Attachment 3(a)

Capital Regional District

Core Area Liquid Waste Management Plan

Wastewater Treatment System Feasibility and Costing Analysis

Technical Memorandum #1

Background and Technical Foundation

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October 14, 2015

Project: 1692.0037.01

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1.0 Introduction and Methodology

1.1 Project Background

Phase 2 analysis is an important chapter in an ongoing decision making process. Phase 1 included a constructive engagement process to characterize sites and option sets and collect public input on their values for wastewater treatment. Future phases, Phase 3 and beyond, allow the Core Area Committee and the Regional Board to confirm detailed performance criteria that ultimately becomes an owners' statement of requirements, or similar, for responses by the treatment and resource recovery market(s) to price, build and commission and potentially operate a core area wastewater solution. It is critical that the Phase 2 methodology respect the multi-phase sequence of this project and deliver on specified milestones, such as to assess systems and technologies, however not to select ultimate products and or technologies but rather to help the Core Area Committee define the required characteristics of the future system and provide a characterization of the option sets. All option sets may proceed to Phase 3 or it may become apparent that a subset of the option sets achieve the desired objectives and move forward to subsequent phases. Overall, the three phase analysis is summarized below.

Process Summary	
Phase 1:	Identify Sites and Option Sets and Collect Public Input on Values
Phase 2:	Confirm Performance Criteria and Characterize Financial/Environmental/Social Aspects of Option Sets
Phase 3+:	Finalize/Narrow Options, Determine Preferred Method to Engage with Private Sector, Confirm Funding Approach, Amend LWMP, Select Partners, Deliver Project(s), Operate Systems

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In effect, Phase 2 technical and costing analysis includes assessments and calculations that enable preliminary performance criteria to be tested and refined. The results of the process and analysis will enable the Committee to decide and direct on future performance criteria and infrastructure siting locations based in part on industry best practice, regional context and long-term service delivery excellence. Phase 2 significantly advances the Committee to confirming its requirements for a Core Area wastewater solution and serves to screen the options based on project criteria.

A process for establishing performance criteria typically involves key ingredients as outlined below.

- **Preliminary Design Criteria:** A project charter frames the project and provides guidance for analysis and outcomes. Preliminary criteria should be derived from the charter goals and commitments and later, the criteria can instruct the engineering and costing analysis.
- **Representative Design:** Employing the preliminary design criteria against technical options and technologies begins to frame up the market possibilities (e.g. technologies, resource recovery pathways, pipe alignments, etc.) for a Core Area system. Representative design includes provisionally selecting technologies and system configurations to characterize the relative value of available options and encourage deeper dialogue on the particulars of any commissioned facilities. While analysis and reporting will refer to specific solutions these are

not recommended outcomes; instead, the results of the representative design allow the criteria to come to life for a deeper understanding including life-cycle costing.

- **Life-Cycle Costing:** Potential ratepayer impacts based on proposed levels of service are crucial to performance criteria. Each option set will be assessed using capital, operating and revenue characteristics which will uncover the trade-offs in Core Area alternatives and likely lead to further iterations in future phases. For Phase 2, these costs are Class D only for the purpose of comparing options with significant contingencies due to the nature of the unknowns.
- **Presentation of Alternatives:** Option sets analysis will convey the ability of multiple solutions to meet the criteria and aspirations of the Core Area. While no single alternative will be able to fully address the criteria, it is the presentation of the alternatives and the ensuing debate that will help to clarify the refined set of technical criteria.
- **Refined Criteria:** Final reporting will center on the evolution and rationale for the stated, refined technical criteria. Future phases will test these criteria further so as to confirm the Committee's final statement of requirements (for one or more contracts) for responses by the wastewater treatment and resource recovery market.

Our work plan and methodology follow these ingredients explicitly. We endeavour to translate the project charter into preliminary design criteria, undertake technical analysis and present alternatives so as to provide information for direction by the Committee on their refined performance criteria. Technology and option set evaluations are provisional for deeper understanding of the criteria.

1.2 Preliminary Criteria

There is a need to focus the broad range of treatment and engineering solutions to arrive at a representative design that can be used to develop Class D life-cycle financial scenarios. While private sector submissions will help to finalize the ultimate system design based on prescribed owner's requirements, establishing criteria based on the Project Charter will guide representative design parameters. These parameters will become a key step in setting performance criteria for the project and ultimately guide the technical analysis through Fall 2015 to support Committee direction on preferred system configurations and outcomes.

These criteria are preliminary but suitable for carrying out Phase 2 and stem from the Committee's Charter. Input from the Technical Oversight Panel and direction by the Committee will enhance these criteria and ensure that design parameters align with Core Area expectations and public input to date. Criteria are used to assess alternatives and arrive at potential options that suit the multiple needs and goals of the project. The Charter's Goals and Commitments (left column) frame the criteria.

Charter Goal/Commitment	Preliminary Charter Criteria
1. Meet or exceed federal regulations for secondary treatment by December 31, 2020.	a. Refer to Section 2.5.4. b. Extent of liquids or solids produced in excess of regulations.
2. Minimize costs to residents and businesses (life cycle cost) and provide value for money.	a. Extent of leveraging of existing infrastructure assets; b. Reduction of consumable and operations costs; c. Extent of revenues from resource recovery;
3. Produce an innovative project that brings in costs at less than original estimates.	a. Extent of alternative to bring in costs less than original estimate.
4. Optimize opportunities for resource recovery to accomplish substantial net environmental benefit and reduce operating costs.	a. Certainty of long-term demand and revenue; b. Extent of support for community building; c. Extent of new infrastructure/services to support resource recovery; d. Extent of integration of other regional waste streams
5. Optimize greenhouse gas reduction through the development, construction and operation phases and ensure best practice for climate change mitigation.	a. Reduction of carbon footprint (buildings, treatment, transportation); b. Ability to produce high-quality air emissions; c. Ability to balance energy needs;
6. Develop and implement the project in a transparent manner and engage the public throughout the process.	a. Ability of an alternative to meet the preliminary criteria
7. Develop innovative solutions that account for and respond to future challenges, demands and opportunities, including being open to investigation integration of other parts of the waste stream if doing so offers the opportunities to optimize other goals and commitments in the future.	a. Ability to phase capacity/expansion with growth; b. Ability to improve effluent quality over life of facility; c. Extent of integration of other regional waste streams (above)
8. Optimize opportunities for climate change mitigation	a. Reduction of carbon footprint (buildings, treatment, transportation); b. Ability to produce high-quality air emissions; c. Ability to balance energy needs;
9. Deliver a solution that adds value to the surrounding community and enhances the livability of neighborhoods.	a. Extent to provide for positive public interaction; b. Reduction of risk to neighborhoods from facility failure; c. Reduction of interruption to neighborhood during normal operation;
10. Deliver solutions that are safe and resilient to earthquakes, tsunamis, sea level rise and storm surges.	a. Site/design resiliency for seismic and sea level rise;

The preliminary criteria outlined in this Technical Memo provide the basis for detailed technical criteria to develop a representative design and also allow for a comprehensive presentation of the option sets toward the end of Phase 2. Direction from the Committee in December 2015 will allow the CRD to take further steps to refine the performance criteria for a market response to a Core Area solution.

Technical Memorandum #2 will apply the initial steps of our methodology and the preliminary criteria against the defined option sets for further analysis. Additional feedback from the Technical Oversight Panel and ultimately, direction by the Committee, will finalize the option set analysis through Fall 2015.

1.3 Proposed Option Sets Evaluation: Considerations for Decision Making

Phase 2 feasibility and technical analysis provides for an evaluation of 4 option sets across the Core Area. Each option set includes different extents of infrastructure, facilities, services, risks and operations. Life-cycle costing is a core element of the option set evaluation.

Committee direction from June 2015 centers on life-cycle costing analysis which includes design and construction contingencies, administration costs, escalation, inflation, environmental costs as well as capital, operating and maintenance costs. This type of analysis is consistent with comparisons of major capital projects to screen options and further, supports staff and consultants in determining potential allocations per municipality.

In addition to financial analysis, each option set will be further assessed based on its performance against the preliminary criteria stemming from the Charter and from public values from previous phases. While the assessment will be primarily qualitative in nature, the characterization of social benefits, environmental values, risks and service governance will be supportive for Committee direction. Neither the financial analysis nor the qualitative assessment are enough on their own to confirm direction, but instead, it's the balance of needs and aspirations reflected across the entire suite of criteria from which reasonable direction can be made.

1.4 Option Set Evaluation Methodology

Evaluating option sets is led by the Project Goals and Commitments and the established technical criteria. Whether centralized or distributed, it is the ability of any one option set to best meet the goals of the project that warrants even further optimization by the Committee in future phases. Designing the option sets must consider the evaluation method, hence why both methods are included.

Option Set Design Consideration

- Confirm flows by catchment area and site node.
- Inventory supply and demand projections for water and heat recovery reuse across site nodes in the Core Area. Locate potential customers and define their product needs including barriers and pricing considerations.
- Locate treatment facilities (liquids and or solids) among available sites with consideration to existing infrastructure, land uses, road access and synergies with neighboring site nodes.

- Apply regulatory requirements and overlay with existing infrastructure to meet reliability needs without excess infrastructure.
- Develop conceptual resource recovery infrastructure systems to convey resources to their demands. Look for synergies with neighboring site nodes to reduce unnecessary infrastructure.
- Incorporate various processes and technologies to meet the resource recovery, regulatory and neighborhood considerations. Each option set should look to address a different level of service (in line with the criteria) to allow for lateral comparison of all option sets.
- Optimize resource recovery infrastructure to suit the supply demand balance e.g. focus toward the size of treatment facility to suit actual reuse needs and look for phasing to support growth.
- Confirm regulatory and risk-management needs including ultimate disposal of water as required. Confirm limitations and service governance considerations for implementation and operation.
- Iterate design considerations for 2030 and 2045 scenarios.

Evaluation

- Summarize the technical and engineering elements and characterize their relative levels of service.
- Create aggregate resource recovery summary (qualitative and quantitative) for comparative and communication purposes including overall benefits to community, climate change considerations, others.
- Inventory life-cycle costing elements including construction, operation, maintenance and revenues.
- Present life-cycle costing results including sensitivity analysis for various risk, revenue and contingency factors.
- Characterize operations and service governance needs, risk considerations, preliminary economic factors (e.g. supply and demand, pricing), qualitative elements such as social-benefits stemming from the ability to deliver on community aspirations such as water reuse, advanced treatment and other returns on investment that aren't readily quantifiable.
- Assess distributed option sets against technical criteria (Section 1.2).
- Discuss option sets against all project goals of the Charter.
- Reflect on criteria, project goals, and financial results and develop balanced scorecard approach to presenting the option sets.
- Consider recommendations for Committee consideration which may include further refinements of the option sets to best suit the needs of the Core Area.

Technical Memorandum #2 will provide extensive inventories of the option set designs whereas Technical Memorandum #3 will present the evaluation of each option set.

2.0 Design Criteria

2.1 Design Horizon

Most of the work undertaken to date targets meeting the population/flow requirements to the year 2030, with preliminary consideration to flows in 2045 and 2065. These design horizons are consistent with funding applications and businesses cases and therefore could be adopted for Phase 2. Phase 2 feasibility and technical analysis will address infrastructure and life cycle costing for both the 2030 and 2045 design years.

2.2 Design Populations

Previous phases of analysis researched and collated residential populations in each of the seven (7) municipalities and two (2) First Nations, as well as developed equivalent populations for the industrial, commercial and institutional sectors within each area. Population and flow projections are a considerable resource for Phase 2 and we propose to utilize available information following a preliminary screening on their suitability at this time.

Growth rates have been estimated a low rate (at 1.3%/year) and a high rate (at 2.1%/year). Aggregate populations provide a scale of growth for the Core Area however Phase 2 design and analysis will consider municipal by municipal growth to account for locally-specific design capacities. Overall, growth rates to 2030 and 2045 are tabulated below and include population equivalent contributions from industrial, commercial, and institutional sources

	@ 1.3%/year growth	@ 2.1%/year growth
Core Area Population (eq.) 2030	436,000	494,000
Core Area Population (eq.) 2045	570,000 (1)	669,000

(1) Derived from Discussion Paper 033-DP-1

Actual flow projections are based on municipal expectations as communicated to the CRD which are outlined in the following section.

2.3 Flows

Table 2.3.1 summarizes the design flows for 2030 and 2045. While there are nuances and potential discrepancies for flow estimates, Table 2.3.1 appears to reflect the most current CRD estimates with general agreement by the municipalities. We intend to move forward for Phase 2 relying upon the flow estimates in column 1, which we note are different than the flow estimates as provided by the Westside Technical Committee.

The flows noted are based on average dry weather flows (ADWF which aligns directly with the regulatory requirements of the Municipal Wastewater Regulation, as outlined in Section 2.5.1.

Recent direction from the Westside Select Committee is that engineering analysis for Westside Option Sets should account for the flows from west Saanich and west Victoria currently destined for the Macaulay outfall. Flows from the Eastside that travel to the Macaulay outfall are represented in Table 2.3.1.

To account for ongoing water conservation programs and demand management initiatives, the projected per capita flow rates decrease around the Core area from 225 to 250 litres per capita per day now to 195 in 2030 and 2045. Flows are presented in megaliters per day (MLD) which is a summation of the population equivalents per catchment area based on the per capita estimates.

Table 2.3.1 - Core Area 2030 and 2045 Design Flow Allocations

Location		ADWF (MLD)		
		2030 (1)	2030 (2)	2045 (3)
A.	**Clover Outfall**			
	- Oak Bay	6.6	-	6.6
	- East Saanich	9.2	-	12.8
	- East Victoria	31.9	-	34.0
	Sub-Total	**47.7**	**-**	**53.4**
B.	**Macaulay Outfall**			
	- Langford	14.1	14.1	23.1
	- Colwood	4.7	4.7	13.1
	- View Royal	3.5	3.5	7.9
	- Esquimalt First Nation	0.3	0.7	0.4
	- Songhees First Nation	0.4	0.7	0.5
	- Esquimalt	7.1	6.2	7.9
	- West Victoria	6.4	1.0	6.8
	- West Saanich	23.7	16.5	32.9
	Sub-Total	**60.2**	**47.4**	**92.6**
	Totals	**107.9**		**146.0**

(1) Core Area LWMP Committee Orientation Presentation, January 7, 2015

(2) Flows assumed by Westside

(3) Derived from CRD 2030 projections (first column). Refer to Appendix A for derivations

2.4 Influent Wastewater Quality and Loads

The CRD collects 24 hour composite samples and tests the influent effluent for numerous parameters. A summary of the 2014 data is included in Appendix B. The most relevant influent sewage concentration data from 2014 are summarized in Table 2.4.1. This data is consistent with historical reports prepared for the Core Area LWMP, the latest being the January 23, 2013 Technical Memo "Indicative/Detailed Design/Wastewater Characterization and Design Loads". Table 2.4.1 also includes a summary of the 2030 maximum month loads, which are used to size the biological components of the plants. To account for flow and load variability, design factors account for the maximum load that the facility will experience in any 30 consecutive days which typically represents the 92 percentile of the data set analyzed for 2014. The proposed flow-load variability factor is set at 1.25 times the average loading.

Table 2.4.1 – Average Influent Quality Concentrations and Maximum Month Loads for 2030 Flows [(1)]

Parameter	Macaulay		Clover	
	Average (mg/L)	Max Month (kg/d)	Average (mg/L)	Max Month (kg/d)
Carbonaceous BOD_5	226	17,010	192	11,450
Total BOD_5	275	20,700	238	14,190
Total Suspended Solids	270	20,320	238	14,190
Chemical Oxygen Demand (COD)	632	47,560	530	31,600
Ammonia	42	3,160	27	1,610
Alkalinity	217	16,330	168	10,020
Total Kjeldal Nitrogen	54	4,060	40	2,385

(1) Note influent pH ranges from 7.3 to 7.7 typically

2.5 Liquid Effluent Criteria

2.5.1 Introduction

Two regulations currently govern effluent discharges in BC – The Federal Wastewater Systems Effluent Regulation (WSER) and the BC Municipal Wastewater Regulation (MWR). The WSER deals only with discharges to surface waters and has marginally different criteria than the MWR. The MWR addresses discharges to surface water, ground, wet weather flows and for reclaimed water. Both provincial and federal governments intend to harmonize the regulations which will affect the effluent criteria.

There is a strong sentiment within the Core Area to reuse reclaimed water as much as possible. To facilitate this sentiment, it is proposed that effluent destined for reuse meet the *Greater Exposure Potential Category* for reclaimed water as defined in the BC Municipal Wastewater Regulation. This level of quality is similar to the requirements of the Canadian Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing and the California Title 22 Regulation and would permit all reclaimed uses except indirect and direct potable reuse applications. It is our understanding that this would also be acceptable for aquifer recharge based on work currently being undertaken by the City of Colwood. If the CRD was to limit the reuse to irrigation on restricted public access sites only, then the standard of effluent quality could be reduced to *Moderate Exposure Potential Category* which is basically equivalent to secondary treatment as defined in Section 2.5.4. Also, secondary treatment is suitable for discharge to most marine environments but the outfall depth must be positioned at 30 m or more which effectively rules out any discharge to the inner harbour.

Stream augmentation is cited in the regulations whereby treatment must be greater than secondary (tertiary) with effluent criteria to suit the receiving environment. However, MWR requires an alternate disposal or storage for reclaimed water (stream augmentation or reuse) as follows:

"Alternate Disposal or Storage

114 (1) A person must not provide or use reclaimed water unless all of the following requirements are met:

(a) There is an alternate method of disposing of the reclaimed water that meets the requirements of this regulation or is authorized by a director.

(b) Treatment processes are built with the minimum number of components specified in the applicable reliability category for the alternate method of disposal, as described in section 35 *[general component and reliability requirements]*;

(c) If there is no immediate means of conveyance of the municipal effluent or reclaimed water to the alternate disposal method, the wastewater facility has 48 hours' emergency storage outside the treatment system.

(2) Despite subsection (1) (a), a director may waive the requirement for an alternate method of disposal for reclaimed water that is not generated from residential development or institutional settings if an alternate method is not required to protect public health or the receiving environment and the wastewater facility has

(a) 48 hours' emergency storage outside the treatment system and the ability to shut down generation of municipal wastewater within 24 hours, or

(b) A dedicated storage system that is designed to accommodate:

i. At least 20 days of design average daily municipal effluent flow at any time,

ii. The maximum anticipated volume of surplus reclaimed water, and

iii. Storm or snowmelt events with a less than 5-year return period.

(3) Despite subsections (1) (a) and (2), if reclaimed water is discharged from a wastewater facility directly into a wetland, a director may waive the requirement for an alternate method of disposal if an alternate method of disposal is not required to protect public health or the receiving environment.

Failure to meet municipal effluent quality requirements

115 (1) If municipal effluent does not meet municipal effluent quality requirements, a provider of reclaimed water must ensure that the municipal effluent is diverted immediately to

(a) An alternate method of disposal, as provided for in section 114 (1) (a) *[alternate disposal or storage]*, or

(b) Emergency storage or a dedicated storage system, as described in section 115 (1) (c) or (2),

Until municipal effluent quality requirements are met and reclaimed water uses may continue.**"**

These regulatory requirements strongly suggest that an alternate ocean outfall is required if stream augmentation is pursued.

A discharge to a wetland may be possible without requiring an alternate method of disposal, but this would require a specific environmental impact study and a waiver from the Director of the Ministry of Environment. A discharge to a wetland has not been considered in our analyses at this time however may be considered at the direction of the Committee.

The MWR and previous liquid waste management plan amendments further regulate the quality of effluent with respect to wet weather flows, as tabulated below:

Effluent Criteria	Macaulay Outfall	Clover Outfall
Secondary	0 – 2 x ADWF	0 – 2 x ADWF
Primary	2 – 4 x ADWF	2 – 3 x ADWF
Screening (6 mm Ø)	> 4 x ADWF	> 3 x ADWF

ADWF = Average Dry Weather Flow

2.5.2 Ammonia and Toxicity

Ammonia and toxicity in wastewater effluent is a complicated topic which is discussed in detail in Appendix C. In summary, the Federal and BC governments have criteria that regulate the amount of ammonia in the effluent, in particular to the un-ionized ammonia concentrations. Our research and analysis concludes (Appendix C) that it is not necessary to reduce ammonia in the wastewater treatment plants to comply with both the federal and provincial regulations before discharging out the Clover and Macaulay outfalls. Enhanced treatment would be required however for any option that contemplates stream augmentation and/or wetland discharges.

2.5.3 Primary Liquid Effluent

The MWR requires primary effluent to meet:

$CBOD_5$ $\leq$ 130 mg/L

TSS $\leq$ 130 mg/L

2.5.4 Secondary Liquid Effluent plus Disinfection

Ocean outfall effluent criteria should best address both the federal and provincial regulations, as proposed in the table below, and based on the requirement of outfall diffusers at a minimum depth of 30 m below the surface.

Parameter	Units	Average Concentration	Maximum Concentration
$CBOD_5$	mg/L	$\leq$ 25	$\leq$ 45
TSS	mg/L	$\leq$ 25	$\leq$ 45
Un-ionized Ammonia in Effluent	mg/L	NA	$\leq$ 1.25 (1)
Un-Ionized Ammonia at End of Dilution Zone	mg/L	NA	$\leq$ 0.016 (1)
Total Residual Chlorine	mg/L	NA	$\leq$ 0.02
Faecal Coliforms	cfu/100 mL	NA	$\leq$ 200 (2)

(1) Only one of these parameters need to be met.

(2) It is our understanding that disinfection will be required. This is the standard concentration for discharge to recreational waters.

The frequency of testing and the averaging period is dependent on flow rates as shown below for continuous flow systems.

Flow Range	Testing Frequency	Averaging Period
$\leq$ 2,500 m^3/d	Monthly	Quarterly
> 2,500 but $\leq$ 17,500 m^3/d	Every 2 Weeks	Quarterly
> 17,500 but $\leq$ 50,000 m^3/d	Weekly	Monthly
> 50,000 m^3/d	3 Days/Week	Monthly

2.5.5 Enhanced Tertiary Liquid Effluent

Secondary Liquid Effluent Treatment with added disinfection achieves tertiary treatment levels. However, in order to provide the ability for reuse we have identified enhanced tertiary treatment targets.

The proposed enhanced tertiary level of treatment is designed to satisfy most reclaimed water applications in the *Greater Exposure Potential* category as defined in the Municipal Wastewater Regulation including aquifer recharge in Colwood, as noted below:

Parameter	Greater Exposure Potential	Monitoring Requirements
pH	6.5 to 9	Weekly
$CBOD_5$	$\leq$ 10 mg/L	Weekly
TSS	$\leq$ 10 mg/L	Weekly
Turbidity	Average 2 NTU Maximum 5 NTU	Continuous Monitoring
Faecal Coliform (1)	Median 1 cfu/100 mL Maximum 14 cfu/100 mL	Daily

(1) Median is based on the last 5 results.

2.5.6 Emerging Contaminants

In the terms of reference for Phase 2 the base case treatment standard is secondary treatment with advanced oxidation. Unfortunately, we have not been able to determine what parameters and effluent criteria this system was intended to meet. There are in the order of 1,700 pharmaceuticals and personal care products (PPCPs) alone. At the present time, there are no published standards in Canada for the discharge of emerging contaminants to marine waters. The CRD has prepared a fact sheet on emerging contaminants which can be found in Appendix D. From this fact sheet it is interesting to note the data collected by the CRD on their Ganges MBR plant and Saanich Peninsula secondary plant (conventional activated sludge) for removal efficiencies. Approximately 80% of the contaminants (211 of 266) had removal efficiencies > 90% for the MBR plant. Approximately 45% of the monitored contaminants (145 of 324) had removal efficiencies > 90% for the activated sludge plant.

Urban Systems and Carollo Engineers are of the opinion that treatment targets for emerging contaminants be approached in the following manner:

- That treatment processes and technologies for emerging contaminants be assessed in the future once effluent criteria for emerging contaminants of concern have been identified by the regulators; thorough analysis of options can be conducted for the addition of further treatment works at that time;
- That further monitoring and research be conducted in the early years of operation of the new Core Area system to assess the level of reduction of emerging contaminants already occurring in the effluent; and
- That future proposals by market proponents indicate the level of reduction of emerging contaminants in their proposed system and that proposals are evaluated, in part, by the level of reduction achieved.

Space could be left in the plant(s) if it was desired for emerging contaminant treatment in the future once the specific effluent criteria are known.

2.5.7 Liquid Treatment Summary

In summary it has been assumed for the remainder of Phase 2 that secondary treatment plus disinfection will be provided for all ocean discharges up to 2x ADWF with primary treatment to 3 x at the Clover Outfall and 4 x ADWF at the Macaulay Outfall and any other new outfalls. Water for reclaimed purposes will be treated to Greater Exposure Potential Tertiary Standards given the water quality requirements for anticipated uses. No specific treatment will be added at this time for additional treatment of emerging contaminants of concern beyond what the secondary or tertiary process will achieve.

2.6 Solids Criteria

Solids management is an integral component of wastewater treatment and the processing and disposal of the solids generated during the treatment of the wastewater must be addressed. Unlike the water, the solids management has additional requirements both from a public perception and the acceptability of the materials produced. As such, defining the goals and metrics that the solids management must achieve is critical for the technology evaluation.

Sludge is defined as untreated residual solids, whereas biosolids are treated to an extent defined in the BC Organic Matter Recycling Regulation.

Solids criteria are dependent on end uses, some of the typical criteria and end uses are summarized below:

Table 2.6.1 - Solids Criteria

Criteria	End Use	Comments
Class B Biosolids	Land Application	Stringent regulatory constraints
Class A Biosolids	Land Application	Option to donate or sell to public
Dewatered Sludge (12 – 20% dry solids)	Landfill	Could be quite odourous; occupies large volume
Dried Sludge (60 – 85% dry solids)	Landfill	Less concern with odours, occupies much less volume
Dried Sludge (60 – 85% dry solids)	Biofuel for Incinerators	Minor quantities of ash to dispose
Dried Sludge (60 – 85% dry solids)	Biofuel for Gasification	Biochar and ash to be disposed

In terms of the application of these criteria the following aspects will be considered:

- CRD has a current policy that does not allow the land application of biosolids, within its boundaries.
- CRD strongly discourages solids being discharged to their landfill e.g. residual solids disposal should be minimized.

2.7 Resource Recovery Markets: Design and Evaluation Methodology

Wastewater provides for multiple resources that can be recovered for a variety of beneficial uses. Previous studies served to narrow the broad list of possibilities toward a reasonable list of potential applications, including: water reclamation, heat recovery, solids recovery including potential energy conversion, and fertilizer supplements (i.e. struvite). While each application requires its own unique infrastructure and service-operation requirements, there are common attributes that apply universally to suit the charter and preliminary criteria. Throughout Phase 2, possibilities for resource recovery will be initially examined through a lens for:

- Long-term revenues and demands
- Minimized processing-technology footprint
- Cost of service
- Energy balance
- Complexity of customer agreements or partnerships
- Ability to support other community amenities
- Synergy with public utility services
- Regulatory feasibility

This list of attributes will frame the scan for market opportunities for resource recovery and help to identify target markets where there is greatest potential for applications to meet the project goals. Further, distributed option sets are designed to situate multiple plants throughout the Core Area to capitalize on resource recovery demands. Heat recovery and water reuse demands are distributed in particular and instruct the proposed methodology for identifying target markets, including:

- Review the broad inventory of water reuse and heat recovery possibilities including existing customers and future development.
- Inventory supply and demand projections for water and heat recovery reuse across site nodes in the Core Area. Locate potential customers and define their product needs including barriers and pricing considerations.
- Scan the broad list of recovery possibilities against the list of criteria above:
- Narrow the recovery options based on the results of the scan.
- Develop conceptual resource recovery infrastructure systems to convey resources to their demands. Look for synergies with neighboring site nodes to reduce unnecessary infrastructure.
- Optimize resource recovery infrastructure to suit the supply demand balance e.g. focus toward the size of treatment facility to suit actual reuse needs and look for phasing to support growth.
- Confirm regulatory and risk-management considerations. Confirm limitations and service governance considerations for risks and opportunities related to implementation and operation.

- Confirm cost and revenue projections for life cycle costing analysis.

Table 2.7.1 outlines the preliminary considerations for resource recovery target markets.

Table 2.7.1 Preliminary Resource Recovery Opportunities

Reclaimed Water	• Large parcels, clustered in areas within a few kilometres of site nodes, for irrigation supply at parks and local green spaces • Potable substitution for toilet flushing (only) in new (future flows) town center developments including commercial uses • Aquifer recharge
Heat Recovery	• Opportunities to support local development and sustainability goals by providing hydronic heat opportunities (e.g. low grade heat recovery systems) from pump stations or treatment facilities at various institutional and commercial buildings • Opportunities to integrate with any imminent district energy systems • Heat capture at major treatment facilities to offset heating costs and other fuel costs
Solids Recovery	• Market possibilities whereby treated biosolids are mixed into a beneficial topsoil product and sold for land application elsewhere • Market possibilities for biochar or dried solids which remain after energy recovery processes
Energy Recovery	• Recovery of methane gas from decomposed organic materials to produce electricity, natural gas, bioplastics, diesel fuels, others. • Thermal conversion opportunities of carbon via gasification, incineration or pyrolysis.
Struvite	• Recovery of ammonia and phosphorous as nutrients for use in fertilizers • Confirmation that market possibilities previously identified remain and that they are congruent with solids recovery processes

Each of these applications presents opportunities to recover resources from wastewater. Further consideration to service governance, responsibilities, risks, investment needs and long-term operation will be presented to the Committee and the public as part of the analysis results.

3.0 Facility Characterization Criteria

Technical criteria from Section 2 inform the facility design, or *facility characterization criteria*, which is a significant step toward establishing a representative design for each site (Section 4.0).

The following tables summarize the proposed Facility Characterization Criteria and how they align with the Preliminary Charter Criteria outlined in Section 1.0.

Table 3.1 - Liquid Discharge Requirements

Facility Characterization Criteria	Preliminary Charter Criteria	Comments
Flow Requirements	Meet Regulations (1a)	System must work as a whole but each site in a solution set may play a different part (i.e. Where we treat the flows over 2x average dry weather flow)
Receiving Environment – Regulatory Limits	Meet Regulations (1a)	Tied to discharge location
Receiving Environment – Emerging Contaminants	Improve Effluent Quality (4c)	As outlined earlier this one requires further dialogue and definition if it is to be included
Reuse Requirements	Support Resource Recovery (2c, 3c)	Highly tied to market demand

Table 3.2 - Solids Discharge Requirements

Facility Characterization Criteria	Preliminary Charter Criteria	Comments
Disposal/Reuse Requirements	Support Resource Recovery (2c, 3c)	Consider scale, synergies with energy and solids resource recovery and integration with other regional waste streams.

Table 3.3 - Site Constraints

Facility Characterization Criteria	Preliminary Charter Criteria	Comments
Adjacent Land Use	Safe Solutions (6b, 6c) Community Support (3b)	Certain technologies and solutions integrate better into residential settings than others.
Livability of Neighbourhood	Positive Public Interaction (6b) Community Support (3b) Reduction of Carbon Footprint (5a) Balance Energy Needs (5c)	Certain technologies and solutions integrate better into residential settings than others

Table 3.4 - Risks

Facility Characterization Criteria	Preliminary Charter Criteria	Comments
Certainty for Demand/Revenue	Certainty of Long-Term Demand and Revenue (3a) Ability to Phase with Growth (4a)	Certain technologies and solutions are more resilient to variations in demand/revenues.
Climate Variability Impacts	Site/Design Resiliency (4b)	Location specific
Seismic	Site/Design Resiliency (4b)	Location specific
Neighborhood Impacts	Reduction to Risks to Neighbourhoods from Facility Failure (6b) Reduction of Normal Interruption to Neighbourhood (6c) Ability to Produce High-Quality Air Emissions (5b)	Acceptable levels of risk beyond regulation vary by land use.
Process Risks – Liquids	Safe Solutions (6b, 6c) Reduction to Risks to Neighbourhoods from Facility Failure (6b)	Acceptable levels of risk beyond regulatory requirements vary by land use.
Process Risks – Solids	Safe Solutions (6b, 6c) Reduction to Risks to Neighbourhoods from Facility Failure (6b) Ability to Produce High-Quality Air Emissions (5b)	Acceptable levels of risk beyond regulatory requirements vary by land use.
Process Risks – Energy Recovery	Safe Solutions (6b, 6c) Reduction to Risks to Neighbourhoods from Facility Failure (6b) Ability to Produce High-Quality Air Emissions (5b)	Acceptable levels of risk beyond regulatory requirements vary by land use.

4.0 Methodology to Select Representative WWTP Technology

As outlined in Section 1, the criteria outlined in Section 2 and 3 will be used to arrive at representative designs for the various facility locations within the option sets. We have proposed that four sample site characterizations be used in order to inform the representative design process. These site characterizations will be used to consider facility design requirements, siting considerations and to review indicative technologies. Once the site locations and option sets are confirmed they can be refined prior to costing analysis. The proposed site characterizations are summarized in the table below:

Table 4.1 - Site Characterization Summary

Site Characterization	Neighbouring Land Use	Flow Range (Average Dry Weather Flow)	Anticipated Plant Purpose – Liquid Train
Small Distributed	Residential	< 5 ML/day	Tertiary treatment for local reuse
Medium Distributed	Residential	6-15 ML/day	Tertiary treatment for local reuse
Large Distributed	Residential	16 – 25 ML/day	Tertiary treatment for local reuse
Extra Large Distributed or Central	Non-Residential	26 + ML/day	Primary & Secondary treatment for outfall and tertiary treatment for local reuse

Representative design and analysis for solids treatment and recovery will adhere to the criteria outlined in section 3.0 and be considered in synergy with the liquid treatment and energy recovery needs/opportunities for the site.

5.0 Costing Factors

5.1 Introduction

Costs will be presented in 2015 Canadian dollars. It is important to recognize that since 2010, and from 2015 until the systems are constructed, prices of all cost elements can be significantly affected by time and typically, cost escalations. For example, the Engineering News Record (ENR) is an industry guide to the construction industry. The ENR states that the construction cost index for Toronto (BC is currently not represented in the ENR) has increased from 9,434 (2010) to 10,515 (2015). This is equivalent to a construction cost increase of 11.5% over the 5 year period. A review of data available from Stats Canada for the Victoria area indicates that their construction price index has risen from 111.5 (2010) to 122.8 (2014; no 2015 data yet available), using a base index of 100 (2007). This is equivalent to a 10.1 % increase over this 4 year period. This would appear to correlate fairly closely with the 11.5 % increase over 5 years for the ENR index. We have used the Stats Canada index for the purposes of calculating all cost escalations.

The impact of the exchange rate between the Euro, the US and Canadian dollars is also relevant, since a portion of the equipment may be manufactured in the USA or Europe.

Some costing considerations are difficult to predict, like the supply and demand and productivity of skilled labour in the Greater Victoria area, especially if other large scale projects in the province were to occur, such as liquefied natural gas and the Metro Vancouver Lion's Gate WWTP. It is also widely known that construction on Vancouver Island carries a premium compared to the mainland.

We will be using all of the recent construction related projects that Urban Systems and Carollo have completed to inform the estimates we provide, including local estimate considerations provided by municipal staff. Previous cost estimating from other consultants on this project have also been reviewed and have been considered in our evaluations.

5.2 Capital Cost Breakdown

Capital cost estimates include multiple factors and contingencies. For Class D cost estimates we have included *general requirements*, *contractor profit and overhead*, *construction and project contingencies, engineering, administration, interim financing and escalation.* Table 5.1 illustrates these cost factors for an example project with a base construction cost estimate of $1,000,000. For comparative purposes the percentages used in this study are the same as those used in previous studies. We have assumed the mid-point of construction is four years or 2019.

Table 5.1 - Capital Cost Breakdown

Description	Total
Construction Cost	$ 1,000,000
General Requirements (Mobilization, Demobilization, Bonds, Insurance, etc.) – 10%	$ 100,000
Contractor Profit/Overhead – 10%	$ 100,000
Construction/Project Contingency – 35%	$ 350,000
Subtotal of Direct Costs	**$ 1,550,000**
Engineering – 15%	$ 233,000
CRD Administration and Project Management and Miscellaneous – 8%	$ 124,000
Interim Financing– 4%	$ 62,000
Escalation to Mid-Point of Construction – 2%/year (4 years)	$ 124,000
Total Capital Project Cost	**$ 2,093,000**

5.3 Pump Stations

The pump stations that will be used to pump effluent from the existing CRD collection system to the proposed treatment plants are typically designed to be low-lift, high-volume facilities. Because of the unique nature of each pump station (siting, access, pump capacity, proximity to major utilities and sensitive areas, geotechnical considerations, etc.), costs for such facilities can vary widely.

Class D cost estimates are commonly derived from cost curves which are based on extensive cost data gathered from the combination of a wide range of pump stations throughout the industry. These curves typically plot station costs against the size of the stations in L/s. Typical curves are shown in Appendix E.

These particular curves were developed by an extensive study undertaken 11 years ago for the Ministry of Public Infrastructure Renewal in Ontario. In conducting our estimates we assessed the application of estimates from Ontario against our experience in the BC market. The unit rates have been multiplied by 1.6 with consideration of the following:

a. 20% - for temporary and permanent site work.
b. 20% - for standby power and SCADA
c. 20% - inflation from 2004 to 2015.

Where possible, the unit rates have been compared to cost data available from recently designed and constructed projects, to confirm general data conformance. These facilities typically comprise a concrete below grade wet well, in which the sewage is collected and from which the sewage is pumped using submersible pumps. An at-grade superstructure (usually concrete block or similar durable material) is located on top of the wet well (typically poured in place concrete), to house mechanical and electrical equipment, including MCCs, PLCs and standby power.

Where pump stations will be included in the design and construction of a wastewater treatment plant, i.e., are not stand alone facilities, experience informs that a 30% cost deduct should be applied to the unit costs rates to account for common infrastructure and other facility synergies.

Below is a summary of a few examples of anticipated pump station costs, based upon the curves in Appendix E and including the 1.6 multiplier. All rates are in 2015 dollars and pertain only to the Construction Cost portion as outlined in Section 5.2, which would be factored up as per Table 5.1.

Pump Station Size	Construction Cost (CDN$)
350 L/s	$ 3,400,000
750 L/s	$ 6,400,000
925 L/s	$ 8,000,000

Estimates and market pricing (historic) for the Craigflower Pump Station upgrade will be examined further in an effort to further refine these estimates, once the tender information is made available.

5.4 Piping

The piping systems that will be used to service the Core Area option sets will comprise PVC pipe installed in existing rights-of-ways, typically existing road allowances. As such, the unit cost rates allow for pavement and any existing surface improvement restoration. In addition, an allowance has been included for temporary site works, traffic control and associated above ground work.

In general, these pipes will provide the connectivity between the existing CRD sewer trunk mains, proposed pump stations, proposed wastewater treatment plants and proposed outfalls. Typically sanitary collection systems are designed for minimum flow velocities of 0.8 m/sec to ensure that material does not build up within the piping systems. From a capital cost and energy perspective, ideally flows should be near 2.5 m/sec. Given the wide range in flows within the CRD system (0 to 4 x ADWF), detailed analysis is required for any pumped and piped system to ensure that the optimum life cycle range of costs are achieved.

For the purposes of this costing exercise, we have sized our pipes such that the resultant velocities are in the 1.5 to 2.5 m/sec range, based upon 2 x ADWF.

The unit cost rates developed are based upon meeting or exceeding accepted industry design standards, such as those detailed by AWWA.

The following is a summary of the unit cost rates developed by Urban Systems as part of the ongoing work with the CRD. All rates are in 2015 CDN dollars and pertain only to the Construction Cost portion outlined in Section 5.2.

Pipe Diameter (mm)	Construction Unit Cost $/m
300	$ 700
350	$ 740
400	$ 780
450	$ 820
500	$ 870
600	$ 950
750	$ 1,130
900	$ 1,350
1050	$ 1,620
1200	$ 1,850
1350	$ 2,100
1575	$ 2,450

5.5 Outfalls

Developing unit cost rates for outfalls into a marine environment proved to be the most challenging task, given the wide range of unknowns and variabilities. Not too dissimilar from pump stations and their unique features, the unit cost rates for outfalls also vary widely. In particular, geotechnical considerations and seabed profiles will have significant impacts on these costs. However, unlike, pump stations, there is not a large data base on which to draw upon and develop cost curves.

Outfalls are anticipated using steel pipes, installed with concrete collars anchored to the sea floor. Based upon the data available, 2015 costs for these sizes were developed as summarized below and pertain only to the Construction Cost portion outlined in Section 5.2.

Pipe Diameter (mm)	Construction Unit Cost $/m
600	$ 6,150
750	$ 7,000
900	$ 7,800
1050	$ 8,600
1200	$ 9,600
1350	$ 10,800

5.6 Methodology to Provide WWTP Cost Estimates

For Wastewater Treatment Plants the costing methodology is more complicated since each plant includes both liquids and solids treatment processes and costs are largely dependent on the technology selected. For this project we will use the experience database developed by Carollo and Urban Systems in order to determine appropriate costs for the representative facilities. Only the representative technology will be costed in order to arrive at comparative cost estimates between the option sets.

5.7 Revenue Sources

Revenue sources will cover the range of incomes based on exchange of goods or services and also monies that offset costs including potential development contributions or potential partnerships which minimize the extent and impact of new works. Examples of revenues include:

- Utility billings, requisitions, transfers and interest gains
- Retail rates for resource recovery systems including water rates, gas/fuel rates (solids recovery) and incomes collected for any sales related to solids residuals
- Development cost charges and other potential private sector development contributions available to local governments
- Municipal cost-shares for example where infrastructure upgrades are needed for both local and regional benefit
- Grants in terms of secured monies available to CRD
- Other offsetting costs for example, homeowner cost savings that may arise through waste diversion as part of integrated solids recovery

This list of preliminary revenue resources will be refined through high-level feasibility analysis in collaboration with CRD and municipal staff.

5.8 Life Cycle Costing

Life-cycle costs will be prepared for each of the option sets, which will be detailed in Technical Memo #2. Life cycle costing includes capital, as well as operating costs and later, consideration to revenues as part of the aggregate financial scenarios. Operating costs will consider typical cost elements as well as revenue (outlined in Section 5.7) which can reasonably be assumed to accrue given the resource recovery opportunities available. The operating and life cycle costing will be completed in Technical Memo #3.

Below is a summary of the inputs into our life cycle costing model. As this is a constant dollar analysis, all costs will be in $2015. The only escalation that will be included will be 2% per year for initial capital projects for the time from today until midway through construction which is assumed to be 2019.

We propose to conduct sensitivity analysis on the discount rate, escalation factors and revenue projections to monetize the risks inherent in long-term capital financing and service delivery. As a base case, our life cycle analysis will be guided by previous analysis and in particular, will suit treasury board guidelines to suit the funding partners.

Life Cycle: 30 years (2015-2045)

Interest Rate: to be confirmed with funding partners (as needed) e.g. 4%

Inflation Rate: to confirmed with funding partners (as needed) e.g. 2%

Discount Rate: to be confirmed with funding partners (as needed) e.g. 3%

Water Cost: Distribution cost from distribution supplier (i.e., CRD for Westshore & Sooke) is $1.81/m³

Electricity Cost: Average rate $0.08/kwh

Chemical Costs; Current market prices

Labour Rates:

Labour Type	2015 Annual Salary [(1)]
Plant Manager	$ 158,000
Chief Plant Operators	$ 135,000
Chief Area Operator	$ 113,000
Plant Operator	$ 90,000
Labourer	$ 56,000

(1) Refer to Appendix F for derivation

Vehicle Rates: $40,000/yr./vehicle

Trucking Rates: Current market prices

Disposal Rates: Current tipping charges to CRD Landfill (i.e. $157 per tonne for screenings and pumpings from Sewage Treatment Plants)

Maintenance/Repairs Pump Stations: 1% of Capital/yr.

Equipment Replacement Reserve: 1% of Capital

Operation & Maintenance Contingency: 10%

While there are multiple financial scenarios to consider, it is important that Phase 2 results remain consistent with previous analysis but also reflect a shift in project outcomes and criteria. Further, qualitative evaluation of various social and environmental factors will support the financial analysis and allow the Committee to review the merits of option sets across a balanced scorecard. Phase 2 evaluations should support the committee in screening away option sets that don't effectively meet the goals and commitments of the project in order to refine the project criteria for ultimate design parameters for a Core Area solution. Additional public investment analysis beyond Phase 2 may be needed (e.g. value for money) to suit the needs of the funding partners.

Appendix A

2045 ADWF Calculation

2045 ADWF Calculation

Area	2015 - 2045 Residential Growth Rates (%) (1)	2045 Residential & ICI Total Population Equivalents (1)	2045 Residential & ICI Flows (MLD) (2)	2045 Base Groundwater Infiltration (MLD) (5)	2045 ADWF (MLD)	
Saanich	0.5	184,424	36.0	9.7	45.7	West = 32.9 / East = 12.8
Victoria	0.5	151,589	(3)	(3)	40.8 (3)	West = 6.8 / East = 34.0
Esquimalt	0.5	30,140	(4)	(4)	7.9 (4)	
Langford	2.9	93,189	18.2	4.9	23.1	
Colwood	1.5	52,697	10.3	2.8	13.1	
View Royal	1.5	31,867	6.2	1.7	7.9	
Oak Bay	0.1	26,670	5.2	1.4	6.6	
Subtotal		**570,576**			**145.1**	
Esquimalt First Nation	-	-	-	-	0.4 (6)	
Songhees First Nation	-	-	-	-	0.5 (6)	
				Total	**146**	

(1) 033-DP-1

(2) Assume 195 Lcd, from CALWMP Amendment #8

(3) Equilavent Population increase estimate from 2030 is 10,000 people - increase 2030 flow by 10,000 x 195 Lcd x 1.27 = 2.5 MLD or 38.3 + 2.5 = 40.8

(4) Population increase estiamte from 2030 is 3274 - increae 2030 flow by 3274 x 195 Lcd x 1.27 = 0.8 MLD or 7.1 + 0.8 = 7.9

(5) LWMP Amendment 8 - 2030 ADWF = 108 MLD for Core Area

Equivalent Population in 2030 is 436,032 x $195 \frac{L}{person \cdot day} = 85$ MLD

Base GWI = 108 - 85 = 23

BGWI is $\frac{23}{85}$ = 27% of the Residential + ICI Flows

(6) Increase 2030 EFN and SFN flows by 145.1/108 = 1.33

Appendix B

Influent Wastewater Quality for 2014

Macaulay **Screened Raw Sewage 2014**

Parameter	State	Unit	Frequency of Detectio	Average Concentration	n	Max Concentration	Min concentration	1:175 Dilution	BC WQG	CCME WQG
alkalinity - total - pH 4.5	TOT	mg/L	75%	217.7	9	273.0	188.0	1.1		
biochemical oxygen demand	TOT	mg/L	100%	275.8	12	376.7	180.0	1.5		
chemical oxygen demand	TOT	mg/L	100%	632.5	12	816.0	433.3	3.3		
carbonaceous biochemical ox	TOT	mg/L	100%	226.4	12	291.0	162.0	1.2		
cyanide-SAD	TOT	mg/L	100%	0.00256	9	0.00334	0.00173	0.00001		
cyanide-WAD	TOT	mg/L	100%	0.00148	10	0.00263	0.00083	0.00001	0.001b	
hardness (as CaCO3)	DISS	mg/L	100%	76.8	12	112.7	55.1	0.5		
hardness (as CaCO3)	TOT	mg/L	100%	88.6	12	127.7	63.6	0.5		
oil & grease, total	TOT	mg/L	100%	8.8	10	17.3	4.9	0.1		
oil & grease, mineral	TOT	mg/L	25%	ND	3	3.30	2.00	0.01		
pH	TOT	pH	100%	7.34	12	7.71	7.10	0.03		
pH @ 15° C	TOT	pH	100%	6.99	12	7.19	6.77	0.03		
specific conductivity - 25°C.	TOT	µS/cm	100%	794.4	12	971.0	649.3	4.0		
sulphate	TOT	mg/L	100%	29.3	2	39.6	18.9	0.2		
sulfide	TOT	mg/L	100%	0.353	11	0.632	0.125	0.003	0.002cf	
temperature	TOT	°C	100%	17.2	12	20.5	13.3	0.1		
enterococci	TOT	CFU/100 mL	100%	2,584,848	12	4,266,667	1,633,333	17,000	20j	35/70n
fecal coliforms	TOT	CFU/100 mL	100%	8,563,636	12	29,000,000	4,200,000	118,000	200j	
N - TKN (as N)	TOT	mg/L	100%	54.4	12	70.3	40.5	0.3		
N - NH3 (as N)	TOT	mg/L	100%	42.4	8	49.0	35.3	0.2		
N - NH3 (as N)- unionized	TOT	mg/L	100%	0.115	12	0.190	0.058	0.001	19.7e	
N - NO2 (as N)	TOT	mg/L	75%	0.041	9	0.253	0.005	0.001		
N - NO3 (as N)	TOT	mg/L	25%	ND	3	0.020	0.005	---		
N - NO3 + NO2 (as N)	TOT	mg/L	0%	ND	0	0.0200	0.0200	---		
P - PO4 - total (as P)	DISS	mg/L	100%	4.3	10	5.75	2.63	0.02		
P - PO4 - total (as P)	TOT	mg/L	100%	5.5	12	6.81	3.89	0.03		
P - PO4 - ortho (as P)	TOT	mg/L	100%	3.8	12	4.96	2.02	0.02		
total organic carbon	TOT	mg/L	100%	82	11	144.0	42.6	0.6		
total suspended solids	TOT	mg/L	100%	270	12	332	168	1.4		
aluminum	TOT	mg/L	100%	0.3	12	0.365	0.203	0.001		
antimony	TOT	mg/L	100%	0.0003	12	0.000399	0.000243	0.000002		
arsenic	TOT	mg/L	100%	0.0006	12	0.00084	0.00044	0.000003	0.0125cg	0.0125
barium	TOT	mg/L	100%	0.02	12	0.0387	0.0137	0.0002	0.5ac	
beryllium	TOT	mg/L	0%	ND	0	0.0000100	0.0000100	---		
cadmium	TOT	mg/L	100%	0.0002	12	0.000275	0.000139	0.000001	0.00012c	0.000120
calcium	TOT	mg/L	100%	21.7	12	29.3	16.8	0.1		
chloride	TOT	mg/L	100%	89.1	8	140.3	75.0	0.6		
chromium	TOT	mg/L	100%	0.002	12	0.00298	0.00116	0.00001		
chromium VI	TOT	mg/L	25%	ND	3	0.00120	0.00100	---		
cobalt	TOT	mg/L	100%	0.0009	12	0.001310	0.000504	0.000005	0.000004	
copper	TOT	mg/L	100%	0.12	12	0.169	0.081	0.001	0.001	0.003bh

Clover **Screened Raw Sewage 2014**

Parameter	State	Unit	Frequency of Detection	Average Concentration	n	Max Concentration	Min concentration	1:175 Dilution	BC WQG	CCME WQG
alkalinity - total - pH 4.5	TOT	mg/L	75%	168	9	179.3	154.3	1.0		
biochemical oxygen demand	TOT	mg/L	100%	238	12	305.0	184.0	1.7		
chemical oxygen demand	TOT	mg/L	100%	530	12	686.0	301.3	3.9		
carbonaceous biochemical oxygen	TOT	mg/L	100%	192	12	248.3	118.3	1.4		
cyanide-SAD	TOT	mg/L	100%	0.002	9	0.00257	0.00158	0.00001		
cyanide-WAD	TOT	mg/L	100%	0.0013	10	0.00216	0.00071	0.00001	0.001b	
hardness (as CaCO3)	DISS	mg/L	100%	63.9	12	90.4	49.0	0.5		
hardness (as CaCO3)	TOT	mg/L	100%	73.2	12	97.9	60.1	0.6		
oil & grease, total	TOT	mg/L	100%	9.7	10	24.3	3.5	0.1		
oil & grease, mineral	TOT	mg/L	42%	ND	5	4.00	2.00	0.02		
pH	TOT	pH	100%	7.33	12	7.71	7.10	0.04		
pH @ 15° C	TOT	pH	100%	6.89	12	7.15	6.24	0.04		
specific conductivity - 25°C.	TOT	µS/cm	100%	528.1	12	568.0	481.0	3.2		
sulphate	TOT	mg/L	100%	20.6	2	24.1	17.0	0.1		
sulfide	TOT	mg/L	100%	0.246	11	0.424	0.092	0.002	0.002cf	
temperature	TOT	°C	100%	18.4	12	21.2	14.9	0.1		
enterococci	TOT	CFU/100 mL	100%	2,255,556	12	4,500,000	766,667	25,714	20j	35/70n
fecal coliforms	TOT	CFU/100 mL	100%	6,433,333	12	14,333,333	3,033,333	81,886	200j	
N - TKN (as N)	TOT	mg/L	100%	40.8	12	51.7	28.9	0.3		
N - NH3 (as N)	TOT	mg/L	100%	27.1	8	34.0	13.3	0.2		
N - NH3 (as N)- unionized	TOT	mg/L	100%	0.058	12	0.120	0.012	0.001	19.7e	
N - NO2 (as N)	TOT	mg/L	92%	0.063	11	0.187	0.005	0.001		
N - NO3 (as N)	TOT	mg/L	50%	ND	6	0.489	0.006	0.003		
N - NO3 + NO2 (as N)	TOT	mg/L	0%	ND	0	0.0200	0.0200	0.0001		
N - Total (as N)	TOT	mg/L	100%	40.3	1	40.3	40.3	0.2		
P - PO4 - total (as P)	DISS	mg/L	100%	3.40	10	4.30	1.88	0.02		
P - PO4 - total (as P)	TOT	mg/L	100%	4.36	12	5.74	2.76	0.03		
P - PO4 - ortho (as P)	TOT	mg/L	100%	2.91	12	4.04	1.75	0.02		
total organic carbon	TOT	mg/L	100%	61.9	11	118.0	30.8	0.7		
total suspended solids	TOT	mg/L	100%	238.4	12	292.0	166.0	1.7		
aluminum	TOT	mg/L	100%	0.310	12	0.435	0.217	0.002		
antimony	TOT	mg/L	100%	0.000258	12	0.000380	0.000186	0.000002		
arsenic	TOT	mg/L	100%	0.00066	12	0.00111	0.00050	0.00001	0.0125cg	0.0125
barium	TOT	mg/L	100%	0.0214	12	0.0253	0.0120	0.0001	0.5ac	
beryllium	TOT	mg/L	8%	ND	1	0.0000103	0.0000100	0.0000001		
cadmium	TOT	mg/L	100%	0.000157	12	0.000260	0.000100	0.000001	0.00012c	0.00012
calcium	TOT	mg/L	100%	18.8	12	25.4	16.3	0.1		
chloride	TOT	mg/L	100%	42.8	8	45.7	39.0	0.3		
chromium	TOT	mg/L	100%	0.00100	12	0.00155	0.00069	0.00001		
chromium VI	TOT	mg/L	0%	ND	0	0.00133	0.00100	0.00001		
cobalt	TOT	mg/L	100%	0.000360	12	0.000506	0.000289	0.000003	0.000004	

Appendix C

Ammonia Toxicity

MEMORANDUM

Date:	September 23, 2015
To:	Chris Town, P.Eng.
cc:	Ehren Lee, P.Eng., Steve Brubacher, P.Eng.
From:	Dr. Joanne Harkness, R.P.Bio.
File:	1692.0037.01
Subject:	Requirements for Ammonia Treatment

1. INTRODUCTION

The CRD is currently assessing options for the management of the sanitary sewage which is produced by the area. The purpose of this memorandum is to provide a summary of the assessment which was completed to determine if treatment for ammonia will be required in order to meet Federal and Provincial regulatory requirements.

2. BACKGROUND TO AMMONIA IN MUNICIPAL WASTEWATER

Ammonia is the predominant form of nitrogen in untreated municipal wastewater and in municipal wastewater effluents where there is no nitrification (biological reduction of ammonia). Ammonia is one of the key parameters of concern with respect to sewage effluents and aquatic toxicity. Both acute and chronic toxicity need to be considered.

Acute toxicity refers to a rapid and extreme response to environmental conditions – i.e. death normally occurs within a short period of time. The standard test for determining acute toxicity in an aquatic environment is the LC50 96 hour rainbow trout bioassay. In this test, 10 young rainbow trout are used per test. If 6 fish die within 96 hours, the test solution is determined to be acutely toxic and has failed the toxicity test. Acute toxicity is the focus for effluent prior to release to the environment.

Chronic toxicity is less easy to define than acute toxicity as this type of toxicity refers to effects which may be observed over a long time period and which may be subtle in nature. Chronic toxicity could equate to impacts on off-spring of exposed individuals, metabolic differences or subtle changes in the ability to survive or reproduce. Due to the complexity of chronic toxicity, acute toxicity has historically been the primary focus for legislation and the regulatory government agencies. Chronic toxicity is the focus for environmental conditions, once the effluent has been released.

Ammonia is present in two forms: ionised and un-ionised, the proportion of which is dependent on pH and temperature. It is the un-ionised form of ammonia which is of particular interest, as this is the form which is toxic to fish. The un-ionised form of ammonia becomes the predominant form of ammonia as the pH increases. As a result, under alkaline conditions, it is possible for very low concentrations of ammonia to cause aquatic toxicity. Total ammonia is the sum of the ionised and un-ionised forms of ammonia.

3. REGULATORY BACKGROUND

3.1 Provincial Legislation and Guidelines

The Municipal Wastewater Regulation (MWR) is the regulatory framework for management of sewage in British Columbia. The MWR was published in April 2012, and replaced the Municipal Sewage Regulation, which was promulgated in 1999. The MWR outlines the effluent quality standards and discharge requirements for municipal wastewater treatment plants in British Columbia. For discharge to surface waters, the MWR indicates the expectations for effluent quality, dilution and defines the concept of an initial dilution zone (IDZ). The IDZ is an area immediately around the point of discharge where it is acceptable for degradation in water quality to occur. With respect to ammonia, the MWR focuses on meeting chronic ammonia concentrations at the edge of the IDZ. The concentration of ammonia in the effluent is to be back calculated based on the need to meet site-specific chronic conditions at the edge of the IDZ.

The Capital Regional District (CRD) has an approved Liquid Waste Management Plan (LWMP). A LWMP is a powerful document which is based on the current legislation. The completion of a LWMP results in a document which takes precedence over any existing permit or the MWR. Although a LWMP can provide an avenue for flexibility, the general intent of a LWMP is to develop a plan which will be implemented over time in order to meet the intent and conditions of the MWR.

The BC Water Quality Guidelines provide guidance as to suitable water quality for a range of different uses including drinking water, aquatic life, recreation and agriculture. The guidelines do not have any direct legal standing but are intended to be used as a tool to provide policy direction for decisions relating to water quality. These guidelines can be used to evaluate appropriate effluent criteria for release from a municipal wastewater treatment plant. For ammonia, there are acute and chronic guidelines for the protection of aquatic life for both marine and freshwater surface waters. The guideline value varies, depending on the temperature and pH. For marine waters, the salinity also needs to be taken into consideration. The BC Water Quality Guidelines define chronic as a 30 day average, based on 5 weekly samples taken over a 30 day period. This definition allows for an increased likelihood that a particular condition may both exist and persist in an environment.

3.2 Federal Legislation and Guidelines

The Federal wastewater regulation (the Wastewater Systems Effluent Regulations) was published in July, 2012 and applies to any surface water discharge in Canada where the average annual incoming flow to the sewage treatment plant is ≥ 100 m^3/d, with the focus being to protect surface waters which are regarded as fisheries resources. The regulation contains National Performance Standards, with the standard for ammonia being a maximum concentration of un-ionised ammonia of 1.25 mg/L, prior to release. The Federal regulation also recognises ammonia conditions after dilution in the receiving environment. In the event that the un-ionised ammonia concentration of 1.25 mg/L cannot be met before effluent release, then there is no need to upgrade for ammonia treatment as long as an un-ionised ammonia concentration of 0.016 mg/L is met in the receiving environment, 100 m away from the point of release. The discharger would need to apply for a temporary authorisation which is valid for 3 years. Re-application for the temporary authorisation would be required every 3 years, if the effluent is still acutely toxic.

3.3 Summary of Legislation

There are three regulatory criteria for ammonia, all of which have direct relevance to each other.

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1. The Federal wastewater regulation stipulates a maximum un-ionised ammonia concentration of 1.25 mg/L, before release. This focuses on acute toxicity to fish.
2. The Federal wastewater regulation stipulates that in the event that the effluent un-ionised ammonia concentration is above 1.25 mg/L, treatment for ammonia is not required as long as the concentration of un-ionised ammonia in the receiving environment is ≤ 0.016 mg/L, at a distance 100 m from the point of effluent release. This focuses on chronic toxicity to fish.
3. The MWR stipulates that the concentration of ammonia at the edge of the IDZ is to meet fisheries chronic concentrations, based on conditions in the receiving environment for temperature and pH. There is no requirement in the MWR for acute ammonia toxicity.

4. EFFLUENT AMMONIA EVALUATIONS

4.1 MWR Evaluations

In order to estimate the chronic total ammonia concentration at the edge of the IDZ, historical data for temperature, pH and salinity were taken from the CRD monitoring program database for locations at the edge of the IDZ. The data indicated little variability in the pH (range pH 7.50 to 7.96). The 90th percentile of the whole dataset (pH 7.83) was used for the evaluation. There was also consistency in the temperature throughout the year, ranging from a low of 7.07 ^{o}C in January to a high of 12.44 ^{o}C in July. The 90th percentile of the July dataset (11.10 ^{o}C) was used for the evaluation. The data indicated that the salinity was in the order of 30 g/kg, which is the highest threshold indicated in the BC Water Quality Guidelines. Based on these data the total ammonia concentration at the edge of the IDZ should be less than or equal to 3.4 mg/L.

The evaluations focused on 90th percentile data rather than the maximum data. Maximum data represent the worst case scenario and the intent was to evaluate the potential for a chronic effect to occur, which requires conditions which have a likelihood of occurring on a regular basis for an extended period of time. Maximum data represent extreme events which occur for short periods of time. This is not the intent of the definitions in the BC Water Quality Guidelines, where chronic conditions are evaluated using 5 data points taken on a weekly basis over 5 consecutive weeks.

Table 4.1 summarises the chronic total ammonia concentration at the edge of the IDZ and the corresponding effluent total ammonia concentration for both the Macauley Point and Clover Point outfalls. The dilution ratio was taken from CRD customized oceanographic/plume modelling of the effluent dilution and dispersion at both outfall locations. The estimations do not take into account the background total ammonia concentration. However, this is a low concern given that the background total ammonia concentration is expected to be close to the analytical detection limit (e.g. in the order of 0.005 mg/L) and the estimated effluent concentrations which would be required to cause chronic ammonia conditions at the edge of the IDZ are significantly higher than what would be expected for untreated municipal wastewater. From this evaluation, since untreated municipal wastewater would have a maximum total ammonia concentration of 45 mg/L, there are no requirements to treat for ammonia to meet chronic ammonia conditions at the edge of the IDZ.

Table 4.1: Summary of End of IDZ Chronic Ammonia Concentration and the Corresponding Effluent Total Ammonia Concentration

Outfall Location	Edge of IDZ Chronic Total Ammonia Concentration to Meet MWR (mg/L)	Edge of IDZ Dilution Ratio	Corresponding Effluent Total Ammonia Concentration (mg/L)
Macaulay Point	≤ 3.4	245:1	≤ 833
Clover Point	≤ 3.4	175:1	≤ 595

4.2 Federal Wastewater Regulation Evaluations

The Federal wastewater regulation recognises both acute toxicity before effluent release and chronic toxicity at a point 100 m away from the point of release. For the effluent prior to release, the standard is a maximum un-ionised ammonia concentration of 1.25 mg/L. Table 4.2 summarises the pH range expected for a typical municipal wastewater effluent and the corresponding total ammonia concentration which would equate to an un-ionised ammonia concentration of 1.25 mg/L. The standard total ammonia concentration for untreated municipal wastewater is 25 mg/L. However, it is reasonable to expect that there will be periodic increases in the wastewater total ammonia concentration, with the concentration potentially being in the order of 45 mg/L. For a wastewater treatment plant that is not designed to nitrify, it is reasonable to expect that the effluent total ammonia concentration will typically be in the 25 mg/L range, but could periodically be as high as 45 mg/L. From this, although there would be no concerns with the acute un-ionised ammonia threshold of 1.25 mg/L being exceeded if the effluent pH is 7.5 or less, this may not be the case if the pH is in the order of 8.0, as the maximum effluent total ammonia concentration is very close to the acutely toxic threshold under these conditions.

Table 4.2: Effluent Total Ammonia Concentration to be Non-acutely Toxic

Effluent pH	Total Ammonia Concentration (mg/L)
7.0	≤ 455
7.5	≤ 148
8.0	≤ 47

In the event that the effluent is acutely toxic before release, there will be the need to consider the ability to meet chronically toxic concentrations after the release. Table 4.3 summarises the effluent un-ionised and total ammonia concentration required in order to meet an un-ionised ammonia concentration of 0.016 mg/L at the edge of the IDZ, which is approximately 100 m away from the point of effluent release, for both the Macaulay Point and Clover Point outfalls. Using the worst case effluent pH of 8.0, the information presented in Table 4.3 indicates that, in the event it is not possible to meet the pre-discharge un-ionised ammonia concentration of 1.25 mg/L, it will be possible to meet the receiving environment concentration of 0.016 mg/L. The calculated corresponding total ammonia concentration for both the Macaulay Point and Clover Point outfalls is significantly higher than what would be expected for ammonia to be present in untreated municipal wastewater. As a point of reference, the effluent pH would need to be in the order of 8.4 before there would be concerns regarding the ability to meet an un-ionised ammonia concentration of 0.016 mg/L in the receiving environment.

Table 4.3: Summary Effluent Total and Un-ionised Ammonia Concentration to Meet Chronic Conditions 100 m Away from the Outfall

Outfall Location	Effluent Un-ionised Ammonia Concentration (mg/L)	Edge of IDZ Dilution Ratio	Effluent Total Ammonia Concentration (mg/L)
Macaulay Point	≤ 3.9	245:1	≤ 146
Clover Point	≤ 2.8	175:1	≤ 104

From the above information, there are no requirements to treat for ammonia to meet the requirements of the Federal wastewater regulation. In the event that the effluent ammonia concentration is deemed to be acutely toxic, the chronic concentrations in the receiving environment can be met and, therefore, this site would be eligible to apply for a temporary authorisation, which is renewable every 3 years, if required.

5. ADDITIONAL INFORMATION – REGULATORY CHANGES

This document considers both the Federal wastewater regulation and the MWR. However, discussion is currently underway to harmonize the BC regulation with the Federal wastewater regulation, which will mean that the Federal wastewater regulation will no longer apply in BC, and the default regulation for an effluent release to a surface water will be the MWR. Preliminary discussions with the BC Ministry of Environment have indicated that, with respect to ammonia, the approach will be to focus on meeting chronic concentrations in the receiving environment, which is consistent with the current conditions in the MWR. However, this approach will need to be confirmed once the harmonization process is complete.

The timing of the harmonization agreement has not been set, but prior to the end of 2015 is considered to be reasonable.

6. SUMMARY

At this point in time, both the Federal and Provincial wastewater regulations need to be considered with respect to effluent ammonia standards. This may not be the case in the future, if the harmonization process is finalised. The default regulation will be the MWR.

The information presented above indicates that there is no requirement to reduce ammonia in order to meet the MWR. Chronic conditions at the edge of the IDZ can be met without ammonia treatment. There is also no requirement to treat for ammonia to meet the Federal wastewater regulation. There could be a slight risk that the effluent could be periodically acutely toxic for ammonia, depending on the operational

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pH. However, there is no risk that the chronic concentration would not be met in the receiving environment. Therefore, in the event that there is an issue with acute effluent toxicity, this site would be eligible to apply for a temporary authorisation, which is renewable every 3 years, if required.

Sincerely,

URBAN SYSTEMS LTD.

Dr. Joanne Harkness, R.P.Bio.
Water and Wastewater Specialist

/jh

Appendix D

CRD Fact Sheet on Emerging Contaminants

Fact Sheet

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DIVISION: Wastewater & Marine Environment Program

FactSheet#: FS2015-002

DATE: March 17, 2015
LAST EDIT: August 6, 2015

SUBJECT: Emerging Contaminants in Wastewater

- Municipal wastewater treatment has two primary streams within the process:
  - Liquid stream
  - Solids stream

- Municipal wastewater treatment effectively reduces many contaminants from the liquid stream of the treatment process.
  - There is no solid stream or liquid stream treatment technology capable of rendering all contaminants completely inert.
  - Removal efficiency depends upon treatment technology, the optimization of the plant, and the chemical characteristics of each individual contaminant
  - Generally, the higher the level of treatment or the more technologies/steps employed, the greater reduction of contaminants in the liquid stream (i.e., influent to effluent)

- Wastewater treatment processes can:
  - Reduce or destroy contaminants making them less toxic
  - Reactivate contaminants making them more toxic
  - Create byproducts that can be more or less toxic than the original contaminant
  - Transfer contaminants to the sludge/biosolids fraction
  - Have no impact on some contaminants (i.e., what goes in the plant comes out of the plant).

- Sewage potentially contain any element or chemical in use by humans.
  - Hydrophilic (water soluble) contaminants predominate in the liquid stream.
  - Hydrophobic contaminants predominate in sludge/biosolids. .

- Contaminants found in wastewater include:
  - ***Polybrominated diphenyl ethers (PBDEs) and other brominated flame retardants***
  - ***Perfluoroalkyl substances (PFOS, PFOA, etc.)****
  - ***Bisphenol A****
  - ***Metals***
  - ***Triclosan****
  - ***Chlorinated alkanes***
  - ***Metals and organometals***
  - ***Parabens***
  - ***Nonylphenol and ethoxylates****
  - ***Siloxanes****
  - ***Pharmaceuticals and personal care products (PPCPs)**** [1]

[1] The Scientist Magazine – Drugging the Environment by Megan Scudellari - http://www.the-

  - ***Polycyclic aromatic hydrocarbons (PAHs)***
  - Phthalates
  - Pesticides
  - Surfactants
  - Polychlorinated biphenyls (PCBs)
  - Dioxins and furans
  - Pathogens
  - Microplastics*
  - Nanoparticles*
  - Many others

- Some of the above contaminants are considered emerging (identified with an *), while others are considered current use or legacy

- Just because you can detect the above contaminants in wastewaters does not automatically mean there is an environmental or health risk associated with them.
  - Analytical capabilities are rapidly improving and our ability to detect contaminants at much lower concentrations (often below known risk levels) is increasing
  - The relative risk of the above classes of contaminants depends upon their propensity to persist, bioaccumulate or have known toxicity effects.
    - Risk assessments for emerging substances are relatively limited, but are ongoing

- Environment Canada's Chemicals Management Plan[2] and the United States Environmental Protection Agency[3] are two of the organizations around the world that are characterizing contaminants in wastewaters.

- Environment Canada has currently prioritized the contaminants in ***bold italics*** above for wastewater (and biosolids) characterization[1].
  - Their findings to date indicate that contaminant removal efficiencies varied by:
    - treatment technology
    - contaminant
    - season (summer versus winter)
  - To reiterate a previous bullet:
    - The majority of contaminants were reduced by treatment (either through destruction or by transfer to the solids stream of the process) rendering them less toxic in the effluent.
    - Some contaminants were increased by treatment (either through reactivation or conversion to more harmful byproducts) rendering them more toxic in effluent.
    - A few contaminants were not impacted by treatment at all, thereby retaining their toxicity in effluent.
  - Their findings will be used to inform environmental and human health risk assessments for wastewater receiving environments and reuse.
  - Their findings can be found in various scientific journal articles[1]
    - MetroVancouver's Annacis Island treatment facility participated in Environment Canada's study and can be identified in their results as the only facility that employs trickling filter/solids contact as a treatment process
      - We have not yet received results from MetroVancouver staff, but they have committed to sending them to us

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scientist.com/?articles.view/articleNo/43615/title/Drugging-the-Environment/ - accessed online August 6, 2015

[2] Environment Canada's Chemicals Management Plan summary presentation - http://www.cwwa.ca/pdf_files/ISO-10_Smyth.pdf

Smyth – 2015 – Monitoring Chemical Substances in Canadian Municipal Wastewater: 5 Years Later. A report prepared for the WEAO 2015 Technical Conference, Toronto, ON by Environment Canada. 14 pp. – PDF available upon request

Many of Environment Canada's results are also contained in scientific journal articles. CRD Marine Programs staff have some of these articles and would be happy to discuss their contents. Licensing restrictions prevent us providing copies.

[3] United States Environmental Protection Agency wastewater assessment - http://water.epa.gov/scitech/wastetech/guide/index.cfm

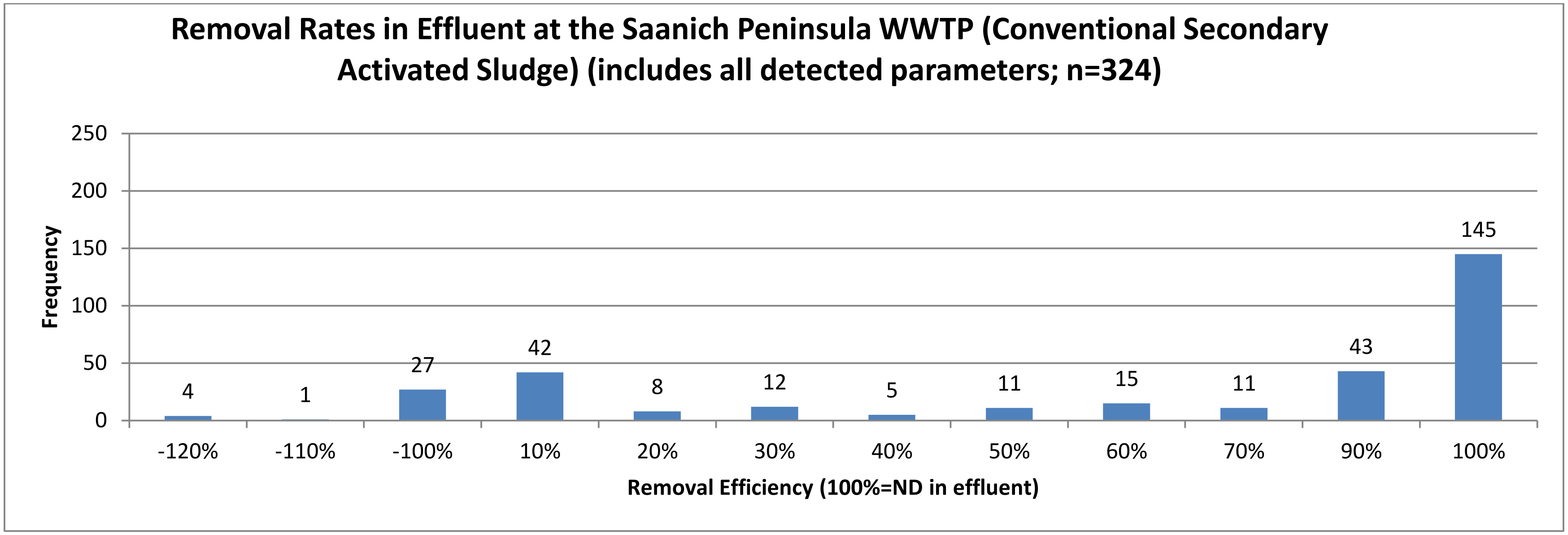
- The CRD also undertakes contaminant monitoring, including some emerging substances, in regional wastewaters and has determined removal efficiencies at two of our facilities:
  - The Saanich Peninsula Wastewater Treatment Plant (WWTP) which employs conventional activated sludge processes to create secondary non-disinfected effluent
  - The Ganges Harbour WWTP which employs membrane bioreactor technology and UV disinfection to create advanced secondary disinfected effluent

- CRD results are summarized in the attached figures and tables
  - The Ganges Harbour WWTP was more effective at reducing/removing contaminants than the Saanich Peninsula WWTP
    - Ganges – approximately 80% of the contaminants (211 of 266) had removal efficiencies >90% while only 2% of the monitored contaminants (5 of 266) had effluent concentrations higher than influent concentrations (i.e., contaminant reactivation during treatment)
    - Saanich Peninsula – approximately 45% of the monitored contaminants (145 of 324) had removal efficiencies >90% while approximately 10% of the monitored contaminants (32 of 324) had effluent concentrations higher than influent concentrations (i.e., contaminant reactivation during treatment)
  - Results confirm Environment Canada's findings that many contaminants are removed/reduced by treatment, some are increased by treatment, and some are not impacted by treatment

- Environmental and human health risk assessments associated with emerging contaminants in wastewaters are ongoing as different contaminants are identified/prioritized. So far, relatively few risks have been identified and these risks have been addressed through the application of water quality guidelines (WQG) or contaminant bans.
  - Currently, very few emerging substances WQG exist. Examples in Canada include:
    - The Province of BC has a WQG for the synthetic birth control chemical 17alpha-ethinylestradiol, but only for aquatic life in freshwater systems.
    - The Canadian Council for Ministers of the Environment is currently considering a Canadian WQG for the antiepileptic drug carbamazepine, but also only for aquatic life in freshwater systems.
    - Additional emerging substance WQG have yet to be developed in Canada as risk assessment is ongoing or wastewater contaminant levels have been well below known risk thresholds.
  - Other legacy and emerging substances have required higher level regulation or bans to protect the environment. Examples include:
    - The legacy PCB compounds, along with several chlorinated pesticides, were banned in Canada in 1970 after it was determined they were persistent, bioaccumulative and toxic
    - PBDEs were banned in Canada in 2010 for the same reasons.
    - Environment Canada is also currently undertaking an assessment of the material preservative and antimicrobial agent triclosan. Preliminary findings indicate it is being discharge to the environment at levels of concern. A regulatory decision in anticipated sometime Spring 2015.
  - Source control is also very important for removing some emerging contaminant concentrations in wastewaters.
    - For example, the CRD's Regional Source Control Program helps promote the Medications Return Program which promotes the proper disposal of unused and expired medications, thereby reducing their release to the environment.

- Additional technologies can be used to supplement primary and secondary treatment thereby enhancing effluent quality.
  - These technologies are typically termed tertiary treatment and are usually installed to address site-specific receiving environment needs

- These technologies are highly variable in design and include everything from wetlands to highly mechanised systems.
- Tertiary treatment processes typically improve effluent quality by:
  - Improving clarity to protect receiving environments and/or improve disinfection
  - Reducing nutrients to prevent eutrophication (i.e., over-fertilization) of receiving environments
  - Removing pathogens to protect human and aquatic life
  - Targeting specific contaminants of concern to protect aquatic life
- Some tertiary treatment technologies are showing promise for the reduction of emerging contaminants, but no single technology can eliminate all contaminants[1]


Removal Rates in Effluent at the Saanich Peninsula WWTP (Conventional Secondary Activated Sludge) (includes all detected parameters; n=324)
Frequency
250
200
150
100
50
0
4
1
27
42
8
12
5
11
15
11
43
145
-120%
-110%
-100%
10%
20%
30%
40%
50%
60%
70%
90%
100%
Removal Efficiency (100%=ND in effluent)

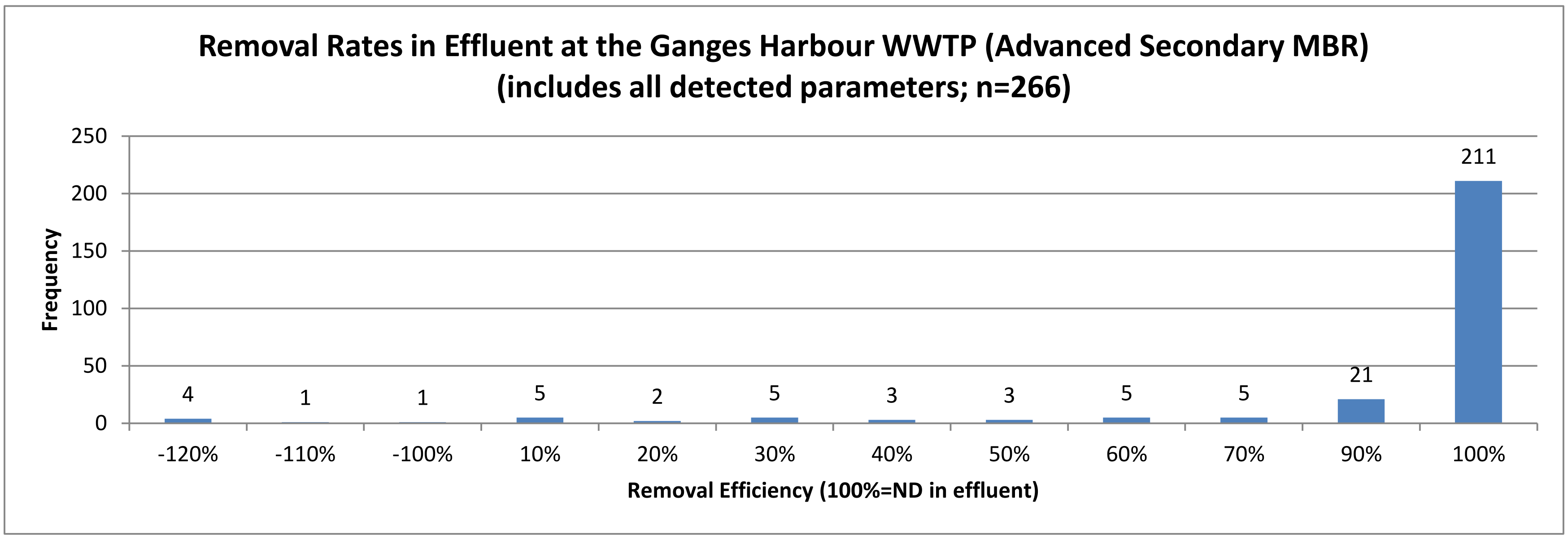

Removal Rates in Effluent at the Ganges Harbour WWTP (Advanced Secondary MBR) (includes all detected parameters; n=266)
Frequency
250
200
150
100
50
0
4
1
1
5
2
5
3
3
5
5
21
211
-120%
-110%
-100%
10%
20%
30%
40%
50%
60%
70%
90%
100%
Removal Efficiency (100%=ND in effluent)

Table 1 - Removal estimates for contaminants monitored in Saanich Peninsula wastewater. Pharmaceutical data represents samples collected approximately bi-weekly from 2011 to 2012. Conventional detection limit results represent the averages from samples collected quarterly in 2013. High resolution chemistry represents samples collected in January 2014 only.

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
1,7-Dimethylxanthine	13.9	1.31	91%
Acetaminophen	64.1	1.11	98%
Albuterol	0.0260	0.0245	6%
Caffeine	48.6	1.51	97%
Carbamazepine	0.293	0.362	-24%
Chlortetracycline	0.0191	0.0177	7%
Cimetidine	0.633	0.297	53%
Clarithromycin	0.430	0.446	-4%
Codeine	1.93	0.851	56%
Cotinine	0.820	0.399	51%
Diltiazem	0.731	0.453	38%
Doxycycline	0.655	0.152	77%
Erythromycin	3.28	1.57	52%
Fluoxetine	0.0588	0.0684	-16%
Gemfibrozil	0.349	0.127	64%
Ibuprofen	14.1	0.443	97%
Lincomycin	0.0222	0.0213	4%
Metformin	43.7	10.3	76%
Oxytetracycline	0.0347	0.0331	5%
Ranitidine	1.61	0.641	60%
Roxithromycin	0.00206	0.000305	85%
Sulfamethazine	0.0130	0.0117	10%
Sulfamethizole	0.0157	0.00838	47%
Sulfamethoxazole	1.04	0.429	59%
Sulfathiazole	0.0351	0.0303	14%
Tetracycline	0.900	0.361	60%
Triclosan	4.84	1.30	73%
Trimethoprim	0.213	0.242	-14%
Tylosin	0.000111	ND	100%
Warfarin	0.0257	0.0248	4%
SAD cyanide	0.0061	0.0122	-100%
WAD cyanide	0.0015	0.0014	6%
Oil & grease, mineral	3.4333	2.0000	42%
Oil & grease, total	19.2500	1.2000	94%
sulphate	23.9500	26.9500	-13%

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
sulfide	1.0968	0.0799	93%
temperature	14.3800	15.8800	-10%
TOC	71.9250	14.8100	79%
TSS	245.0000	8.8667	96%
Enterococci	8208333	22825	up to 100%
Fecal Coliforms	14691666	108133	99%
N - TKN (as N)	52.5500	4.1025	92%
N - NH3 (as N)	34.3364	1.3800	96%
N - NO2 (as N)	0.2276	1.4228	-525%
N - NO3 (as N)	0.2670	12.2825	-4500%
P - PO4 - ortho (as P)	4.6833	4.7400	-1%
P - PO4 - total (as P)	4.0517	3.5317	13%
P - PO4 - total (as P)	5.3058	3.8100	28%
aluminum	0.2096	0.0349	83%
antimony	0.0001	0.0002	-38%
arsenic	0.0003	0.0002	29%
barium	0.0135	0.0064	52%
cadmium	0.00014	0.00007	49%
calcium	17.6000	17.0000	3%
chloride	72.6667	62.6667	14%
chromium	0.0018	0.0006	66%
chromium VI	0.0024	0.0021	13%
cobalt	0.0003	0.0002	30%
copper	0.0712	0.0296	58%
iron	0.4162	0.0859	79%
lead	0.0023	0.0007	70%
magnesium	7.0450	6.7875	4%
manganese	0.0410	0.0319	22%
mercury	0.000010	0.000008	21%
molybdenum	0.0008	0.0008	3%
nickel	0.0039	0.0030	21%
potassium	15.6667	15.1250	3%
selenium	0.0003	0.0002	29%
silver	0.0002	0.0001	79%
thallium	0.0000043	0.0000040	8%
tin	0.0011	0.0053	-364%
zinc	0.0739	0.0404	45%
aluminum	0.0284	0.0168	41%

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
antimony	0.0002	0.0002	-22%
arsenic	0.0003	0.0002	19%
barium	0.0059	0.0055	6%
beryllium	0.00002	0.00002	0%
cadmium	0.00002	0.00005	-118%
calcium	15.1750	16.8667	-11%
chloride	72.0000	76.0000	-6%
chromium	0.0009	0.0005	41%
cobalt	0.0002	0.0002	3%
copper	0.0527	0.0219	58%
iron	0.2413	0.0612	75%
lead	0.0009	0.0005	43%
magnesium	6.5258	6.5692	-1%
manganese	0.0294	0.0271	8%
mercury	0.00001	0.00001	0%
molybdenum	0.0009	0.0008	11%
nickel	0.0031	0.0026	17%
potassium	14.9333	14.6500	2%
selenium	0.00020	0.00016	23%
silver	0.00023	0.00004	82%
thallium	0.0000054	0.0000040	26%
tin	0.0011	0.0007	37%
zinc	0.0188	0.0359	-91%
Methyl Mercury	0.0001	0.0001	0%
Monobutyltin	0.000006	0.000007	-22%
Monobutyltin Trichloride	0.000010	0.000012	-21%
total phenols	0.0689	0.0091	87%
phenol	0.0293	0.0031	89%
fluoranthene	0.00007	0.00001	85%
fluorene	0.00050	0.00002	97%
phenanthrene	0.00015	0.00003	80%
pyrene	0.00006	0.00001	78%
Total HMW-PAH's	0.00017	0.00002	86%
Total LMW-PAH's	0.00121	0.00024	80%
total PAHs	0.00122	0.00025	80%
bis(2-ethylhexyl)phthalate	0.0117	0.0050	57%
diethyl phthalate	0.0014	0.0003	82%
dichloromethane	0.0240	0.0021	91%

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
trichloromethane	0.0051	0.0016	69%
dimethyl ketone	0.0520	0.0150	71%
alpha-terpineol	0.0186	0.0050	73%
PCB-1	24.7000	12.4000	50%
PCB-2	12.7000	10.3000	19%
PCB-3	26.3000	10.2000	61%
PCB-4	23.1000	ND	up to 100%
PCB-6	25.3000	ND	up to 100%
PCB-7	6.7800	ND	up to 100%
PCB-8	76.8000	10.0000	87%
PCB-9	5.3100	ND	up to 100%
PCB-11	416.0000	89.7000	78%
PCB-12	14.8000	ND	up to 100%
PCB-15	39.7000	7.6700	81%
PCB-16	48.7000	7.3300	85%
PCB-17	45.9000	8.3000	82%
PCB-18	90.9000	13.9000	85%
PCB-19	13.3000	22.8000	-71%
PCB-20	188.0000	10.7000	94%
PCB-21	107.0000	9.4300	91%
PCB-22	68.3000	ND	up to 100%
PCB-24	ND	2.1100	-100%
PCB-25	11.5000	5.1400	55%
PCB-26	27.3000	ND	up to 100%
PCB-27	6.4000	ND	up to 100%
PCB-30	ND	21.0000	-100%
PCB-31	159.0000	5.9300	96%
PCB-32	31.6000	ND	up to 100%
PCB-34	ND	3.1400	-100%
PCB-35	17.3000	ND	up to 100%
PCB-36	3.9100	ND	up to 100%
PCB-37	38.0000	ND	up to 100%
PCB-38	ND	9.2100	-100%
PCB-40	88.5000	4.4400	95%
PCB-42	39.1000	25.4000	35%
PCB-43	4.9200	5.0300	-2%
PCB-44	234.0000	ND	up to 100%

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
PCB-45	35.7000	ND	up to 100%
PCB-46	9.6500	4.7000	51%
PCB-47	ND	10.4000	-100%
PCB-48	39.6000	2.6300	93%
PCB-49	100.0000	ND	up to 100%
PCB-50	20.5000	28.8000	-40%
PCB-52	281.0000	ND	up to 100%
PCB-54	ND	6.5200	-100%
PCB-55	2.9400	ND	up to 100%
PCB-56	68.3000	ND	up to 100%
PCB-57	ND	1.3800	-100%
PCB-58	ND	3.6000	-100%
PCB-59	13.3000	32.8000	-147%
PCB-60	45.1000	ND	up to 100%
PCB-61	378.0000	ND	up to 100%
PCB-62	ND	8.7100	-100%
PCB-63	7.2300	ND	up to 100%
PCB-64	72.7000	14.7000	80%
PCB-66	136.0000	ND	up to 100%
PCB-67	4.8600	ND	up to 100%
PCB-68	10.7000	ND	up to 100%
PCB-77	9.9000	ND	up to 100%
PCB-79	3.5600	ND	up to 100%
PCB-80	3.1500	ND	up to 100%
PCB-81	ND	18.8000	-100%
PCB-82	22.6000	5.4400	76%
PCB-83	165.0000	6.3200	96%
PCB-84	73.9000	21.2000	71%
PCB-85	43.6000	ND	up to 100%
PCB-86	181.0000	4.3400	98%
PCB-88	37.4000	29.5000	21%
PCB-90	300.0000	5.0300	98%
PCB-91	ND	25.6000	-100%
PCB-92	52.1000	ND	up to 100%
PCB-93	254.0000	ND	up to 100%
PCB-103	3.6900	7.1700	-94%
PCB-104	1.8600	ND	up to 100%
PCB-106	7.0400	ND	up to 100%

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
PCB-107	9.2400	ND	up to 100%
PCB-108	ND	24.7000	-100%
PCB-109	14.2000	ND	up to 100%
PCB-110	256.0000	ND	up to 100%
PCB-112	ND	1.1900	-100%
PCB-114	7.0300	ND	up to 100%
PCB-116	ND	15.7000	-100%
PCB-118	174.0000	ND	up to 100%
PCB-121	2.0300	ND	up to 100%
PCB-123	2.7300	ND	up to 100%
PCB-126	ND	3.8000	-100%
PCB-127	ND	22.1000	-100%
PCB-128	29.0000	ND	up to 100%
PCB-129	281.0000	ND	up to 100%
PCB-130	13.5000	5.1700	62%
PCB-131	3.4300	ND	up to 100%
PCB-132	65.9000	1.9500	97%
PCB-133	4.9200	6.7800	-38%
PCB-134	11.8000	3.3100	72%
PCB-135	79.4000	1.8800	98%
PCB-136	29.3000	ND	up to 100%
PCB-137	16.3000	ND	up to 100%
PCB-139	6.4000	3.6500	43%
PCB-141	38.9000	ND	up to 100%
PCB-144	10.9000	3.3200	70%
PCB-145	ND	13.2000	-100%
PCB-146	40.1000	ND	up to 100%
PCB-147	178.0000	ND	up to 100%
PCB-148	1.4700	ND	up to 100%
PCB-150	2.0900	ND	up to 100%
PCB-151	ND	24.3000	-100%
PCB-153	288.0000	1.6400	99%
PCB-154	ND	3.8400	-100%
PCB-155	18.3000	ND	up to 100%
PCB-156	40.2000	1.8500	95%
PCB-158	21.5000	ND	up to 100%
PCB-164	11.3000	ND	up to 100%
PCB-167	9.6000	ND	up to 100%

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
PCB-168	ND	2.7700	-100%
PCB-170	63.8000	ND	up to 100%
PCB-171	13.9000	ND	up to 100%
PCB-172	10.9000	4.1900	62%
PCB-174	35.1000	ND	up to 100%
PCB-175	3.1800	ND	up to 100%
PCB-176	7.6500	ND	up to 100%
PCB-177	24.3000	1.6900	93%
PCB-178	21.4000	13.3000	38%
PCB-179	21.6000	ND	up to 100%
PCB-180	185.0000	ND	up to 100%
PCB-181	ND	4.6500	-100%
PCB-182	ND	3.0400	-100%
PCB-183	39.3000	ND	up to 100%
PCB-184	34.5000	ND	up to 100%
PCB-185	ND	5.5100	-100%
PCB-187	89.2000	ND	up to 100%
PCB-189	2.8100	ND	up to 100%
PCB-190	11.3000	ND	up to 100%
PCB-191	1.8100	ND	up to 100%
PCB-194	35.7000	ND	up to 100%
PCB-195	11.4000	ND	up to 100%
PCB-196	14.4000	3.8700	73%
PCB-197	5.2000	ND	up to 100%
PCB-198	49.0000	ND	up to 100%
PCB-201	4.3100	ND	up to 100%
PCB-202	13.4000	ND	up to 100%
PCB-203	26.7000	ND	up to 100%
PCB-206	25.9000	ND	up to 100%
PCB-207	3.5400	2.7400	23%
PCB-208	9.1800	ND	up to 100%
PCB-209	13.7000	ND	up to 100%
4-Nonylphenols	1940.0000	206.0000	89%
4-Nonylphenol monoethoxylates	ND	98.2000	-100%
4-Nonylphenol diethoxylates	ND	27.6000	-100%
PBDE-8	8.9600	ND	up to 100%
PBDE-12	6.2800	ND	up to 100%
PBDE-15	71.8000	ND	up to 100%

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
PBDE-17	269.0000	39.5000	85%
PBDE-28	734.0000	56.2000	92%
PBDE-35	15.6000	ND	up to 100%
PBDE-37	11.7000	ND	up to 100%
PBDE-47	38000.0000	3200.0000	92%
PBDE-49	1020.0000	99.3000	90%
PBDE-51	122.0000	14.9000	88%
PBDE-66	668.0000	38.4000	94%
PBDE-71	139.0000	19.2000	86%
PBDE-75	61.0000	11.5000	81%
PBDE-79	65.2000	25.9000	60%
PBDE-85	1370.0000	119.0000	91%
PBDE-99	34900.0000	2920.0000	92%
PBDE-100	6930.0000	550.0000	92%
PBDE-119	125.0000	ND	up to 100%
PBDE-138	281.0000	ND	up to 100%
PBDE-140	99.1000	ND	up to 100%
PBDE-153	2790.0000	212.0000	92%
PBDE-154	2300.0000	197.0000	91%
PBDE-155	204.0000	ND	up to 100%
PBDE-183	471.0000	44.1000	91%
PBDE-203	1020.0000	ND	up to 100%
PBDE-206	8690.0000	ND	up to 100%
PBDE-207	18100.0000	550.0000	97%
PBDE-208	13800.0000	372.0000	97%
PBDE-209	131000.0000	2480.0000	98%
1,4-Dichlorobenzene	248.0000	34.2000	86%
1,2-Dichlorobenzene	3.9000	0.6120	84%
1,2,4-Trichlorobenzene	0.2680	ND	up to 100%
Pentachlorobenzene	0.1620	0.0960	41%
Hexachlorobutadiene	0.0710	0.0300	58%
Hexachlorobenzene	0.4490	0.2400	47%
HCH, alpha	0.0570	0.0560	2%
HCH, beta	0.2730	0.0820	70%
HCH, gamma	0.2380	0.1850	22%
Aldrin	0.0470	ND	up to 100%
Octachlorostyrene	ND	0.0110	-100%
Chlordane, oxy-	0.1290	ND	up to 100%

Sample Parameter	Influent Concentration mg/l	Effluent Concentration mg/l	% reduction
Chlordane, gamma (trans)	0.2550	ND	up to 100%
Chlordane, alpha (cis)	0.2700	ND	up to 100%
Nonachlor, trans-	0.2440	ND	up to 100%
Nonachlor, cis-	0.0660	ND	up to 100%
2,4'-DDD	5.0400	0.0730	99%
4,4'-DDD	0.2870	ND	up to 100%
2,4'-DDT	0.1340	ND	up to 100%
4,4'-DDT	0.3580	ND	up to 100%
HCH, delta	0.1660	ND	up to 100%
alpha-Endosulphan	0.7910	0.1850	77%
Endrin	0.6210	0.6820	-10%
beta-Endosulphan	0.3150	ND	up to 100%
Endrin Ketone	0.3010	ND	up to 100%
Furosemide	2900.0000	1140.0000	61%
Gemfibrozil	434.0000	41.7000	90%
Glyburide	14.8000	6.1800	58%
Hydrochlorothiazide	541.0000	258.0000	52%
2-Hydroxy-ibuprofen	83100.0000	ND	up to 100%
Ibuprofen	26900.0000	ND	up to 100%
Naproxen	10200.0000	92.1000	99%
Triclocarban	183.0000	23.5000	87%
Triclosan	770.0000	162.0000	79%
Warfarin	18.4000	11.2000	39%

Table 2 - Removal estimates for contaminants monitored in Ganges wastewater. Data represents samples collected in July 2014.

Sample Parameter	Unit	Influent Concentration	Effluent Concentration	% reduction
biochemical oxygen demand	mg/L	331	ND	up to 100%
chemical oxygen demand	mg/L	730	ND	up to 100%
carbonaceous biochemical oxygen demand	mg/L	274	ND	up to 100%
cyanide-SAD	mg/L	0.00328	0.00249	24%
cyanide-WAD	mg/L	0.002	0.00186	7%
oil & grease, total	mg/L	21	ND	up to 100%
oil & grease, mineral	mg/L	ND	ND	up to 100%
sulfide	mg/L	0.256	ND	up to 100%
temperature	°C	---	---	up to 100%
enterococci	CFU/100 mL	3300000	10	up to 100%
fecal coliforms	CFU/100 mL	14000000	ND	up to 100%
N - TKN (as N)	mg/L	37.1	0.257	99%
N - NH3 (as N)	mg/L	33	0.26	99%
P - PO4 - total (as P)	mg/L	5.61	0.138	98%
P - PO4 - total (as P)	mg/L	6.76	0.144	98%
P - PO4 - ortho (as P)	mg/L	4.12	ND	up to 100%
total organic carbon	mg/L	101	16.4	84%
total suspended solids	mg/L	314	ND	up to 100%
aluminum	mg/L	0.272	0.0251	91%
antimony	mg/L	0.000123	0.000259	-111%
arsenic	mg/L	0.000651	0.00027	59%
barium	mg/L	0.0144	0.00783	46%
cadmium	mg/L	0.000143	0.000104	27%
calcium	mg/L	14.5	13.8	5%
chromium	mg/L	0.00103	0.00038	63%
cobalt	mg/L	0.000395	0.000159	60%
copper	mg/L	0.103	0.00603	94%
iron	mg/L	0.93	0.0662	93%
lead	mg/L	0.00187	0.00031	83%
magnesium	mg/L	6.14	4.75	23%
manganese	mg/L	0.0699	0.0404	42%
mercury	mg/L	0.0000128	ND	up to 100%
molybdenum	mg/L	0.000679	0.000178	74%
nickel	mg/L	0.00345	0.000915	73%
potassium	mg/L	20.6	16.6	19%
selenium	mg/L	0.000222	0.000093	58%
silver	mg/L	0.000261	0.000021	92%
thallium	mg/L	0.000005	ND	up to 100%
tin	mg/L	0.00091	0.00031	66%
zinc	mg/L	0.0994	0.0483	51%
methyl mercury	mg/L	0.00000128	ND	up to 100%

Sample Parameter	Unit	Influent Concentration	Effluent Concentration	% reduction
monobutyltin	mg/L	0.000001	0.000002	-100%
monobutyltin trichloride	mg/L	0.000002	0.000003	-50%
total phenols	mg/L	0.097	0.0057	94%
phenol	mg/L	0.0025	0.0165	-560%
naphthalene	mg/L	0.00001	0.000033	-230%
phenanthrene	mg/L	0.000015	ND	up to 100%
total LMW-PAH's	mg/L	0.000015	ND	up to 100%
bis(2-ethylhexyl)phthalate	mg/L	0.005	0.0141	-182%
diethyl phthalate	mg/L	0.00025	0.00029	-16%
toluene	mg/L	0.01	ND	up to 100%
trichloromethane	mg/L	0.011	0.0012	89%
bromodichloromethane	mg/L	0.0011	ND	up to 100%
dimethyl ketone	mg/L	0.064	ND	up to 100%
methyl ethyl ketone	mg/L	0.01	ND	up to 100%
alpha-terpineol	mg/L	0.005	0.0153	-206%
HIGH RESOLUTION				
Nonylphenols				
4-Nonylphenols	ng/L	1690	213	87%
4-Nonylphenol monoethoxylates	ng/L	4790	ND	up to 100%
4-Nonylphenol diethoxylates	ng/L	2070	31.3	98%
PAHs				
Naphthalene	ng/L	35	4.19	88%
Acenaphthylene	ng/L	1.81	ND	up to 100%
Acenaphthene	ng/L	12.3	1.48	88%
Fluorene	ng/L	13.4	3.1	77%
Phenanthrene	ng/L	65.6	5.53	92%
Anthracene	ng/L	11.1	0.291	97%
Fluoranthene	ng/L	31.9	1.04	97%
Pyrene	ng/L	36.4	2.14	94%
Benz[a]anthracene	ng/L	10.1	ND	up to 100%
Chrysene	ng/L	15.1	0.398	97%
Benzo[b]fluoranthene	ng/L	7.76	ND	up to 100%
Benzo[j,k]fluoranthenes	ng/L	7.85	ND	up to 100%
Benzo[e]pyrene	ng/L	10.5	ND	up to 100%
Benzo[a]pyrene	ng/L	7.27	ND	up to 100%
Perylene	ng/L	3.81	ND	up to 100%
Indeno[1,2,3-cd]pyrene	ng/L	6.88	ND	up to 100%
Benzo[ghi]perylene	ng/L	14.8	ND	up to 100%
2-Methylnaphthalene	ng/L	15.2	1.79	88%
2,6-Dimethylnaphthalene	ng/L	8.44	ND	up to 100%
2,3,5-Trimethylnaphthalene	ng/L	12.1	0.589	95%
1-Methylphenanthrene	ng/L	13.4	ND	up to 100%
Dibenzothiophene	ng/L	11.1	0.821	93%
PBDEs				
PBDPE-7	pg/L	4.06	1.93	52%

Sample Parameter	Unit	Influent Concentration	Effluent Concentration	% reduction
PBDPE-8	pg/L	7.24	2.38	67%
PBDPE-12	pg/L	4.94	ND	up to 100%
PBDPE-15	pg/L	37.1	4.99	87%
PBDPE-17	pg/L	373	29.8	92%
PBDPE-28	pg/L	1110	36.2	97%
PBDPE-32	pg/L	3.22	ND	up to 100%
PBDPE-35	pg/L	7.7	ND	up to 100%
PBDPE-37	pg/L	20	19.1	4%
PBDPE-47	pg/L	48000	431	99%
PBDPE-49	pg/L	1320	28.3	98%
PBDPE-51	pg/L	217	7.1	97%
PBDPE-66	pg/L	1020	21	98%
PBDPE-71	pg/L	123	2.76	98%
PBDPE-75	pg/L	82.5	3.98	95%
PBDPE-85	pg/L	1480	8.47	99%
PBDPE-99	pg/L	39400	172	up to 100%
PBDPE-100	pg/L	7990	44.5	99%
PBDPE-119	pg/L	84.3	3.61	96%
PBDPE-126	pg/L	23	ND	up to 100%
PBDPE-138	pg/L	370	ND	up to 100%
PBDPE-140	pg/L	113	ND	up to 100%
PBDPE-153	pg/L	8470	10.6	up to 100%
PBDPE-154	pg/L	1980	11.2	99%
PBDPE-155	pg/L	229	ND	up to 100%
PBDPE-183	pg/L	478	9.17	98%
PBDPE-190	pg/L	61	ND	up to 100%
PBDPE-203	pg/L	420	34.6	92%
PBDPE-206	pg/L	3220	271	92%
PBDPE-207	pg/L	3270	220	93%
PBDPE-208	pg/L	1930	281	85%
PBDPE-209	pg/L	46700	4610	90%
PCBs				
Total Monochloro Biphenyls	pg/L	64.9	18.1	72%
Total Dichloro Biphenyls	pg/L	1970	127	94%
Total Trichloro Biphenyls	pg/L	1160	55.1	95%
Total Tetrachloro Biphenyls	pg/L	1410	54.5	96%
Total Pentachloro Biphenyls	pg/L	1300	38.3	97%
Total Hexachloro Biphenyls	pg/L	973	8.6	99%
Total Heptachloro Biphenyls	pg/L	421	3.68	99%
Total Octachloro Biphenyls	pg/L	106	ND	up to 100%
Total Nonachloro Biphenyls	pg/L	12.3	ND	up to 100%
Decachloro Biphenyl	pg/L	5.98	ND	up to 100%
TOTAL PCBs	pg/L	7420	305	96%
PCB-1	pg/L	9.9	5.29	47%
PCB-2	pg/L	9.44	3.69	61%

Sample Parameter	Unit	Influent Concentration	Effluent Concentration	% reduction
PCB-3	pg/L	45.6	9.11	80%
PCB-4	pg/L	15.6	ND	up to 100%
PCB-6	pg/L	16.6	ND	up to 100%
PCB-8	pg/L	50.7	4.81	91%
PCB-11	pg/L	1850	113	94%
PCB-15	pg/L	36.6	6.2	83%
PCB-16	pg/L	40.1	4.13	90%
PCB-17	pg/L	41.1	2.82	93%
PCB-18	pg/L	87.2	9.14	90%
PCB-19	pg/L	10	1.7	83%
PCB-20	pg/L	175	9.23	95%
PCB-21	pg/L	95.2	3.97	96%
PCB-22	pg/L	61.4	3.7	94%
PCB-25	pg/L	9.23	ND	up to 100%
PCB-26	pg/L	22.5	1.99	91%
PCB-27	pg/L	6.05	ND	up to 100%
PCB-31	pg/L	153	8.08	95%
PCB-32	pg/L	29.3	2.47	92%
PCB-35	pg/L	339	6.15	98%
PCB-36	pg/L	54.8	1.73	97%
PCB-37	pg/L	41.9	2.2	95%
PCB-40	pg/L	86.4	3.56	96%
PCB-42	pg/L	33.7	1.49	96%
PCB-43	pg/L	8.44	ND	up to 100%
PCB-44	pg/L	219	9.06	96%
PCB-45	pg/L	38	2.17	94%
PCB-46	pg/L	9.2	ND	up to 100%
PCB-48	pg/L	36.1	1.25	97%
PCB-49	pg/L	88.8	3.55	96%
PCB-50	pg/L	20.3	1.48	93%
PCB-52	pg/L	229	12	95%
PCB-56	pg/L	61.8	2.1	97%
PCB-59	pg/L	12.8	0.825	94%
PCB-60	pg/L	41.4	1.11	97%
PCB-61	pg/L	285	11	96%
PCB-63	pg/L	4.68	ND	up to 100%
PCB-64	pg/L	66.1	2.66	96%
PCB-66	pg/L	120	3.74	97%
PCB-67	pg/L	3.02	ND	up to 100%
PCB-68	pg/L	10.3	ND	up to 100%
PCB-77	pg/L	28.5	0.781	97%
PCB-78	pg/L	4.46	ND	up to 100%
PCB-79	pg/L	7.16	ND	up to 100%
PCB-82	pg/L	24.4	ND	up to 100%
PCB-83	pg/L	121	2.46	98%

Sample Parameter	Unit	Influent Concentration	Effluent Concentration	% reduction
PCB-84	pg/L	57.4	2.06	96%
PCB-85	pg/L	30.5	1.02	97%
PCB-86	pg/L	141	7.46	95%
PCB-88	pg/L	29.5	1.03	97%
PCB-89	pg/L	3.05	ND	up to 100%
PCB-90	pg/L	214	7.34	97%
PCB-92	pg/L	35.5	1.54	96%
PCB-93	pg/L	180	8.38	95%
PCB-96	pg/L	1.77	ND	up to 100%
PCB-103	pg/L	2.12	ND	up to 100%
PCB-104	pg/L	0.742	ND	up to 100%
PCB-105	pg/L	64.7	2.22	97%
PCB-107	pg/L	5.57	ND	up to 100%
PCB-109	pg/L	9.01	ND	up to 100%
PCB-110	pg/L	210	7.04	97%
PCB-114	pg/L	4.52	ND	up to 100%
PCB-118	pg/L	166	6.21	96%
PCB-123	pg/L	3.97	ND	up to 100%
PCB-128	pg/L	28	1.23	96%
PCB-129	pg/L	238	5.49	98%
PCB-130	pg/L	15.2	ND	up to 100%
PCB-131	pg/L	3.24	ND	up to 100%
PCB-132	pg/L	61.8	1.46	98%
PCB-133	pg/L	3.27	ND	up to 100%
PCB-134	pg/L	11.1	ND	up to 100%
PCB-135	pg/L	62.7	1.47	98%
PCB-136	pg/L	24.2	0.942	96%
PCB-137	pg/L	12.5	ND	up to 100%
PCB-139	pg/L	4.9	ND	up to 100%
PCB-141	pg/L	36.5	1.49	96%
PCB-144	pg/L	8.52	ND	up to 100%
PCB-146	pg/L	33.5	0.829	98%
PCB-147	pg/L	144	4.01	97%
PCB-148	pg/L	1.4	ND	up to 100%
PCB-150	pg/L	1.36	ND	up to 100%
PCB-153	pg/L	232	4.09	98%
PCB-155	pg/L	13.1	ND	up to 100%
PCB-156	pg/L	33.3	0.806	98%
PCB-158	pg/L	18.8	0.786	96%
PCB-164	pg/L	11.2	ND	up to 100%
PCB-167	pg/L	9.19	ND	up to 100%
PCB-170	pg/L	54.3	0.836	98%
PCB-171	pg/L	16.4	ND	up to 100%
PCB-172	pg/L	10.2	ND	up to 100%
PCB-174	pg/L	34.9	ND	up to 100%

Sample Parameter	Unit	Influent Concentration	Effluent Concentration	% reduction
PCB-175	pg/L	1.65	ND	up to 100%
PCB-176	pg/L	5.43	ND	up to 100%
PCB-177	pg/L	22.1	ND	up to 100%
PCB-178	pg/L	14.5	ND	up to 100%
PCB-179	pg/L	19.5	ND	up to 100%
PCB-180	pg/L	139	2.1	98%
PCB-183	pg/L	33.5	0.719	98%
PCB-184	pg/L	23.2	ND	up to 100%
PCB-187	pg/L	67.7	1.58	98%
PCB-189	pg/L	2.81	ND	up to 100%
PCB-190	pg/L	9.41	ND	up to 100%
PCB-191	pg/L	1.89	ND	up to 100%
PCB-194	pg/L	29.8	ND	up to 100%
PCB-195	pg/L	9.34	ND	up to 100%
PCB-196	pg/L	10.6	ND	up to 100%
PCB-197	pg/L	4.24	ND	up to 100%
PCB-198	pg/L	35.9	1.15	97%
PCB-201	pg/L	5.37	ND	up to 100%
PCB-202	pg/L	10.7	ND	up to 100%
PCB-203	pg/L	18.9	ND	up to 100%
PCB-206	pg/L	12.3	ND	up to 100%
PCB-208	pg/L	3.84	ND	up to 100%
PCB-209	pg/L	5.98	0.966	84%
OC Pesticides				
1,3-Dichlorobenzene	ng/L	50.6	3.8	92%
1,4-Dichlorobenzene	ng/L	656	62.4	90%
1,2-Dichlorobenzene	ng/L	4.06	0.837	79%
1,3,5-Trichlorobenzene	ng/L	0.245	ND	up to 100%
Pentachlorobenzene	ng/L	0.109	0.066	39%
HCH, alpha	ng/L	0.07	0.054	23%
HCH, beta	ng/L	0.244	0.155	36%
HCH, gamma	ng/L	0.238	0.176	26%
Chlordane, gamma (trans)	ng/L	0.384	ND	up to 100%
4,4'-DDD	ng/L	0.127	ND	up to 100%
4,4'-DDE	ng/L	1.02	ND	up to 100%
2,4'-DDT	ng/L	0.116	ND	up to 100%
4,4'-DDT	ng/L	0.337	ND	up to 100%
alpha-Endosulphan	ng/L	0.366	0.252	31%
Dieldrin	ng/L	0.592	0.129	78%
Endosulphan Sulphate	ng/L	0.238	ND	up to 100%
Methoxychlor	ng/L	0.337	ND	up to 100%
PPCPs				
Furosemide	ng/L	3430	211	94%
2-Hydroxy-ibuprofen	ng/L	41900	342	99%
Ibuprofen	ng/L	17200	137	99%

Sample Parameter	Unit	Influent Concentration	Effluent Concentration	% reduction
Triclocarban	ng/L	75.3	ND	up to 100%
Triclosan	ng/L	960	ND	up to 100%
Warfarin	ng/L	15.9	6.32	60%
Glyburide	ng/L	15.7	ND	up to 100%
Hydrochlorothiazide	ng/L	771	638	17%
Gemfibrozil	ng/L	37.3	ND	up to 100%
Naproxen	ng/L	16800	149	99%

Appendix E

Pump Station Cost Curves

Sewage Lift Stations

PIR Base Asset Code:

C2 Sewage Lift Stations <500 L/s

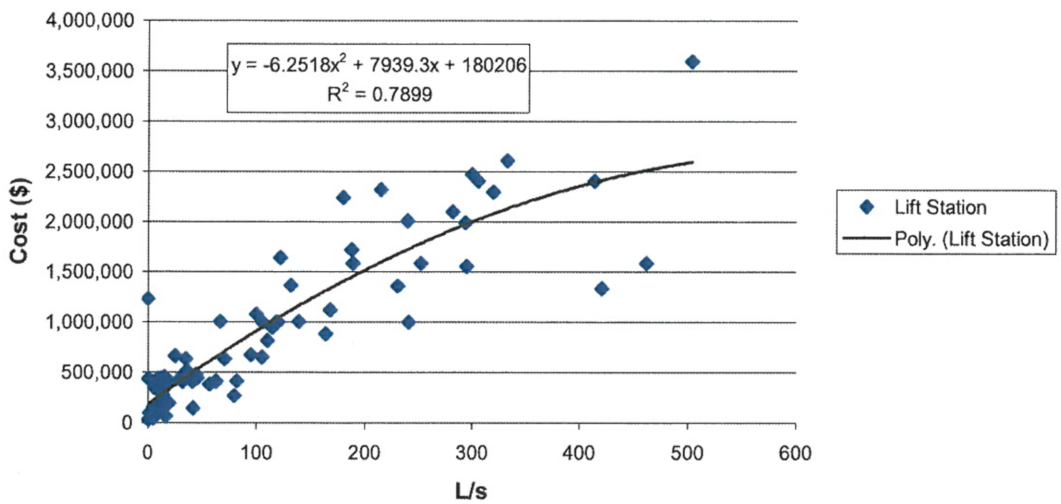
Capacity Measure:

Capacity of the wastewater pumps in L/s

Equation: <500 L/s $y = -6.2518x^2 + 7939.3x + 180206$

R^2: <500 L/s 0.7899

C2 Lift Station <500 L/s



Assumptions and Comments:

- Combined General Multiplier = 1.33 (to be added to base cost curve)
- Costs associated with this asset include the wastewater pumps, manhole structure and associated mechanical and electrical components
- Breakpoint identified at +/- 500 L/s

Sewage Lift Stations

PIR Base Asset Code:

C2 Sewage Lift Stations >500 L/s

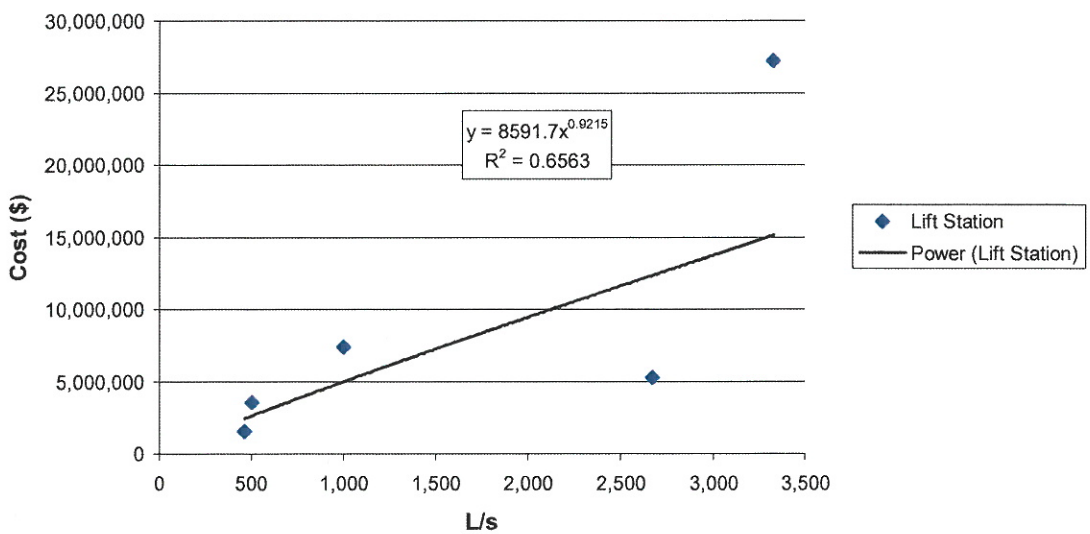
Capacity Measure:

Capacity of the wastewater pumps in L/s

Equation: >500 L/s $y = 8591.7x^{0.9215}$

R^2: >500 L/s 0.6563

C2 Lift Station >500 L/s



Assumptions and Comments:

- Combined General Multiplier = 1.33 (to be added to base cost curve)
- For additional comments see C2 < 500 L/s

Appendix F

Derivation of Labour Costs

Appendix F

Derivation of Labour Costs

Labour Type	2009 Annual Salary [(1)]	2015 Annual Salary [(2)]
Plant Manager	$ 140,000	$ 158,000
Chief Plant Operators	$ 120,000	$ 135,000
Chief Area Operator	$ 100,000	$ 113,000
Plant Operator	$ 80,000	$ 90,000
Labourer	$ 50,000	$ 56,000

[(1)] Stantec Option 1A, Appendix A, December 2009 (includes pension, overheads)

[(2)] CRD rate increase for WWTP operators averaged 2%/year for 2014 to 2016. Multiply by $1.02^6 = 1.126$