BC Water & Waste Association

2016 Student Design Competition

Project Statement

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BCWWA
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WHISTLER

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2016 BCWWA Student Design Competition

Resort Municipality of Whistler Wastewater Treatment Plant – Effluent Polishing Options

1.0 Project Statement

Students interested in entering the 2016 BC Water & Waste Association (BCWWA) Student Design Competition (SDC) are encouraged to form teams to:

Design a tertiary treatment system for the wastewater treatment plant serving the Resort Municipality of Whistler that will ensure compliance with permitted phosphorus discharge limits to the Cheakamus River. In addition, provide treatment options that consider natural treatment systems, physical-chemical systems or combinations of these. Evaluate these options using quantitative and qualitative criteria and present your recommended approach with justification.

2.0 Background

According to the 2011 Census conducted by Statistics Canada, the Resort Municipality of Whistler (RMOW) had a permanent resident population of 9,824 living in approximately 3,900 private dwellings. However, as a tourist destination the actual population is generally much higher and can be measured using the concept of Bed Units and their associated occupancy levels. The concept of Bed Units is described in the RMOW's 1993 Official Community Plan. The number of Bed Units developed as of 2013 was 53,746, with a potential build-out capacity of 61,285 Bed Units. Complete occupancy of 55,935 Bed Units was used to calculate design flows of the existing wastewater treatment plant (WWTP).

In Whistler, treated wastewater is discharged to the Cheakamus River which flows south, joining the Squamish River, and ultimately flowing to the head of Howe Sound. Before reaching the Squamish River, the Cheakamus is dammed for hydroelectric generation and forms the Daisy Lake Reservoir.

The WWTP discharge limits were developed to protect the aquatic habitat of the Cheakamus River and the downstream environment from the harmful effects of wastewater effluent. In particular, phosphorus limits are imposed to reduce the potential for eutrophication events.

2.1. Treatment Process Overview

Raw sewage is collected by gravity sewers and conveyed to the WWTP near the Cheakamus Crossing neighborhood. The influent pump station lifts raw sewage to the plant headworks which provides preliminary treatment by screening and grit removal. Influent flow is measured by Parshall flumes located downstream of grit removal. Primary treatment is performed by up to four rectangular sedimentation basins. Each basin is sufficiently large such that, at current average flows, adequate treatment is achieved with only two basins in service. The influent pump station, headworks and primary clarifiers are enclosed structures and foul air from these is directed to a bio-trickling filter tower for odour control.

Secondary treatment involves two parallel bioreactors, each sized to treat a flow of 10,000 m^3/d. These bioreactors are designed to remove both organics and nutrients (nitrogen and phosphorus) using the Modified Johannesburg Process configuration. This configuration consists of a series of four consecutive zones: anoxic, anaerobic, anoxic, and aerobic. It also includes equipment for mixing and internal recycling. Air is supplied to the aerobic zones via blowers and a grid of fine bubble diffusers.

Mixed liquor from the bioreactors flows to one of four secondary clarifiers for solid-liquid separation via a flow splitter box. Settled solids form the return activated sludge (RAS) are recycled to a splitter box before the first anoxic zone of the bioreactors.

Accumulated solids are removed from the system via surface wasting of mixed liquor from the bioreactors and referred to as waste activated sludge (WAS). The WAS is thickened by dissolved air flotation (DAF) after polymer addition. Thickened WAS is then combined with primary settled solids and additional polymer to be dewatered by centrifugation. The dewatered solids are then transported to a composting facility off-site by truck. Some centrate flows to the headworks during dewatering, with the balance of centrate stored in a tank and fed back to the headworks over an approximate 24 hour period, to help with low influent wastewater flow periods, and smooth out nutrient loading during peak flows. There are four circular secondary clarifiers, two large 22.5 m diameter tanks and two smaller 16 m diameter tanks. The two smaller tanks have the combined capacity of a single larger tank. The number and combination of secondary clarifiers in service at any time depends on the total flow. Secondary effluent then flows to the outfall for discharge to the river. During the summer months, the secondary effluent is disinfected by ultraviolet radiation prior to discharge. No disinfection occurs during winter months.

Biological phosphorus removal is enhanced by the introduction of a readily available source of organic carbon to the anaerobic zone. Typically, acetic acid and propionic acid serve this function and are referred to as volatile fatty acids (VFAs). Acetic acid may be purchased as a bulk chemical or VFAs may be produced on-site via fermentation of primary solids. The Whistler WWTP is equipped with a fermenter designed to generate VFAs and pump the VFA rich fermenter supernatant to the anaerobic zone.

In addition to biological phosphorus removal, chemical precipitation using alum is available to ensure compliance with discharge limits. The periodic use of alum is referred to as alum trim dosing and is triggered by the measurement of orthophosphate in the secondary clarified effluent above a pre-set concentration using an online measurement system. Bulk alum is stored on-site in two 20 m^3 volume tanks and dosed to the mixed liquor in the flow splitter box upstream of the secondary clarifiers. Alum reacts with phosphorus to produce insoluble aluminium phosphate along with a larger amount of aluminum hydroxide, a gelatinous sludge. The use of alum has the undesirable impact of producing additional sludge for disposal with less biologically available phosphorus in the final compost. Excessive alum sludge in the RAS may also upset the bioreactor. One of the main drivers for this project is the elimination or reduction of reliance on alum for phosphorus removal.

2.2 Parameters Used for Existing Treatment Plant Design

The following information was provided by the RMOW from documentation prepared by engineering consultants involved in design of the existing plant.

2.2.1 Influent Flows

The design flows used for the existing plant are summarized in Table I. Peak hour flow was used to calculate the peak hydraulic loading to the plant. Maximum month flow was used for process design.

Table 1: Design Flows

Flow	Value
Total Occupied Bed Units	55,935
2016 Annual Average Flow (m^3/d)	14,700
2016 Maximum Month Flow (m^3/d)	20,000
2016 Peak Hour Flow (m^3/d)	53,600
TSS load (kg/d)	6,153
BOD load (kg/d)	6,647
Total P load (kg/d)	145

2.2.2 Influent Criteria

The influent parameters used for process design are summarized in Table 2.

Table 2: Influent Parameters

Parameter	Concentration (mg/L)	Average Daily Load (kg/d)	Max Monthly Loading (kg/d)
cBOD	290	4,263	5,800
TSS	290	4,263	5,800
TKN	40	588	800
NH_3-N	25	367	500
TP	7	103	140
Flow (m^3/d)	-	14,700	20,000

2.2.3 Effluent Criteria

The effluent quality requirements are summarized in Table 3 and are taken from the WWTP's Operational Certificate ME 12215.

Table 3: Effluent Quality Requirements

Parameter	Permit Limit (never to exceed)
cBOD	30 mg/L
TSS	40 mg/L
Orthophosphate concentration (as P)	1.75 mg/L
Orthophosphate Load (as P)	36.6 kg/month (May 15 to September 15)
96 hour LC_{50} (Fish Bioassay)	100% effluent strength

2.3. Existing Facility

The layout of the current WWTP can be seen in the aerial view shown in Figure 1.

Figure 1: Aerial view of the RMOW WWTP

Available space for the additional treatment system includes the open area between the UV disinfection building and the Administration/Lab Building (approx. 20 m x 25 m) and the strip of land along the perimeter fence (approx. 125 m x 10 m). Refer to Figure 2 for location of available space at existing facility. Some space is also available adjacent the primary clarifiers (approx. 20 m x 20 m).

Figure 2: Approximate Area Available at Existing WWTP (in yellow)

2.4 Orthophosphate Loading Limit

While phosphorus in wastewater exists in multiple forms, it is only orthophosphate (i.e. PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$, and H_3PO_4) that is specified in the discharge limits for Whistler. Wastewater concentrations and loads of orthophosphate are typically expressed in units of elemental phosphorus (as P). Whistler's effluent concentration limit of orthophosphate (1.75 mg/L as P) applies year round. However, an additional limit is imposed during the warm months from May 15th to September 15th, whereby the maximum monthly load must not exceed 36.6 kg as P/month.

The existing plant is an enhanced biological phosphorus removal (EBPR) plant and has the capability to comply with the year-round effluent concentration limit without alum dose trimming. During the summer months and under average flows, the plant must operate near the technological limit of a typical EBPR plant (~0.1 mg/L as P). Any process upset during the summer may thus result in exceeding the monthly orthophosphate load permitted to the river. The provision for alum dose trimming as a polishing step is intended to ensure compliance with challenging summer loading limits and is a technique often practiced at similar EBPR plants elsewhere. Alum may also be used to reduce phosphorus levels in effluent during other times of the year when needed.

2.5 Environmental Stewardship and Sustainability

Protection of the environment has been identified as one of the priorities of the Whistler strategic plan for sustainability. This involves adoption of the Precautionary Principle and a vision in which:

> "*Whistler's water provision and discharge practices and infrastructure emulate natural systems, not drawing more water than nature is able to provide. Volumes of effluent discharged into the Cheakamus River are lower than they were in the past, and the wastewater is clean and readily assimilated without disturbing aquatic habitat or downstream water uses."*
> *(Whistler 2020: Moving Toward a Sustainable Future, 2nd edition)*

In practice, this vision involves the goals of:

1. Reducing orthophosphate loading to as low a level as is feasible;
2. Eliminating or reducing the use of chemical treatment; and
3. Utilizing natural treatment systems as a tertiary polishing step if feasible.

Natural treatment systems are interpreted here as processes that involve living matter, unassisted by mechanical or chemical means, to achieve treatment. Treatment occurs in a "reactor" containing an ecosystem and involves not only the physical, chemical and biological processes occurring in conventional wastewater treatment, but also such processes as photosynthesis and uptake by vegetation. An example of a natural treatment system is a constructed wetland.

3.0 Objectives

Design a tertiary treatment facility for the wastewater treatment plant serving the RMOW that will ensure compliance with permitted phosphorus discharge limits to the Cheakamus River. In addition, identify and describe the best available treatment options that use natural treatment systems, physical-chemical systems, or combinations of these. Evaluate these options using quantitative and qualitative criteria and present your recommended approach with justification.

3.1 Design Considerations and Scope of Work

The following criteria and important considerations are provided:

i. One or more years of influent flow and quality data;

ii. More detailed information on available footprint area;

iii. The most recent Cheakamus River Study;

iv. Assume the existing plant is capable of achieving an effluent orthophosphate concentration of 1.0 mg/L as P without the use of alum;

v. Assume alum is received as a 48% w/v solution of $Al_2(SO_4)_3 \cdot 14\ H_2O$, and $0.394 per litre is the cost including delivery;

vi. Assume an Al/P mole ratio of 3.5 is required to reduce the orthophosphate concentration from 1.0 to 0.1 mg/L as P by chemical precipitation with alum;

vii. Assume the alkalinity of the bioreactor effluent (i.e. mixed liquor) to be 100mg/L as $CaCO_3$;

viii. Assume the cost of electrical energy is $0.11 per KWh;

ix. Cost of sludge disposal is $120 per metric tonne, $105 per truckload;

x. Assume an operating design life of 25 years for tertiary treatment system;

xi. Interest rate, depreciation rate, and other economic parameters will be provided;

xii. Hydraulic profile of existing plant will be provided;

xiii. The location of existing pipes running through the available area will be provided;

xiv. If pipe relocation is required, the cost of the relocation is to be included in the cost analysis. Alternatively, any new process can be specifically sited to allow periodic access to these pipes, or designed to be removable;

xv. Personnel of existing WWTP comprises a staff of seven members, including one supervisor, two level-1 operators, one level-2 operator, two level-3 operators, one level-4 operator (infrastructure lead), and one millwright;

xvi. A site visit will be conducted, which must be attended by at least one member of each team to maintain competition eligibility of a team.

The scope of work includes, but is not limited to the following:

i. Research and report on key governing regulations and guidelines regarding effluent quality and environmental impact;

ii. Identify potential methods other than tertiary treatment for reducing the orthophosphate load to the Cheakamus River from Whistler;

iii. Evaluate the natural treatment and physical-chemical processes capable of reducing the orthophosphate concentration to below 0.1 mg/L as P from secondary clarified effluent;

iv. Determine the land requirements for each process alternative, identify which can be accommodated by the available footprint, and comment on expansion capability;

v. Estimate the lifecycle costs of each process alternative and compare this to the existing chemical P removal system (i.e. alum trim dosing);

vi. Evaluate and score each process alternative, as well as the current chemical system using alum, according to "benefits" related to ecological, social, economic, and technical criteria, giving equal weight to each category. Technical criteria may include factors such as process reliability and performance, system complexity, compatibility with existing facility, impact on disinfection, and required level of operator skill. Refer to the goals and vision identified in *Whistler 2020* for guidance with other criteria;

vii. Recommend the preferred alternative tertiary treatment option and perform a conceptual design, including a process description, process flow diagram, equipment list with sizing, site layout, hydraulic profile, by-pass structure (if any), chemical feed system (if any), solids balance and shipping requirements, energy and labour requirements.

3.2 Deliverables

i. Progress Report;

ii. Design Notebook (Formatted according to the Competition Guidelines). Containing the following:

1. Summary of important governing regulations and guidelines;
2. Basis for Design:
    - Summary of existing permit requirements and most recent Cheakamus River Study findings;
    - Review of historical effluent data (discharge flows and quality);
    - Development of viable effluent polishing options.
3. Recommendation of preferred solution:
    - Cost Estimates;
    - Evaluation of non-financial indicators;
    - Decision matrix for options.
4. Conceptual design of preferred solution:
    - Process description;
    - Process flow diagram;
    - Process control narrative;
    - Equipment list (complete with sizing);
    - Site layout;
    - Hydraulic profile;
    - By-pass structure (if any);
    - Solids balance and shipping requirements;
    - Energy and labour requirements.

iii. Oral Presentation.

3.3. Supporting Information

1. 2016 BCWWA Competition Guidelines
2. WWTP site maps
3. WWTP hydraulic profile
4. Discharge permit (Ministry of Environment)
5. Flow and Water Quality data
6. Most recent Cheakamus River Study
7. Liquid Waste Management Plan
8. Whistler's Official Community Plan of 1993
9. Whistler 2020: Moving Toward A Sustainable Future, 2nd edition

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