Duffin Creek Water Pollution Control Plant

Technically Speaking

An Overview

DURHAM REGION

York Region

What we do

The prudent handling of wastewater is a highly sophisticated process. Think of it as a complex engineering system of tanks, pipes, specialized equipment and facilities covering the equivalent of 400 football fields. It is a massive operation with a vital job. Serving York and Durham Regions, the Plant treats wastewater from homes, businesses and industry. Once treated, the clear water is returned to Lake Ontario. Let's drill down on the process and technology behind this impressive Plant.

An overview

From the archives

The Plant's history goes back to the 1960s when Ontario faced declining quality in the rivers and streams in the Greater Toronto Area (GTA). Couple this with a growing population and a booming economy and the challenge was clear. Invest in a major, central facility to serve the Regions and meet the requirements of the Canada-U.S. Great Lakes Water Quality Agreement. Since 1969 when the Plant opened, all levels of government have invested $850 million to meet the area's service requirements while protecting the environment.

In 1997, the Plant's ownership was transferred from the province, to the Regional Municipalities of Durham and York.

Today the Plant is operated jointly by Durham and York Regions, with environmental sustainability and innovation top of mind. The Plant holds ISO 14001 certification and is classified a Class 4 conventional activated sludge treatment plant, under the auspices of the Ministry of the Environment, Conservation and Parks (MECP).

Strict compliance

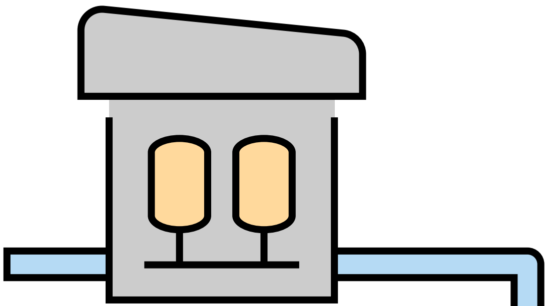
Simply put, wastewater flows into the Plant and solid materials, nutrients and bacteria must be removed from the wastewater. The Ministry sets limits on the amount and types of substances in the clear water, known as effluent, released into Lake Ontario. These limits are known as Environmental Compliance Approvals and they are enforced and monitored. The Plant has consistently achieved or exceeded these stringent requirements.

A multi-pronged approach

Making sure the effluent released is safe is a complex undertaking. The treatment process at the Plant consists of seven stages using physical, chemical and biological mechanisms to remove contaminants. They are influent works (essentially pumping raw sewage into the Plant), screening and grit removal, primary treatment, secondary treatment, disinfection and discharge. Biological solids captured during the process are removed and receive further treatment.

There are three different mechanisms for removal: physical, biological and chemical. Physical removal involves gravity and a mechanical unit to actively remove the waste material. Chemical removal involves a reaction between two substances to form solid particles that are able to settle out of the water. Biological removal involves living bacterial organisms that break down or consume organic waste from the wastewater.

Seven steps to clear discharge

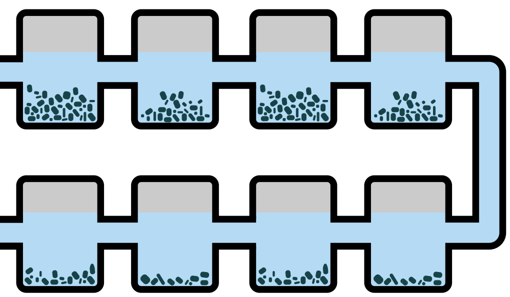


1 Influent works

The wastewater (raw sewage) enters one of the two influent pumping stations where 16 pumps direct the wastewater to the preliminary treatment stage. Wastewater flows by gravity through the remaining stages of treatment.

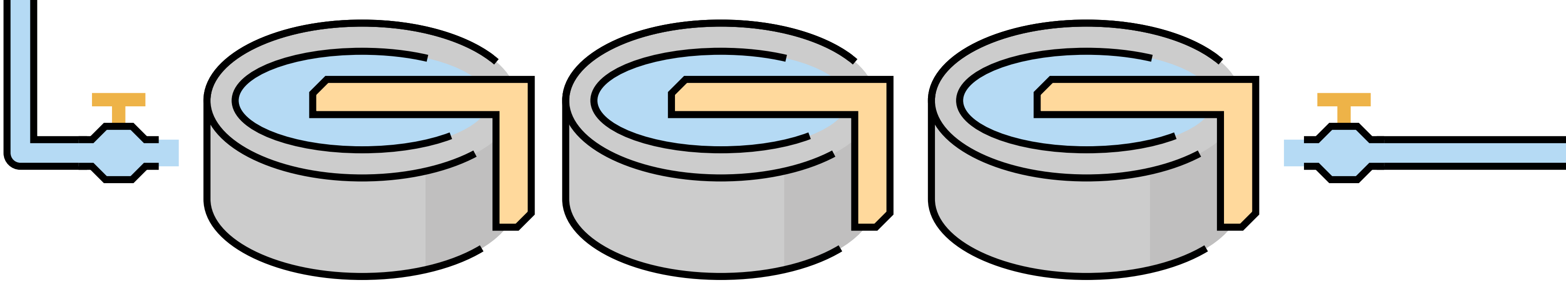
2 Preliminary treatment

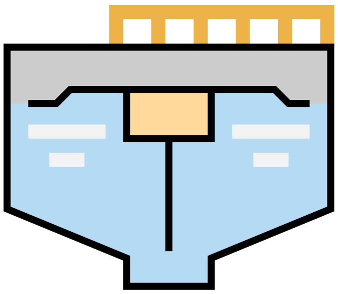
Preliminary treatment removes large solid materials from the wastewater using mechanical bar screens and grit tanks. Large materials or screenings are removed from the influent by 12 bar screens that are both mechanically and manually cleaned. Eight grit tanks slow the flow of influent to allow solids to settle out. Heavy suspended material such as sand and gravel settle to the bottom of the tank, where they are collected and dewatered through grit clarifiers.



3 Primary treatment (clarifiers)

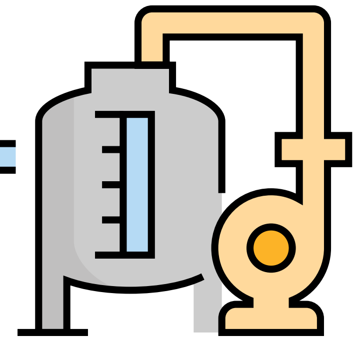
Any remaining solids from the preliminary phase settle by gravity in 14 large settling tanks. A slow-moving travelling bridge mechanism scrapes the bottom and pushes the settled sludge into hoppers before it is pumped into either anaerobic digester tanks or to sludge-blending tanks. Lighter particles such as fat, oil and grease float to the surface as scum, where they are collected and directed to digester tanks. Primary treatment removes approximately 60 per cent of suspended solids and 30 per cent of the biochemical oxygen demand (BOD) in the wastewater.





5 Disinfection

To kill pathogenic microorganisms in the final effluent, chlorine in the form of liquid sodium hypochlorite, is added. Due to the toxicity of chlorine, sodium bisulphite is added to neutralize chlorine before it enters Lake Ontario. Too much chlorine in the effluent is toxic to aquatic life so its use is carefully monitored.



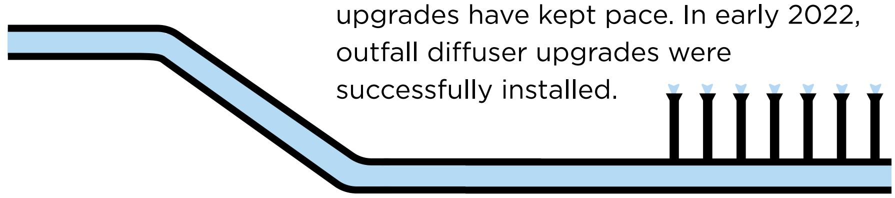
4 Secondary Clarification

Here small organic material and nutrients are removed by pumping air into wastewater to promote the growth of bacteria. The process involves 14 aeration tanks, each containing anoxic and aerobic zones. Each tank is rich with microorganisms that break down and consume organic material. Each aeration tank contains an anoxic zone where no air has been added; this allows for denitrification to occur. The tank containing the aerobic zone is where air is diffused into the water and facilitates nitrification and the final breakdown of organic material.

Following aeration, broken down organic matter and microorganisms are directed to 22 secondary clarifiers where final settling of sludge occurs. The settled material is called activated sludge. The majority of the activated sludge is pumped back to the head of the aeration process to be reused and is referred to as return activated sludge. The remaining portion is referred to as waste activated sludge and is pumped to the primary clarifiers where it will thicken with raw sludge before it is pumped to anaerobic digesters or sludge blending tanks.

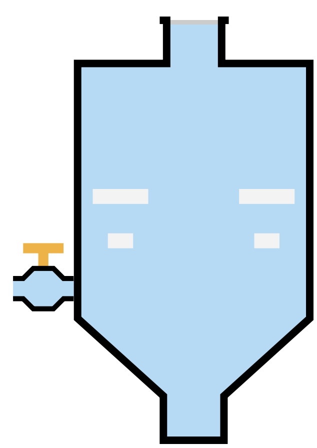
6 Discharge

The final step delivers clear treated water safely back into Lake Ontario through an outfall pipe, 3 metres in diameter and 1.1 kilometre long. The pipe runs 30 metres below the surface and is equipped with 63 diffuser ports. This allows for an even distribution of water into the lake with minimal disruption to the natural environment. As the Plant processes increased wastewater flows, diffuser upgrades have kept pace. In early 2022, outfall diffuser upgrades were successfully installed.



7 Solids treatment

Biosolids or sludge is a product of the wastewater treatment process. Sludge produced at the Plant is dewatered and burned in the Plant's incinerators as fuel, producing steam that's used to offset energy consumption and the Plant's heating requirements.



Definition of terms

Influent is the incoming wastewater that is untreated and contaminated.

Effluent is the clear treated water released into a body of water after rigorous processing at a wastewater treatment plant.

Polymer:
A substance that has a molecular structure consisting of a large number of similar units bonded together.

Hopper:
A tapered container that collects waste and is able to discharge its contents.

Phosphorus:
Found naturally in the environment, phosporous is also found in animal and human waste, rotting plants and in common household products. Higher levels in rivers and lakes come from water run off from farms and urban areas (stormwater), discharge from septic systems, and wastewater treatment plants.

The Plant uses technology to ensure the clear treated water released into Lake Ontario achieves or betters regulatory requirements.

Enhanced phosphorus removal
Ferric chloride is used in the treatment process to help remove phosphorus and suspended solids. This chemical reacts with phosphorus to form phosphate precipitates which can be settled out of the wastewater in the secondary clarifiers. Polymers can also be used by increasing the settlement of suspended solids.

Denitrification is the process of converting nitrates to inactive nitrogen gas in wastewater treatment.

Anoxic zone is an area where no air has been added into the wastewater.

Aerobic zone is an area where air has been diffused into the water.

Dewatering:
The Plant uses eight dewatering solid bowl centrifuges to separate solids from liquid waste to create semi-solid sludge or a sludge cake. This process increases the solids content of sludge from approximately two per cent to 25 per cent. The dewatered sludge cake is incinerated.

The Plant's dewatering facility holds a **LEED (Leadership in Energy and Environmental Design)** Certification award – an international symbol of sustainability and green building leadership.

Incineration:
These facilities consist of four fluidized bed reactors where the sludge cake is combusted info ash and flue gas. Each reactor has three main zones: a windbox, a sand bed and a freeboard.

The windbox provides sufficient air to fluidize the sand bed and begin the mixing process. Sand is used to break up the sludge cake into smaller pieces to ensure an efficient process. Think of this as a powerful sand storm that pulverizes the sludge cake.

The third part of the reactor, the freeboard, is located at the top of the reactor. This zone eliminates process odours and contaminants in a final combustion process when water vapour and combustion by-products are destroyed. The inert material left over from burning biosolids is ash.

Gases emitted from the reactor's freeboard enters the waste heat boiler where heat is recovered for various purposes. Gases then enter a wet scrubber where solid and liquid particles are removed, while the solvent polymer composite unit (SPC) further reduces mercury concentrations in emissions.

Fast Fact:
The Plant has a current rated capacity of 630,000 m^3/day.

Did you know?
Certain types of bacteria work naturally to clean water by consuming and breaking down organic waste into smaller, less harmful substances. The Plant uses this same mechanism of removal, but on a much larger scale.

Treatment efficiency

The Duffin Creek Plant meets or surpasses effluent quality standards with over 90 per cent treatment efficiency for the removal of wastewater contaminants.

	Raw Wastewater*	Treated Effluent*	ECA Limit	Percent Removed
Total Phosphorus (TP) mg/L	6.3	0.28	0.8	96%
Total Suspended Solids (TSS) mg/L	315	5.3	25.0	98%
Biochemical Oxygen Demand (BOD^5) mg/L	204	3.4	25.0	98%
Total Ammonia Nitrogen (TAN) Summer mg/L	29.9	0.49	6.0	98%
Total Ammonia Nitrogen (TAN) Winter mg/L	30.3	0.34	10.0	98%
Escherichia Coliform Sampling (Geometric Mean Density)	N/A	30	200	99%

Values are representative of the 2021 MECP Annual Plant Performance Report and are subject to change.

Total Phosphorus:
All forms of phosphorus in wastewater (both solid and dissolved particles). Total phosphorus is used as an indicator of water quality and plant performance.

Total Suspended Solids:
The amount of material suspended in a water sample. Total Suspended Solids is used as an indicator of water quality and plant performance.

Biochemical Oxygen Demand (BOD^5):
A measure of the amount of oxygen that is used by living organisms in wastewater to breakdown organic matter over a period of five days. When BOD^5 levels are high, dissolved oxygen in the water decreases; creating a difficult environment for fish and other aquatic organisms to survive.

Total Ammonia Nitrogen (Summer/Winter):
In wastewater, ammonia exists in two forms: NH_3 (unionized ammonia) and NH_4^+ (ionized ammonia). Ammonia will promote excess algae growth if discharged into Lake Ontario. High levels of unionized ammonia is toxic to aquatic life.

Escherichia Coliform (*E.coli*) Sampling:
A type of bacteria commonly found in wastewater at high concentrations. *E.coli* is removed from wastewater to keep the lake ecologically safe.

Meeting or bettering environmental standards

Treated water discharged to Lake Ontario must meet the environmental protection requirements determined by the Ministry of the Environment, Conservation and Parks (MECP) and Fisheries and Oceans Canada. Legislation includes the Ontario Water Resources Act, Environmental Protection Act and the Wastewater System Effluent Regulations under the federal government's Fisheries Act.

The MECP issues Environmental Compliance Approvals which set the limits of substances allowed into Lake Ontario and the atmosphere. With new atmospheric sulfur dioxide limits coming into effect, the Plant is preparing to meet or bettering those limits. Both Regions are committed to maintaining the mandated policy of zero bypass discharges into Lake Ontario.

Smart upgrades garner energy savings

After undertaking an Environmental Study Report, findings targeted reducing Soluble Reactive Phosphorus (SRP) in the Plant's effluent. This will be achieved through optimizing the chemically enhanced Phosphorus removal in the secondary treatment process.

Linear motion mixers will be installed on each primary digester used in the anaerobic digestion process. Linear motion mixers pulsate up and down at high speed to produce a nearly uniform mixing. The benefits of this innovative technology include quick installation on an existing structure, and a complete and thorough mixing of the material. There's also an impressive energy savings of 33 per cent overall, as compared to the existing technology.

Duffin Creek continues to be vigilant when it comes to cybersecurity and software solutions. The facility also contracts specialized service providers who assist in troubleshooting and the timely diagnosis of issues. By working remotely, these providers enable the Plant to respond quickly to maintenance or operational issues. Recent initiatives include operational dashboards and a data management program that assists with monitoring, reporting and data analysis.

With the capacity to be Ontario's second largest wastewater plant, asset management and refurbishment are critical.

While the Plant maintains high standards and performance metrics, innovation remains a top priority. The Regions' focus on sustainability and environmental protection drive the Plant's operating efficiencies.

Interestingly, the ash left over from burning biosolids, contains in-demand properties used in manufacturing of cement. The Plant recycles the ash to St. Marys Cement, a local manufacturing company serving the Great Lakes Region. Recycling the ash also lessens the need for this company to source the materials from the natural environment.

It's a win-win for all.

Duffin Creek Plant Specifications

Liquid Process

Stage 1 and 2 Average Design Capacity — 330 MLD*

Stage 3 Average Design Capacity — 300 MLD*

Influent Pumping Station
16 Submersible Pumps
Capacity of each: 180,835 m^3/day
Total Capacity: 1,446,682 m^3/day

Screening and grit removal
Eight Hydraulically Activated Bar Screens, 2.1 m long with 12 mm bar spaces and four Manual Bar Screens
Eight Aerated Grit Tanks: each 17 m x 7 m x 4.5 m

Primary sedimentation
Stage 1 & 2
Eight Tanks:
each 64 m x 24.5 m x 3.6 m
Volume: each 5,644.80 m^3
Surface Overflow Rate:
28.95 m^3/day/m^2
Hydraulic Retention Time**: 2.98 h
Total Volume: 45,158.4 m3
Stage 3
Six Tanks:
each 65 m x 24 m x 3.7 m
Volume: each 5,772 m^3
Surface Overflow Rate:
33.12 m^3/day/m^2
Hydraulic Retention Time**: 2.68 h
Total Volume: 34,632 m^3

Aeration — fine bubble air diffusion
Stage 1 & 2
Eight Tanks:
each 22.75 m x 22.9 m x 5.8 m
Each containing four Cells per tank
Volume: each 12,086.62 m^3
Hydraulic Retention Time**: 6.39 h
Total Volume: 96,692.96 m^3
Stage 3
Six Tanks:
each 26.25 m x 24.9 m x 5.75 m
Each containing four Cells per tank
Volume: each 15,033.38 m^3
Hydraulic Retention Time**: 6.98 h
Total Volume: 90,200.25 m^3

Secondary clarification
Stage 1 & 2
16 Circular Tanks:
each 41.2 m (dia.) x 3.7 m (deep)
Volume: each 4,932.71 m^3
Surface Overflow Rate:
17.03 m^3/day/m^2
Hydraulic Retention Time**: 5.22 h
Total Volume: 78,923.38 m^3
Stage 3
Six Tanks:
each 26.25 m x 24.9 m x 5.75 m
Each containing four Cells per tank
Volume: each 15,033.38 m^3
Hydraulic Retention Time**: 6.98 h
Total Volume: 90,200.25 m^3

Chlorination
Stage 1 Contact Chamber
Volume of Tank: 2,463 m^3
Detention Time***: 5.63 min
Stage 2 Contact Chamber
Volume of Tank: 2,735 m^3
Detention Time***: 6.25 min
Stage 3 Contact Chamber
Two Chambers:
75 (l) x 30 (baffle width) x 4 m (d)
Total Volume: 18,000 m^3
Detention Time***: 41.1 min

Discharge
Length of Overall Pipe: 1,100 m
Outfall Diameter: 3 m
63 diffusers in use

* MLD – Mega litres per day
** Hydraulic Retention Times are calculated at designed average daily flow.
*** Detention Times are calculated at average day flows of the rated capacities.

Solid Process

Raw Sludge Blending Tank
Two Tanks:
each 33.5 m dia. x 9.1 m
Volume: each 8,020.85 m^2

Anaerobic Digesters
Four Primary Digesters and two Secondary Digesters
Each 33.5 m dia. x 9.1 m
Volume: each 8,020.85 m^2

Dewatering Centrifuges
Eight Centrifuges
Capacity: each 2.5 dry tonne/h
Total capacity of centrifuges: 20 dry tonne/h

Sludge Cake Pumps
Eight Sludge cake pumps
Capacity: each 15 m^3/h

Incineration
Four Reactors:
each 105 dry tonne/d
Total Capacity: 420 dry tonne/d

Ash Thickening Tanks
Three Circular Tanks:
11 m in (dia.), 4.69 m (deep)
Capacity of Each: 445.706 m^3

Ash Vacuum Filters
Two Filters: each 4,1 000 kg TSS/h
Total Capacity: 8,200 kg TSS/h

Duffin Creek WPCP Stage 3 liquids process.

An aerial view of Duffin Creek WPCP circular clarifiers in Stage 1 and 2.

The end of primary clarifier tanks with wastewater continuing to the next process of aeration.

View of Duffin Creek WPCP looking south-west. The Incineration facility is front and centre.

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