Earth Tech
Water Quality
& Treatment

The Town of Ladysmith / Saltair Water Supply & Distribution Preliminary Design

FINAL Report

Prepared for:

The Town of Ladysmith and Saltair
P.O. Box 220
Ladysmith, B.C. V9G 1A2

Prepared by:

Earth Tech (Canada) Inc.
1901 Rosser Avenue, 6th Floor
Burnaby, BC V5C 6S3
Phone: 604.298.6181 Fax: 604.294.8597
Contact: Simon Breese

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA S.M. BREESE #28323
24/9/03

Submittal Date:

July 18th, 2003

Project No. 55059-03

TOWN OF LADYSMITH / SALTAIR – WATER SUPPLY & DISTRIBUTION PRELIMINARY DESIGN

Earth Tech
Water Quality
& Treatment

TOWN OF LADYSMITH / SALTAIR – WATER SUPPLY & DISTRIBUTION PRELIMINARY DESIGN

TABLE OF CONTENTS

List of Appendices

List of Figures

List of Tables

Glossary of Terms

Technical Term	Definition
activated carbon	A highly adsorptive material used to remove organic substances from water. (See *adsorption.)*
adsorption	The water treatment process used primarily to remove organic contaminants from water. Adsorption involves the adhesion of the contaminants to an adsorbent such as activated carbon.
aeration	The process of bringing water and air into close contact to remove or modify constituents in the water.
after-precipitation	The continued precipitation of a chemical compound (primarily calcium carbonate in the softening process) after leaving the sedimentation or solids-contact basin. This can cause scale formation on the filter media and in the distribution system.
agglomeration	The action of microfloc particles colliding and sticking together to form larger settleable floc particles.
aggressive	See *corrosive.*
air binding	A condition that occurs in filters when air comes out of solution as a result of pressure decreases and temperature increases. The air clogs the voids between the media grains, which causes increased head loss through the filter and shorter filter runs.
air gap	A method to prevent backflow by physically disconnecting the water supply and source of contamination.
air scouring	The practice of admitting air through the underdrain system to ensure complete cleaning of media during filter backwash. Normally an alternative to using a surface wash system.
air stripper	A packed-tower aerator consisting of a cylindrical tank with a packing material made of plastic or other material. Water is usually distributed over the packing at the top of the tank and forced in at the bottom using a blower.
alum	The most common chemical used for coagulation. It is also called aluminium sulphate.
aluminium sulphate	See *alum.*
anaerobic	Having no air or free oxygen.
anionic	Having a negative ionic charge.
anionic polyelectrolyte	A polyelectrolyte that forms negatively ions when dissolved in water.
backflow	A hydraulic condition, caused by a difference in pressures, causing non-potable water or other fluid to flow into a potable system.
backwash	The reversal of flow through a filter to remove the material trapped on and between the grains of filter media.
baffle	A metal, wooden, or plastic plate installed in a flow of water to the water velocity and provide a uniform distribution of flow.

Glossary of Terms (Continued)

Technical Term	Definition
bar screen	A series of straight steel bars welded at their ends to horizontal steel beams, forming a grid. Bar screens are placed on intakes or in waterways to remove large debris.
bivalent ion	An ion that has a valence charge of two. The charge can be positive or negative.
breakthrough	The point in a filtering cycle at which turbidity-causing material starts to pass through the filter.
calcium carbonate ($CaCO_3$)	The principal hardness- and scale-causing compound in water.
calcium hardness	The portion of total hardness caused by calcium compounds such as calcium carbonate and calcium sulphate.
carbon dioxide (CO_2)	A common gas in the atmosphere that is very soluble in water. High concentrations in water can cause the water to be corrosive. Carbon dioxide is added to water after the lime-softening process to lower the pH in order to reduce calcium carbonate scale formation. This process is known as recarbonation.
carbonate hardness	Hardness caused primarily by compounds containing carbonate (CO_3^{2-}) such as calcium carbonate and magnesium carbonate.
carcinogen	A chemical compound that can cause cancer in animals or humans.
cation	A positive ion.
cation exchange	Ion exchange involving ions that have positive charges, such as calcium and sodium.
cationic	Having a positive ionic charge.
cationic polyelectrolyte	Polyelectrolyte that forms positively charged when dissolved in water.
chlorination	The process of adding chlorine to water to kill disease-causing organisms or to act as an oxidizing agent.
chlorinator	Any device that is used to add chlorine to water.
clarification	Any process or combination of processes that reduces the amount of suspended matter in water.
clarifier	See *sedimentation basin*.
coagulant	A chemical used in water treatment for coagulation. C examples are aluminium sulphate and ferric sulphate.
coagulant aid	A chemical added during coagulation to improve the by stimulating floc formation or by strengthening the floc so it together better.
coagulation	The water treatment process that causes very small suspended particles to attract one another and form larger particles. This is accomplished by the addition of a chemical, called a coagulant, that neutralizes the electrostatic charges on the particles that cause them repel each other.
coagulation-flocculation	The water treatment process that converts particles of suspended solids into larger, more settleable dumps.

Glossary of Terms (Continued)

Technical Term	Definition
colloidal solid	Finely divided solid that will not settle out of water for long periods of time unless the used.
combined chlorine residual	The chlorine residual produced by the reaction of chlorine with substances in the water. Because the chlorine is "combined," it is not as effective a disinfectant as free chlorine residual.
conventional filtration	A term that describes the treatment process used by most US surface water systems, consisting of the steps of coagulation, flocculation, sedimentation, and filtration.
corrosion	The gradual deterioration or destruction of a substance or material by chemical action. The action proceeds inward from the surface.
corrosive	Tending to deteriorate material, such as pipe, through electrochemical processes.
coupon test	A method of determining the rate of corrosion or scale formation by placing metal strips (coupons) of a known weight in the pipe and examining them for corrosion after a period of time.
Cryptosporidium Parvum	A protozoan pathogen which forms oocysts when released to the environment which are highly resistant to the most commonly used disinfectants
CT value	The product of the residual disinfectant concentration *C*, in milligrams per litre, and the corresponding disinfectant contact time *T*, in minutes. Minimum *CxT* values are specified by the Surface Water Treatment Rule as a means of ensuring adequate kill or inactivation of pathogenic micro-organisms in water.
density current	A flow of water that moves through a larger body of water, such as a reservoir or sedimentation basin, and does not become mixed with the other water because of a density difference. This difference usually occurs because the incoming water has a different temperature or suspended solids content than the water body
destratification	Use of a method to prevent a lake or reservoir from becoming stratified. Typically consists of releasing diffused compressed air at a low point on the lake bottom.
detention time	The average length of time a drop of water or a suspended particle remains in a tank or chamber. Mathematically, it is the volume of water in the tank divided by the flow rate through the tank.
diaphragm-type metering pump	A pump in which a flexible rubber, or metal diaphragm is fastened at the edges in a vertical cylinder. As the diaphragm is pulled back, suction is exerted and the liquid is drawn into the pump. When it is pushed forward, the liquid is discharged.
diffuser	(1) Section of a perforated pipe or porous plates used to inject a gas, such as carbon dioxide or air, under pressure into water. (2) A type of pump.
direct filtration	A filtration method that includes coagulation, flocculation, and filtration but excludes sedimentation. Only applicable to raw water relatively low in turbidity because all suspended matter must be trapped by the filters.

Glossary of Terms (Continued)

Technical Term	Definition
disinfectant residual	An excess of chlorine left in water after presence of residuals indicates that an adequate amount of been added at the treatment stage to ensure completion of all reactions with some chlorine remaining.
disinfection	The water treatment process that kills disease-causing organisms in water, usually by the addition of chlorine.
disinfection by-products (DBPs)	New chemical compounds formed by the reaction of disinfectants with organic or inorganic compounds in water. At elevated concentrations, many disinfection by-products are considered a danger to human health.
dissolved air flotation (DAF)	A clarification process in which gas generated in a basin so that they will attach to solid particles to cause them to rise to the surface. The sludge that accumulates on the surface is then periodically removed by flooding or mechanical scraping.
dissolved solid	Any material that is dissolved in water and can be recovered by evaporating the water after filtering the suspended material.
divalent	See *bivalent ion.*
dual-media filtration	A filtration method designed to operate at a higher rate by using two different types of filter media, usually sand and finely granulated anthracite.
epilimnion	The upper, warmer layer of water in a stratified lake.
erosion	The wearing away of a material by physical means.
filter agitation	A method used to achieve more effective cleaning of a filter bed. The system typically uses nozzles attached to a fixed or pipe installed just above the filter media. Water or an air-water mixture is fed through the nozzles at high pressure to help agitate the media and break loose accumulated suspended matter. It can also be auxiliary scour or surface washing.
filter sand	Sand that is prepared according to detailed specifications for in filters.
filtration	The water treatment process involving the removal of suspended matter by passing the water through a porous medium such as sand.
flash mixing	See *rapid mixing*
floc	Collections of smaller particles (such as silt, organic matter, and micro-organism) that have come together (agglomerated) into large more settleable particles as a result of the coagulation-flocculation process.
flocculation	The water treatment process, following coagulation, that uses gentle stirring to bring suspended particles together so that they form larger, more settleable clumps called floc.
flow measurement	A measurement of the volume of water flowing through a given point in a given amount of time.
flow proportional control	A method of controlling chemical feed rates by having the feed rate increase or decrease as the flow increases or decreases.

Glossary of Terms (Continued)

Technical Term	Definition
free chlorine residual	The residual formed once all the chlorine demand has been satisfied. The chlorine is not combined with other constituents in the water and is free to kill micro-organisms.
fulvic acids	Organic acids which result from the decay of natural organic matter (NOM) in the environment
GCDWQ	Guidelines for Canadian Drinking Water Quality
Giardia Lamblia	A protozoan pathogen which forms cysts when released to the environment which are quite resistant to the most commonly used disinfectants
granular activated carbon (GAC)	Activated carbon in a granular form, which is used in a bed, much like a conventional filter, to adsorb organic substances from water.
gravel bed	Layers of gravel of specific sizes that support the filter media and help distribute the backwash water uniformly.
haloacetic acids	A family of halogenated disinfection by-products believed to cause cancer in humans
hardness	A characteristic of water, caused primarily by the salts of calcium and magnesium. Hardness causes deposition of scale in boilers, damage in some industrial processes, and sometimes objectionable taste.
head loss	The amount of energy used by water in moving from one point to another.
humic acids	Organic acids which result from the decay of natural organic matter (NOM) in the environment
humic substance	Material resulting from the decay of leaves and other plant matter.
hypochlorination	Chlorination using solutions of calcium hypochlorite or sodium hypochlorite.
hypolimnion	The lower layer of water in a stratified lake. The water temperature is near 4°C, at which water attains the maximum density.
injector	See *ejector*
inlet zone	The initial zone in a sedimentation basin. It decreases the velocity of the incoming water and distributes it evenly across the basin.
iron	An abundant element found naturally in the earth. As a result, dissolved iron is found in most water supplies. When the concentration of iron exceeds 0.3mg/L, it causes red stains on plumbing fixtures and other items in contact with the water. Dissolved iron can also be present in water as a result of corrosion of cast-iron or steel pipes. This is usually the cause of red-water problems.
iron bacteria	Bacteria that use dissolved iron as an energy source. They can create serious problems in a water system because they form large slimy masses that clog well screens, pumps, and other equipment.
jar test	A laboratory procedure for evaluating coagulation, flocculation, and sedimentation processes. Used to estimate the proper coagulant dosage.
Langelier Saturation Index (LSI)	A numerical index that indicates whether calcium carbonate will be deposited or dissolved in a distribution system. The index is also used to indicate the corrosivity of water.
loading rate	The flow rate per unit area at which the water is passed through a filter or ion exchange unit.

Glossary of Terms (Continued)

Technical Term	Definition
magnesium hardness	The portion of total hardness caused by magnesium compounds such as magnesium carbonate and magnesium sulphate.
manganese	An abundant element found naturally in the earth. Dissolved manganese is found in many water supplies. At concentrations above 0.05 mg/L, it causes black stains on plumbing fixtures, laundry, and other items in contact with the water.
manifold	A pipe with several branches or fittings to allow water or gas to be discharged at several points. In aeration, manifolds are used to spray water through several nozzles.
maximum contaminant level (MCL)	The maximum allowable concentration of a contaminant in drinking water, as established by state and/or federal regulations. Primary MCLs are health related and mandatory. Secondary MCLs are related to the aesthetics of the water and are highly recommended but not required.
membrane processes	Water treatment processes in which relatively pure water passes through a porous membrane while particles, molecules, or ions of unwanted matter are excluded.
microfiltration	Membrane filtration with membranes of nominal pore size of the order of 0.1 – 0.2 microns. MF membranes are typically capable of 4-log removal of *Giardia* and *Cryptosporidium*, as well as a 2-log virus removal.
monovalent ion	An ion having a valence charge of one. The charge can either positive or negative.
mudball	An accumulation of media grains and suspended material that creates clogging problems in filters.
multimedia filter	A filtration method designed to operate at a high rate by utilizing three or more different types of filter media. The media types typically used are silica sand, anthracite, and garnet sand.
nephelometric turbidimeter	An instrument that measures turbidity by measuring the amount of light scattered by turbidity in a water sample. It is the only instrument approved by the US Environmental Protection Agency to measure turbidity in treated drinking water.
nephelometric turbidity unit (NTU)	The amount of turbidity in a water sample as measured by a nephelometric turbidimeter.
non-carbonate hardness	Hardness caused by the salts of calcium and magnesium.
non-ionic polyelectrolyte	Polyelectrolyte that forms both positively and negatively charged ions when dissolved in water.
NTU	See *nephelometric turbidity unit.*
on-line turbidimeter	A turbidimeter that continuously samples, monitors, and records turbidity levels in water.

Glossary of Terms (Continued)

Technical Term	Definition
oxidation	(1) The chemical reaction in which the valence of an element increases because of the loss of electrons from that element. (2) The conversion of organic substances to simpler, more stable forms by either chemical or biological means.
oxidize	To chemically combine with oxygen.
ozonation	The process of applying ozone to water for the purposes of disinfection, or oxidation
ozone contactor	A tank used to transfer ozone to water. A common type applies ozone under pressure through a porous stone at the bottom of the tank.
ozone generator	A device that produces ozone by passing an electrical current through air or oxygen.
packing material	The material placed in a packed tower to provide a large surface area over which water must pass to attain a liquid-gas transfer.
pathogen	A disease-causing organism.
percolation	The movement or flow of water through the pores of soil, usually downward.
permanent hardness	Another term for non-carbonate hardness, derived from the fact that the hardness-causing non-carbonate compounds do not precipitate when the water is boiled.
pilot filter	A small tube, containing the same media as treatment plant filters, through which flocculated plant water is continuously passed, with a recording turbidimeter continuously monitoring the effluent. The amount of water passing through the pilot filter before turbidity breakthrough can be correlated to the operation of the plant filters under the same coagulant dosage.
pipe lateral system	A filter underdrain system using a main pipe (header) with several smaller perforated pipes (laterals) branching from it on both sides.
plain sedimentation	The sedimentation of suspended matter without the use of chemicals or other special means.
polyelectrolyte	High-molecular-weight, synthetic organic compound that forms ions when dissolved in water. It is also called a polymer.
pre-sedimentation	A preliminary treatment process used to remove gravel. sand, and other gritty material from the raw water before it enters the main treatment plant. This is usually done without the use of coagulating chemicals.
pre-sedimentation impoundment	A large earthen or concrete basin used for pre-sedimentation of raw water. It is also useful for storage and for reducing the impact of raw-water quality changes on water treatment processes.
pressure-sand filter	A sand filter placed in a cylindrical steel vessel. The water is forced through the media under pressure.
pre-treatment	See *preliminary treatment*.

Glossary of Terms (Continued)

Technical Term	Definition
rapid mixing	The process of quickly mixing a chemical solution uniformly through the water.
reducing agent	Any chemical that decreases the positive valence of an ion.
regeneration	The process of reversing the ion exchange softening reaction of ion exchange materials. Hardness ions are removed from the used materials and replaced with non-troublesome ions, thus rendering the materials fit for reuse in the softening process.
residual	See *disinfectant residual.*
residual flow control	A method of controlling the chlorine feed rate based on the residual chlorine after the chlorine feed point.
sedimentation	The water treatment process that involves reducing the velocity of water in basins so that the suspended material can settle out by gravity
sedimentation basin	A basin or tank in which water is retained to allow settleable matter, such as floc, to settle by gravity. Also called a settling basin, settling tank, or sedimentation tank.
sedimentation tank	See *sedimentation basin.*
sequestering agent	A chemical compound such as EDTA or certain polymers that chemically tie up (sequester) other compounds or ions so that they cannot be involved in chemical reactions.
settling basin	See *sedimentation basin.*
settling tank	See *sedimentation basin.*
settling zone	The zone in a sedimentation basin that provides a calm area so that the suspended matter can settle.
sludge	The accumulated solids separated from water during treatment.
sludge-blanket clarifier	See *solids-contact basin.*
sludge lowdown	The controlled withdrawal of sludge from a solids contact basin to maintain the proper level of settled solids in the basin.
surface overflow rate	A measurement of the amount of water leaving a sedimentation tank per square foot of tank surface area.
surface washing	See *filter agitation.*
suspended solid	Solid organic and inorganic particle that is held in suspension by the action of flowing water.
synthetic organic chemical	A carbon-containing chemical that has been manufactured, as opposed to occurring in nature.
temporary hardness	Another term for carbonate hardness, derived from the fact that the hardness-causing carbonate compounds precipitate when water is heated.
THM	See *trihalomethane.*
total organic carbon (TOC)	The amount of carbon bound in organic compounds in a water sample as determined by a standard laboratory test.

Glossary of Terms (Continued)

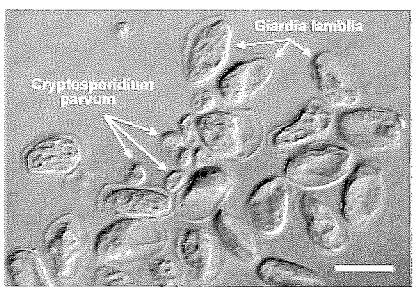
Technical Term	Definition
trivalent ion	An ion having three valence charges. The charges can be positive or negative.
Tubercules	Knobs of rust formed on the interior of cast-iron pipes as a result of corrosion.
turbidity	A physical characteristic of water making the water appear cloudy The condition is caused by the presence of suspended matter.
turbulence	A flow of water in which there are constant changes in flow velocity and direction resulting in agitation.
underdrain	The bottom part of a filter that collects the filtered water and uniformly distributes the backwash water.
uniform corrosion	A form of corrosion that attacks a material at the same rate over the entire area of its surface.
up flow clarifier	See *solids contact basin.*
UV disinfection	Disinfection using ultraviolet light.
viscosity	The resistance of a fluid to flowing due to internal molecular forces.
volatile	Capable of turning to vapour (evaporating) easily
volatile organic chemicals (VOC's)	A class of manufactured, synthetic chemicals that are generally used as industrial solvents. They are classified as known or suspected carcinogens or as causing other adverse health effects. They are of particular concern to the water supply industry because they have widely been found as contaminants in groundwater sources.

SECTION ES
EXECUTIVE SUMMARY

The Town of Ladysmith (hereinafter referred to as the Town) and the Cowichan Valley Regional District, Area "G", Saltair (hereinafter referred to as Saltair) have been enjoying a burgeoning population over the last several years, bolstered by the obvious attractions of the region's location and climate, as well as the availability of employment with the local commercial & industrial sector both in the Ladysmith area, and in nearby Nanaimo.

As this population has grown, so too has the demand for water. Fortunately, both Ladysmith and Saltair have always been able to keep pace with these growing demands, having been able to provide an ample supply of wholesome drinking water to its customers through the availability of two water sources of generally excellent quality (Holland Lake and Stocking Lake, in the mountainous catchment areas to the west of the Town).

Drinking water is more than ever in the public focus in recent years, with unfortunate outbreaks of waterborne disease in Walkerton, Ontario, North Battleford, Saskatchewan, Milwaukee, Wisconsin, and other towns and cities across North America causing widespread sickness and even death, catching the eye both of the general public and regulators alike. Even the Town of Ladysmith has not been immune, with a contamination event of unknown origin occurring in the Arbutus Reservoir in July, 2001. Driven by these events, but also an improved understanding of the epidemiology of some of the emerging drinking water contaminants, drinking water regulations are becoming ever more stringent.



Outbreaks of waterborne disease due to pathogens such as Giardia and Cryptosporidium have forced Canadian regulators to consider significant changes to microbiological water quality regulations in this country

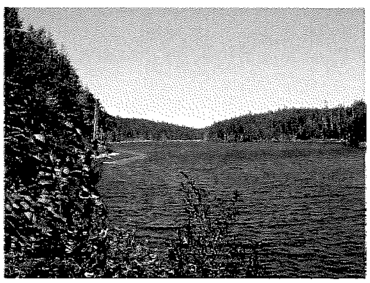
Recognizing the pressures both increasing demands for potable water, and increasingly strict water quality regulations will place on their existing water supply infrastructure in years to come, both the Town and Saltair have been proactively planning significant upgrades to the system as a whole for the last several years. This report documents a detailed analysis of the Ladysmith & Saltair existing system, and presents a preliminary design for staged upgrading to this infrastructure to help Ladysmith & Saltair meet these challenges into the future. The study includes analysis of the feasibility of including the supply of potable water to Saltair under the Town of Ladysmith's responsibility.

In this section, the key findings of the study are briefly summarized to allow an executive level overview of the recommended upgrades. The salient findings of the study are as follows:

- Historical population growth in the area has averaged 4% in recent years. Continued growth at this rate is not considered sustainable, due to a diminishing supply of available land for further growth, as well as a decline in some of the local core industries in recent years.
- The projected population within the Town of Ladysmith service area, including Diamond Improvement

District, as well as Saltair is 12,856 by the Year 2022. Projected average and peak day demands for water are expected to reach 6,200 m^3/d (72 L/s) and 13,100 m^3/d (152 L/s) respectively over the same time period.

- The combined drought year reliable yield of water from Stocking Lake and the Holland Creek watershed combined is estimated at approximately 140 L/s, well above the projected average day demand of 72 L/s (for 12,856 people). While some of the reliable yield must be allocated for spillage to maintain adequate stream flows, it would appear that an ample supply of water is available to meet the needs of the Town and Saltair's customers well into the future.
- The Town routinely exceeds their licensed withdrawals from Stocking Lake on a volume per day basis, by switching the entire supply to Stocking Lake in the winter due to water quality considerations (see below). Despite this fact, the total annual withdrawal from Stocking Lake is routinely well below the licensed amount. Saltair withdraws water within its licensed limits from Stocking Lake.
- Water drawn from Stocking Lake is consistently of excellent quality, and present B.C. regulations and Federal Canadian Guidelines for Drinking Water Quality can be easily met through simple chlorination.



Stocking Lake provides a consistently excellent water quality, although the reliable yield of the Lake is comparatively low, forcing the Town to rely on the lower quality Chicken Ladder source

- Water drawn from the Holland Creek watershed at the Chicken Ladder Dam is generally of excellent quality, but is prone to seasonal deterioration in quality due to rainfall events. Rainfall in the watershed commonly triggers short term turbidity spikes (1 – 2 days), and/or extended periods of elevated colour levels. During these events, the Town typically switches to the Stocking Lake supply, since the Town would be unable to meet all Canadian Guidelines for Drinking Water Quality during such events using the present level of treatment.
- Town staff report the presence of slight depression in the lie of the land immediately to the south of the confluence of Holland Creek and South Holland Creek. It has been anecdotally reported that this area routinely becomes a sink for runoff during the year, and collects standing water for much of the year. During the time this water stands in this depression, colour causing compounds are leached from natural organic matter which also naturally collects in the depression. When the rains begin, it has been reported that this area eventually overflows into Holland Creek, causing highly coloured water to begin to enter the Creek.

  It is recommended that further reconnaissance of this area be undertaken early in the rainy season, to gather further information on this area, and confirm whether this phenomenon occurs. If this does prove to be a significant contributor to the development of colour in the Chicken Ladder supply, it is conceivable that this issue might be mitigated through simple earthworks, to aid in the drainage of the standing water on a more continual basis.
- It is recommended that the Town and Saltair formally adopt the Canadian Guidelines for Drinking Water

Quality as drinking water quality objectives. It is also recommended that the Town and Saltair adopt selected water quality objectives presently regulated only in the U.S.A.. Canadian regulations have shown a marked tendency to emulate U.S. regulations over time, and it is considered prudent for the Town and Saltair to adopt some of these more stringent objectives for contaminants which potentially pose a risk to the water supply.

Specifically, microbiological objectives for the pathogens *Giardia*, and *Cryptosporidium*, as well as viruses are recommended. These pathogens are significantly more resistant to chlorine than most bacteria, and the risk of contamination of the water is considered to be moderate. These pathogens are routinely carried as parasites by many species of wildlife. Logging activities in the watershed may favour transport of fecal material into the water supply during rainfall events, by reducing the soil binding effects of the roots of trees and plants.

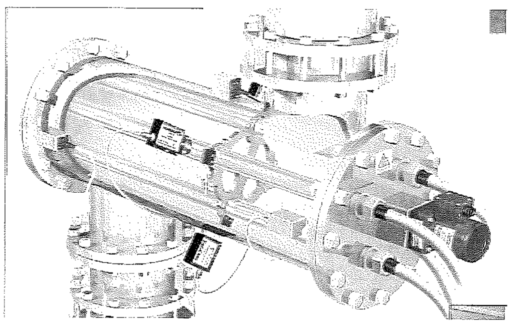
In addition, it is recommended that the Town and Saltair adopt the more stringent U.S. water quality objectives for chlorinated disinfection by-products, such as the families of trihalomethanes (THM's) and haloacetic acids (HAA's). These compounds form through the reaction of organic compounds naturally present in the water with chlorine, and are believed to pose a long term risk for the development of cancer in humans if water containing elevated levels of these compounds is consistently consumed. At present, THM's are regulated in Canada (but at a higher concentration than in the U.S.), while HAA's are not regulated in Canada.

- Draft guidelines have recently been released by Health Canada which provide a list of criteria purveyors of water must meet in order to continue supply of drinking water without filtration. Most important among these criteria is the stipulation that the raw water not consistently exceed a turbidity of 5 NTU. While water drawn from the Holland Creek watershed via Chicken Ladder does occasionally exceed 5 NTU for brief periods, it is feasible for the Town to ensure that raw water turbidity is never greater than 5 NTU through source selection. This is highly significant, since it would allow the Town to meet these Filtration Avoidance criteria, and potentially avoid construction of a filtration plant under this guideline.
- Although the switching of sources of supply is considered sustainable to mitigate turbidity concerns in the source water, due to the short duration of turbidity spikes, this practice is not sustainable for mitigating colour spikes, due to the extended duration of these spikes. In order to meet the recommended water quality objectives therefore, treatment for the removal of colour from the Chicken Ladder supply will be required. In addition, enhanced disinfection for the inactivation of *Giardia*, *Cryptosporidium*, and viruses is recommended.
- Present open raw water reservoirs such as Arbutus Reservoir present an increased risk for deliberate contamination of the water supply through sabotage, as the reservoir itself is relatively close to the fence line. In some instances, notably at the Balancing Reservoir, it was noted that the integrity of the fence itself had been compromised by a falling tree. Construction of water treatment facilities upstream of Arbutus Reservoir will render the raw water reservoir redundant. New treated water reservoirs will need to be constructed, to provide fire storage, balancing storage (so that treatment facilities need only be sized for peak day flow, not peak hour), and emergency storage (to protect against loss of source).
- It is concluded that water supply to North Ladysmith and Diamond District should be carried out through a consolidated 10.1 ML/d treatment facility located near the existing Arbutus Reservoir. The new Arbutus WTP would incorporate ozonation for removal of colour in the Chicken Ladder supply, plus UV disinfection for enhanced disinfection, and chlorination for the establishment of a protective disinfectant residual for the distribution system. The plant would be designed to treat either Chicken Ladder or Stocking Lake water. The ozonation system at the plant would be operated only when treating coloured

Chicken Ladder water, and could be switched off to save power costs for the remainder of the year.

The facility would also be provided with a new 5.7 ML treated water reservoir, to provide fire, balancing, and emergency storage for the north end of the Town.

- Pilot testing of ozonation of Holland Lake water is strongly recommended. Ozone demands for effective colour removal have been shown to be site specific, and will need to be confirmed in advance of design of new facilities. In addition, pilot testing will shed some light on the potential for conversion of naturally occurring organic carbon into assimilable organic carbon (AOC), which might promote bacterial re-growth in the distribution system.



Significant advances in Ultraviolet (UV) disinfection have revolutionized the drinking water industry, making the protection of water supplies against Giardia and Cryptosporidium cost effective

- It is concluded that a consolidated approach to water supply to South Ladysmith and Saltair is both feasible and cost effective. The new 3.1 ML/d South End WTP would treat only Stocking Lake water, and would incorporate UV disinfection for enhanced disinfection, and chlorination for the establishment of a protective disinfectant residual for the distribution system.

  The facility would also be provided with a new 3.9 ML treated water reservoir, to provide fire, balancing, and emergency storage for the south end of the Town, and Saltair.

- Estimated capital costs for the recommended upgrades totals $ 8.64 million, including engineering and contingencies. Estimated O&M costs for the Arbutus and South End WTP's would be $ 81,200 per year, and $ 29,300 per year respectively, including process and building energy, chemical costs, maintenance materials, and operating and maintenance labour. These O&M costs would be in addition to costs presently incurred by the Town for distribution system operation & maintenance activities, which amounted to $76,340 in the last fiscal year.

- Additional water quality sampling is recommended, to better characterize seasonal variation in water quality for several parameters. These parameters include raw water **true** colour, total organic carbon (TOC), dissolved organic carbon (DOC), UV absorbance at 254 nm, as well as *Giardia* and *Cryptosporidium*, as well as treated water trihalomethanes (THM's) and haloacetic acids (HAA's), using water samples drawn at the extremities of the distribution system.

- It is recommended that the Town & Saltair embark upon a program of performing Simulated Distribution System (SDS) THM and HAA formation potential trials on a quarterly basis, to better characterize the potential risk posed by DBP's. It is recommended that such trials be performed on Stocking Lake water, drawn at the Contact Tank, as well as Holland Lake water drawn at Chicken Ladder Dam. SDS trials involve chlorination of raw water samples for a period commensurate with the residence time in the existing distribution system, to simulate the likely levels of DBP's formed in the finished water on a seasonal basis.

- Although Town staff do not report the receipt of any significant corrosion related complaints, the source waters are expected to be corrosive to common piping materials. Careful monitoring of customer complaint logs is recommended for evidence of such issues developing in the future.

SECTION 1.0
INTRODUCTION

In Canada, a land blessed by one of the most abundant supplies of fresh water on the planet, safe drinking water has long been taken for granted by the general public. Over the last several years however, events such as the Walkerton E.*Coli* outbreak, and terrorist attacks in the U.S. have brought public concerns over the safety of the water supply into sharp focus. These concerns were brought home to the citizens of the Town of Ladysmith in July, 2001, when Arbutus Reservoir, the main treated water reservoir serving the Town, was subject to a contamination event of unknown cause.

Although these events have brought the issues into the forefront of public interest, the Town of Ladysmith and Saltair have long recognized the need for significant upgrades to their existing water supply infrastructure, and have been proactively planning major upgrades to their water supply infrastructure for several years. This planning process has included the request for funding under the B.C./Canada Infrastructure Program for the construction of miscellaneous upgrades, including the provision of enhanced water treatment facilities.

This report documents the preliminary design of the proposed facilities. The remainder of this report is sub-divided into several sections, as follows:

- **Section 2 – Project Background & Design Criteria** summarizes the history of water supply in the Town of Ladysmith and Saltair, including a summary of existing infrastructure, projection of future water demands, and a look at the availability of water, and water quality issues.
- **Section 3 – Development of Alternatives** builds upon the design criteria established in the previous Section, and formulates a selection of alternative scenarios which could meet the needs of the Town & Saltair into the future.
- **Section 4 – Alternatives Analysis** presents the findings of a detailed engineering analysis of each of the alternative scenarios, including consideration of construction and operating & maintenance costs, the availability of land suitable for new construction, and incorporation into the existing hydraulic profile. The section culminates in a recommendation regarding the preferred alternative for further development to a preliminary design level.
- **Section 5 – Preferred Alternative** develops the recommended alternative established in the previous section to a preliminary design level.

PREVIOUS RELEVANT STUDIES

Previous studies which were reviewed in the preparation of this report are:

- B.C. Environment Water Management Division "*Water Quality Assessment and Objectives for Holland Creek and Stocking Lake Watersheds, Vancouver Island*", July, 1993
- Koers and Associates: "*Water Study*" – February, 1995
- Koers and Associates: "*Water System Improvements – Pre-design Investigation*", August, 1996
- Applied Oxidation Technologies, "*Town of Ladysmith, Synopsis of Drinking Water Resources and Treatment Plant Design*" – May, 1998
- Reid Crowther & Partners Limited, "*Application for Funding Supporting Documentation*" – February, 1999

- Montgomery Watson, in association with Herold Engineering, "***Application for Funding Supporting Documentation***" – March 7, 2001
- Earth Tech Canada Inc. "***Water Quality Monitoring Report***", Earth Tech (Canada) Inc., September 11, 2001

ACKNOWLEDGEMENTS

The gracious assistance of Messrs. Joe Friesenhan, and Ken Fleckenstein of the Town of Ladysmith, and Ms. Jeralyn Jackson of the Cowichan Valley Regional District in the preparation of this Report is duly acknowledged, and has been much appreciated.

SECTION 2.0
PROJECT BACKGROUND & DESIGN CRITERIA

EXISTING WATER SUPPLY INFRASTRUCTURE

Figure 2-1 presents an overview of the Town of Ladysmith and Saltair existing water supply system. Water is drawn from two distinct sources, which provide water through separate facilities at the north and south ends of the Town. The northern, larger portion of the Town is supplied by the Holland Lake and Holland Creek watershed which enters the water supply system at a diversion point at the Chicken Ladder Dam, a small stilling basin located approximately 2.5 km upstream from the Public Works Yard. This source flows directly to the open Arbutus Reservoir, where it is chlorinated and distributed by gravity to North Ladysmith and the Diamond Improvement District.

The Chicken Ladder intake on Holland Creek is downstream of the Holland Lake reservoir (Elevation 656 m), which holds 1,368,000 m^3. Flow may also be diverted seasonally from Banon Creek to help fill the reservoir. The Chicken Ladder intake is at an elevation of approximately 189 metres, and feeds the open Arbutus Reservoir, which is at an elevation of approximately 140 m, and has a capacity of 5,500 m^3.

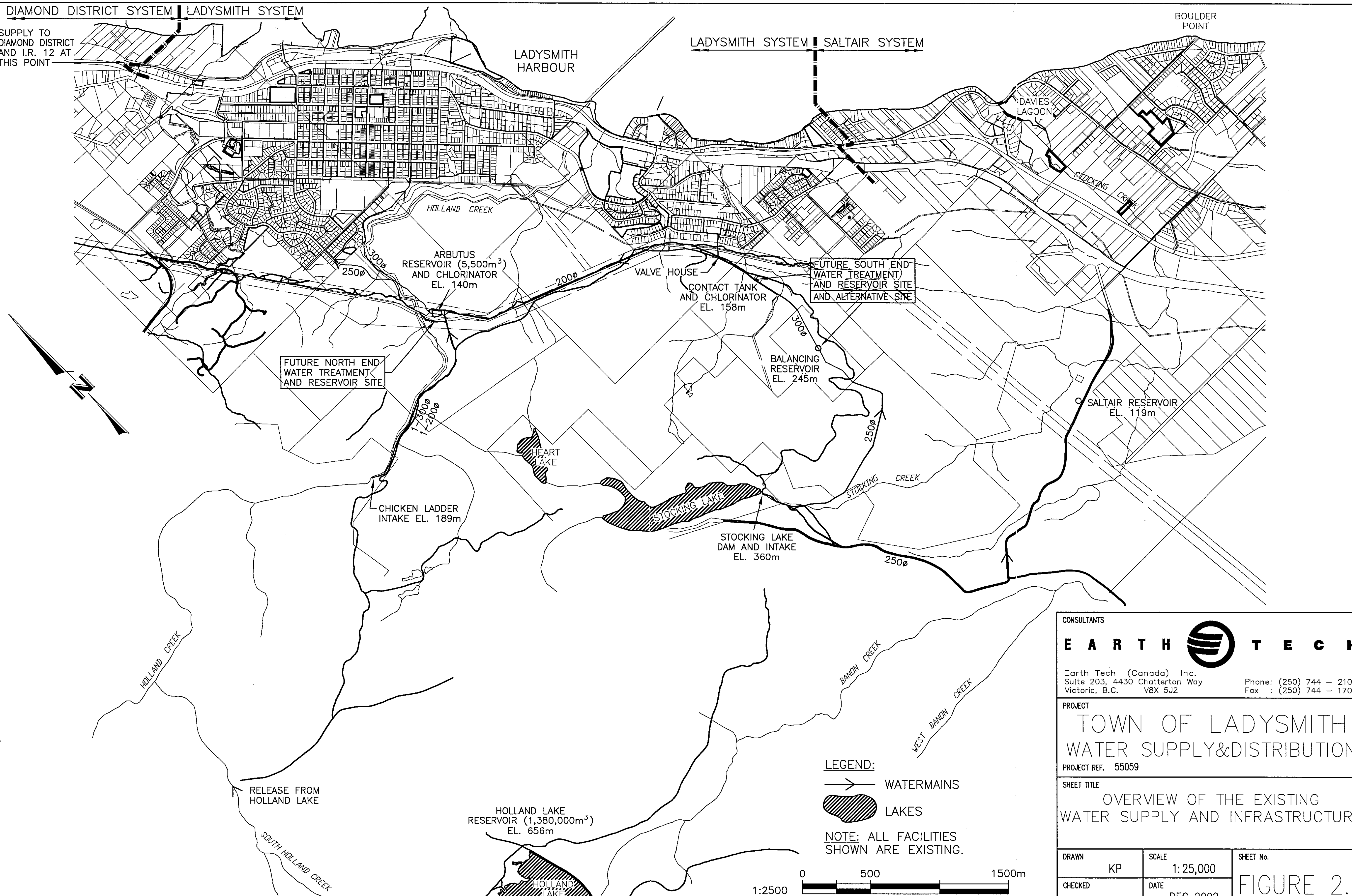
The southern portion of the Town is supplied by an intake and pipeline from Stocking Lake (Elevation 360 m) which jointly serves Saltair within the Cowichan Valley Regional District (CVRD).

A pipeline carries flow for Ladysmith to the Balancing Reservoir (Elevation 245 m), where the high pressure in the pipeline is released and a small amount of storage is provided. From there flow is piped to the chlorination and Contact Tank area (Elevation 158 m) then delivered to the south end of the Town of Ladysmith.

A separate 450 mm pipeline ties into the main pipeline just south of Stocking Lake, and feeds an existing 50,000 Imperial Gallon (227.3 m^3) reservoir above and to the west of Saltair. The existing pipeline approximately follows the alignment of Stocking Creek. There exists also the potential of feeding Saltair directly from the Ladysmith distribution system, as the two systems are interconnected, at the Town boundaries via two permanently locked connections. Since South Ladysmith system and the Saltair system are fed from reservoirs at different grades, the distribution systems on each side of these connections operate at distinctly different pressures.

The Arbutus Reservoir and Contact Tank top water levels provide the static hydraulic grade lines (HGL's) for the north and south portions of the Town respectively. There is a 2,700 m long, 200 mm diameter Asbestos Cement (AC) water main (hereinafter referred to as the Crossover Main) connecting these two points which is used, at times of poor water quality in Holland Creek, to fill the Arbutus Reservoir. Thus Stocking Lake becomes the only water source at these times. A valve house at Arbutus Reservoir controls inflow from both sources.

The topography of the Town of Ladysmith slopes steeply towards the waterfront, resulting in a large range in water pressures within the Town of Ladysmith's water system from 280 kPa(g) to 1,260 kPa(g). There are only a few pressure reducing valves in the system and no formal pressure zones.



CONSULTANTS

EARTH TECH

Earth Tech (Canada) Inc.
Suite 203, 4430 Chatterton Way
Victoria, B.C. V8X 5J2
Phone: (250) 744 – 2100
Fax : (250) 744 – 1700

PROJECT

TOWN OF LADYSMITH WATER SUPPLY&DISTRIBUTION

PROJECT REF. 55059

SHEET TITLE

OVERVIEW OF THE EXISTING WATER SUPPLY AND INFRASTRUCTURE

DRAWN	SCALE	SHEET No.
KP	1:25,000	FIGURE 2.1
CHECKED	DATE DEC 2002	

POPULATION AND DEMAND PROJECTIONS

One of the most important issues not adequately addressed in earlier studies was the development of reasonable and rational projections of population growth in the Town of Ladysmith & Saltair service areas, and from that a determination of future demands for drinking water. Along with the demands of the Town of Ladysmith itself, it is necessary also to formulate projections for other communities presently or proposed to be served by the Town, including Saltair, presently within the CVRD, as well as the Diamond Improvement District.

POPULATION PROJECTIONS

Historically, the Town has consistently experienced a steady, and rapid growth rate of the order 4% per annum, bolstered by the obvious attractions of the Town's geographical location to its residents, as well as local commercial & industrial sectors focused on tourism, and the logging and timber industry.

Through discussion with Town personnel[1], it was agreed that a population growth rate of 4% was unlikely to be sustainable into the long term, due partially to a recent decline in the timber industry, but also because the land for further residential development is becoming increasingly scarce in a Town hemmed in between Ladysmith Harbour to the east and steep mountainous areas to the west.

In light of these considerations, the following residential growth rates were assumed for the various areas to be served by the Town:

- North Ladysmith, Diamond District, and Saltair: 2% per annum
- South Ladysmith, i.e. south of Holland Creek: 0.5% per annum, to allow for existing limitations in available areas zoned for residential growth

The decentralized nature of the existing water supply system for Ladysmith, Saltair, and the Diamond District make it important to develop population and demand projections for each of these areas individually, as the sizing of facilities will have to reflect regional demands if a decentralized approach to water supply is to be maintained.

Using these regionally sensitive projected population growth rates, the following population projections can be formulated (Table 2-1). Design population for the entire service area, based upon the 20-year design horizon of 2022, is therefore 12,856 people. Projected distribution of population between the various areas presently served from the Stocking Lake & Holland Lake system is as follows:

- North Ladysmith and Diamond District (presently served through Arbutus Reservoir): 10,104
- South Ladysmith (presently served from Stocking Lake via the Contact Tank): 594
- Saltair (presently served from Stocking Lake by a dedicated connection): 2,157

DEMAND PROJECTIONS

Residential water demands for the Town in recent years have averaged 533 Litres per capita per day (Lpcd), with an additional 0.7 ML/d of average day commercial & industrial water demands.

[1] Joe Friesenhan, Town of Ladysmith, Personal Communication, October, 2002

Table 2-1
Population Projections for the Town of Ladysmith
Water Supply Service Area, 2002 - 2022

Year	North Ladysmith	South Ladysmith	Total Ladysmith	Diamond D.	Saltair	Total
2002	6,300	400	6,700	500	1,452	8,652
2003	6,426	408	6,834	510	1,481	8,825
2004	6,555	416	6,971	520	1,511	9,001
2005	6,686	424	7,110	531	1,541	9,181
2006	6,819	433	7,252	541	1,572	9,365
2007	6,956	442	7,397	552	1,603	9,552
2008	7,095	450	7,545	563	1,635	9,743
2009	7,237	459	7,696	574	1,668	9,938
2010	7,381	469	7,850	586	1,701	10,137
2011	7,529	478	8,007	598	1,735	10,340
2012	7,680	488	8,167	609	1,770	10,547
2013	7,833	497	8,331	622	1,805	10,757
2014	7,990	507	8,497	634	1,841	10,973
2015	8,150	517	8,667	647	1,878	11,192
2016	8,313	528	8,841	660	1,916	11,416
2017	8,479	538	9,017	673	1,954	11,644
2018	8,649	549	9,198	686	1,993	11,877
2019	8,822	560	9,382	700	2,033	12,115
2020	8,998	571	9,569	714	2,074	12,357
2021	9,178	583	9,761	728	2,115	12,604
2022	9,361	594	9,956	743	2,157	12,856

In developing projections of the demand for water into the future, it is important to consider the expressed desire of the Town to implement a water conservation and metering program, by which the Town expects to be able to reduce per capita demands by 20%. In our experience, this reduction is at the high end of the scale compared to other B.C. communities which have implemented metering (15% is more typical), however it is considered achievable if an aggressive program of water conservation and demand side management is undertaken concurrently with the introduction of metering.

An additional consideration is the likelihood that commercial and industrial demands will also grow, and potentially at a pace outstripping that projected for the residential growth. There has been discussion of a significant industrial water user potentially moving into the South Ladysmith and/or Saltair areas, and it is considered to prudent to allow for higher projections in industrial & commercial growth in these two areas than allowed for in the residential sector. For the purposes of this study, the following industrial & commercial growth rates were used:

- North Ladysmith, and Diamond District: 2% per annum
- South Ladysmith and Saltair: 4% per annum, to allow for existing availability of areas zoned for industrial growth.

Based upon these assumptions, the following 20-year demands for water are projected in the various communities comprising the service area (Table 2-2). These demand projections are presented in detail as Appendix "A" to this report.

Table 2-2
Water Demand Projections for a 20-year horizon

Area	Year 2022 Demand Projections (ML/d)		
	Average Day	Peak Day‡	Peak Hour†
North Ladysmith & Diamond District	4.8	10.1	20.1
South Ladysmith	0.3	0.6	1.3
Saltair	1.1	2.4	4.7
TOTAL	6.2	13.1	26.1

‡: Peak day demand is calculated using a peak day demand-to average day demand ratio (or peaking factor) of 2.0

†: Peak hour demand is calculated using a peak hour demand-to peak day demand ratio (or peaking factor) of 2.1

THE AVAILABILITY OF WATER

WATERSHED RELIABILITY

A hydrology model was previously developed for the Holland Creek watershed to aid in the estimation the reliable drought flows at Chicken Ladder[2]. The model projects a 50-year minimum reliable supply rate of 121 L/s, without allowances for releases for aquatic habitat.

To estimate Stocking Lake's drought reliability, a similar model to the Holland Creek model was developed. The storage volume used in the model for Stocking Lake is the maximum storage volume as indicated in the

[2] Earth Tech (Canada) Inc., "*Town of Ladysmith – Water Quality Monitoring Project*", September 11, 2001

water licence (666,000 m³), as bathymetric information was not available. The 50 year minimum reliable supply rate from Stocking Lake has been estimated at 18 L/s. This assumes complete filling of the reservoir occurs in the winter following a period of maximum draw down. The average yield of the Stocking Lake reservoir is approximately 36 L/s. No monitoring has been performed to confirm the hydrology estimates.

Combined 50-year reliable yield from the two sources is therefore 139 L/s, which compares to the 20-year projected demand of 6.23 ML/d, or 72 L/s. Figure 2-2 correlates the projected growth in demands for water over the next 30 years against the reliable combined yield of the sources. The data clearly demonstrates that projected average day demands for the entire system fall well short of the reliable yield of the system far into the future. While it is important however to point out that the reliable yield data listed above does not include allowances for spillage to ensure stream flow is maintained in Holland and Stocking Creeks, it would appear that ample water supply is available from the Lakes to sustain growth well into the future.

WATER LICENCES

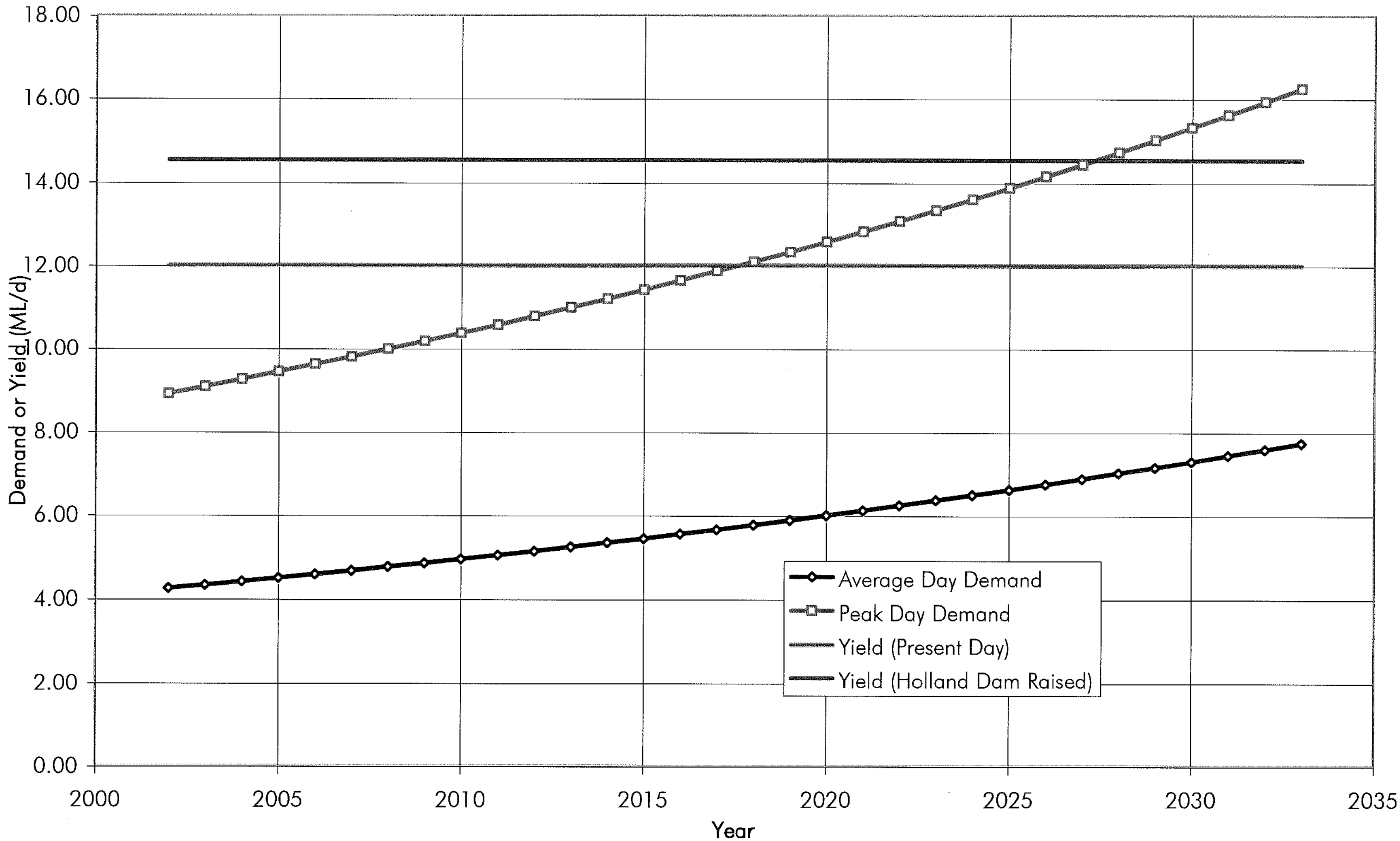
The Town of Ladysmith holds water licences on both Stocking Creek and Holland Lake. The Holland Creek water licenses were described in the above noted Water Quality Monitoring Project report which states that the combined maximum permitted withdrawal rate from Chicken Ladder is 73.7 L/s.

Table 2-3 summarizes existing licenses held by the Towns of Ladysmith and Saltair on Stocking or Holland Lakes.

Table 2-3
Summary of Existing Water Licences held by the Town of Ladysmith & the Cowichan Valley Regional District

Licence Number	Water Source	Details of Licence
Town of Ladysmith		
CL 005333	Stocking Lake or Creek	2.273 ML/d allowable withdrawal
CL017746	Holland Creek	2.727 ML/d allowable withdrawal
CL 021164	Holland Lake	247 ML storage
CL 029821	Holland Creek / Prevost Lake	123 ML storage
CL 067480	Banon Creek	Maximum withdrawal 1,819 ML between November 1st and May 31st. Of this amount, 771 ML may be diverted through Holland Lake and into Holland Creek at a rate not to exceed 3.64 ML/d during this same period. The remaining amount (1,048 ML) may be stored in Holland Lake, and released during the remainder of the year through Holland Lake into Holland Creek.
Cowichan Valley Regional District		
CL 067481	Stocking Creek	448 ML/yr allowable withdrawal
CL 067482	Stocking Creek	447 ML/yr allowable withdrawal
CL 067483	Stocking Lake	123 ML storage
CL 067484	Stocking Lake	802 ML storage

Figure 2-2
Town of Ladysmith
Water Demand Projections, Year 2002-2032



The water licence held for Stocking Lake is for withdrawal only as the CVRD holds the storage licence. Ladysmith's licence permits a maximum annual withdrawal volume of 454,600 m^3 (14.4 L/s average rate), and no more than 2273 m^3 (26.3 L/s) in any one day. The CVRD's water licences on Stocking Lake include storage totalling 666,000 m^3 with an annual withdrawal of 925,000 m^3 (29.3 L/s). The combined licensed withdrawal for Ladysmith and the CVRD is 1,379,600 m^3 (43.8 L/s) which greatly exceeds the estimated 50-year minimum reliable average supply of 18 L/s. It appears that the lake is significantly over licensed, however the Saltair demand only averages 9.3 L/s (based on previous six years of recorded flows).

The total of both Ladysmith water licences will provide on average 88.1 L/s throughout the year. This exceeds the calculated 2022 average daily demand for the Ladysmith water system of 72.1 L/s (6.23 ML/d). Overall there appears to adequate water supply for the community however licensed peak withdrawal rates need adjustment. The combined sources can provide a sustained withdrawal rate of 139 L/s (121 L/s from Holland Creek and 18 L/s from Stocking Lake) through the summer lake drawdown period which is nearly equal to the 2022 maximum day demand for all four communities of 151 L/s (13.07 ML/d). Note that maximum day demand is typically not sustained for more than a few days per year.

WATER QUALITY ISSUES

The Town of Ladysmith completed a significant water quality monitoring study in 2001[3] which summarized the key water quality issues. For details on the specific water quality sampling program, the reader is referred to this study. For the sake of brevity, only those issues which would potentially impact treatment strategies are discussed herein.

DISINFECTION

It is considered that there exists a low to moderate risk for the contamination of the water supply due to *Giardia* or *Cryptosporidium*, although sampling for such pathogens needs to be performed to better quantify the real risk. These pathogens are particularly resistant to traditional disinfectants, and have been implicated in several outbreaks of water borne disease in North America over the last two decades. Concern is particularly high in the drinking water community over *Cryptosporidium*, which is essentially completely resistant to chlorination, and has been linked to several deaths, notably among the immuno-compromised community, in the wake of some of the widely publicized outbreaks. The most well known outbreak occurred in 1996 in Milwaukee, Wisconsin, where over 600,000 people developed *Cryptosporidiosis*.

No sampling for pathogens such as *Giardia* and *Cryptosporidium* has yet been performed by the Town of Ladysmith or Saltair; however activities such as logging are widely practiced in the watershed. Logging activities strip the land of ground cover and root systems which bind the soil. Consequently, topsoil is more easily washed into the water supply during rainfall events, exacerbating turbidity spikes, and potentially providing a pathway for contamination of the supply with *Giardia* and/or *Cryptosporidium* if this runoff contains fecal material from infected wildlife.

Presently, raw water is treated only using chlorination for secondary disinfection, i.e. for the formation of a chlorine residual to protect against growth in the distribution system. Contact times between the point of chlorination and the first customer are inadequate to provide effective inactivation of *Giardia* and viruses. Chlorination is totally ineffective against *Cryptosporidium*.

[3] Earth Tech Canada, "***Water Quality Monitoring Report***", September 11, 2001

Turbidity

While raw water from both Holland and Stocking Lakes is typically of very low turbidity (< 1 NTU), the Town does not draw raw water directly from Holland Lake, but rather allows this water to spill into Holland Creek. As Holland Creek flows towards the Chicken Ladder dam, it converges with several other watercourses, which pick up runoff from heavily logged areas in the watershed. As such, by the time Holland Creek reaches Chicken Ladder, the volume of water is not only swelled by the influx of other streams, but is susceptible to occasional spikes in turbidity during and immediately following rainfall events in the watershed. These turbidity spikes commonly last only 1 or 2 days, and typically reach up to 10 NTU, although more significant spikes have occurred in the past.

Conversely, raw water drawn from Stocking Lake for use in the Town or Saltair is conveyed almost entirely by pipeline, and is not subject to mixing with flashy streams. Turbidity monitoring data from the Contact Tank indicates that water drawn through this branch never exceeds a turbidity of 1 NTU.

Colour

While colour by itself does not pose a health concern, it may be an indicator of other concerns which do pose a health effect (see disinfection by-products below). In addition, discoloured water is decidedly unpalatable to customers, and is one of the most frequent causes of customer complaints.

Town staff anecdotally report seasonal colour events, wherein the water drawn at Chicken Ladder is slightly yellowish in nature. This colour begins to appear almost immediately once the rainy season begins, but tends to persist for an extended period once it has begun. In recent years, this has forced the Town to switch water supply entirely to draw from Stocking Lake in the winter months, since this source is not prone to colour.

Limited data is available to properly quantify these colour events, as the Town historically have completed only apparent colour analyses, by performing colour analyses without pre-filtration of the sample. This results in an abnormally high colour reading, due to interference by particulate matter in the water.

Typical apparent colour readings during colour events range between 20 ACU and 60 ACU, and last for an extended period. The colour is believed to be caused by the leaching of humic and fulvic acids from the decay of natural organic matter (NOM), including soils, leaves, coniferous debris, etc., a phenomenon very common among water sources on Vancouver Island.

Town staff report the presence of slight depression in the lie of the land immediately to the south of the confluence of Holland Creek and South Holland Creek. It has been anecdotally reported that this area routinely becomes a sink for runoff during the year, and collects standing water for much of the year. During the time this water stands in this depression, colour causing compounds are leached from natural organic matter which also naturally collects in the depression. When the rains begin, it has been reported that this area eventually overflows into Holland Creek, causing highly coloured water to begin to enter the Creek.

It is recommended that further reconnaissance of this area be undertaken early in the rainy season, to gather further information on this area, and confirm whether this phenomenon occurs. If this does prove to be a significant contributor to the development of colour in the Chicken Ladder supply, it is conceivable that this issue might be mitigated through simple earthworks, to aid in the drainage of the standing water on a more continual basis.

DISINFECTION BY-PRODUCTS

Humic and fulvic acids formed through the decay of NOM are widely reported to be precursors for the development of chlorinated disinfection by-products, or DBP's. These DBP's are the by-products of the reaction of chlorine with these organic substances, and in many cases have been linked to health effects such as cancer in humans.

The most well known of these chlorinated DBP's are the family of trihalomethanes (or THM's), which at present are the only such compounds regulated under the Canadian Guidelines for Drinking Water Quality (GCDWQ). A lesser known family of chlorinated DBP's are the haloacetic acids, or HAA's, which are as yet unregulated in Canada, but which are regulated in the US.

Occasional DBP sampling has been done by the Town, or through previous water quality testing programs, and to date, no evidence of the formation of THM's or HAA's to levels of concern have been documented in any of this data. This is considered to be partially because it is typical to switch to the higher quality Stocking Lake source in the winter, when colour becomes an issue at the Chicken Ladder intake. As such, the opportunities for testing Chicken Ladder source water for DBP's have historically been rare.

No action is recommended to address DBP's at this time. Health effects due to DBP's are believed to result from the chronic consumption of water high in DBP's. Current regulations in effect for DBP's are concerned more with chronic levels of DBP's in drinking water, and are based typically upon a running average of DBP concentrations in finished water. With organic carbon levels at Chicken Ladder varying seasonally, it is not anticipated that running average DBP concentrations would be cause for concern even if the coloured water were used as a source in the winter.

It is recommended that the Town of Ladysmith & Saltair embark upon a program of performing Simulated Distribution System (SDS) THM and HAA formation potential trials on a quarterly basis, to better characterize the potential risk posed by DBP's. It is recommended that such trials be performed on Stocking Lake water, drawn at the Contact Tank, as well as Holland Lake water drawn at Chicken Ladder Dam.

POTENTIAL FOR CORROSION OF PIPING MATERIALS

Both Stocking and Holland Lakes are known to be sources very low in alkalinity, again very typical of Vancouver Island source waters. Such waters are known to have the tendency to be corrosive towards distribution system piping materials over the long term. This can be particularly true of Asbestos Cement (AC) piping, which is primarily a matrix of calcium carbonate, often with a high tendency to dissolve in waters low in natural alkalinity.

Corrosion might manifest itself in many ways, either through the visible deterioration of pipe walls, valves, or other fittings, or indirectly through staining of laundry or fixtures due to dissolution of metallic piping materials such as copper. It is not uncommon for water utilities to learn of corrosion issues in the water supply through a preponderance of customer complaints due to staining.

Fortunately, discussion with Town staff does not reveal any real or perceived issues with corrosion of piping materials. For the present time therefore, no specific action is recommended to address the potential for corrosion issues, however careful monitoring of customer complaint logs is recommended, for evidence of such issues developing in the future.

SUMMARY OF PRESENT AND ANTICIPATED FUTURE WATER QUALITY REGULATIONS

Having summarized the key water quality issues, it is worthwhile to analyze the present and anticipated future regulatory environment in B.C. for drinking water quality issues, as these will form the framework for the development of water quality objectives.

Historically, drinking water quality objectives in British Columbia have been relatively rudimentary compared to objectives of other provinces in Canada, as B.C. municipalities enjoy a relative abundance of high quality sources. With water rates in B.C. being among the lowest in the Western world, funding issues have also been an obstacle to the release of more stringent standards, for it is of limited use for regulators to establish goals if the means for utilities to achieve these goals are not available.

Recent outbreaks of waterborne disease in Canada have however spurred regulators into action. New and significantly revised regulations for drinking water quality are under development[4], and are likely to be released in 2003. Not surprisingly, initial indications are that these regulations will follow the trend set by other provinces, and will likely be an amalgam of the Guidelines for Canadian Drinking Water Quality and some of the more stringent regulations set by the U.S. Environmental Protection Agency (USEPA).

Unfortunately for purveyors of water, drinking water regulations tend to be a "moving target", and are continually evolving as a greater understanding of the health effects of contaminants in drinking water is developed. It is therefore good practice in the design of new facilities to consider not only the regulatory environment as it exists today, but also to make attempt to anticipate the direction of future regulations, and to build these considerations into design wherever practical and cost effective.

Historically, drinking water regulations in Canada have a history of mimicking, typically with a time lag of several years, drinking water regulations developed by the USEPA. Before we can therefore establish a reasonable set of water quality objectives to serve into the future, it is prudent therefore not only to summarize the present B.C. and Canadian Federal regulations and guidelines, but also the USEPA regulations of relevance.

EXISTING B.C. REGULATIONS

British Columbia has historically boasted some of the more "pristine" raw water sources in Canada, and many of the largest Municipalities in the Province continue to supply unfiltered, disinfected water to the public.

The body of law governing water supply in British Columbia is reasonably simple, as far as drinking water quality is concerned. The Safe Drinking Water Regulation (1994) required primary disinfection of the water, and that the water should generally be essentially free of coliform bacteria. In response to pressures to re-visit this regulation, the B.C. government recently repealed the previous regulation, and issued the Drinking Water Protection Regulation[5]. From the standpoint of water quality however, this new regulation is only marginally more stringent than the previous regulation, re-iterating standards for fecal and total coliforms, and specifying a goal for *E.Coli*.

Many of the larger municipalities in B.C., and indeed across Canada have chosen to pursue a more proactive response to drinking water quality, by adopting drinking water quality goals that exceed the B.C. regulation. The Federal government has published 6 editions to date of a set of guidelines for drinking water quality that in many provinces still far exceed the provincial regulations. These guidelines set limits for many drinking water parameters, based either upon known or suspected health effects as determined by epidemiological study, or

[4] B.C. Drinking Water Review Panel – "***Interim Report***", Submitted to the Ministry of Water, Land, and Air Protection, December 14th, 2001
[5] Province of British Columbia – ***"Drinking Water Protection Regulation"***, May 16th, 2003

upon thresholds beyond which complaints may occur due to un-palatability of the water to the consumer. These Guidelines for Canadian Drinking Water Quality (GCDWQ) have formed the cornerstone for water quality goals for many of these more proactive municipalities.

GUIDELINES FOR CANADIAN DRINKING WATER QUALITY

The Guidelines for Canadian Drinking Water Quality (GCDWQ) were published most recently in the 6th edition in 1996[6]. In order to keep interested parties informed of changes to the Guidelines, a summary table is updated and published every Spring on Health Canada's Web site, the most recent update being in April, 2002[7]. The Guidelines were prepared by the Federal-Provincial-Territorial Subcommittee on Drinking Water of the Federal-Provincial-Territorial Committee on Environmental and Occupational Health, and the Guidelines were published by authority of the Minister of Health. The guidelines include limits for a variety of drinking water parameters, and sub-classify those parameters into 3 sub-groups:

- Those which have a known or suspected health effect, based upon epidemiological and toxicological study. These parameters have been granted a Maximum Acceptable Concentration, or MAC beyond which these health effects may occur, based upon lifelong consumption of drinking water containing the substance at that concentration. Common drinking water parameters for which an MAC is specified in the GCDWQ include: mercury, cyanide, and turbidity. It is of note that the MAC for turbidity is specified not due to direct health effects, but rather due to the fact that elevated turbidity can lead to indirect health effects by hindering effective disinfection.
- Those parameters for which there is believed to be a health effect, but for which insufficient toxicological data has been collected at present. For these parameters, an Interim MAC (or IMAC) is specified, based upon what is believed to be the MAC, but with an increased factor of safety included to compensate for the lack of available data. IMAC's by definition are subject to amendment as further data becomes available. Common drinking water parameters which have been granted an IMAC in the 6th Edition include arsenic, and total trihalomethanes
- Those parameters which may adversely affect the palatability of the water to consumers. An aesthetic objective, or AO, has been specified for these parameters. Common drinking water parameters governed by aesthetic objectives include iron, manganese, turbidity (direct effect only), true colour, taste and odour, and pH.

Table 2-4 below presents a list of some of the most common drinking water parameters of concern, and includes the MAC, IMAC, or AO for each of these parameters. It is to be noted that the parameters listed in Table 2-4 focus primarily upon chemical or physical properties of the water, and none of the parameters in the Table are microbiological in nature. The GCDWQ do provide guidelines for the microbiological quality of the drinking water, but the focus is on total and faecal coliform bacteria. Section 3.4 of the Guidelines stipulates a sampling frequency that must be followed, and Section 3.2 specifies a MAC for total coliform bacteria. Heterotrophic plate counts (HPC) can also be used to estimate background colony counts. The MAC for coliforms published in the Guidelines is zero organisms detectable per 100 mL. However, the Guidelines also present an alternative list of conditions by which drinking water may detect coliforms occasionally but still be considered in compliance with the MAC for coliform bacteria. These conditions consist of:

- No sample should contain more than 10 total coliforms per 100 mL, none of which should be faecal
- No consecutive sample from the same site should show the presence of coliform organisms

[6] Health Canada – "***Guidelines for Canadian Drinking Water Quality***", 6th Edition, 1996.
[7] The update are available on the Internet at: http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/summary.pdf

- For a community drinking water system, no more than one set of samples taken from the community on a given day should show the presence of coliform organisms, and not more than 10% of the samples based upon a minimum of 10 samples should show the presence of coliform bacteria.
- Recommended minimum sampling frequency for a community the size of Ladysmith is 1 sample per month per 1000 population, or at least 12 samples per month (based upon the design population in excess of 12,000).

Currently limited guidance is provided on other pathogens, particularly *Giardia* and viruses, but also *Cryptosporidium*. The GCDWQ specifies that "it is desirable, however, that no viruses or protozoa (e.g. *Giardia*) be detected. A water treatment system that provides effective filtration and disinfection and maintains an adequate disinfectant residual should produce water of an acceptable quality in this regard". Essentially, the GCDWQ advocates a finished water devoid of viruses or protozoa, without providing concrete guidelines for meeting this objective.

Table 2-4
Some Common Drinking Water Parameters included in the GCDWQ

Parameter	MAC, mg/L (unless otherwise noted)	IMAC, mg/L (unless otherwise noted)	AO, mg/L (unless otherwise noted)
Arsenic		0.025	
Barium	1.0		
Cadmium	0.005		
Chloramines (total)	3.0		
Chloride			≤ 250
Chromium	0.05		
True Colour			≤ 15 TCU[1]
Copper			≤ 1.0
Cyanide	0.2		
Fluoride	1.5		
Iron			≤ 0.3
Lead	0.01		
Manganese			≤ 0.05
Mercury	0.001		
Nitrate	45		
pH			6.5 - 8.5
Sodium			≤ 200
Sulphate			≤ 500
Taste & Odour			Inoffensive
Temperature			≤ 15 °C
Total Dissolved Solids			≤ 500
Trihalomethanes (total)		0.1	
Turbidity (see note 3 below)	1 NTU[2]		≤ 5 NTU[2]

Notes:

1. TCU: True Colour units. Denotes the use of a colorimetric colour analysis to determine colour of the water against a standard (blank) sample. The true colour test involves pre-filtration of the source water to eliminate interference effects due to turbidity.
2. NTU: Nephelometric Turbidity Units.
3. The GCDWQ specify two discrete limits for turbidity; An MAC of 1 NTU leaving the plant, to ensure that disinfection is not compromised by the masking of micro-organisms within particles, and an AO of 5 NTU at the point of consumption, to ensure that the cloudiness of the water does not reach unpalatable levels to the consumer.

If any of the above criteria are exceeded, corrective action should be taken immediately. The most common immediate actions include re-sampling to confirm positive results. If the presence of coliforms is confirmed, the cause should be determined if possible, and corrective action taken as appropriate.

Note: In October, 2002 The Federal-Provincial-Territorial Subcommittee on Drinking Water prepared a Document for Public Comment on Turbidity in Drinking Water. The purpose of the Document is to gather comment on the approach used to develop proposed guidelines on Turbidity in Drinking Water and the potential economic costs of implementing them. The part of the Proposed Guidelines most relevant to Ladysmith is the Section "Criteria for Avoiding Filtration for the Waterworks Systems". This section states that "filtration of a surface water source or a groundwater source subject to direct surface influence may not be necessary if all the following conditions are met:

1. Disinfection reliably achieves at least 99.9% (3-log) reduction of *Giardia lamblia* cysts and *Cryptosporidium* oocysts and a 99.99% (4-log) reduction of viruses. Overall inactivation must be met using a minimum of two disinfectants. More than 99.9% (3-log) reduction of Giardia lamblia cysts and *Cryptosporidium* oocysts must be achieved if source water cyst/oocyst levels are greater than 1/100L. Background levels for *Giardia lamblia* cysts and *Cryptosporidium* oocysts in the source water must be established by monitoring every quarter or more frequently during the periods of expected highest levels (e.g., during spring runoff or after heavy rainfall).
2. Prior to the point where the disinfectant is applied, the source water *E.Coli* concentration does not exceed 20/100mL, in at least 90% of the weekly samples from the previous six months.
3. Average daily source water turbidity levels measured at equal intervals (at least every four hours) immediately prior to where the disinfectant is applied do not exceed 5.0 NTU for more than two days in a 12-month period.
4. A watershed control program (e.g. protected watershed, controlled discharges, etc.) is maintained that minimizes the potential for faecal contamination in the source water.

This draft guidelines closely mimics the language of the filtration avoidance criteria specified under the U.S. Surface Water Treatment Rule (SWTR), and is of particular relevance, as it indicates that if source waters can be managed in such a fashion as to never exceed 5 NTU, then filtration need not be provided on the water supply.

Relevant Existing and Anticipated Future U.S. Drinking Water Regulations

Background

The Safe Drinking Water Act (SDWA) was enacted by the United States Congress and signed into law in 1974. Through the SDWA, the federal government gave the United States Environmental Protection Agency (the USEPA) the authority to set standards for contaminants in drinking water supplies.

In 1986 and 1996, U.S. Congress passed two sets of amendments to the SDWA. The provisions of these amendments currently govern the process through which the USEPA develops drinking water regulations and sets compliance dates. Under these provisions, the USEPA has published a Drinking Water Contaminant Candidate List (CCL). The contaminants on this list are not currently regulated and every five years, the USEPA is charged to select five contaminants from this list to determine whether or not to regulate their concentration in drinking water.

Current Federal Regulations

In accordance with the SDWA and its amendments, the USEPA has established a number of drinking water regulations and the major ones are discussed below. For the sake of brevity, only those regulations which may one day have impact on the Town of Ladysmith or Saltair by forming a benchmark for future Canadian Federal or Provincial regulations are discussed herein.

National Primary Drinking Water Regulations (Finalized in 1975)

This included standards for 22 compounds that were originally adopted by the USEPA under the SDWA. These contaminants have since been updated or replaced by subsequent regulations. See Table 2-5 for a list of current maximum contaminant levels.

Secondary Drinking Water Regulations (Finalized in 1979, 1991)

Standards for compounds established under this regulations are advisory in nature from the USEPA and are applied as determined by each State. These standards generally address aesthetic issues related to drinking water.

Trihalomethane Regulation (Finalized in 1979)

This regulation established a maximum contaminant level of 100 μg/L for total trihalomethanes in the distribution system. It has since been replaced by subsequent regulations that address trihalomethanes as well as other disinfection by-products.

Surface Water Treatment Rule (Finalized in 1989)

The Surface Water Treatment Rule (SWTR) was promulgated to control the levels of turbidity, *Giardia lamblia, Legionella,* viruses, and heterotrophic plate count bacteria in drinking waters. Filtration is required for all surface water supplies and groundwater supplies under the influence of surface waters. Exemptions to filtration are given only when the utility has control of the source watershed and the watershed produces a pristine water supply that meet rigid water quality standards.

The turbidity requirements established in the SWTR for conventional filtration plants include:

a. "...the turbidity of representative samples of a system's filtered water must be less than or equal to 0.5 NTU in at least 95 percent of the measurements taken each month..."

b. "The turbidity level of representative samples of a system's filtered water must at no time exceed 5 NTU..."

The disinfection requirements for systems that filter include:

a. "The disinfection treatment must be sufficient to ensure that the total treatment processes of that system achieve at least 99.9 percent (3-log) inactivation and/or removal of *Giardia lamblia* cysts and at least 99.99 percent (4-log) inactivation and/or removal of viruses, as determined by the State."

b. "The residual disinfectant concentration in the water entering the distribution system...cannot be less than 0.2 mg/L for more than 4 hours."

c. "The residual disinfectant concentration in the distribution system ...cannot be undetectable in more than 5 percent of the samples each month. ...Water in the distribution system with a heterotrophic bacteria concentration less than or equal to 500/mL, ...is deemed to have a detectable disinfectant residual for purposes of determining compliance with this requirement."

A conventional water treatment plant meeting SWTR requirements is given 2.5-log removal credit for *Giardia* and 2.0-log removal credit for viruses. The remaining required log removal is met through disinfection with sufficient contact times as determined in the USEPA Guidance Manual to the SWTR.

The SWTR also allows provision for utilities to provide drinking water to customers without filtration, but defines a specific list of criteria which need to be met for "Filtration Avoidance" to be claimed. The most important of these criteria are as follows[8,9]:

- At least 90 percent of the source water samples collected during the previous 6 months must have coliform concentrations less than or equal to 20 per 100 mL for faecal coliforms, and ≤ 100 per 100 mL for total coliforms.
- Each day the system serves water to the public and the turbidity of the source water exceeds 1 NTU, one raw water sample must be collected for faecal or total coliform analysis.
- Generally speaking, the raw water turbidity can at no time exceed 5 NTU. However, the individual State regulator may allow a system to exceed this level if both of the following conditions are met:
  - It is determined that the turbidity exceedance was caused by circumstances that were unusual or unpredictable, and;
  - Counting the current instance of excess turbidity, there have not been more than 2 events in the last 12 months, or 5 events in the last 120 months where source water turbidity exceeded 5 NTU for any reason. "Events" are defined as a series of more than one consecutive days where any single turbidity measurement exceeded 5 NTU.
- The disinfection treatment process used by non-filtering systems must ensure 99.9% (3-log) inactivation of *Giardia* and 99.99% (4-log) inactivation of viruses.
- The water system must maintain a watershed control program that minimizes the potential for contamination in the source water.

[8] Von Huben, H. – "**Surface Water Treatment – The New Rules**", American Waterworks Association, 1991
[9] USEPA – "**Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems using surface Water Sources**"

Total Coliform Rule (Finalized in 1989)

The Total Coliform Rule (TCR) details the frequency and type of monitoring for total coliform in the distribution system and sets the maximum contaminant level for total coliforms as the following:

1. For a system collecting more than 40 samples per month there can be no more than 5.0% of the samples collected during the month total coliform-positive (non-acute violation).

2. For systems collecting less than 40 samples per month, a non-acute violation occurs when there is more than one positive coliform sample in a given month (non-acute violation).

3. Any faecal coliform-positive repeat sample or *E.Coli* positive repeat sample, or any total coliform-positive repeat sample following a faecal coliform or *E.Coli* positive routine sample constitutes an acute violation of the MCL for total coliforms.

This classification is given under two conditions. First, condition is when an initial sample is total coliform positive and is determined to be either faecal or *E.Coli* positive. The second condition is when two repeat samples are total coliform-positive but neither sample is faecal coliform or *Positive*-positive These conditions are not considered a violation of an MCL; however it does require notification to the State regulator.

Lead and Copper Rule (Finalized in 1991, 1996)

The objective of the Lead and Copper Rule (LCR) is to minimize the corrosion of lead and copper-containing plumbing materials in distribution systems by requiring utilities to optimize system corrosion control. The rule includes requirements for home tap monitoring at worst case sites, corrosion control treatment, source water treatment, lead service line replacement, and public education. The LCR establishes "action levels" in lieu of MCLs. The action level for lead was established at 0.015 mg/L while the action level for copper was set at 1.3 mg/L. An action level is exceeded when greater than 10 percent of samples collected from the sample pool contain lead levels above 0.015 mg/L or copper levels above 1.3 mg/L. Unlike an MCL, a utility is not out of compliance with the LCR when an action level is exceeded; rather, utilities are required to take additional steps to reduce system corrosion.

This regulation is potentially of interest, as it might eventually become adopted in Canada in the future, and would force a closer look at the potential for distribution system corrosion in the distribution system.

Interim Enhanced Surface Water Treatment Rule (1998)

This rule amended the existing SWTR and added requirements for inactivation of *Cryptosporidium*. This rule was promulgated along with the Stage 1 D/DBP rule (see below) to address risk trade-offs with disinfection by-products. Under this rule, systems must continue to meet existing requirements for *Giardia lamblia* and viruses plus meet the following:

- 2-log *Cryptosporidium* removal requirements for systems that filter
- Strengthened combined filter effluent turbidity performance standards
- Individual filter turbidity monitoring provisions
- Requirements for covers on new finished water reservoirs

In addition, the rule includes disinfection profiling and benchmarking provisions to assure continued levels of microbial protection while facilities take the necessary steps to comply with new DBP standards. Conventional and direct filtration plants that meet the strengthened turbidity performance standards are granted 2-log *Cryptosporidium* removal credit. Utilities must have been in compliance with this rule by January 1, 2002.

Stage 1 D/DBP Rule (Finalized 1998)

This rule revised the maximum contaminant level for trihalomethanes to 80 ug/L. It also sets maximum contaminant levels for haloacetic acid (5) at 60 ug/L, chlorite at 1 mg/L and bromate at 10 ug/L. In addition, the rule sets maximum residual disinfectant level for chlorine and chloramine at 4 mg/L (as Cl_2) and for chlorine dioxide at 0.8 mg/L (as ClO_2). Furthermore, conventional treatment plants whose source water is a surface supply must reduce total organic carbon through the use of enhanced coagulation. Utilities must have been in compliance with this rule by January 1, 2002.

Long Term 1 Enhanced Surface Water Treatment Rule (Finalized Jan 2002)

This rule extends the requirements (with some modifications) of the Interim Enhanced Surface Water Treatment Rule to smaller water systems (i.e. systems serving less than 10,000 people). Compliance date for most of the rule requirements will be in 2005.

Table 2-5
U.S. Primary Drinking Water Standards

Parameter	Value
Disinfectants & Disinfection By-products	**MCL (mg/L)**
Bromate	0.01
Chloramines (as Cl_2)	MRDL=4.0
Chlorine (as Cl_2)	MRDL=4.0
Chlorine dioxide (as ClO_2)	MRDL=0.8
Chlorite	1
Haloacetic acids (HAA_5)	0.06
Total Trihalomethanes (TTHM's)	0.08
Inorganic Chemicals	**MCL (mg/L)**
Antimony	0.006
Arsenic	0.05
Asbestos	7 MFL
Barium	2
Beryllium	0.004
Cadmium	0.005
Chromium (total)	0.1
Copper	Action Level=1.3
Cyanide (as free cyanide)	0.2
Fluoride	4
Lead	Action Level=0.015
Mercury (inorganic)	0.002
Nitrate (measured as Nitrogen)	10
Nitrite (measured as Nitrogen)	1
Selenium	0.05
Thallium	0.002

Notes:

1. MRDL: Maximum Residual Disinfectant Level
2. MCL: Maximum Concentration Limit, equivalent to the MAC, or Maximum Acceptable Concentration in the GCDWQ

3. Action Level: The point at which a purveyor of water must take action to mitigate levels of contaminant in the water supply

Anticipated Future U.S. Federal Regulations

In addition to the current regulations, the USEPA is developing a number of new regulations to safeguard public drinking water. Some of these regulations have been officially proposed and have gone through the public comment period. Others are still being developed by the USEPA with input from various advisory panels. These anticipated regulations are briefly described below. It is important to note that these descriptions reflect the general understanding of the direction that the USEPA may take with these regulations as of December, 2002. Until these regulations are finalized, the content of the regulations remain subject to change.

Anticipated Stage 2 D/DBP Rule

In December, 2000, the Federal Advisory Committee signed an Agreement in Principle which will guide the USEPA in preparing a proposal for the anticipated Stage 2 D/DBP Rule. A pre-proposal draft of the preamble and regulatory language of this rule was released in 2001. The proposed rule is expected to keep the maximum contaminant levels established for THM's, HAA_5, bromate and chlorite the same as those established in the Stage 1 D/DBP Rule; however, the methods for determining compliance are expected to change. First, an initial distribution system evaluation will be required for utilities to locate areas in their system with the highest concentrations of THM's and HAA_5. Utilities will be required to change some of their sampling locations for compliance monitoring to new locations with historically higher THM and HAA_5 levels.

To determine compliance, the running averages of four quarterly samples will be reported for each sample location and will not be averaged across locations. This method of locational averaging instead of the system-wide averaging may be more difficult for utilities to be in compliance, due to areas where DBP levels are much higher than system average. To transition from the system-wide averaging to the locational averaging methods, the Stage 2 Rule will include interim maximum contaminant levels. Beginning with three years after promulgation of the Stage 2 Rule, the maximum contaminant level for THM and HAA_5 using the new locational running annual average (LRAA) method will be 120 ug/L and 100 ug/L, respectively. During this period, utilities must continue to meet the requirements of Stage 1 D/DBP rule. This interim standard will last for three years before compliance with 80 ug/L of THM and 60 ug/L of HAA_5 is expected using the new locational averaging method. The Stage 2 D/DBP Rule was expected to be proposed by third quarter 2002 and finalized by third quarter 2003.

Anticipated LT2 Enhanced Surface Water Treatment Rule

In December, 2000, the Federal Advisory Committee signed an Agreement in Principle which will guide the USEPA in preparing a proposal for the anticipated Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). The USEPA released the pre-proposal draft of this rule in 2001. The anticipated LT2ESWTR will classify water systems into categories of additional *Cryptosporidium* removal requirements based on results from 24 months of monitoring. If the system's source water is classified in the lowest bin, no additional *Cryptosporidium* inactivation will be required. The bin classifications are as follows (where "C" is the annual average *Cryptosporidium* oocyst counts per Litre (Table 2-6).

Table 2-6

Cryptosporidium Bin Definitions under the Proposed U.S. the USEPA LT2ESWTR

Cryptosporidium Average Concentration (oocysts per L)	Overall *Cryptosporidium* Objective
C < 0.075/L (**Bin #1**)	3-log (99.9% removal or inactivation)
0.075 < C < 1.0 counts/L (**Bin #2**)	4-log (99.99% removal or inactivation)
1.0 < C < 3.0 counts/L (**Bin #3**)	5-log (99.999% removal or inactivation)
C ≥ 3.0 counts/L (**Bin #4**)	5.5-log (99.9997% removal or inactivation)

Systems in the highest bin will require 2.5 log of additional *Cryptosporidium* inactivation in addition to the requirements of the Interim Enhanced Surface Water Treatment Rule. The proposed rule is expected to provide a "toolbox" of options to meet the treatment requirements. The rule will also address uncovered finished water reservoirs. The reservoirs must either be covered, be treated at the outlet to achieve 4-log virus inactivation, or be deemed by the state as having adequate risk mitigation in the areas of physical access, surface water run-off, animal and bird waste, and on-going water quality assessment. The Stage 2 DBP Rule was expected to be proposed by third quarter 2002 and finalized by third quarter 2003.

RECOMMENDED WATER QUALITY OBJECTIVES

Armed with the knowledge of the present and anticipated future drinking water regulatory environment, a set of reasonable water quality objectives can be formulated. These recommended water quality goals are presented as **Table 2-7**. The Table shows for each parameter, the present or anticipated future standard in B.C., and the recommended goal.

Table 2-7

Recommended Water Quality Goals

Parameter	Present B.C. Standard	Anticipated Future B.C. Standard	Recommended Goal
All parameters listed under the GCDWQ	Not applicable at present	GCDWQ	The standard listed in the GCDWQ, except where superseded below
Trihalomethanes	None	100 ug/L	LRAA: 80 ugL
Haloacetic Acids	None	Unclear at present, still not regulated by the GCDWQ	LRAA: 60 ug/L
Giardia cysts	None	3-log removal or inactivation	3-log removal or inactivation
Viruses	None	4-log removal or inactivation	4-log removal or inactivation
Cryptosporidium oocysts		3-log removal or inactivation	3-log removal or inactivation

Notes:

1. LRAA= Locational Running Annual Average. This involves the monitoring of the running annual average at each sampling point. The worst case sampling location is used as the benchmark for comparison against the goal. Existing Canadian regulation for DBP's allows the averaging of sample results from all sampling locations in the system, such that poor results at a single location might be offset by better results at other locations. The LRAA is therefore a more stringent approach to the monitoring of DBP's.

SUMMARY OF OTHER PROJECT DESIGN CRITERIA

In addition to the objectives for water quality, which will inevitably drive the design of any new water treatment facilities, it is prudent also to summarize design criteria or standards used in the sizing of all other facilities included under this study.

RESERVOIR SIZING

It is a common industry practice to include at least three, and possibly four distinct components of storage in the design of reservoirs. These as are follows:

1. Balancing Storage – In a water system such as the Town of Ladysmith / Saltair system, the existing chlorination facilities must be designed to deliver the design chlorine dosage at all times during the day, even when peak hour demands are experienced. If more advanced treatment techniques are employed, it is generally not cost effective to design these systems to handle peak hour demands. Balancing storage is therefore commonly provided downstream of the treatment plant so that the treatment facilities can be designed to handle peak day demand, and the balancing storage is used to "shave" spikes in demand. The actual volume required for this purpose is typically calculated during detailed design, and is based upon actual diurnal demand curves. For the purposes of this preliminary design study, a volume equivalent to 25% of the maximum day demand has been used.
2. Emergency Storage – This is emergency storage to cover interruptions to the supply. The volume is also estimated at 25% of the maximum daily demand. For a two source supply, this volume is estimated for failure of the larger source and is equivalent to 25% of the maximum day demand less the supply rate available from the smaller source.
3. Fire Storage – Fire storage is calculated as 2 hours of the maximum fire flow demand. This volume of fire storage must be able to be recharged within 24 hours.
4. CT Storage – That volume of water required to provide disinfection. If the reservoir is being used for this purpose, and since disinfection needs to be maintained at all times, this volume is sometimes included in addition to the other three forms of storage, to ensure that effective disinfection was maintained even under the worst case conditions when all other storage reserves had been exhausted. The actual volume required for this purpose is contingent upon the specific degree of disinfection required.

FIRE FLOW RATES

The fire flow demand rates have been estimated from the 'Guide for Determination of Required Fire Flow, Fire Underwriters Survey'. For this study, detailed fire flow calculations were not completed for actual buildings throughout the system; they were simply estimated for general types of buildings and the critical locations for these buildings were determined based on the Town of Ladysmith's Official Community Plan. The fire flow rates were estimated as follows:

Detached Dwellings	80 L/s
Townhouses and Apartment Buildings	170 L/s
Commercial, Industrial & Institutional Buildings	330 L/s

SECTION 3.0
DEVELOPMENT OF ALTERNATIVES

RAW WATER CONVEYANCE

Hydraulic modeling of the water conveyance and distribution piping network was completed using the EPANet program as embodied within WATSYS. The Town provided the basic model network and Earth Tech updated the nodal demands to reflect the current projections and fire flows.

The capacities and corresponding design flows for main conveyances are tabulated below (Table 3-1):

Table 3-1
Estimated Capacity of Raw Water Conveyance Pipelines

Pipe Locations	Size & Type (mm diameter)	Maximum Capacity (L/s)‡	Maximum Day Demand (L/s)
Chicken Ladder to Arbutus Reservoir	Two mains (300 AC and 200 AC)	270	151
Stocking Lake to Balancing Reservoir	250 CI	170	151
Balancing Reservoir to Contact Tank	300 AC	> 300	151
Contact Tank to Valve House	Two mains (300 AC and 250 PVC)	≈ 250	151
Valve House to Arbutus Reservoir (Crossover Main)	200 AC	80	117
Stocking Lake to Saltair	250 AC	≈ 200	35.5

Notes:

‡: Assuming the entire demand is drawn from either the Holland Creek or Stocking Lake source.

AC: Asbestos Cement

PVC: Polyvinyl Chloride

CI: Cast Iron

Figure 3-1 illustrates the main water supply conveyance pipelines. All conveyances have adequate capacity for anticipated future demands, with the exception of the crossover main, which has a calculated capacity of only 80 L/s. Even though the crossover main does not have capacity to convey the maximum day demand from the Stocking Lake source to the Arbutus Reservoir for the north end demand (for alternatives that consolidate water treatment near the Balancing Reservoir), maximum day capacity should not be required as the high turbidity events on Holland Creek that force closure of the intake will not occur during maximum day periods. Since the crossover main is required in some future supply options and not others and its life expectancy is expected to be less than that of the other proposed facilities, its future replacement value in 15 years been included in the cost comparisons.

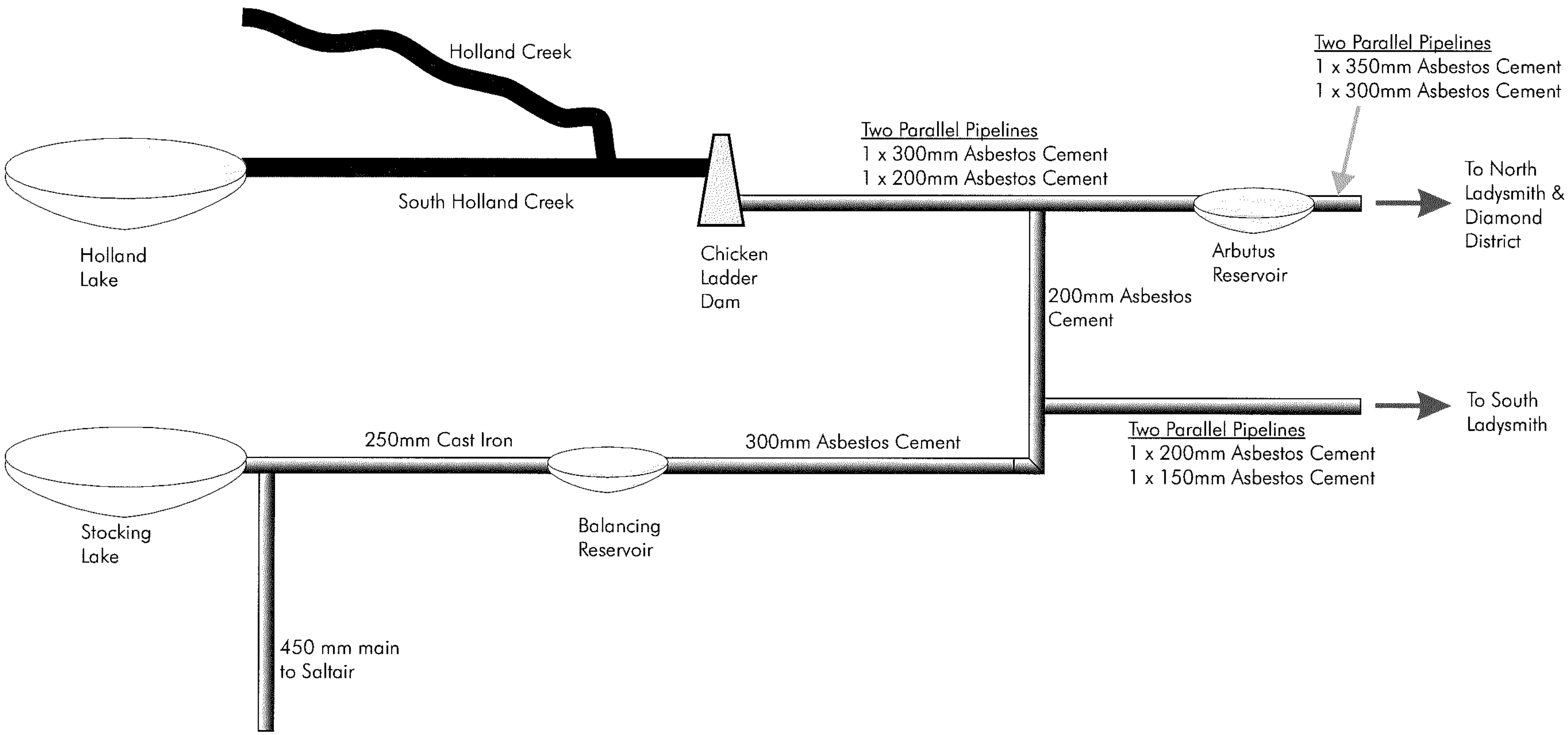


Figure 3-1: Main Conveyance Pipelines

The main deficiencies in the raw water conveyance system include the lack of an automatic system that would help provide a steady release of creek flow downstream from the Chicken Ladder intake (for environmental protection reasons) while minimizing the wastage of water, as well as a lack of automation on the raw water supply upstream of the existing treatment facilities, to give advanced notice of changes in raw water quality.

WATER TREATMENT PROCESS OPTIONS

Water treatment requirements will depend heavily upon which of the two source waters needs to be treated. Since Stocking Lake does not experience the colour and turbidity issues experienced seasonally from the Holland Lake source, facilities which treat only this source can necessarily be much simpler in design, needing only to ensure that disinfection targets are met.

Conversely, facilities which will treat water from Holland Lake, whether they treat exclusively this water, or a blend of Holland and Stocking Lake will need to be able to address colour removal and turbidity spiking while at the same time meeting disinfection targets.

As a starting point in the formulation of viable treatment trains, it is valuable to consider some of the potential treatment techniques in the treatment "toolbox" which might be viable. Table 3-2 lists each of these techniques, and summarizes treatment goals these techniques might be used to address, as well as their typical efficacy in addressing these goals.

Table 3-2
Possible Treatment Techniques

Treatment Technique	Treatment Objective					
	Bacteria	*Giardia*	*Cryptosporidium*	Viruses	Colour Removal	Turbidity Removal
Chlorination	☆☆☆☆☆	☆☆	☆	☆☆☆☆	☆	
Chloramination	☆☆☆	☆	☆	☆☆		
Ozonation	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	
Chlorine Dioxide	☆☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆	
Ultraviolet (UV Disinfection	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆	☆	
Direct Filtration	☆☆☆	☆☆☆	☆☆☆	☆☆☆	☆☆	☆☆☆☆☆
Clarification-Filtration	☆☆☆	☆☆☆	☆☆☆	☆☆☆	☆☆☆☆☆	☆☆☆☆☆
Membrane Filtration	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆		☆☆☆☆☆
Membrane Filtration with Pre-treatment	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆

Note:

1. The treatment processes are rated subjectively as follows:

No stars:	No removal
☆:	Poor
☆☆:	Mediocre
☆☆☆:	Average
☆☆☆☆:	Good
☆☆☆☆☆:	Excellent

The follow paragraphs present a brief description of each of the various process options.

CHLORINATION & CHLORAMINATION

Chlorination is the only method of treatment presently practiced, and involves the addition of chlorine to the water for the purposes of disinfection. The chlorine can take many forms, including gaseous chlorine (as is presently used), sodium hypochlorite, or calcium hypochlorite. For the purposes of further evaluation under this study, it is assumed that if chlorination were to be continued, it would be in the gaseous form, as it is the form currently in use, and is the most cost effective.

Chlorine is an excellent disinfectant for bacteria, but is less effective against some other common pathogens of concern, including viruses, and *Giardia*. It is essentially completely ineffective against *Cryptosporidium*.

In addition to its benefits as a primary disinfectant, i.e. a disinfectant used to kill pathogens, it is an outstanding secondary disinfectant, able to protect the distribution system from biological re-growth, due to its ability to form a residual and decay reasonably slowly.

One of the potential drawbacks of chlorination is the tendency to react with natural organic matter (NOM) to form disinfection by-products.

Chloramination is a variant of chlorination involving the combined use of chlorine with ammonia. It is a considerably weaker disinfectant than chlorine, but tends to decay much more slowly than chlorine, and forms much lower levels of DBP's than chlorine. As such, it is used in the drinking water industry primarily as a secondary disinfectant, and is particularly well suited for carrying a disinfectant residual through extensive distribution systems. The CRD have historically used chloramines for protection of the distribution system throughout Victoria, and into the Saanich Peninsula.

Since loss of chlorine residual in the distribution has not been documented to be a problem in the Ladysmith / Saltair system, there is little advantage in considering chloramines, and they are therefore not considered further in this evaluation.

OZONATION

Ozonation involves the contacting of the water to be treated with ozone. Ozone is one of the strongest disinfectants available for drinking water treatment, and is also an extraordinarily powerful oxidant. It is highly unstable, and rapidly decays in solution. As such, it is generated on-site using oxygen as the raw material (either in the form of liquid oxygen or in air):

$$O_{2(g)} + \text{Electrical Energy} \Rightarrow O_{3(g)} \quad \text{.......(8)}$$

Oxygen + Electrical Energy ⇒ Ozone

Ozone is highly effective for kill of bacteria, viruses, *Giardia*, and *Cryptosporidium*, but is also capable of chemically attacking colour causing compounds such as the humic and fulvic acids, by cleaving them into smaller organic compounds, which no longer impart a colour to the water. Although the actual dosages required for effective colour removal using ozone vary considerably by case, many studies show that for colour levels up to 50 TCU, a dosage of 1 mg/L ozone will typically achieve approximately 10 TCU colour removal[10].

As a treatment alternative for the Town of Ladysmith supply, ozonation would offer several potential benefits, being able to specifically target most of the treatment issues faced by the Town of Ladysmith, with the exception of turbidity removal.

A potential drawback of ozonation is also derived from the well documented oxidizing capability of ozone, which in the process of cleaving long chain organic molecules into shorter chain molecules, generally tends to form organic substances more easily assimilable as a food source by bacteria. This formation of assimilable organic carbon (AOC) can result in an increased tendency towards bacterial re-growth in the distribution system. In cases where this has proven to be an issue, often the use of chloramination for secondary disinfection has proven helpful, as it has often improved effectiveness against bacterial re-growth than chlorine[11].

Both the determination of design ozone dosages for effective colour removal, and the potential for increased re-growth due to AOC formation are significant issues which would need to be investigated prior to design of new facilities through pilot scale testing.

Chlorine Dioxide

Although chlorine dioxide has been a commercially viable disinfection alternative for some time, it is only in recent years that interest in the technology has grown, driven by its documented ability to provide inactivation of micro-organisms such as *Cryptosporidium* that are chlorine resistant, and the reduced tendency for DBP formation compared to chlorine.

Chlorine dioxide is generated on-site through the reaction of chlorine with sodium chlorite:

$$Cl_{2(g)} + 2\ NaClO_2 \Rightarrow 2\ ClO_2 + 2\ NaCl$$

Chlorine + Sodium Chlorite ⇒ Chlorine Dioxide + Salt

As a disinfectant, chlorine dioxide is stronger than chlorine, however it typically shows a tendency to decay more rapidly in the distribution system. It has been shown to be effective in the control of many taste & odour issues in drinking water, but in isolated cases has been documented to cause a cat-urine like odour in some applications, due to chlorine dioxide off-gassing at the customer tap.

UV Disinfection

UV disinfection has been the focus of intense research in the drinking water industry, due to the finding that *Cryptosporidium* can be inactivated cost effectively using this technology. Until a few years ago, the use of UV for primary disinfection in drinking water was rare, as systems were designed to kill pathogens, and large UV fluences (or dosages) were required. More recent research led to the breakthrough finding that much lower fluences could be effective, not through killing the pathogens, but by causing an alteration of the DNA structure, precluding the oocyst from reproducing.

UV disinfection utilizes light within the UV spectrum, typically consisting of wavelengths from 230-300 nm with

[10] AWWARF, Compagnie Generale des Eaux – "**Ozone in Water Treatment – Application & Engineering**", Lewis Publishers, 1991, p. 162.
[11] Reid Crowther & Partners – "**Greater Victoria Water District – Ozone Pilot Testing Report**", 1994

254 nm being the standard for low-pressure UV lamps. UV systems differ in the types of lamps used and include low-pressure mercury lamps, low-pressure high output mercury lamps and medium pressure lamps. These lamps differ in the amount of power required, wavelength and operating life. Although properties of the lamps differ, the disinfection effectiveness is based on UV fluence (or dose), and is defined as the radiant energy of all wavelengths passing from all directions through a cross sectional area and is expressed in mJ/cm^2. Research efforts within the last five years have demonstrated that a UV dose of 40 mJ/cm^2 will consistently achieve greater than 3-log reductions for both *Giardia* and *Cryptosporidium*.

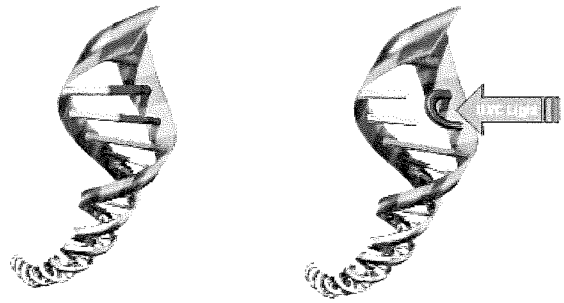


Figure 3-2: UV Irradiation causes disruption of DNA, eliminating the possibility of reproduction

UV disinfection consists simply of a UV reactor placed within water pipelines. The necessity to provide redundancy generally mandates the placement of multiple UV reactors in parallel. The UV reactors are designed to ensure complete hydraulic mixing is achieved, which ensures that the UV dose is applied uniformly to the water passing through the reactor. UV does not provide for any residual disinfectant and therefore must be followed by some type of chlorination for the distribution system.

DIRECT (OR IN-LINE) FILTRATION

This technique involves the granular media filtration of the water without pre-treatment clarification processes upstream of the filters to reduce solids loading to the filters. Since all solids in the raw water pass directly onto the filter, it is generally only to use direct filtration for source waters of high quality, i.e. typically < 5 – 8 NTU, to ensure that filter run times are maximized. Direct filtration utilizes both coagulation and flocculation upstream of the filter to generate floc particles which are optimized for filtration. In-line filtration differs from direct filtration in the fact that only coagulation, and not flocculation is provided.

Based upon our experience, both direct and in-line filtration would likely be viable processes for both the Stocking and Holland Lake source water, but only when colour levels are low in the Holland source. Coagulant dosages would need to be increased during elevated colour events, thereby significantly increasing solids loading to the filters, and likely reducing filter run times and possibly performance during the period that the colour persisted.

CLARIFICATION/FILTRATION

This technique involves the use of a clarification process upstream of the filters, to reduce solids loading to the filters, and extend filter runs. Provision of clarification would allow even the coloured Holland Lake water to be treated, as coagulation can provide for highly effective colour removal in the clarification process without burdening the filters. Several clarification techniques are potentially viable, including horizontal sedimentation, high rate sedimentation with plate or tube settling modules, dissolved air flotation (DAF), and ballasted sedimentation (ActiFlo©). Of these clarification techniques, DAF is ideally suited to the clarification of coloured, impounded source waters which tend to carry low density turbidity particles, and which generally form a light floc during coagulation. The DAF process is a high rate process, allowing a very compact layout to be employed.

DAF employs the use of a cloud of microbubbles, following flocculation, to attach themselves to the floc, and carry them to the surface, where they can be easily removed. The cloud of microbubbles is produced using a recycle stream from the clarified effluent of the DAF clarifier. The recycle stream is pumped into a pressure vessel in which the water is saturated with air supplied from an air compressor. As the water is under pressure more air is entrained within the water than would be at near atmospheric pressure. The saturated water is directed to the inlet of the DAF clarifier at which point the pressure is suddenly released resulting in the air coming out of solution. The microbubbles that are formed typically have a diameter within the range of 10-100 μm. These bubbles attach themselves to the light flocs and the buoyant forces of the bubbles cause the floc to rise.

Membrane Filtration

Interest in low pressure membrane filtration techniques such as micro- (MF) or ultra-filtration (UF) has grown significantly in recent years, as unit costs have declined rapidly through advances in research & development efforts. Besides the increasingly attractive cost of membranes, an additional strong attraction to the technology is derived from the fact that both MF (typical pore size 0.1 – 0.2 microns) and UF membranes (typical pore size 0.01 microns) possess nominal pore sizes smaller than the nominal size of both *Giardia* and *Cryptosporidium* cysts (pore sizes in the 1 – 7 micron range), thereby representing a physical barrier to passage of the pathogens into the treated water, as long as the membranes remain intact.

MF and UF membranes will typically be granted the following log removal credits for pathogens of concern:

MF: 4-log *Giardia*, 4-log *Cryptosporidium*, 2-log viruses

UF: 4-log *Giardia*, 4-log *Cryptosporidium*, 4-log viruses

As such, both MF or UF are capable of meeting overall removal objectives for these pathogens in a single process.

Neither type of membrane are capable of achieving any appreciable removal of colour without pre-treatment however, due to the fact that colour is generally imparted by dissolved substances.

Membrane Filtration with Pre-Treatment

Both MF and UF membranes can be employed with pre-treatment, specifically targeted for colour removal. Since pore sizes are so small, effective colour removal can often be achieved with coagulation only, as only a pin floc needs to be developed for effective removal by the membranes.

Clarification techniques are also increasingly being employed upstream of membrane filtration systems, as the combination of effective coagulation, flocculation, and clarification should significantly reduce the loading of solids and organic compounds to the membranes. This can not only allow higher membrane fluxes to be used in design, resulting in the need for fewer membranes, but can also extend membrane life substantially.

Armed with an understanding of the capabilities of the various unit processes to deal with the relevant water quality issues, it is possible to conceptualize potential treatment trains composed of these processes designed to meet the overall goals.

Figures 3-3 through 3-8 illustrate schematically each of the process trains considered viable. It will be noted that each schematic demonstrates how source water from the Holland Creek watershed or Stocking Lake would be treated. Viable process trains include:

Ozonation-Chlorination (Figure 3-3)

Under this option, ozonation would be provided for the purposes of both colour removal and primary disinfection, for inactivation of *Cryptosporidium*, *Giardia*, and other pathogens. Chlorination is provided for secondary disinfection, to provide a chlorine residual for protection of the distribution system. The Town would operate primarily using Chicken Ladder as the source, and could discontinue the practice of switching to the Stocking Lake source when true colour levels increase in the Chicken Ladder source. Raw water turbidity monitoring would be needed on the Chicken Ladder supply to allow switching to Stocking if a turbidity event occurred.

Since ozonation is providing the dual purpose of primary disinfection and colour removal, the process must be maintained in service at all times, to ensure these goals are consistently met. This process train would not be expected to achieve any removal of turbidity however, and source selection would have to be practiced to ensure raw water turbidity stayed consistently below the filtration avoidance targets.

A key benefit of this approach is that no chemicals other than chlorine are added to the water, and no sludges are produced.

UV-Chlorination (Figure 3-4)

Under this option, UV disinfection is provided for inactivation of *Cryptosporidium*, *Giardia*, and other pathogens. Chlorination is provided for secondary disinfection, to provide a chlorine residual for protection of the distribution system. Both Chicken Ladder and Stocking water would be treated in the same fashion.

The primary drawback of this treatment approach, while it would certainly be the lowest cost alternative, is that neither UV or chlorination are capable of consistently meeting turbidity or colour removal goals when treating Chicken Ladder water (colour removal using UV requires significantly higher dosages than those typically employed for disinfection). As such, it would still be necessary to switch from Chicken Ladder to Stocking for extended periods during the winter months while water quality deteriorates. Although this is feasible at present, as demands rise it will become increasingly difficult to do so, and will reduce operational flexibility significantly.

A key benefit of this approach is that no chemicals other than chlorine are added to the water, and no sludges are produced.

Pre-Sedimentation-UV-Chlorination (Figure 3-5)

Under this option, a large pre-sedimentation pond or basin would be provided for pre-treatment of the water. Coagulant may or may not be added as needed. The pond could serve to reduce both colour and turbidity in Chicken Ladder water. If Chicken Ladder source water quality was good, then the pond could be by-passed. If the Chicken Ladder source is used during turbidity spikes, then the Town would be unable to leverage the filtration avoidance criteria, and would likely be required to provide filtration under the draft guidelines.

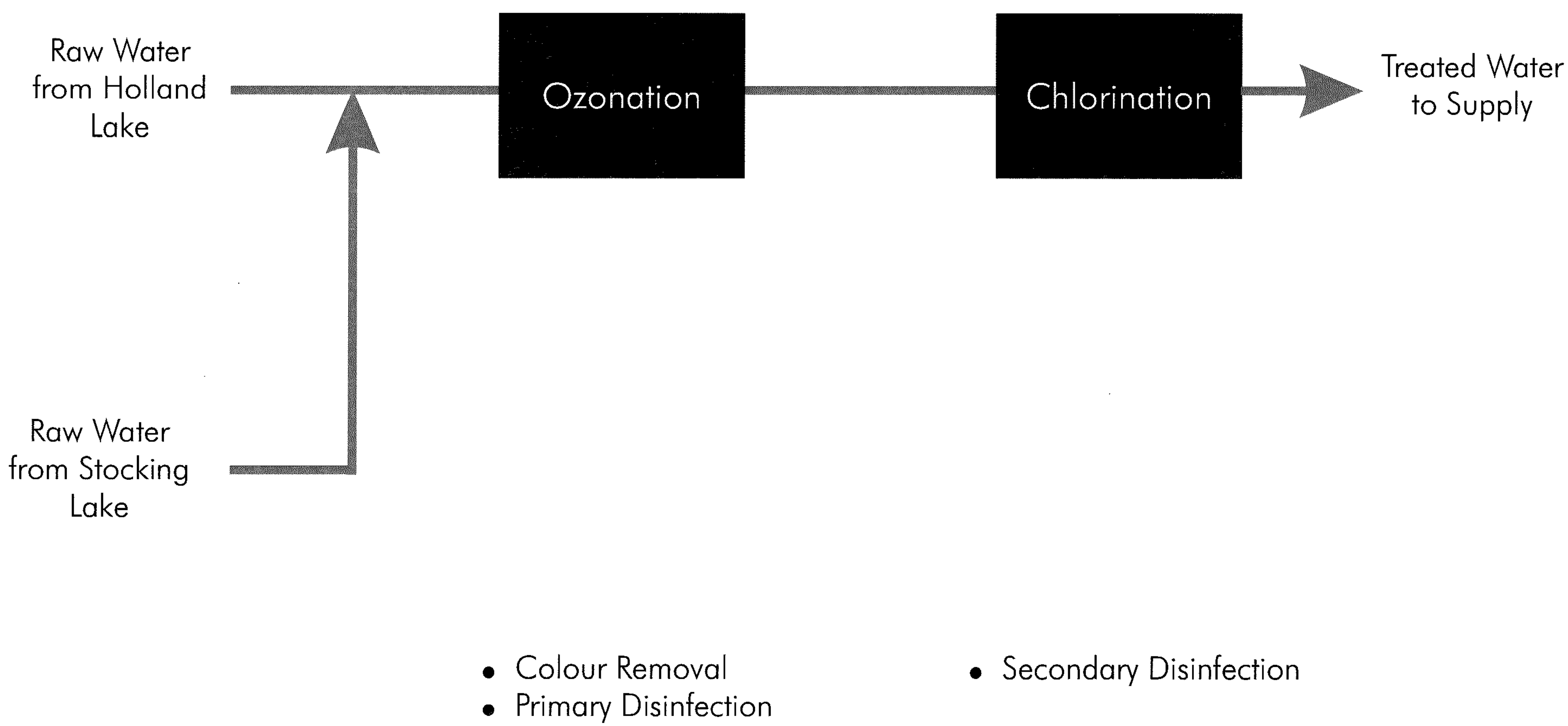


Figure 3-3:
Ozonation -Chlorination

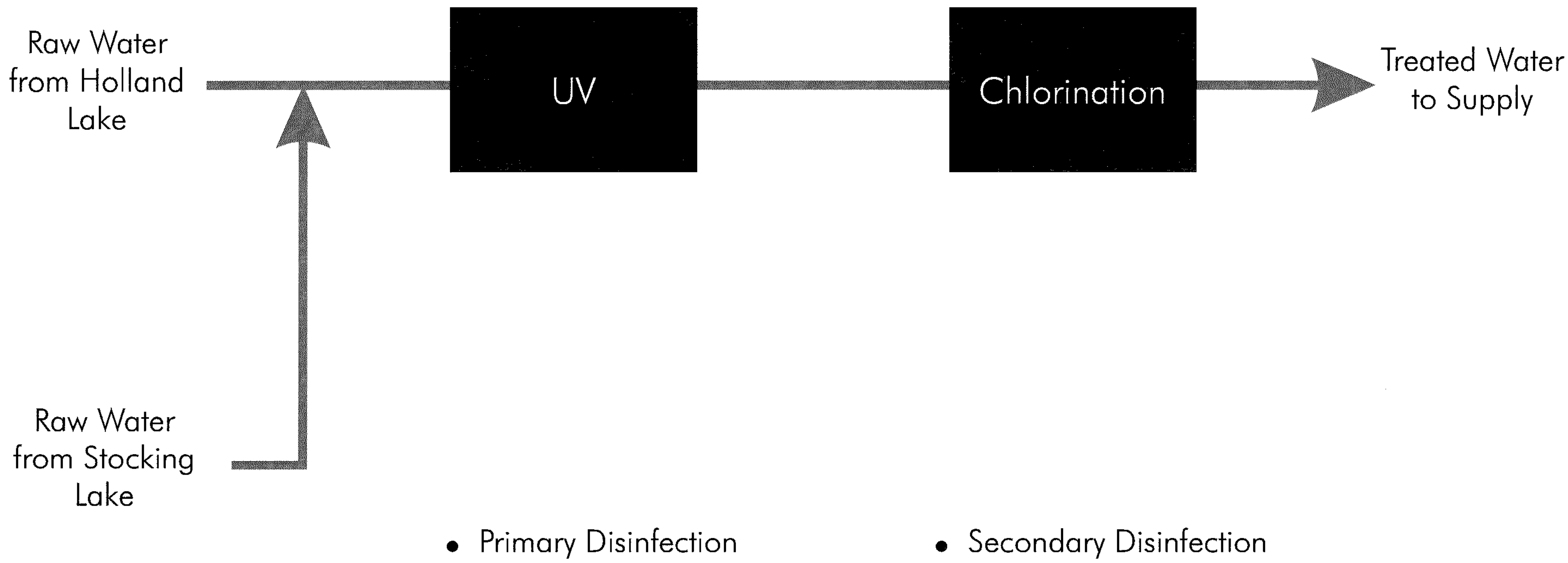


Figure 3-4:
UV -Chlorination

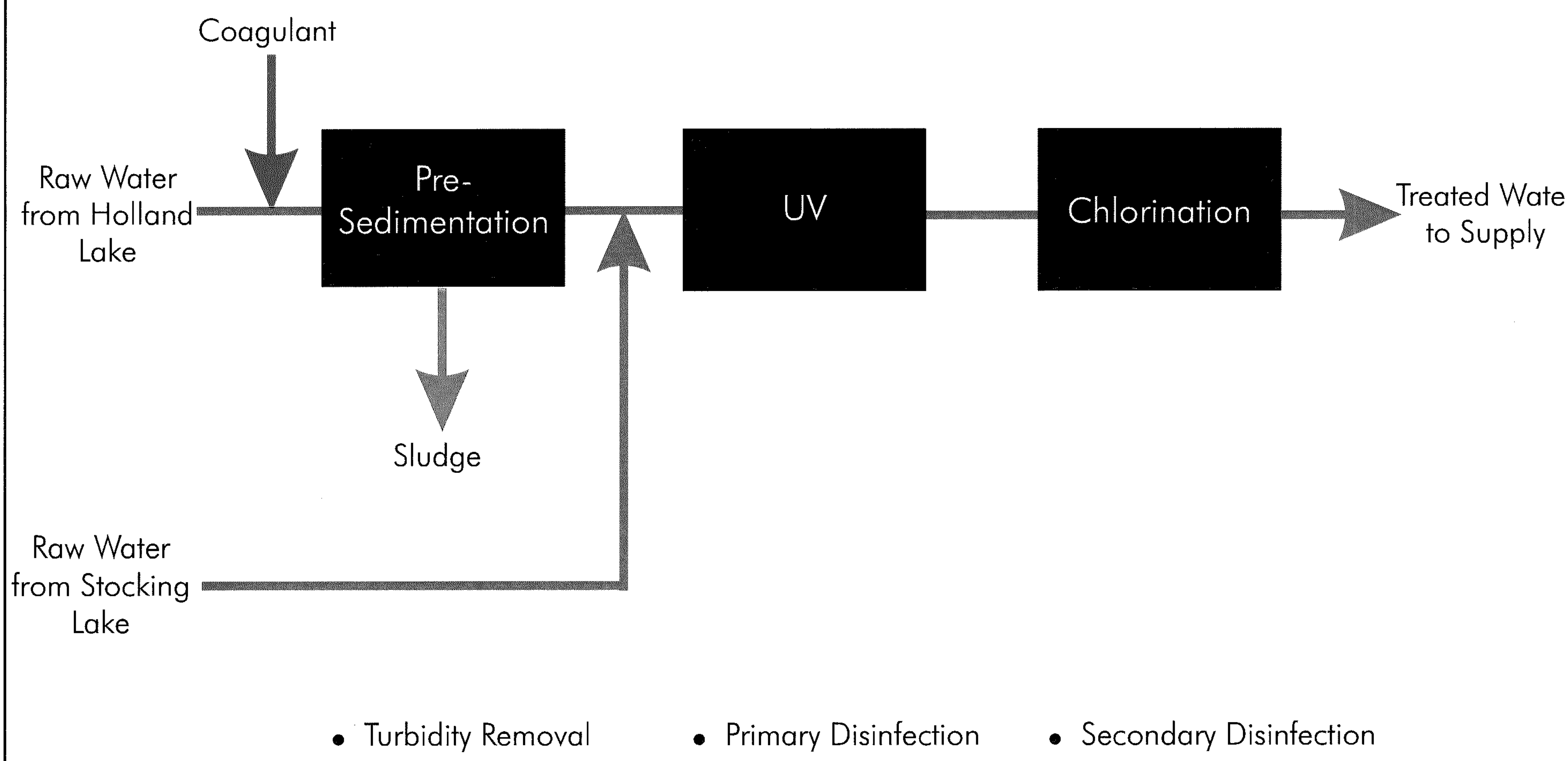


Figure 3-5
Pre-Sedimentation - UV - Chlorination

Earth Tech
Water Quality
& Treatment

Town of Ladysmith
Water Supply and
Distribution
Preliminary Design

Under such an approach therefore, switching to Stocking as the source would still be required during turbidity spikes.

A significant drawback of this approach would be that sludge would accumulate in the pre-sedimentation basins, requiring the pond to be removed from service occasionally for sludge removal and disposal. Pre-sedimentation basins also are typically designed for a very low surface loading rate (i.e. flow per unit basin area), and therefore occupy a sizeable area.

Ozonation-UV-Chlorination (Figure 3-6)

Under this option, ozone is used only for colour removal, UV disinfection is provided for inactivation of *Cryptosporidium*, *Giardia*, and other pathogens. Chlorination is provided for secondary disinfection, to provide a chlorine residual for protection of the distribution system. In the event of turbidity spiking at Chicken Ladder, the Town would switch to Stocking while the turbidity event persisted. If neither elevated colour nor turbidity were present in Chicken Ladder, then the ozonation could be turned off, and the water treated only with UV and chlorine.

The oxidation of colour using ozone is a very rapid process, and does not require the long contact times and high ozone dosages required for *Cryptosporidium* inactivation.

A significant benefit of this approach is that no chemicals other than chlorine are added to the water, and no sludges are produced. One drawback is Chicken Ladder water could not be used year round, as no mechanism for turbidity removal is provided, however since turbidity spikes are historically very brief in duration, switching to Stocking during turbidity events only minimally reduces the Town's flexibility.

DAF (or other clarification technology)-UV-Chlorination (Figure 3-7)

Under this option, granular media filtration is provided (for Chicken Ladder water only), complete with a high rate clarification process upstream. This would provide for an overall finished water quality higher than those provided by all the above options, as year round filtration would significantly reduce turbidity. A high rate pre-treatment process such as DAF with effective coagulation would provide for excellent colour removal, and long filter run times. If colour was not present, The DAF process could be shut down and by-passed, converting to direct filtration, and minimizing power costs.

Filtered water would then be disinfected using UV disinfection, and chlorination provided for secondary disinfection. Effective UV disinfection could be achieved using lower power costs using this option, since filtration provides for increased transmittance of UV light through the water.

UF Membrane Filtration-UV-Chlorination (Figure 3-8)

Under this option, ultrafiltration (UF) membrane filtration is provided for Chicken Ladder water, complete with the option for coagulation as a pre-treatment to provide for colour removal. DAF might also be provided as a pre-treatment to the membranes for enhanced performance. Since UF membranes are typically granted a 4-log removal credit for *Giardia*, *Cryptosporidium*, and viruses, no additional disinfection would be required in theory for waters treated using this approach[12]. UV disinfection would be provided for Stocking Lake water, and chlorination provided for both Chicken Ladder or Stocking water for protection of the distribution system. This approach would probably provide the highest overall finished water quality.

[12] While in theory, membranes are an absolute barrier to the passage of pathogens, regulators commonly mandate a nominal additional inactivation credit downstream of the membranes, as part of a multi-barrier approach.

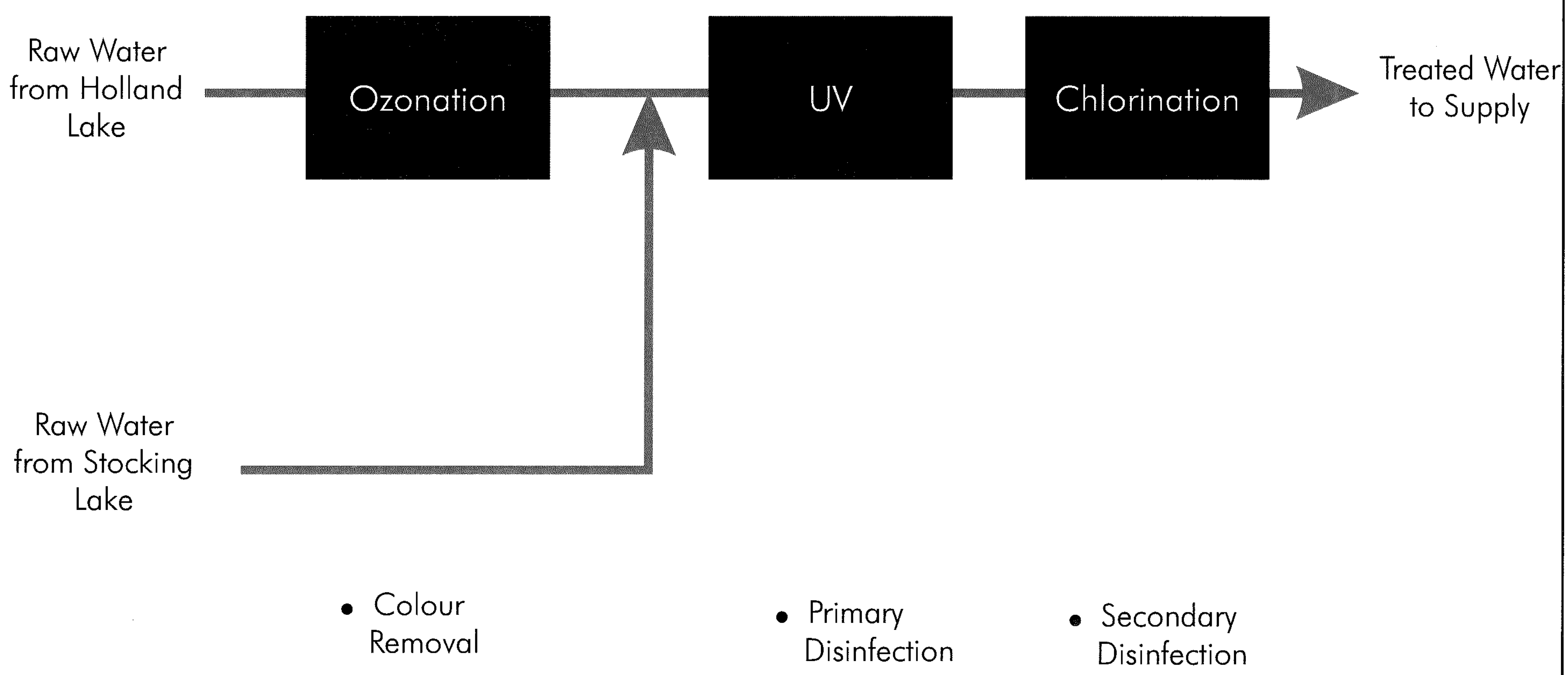


Figure 3-6:

Ozonation -UV-Chlorination

Earth Tech
Water Quality
& Treatment

Town of Ladysmith
Water Supply and
Distribution
Preliminary Design

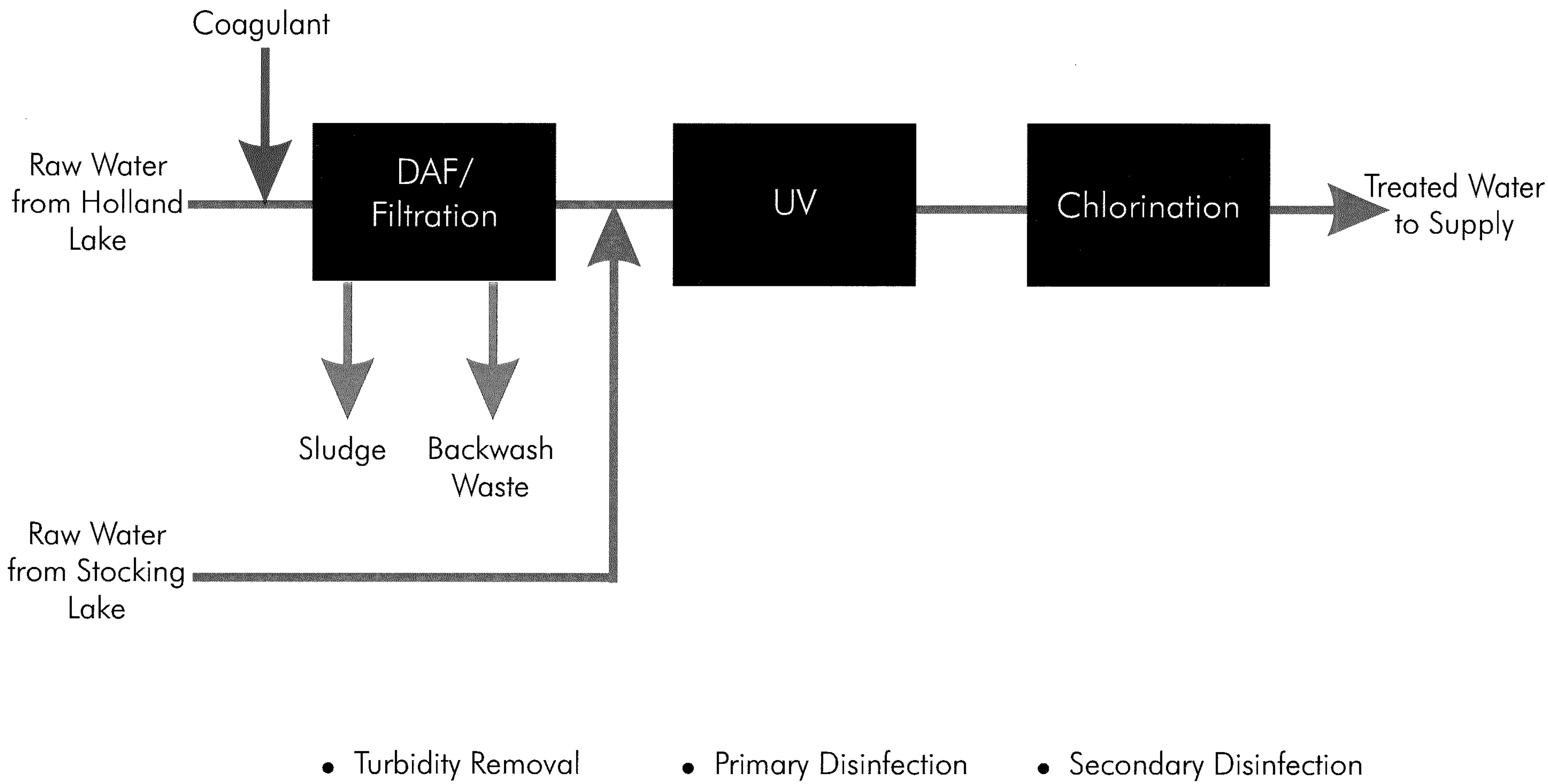


Figure 3-7:
DAF - UV - Chlorination
Filtration

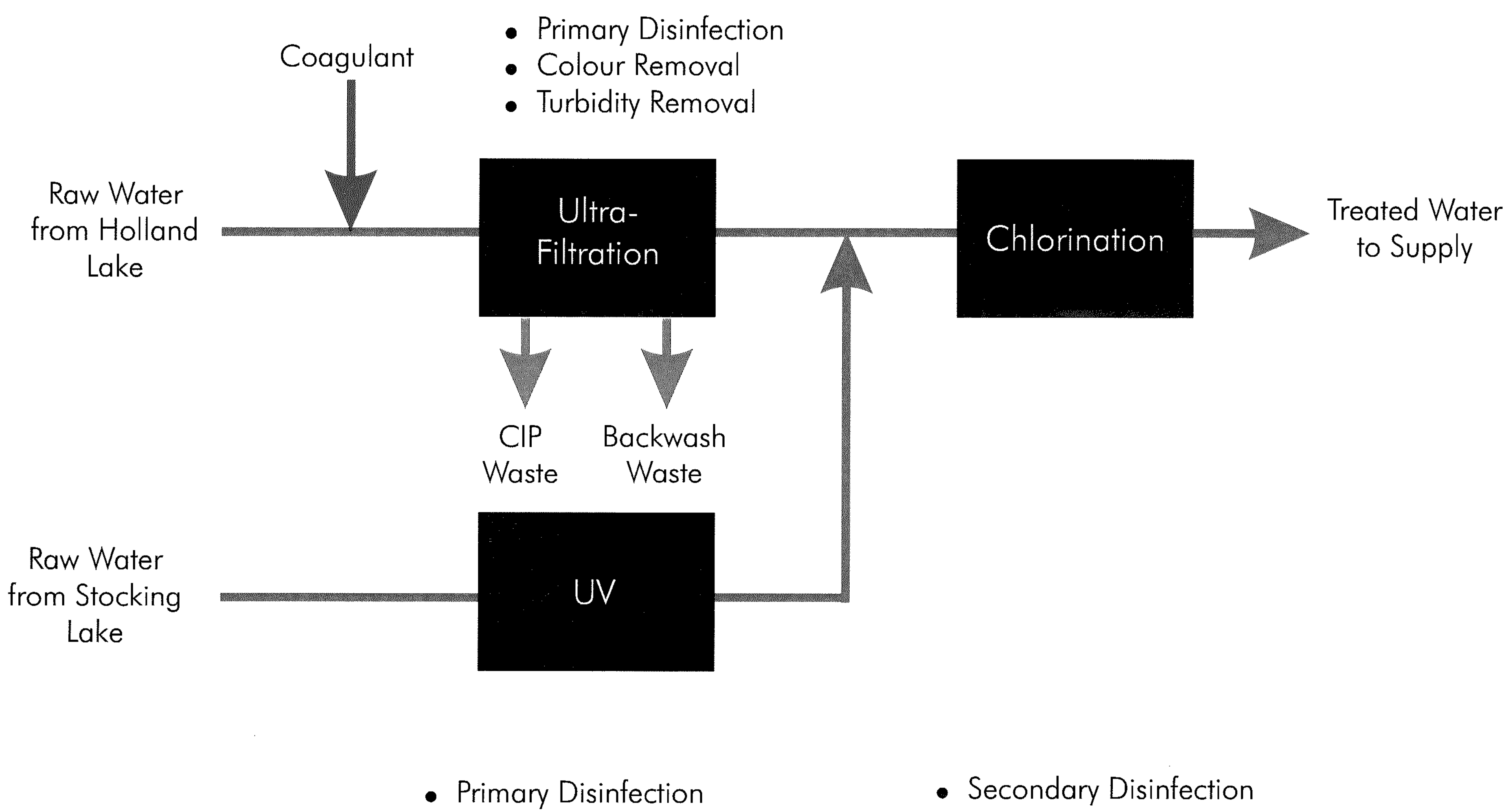


Figure 3-8:
UF Membrane Filtration -UV-Chlorination