Process Evaluation & Selection

Of the above process trains listed, all are considered capable of consistently meeting long term water quality objectives, although some options require careful source selection for supply to the north end of Town under certain water quality conditions.

Presently, use of Chicken Ladder as a source is suspended for several months at a time when colour and/or turbidity appear in the Chicken Ladder water. This practice is technically in violation of present requirements of the Town of Ladysmith's water licenses on Stocking, which mandate a daily maximum flow from Stocking.

Even if this licensing constraint were not an issue however, as demands grow in the future, the need to switch to Stocking in the winter months poses a significant constraint to operational flexibility, as they presently have no means to use their most abundant source for several months a year due to water quality issues.

In reality, it is the colour issue which forces this lengthy shutdown. Elevated colour levels last typically for several weeks or months at a time, while historical turbidity events are consistently evanescent in nature, lasting typically only 1 or 2 days.

This allows an important distinction to be made. With turbidity events being infrequent and brief in duration, switching to Stocking due to turbidity events is considered to be a means to avoid the need for construction of costly filtration facilities, by managing raw water supply such that the source water always meets the criteria for filtration avoidance under the draft Health Canada guidelines (i.e. always < 5 NTU).

If treatment for colour removal is provided for the Chicken Ladder supply, then the present reliance on Stocking Lake water will be all but eliminated, thereby significantly increasing operational flexibility by allowing it to leverage its most abundant source for the majority of the year, without spending the significant additional capital cost necessary to construct filtration facilities so that this source can be used year round.

If filtration avoidance is to form part of the strategy in process selection, other significant considerations are also worthy of discussion. These include:

- Options which involve either solids-liquid separation (such as pre-sedimentation) or the use of coagulant to provide for colour removal will inevitably produce a sludge requiring disposal. Two options would be available: on-site processing of the sludge to dewater it, and direct disposal to a landfill site, or connection into the sanitary sewer system. While the latter option is probably the lower cost alternative, it merely transfers the problem to the wastewater treatment plant, which at present is not designed to handle such sludges. Possible impacts of inorganic sludge on the electro-flocculation process being considered by the Town of Ladysmith at the wastewater treatment plant are unknown.

- Options which involve the addition of chemicals such as coagulants to the water, particularly aluminium based coagulants, commonly raise public concerns in British Columbia, due to a perceived link between these chemicals and possible health effects.

- Options involving granular media filtration produce up to 5% of their design flow as backwash waste. This can either be captured and bled at a constant rate to the wastewater treatment plant, or treated and recycled to blend with the plant influent. Facilities for equalizing the short term, high volume backflow flows can be space intensive, adding to the overall footprint of the new facilities.

- Options involving membrane filtration can produce up to 10% of their design flow as backwash waste. Several chemicals are also commonly used to assist backwash. This can either be captured and bled at a constant rate to the wastewater treatment plant, or treated and recycled to blend with the plant influent. The presence of chemicals in the backwash water complicates backwash recycling, due to potential impacts on the main process. Membrane filtration systems also utilize a periodic clean-in-place (CIP) cycle, to recover reversible fouling of the membranes. This CIP process produces a waste stream often containing chemicals requiring special handling.

- Use of processes which achieve multiple treatment objectives simultaneously appear attractive from a capital cost standpoint, but in some ways reduce flexibility of the system, since these processes will need to be operational at all times, even if water quality doesn't require it.
- Recent research has clearly demonstrated that UV disinfection for *Cryptosporidium* and *Giardia* inactivation is commonly approximately half the life cycle cost of ozonation for the same purpose.

Table 3-3 summarizes some of these considerations for each of the process trains under evaluation.

Table 3-3
Summary of Process Selection Considerations

Process	Achieve WQ Goals ??	Requires new Chemicals and/or Produces Sludge ??	Relative Capital Cost	Relative O&M Cost
Ozonation-Chlorination	Yes, but switch to Stocking during turbidity events	No	Moderate	Moderate to High
UV-Chlorination	Yes, but switch to Stocking during colour and turbidity events	No	Low	Low
Pre-Sedimentation-UV-Chlorination	Yes, but switch to Stocking during turbidity events	Yes	Moderate	Moderate
Ozonation-UV-Chlorination	Yes, but switch to Stocking during turbidity events	No	Moderate	Low to Moderate
DAF-Filtration-UV-Chlorination	Yes	Yes	High	High
UF-UV-Chlorination	Yes	Yes	High	High

Of all the various options, those options including either granular media or membrane filtration will certainly provide a finished water quality of a higher standard than any of the other options. In addition, this process would be able to treat Chicken Ladder year round without needing to switch to Stocking when the Chicken Ladder water quality deteriorates.

Nevertheless, of the other options, the combination of ozone-UV-and chlorination will be able to treat Chicken Ladder water for the majority of the year, except when turbidity spiking occurs from Chicken Ladder. With the duration of these spikes being short-lived, it is considered that switching of sources during these infrequent and transient events is not only a sustainable approach, but is also cost effective approach to production of drinking water. Such an approach would substantially reduce reliance on the high quality Stocking source, by providing treatment for colour on the Chicken Ladder supply which can be switched off when colour is not an issue.

Based upon these considerations, the following processes have been selected for carrying forward into preliminary design:

- For all facilities using Chicken Ladder as a source, Ozonation-UV-Chlorination. Chicken Ladder would be used most of the time, with the ozone switched on only if colour was elevated in the raw water. If turbidity spiking appeared in the Chicken Ladder source, a switch to Stocking would be made.
- For all facilities using ONLY Stocking Lake as a source, UV-Chlorination. Ozonation is not required on the Stocking source since colour is not an issue.

Although filtration is not included in the preliminary design at this juncture, it is recommended that preliminary design allow for the future retrofit of filtration, in the event of further deterioration in water quality from either source, or if water quality regulations change.

An additional important consideration with the recommended approach is that pilot testing of ozonation on the Chicken Ladder supply 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 conversion of naturally occurring organic carbon into assimilable organic carbon (AOC), which might promote bacterial re-growth in the distribution system.

A program of regular water quality analyses is recommended for the following parameters, to improve the existing database on water quality issues:

- Chicken Ladder raw water **true** colour, as opposed to the **apparent** colour analyses the Town has historically performed.
- Raw water total organic carbon (TOC) from both Chicken Ladder & Stocking Lake.
- Raw water dissolved organic carbon (DOC) from both Chicken Ladder & Stocking Lake.
- Raw water UV absorbance at 254 nm (UV_{254}) from both Chicken Ladder & Stocking Lake.
- Treated water trihalomethanes (THM's), using water samples drawn at the extremities of the distribution system.
- Treated water haloacetic acids (HAA's), using water samples drawn at the extremities of the distribution system.
- Simulated Distribution System (SDS) THM and HAA formation potential for raw water drawn from Stocking Lake and at Chicken Ladder.
- Raw water *Giardia* and *Cryptosporidium*, from both Chicken Ladder & Stocking Lake.

Quarterly sampling is recommended initially, in the attempt to characterize seasonal changes in water quality experienced in the water supply.

TREATED WATER DISTRIBUTION

The distribution system has not been analyzed in detail under this study. However, for the hydraulic modeling that was completed, the following information was determined.

- The fire flow rate that has been determined for the Industrial / Commercial planning areas cannot generally be delivered through the water system grid. Two fire flow scenarios have been tested to assess the adequacy of the existing supply mains between the proposed reservoirs and the distribution grid. For test purposes the fire flow demand for Industrial / Commercial areas (330 L/s) has been combined with the maximum daily demand.
- For the North End, experiencing a fire flow at Baden-Powell Street and Second Avenue (Node 41), the velocities in the two main delivery pipes from Arbutus Reservoir are relatively high. For the 350 mm diameter AC line from the reservoir to Colonial Drive the flow velocity will be 2.6 m/s and in the 300 mm AC line from the reservoir to Baden-Powell Street the velocity will be 2.8 m/s. These velocities generate head losses in the range of 20 to 35 m / 1000m of pipe length leaving little residual pressure for further losses within the distribution system. Ultimately an enlarged conveyance to Baden-Powell Street will be required.
- For the South End, the pipe system from the Contact Tank to the Value House consists of a 300 mm diameter AC and a 250 mm diameter PVC and from the Valve House to Battie Drive there is a 200 mm diameter AC and a 150 mm diameter AC line. For a fire flow at Davis Road and Mylene Crescent (Node 514) the pipe velocity in the twin pipes from the Contact Tank will be approximately 2.0 m/s which is acceptable. However, the 300 mm pipe is only available if it is not being used to convey raw water to the Arbutus Reservoir, as is required for the alternatives where water treatment is consolidated at the Arbutus Reservoir. For this case upgrading of the initial section of distribution main is required. The next section from the Valve House in Battie Street is significantly undersized and will definitely require upgrading. A better solution would likely be to construct a new line from the Contact Tank southeasterly around the South End to be into the Saltair systems.

The Ladysmith and Saltair systems are connected through normally closed valves on Chemainus Road and the Highway. When opened, Ladysmith could supply maximum day demands to Saltair. The higher pressures in the Ladysmith system will require pressure reduction for the low lying areas of Saltair. Fire flow upgrades in the form of a new 2400 m long by 300 mm diameter looped main through the South End to Saltair would also be required in a combined system.

Pressure zones in a stand-alone Ladysmith system or in a combined Ladysmith/Saltair system should be reviewed. The Ladysmith system has three pressure zones including the 140 m Zone due to the Arbutus Reservoir, the 158 m Zone due to the Contact Tank and the (poorly defined) 100 m Zone below the PRV's in the lower part of Town. Currently some of the low areas are not protected by a PRV and the maximum pressures are too high, at approximately 1260 kPa. The Saltair system has a 119 m Zone due to the reservoir and an 86 m Zone, created by three PRV's, which generally serves the area below the railway grade. In the consolidated systems the latter hydraulic grade line may be an appropriate pressure zone for all of the sections of Ladysmith that currently have excessive pressure.

SECTION 4.0
ANALYSIS OF ALTERNATIVES

Having determined treatment requirements for the various sources to meet the water quality objectives established in Section 3.0, four distinct alternative scenarios were developed for the water supply system as a whole, each of which would ensure that an adequate supply of water meeting the water quality objectives could reliably be delivered. The four alternatives analyzed under this study were as follows:

Alternative "A" Construction of consolidated treatment facilities in the vicinity of the existing Arbutus Reservoir

Alternative "B" Construction of Separate Treatment Facilities to supply separate service areas

Alternative "C" Diversion of Holland Lake flows into Stocking Lake, including new treatment facilities near the Balancing Reservoir

Alternative "D" Diversion of Stocking Lake into the Holland Creek Watershed, including new treatment facilities near Arbutus Reservoir

The main facilities (treatment plants and treated water reservoirs) required under each Alternative are summarized in Tables 4-1 and 4-2. Table 4-1 lists the location of each treatment facility, the design capacity of the treatment plant, and the unit treatment processes required at each location. Table 4-2 lists the location of each reservoir, the size and approximate water surface elevation of the reservoir, and how the total volume is divided between fire, balancing, and emergency storage.

It is to be noted that these tables reflect the division of the water supply system into two discrete halves:

- A consolidated supply of treated water for North Ladysmith and the Diamond District, and;
- A consolidated supply of treated water for South Ladysmith and Saltair.

It is also technically feasible that South Ladysmith and Saltair be supplied completely separately, using the two discrete conveyance systems presently in use. Presently, South Ladysmith is supplied through the Contact Tank, while Saltair is supplied through a separate pipeline aligned along Stocking Creek. Continued operation of these two systems separately would require not only the construction of two separate new treatment facilities, but also separate reservoirs, each sized to include fire flow. Hydraulic modeling demonstrates that it is possible to revert to feeding Saltair from a consolidated reservoir near the Contact Tank, however hydraulic limitations in the water conveyance piping would preclude the delivery of fire flow to Saltair. Nonetheless, it is more cost effective to upgrade the conveyance system to remove this hydraulic limitation than to continue to keep the two supplies separate. For the purposes of this evaluation therefore, all alternatives considered in detail involve the consolidated South Ladysmith/Saltair supply.

Before embarking upon a more detailed analysis of the various options, it is worthwhile to dwell a little on a potential concept which has been evaluated, but not included in any of the four alternatives. The 1995 Koers Report considered the construction of a new raw water conveyance pipeline to convey water directly to the Chicken Ladder Intake, and bypassing the Holland Creek Watershed. While this option would certainly reduce the deleterious impacts on water quality caused by rainfall events in the watershed, it would also reduce substantially the volume of water available for water supply, since all water which presently flows in the creek would be "wasted" from a water supply standpoint.

Table 4-1
Treatment Facilities required under each Alternative

Alternative	Near Arbutus Reservoir	Near Existing Contact Tank	Near the Balancing Reservoir
"A"	13.2 ML/d (Ozone, UV, Chlorination)	-	-
"B"	10.1 ML/d (Ozone, UV, Chlorination)	3.1 ML/d (UV, Chlorination)	-
"C"	-		13.2 ML/d (Ozone, UV, Chlorination)
"D"	13.2 ML/d (Ozone, UV, Chlorination)		-

Table 4-2
Storage Reservoirs required under each Alternative

Alternative	Near Arbutus Reservoir 140 metres Elevation	Near Existing Contact Tank (158 metres elevation)
"A"	6.0 ML total storage 2.4 ML fire 2.7 ML balancing 0.9 ML emergency	3.9 ML total storage 2.4 ML fire 0.75 ML balancing 0.75 ML emergency
"B"	5.7 ML total storage 2.4 ML fire 2.5 ML balancing 0.8 ML emergency	3.9 ML total storage 2.4 ML fire 0.75 ML balancing 0.75 ML emergency
"C"	7.4 ML total storage 2.4 ML fire 2.5 ML balancing 2.5 ML emergency	3.9 ML total storage 2.4 ML fire 0.75 ML balancing 0.75 ML emergency
"D"	7.8 ML total storage 2.4 ML fire 2.7 ML balancing 2.7 ML emergency	3.9 ML total storage 2.4 ML fire 0.75 ML balancing 0.75 ML emergency

Although Table 2-2 demonstrates that the existing sources of supply are sufficient for at least the next 20 years, it is considered unwise to make such modifications to the raw water supply that limit the availability of water from the Holland Creek watershed. To eliminate Holland Creek as a potential source of water would force the Town into a position of seeking alternate water supplies earlier than would be required. With existing water quality at Chicken Ladder being relatively good even in the winter, i.e. readily treatable if required, it is recommended that the pipeline not be constructed, and none of the alternatives considered include this as a component.

OVERVIEW OF THE ALTERNATIVES

ALTERNATIVE "A": CONSOLIDATED TREATMENT FACILITIES

This alternative (see Figure 4-1) consolidates all water treatment facilities for the entire service area, including Saltair, at the existing Arbutus Reservoir site. The consolidation of the treatment facilities for the Ladysmith / Saltair water supply will facilitate operations, but would result in a higher operational cost for the system due to the need to pump a portion of the supply to South Ladysmith and Saltair. No additional creek diversions are required, which is beneficial from an environmental perspective. New facilities to be constructed under Alternative "A" include:

1. Construction of a new 13.2 ML/d water treatment plant (the "Arbutus WTP") in the vicinity of the existing Arbutus Reservoir. This plant would be designed to treat water from either Stocking Lake or the Chicken Ladder intake. The plant would include ozonation for colour removal, UV primary disinfection, and chlorination for secondary disinfection. The plant would operate almost exclusively using Holland Lake as the source, as it would be designed to handle the extended colour spiking experienced seasonally from this source. On-line turbidity monitoring would be provided on the water drawn from Chicken Ladder, to allow detection of turbidity spikes in this source. When turbidity events are detected, operation of the plant would be switched from Chicken Ladder to Stocking, ensuring that raw water turbidity at the plant always meets the criteria for filtration avoidance.
2. Construction of a new 6.0 ML treated water reservoir ("The new Arbutus Reservoir") at the Arbutus WTP with a top water surface elevation of 140 metres, to provide fire, balancing, and emergency storage for North Ladysmith and the Diamond District. The existing water supply system includes no in-line balancing storage between Chicken Ladder and the Town, and consequently must meet peak hour demands. With construction of costly treatment facilities along this branch, it is more cost effective to design balancing storage, such that the treatment plant need only be sized for peak day demand.
3. A new 3.9 ML reservoir (the South End Reservoir), sited in the vicinity of the Contact Tank at elevation 158 m, to provide fire, emergency, and balancing storage for South Ladysmith and Saltair. Disinfection storage volume is not required, since disinfection requirements are met by UV disinfection at Arbutus WTP.
4. Construction of a new 36 L/s treated water pump station at the Arbutus WTP, to pump treated water from the new Arbutus Reservoir to the new South End reservoir near the existing Contact Tank. With all water supply to the Town and Diamond District passing through Arbutus WTP, it would become impossible to continue to serve South Ladysmith and Saltair by gravity. As such, this option requires construction of a treated water pump station at the Arbutus WTP, to pump treated water from the Arbutus WTP to the new South End reservoir serving South Ladysmith and Saltair.
5. A new 2.7 km, 200 mm pipeline would be required to convey treated water from the Arbutus WTP pump station to the existing point where South Ladysmith is fed, in the vicinity of the Contact Tank.
6. Construction of new 2.400 km, 300 mm diameter pipeline from the South End Reservoir tying into the north end of the Saltair system, to facilitate delivery of fire flows to South Ladysmith and Saltair.
7. Construction of a new PRV station near the existing South Ladysmith / Saltair boundary, to reduce pressures feeding the Saltair system.

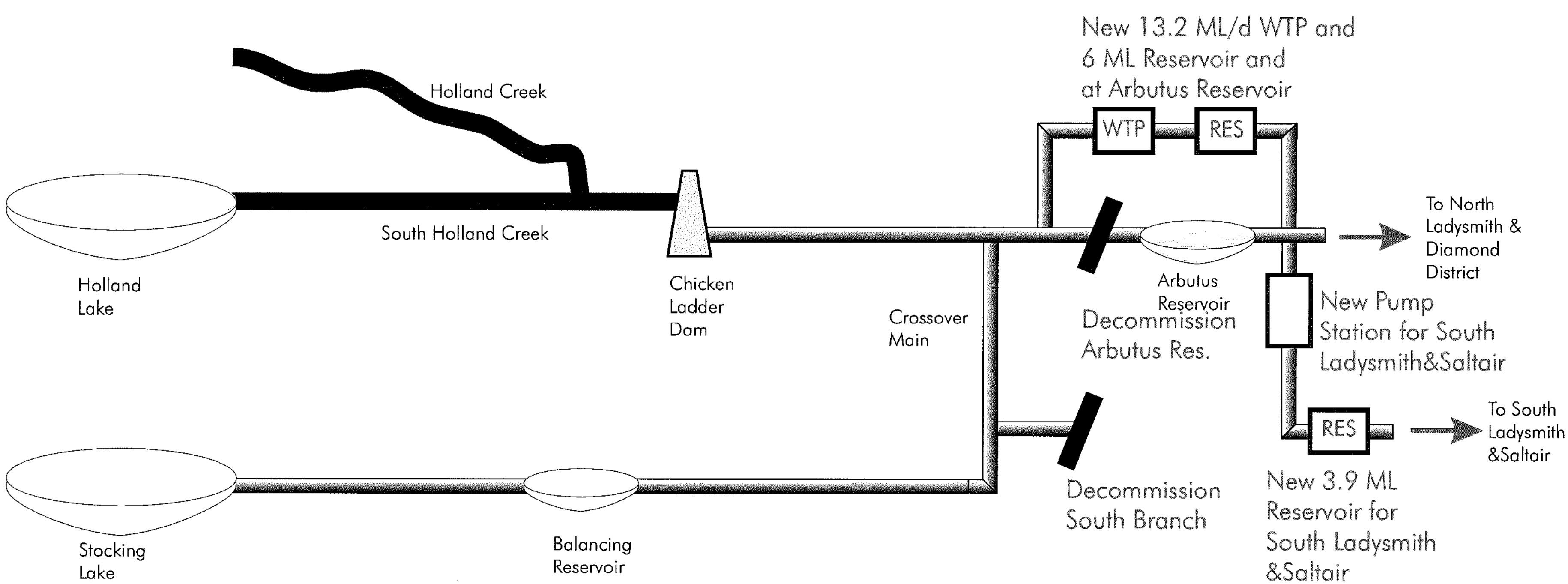

Figure 4-1: Alternative: "A": Consolidated Treatment at Arbutus Reservoir

Decommissioning and bypassing of the existing, open Arbutus Reservoir and the existing Contact Tank.

8. Miscellaneous piping modifications to connect the new Arbutus and South End reservoirs to the existing system.

An variant approach for this alternative would have been to provide a fire pump at the new Arbutus reservoir to deliver fire flow to South Ladysmith, such that a smaller reservoir could be constructed for South Ladysmith without inclusion of fire storage. Consideration of the net present value of the two approaches shows that it is lower cost overall to provide the larger dedicated reservoir for South Ladysmith and Saltair.

ALTERNATIVE "B": SEPARATE TREATMENT FACILITIES

This Alternative (see **Figure 4-2**) provides separate facilities to serve the north and south ends of service area. All water supply would be by gravity. No additional creek diversions are required. New facilities to be constructed under Alternative "B" include:

1. Construction of a new 10.1 ML/d water treatment plant ("the Arbutus WTP") in the vicinity of the existing Arbutus Reservoir. This plant would be designed to treat water from either Stocking Lake or the Chicken Ladder intake. The plant would include ozonation for colour removal, UV primary disinfection, and chlorination for secondary disinfection. The plant would operate almost exclusively using Holland Lake as the source, as it would be designed to handle the extended colour spiking experienced seasonally from this source. On-line turbidity monitoring would be provided on the water drawn from Chicken Ladder, to allow detection of turbidity spikes in this source. When turbidity events are detected, operation of the plant would be switched from Chicken Ladder to Stocking, ensuring that raw water turbidity at the plant always meets the criteria for filtration avoidance. It is to be noted that the design capacity of the plant is smaller than that required under Alternative "A", since the supply for South Ladysmith and Saltair would be treated at a site remote to this plant under this Alternative.

2. Construction of a new 5.7 ML reservoir ("the new Arbutus Reservoir") near the new Arbutus WTP, with a top water elevation of 140 metres. The size of the reservoir can be reduced slightly versus that required under Alternative "A", since balancing, and emergency storage for South Ladysmith and Saltair are provided elsewhere. Disinfection storage volume is not required, since disinfection requirements are met by UV disinfection.

3. Construction of a new 3.1 ML/d water treatment plant for South Ladysmith and Saltair, incorporating UV disinfection for primary disinfection, and chlorination for secondary disinfection. Since South Ladysmith and Saltair are served exclusively from Stocking Lake, it is not necessary to provide ozonation on this separate supply.

4. Construction of a new 3.9 ML reservoir for South Ladysmith and Saltair, to provide fire, balancing, and emergency storage. Disinfection storage volume is not required, since disinfection requirements are met by UV disinfection.

5. Construction of new 2.4 km, 300 mm diameter pipeline from the South End Reservoir tying into the north end of the Saltair system, to facilitate delivery of fire flows to South Ladysmith and Saltair.

6. Construction of a new PRV station near the existing South Ladysmith / Saltair boundary, to reduce pressures feeding the Saltair system.

7. Decommissioning and bypassing of the existing, open Arbutus Reservoir and the existing Contact Tank.

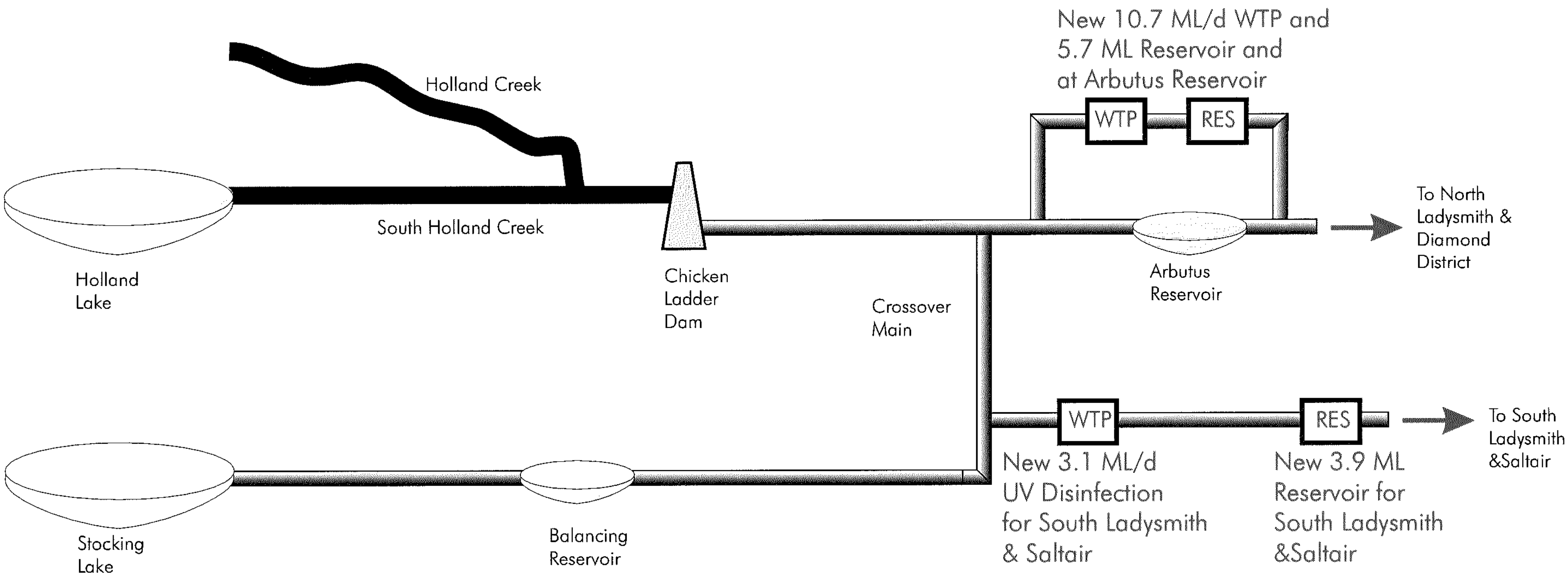

Figure 4-2: Alternative "B": Separate Treatment

8. Miscellaneous piping modifications to connect the new reservoirs at the Arbutus Reservoir and the Contact Tank to the existing system.

ALTERNATIVE "C": DIVERT FROM HOLLAND CREEK TO STOCKING LAKE

Under this alternative (see Figure 4-3), water would be diverted from Holland Creek into Stocking Lake. This transfer would be done by gravity, since Holland Lake and a significant portion of the Holland Creek watershed lies at a higher elevation than Stocking Lake. It would not be possible to capture all of the Holland Lake watershed by gravity under this option, and so the overall availability of water would be reduced under this Alternative.

All water supply would then be provided from Stocking Lake, allowing for some degree of consolidation of water treatment facilities. While this allows facilities to be planned to take advantage of economies of scale, there is the potential that year round blending of Holland Creek water into Stocking Lake might reduce in an overall reduction in net water quality. This might occur for two reasons:

- Holland Creek water is inherently a lower quality water for much of the year.
- The diversion process would markedly increase the influx of water into Stocking Lake, and water would consequently have a greatly reduced opportunity to quiesce in the reservoir. It is therefore anticipated that this diversion would result in an increase in the average turbidity of the water supply. For the purposes of this study, it is assumed that the increase in turbidity would not be so high as to exceed the filtration avoidance criteria for turbidity, and force installation of filtration as part of the treatment plant.

In addition to the potential impacts on the quality of the water supply, there are significant issues due to the environmental sensitivity of transferring water from one basin to another. A complete report on these environmental issues is included as Appendix "B".

New facilities to be constructed under Alternative "C" include:

1. Facilities to allow diversion of water from the Holland Creek Watershed to Stocking Lake. There are several means by which this could be accomplished, including:
   - Diversion of South Holland Creek at the new bridge on the forestry access road, approximately 1.0 km upstream from the confluence with North Holland Creek. The intake location and pipeline route have been field confirmed. This results in a reduction in the total watershed area from 4,582 hectares to 2,857 hectares (38%), however with Stocking Lake now effectively at the bottom of the watershed, the runoff utilization can be much greater. Net effect on yield for summer drawdown may be minimal. A 3,000 metre long by 300 mm diameter diversion pipeline along the forestry road is required to convey south Holland Creek flow to Stocking Lake.
   - Diversion of North and South Holland Creeks near their confluence. This alternative would require a 3,000 m pipe or channel along the ridge above the Chicken Ladder intake area. This route has not been field confirmed, and due to the low gradient available, significant cuts and fills along route may be required to maintain gravity flow of the diverted supply. Also the intake area is in a relatively broad valley which makes diversions structure relatively costly. The advantage of this sub-alternative is the potential capture of most of the watershed.

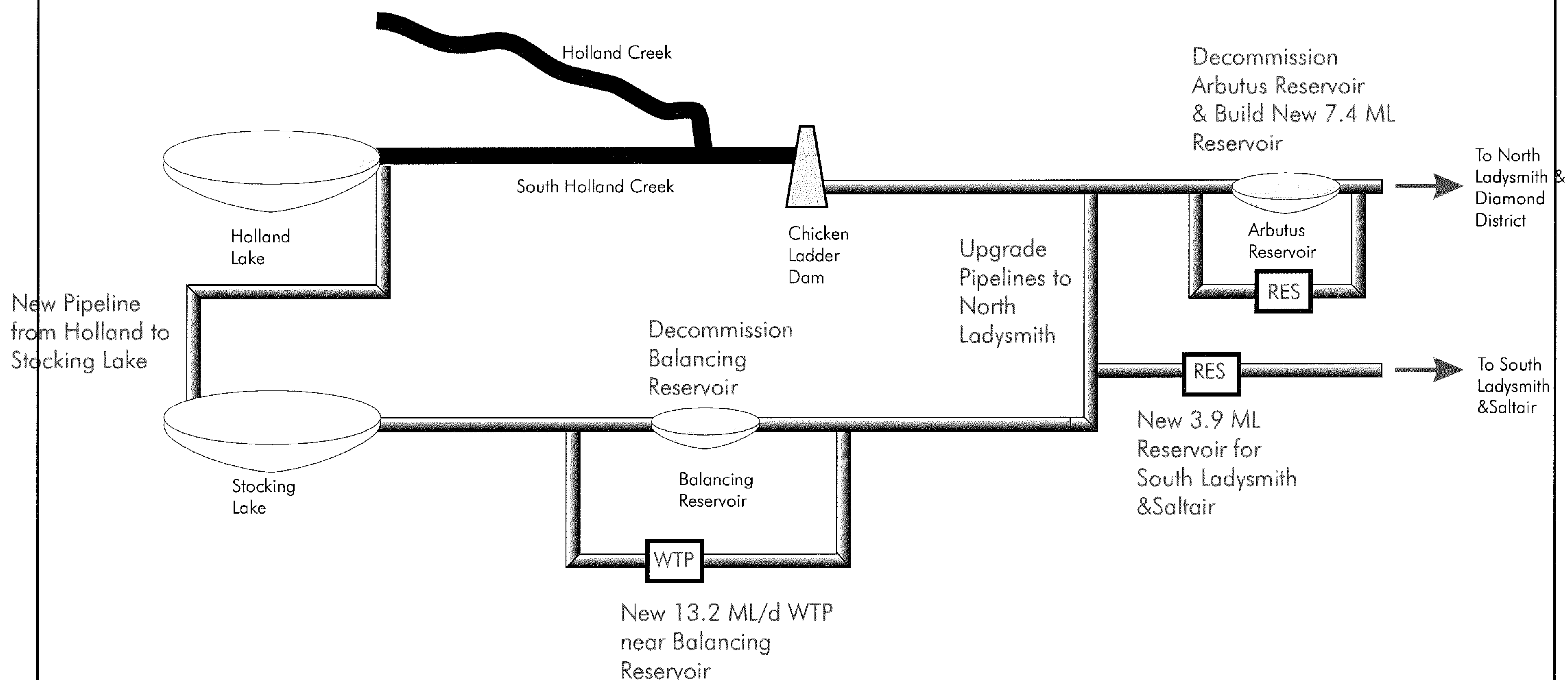

Figure 4-3: Alternative "C": Divert Holland Lake to Stocking Lake

- Redirection of Holland Lake Reservoir flows to Banon Creek and construction of a new intake on Banon Creek with a pipeline to Stocking Lake. This requires a new outlet through the Holland Lake dam and approximately 2.0 km of pipeline. The intake location and pipeline route have not been field confirmed. This sub-alternative results in a reduction in the total watershed catchment area for 4,582 hectares to 2664 hectares (43%), however as for Sub-Alternative 1, the net effect on watershed yield will be much less due to the availability of storage for the diverted flow from Banon Creek.

For the purposes of this evaluation, the first option has been carried forward in the evaluation for cost comparison with the other main alternatives, since this diversion would be the easiest to implement, and due to the known availability of a suitable point of diversion and pipeline alignment.

2. Construction of a new, consolidated 13.1 ML/d water treatment plant ("The Balancing Reservoir WTP") serving all of Ladysmith, Saltair and the Diamond District would be located in the vicinity of the existing Balancing Reservoir. The plant would include ozonation for colour removal, UV disinfection for primary disinfection, and chlorination for secondary disinfection. As discussed, it is conceivable that filtration might be required under this option, due to the likelihood that source water turbidity would increase due to reduced residence times in Stocking Lake.
3. Construction of a new 7.4 ML reservoir ("the new Arbutus Reservoir") near the existing Arbutus Reservoir, with a top water elevation of 140 metres. Disinfection storage volume is not required, since disinfection requirements are met by UV disinfection.
4. Construction of a new 3.9 ML reservoir ("the South End Reservoir") in the vicinity of the existing Contact Tank, and sharing the same elevation as the existing Arbutus Reservoir, i.e. 158 metres.
5. Construction of a new 250 mm pipeline from the Valve House to the new reservoir located at the existing Arbutus Reservoir location, to allow supply of the peak day flow to the north end of Town. The existing Balancing Reservoir, Contact Tank, and Arbutus Reservoir will all have to be decommissioned. Pipe works will be required to connect the new treatment plant and reservoirs to the existing system.
6. Construction of new 2.4 km, 300 mm diameter pipeline from the South End Reservoir tying into the north end of the Saltair system, to facilitate delivery of fire flows to South Ladysmith and Saltair.
7. Construction of a new PRV station near the existing South Ladysmith / Saltair boundary, to reduce pressures feeding the Saltair system.

ALTERNATIVE "D": DIVERT FROM STOCKING LAKE TO CHICKEN LADDER

This alternative (see Figure 4-4) would consolidate the treatment at Arbutus Reservoir (as in Alternative "A") by diverting the flow from Stocking Lake through Heart Lake, and then into the pipelines supplying Arbutus Reservoir from the Chicken Ladder intake.

The upgrades for this option are the same as in Alternative "A", but also require significant new construction to allow for the diversion of flow from Stocking and Heart Lakes into the system. The Arbutus Reservoir will also have to be larger than in Alternative "A", at approximately 7.8 ML, to provide for increased standby storage with reliance on a single source.

Environmental impacts are significant, as discussed in detail in the environmental report in Appendix "B".

Additional facilities (over and above those listed under Alternative "A") would include:

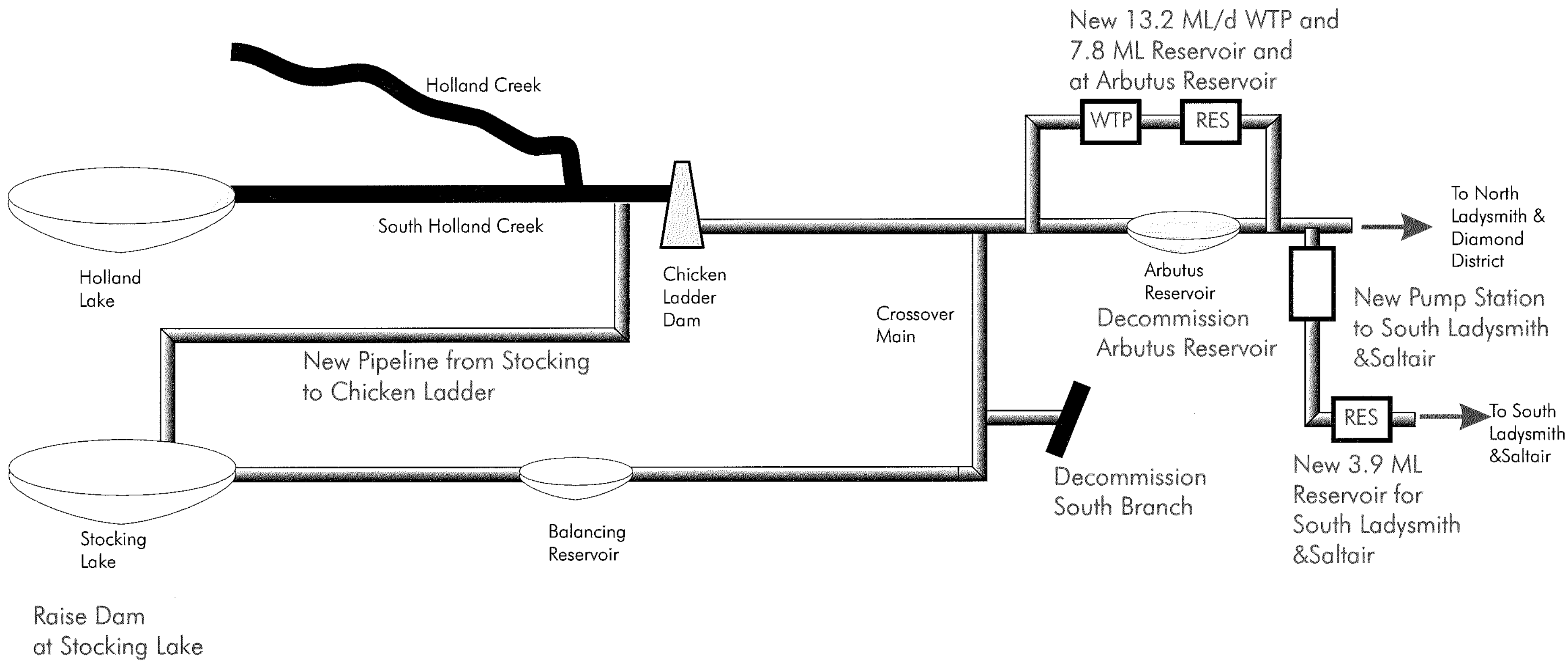

Figure 4-4: Alternative "D": Divert Stocking Lake to Chicken Ladder

1. Raising of the Stocking Lake dam to bring Stocking Lake level up to that of Heart Lake (as much as 5 or 6 metres). This would result in the raising of the water level in Stocking Lake, and the consolidation of Heart and Stocking Lakes into a single body of water.
2. Construction of a new intake structure on the north end of Heart Lake, as well as a 400 metre long, 250 mm diameter pipeline to direct the flow to Chicken Ladder where it would tie into the existing pipelines.

Like Alternatives "A" and "C", this alternative beneficially consolidates the treatment for the Ladysmith water supply and it will rely solely on gravity for distribution. The larger amount of storage in Stocking and Heart Lakes will provide a greater supply reliability than the other alternatives.

COST ANALYSES

Having itemized the specific upgrades required for each Alternative, capital and O&M cost estimates were developed for each Alternative, to facilitate the decision making process. Table 4-3 summarizes the cost analyses. For the purposes of the analysis between the Alternatives, O&M cost estimates were not developed, as in most cases these will be identical among the Alternatives, and will have no influence on the relative decision. In cases where O&M costs would differ, these costs have been calculated, and the Net Present Value (NPV) of these costs included in Table 4-3, to assist in the "apples-to-apples" comparison of costs. More detailed cost estimates, complete with back-up calculations, are included as Appendix "C". Complete capital and operating & maintenance cost estimates were developed for the recommended Alternative, and these costs are presented in Section 5.0.

Table 4-3
Estimated Capital Costs for each Upgrade Alternative

Alternative	Estimated Total Capital Cost for All upgrades[1]
Alternative "A"- Consolidated Treatment at Arbutus Reservoir	$ 9,640,000
Alternative "B" - Separate Treatment	$ 8,640,000
Alternative "C" - Divert Holland Creek to Stocking Lake	$ 11,010,000
Alternative "D" - Divert Stocking Lake to Holland Creek	$ 10,425,000

Note:

1: Includes engineering at 10%, and contingency at 20%

RECOMMENDED ALTERNATIVE

The cost analysis clearly shows that **Alternative "B" is the most cost effective Alternative**, and by a by a significant margin. While this Alternative does not allow for the consolidation of treatment and storage facilities at a single location, it does allow for all areas of the Ladysmith system to be fed entirely by gravity, thereby resulting in the most cost effective operation overall despite the slightly increased O&M labour requirement for serving two separate facilities. Selection of this Alternative also does not present any significant environmental impacts, due to the diversion of water from one watershed to another.

SECTION 5.0
THE PREFERRED ALTERNATIVE

With the decision made to proceed with Alternative "B", preliminary design was completed for this Alternative. This section describes the proposed facilities in further detail.

RAW WATER CONVEYANCE SYSTEMS

Minimal upgrading of the existing raw water conveyance infrastructure will be required to tie the new water treatment facilities into the system. During construction, a switch will be made to the Stocking Supply, to allow tie-ins to be made to the existing Chicken Ladder supply to Arbutus Reservoir.

A 400 mm manifold will be constructed, tying together the existing 300 mm and 200 mm mains from Chicken Ladder. The existing mains downstream of this point will also be tied into the new manifold, and valves provided, to allow the supply to be routed through the existing Arbutus Reservoir while construction continues.

A new 400 mm raw water main will tie into this manifold, and provide raw water feed to the Arbutus WTP. Once this tie-in is complete, a new tie-in will be made to the existing 200 mm crossover main bringing Stocking Lake water to the existing Arbutus Reservoir, so that Stocking Lake water can be routed to the new WTP, downstream of the ozonation system, and immediately upstream of the UV reactors.

WATER TREATMENT SYSTEMS

As discussed in previous sections, two discrete water treatment plants will be provided, as follows:

- The 10.1 ML/d Arbutus WTP, including ozonation for colour removal, UV disinfection for primary disinfection, and chlorination for secondary disinfection. This plant will be designed to treat either of Chicken Ladder water or Stocking Lake, and would provide supply to North Ladysmith and the Diamond District.
- The 3.1 ML/d South End WTP, including UV disinfection for primary disinfection, and chlorination for secondary disinfection. The plant will treat exclusively Stocking Lake water, and will provide supply to South Ladysmith and Saltair.

The Arbutus Water Treatment Plant

The following figures present the proposed Arbutus WTP. The figures also show the proposed location of the new Arbutus treated water reservoir.

Figure 5-1: Overall Process Flow Schematic

Figure 5-2: Site Plan

Figure 5-3: Plant Layout

Presently, water supply is provided to the Arbutus Reservoir using two parallel pipelines, one 200 mm and one 300 mm. A new 400 mm epoxy coated carbon steel header would be constructed to tie into these pipelines, and convey the raw water to the new WTP location on the opposite side of the existing access road, immediately to the south of the existing Arbutus Reservoir. This tie-in will be made early in construction, by switching to the Stocking supply while the tie-in is made. A second tie-in to the existing supply pipeline will be

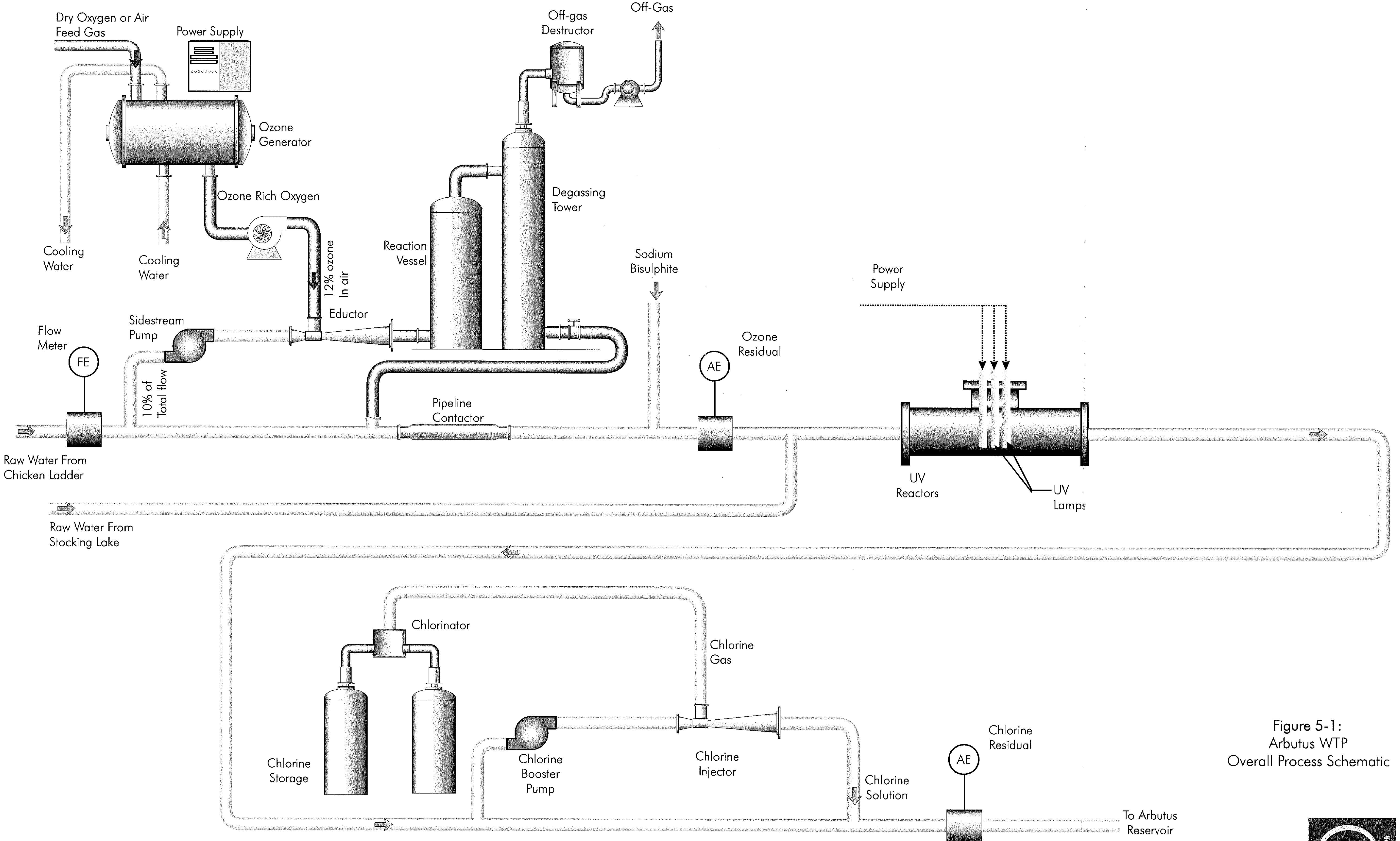

Figure 5-1:
Arbutus WTP
Overall Process Schematic

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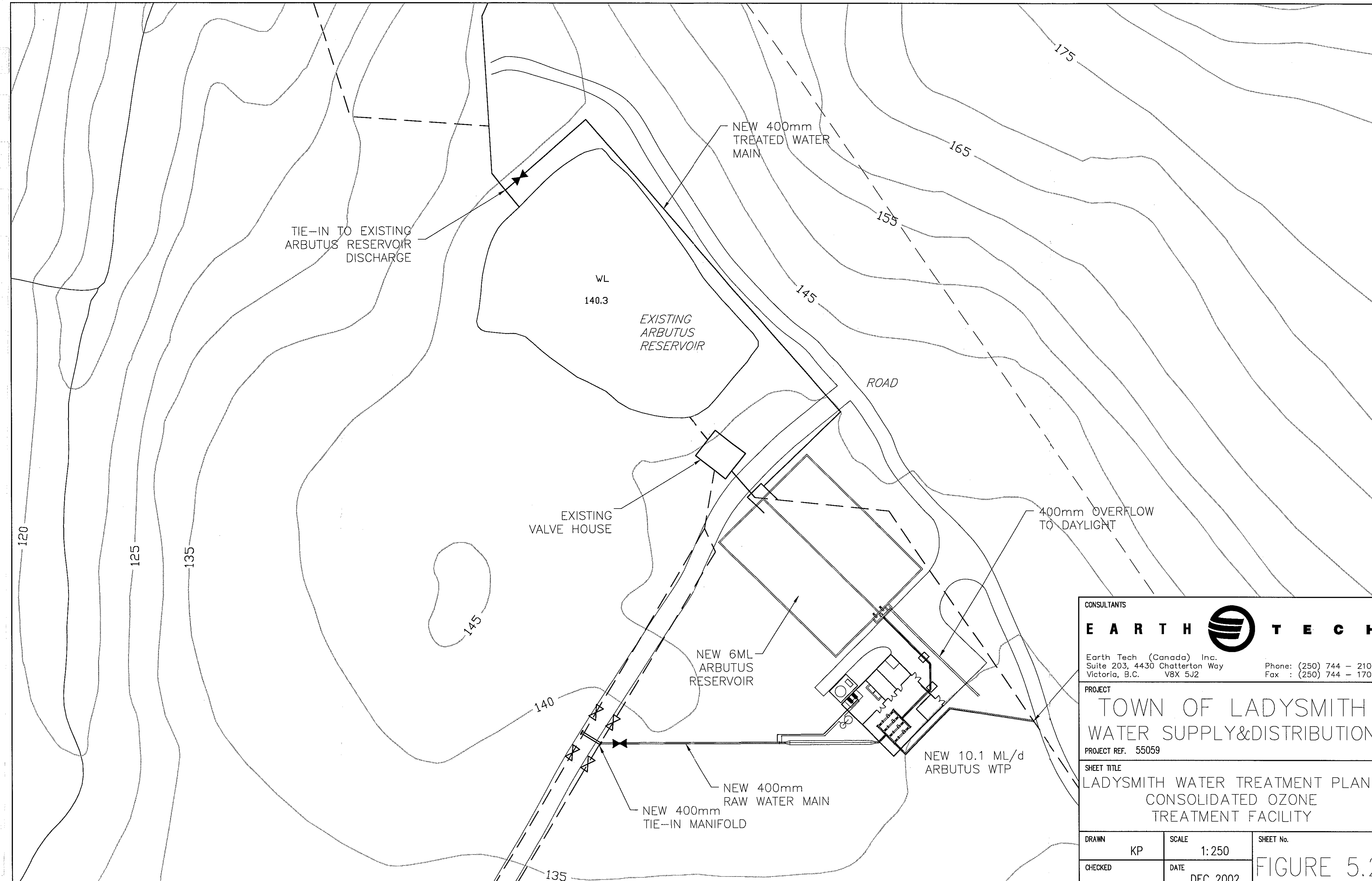
Town of Ladysmith
Water Supply and
Distribution
Preliminary Design


NEW 400mm
TREATED WATER
MAIN
175
165
155
145
TIE-IN TO EXISTING
ARBUTUS RESERVOIR
DISCHARGE
WL
140.3
EXISTING
ARBUTUS
RESERVOIR
ROAD
EXISTING
VALVE HOUSE
400mm OVERFLOW
TO DAYLIGHT
120
125
135
145
NEW 6ML
ARBUTUS
RESERVOIR
140
NEW 10.1 ML/d
ARBUTUS WTP
NEW 400mm
RAW WATER MAIN
NEW 400mm
TIE-IN MANIFOLD
135
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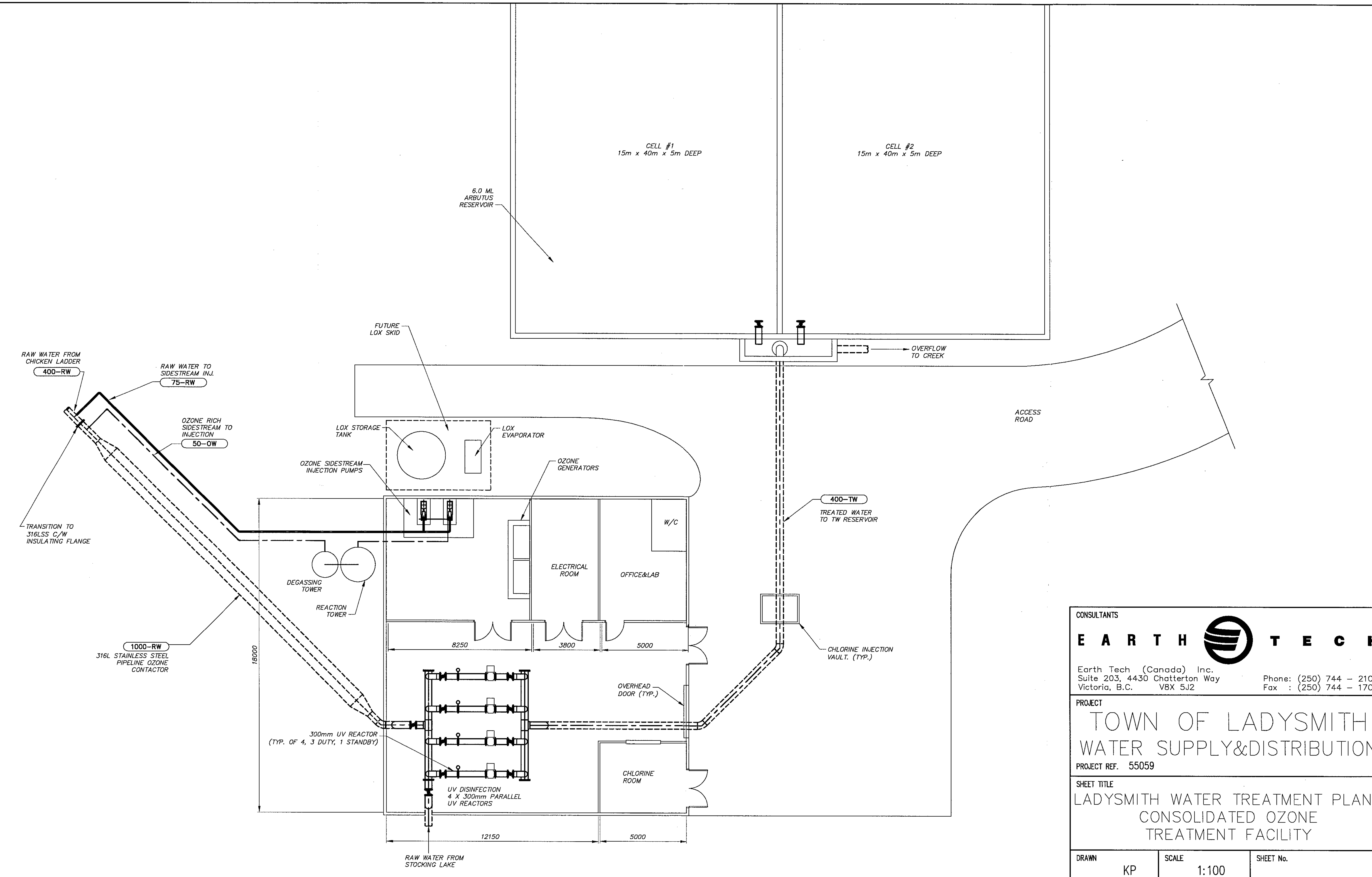
PROJECT
TOWN OF LADYSMITH
WATER SUPPLY&DISTRIBUTION
PROJECT REF. 55059
SHEET TITLE
LADYSMITH WATER TREATMENT PLANT
CONSOLIDATED OZONE
TREATMENT FACILITY
DRAWN KP
SCALE 1:250
SHEET No.
CHECKED
DATE DEC 2002
FIGURE 5.2



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PROJECT

TOWN OF LADYSMITH
WATER SUPPLY&DISTRIBUTION

PROJECT REF. 55059

SHEET TITLE

LADYSMITH WATER TREATMENT PLANT CONSOLIDATED OZONE TREATMENT FACILITY

DRAWN	SCALE	SHEET No.
KP	1:100	FIGURE 5.3
CHECKED	DATE DEC 2002	

made downstream of the existing Arbutus Reservoir, to allow treated water from the new treated water reservoir to tie into the existing water supply mains. Once complete, the existing Arbutus Reservoir can continue to be kept in service during construction.

Both tie-ins will include a 400 mm isolation butterfly valve to isolate the new plant from the existing service header. Shortly downstream of the valve at the inlet end of the plant, a 75 mm suction line for the ozone sidestream injection system will be drawn from the main header. Still further downstream, transition will be made from epoxy coated carbon steel to 316L stainless steel, with isolating flanges to prevent galvanic corrosion due to dissimilar materials. 316L stainless steel piping is required for ozone service, due to the highly corrosive nature of water carrying an ozone residual to most metallic piping materials.

A new 65 mm 316L injection diffuser will be fitted across this 400 mm header, to re-inject the ozone sidestream loop back into the pipeline, now carrying dissolved ozone. After the ozone is injected, a 20 metre length of 1000 mm 316L stainless steel pipeline will be constructed, to provide 2 minutes of ozone contact time at design flow. Oxidation reactions of colour causing compounds are typically very quick using ozone, and long contact times are not necessary.

As the ozonated water leaves the pipeline contactor, the pipeline diameter is once again reduced to 400 mm, and a sample tap will draw a sample of water, piped to an ozone residual analyzer. The analyzer will monitor ozone residual in the contactor discharge, and will provide the control signal for injection of a small dose of sodium bisulphite into the ozonated water, a strong reducing agent which reacts with and destroys residual ozone.

Once the ozone residual has been destroyed, a transition will once again be made in the 400 mm header to return to epoxy coated carbon steel piping, which will carry the flow into the treatment plant itself. As the Chicken Ladder main enters the building, it will merge with an extension of the raw water pipeline from Stocking Lake, so that Stocking water can be introduced into the plant just upstream of UV disinfection.

4 parallel 300 mm UV reactors (3 duty, 1 standby) will be provided, with a design fluence of 40 mJ/cm^2, to provide for a 3-log *Giardia* and *Cryptosporidium* inactivation, and a 2-log virus inactivation[13]. The reactors will be placed approximately 2 metres apart (on centre), to allow ample access to the UV lamps on each reactor. Flow distribution across each reactor will be balanced using flow orifices.

The 4 parallel reactors will once again tie together into a single 400 mm header, and chlorine solution will be injected using a pipeline diffuser. The now treated water will leave the plant, and will pass to the 6 ML Arbutus Reservoir. A small compartment will be placed at the inlet end of the reservoir to achieve the 2-log virus inactivation requirement necessary to meet the overall 4-log virus inactivation credit.

Two ozone generators will be provided, each rated to provide a peak of 60 kg/d of ozone. For small generators such as this, either air or oxygen may be used as a raw material for ozone generation. Although air fed systems are falling out of favour somewhat in the industry, in this case selection of an air fed system would offer the substantial benefit of eliminating the need for liquid oxygen (LOX) tankers to navigate the existing roadway to the Arbutus site. It is recommended that a more detailed analysis of air versus oxygen feed be conducted during detailed design. For the purposes of this report, it is assumed that air is used as the feed source.

Design ozone dosages will be 3 mg/L average, and 5 mg/L peak. The ozone generators would operate in a "lead-lag" mode of operation, with ozone drawn into the sidestream pumping loop using two 316L stainless

[13] Mofidi et al. (Journal AWWA, 2001) demonstrate inactivation of at least 2.0-log *Giardia* and *Cryptosporidium* at UV fluence of 11 mJ/cm^2, with no safety factor. The U.S. EPA Surface Water Treatment Rule allows a 2.0-log virus credit for UV fluences of 36 mJ/cm^2 or more (which includes a safety factor of three). A design fluence of 40 mJ/cm^2 will therefore reliably provide at least 3.0-log inactivation of *Giardia*, *Cryptosporidium*, and 2.0-log viruses.

steel "Mazzei" injectors, followed by a skid mounted ozone dissolution/reaction and off-gassing tower, to ensure that the ozone gas is fully dissolved in the water. Excess ozone gas will be continually vented from the top of the degassing tower via a catalytic ozone off-gas destructor, to ensure that all ozone in the off-gas is completely destroyed before the off-gas is vented to atmosphere.

The ozone-rich sidestream water will then be re-routed back to the inlet of the pipeline contactor, where it will be injected into the main plant flow using a pipeline diffuser. The entire facility will be housed inside an 18 m x 18 m pre-engineered building, constructed on a slab on grade. The site will be graded, and an access road provided to facilitate access to the site by LOX tankers and other vehicles. A new 150 kVA power supply will be brought in to provide power to the new facility, tying into the existing B.C. Hydro power lines passing just to the east of the proposed facilities.

To allow for the eventuality that filtration may be required in the future, in the event of changing regulations or deterioration in water quality, space will be reserved immediately to the south end of the new facility, to provide for an extension to the plant for the retrofit of filtration. The addition of filtration would by no means be incompatible with the process as it is proposed now, as most likely direct filtration would be provided in this case, without clarification. If this addition was completed, ozonated water would provide a feed to the filters, and filtered water would then be returned back into the plant just upstream of the UV disinfection system.

The land to the south of the existing Arbutus Reservoir slopes gradually downwards to the south. It is proposed that the entire site area be graded to approximately 140.5 m, such that the treatment plant is above the top water level of the treated water reservoir. The treated water reservoir will for the most part be buried, with approximately 0.75 m above grade. Lockable security hatches will be provided to control access to the reservoir. With only limited truck traffic required to access the site, extensive upgrading of the existing road network is not proposed, other than the provision of a new roadway to access the proposed site, tying into the existing road network. No geotechnical findings which would discourage use of this site or the South End site for the proposed purpose were found during the preliminary Geotechnical site investigation, with the complete report included as Appendix "D".

The South End Water Treatment Plant

The following figures present the proposed South End WTP. The figures also show the proposed location of the new South End treated water reservoir.

Figure 5-4: Overall Process Flow Schematic

Figure 5-5: Site Plan

Figure 5-6: Plant Layout

The South End WTP, which will always utilize Stocking Lake as the source water, can necessarily be substantially simpler than the Arbutus WTP, since ozonation is not needed. Since it will also be a satellite facility, only minimal facilities will be provided for operator comfort, since it is not envisioned that the plant will normally be manned, and will be operated remotely. Raw water will enter the plant via a new 200 mm main tied into the main pipeline from Stocking Lake, close to the present tie-in for the Contact Tank. UV disinfection of the water will be provided using 2 parallel 300 mm UV reactors (1 duty, 1 stand-by), each sized to provide a design fluence of 40 mJ/cm^2, and an overall pathogen inactivation of 3-log (99.9%) *Giardia* and *Cryptosporidium*, and 2-log (99%) viruses. Chlorination will also be provided using gas chlorination, to provide the remaining 2-log virus inactivation credit required to achieve the overall 4-log virus inactivation goal.

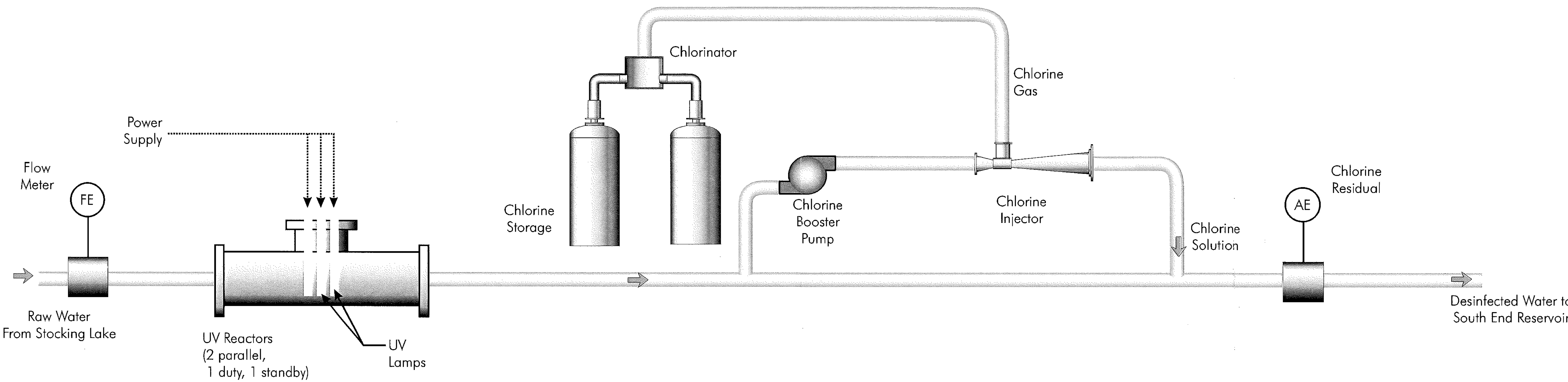
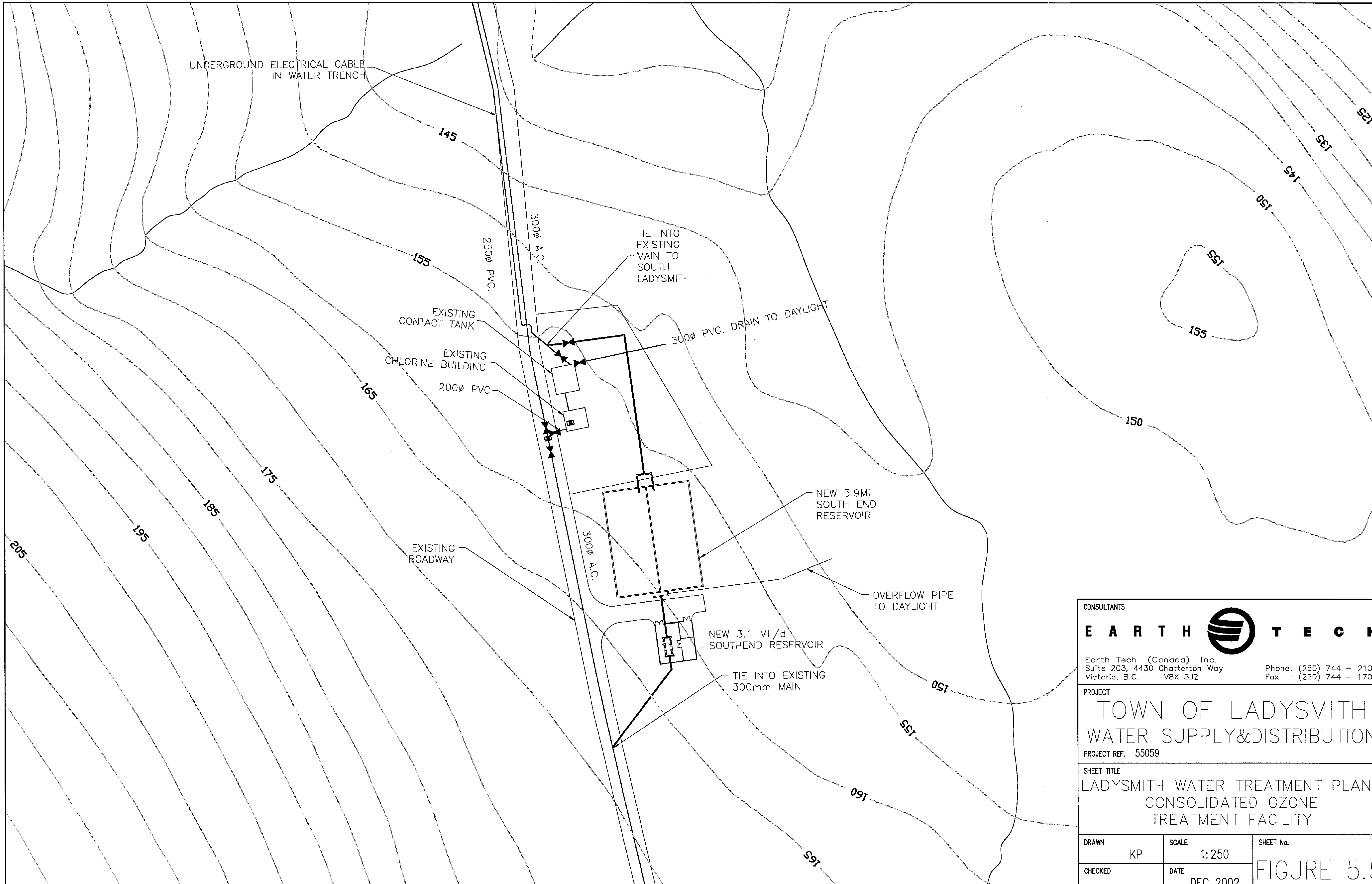


Figure 5-4:
South End WTP
Overall Process Schematic



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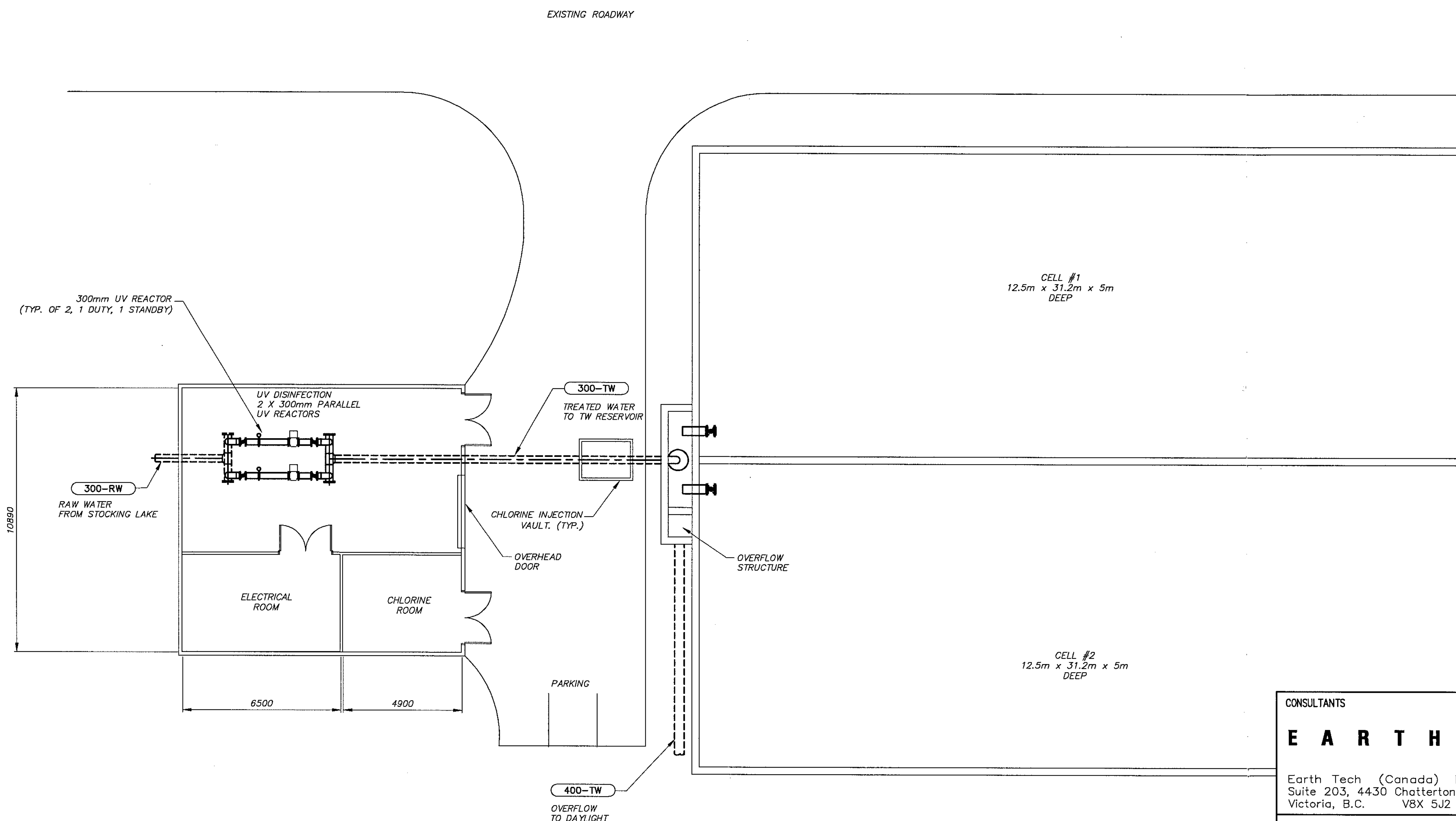
PROJECT	TOWN OF LADYSMITH WATER SUPPLY&DISTRIBUTION PROJECT REF. 55059
SHEET TITLE	LADYSMITH WATER TREATMENT PLANT CONSOLIDATED OZONE TREATMENT FACILITY
DRAWN	KP
CHECKED	
SCALE	1:250
DATE	DEC 2002
SHEET No.	FIGURE 5.5



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PROJECT

TOWN OF LADYSMITH
WATER SUPPLY&DISTRIBUTION

PROJECT REF. 55059

SHEET TITLE

LADYSMITH WATER TREATMENT PLANT CONSOLIDATED OZONE TREATMENT FACILITY

DRAWN	SCALE	SHEET No.
KP	1:100	FIGURE 5.6
CHECKED	DATE	
	DEC 2002	

The new facility will be an 11.5 m x 11m pre-engineered building constructed on a slab on grade. A new 50 kVA power supply will be brought into the new facilities, tying into the existing B.C. Hydro immediately to the east of the facilities.

The land to the south of the existing Contact Tank slopes gradually upwards relatively steeply to the south and west. It is proposed that the area around the WTP building be graded to approximately 159 m, such that the treatment plant is above the top water level of the treated water reservoir (158 m). The treated water reservoir will for the most part be buried, with approximately 0.75 m above grade. Lockable security hatches will be provided to control access to the reservoir.

With only limited truck traffic required to access the site, extensive upgrading of the existing road network is not proposed, other than the provision of a new roadway to access the proposed site, tying into the existing road network.

TREATED WATER STORAGE & DISTRIBUTION

Two new treated water reservoirs will be constructed, one at each of the two water treatment plants. Each reservoir will be constructed downstream of the plants, and will store treated water, such that the plants can be designed for peak day demand, rather than peak hour demand, or even fire flow. The new reservoirs will be as follows:

- A new 5.7 ML Arbutus Reservoir, sited immediately to the north of the new Arbutus WTP with a top water surface elevation of 140 metres, i.e. same as the existing Arbutus Reservoir, to ensure compatibility with existing system hydraulics. The reservoir will be designed in two separate, equally size cells to allow one cell to be removed from service for maintenance. Each cell will 15 m wide x 40 m long, and have a water depth of 5 metres, and on overall depth of 5.5 metres.

  The new reservoir will provide fire storage, as well as balancing and emergency storage for North Ladysmith and the Diamond District. Flow will enter the existing distribution system by gravity from the reservoir via a valved tie-in. An overflow structure will also be provided at the inlet end of the reservoir, to protect against over-filling.

- A new 3.9 ML South End Reservoir, sited immediately to the north of the new South End Water Treatment Plant, with a top water surface elevation of 158 metres, i.e. same as the existing contact Tank, to ensure compatibility with existing system hydraulics. The reservoir will be designed in two separate, equally size cells to allow one cell to be removed from service for maintenance. Each cell will 15 m wide x 40 m long, and have a water depth of 5 metres, and on overall depth of 5.5 metres.

  The new reservoir will provide fire storage, as well as balancing and emergency storage for South Ladysmith and Saltair. Flow will leave the reservoir via a new 300 mm main, which will be constructed to improve the ability to provide fire flow to South Ladysmith and Saltair. An overflow structure will also be provided at the inlet end of the reservoir, to protect against over-filling.

COST ESTIMATES

Capital and operating cost estimates (for treatment only) have been developed for the preferred alternative, and summary tables of these costs are presented as Tables 5-1 and 5-2 respectively.

Table 5-1
Estimated Capital Costs for the Recommended Upgrades

Upgrade Requirements	Amount	Unit	Unit Cost	Total Cost
Water Treatment Plants				
New 10.1 ML/d Arbutus Water Treatment Plant		Lump Sum		$ 2,200,000
New 3.1 ML/d South End Water Treatment Plant		Lump Sum		$ 600,000
Treated Water Reservoirs				
New 5.7 ML Arbutus Reservoir	5,700	m^3	240	$ 1,368,000
New 3.9 ML South End Reservoir	3,900	m^3	240	$ 935,000
Conveyance Systems				
NPV of 200 AC replacement in 15 years from valve house to Arbutus	-	Lump Sum	-	$ 332,000
New 2,400 m of 300 mm Main for South Ladysmith & Saltair	2,400	m	300	$ 720,000
New PRV Station at the South Ladysmith & Saltair Boundary				$ 50,000
Valves and Controls at existing Arbutus Reservoir	-	Lump Sum	-	$ 100,000
Valves and Controls at Contact Tank	-	Lump Sum	-	$ 50,000
Miscellaneous				
SCADA Upgrades		Lump Sum		$ 250,000
Decommissioning of existing Arbutus Reservoir	-	Lump Sum	-	$ 20,000
Decommissioning of existing Contact Tank	-	Lump Sum	-	$ 20,000
Sub-Total				$ 6,646,000
Engineering at 10%				$ 665,000
Contingencies at 20%				$ 1,329,000
Grand Total				$ 8,640,000

Table 5-2
Estimated Operating and Maintenance Costs for Treatment Works[5]

Arbutus WTP	
Energy Costs[1]	$ 38,900
Chemical Costs[2]	$ 700
Maintenance Materials Costs[3]	$ 16,000
Labour Costs[4]	$ 25,600
Estimated Total Annual O&M Costs	**$ 81,200[6]**
South End WTP	
Energy Costs	$ 14,300
Chemical Costs	$ 200
Maintenance Materials Costs	$ 3,800
Labour Costs	$ 11,000
Estimated Total Annual O&M Costs	**$ 29,300[6]**

Notes:

1: Includes costs for process energy for ozonation, UV disinfection, and chlorination, with ozonation in operation only for 4 months per year, plus building energy. Energy costs are estimated at 7¢ per kWh.

2: Includes costs for gas chlorine, and sodium bisulphite (for Arbutus WTP only).

3: Includes costs for spare parts, UV lamp replacement, and other miscellaneous maintenance materials.

4: Labour costs are estimated at $60 per man-hour.

5: Total costs do not include royalty costs for the use of UV disinfection. Calgon Corporation are involved in an ongoing attempt to claim patent royalties on a $ per m^3 of water basis. Although the debate is as yet unresolved, it is considered unlikely that Calgon will be able to carry through this claim.

6: It is to be noted that these O&M costs relate to the operation and maintenance of new treatment facilities only, and do not include costs for operation and maintenance of the distribution system. O&M costs for the last fiscal year were $76,340.