significant proportion of pollutants. The two alternatives with wetland components offer further degrees of stormwater treatment, and attendant benefits in aesthetic, interpretive, and habitat enhancement.

7. RECOMMENDATIONS

7.1 INTRODUCTION

This section is based on all foregoing information and presents recommendations summarized under three broad categories. The recommendations form an action plan for the Board of Parks and Recreation in moving forward with implementation of the Stormwater Management Plan.

7.2 CAUSEWAY DRAINAGE PLAN & CAUSEWAY CONSTRUCTION

Several interim recommendations have been made previously as discussed in Section 3 and documented in Appendix A. The final recommendations as they correspond and integrate with the Stormwater Management Plan are listed here. It is recommended that:

1. The ditch subdrains on the east side of the Causeway at Sta 79+00 be interconnected, and the connection to the storm sewer eliminated.

2. The ditch subdrains on both sides of the causeway at manholes 51-2 and 51-5 be connected *both* to the storm sewer and to the existing surface watercourse with provision for future plugging of either connection.

3. One continuous storm sewer system be constructed with discharge to Lost Lagoon, and no discharge to Beaver Lake.

4. A model 3000 Stormceptor be installed online with the storm sewer in the general vicinity of the pedestrian/equestrian bridge, and a model 4000 Stormceptor be installed near Lost Lagoon. If only one Stormceptor is to be provided[1], at Lost Lagoon, it is recommended that a model 5000 be installed.

5. No construction or additional design work be done on the storm sewer configuration between the Causeway and Lost Lagoon, until the Stormwater Management Plan is approved and detailed design of facilities in this area is completed.

6. The Board of Parks request a review of the design drawing changes that will result from the recommendations 1 through 5 prior to construction, to ensure that the design changes meet the requirements of the stormwater management plan.

These recommendations have been communicated to the BCTFA by memorandum and in meetings by KWL as directed by the Board of Parks, and by the Board of Parks.

[1] At the time of writing, the provision of only one Stormceptor remains a possibility, depending on findings of the BCTFA and permissions of the Board of Parks and Recreation

7.3 STORMWATER MANAGEMENT PLAN

Section 6 presented the recommended Stormwater Management Plan, the components of which are listed in Section 6.6 (Schedule of Works and Cost Estimate). Based on this information, it is recommended that:

7. The Stormwater Management Plan, consisting primarily of an engineered wetland in the northeast corner of Lost Lagoon, be endorsed and approved by the Board of Parks and Recreation.

8. Alternatively, if capital costs must be reduced, that a Stormwater Management Plan consisting primarily of a wet pond in the northeast corner of Lost Lagoon, be endorsed and approved by the Board of Parks and Recreation.

9. The BCTFA be advised of the contents of the Plan, its impact on the Causeway Drainage Plan, the estimated cost, and the anticipated schedule for detailed design.

7.2 DETAILED DESIGN

Since the BCTFA is progressing with Causeway construction work, there is a pressing need for the detailed design of the storm sewer works between the Causeway and Lost Lagoon. It is therefore recommended that:

10. The Causeway discharge storm sewer (between the Causeway and Lost Lagoon) be designed as soon as possible. This will allow the appropriate change orders to be issued by the BCTFA, and Causeway construction to continue in a timely manner.

11. An application to the VPA be made for approval to proceed with construction of the recommended stormwater management plan. This application may consist of a copy of this document, or an abridged version including Figure 6-2.

12. A topographic survey (bottom soundings and sediment depth) in the proposed wetland area be completed.

13. A sediment sampling program be initiated to determine the quantity and quality of Lost Lagoon sediments at the proposed wetland area.

14. A geotechnical assessment of the proposed wetland area be completed to refine the construction techniques and wetland foundation design.

15. A Lagoon Operations Plan be completed to document Lost Lagoon control levels and operational procedures.

16. Flows in the ditch that currently discharges into Lost Lagoon along the north edge of the proposed wetland facility be monitored in August and September of 1999 to assist in determining baseflows that will be available to the proposed facility.

17. The wetland facility be designed pending results of recommendations 10 through 16, in accordance with the guidance given in Section 6. This should include landscape design, wetland design, construction mitigation plans, a construction specification, and a Class 'A' cost estimate.

APPENDIX E

ENVIRONMENTAL OVERVIEW OF LOST LAGOON AND BEAVER LAKE SYSTEM

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

Coast River Environmental Services Ltd. has collected the following overview background information describing the fisheries and aquatic habitat values of Lost Lagoon and the Beaver Lake system. This information has been supplemented by our site visits for the purpose of providing input to a stormwater management plan serving a portion of Stanley Park.

LOST LAGOON

Lost Lagoon is a shallow brackish lagoon covering an area of approximately 16 hectares. It is of historical significance that Stanley Park was once circumnavigable by canoe at high tide. The Stanley Park causeway, constructed in 1916, isolated Lost Lagoon from Coal Harbour (Carl 1932). This had important implications for the fisheries and aquatic resources of Lost Lagoon. From 1916 to 1929, Lost Lagoon was cut off from most water supply other than rain. Evaporation increased salinity to the point where the lagoon could no longer support fresh water aquatic life. Consequently, in 1929, the local fly fishing association raised funds to convert Lost Lagoon into a fresh water lake in order to introduce trout. The first stockings of fish and shrimp were unsuccessful, subsequent introductions of water lilies, water-weeds (myriophyllum) and cutthroat trout took hold. Other species recorded in the lake's early development included cattails (*Typha latifolia*), reeds (*Scirpus robustus*), water-cress (*Radicula nosturtium aquaticum*), and an algal species of marine origin (*Enteromorpha* sp.) (Carl 1932). Most of these plants are still present today, but are under heavy grazing pressures from waterfowl.

Carl's (1932) inventory of aquatic flora and fauna of Lost Lagoon also included several species of algae, diatoms, protozoans, crustaceans, and 6 orders of insects. These organisms are fundamental to aquatic food chains, and support the presence of many breeding and wintering bird species in Lost Lagoon today (Price, pers. comm.). In 1932, three species of fish were present: threespine stickleback (*Gasterosteus cataphractus), prickly sculpin (Cottus asper richardson)* and *cutthroat trout (Salmo clarkii).* Fish species recently documented in the lake are carp (*Cyprinius carpio),* brown bullhead (*Ictalurus nebulosus),* and threespine stickleback (*Gasterosteus aculeatus*) (McIntosh and Graham, pers. com.).

Water quality has always been problematic in Lost Lagoon. In 1932, little polluted water entered the lagoon, as its water supply comes mainly from the city water system and a small creek in Stanley Park (Carl 1932). However, chronic phosphate and nitrate loading from the faecal waste of breeding and wintering birds (McIntosh, pers. com.), caused water quality conditions to decline. Currently, the salinity level of Lost Lagoon is maintained through the addition of freshwater from the City of Vancouver's water supply in Ceperley Meadows at the west end of the lagoon. Approximately 180 gallons are pumped into the Lagoon per minute (Graham, pers.comm.). A flap gate control valve under the Stanley Park causeway is designed to let water out whilst preventing the inflow of saltwater from Coal Harbour. In August and September 1994, a malfunction in this control valve allowed

sea water to enter the lagoon. A large number of carp died as a result of low dissolved oxygen levels and excessive salinity in the lagoon.

Recent field inspections during July 1999 at the potential Lost Lagoon marsh creation site revealed the following tree and forb species adjacent to the lake margin.

Common Name	Native, Introduced or Unknown	Latin Name	Notes
Trees and Shrubs			
weeping willow	I	*Salix sp.*	1 large tree
Hooker's willow	N	*Salix hookeriana*	shrub
Pacific willow	N	*Salix lasiandra*	shrub
salmonberry	N	*Rubus spectabilis*	shrub
Forbs			
cattail	N	*Typha latifolia*	dominant along wetland margin
Pacific water-parsely	N	*Oenanthe sarmentosa*	intermixed with Typha
orchard grass	I	*Dactylis glomerata*	sporadic
purple loosestrife	I	*Lythrum salicaria*	sporadic along margin
dock	U	*Rumex* sp.	sporadic along margin
common plantain	I	*Plantago lanceolata*	sporadic trail edge
self-heal	I	*Prunella vulgaris*	sporadic trail edge
yellow-flag iris	I	*Iris pseudacorus*	mixed with Typha
European bittersweet	I	*Solanum dulcamara*	north end
morning glory	I	*Convolvulus arvensis*	north end
yellow loosestrife	I	unknown	north end
bentgrass species	U	*Agrostis* sp.	trail edge
red clover	I	*Trifolium pratense*	trail edge
Pacific silverweed	N	*Potentilla pacifica*	south; trail edge
lady fern	N	*Athyrium filix-femina*	rare
buttercup	N	*Ranunculus* sp.	sporadic

It is evident that Lost Lagoon provides important habitat values for aquatic insects, introduced fish, waterfowl, wildlife and vegetation. Based on our preliminary field review of the site and understanding of the Lost Lagoon ecosystem, it is our view that a freshwater marsh constructed with care at the northeastern margin of the lagoon could benefit the local ecosystem through improvement of water quality and increased habitat diversity at the site. It is also important to note that the creation of a stormwater treatment marsh that extends into the lake would not preclude any number of possible future ecological or esthetic enhancements of the lagoon.

BEAVER LAKE SYSTEM

The Beaver Creek system forms the largest watercourse in Stanley Park. It drains an area of approximately 112 ha, with a total stream channel length (including tributaries) of approximately 1.9 km. The system is comprised of the Prospect Creek mainstem and an

unnamed tributary joining it downstream from the causeway, Beaver Lake, and Beaver Creek which extends from the outlet of the lake to Burrard Inlet.

Prospect Creek originates from a 100 mm domestic water supply in the vicinity of the Prospect Point Picnic Area. Prospect Creek discharges into Beaver Lake. Based on information received from the Vancouver Salmon Stream Society in 1994, resident cutthroat trout and introduced coho salmon are present in the creek. There is apparently a barrier to upstream fish migration at the outlet of Beaver Lake. However, fish were observed approximately 250 m upstream of Beaver Lake in 1995.

The habitat available in Prospect Creek appeared to be capable of supporting small numbers of salmonids, although several barriers in the form of debris jams, steep sections of channel incised in the native underlying clay till, and the culvert under the causeway are barriers to fish movement. However, it is possible for small numbers of resident trout to be present in sections of Prospect Creek, especially downstream of the causeway. Chlorine in the drinking water supply, which serves as the main water source for the creek, is evident by its odour in the stream at the causeway crossing. It is likely; therefore, that chlorine concentrations upstream from the causeway exceed fish tolerance levels. The lack of aquatic invertebrates in the stream channel substrates above the causeway supports this hypothesis.

Beaver Lake is a rapidly infilling shallow basin marsh of approximately 3.2 ha. Cutthroat trout are present in Beaver Lake, their survival assured by the freshwater inflow. Water lilies and other aquatic plants have been introduced into the lake and have led to lake infilling and succession. Several schemes have been proposed in the past to increase the depth of the lake and reduce the near lethal high summer temperatures that commonly occur (above 22°C).

Beaver Creek is the largest stream in the system, with a length of 225 meters. Its discharge during the study was estimated at 2.5 l/s. In the early 1980s Beaver Creek still supported wild populations of spawning cutthroat trout and coho salmon (Johnson, pers. comm.). Coho fry from the Capilano River hatchery have been released into Beaver Creek over the past several years. Other enhancement efforts have also been undertaken by the Vancouver Salmon and Stream Society and the Salmonid Enhancement Program including riparian planting, streamside fencing, and instream habitat complexing (Hollier, pers. comm.). The obstruction at the mouth of Beaver Creek is apparently passable to anadromous fish during high tides (Hollier, pers. comm.). However, the obstruction under Pipeline Road and the culvert structure at the outlet of Beaver Lake are fish passage barriers under all flows. Improvement of fish passage likely represents the best enhancement opportunity in the system.

Two salmonids (unidentified) were observed during recent field surveys (July 1999) in Prospect Creek downstream from the causeway: one under the bridge where the Northern Creek Trail crosses Prospect Creek and the other under the bridge where the Lake Trail

crosses the creek. The first sighting is approximately 300 metres above the highest sighting in 1995.

Stream flow in the upper unnamed tributary to Prospect Creek was very low during our recent survey (July 1999) despite wet seasonal conditions and rain that was falling at the time. Downstream from the causeway, flow was subsurface at a number of locations, disappearing under the roots of trees and re-appearing some distance further down. In addition, the channel was plugged with debris in many locations. At its confluence with Prospect Creek, the wetted channel was close to a metre in width, but was less than 1 cm deep, the water flowing through the surface of the gravel substrate. Under present conditions, this watercourse is not accessible to fish from Prospect Creek.

Prospect Creek, its unnamed tributary, Beaver Lake and Beaver Creek form a stable and mature drainage complex within Stanley Park. Beaver Lake is a shallow wetland that is showing evidence of progressive infilling through an on-going process and appears to be particularly sensitive to adverse water quality inputs. The system is presently maintained by the controlled input of chlorinated domestic water from the GVRD pipeline via Prospect Creek. We recommend that Beaver Lake's natural watershed drainage be maintained and that the system be protected from any risk of severely altered water quality through chronic or accidental events.

INSTREAM WORKS

The timing of in-water works in Lost Lagoon will need to accommodate both fisheries and wildlife sensitivities. The normal fisheries timing window for instream works is August 1, to September 15. In addition, wildlife sensitivities will be evaluated for this project by the environmental agencies. Active breeding and nesting periods for waterfowl and other birds at the site may introduce additional timing constraints on the construction period.

The general sensitivity of fish and other aquatic resources in Lost Lagoon and other nearby drainages will require that all work be undertaken and completed in such a manner as to prevent the release of sediment, concrete or concrete leachate, or other deleterious substances into the aquatic environment.

Construction staging, timing, sequencing, and specific mitigation measures for sediment control and habitat protection will all need to be addressed in detail within an application or environmental approval by the agencies prior to undertaking these works.

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