HOLLAND LAKE AND STOCKING LAKE HYDROLOGY UPDATE

PRESENTED TO

The Town of Ladysmith

SEPTEMBER 2014
ISSUED FOR USE
FILE: V13203036-01

CONSULTING ENGINEERS & SCIENTISTS · www.eba.ca

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EXECUTIVE SUMMARY

The Town of Ladysmith (the Town) retained Tetra Tech EBA Inc. (Tetra Tech EBA) in January 2014 to carry out a hydrology update for Holland Lake and Stocking Lake in support of the Town's long-term planning for its surface water supply system. In February 2008, Tetra Tech EBA completed the Stocking Lake Dam Hydrotechnical Assessment for the Town. This earlier study included the hydrologic and hydraulic analyses performed for the water sources available in the Stocking Lake watershed, the Holland Lake/Creek watershed, and the Banon Creek watershed. Subsequent to the 2008 study, the Town required an update of the 2008 hydrological model (water balance) to consider the impacts of current water licence limitations, current minimum flow requirements, updated water demand projections and climate change. This report covers the hydrology update and findings from the evaluation of five water supply options identified.

Additional hydrometric/climatic data and water consumption records/projections subsequent to the 2008 study were collected and analyzed. The 2008 hydrological model developed by generating rating curves at reservoirs, by taking into account average water losses throughout the water supply and distribution systems, by using a time series of calibrated synthetic inflows at various points of interest was used as the basis for the current study. Current water licence limitations (both at Stocking Lake and in the Holland Lake/Creek system) and minimum flow requirements (10% of the mean annual discharge at point of diversion) were considered in the model update. As requested by the Town, future water demand projections when the population of Ladysmith (excluding other service areas) reaches the thresholds of 18,000 and 30,000 were considered in the current analysis. A review of research on the impacts of climate change on the hydrology of the Vancouver Island region was also conducted. Based on the findings in the research, changes were applied to the seasonal inflows developed for the Holland and Stocking Lake watersheds to take into account the impacts of climate change. Based on discussion with the Town and Koers & Associates Engineering Ltd., five water supply options were developed, resulting in a total of 25 model scenarios for the years of 2013, 2054 with and without climate change considerations, and 2080 with and without climate change considerations. The five water supply options evaluated are as follows:

- Option 1: Existing Conditions with Banon Creek Diversion (with manual flows released from Holland Lake)
- Option 2: Banon Creek Diversion with Water Treatment Plant (with manual flows released from Holland Lake)
- Option 3: Banon Creek Diversion, Holland Lake Diversion Pipeline and Water Treatment Plant
- Option 4: Banon Creek Diversion with Water Treatment Plant and Chicken Ladder Storage
- Option 5: Banon Creek Diversion with Water Treatment Plant, Chicken Ladder Storage and Raised Holland Lake Dams

A matrix of simulation scenarios was developed with different combinations of demand assumptions, water supply options and climate change considerations. Frequencies of depletion and spilling were determined over a period of 51 years for each case. The return period to reach the deficiency level (minimum lake level in the final water source beyond which supply is not possible) for each case based on 51 years of available hydrometric record was also determined. Based on the findings from this study, it is recommended that:

- Option 4, which includes a water treatment plant with additional storage at Chicken Ladder, is further explored. Results from the analysis suggest that this option would result in a more reliable long-term water supply for the Town of Ladysmith.

- Option 3, which includes a diversion pipeline from Holland Lake to Stocking Lake, should also be further considered in view of its advantage with regards to long-term water supply reliability for Saltair.
- Option 5, which includes raising the Holland Lake Dams by 1.5 metres, would provide enhanced long-term water supply reliability if combined with diversion from Banon Creek, a water treatment plant and additional Chicken Ladder storage.
- The Town continues with the review of existing water licences in conjunction with the Cowichan Valley Regional District and the Province and consideration of new water licences for potential surface water source improvements to sustainably meet the future water demand from both the Stocking Lake and Holland Lake/Creek systems.
- The potential effects of climate change are further assessed, to support the development of a long-term strategy to achieve system resiliency.
- The potential reduction of storage capacity due to sedimentation, in both Stocking and Holland Lakes should be assessed for the long-term analyses including climate change conditions.
- A more user friendly water balance tool is developed to help the Town of Ladysmith assess various water policy and operational rules in a quicker system, easier to communicate and transfer. A suggested software package to achieve this is GoldSim.
- Further model calibration to be conducted to refine the synthetic inflow time series developed for Stocking Lake if more historical water levels and consumption records can be retrieved.
- Continuous flow monitoring at Stocking Creek is conducted.
- Continuous flow monitoring to be conducted on Holland Lake/Creek for further refinement of the synthetic inflow time series for Holland Lake and Holland Creek. Also, in order to calibrate the Holland Lake/Creek hydrological model, actual diversion rates from Banon Creek, water levels at Holland Lake, and consumption records will be required. It is recommended that the Town to consider these additional hydrometric monitoring programs in the long-term planning of its water supply system.

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LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the Town of Ladysmith and its agents. Tetra Tech EBA Inc. (Tetra Tech EBA) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the Town of Ladysmith, or for any Project other than the proposed water supply options evaluated in the current study. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech EBA's Services Agreement. Tetra Tech EBA's General Conditions are provided in Appendix A of this report.

1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) has been retained by the Town of Ladysmith (the Town) to carry out a hydrology update for Holland Lake and Stocking Lake in support of the Town's long-term planning for its surface water supply system. In February 2008, Tetra Tech EBA completed the Stocking Lake Dam Hydrotechnical Assessment for the Town. This earlier study included the hydrologic and hydraulic analyses performed for the water sources available in the Stocking Lake watershed, the Holland Lake/Creek watershed, and the Banon Creek watershed. It is our understanding that the Town requires an update of the 2008 hydrological model to consider the impacts of current water licence limitations, current minimum flow requirements, updated water demand projections and climate change. Based on discussions with representatives from the Town and Koers & Associates Engineering Ltd. (Koers), a number of water supply options were developed. Tetra Tech EBA is pleased to submit this report to summarize the results of the hydrology update.

2.0 SCOPE OF WORK

The scope of work for the current assignment is listed as follows:

- Update the 2008 Holland Lake and Stocking Lake hydrological model to include:
  - All water licences on Holland Lake and Stocking Lake for the Town and the Cowichan Valley Regional District;
  - Minimum flow requirements at various points of diversion equivalent to 10% of mean annual discharge;
  - Updated water demand projections; and
  - Consideration of climate change.
- Determine the statistical return period of water deficiency events, for selected water supply scenarios; and
- Prepare a report to summarize the findings.

3.0 REVIEW OF BACKGROUND INFORMATION

The following data provided by the Town and Koers were reviewed to extract relevant information with respect to the hydrology and hydraulics of the project site:

- Current water licence information for the study area;
- Recent water usage information by Ladysmith and Saltair and water demand projections;
- Historical water levels for Stocking Lake and Holland Lake; and
- Additional rainfall data within the study area from 2011 to 2013.

4.0 SITE DESCRIPTION

Located in the Cowichan Valley Regional District and along the east coast of Vancouver Island, Ladysmith is approximately 23 km south of Nanaimo and 97 km north of Victoria on Highway #1. Two nearby communities are Diamond Improvement District and Saltair located just north and south of Ladysmith, respectively. The main sources of water supply for these three communities are the Stocking Lake system and the Holland Lake/Creek system (Figure 4.1). The following sections provide general descriptions of the water supply sources within the study area and the water licences currently held by the Town of Ladysmith and CVRD.

4.1 Operation of Water Supply Sources

In 2007/2008, a new covered reservoir (Arbutus Reservoir) was constructed to replace the previous open reservoir. The new Arbutus Reservoir collects water from both the Stocking Lake and the Holland Lake/Creek systems and distributes water either to South Ladysmith or North Ladysmith/Diamond District. In addition, a separate pipeline, approximately following the alignment of Stocking Creek, ties in to the main pipeline just south of Stocking Lake, and feeds to the Saltair (CVRD) system.

Water released from Holland Lake and available at Holland Creek enters the water supply system at a diversion point at a small stilling basin called Chicken Ladder Dam. This source is conveyed to the new Arbutus Reservoir, where it combines with the water from the Stocking Lake system. Additional flow is also available via seasonal diversion from Banon Creek to help fill Holland Lake.

4.2 Watershed Characteristics

The Stocking Lake, Holland Lake/Creek and Banon Creek watersheds are all located along the east side of Vancouver Island. Figure 4.2 shows the major watershed boundaries within the study area. The following paragraphs provide brief descriptions of the characteristics of each watershed.

The Stocking Lake watershed is small compared to other watersheds in the area. It has a drainage area of approximately 1.65 km^2, and varies in elevation from 360 m to 600 m, with a median elevation of 380 m. Overflows from Stocking Lake flow to Stocking Creek, which runs in a southeast direction for about 3.2 km and then northeast for about 2.2 km before it drains into Stuart Channel.

The Holland Lake/Creek watershed at the Chicken Ladder Dam has a drainage area of approximately 25 km^2 and varies in elevation from 189 m to 1300 m. Holland Lake, located in the upper watershed, has a drainage area of approximately 1.75 km^2 at its outlet. Water stored in Holland Lake is released to South Holland Creek and collected at Chicken Ladder on Holland Creek where it is diverted to town via the Arbutus Reservoir. The median basin elevations of the Holland Lake watershed and the remaining portions of Holland Creek watershed are 670 m and 580 m, respectively.

Banon Creek, a tributary of the Chemainus River, has a drainage area of approximately 7 km^2 at the point of diversion to Holland Lake. The watershed elevation ranges from 660 m to 1300 m. The Banon Creek watershed shares a boundary with the Holland Creek watershed in the north. Banon Creek is joined by West Banon Creek downstream before it flows into the Chemainus River.

4.3 Climatic Data

A number of climate stations operated by the Meteorological Service of Canada (MSC) are located within the study region. In view of their close proximity to the project site, elevation, and relatively long period of record, the following stations were considered to have climatic data that are useful in determining the climate conditions at the project site.

Table 4.1: Environment Canada Climate Stations

Station ID	Station Name	Elevation (m)	Period of Record
1025370	Nanaimo Airport	28.4	1971 – 2010
1021830	Comox A	25.6	1971 – 2010
1016940	Saanichton CDA	61.0	1971 – 2010
10253G0	Nanaimo City Yard	114	1971 - 2010

According to the 1981 to 2010 climate normal, the mean annual precipitation at Nanaimo Airport station and at Nanaimo City Yard station are 1,165 mm (1,098 mm of rainfall and 69 mm of snowfall) and 1,140 mm (1,100 mm of rainfall and 40 mm of snowfall), respectively. Most rainfall occurs in the fall and winter (November to March) while most snowfall occurs in winter (December to January). Mean daily temperatures at Nanaimo Airport station ranges from about 3^{o}C in December to 18^{o}C in August.

It should be noted that recent rainfall data has been collected at Ladysmith Secondary School and at a local logging site situated at an elevation of 490 m GSC. Based on data provided by the Town, the 2013 annual rainfall total at Ladysmith Secondary School is within 10% of that collected at Nanaimo Airport station while the mean annual rainfall total at the local logging site from 2011 to 2013 is about 50% higher than that at Nanaimo Airport station, likely due to the higher basin elevation at the local logging site.

4.4 Hydrometric Data

Historical streamflow data were gathered from Environment Canada to characterize the hydrology of the study area. It should be noted that there is no long-term stream discharge information available within the Stocking Lake and Holland Lake/Creek watersheds. The hydrologic characteristics of these watersheds must be inferred from regional hydrometric stations. The regional hydrometric stations used in this study are listed in Table 4.2.

Table 4.2: Water Survey of Canada Hydrometric Stations

Station ID	Station Name	Drainage Area (km^2)	Period of Record	Years of Data	Status
08HA001	Chemainus River near Westholme	355	1914 - 2012	65	Active
08HA003	Koksilah River at Cowichan Station	209	1914 - 2012	63	Active
08HA016	Bings Creek near the mouth	15.5	1961 - 2012	52	Active
08HB002	Englishman River near Parksville	324	1913 - 2012	41	Active
08HB003	Haslam Creek near Cassidy	95.6	1914 - 1998	22	Inactive
08HB027	Millstone Creek near Wellington	46.1	1961 - 1974	10	Inactive
08HB032	Millstone Creek at Nanaimo	86.2	1961 - 2012	32	Active
08HB041	Jump Creek at the mouth	62.2	1970 - 2012	43	Active

Of the above selected hydrometric stations, Chemainus River near Westholme station has the largest drainage area and the longest period of record. Bings Creek near the mouth station has the smallest drainage area and a fairly long period of record.

As part of a source water quality monitoring project conducted by Earth Tech in 2000 for the Town, daily flow data on Holland Creek were obtained from May 2000 to June 2001. This information was utilized later for calibrating calculated inflows on Holland Creek.

4.5 Water Licences

Current water licence information for the Town of Ladysmith and the Cowichan Valley Regional District (CVRD) within the study area was provided by Koers and is summarized in the following table.

Table 4.3: Current Water Licence Information

Licensee – The Town of Ladysmith	
Stocking Lake System	
CL 005333	500,000 gal/day (2,273 m^3/day) maximum from Stocking Lake; or 182,500,000 gal/year (829,662 m^3/year) from Stocking Lake
Holland Creek System	
CL 017746	600,000 gal/day (2,728 m^3/day) maximum from Holland Lake; or 219,000,000 gal/year (995,594 m^3/year) from Holland Creek
CL 112812	200 ac-ft per annum (246,696 m^3/year) storage from Holland Creek in Holland Lake
CL 125167	1,475 ac-ft per annum (1,819,396 m^3/year) from Banon Creek between November 1 and May 31/A maximum of 1,475 ac-ft per annum (1,819,396 m^3/year) at a rate not to exceed 800,000 gal/day (3,637 m^3/day) may be re-diverted from Holland Lake for waterworks purpose.
Licensee – The Cowichan Valley Regional District (CVRD)	
CL 067481	98,550,000 gal/year (448,017 m^3/year) from Stocking lake and Stocking Creek
CL 067482	105,000,000 gal/year (477,340 m^3/year) from Stocking Lake and Stocking Creek
CL 067483	100 ac-ft per annum (123,348 m^3/year) storage from Stocking Creek in Stocking Lake
CL 067484	650 ac-ft per annum (801,762 m^3/year) storage from Stocking Creek in Stocking Lake

The licences that permit the diversion of water by the Town, allow a maximum annual usage/storage of:

Stocking Lake System

<u>Withdrawal</u>

CL 005333 500,000 gal/day (2,273 m^3/day) maximum or 830,000 m^3

Note: Water withdrawal subject to the availability of inflow to Stocking Lake

Holland Creek System

Withdrawal		Storage	
CL 017746	996,000 m^3	CL 112812	247,000 m^3
(600,000 gal/day or 2,728 m^3/day max)		CL 125167	1,819,000 m^3

CL 125167 1,327,500 m^3 re-diverted from Holland Lake with diversion from Banon Creek

(800,000 gal/day or 3,637 m^3/day max)

Note: Minimum flow requirement of 10% mean annual discharge applies on Holland Creek

Annual Total	**2,323,500 m^3**	**Annual Total**	**2,066,000 m^3**

The licences that permit the diversion of water by CVRD, allow a maximum annual usage of:

Stocking Lake System

Withdrawal		Storage	
CL 067481	448,000 m^3	CL 067483	123,000 m^3
CL 067482	477,000 m^3	CL 067484	802,000 m^3
Total	**925,000 m^3**	**Total**	**925,000 m^3**

It should be noted that Conditional Water Licence No. 125167 is an amendment to Conditional Water Licence No. 112813. The new water licence has been issued due to a change of works request for the addition of a pipe from Holland Lake to Stocking Lake pipeline and for administrative reasons to correct the spelling of the water source, Banon Creek. There has been no change to the rights authorized by former Conditional Water Licence No. 112813. However, the Town is required to release 10% of the mean annual discharge of Holland Creek to the original watercourse in order to maintain flow for fish.

Also, it is our understanding that Water Licence No. 5333, which allows the Town to withdraw a theoretical rate of 500,000 imperial gallons per day from Stocking Lake during the entire year, is subject to the availability of inflow to Stocking Lake.

5.0 HYDROLOGY UPDATE

An update of the 2008 hydrological model (water balance) was carried out for the Stocking Lake and Holland Lake/Creek systems to incorporate recent water usage and water demand projections, additional flow data available from Water Survey of Canada for the study area, current water licence limitations, minimum flow requirements, and climate change considerations. Five water supply options were developed through discussions with the Town and Koers, resulting in a total of 20 model scenarios.

5.1 Model Components

A hydrological model was developed to simulate water levels in Stocking Lake and Holland Lake and to evaluate different water supply options to meet future water demand. The model was developed using Excel and successfully met the requirements of this project, however the Town should consider implementing the model using GoldSim, a more user friendly tool to enable quick assessment of water policies and operational rules. The following sections present the methodology used in updating the 2008 base model.

5.1.1 Volume-Elevation Relationship

The volume-elevation relationships for Stocking Lake and Holland Lake were provided by the Town in 2008 in the following documents:

- Ministry of Environment Water Management Branch, May 1986. Storage Inventory Programme Cowichan Basin – Vancouver Island System, Stocking Lake Reservoir Plan of Reservoir (Dwg. No. 4984-12).
- Stantec Consulting Ltd., November 2003. Holland Lake Topographic Survey Drawing No. 60501BASE and Reservoir Storage Information.

Based on the above information, Stocking Lake has a bottom elevation of 333.63 m GSC (Geodetic Survey of Canada) and a capacity of approximately 1,074,400 m^3 when the water level is at the spillway crest (360.55 m GSC). Holland Lake has a bottom elevation of 646.16 m GSC and a capacity of approximately 1,704,000 m^3 when the water level is at the drop inlet pipe spillway crest at an elevation of 654.16 m GSC. Based on discussion with the representatives of the Town and additional survey information available, it is our understanding that the spillway crest at Holland Lake was raised prior to the 2003 survey. Therefore, the 2003 survey presents the volume-elevation relationship with respect to the existing or raised spillway crest elevation of 654.16 m GSC.

5.1.2 Rating Curve

Stocking Lake Dam was constructed in 1902 and reconstructed in 1964. In 1966, the earth-fill dam was raised by 1.3 m to the existing dam crest elevation (361.75 m GSC). The dam contains a rough, masonry-lined broad-crested spillway with a crest length of 4 m and a crest elevation of 360.55 m GSC. There is a 450 mm diameter low level outlet (upstream invert elevation at 654.53 m GSC) as the water intake. The dam has a granular foundation, which is reportedly leaking.

There are two dams, East Dam and West Dam, impounding water in Holland Lake. The dams were constructed in 1980. The West Dam has a crest length of 460 m and the East Dam is 915 m long. The dams have an average height of 4.6 m and a maximum height of 7.6 m. The dams were constructed mainly with silty, sandy gravel. On the East Dam, at the south abutment, there is a water diversion conduit designed to divert water from Banon Creek into Holland Lake. On the West Dam, there is a low level conduit and a spillway. The 300 mm diameter low level conduit is controlled by two valves. The drop inlet pipe spillway consists of a concrete square box weir structure with a 1.2 m inside diameter, precast, segmental concrete conduit (upstream invert elevation at 652.45 m GSC) passing through the dam at an approximate slope of 10%.

The discharge for the broad-crested spillway at Stocking Lake Dam was estimated based on the following equation (Smith, 1995):

$$Q = CLH^{1.5} \qquad \text{Equation (1)}$$

where

Q = Discharge (m^3/s);

C = Discharge coefficient, 1.705 (for broad-crested spillway);

L = Effective spillway length (m); and

H = Head above spillway crest (m)

The discharge for the drop inlet pipe spillway at the West Dam on Holland Lake was estimated based on Equation (1) for the weir flow with the discharge coefficient varying based on the ratio of the head above spillway crest (H) to the effective spillway length (L). For pipe flow, the following equations were used:

$$Q = 0.785D_o^2(2gh/(1.3+fL/D_o))^{0.5} \qquad \text{Equation (2)}$$

where

Q = Discharge (m^3/s);

D_o = Pipe diameter (m);

g = Acceleration of gravity, 9.81 m/s^2;

h = Effective head, $H - z + S_oL + D_o/2$, (m);

$$fL/D_o = 2gn^2L/R^{1.33} \qquad \text{Equation (3)}$$

where

n = Manning's n, 0.013 for concrete;

L = Length of pipe (m);

R = Flow area over wetted perimeter or $D_o/4$ at full flow (m);

H = Water surface elevation (m);

z = Inlet pipe spillway crown elevation (m); and

S_o = Inlet pipe spillway slope.

The rating curves developed for the spillways at Stocking Lake and at Holland Lake were then used in the hydrological model.

5.1.3 Mean Annual Runoff and Synthetic Inflows

The 2008 hydrological model was developed using hydrometric/climatic data available at the time of the study. In general, a regional analysis was first conducted to estimate the preliminary mean annual runoff for the watersheds of interest, followed by the development of synthetic inflow time series at various points of interest based on selected monthly streamflow data in the region. The synthetic inflow time series adjusted to match with the mean annual runoff values were then further calibrated using available historical water levels in Stocking Lake and available flow data on Holland Creek.

For the current analysis, additional streamflow data from 2005 to 2012 at all selected regional hydrometric stations were incorporated, resulting in an extended period of record of 51 years. As in the 2008 hydrological analysis, the Bings Creek near the mouth (08HA016), the Millstone Creek at Nanaimo (08HB032) and the Jump Creek at the Mouth (08HB041) stations were used to develop the synthetic inflow time series at various points of interest. To calibrate the synthetic inflows for Stocking Lake, available historical water levels and water usage information for Stocking Lake were reviewed. A model calibration was carried out using Stocking Lake water levels from 2003 to 2005. In order to minimize the difference between calculated and measured water levels, a reduction factor (0.79) was applied to the synthetic inflow time series. It is recommended that to further refine the synthetic inflow times series developed for Stocking Lake, additional model calibration be conducted if more historical water levels and consumption records can be retrieved.

Calibration of synthetic inflows for Holland Lake/Creek was performed by using available flow data on Holland Lake/Creek measured in 2000 and 2001. A reduction factor (0.69) was determined and applied to the synthetic inflow time series for Holland Lake/Creek. It is recommended that flow measurements be made on Holland Lake/Creek in the future for further refinement of the synthetic inflow time series for Holland Lake and Holland Creek. Furthermore, in order to calibrate the Holland Lake/Creek hydrological model, actual diversion rates from Banon Creek, water levels at Holland Lake, and consumption records will be required. It is recommended that the Town to consider these additional hydrometric monitoring programs in the long-term planning of its water supply system. Table 5.1 summarizes the mean monthly and mean annual runoff for the various watersheds of interest.

Table 5.1: Mean Monthly and Mean Annual Runoff (mm)

Watershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Stocking Lake	196	135	122	67	42	21	10	9	10	35	124	187	960
Holland Lake	260	179	163	89	56	29	14	12	13	47	165	248	1277
Holland Creek*	232	160	146	79	50	26	12	10	12	42	147	222	1141

Notes: *Holland Creek watershed excluding Holland Lake watershed

5.1.4 Lake Evaporation and Other Losses

Other losses such as leakage through the Stocking Lake system supply pipe (0.002 m^3/s) and seepage through Stocking Lake Dam (0.001 m^3/s) remain the same as determined in the 2008 study. However, evaporation rates in the lakes were updated based on the more recent climate normal values (1981 to 2010) available at Sannichton CDA and Comox A climate stations. The mean annual lake evaporation was determined to be 642 mm for the study area.

5.1.5 Minimum Flow Requirements

Due to the likeliness of the need for amendment or adjustment of existing water licences, consideration of new water licences for potential surface water source improvements, and conditions required in Water Licence No. 125167, a minimum flow equivalent to 10% of the mean annual discharge was assumed at each point of diversion in the analysis. Such minimum flows estimated for Holland Lake, Holland Creek at Chicken Ladder Dam and Stocking Lake are 0.007 m^3/s, 0.09 m^3/s and 0.005 m^3/s, respectively.

5.1.6 Existing and Future Water Demand

Recent water usage information of the Town and Saltair from the Stocking Lake and Holland Lake/Creek systems was provided to Tetra Tech EBA by Koers. The information for the year of 2013 is tabulated in Table 5.2, and in particular, this recent water usage pattern was used in the current analysis for the monthly water demand projections.

Table 5.2: 2013 Monthly Water Usage Information, m^3

From Stocking Lake System*				From Holland Lake/Creek System**		Total Water Usage by Ladysmith
Month	**Ladysmith**	**Saltair**	**Total**	**Month**	**Ladysmith**	
Jan	89,759	21,439	111,198	Jan	0	89,759
Feb	86,235	18,319	104,554	Feb	0	86,235
Mar	92,544	20,410	112,954	Mar	2,981	95,525
Apr	46,305	21,140	67,445	Apr	38,418	84,723
May	15,166	24,758	39,924	May	92,829	107,995
Jun	23,506	27,523	51,029	Jun	94,528	118,034
Jul	1,922	40,234	42,156	Jul	168,656	170,578
Aug	1,333	38,034	39,367	Aug	148,963	150,296
Sep	11,610	23,618	35,228	Sep	94,429	106,039
Oct	20,307	20,774	41,081	Oct	70,124	90,431
Nov	52,620	19,331	71,951	Nov	30,010	82,630
Dec	7,444	20,630	28,074	Dec	89,067	96,511
Annual	448,751	296,211	744,962	Annual	830,005	1,278,756

Notes: *Water usage from Stocking Lake System by Ladysmith/Diamond and Saltair
**Water usage from Holland Lake/Creek System by Ladysmith/Diamond only

As requested by the Town, future water demand projections when the population of Ladysmith (excluding other service areas) reaches the thresholds of 18,000 and 30,000 were considered in the current analysis. It was assumed that Ladysmith will have an annual growth rate of 2%. The years of interest were therefore determined to be 2054 and 2080, with the population in Saltair, with an annual growth rate of 1%, reaching 2,740 and 3,550, respectively. Based on discussion with the Town and Koers, various annual growth rates were also applied to the Diamond Improvement District, IR12 and IR13. The water demand per capita for Ladysmith/Diamond was estimated to be 430 L/cap/day while that for Saltair, IR12 and IR13 was assumed to be 490 L/cap/day. The 2013 water usage percentage from each system by Ladysmith/Diamond was assumed as a starting point. The following tables provide a summary of the future water demand projections.

Table 5.3: Population Projections

Area	Ladysmith	Diamond	IR 12	IR 13	Ladysmith (All Serviced Areas)	Saltair
Annual Growth Rate	2%	1%	14% up to 1,800	3% up to 3,120	N/A	1%
Year 2013	8,077	614	0	0	8,691	1,822
Year 2054	18,191	923	1,800	1,767	22,681	2,740
Year 2080	30,441	1,196	1,800	3,120	36,557	3,549

Table 5.4: Future Water Usage, m^3

Year 2054				Year 2080			
Month	Ladysmith (All Serviced Areas)	Saltair	Total	Month	Ladysmith (All Serviced Areas)	Saltair	Total
Jan	255,527	35,491	291,018	Jan	410,583	45,970	456,552
Feb	245,495	30,326	275,821	Feb	394,463	39,280	433,743
Mar	271,942	33,788	305,729	Mar	436,958	43,764	480,722
Apr	241,191	34,996	276,186	Apr	387,547	45,328	432,875
May	307,442	40,984	348,426	May	493,999	53,085	547,085
Jun	336,021	45,563	381,584	Jun	539,921	59,016	598,937
Jul	485,604	66,605	552,209	Jul	780,272	86,271	866,543
Aug	427,865	62,962	490,827	Aug	687,496	81,552	769,048
Sep	301,873	39,098	340,971	Sep	485,052	50,642	535,694
Oct	257,440	34,390	291,830	Oct	413,657	44,544	458,201
Nov	235,232	32,001	267,233	Nov	377,973	41,450	419,423
Dec	274,749	34,151	308,900	Dec	441,468	44,235	485,703
Annual	3,640,379	490,355	4,130,734	Annual	5,849,389	635,136	6,484,525

5.1.7 Climate Change Considerations

A review of research on the impacts of climate change on the hydrology of the Vancouver Island region was conducted. In general, by the 2050s, southern and central BC regions are expected to become drier in the summer while wetter winters are expected across BC. In particular, in the Vancouver Island and Lower Mainland watersheds, more of the precipitation will fall as rain rather than snow. Fall and winter flows will generally increase while spring and summer flows will generally decrease.

In 2009, the Comox Valley Regional District completed a climate change impact analysis for the Comox Lake reservoir (KWL, 2009). The purpose of this study was to assess impacts of future climate change on temperature, precipitation and inflow into the lake and to assess how these changes will impact the availability of storage for future water supply purposes. Based on the results of this analysis, it was determined that climate change is expected to cause the following impacts for the region:

- Increased temperature year round with higher winter precipitation and lower summer precipitation (from about +0.7°C to +1.1°C by 2020 and from about +1.3°C to +1.9°C by the 2050s);

- Increased winter inflows (about 11% to 16% higher by the 2020s and about 14% to 21% by the 2050s), increased spring inflows (about 0.3% to 2.3 % higher by the 2020s and about 0.9% to 4.3% higher by the 2050s), decreased summer inflows (about 4% to 5% lower by 2020s and about 14% to 20% lower by the 2050s), and increased fall inflows (about ;9.3% to 11% higher by the 2020s and about 12% to 19% higher by the 2050s);
- Slightly increased total annual inflow to the lake (about 5% to 6% higher by the 2020s and about 4% to 7% higher by the 2050s).

In 2010, the Arrowsmith Water Service developed an updated water management framework for the Englishman River, which included a general review of streamflows in the Englishman River with climate change considerations (KWL, 2010). The results of this climate change impact assessment again indicated that fall and winter flows could increase while spring and summer flows could decrease in general.

Based on the above findings in the Vancouver Island region, changes were applied to the seasonal inflows developed for the Holland and Stocking Lake watersheds to take into account the impacts of climate change. Table 5.5 summarizes the percentage changes applied to the seasonal inflows for the current study. It should be noted that the same percentage changes were applied to both the 2054 and 2080 model scenarios.

Table 5.5: Seasonal Changes to Inflows by 2054 and 2080

Winter (Jan to Mar)	Spring (Apr to Jun)	Summer (Jul to Sep)	Fall (Oct to Dec)
+15%	+2.5%	-15%	+15%

It was assumed that the storage capacity of both lake systems remained the same for the long-term hydrological assessments conducted in this study, however it can be expected that with increased flow rates, sediment pick-up rates will increase and in-lake sedimentation will lead to a reduction in the storage capacity.

5.2 Water Supply Options

Five water supply options were identified based on discussions with representatives from the Town and Koers (schematics can be found in Appendix B), and they are listed as follows:

- Option 1: Existing Conditions with Banon Creek Diversion (with manual flows released from Holland Lake)
  - Option 1 includes existing conditions with the Banon Creek diversion to Holland Lake as per Water Licence No. 125167, allowing the Town to divert 1,819,396 m^3 of water from Banon Creek to Holland Lake between November 1st and May 31st each year. A drainage area of 7 km^2 is available at this point of diversion on Banon Creek, and a maximum diversion rate of 0.099 m^3/s can be diverted from Banon Creek to Holland Lake during the diversion period in accordance with the existing water licence.
  - The Town will continue to release water from Holland Lake to Holland Creek, maintaining the minimum flow requirement (10% of the mean annual discharge) at the outlet of Holland Lake and at Chicken Ladder when necessary.
  - The Town will continue to draw water from the Chicken Ladder intake on Holland Creek following the 2013 water usage pattern, which may be exceeding the current water licence limitations (maximum daily withdrawal rate) at certain times.

- The Town will continue to draw water from Stocking Lake under Water Licence No. 5333 in accordance with the 2013 water usage pattern, which may occasionally be exceeding the current water licence limitations (maximum daily withdrawal rate).

- Saltair will continue to draw water from the Stocking Lake outlet pipe following the 2013 water usage pattern.

- During low flow periods, the Town will have to release sufficient water from Holland Lake to provide the maximum day withdrawal at Chicken Ladder and to meet the minimum flow requirements. When the Arbutus Reservoir is full and no water is being drawn into the Chicken Ladder intake, Holland Lake storage water will be spilled over the dam at Chicken Ladder. To model this potential issue, three sets of monthly flow release rates representing the three water demand projection scenarios were applied in the hydrological model.

- Option 2: Banon Creek Diversion with Water Treatment Plant (with manual flows released from Holland Lake)

  - Option 2 includes the Banon Creek diversion and a water treatment plant. With a treatment plant in place, it was assumed that the Holland Creek system can provide water to the service areas all year round. In other words, whenever depletion occurs in Stocking Lake, the Holland Creek system serves as the back-up source to meet the overall water demand.

  - The Town will continue to release water from Holland Lake to Holland Creek to meet the minimum flow requirements (10% of the mean annual discharge) at its outlet and at Chicken Ladder when necessary.

  - The Town will continue to draw water from the Chicken Ladder intake on Holland Creek following the 2013 water usage pattern. However, it was assumed that the Town will only draw water from the Stocking lake system up to the licenced limits (i.e. The Town will draw water from Stocking Lake at a maximum rate of 500,000 gal/day from mid-September to the end of March over 200 days in accordance with the terms of the water licence).

  - Saltair will continue to draw water from the Stocking Lake outlet pipe.

  - Similar to Option 1, during low flow periods, the Town will have to release sufficient water from Holland Lake to provide the maximum day withdrawal at Chicken Ladder and to meet the minimum flow requirements. When the Arbutus Reservoir is full and no water is being drawn into the Chicken Ladder intake, Holland Lake storage water will be spilled over the dam at Chicken Ladder. To model this potential issue, three sets of monthly flow release rates representing the three water demand projection scenarios were applied in the hydrological model.

  - Another potential issue with this option is that there is a possibility that a hydrocarbon contamination event may take place again on Holland Creek, and the Town will have to shut off the Chicken Ladder intake and exceed its allowable withdrawal from Stocking Lake until the Holland Creek contamination event passes.

- Option 3: Banon Creek Diversion, Holland Lake Diversion Pipeline and Water Treatment Plant

  - Option 3 includes the Banon Creek diversion, a diversion pipeline constructed between Holland Lake and the outlet pipe at Stocking Lake, and a water treatment plant. Holland Lake serves as the water source for both the Holland Creek and Stocking Lake systems to meet overall water demand. A connection between Holland Lake and Stocking Lake was established in the model; whenever depletion occurs in Stocking Lake, Holland Lake serves as the back-up source to meet the overall water demand. The main advantage with this option would be that the Town could continue to use water both at Chicken Ladder and in Holland Lake even if the turbidity is high because the treatment plant would be in place. In addition, the Town could provide water to Saltair through the diversion pipeline in the event that Stocking Lake cannot be recovered during dry years.

- The Town will only release sufficient water from Holland Lake to Holland Creek to meet the minimum flow requirements (10% of the mean annual discharge) at the outlet of Holland Lake and at Chicken Ladder where necessary.
- The Town will draw water from the Chicken Ladder intake on Holland Creek but at a maximum rate of 600,000 imperial gallons per day (0.0316 m^3/s) in accordance with Water Licence No. 17746 while meeting the instream flow requirement. It is expected that the Town will attempt to use this water supply from early spring to early summer and capture the snowmelt in the Chicken Ladder watershed.
- The Town will continue to draw water from Stocking Lake but at a maximum rate of 500,000 imperial gallons per day (0.0263 m^3/s) from mid-September to the end of March (200 days) in accordance with the terms of the water licence.
- All additional water required by the Town will be drawn from the Holland Lake diversion pipeline.
- Saltair will continue to draw water from the Stocking Lake outlet pipe.

- Option 4: Banon Creek Diversion with Water Treatment Plant and Chicken Ladder Storage
  - Option 4 is similar to Option 3 except that it was assumed there will be no spilling of Holland Lake water at Chicken Ladder during non-spillway operation. It was assumed that the Town will increase the size of the Chicken Ladder balancing reservoir in Holland Creek to eliminate the spilling issue. Typically only the minimum flow required (10% of the mean annual discharge) will pass downstream of the upgraded Chicken Ladder balancing reservoir in the summer.
- Option 5: Banon Creek Diversion with Water Treatment Plant, Chicken Ladder Storage, and Raised Holland Lake Dams
  - Option 5 is similar to Option 4 except that the Holland Lake Dams are raised by 1.5 metres (storage increased by approximately 736,000 m^3, which equates to 43% of the existing capacity (1,704,000 m^3) of Holland Lake). The volume-elevation relationship at Holland Lake was extended based on the approximate surface area of Holland Lake at an elevation of 660 m GSC, and the rating curve of the spillway at Holland Lake was also adjusted. The purpose of this option is to determine whether increased storage in the Holland Lake would be beneficial in the long-term.

5.3 Model Result Analysis

A matrix of simulation scenarios was developed with different combinations of demand assumptions, water supply options and climate change considerations. Frequencies of depletion and spilling were determined over a period of 51 years for each case. For example, when the monthly water level reaches the minimum allowable level in the governing water body (i.e. 1 m above the intake invert at Stocking Lake and 1 m above the lake bottom at Holland Lake), the system is considered to be depleted in that month. Consecutive months with depletion were grouped together to represent one occurrence of depletion in the system. The return period to reach the deficiency level (minimum lake level in the final water source beyond which supply is not possible) for each case based on 51 years of available hydrometric record was also determined. A summary of results is listed as follows:

- Option 1: Existing Conditions with Banon Creek Diversion (with manual flows released from Holland Lake)
  - With the existing conditions including the diversion from Banon Creek to Holland Lake, the return periods to reach the minimum lake level in the final water source for this option are more than 51 years in 2013 and 1 year in other modelled scenarios. It should be noted that this option was evaluated for the purpose of recognizing that the management of the water supply sources need to be improved. It should also be noted that during non-spillway operation, Chicken Ladder continues to spill water in excess of the water licence limits. With and without consideration of climate change, this option has a low reliability. Results of this option indicate that the current operation of the Holland Lake valve and the Chicken Ladder intake is inefficient. It is recommended that the Town continues with the review of the existing water licences and consideration of new water licences for potential surface water source improvements to sustainably meet the future water demand from both the Stocking Lake and Holland Lake/Creek systems.
- Option 2: Banon Creek Diversion with Water Treatment Plant (with manual flows released from Holland Lake)
  - Although a water treatment plant is in place in this option, possible excess of Holland Lake water at the Chicken Ladder intake was taken into account. At the same time, the Town would be limited to drawing water from Stocking Lake in accordance with the water licence. As a result, the return periods to reach the minimum lake level in the final water source for the 2054 scenarios are 51 years while that for the 2080 scenarios are only 2 years.
- Option 3: Banon Creek Diversion, Holland Lake Diversion Pipeline and Water Treatment Plant
  - With the Holland Lake diversion pipeline in place to divert water directly from Holland Lake to the Stocking Lake outlet pipe, there will be no depletion at Holland Lake in the 2013 scenario. The return periods to reach the minimum lake level in the final water source are 17 years without climate change consideration and 13 years with climate change consideration in the 2054 Scenario. However, the reliability of the system becomes low in the 2080 scenarios. It should be noted that there would be no excess of Holland Lake water at Chicken Ladder intake in this case because the Holland Lake diversion pipeline would draw from Holland Lake as the final water source for the water supply system. It should also be noted that this option would allow the Town to provide water to Saltair through the diversion pipeline in the event that Stocking Lake cannot be recovered during dry years.
- Option 4: Banon Creek Diversion with Water Treatment Plant and Chicken Ladder Storage
  - By comparing to other options, the reliability of the system in this case is relatively high due to the assumption that there would be no spilling of Holland Lake water at the Chicken Ladder intake. This indicates that the additional storage available at the Chicken Ladder intake would be an important component in maximizing the benefits of having a water treatment plant in place. In particular, no depletion was determined in this option for the 2054 scenario without consideration of climate change. It is recommended that the Town to further consider this option in the long-term.
- Option 5: Banon Creek Diversion with Water Treatment Plant, Chicken Ladder Storage and Raised Holland Lake Dams
  - Raising Holland Lake Dams by 1.5 metres combined with a water treatment plant and additional storage at Chicken Ladder resulted in return periods of reaching the minimum lake level at Holland Lake being greater than 51 years in the 2054 scenarios. The reliability of the system remains relatively high for the 2080 scenarios, with return periods of deficiency events equal to 51 years. Results of this option indicate that raising the Holland Lake Dams by 1.5 metres for increasing available live storage in Holland Lake would be beneficial when combined with diversion from Banon Creek, a water treatment plant and additional Chicken

Ladder storage. It is recommended that the Town to consider increasing storage available in Holland Lake in the long-term planning.

A summary table of the return periods to reach the minimum lake level at the final water source for each modelled scenario is provided in Table 5.6.

Table 5.6: Summary of Return Periods Reaching Minimum Lake Level (Years)

Scenario	2013	2054	2054 (Climate Change)	2080	2080 (Climate Change)
Ladysmith Population	**8,077**	**18,191**		**30,441**	
Total Ladysmith Population*	**8,691**	**22,681**		**36557**	
Saltair Population	**1,822**	**2,740**		**3,549**	
Option 1	>51	1	1	1	1
Option 2	>51	51	51	2	2
Option 3	>51	17	13	1	1
Option 4	>51	>51	51	2	2
Option 5	>51	>51	>51	51	51

Note: *Total Ladysmith population includes Diamond, IR12 and IR13.

6.0 CONCLUSIONS

- An update of the 2008 hydrological model to consider the impacts of current water licence limitations, current minimum flow requirements, updated water demand projections and climate change has been conducted.
- The 2013 water usage pattern was used in the current analysis for the monthly water demand projections. Future water demand projections when the population of the Town of Ladysmith reaches the thresholds of 18,000 and 30,000 were considered in the current analysis.
- For the model update, additional streamflow data from 2005 to 2012 at all selected regional hydrometric stations were incorporated, resulting in an extended period of record of 51 years.
- A minimum flow equivalent to 10% of the mean annual discharge was assumed at each point of diversion in the water supply system.
- A review of research on the impacts of climate change on the hydrology of the Vancouver Island region was conducted. Based on the findings in the research, changes were applied to the seasonal inflows developed for the Holland and Stocking Lake watersheds to take into account the impacts of climate change.
- Five water supply options were developed, resulting in a total of 25 model scenarios. A matrix of simulation scenarios was developed with different combinations of demand assumptions, water supply options and climate change considerations.

7.0 RECOMMENDATIONS

Based on the findings from this study, it is recommended that:

- Option 4, which includes a water treatment plant with additional storage at Chicken Ladder, is further explored. Results from the analysis suggest that this option would result in a more reliable long-term water supply for the Town of Ladysmith.
- Option 3, which includes a diversion pipeline from Holland Lake to Stocking Lake, should also be further considered in view of its advantage with regards to long-term water supply reliability for Saltair.
- Option 5, which includes raising the Holland Lake Dams by 1.5 metres, would provide enhanced long-term water supply reliability if combined with diversion from Banon Creek, a water treatment plant and additional Chicken Ladder storage.
- The Town continues with the review of existing water licences in conjunction with the CVRD and the Province and consideration of new water licences for potential surface water source improvements to sustainably meet the future water demand from both the Stocking Lake and Holland Lake/Creek systems.
- The potential effects of climate change are further assessed, to support the development of a long-term strategy to achieve system resiliency.
- The potential reduction of storage capacity due to sedimentation, in both Stocking and Holland Lakes should be assessed for the long-term analyses including climate change conditions.
- A more user friendly water balance tool is developed to help the Town of Ladysmith assess various water policy and operational rules in a quicker system, easier to communicate and transfer. A suggested software package to achieve this is GoldSim.
- Further model calibration to be conducted to refine the synthetic inflow time series developed for Stocking Lake if more historical water levels and consumption records can be retrieved.
- Continuous flow monitoring at Stocking Creek is conducted.
- Continuous flow monitoring to be conducted on Holland Lake/Creek for further refinement of the synthetic inflow time series for Holland Lake and Holland Creek. Also, in order to calibrate the Holland Lake/Creek hydrological model, actual diversion rates from Banon Creek, water levels at Holland Lake, and consumption records will be required. It is recommended that the Town to consider these additional hydrometric monitoring programs in the long-term planning of its water supply system.

8.0 CLOSURE

We trust report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

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/ML

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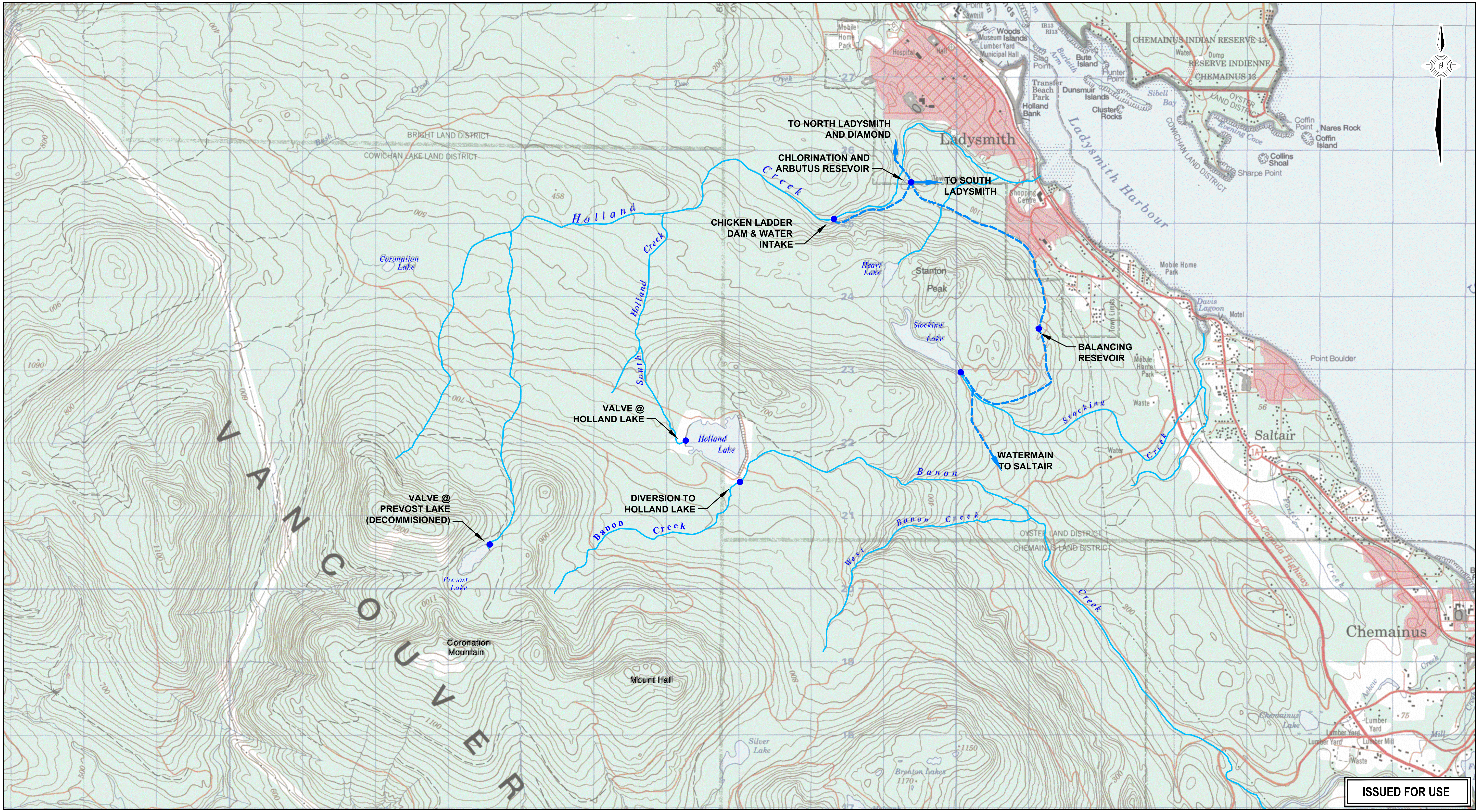
FIGURES



LEGEND

WATERMAIN

POINT OF INTEREST

SCALE 1:50,000

0.5 0 0.5 1.0 2.0km

NOTES

CLIENT

LADYSMITH

TETRA TECH EBA

HOLLAND & STOCKING LAKES HYDROLOGY UPDATE

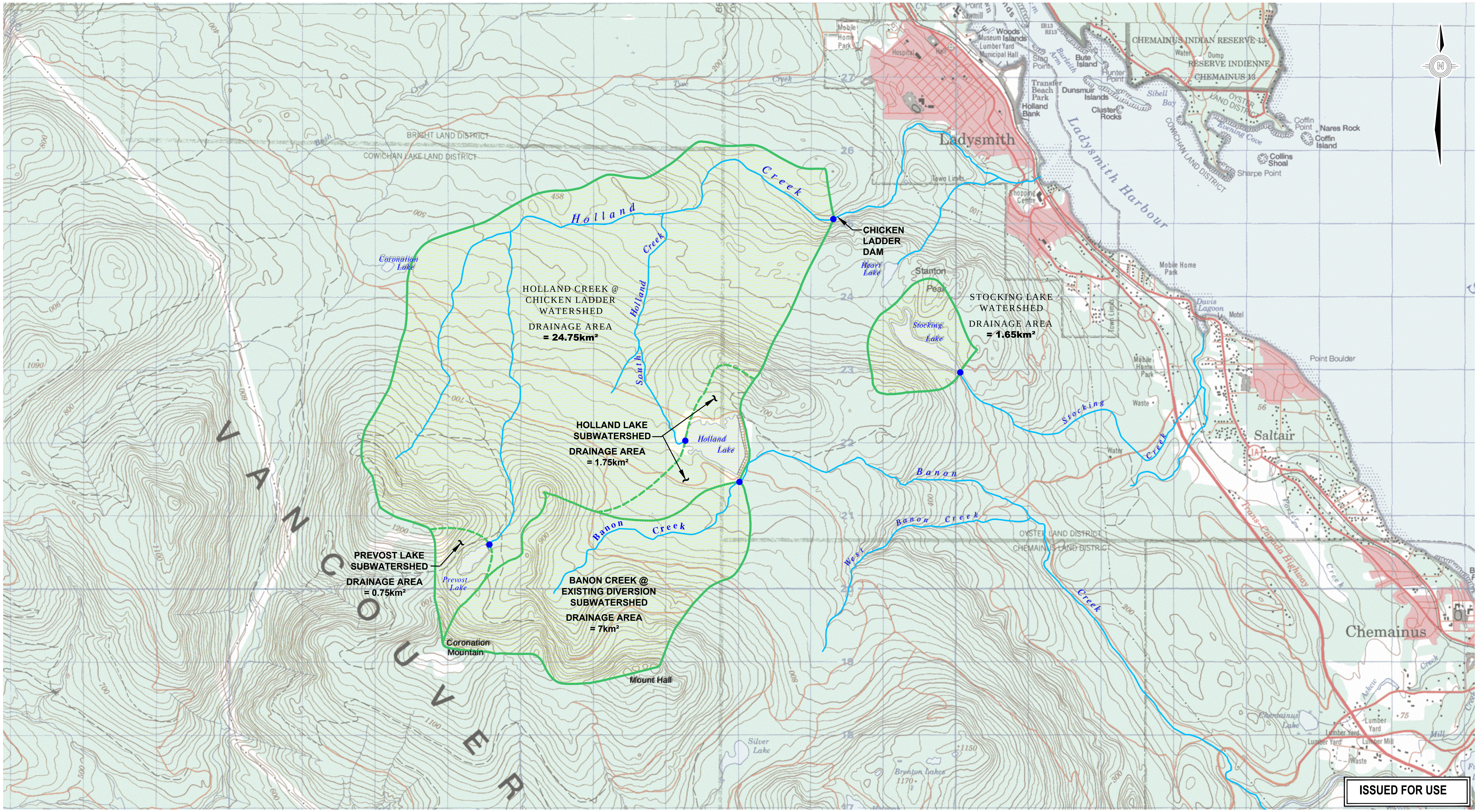
LAYOUT OF EXISTING WATER SUPPLY AND DISTRIBUTION SYSTEM

PROJECT NO.	DWN	CKD	REV
V13203036-01	JDM	ML	0

OFFICE	DATE
VANC	Sep, 2014

Figure 4.1

Q:\Vancouver\Engineering\V132\Projects\V13203036 Holland and Stocking Lakes Hydrology Update\005 CAD\V13203036_FIG 3.1-3.2_R0.dwg [FIGURE 3.1] June 11, 2014 - 11:14:37 am (BY: MANG, JUSTIN)



LEGEND

- WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY
- POINT OF INTEREST

SCALE 1:50,000

0.5 0 0.5 1.0 2.0km

NOTES

CLIENT

LADYSMITH

TETRA TECH EBA

HOLLAND & STOCKING LAKES HYDROLOGY UPDATE

STUDY AREA WATERSHED BOUNDARIES

PROJECT NO.	DWN	CKD	REV
V13203036-01	JDM	ML	0

OFFICE	DATE
VANC	Sep, 2014

Figure 4.2

Q:\Vancouver\Engineering\V132\Projects\V13203036 Holland and Stocking Lakes Hydrology Update\005 CAD\V13203036_FIG 3.1-3.2_R0.dwg [FIGURE 3.2] June 11, 2014 - 11:31:15 am (BY: MANG, JUSTIN)

APPENDIX A
TETRA TECH'S GENERAL CONDITIONS

GENERAL CONDITIONS

DESIGN REPORT

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This Design Report pertains to a specific site, a specific development, and a specific scope of work. The Design Report may include plans, drawings, profiles and other support documents that collectively constitute the Design Report. The Report and all supporting documents are intended for the sole use of Tetra Tech EBA's Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, analyses or other contents of the Design Report when it is used or relied upon by any party other than Tetra Tech EBA's Client, unless authorized in writing by Tetra Tech EBA. Any unauthorized use of the Design Report is at the sole risk of the user.

All reports, plans, and data generated by Tetra Tech EBA during the performance of the work and other documents prepared by Tetra Tech EBA are considered its professional work product and shall remain the copyright property of Tetra Tech EBA.

2.0 ALTERNATIVE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA's instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless so stipulated in the Design Report, Tetra Tech EBA was not retained to investigate, address or consider, and has not investigated, addressed or considered any environmental or regulatory issues associated with the project specific design.

4.0 CALCULATIONS AND DESIGNS

Tetra Tech EBA has undertaken design calculations and has prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, Tetra Tech EBA's client. These designs have been prepared to a standard that is consistent with industry practice. Notwithstanding, if any error or omission is detected by Tetra Tech EBA's Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of Tetra Tech EBA.

5.0 GEOTECHNICAL CONDITIONS

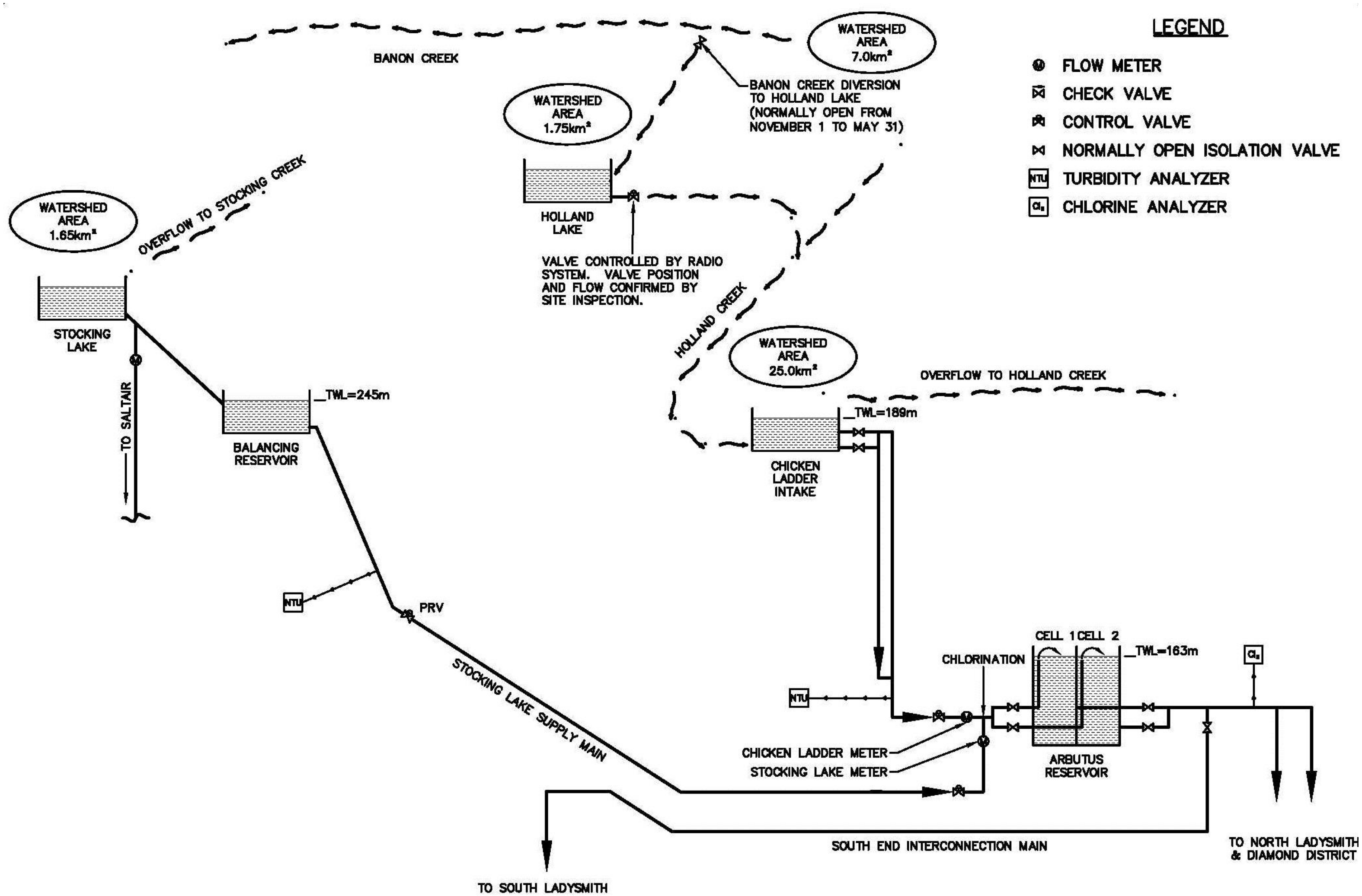
A Geotechnical Report is commonly the basis upon which the specific project design has been completed. It is incumbent upon Tetra Tech EBA's Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by Tetra Tech EBA, it will be included in the Design Report. The Geotechnical Report contains General Conditions that should be read in conjunction with these General Conditions for the Design Report.

6.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

APPENDIX B
WATER SUPPLY OPTIONS SCHEMATICS



LEGEND

NOTES

Schematics provided by Koers & Associates Engineering Ltd. dated July 14, 2014

STATUS

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Town of Ladysmith

TETRA TECH EBA

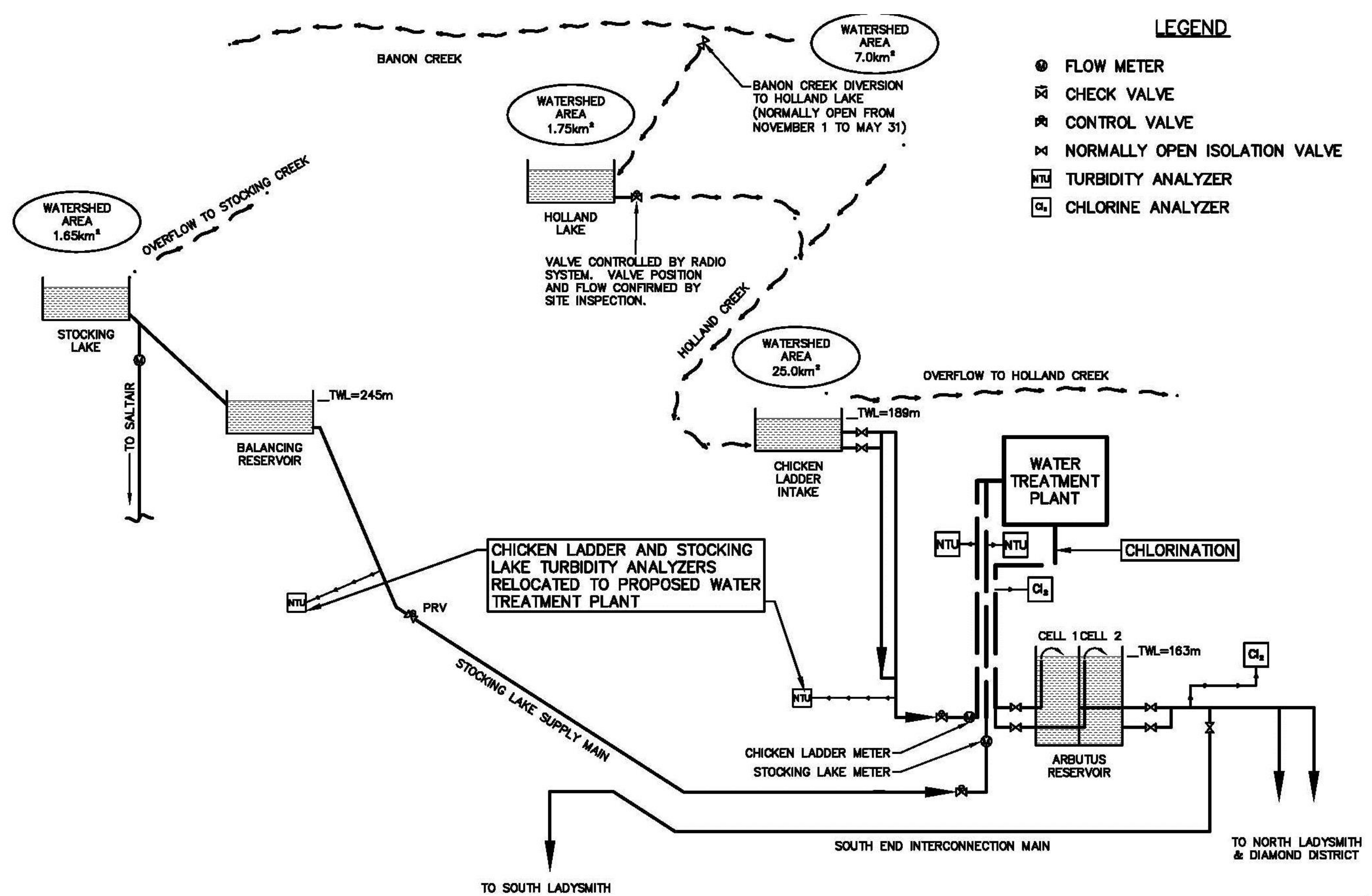
HOLLAND & STOCKING LAKES HYDROLOGY UPDATE

WATER SUPPLY OPTION 1

PROJECT NO.	DWN	CKD	APVD	REV
V13203036-01	ML	ML	MH	0

OFFICE	DATE
EBA-VANC	Sep, 2014

Figure 1



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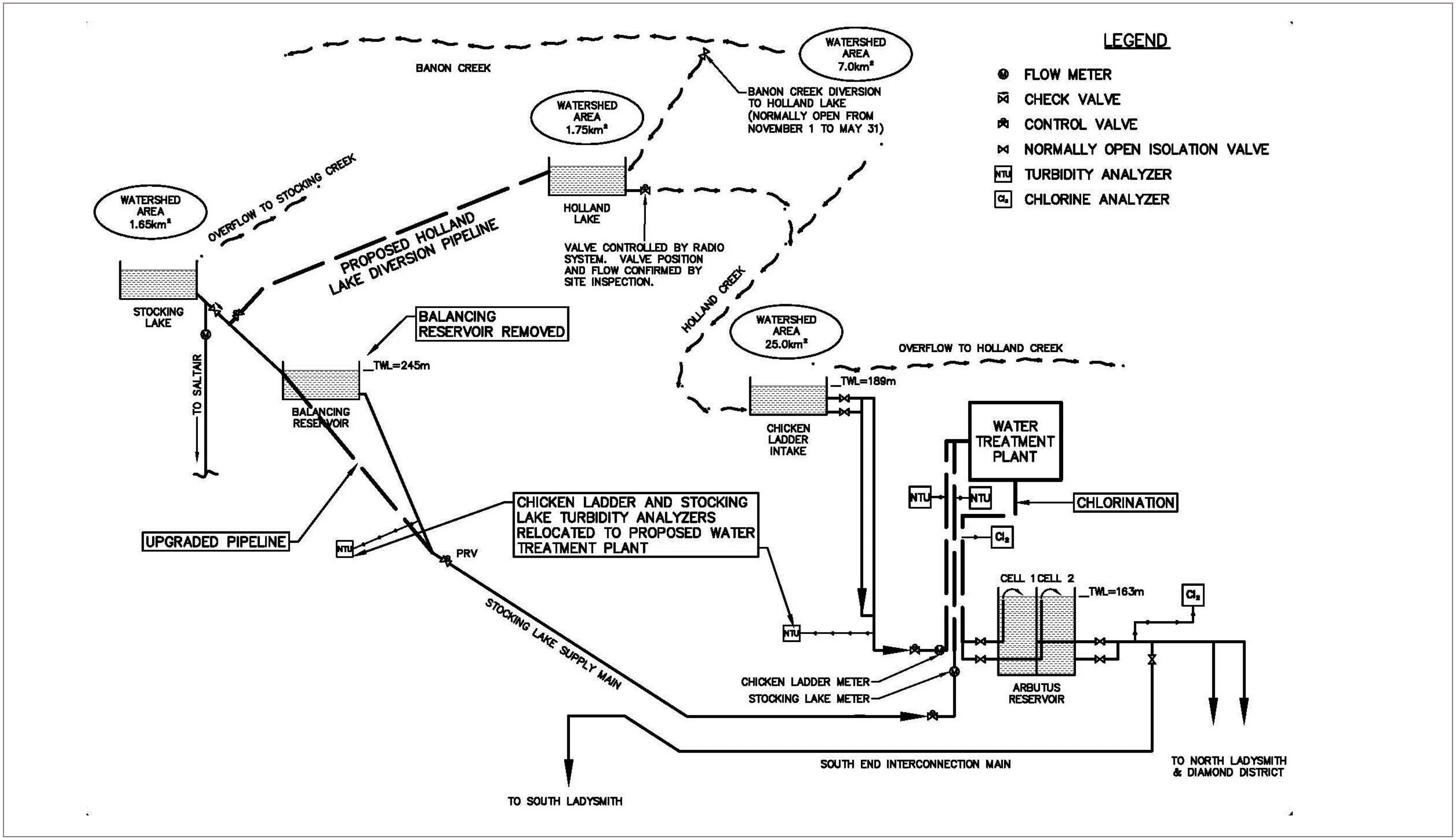
HOLLAND & STOCKING LAKES HYDROLOGY UPDATE

WATER SUPPLY OPTION 2

PROJECT NO.	DWN	CKD	APVD	REV
V13203036-01	ML	ML	MH	0

OFFICE	DATE
EBA-VANC	Sep, 2014

Figure 2



LEGEND

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Town of Ladysmith

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HOLLAND & STOCKING LAKES HYDROLOGY UPDATE

WATER SUPPLY OPTION 3

PROJECT NO.	DWN	CKD	APVD	REV
V13203036-01	ML	ML	MH	0

OFFICE	DATE
EBA-VANC	Sep, 2014

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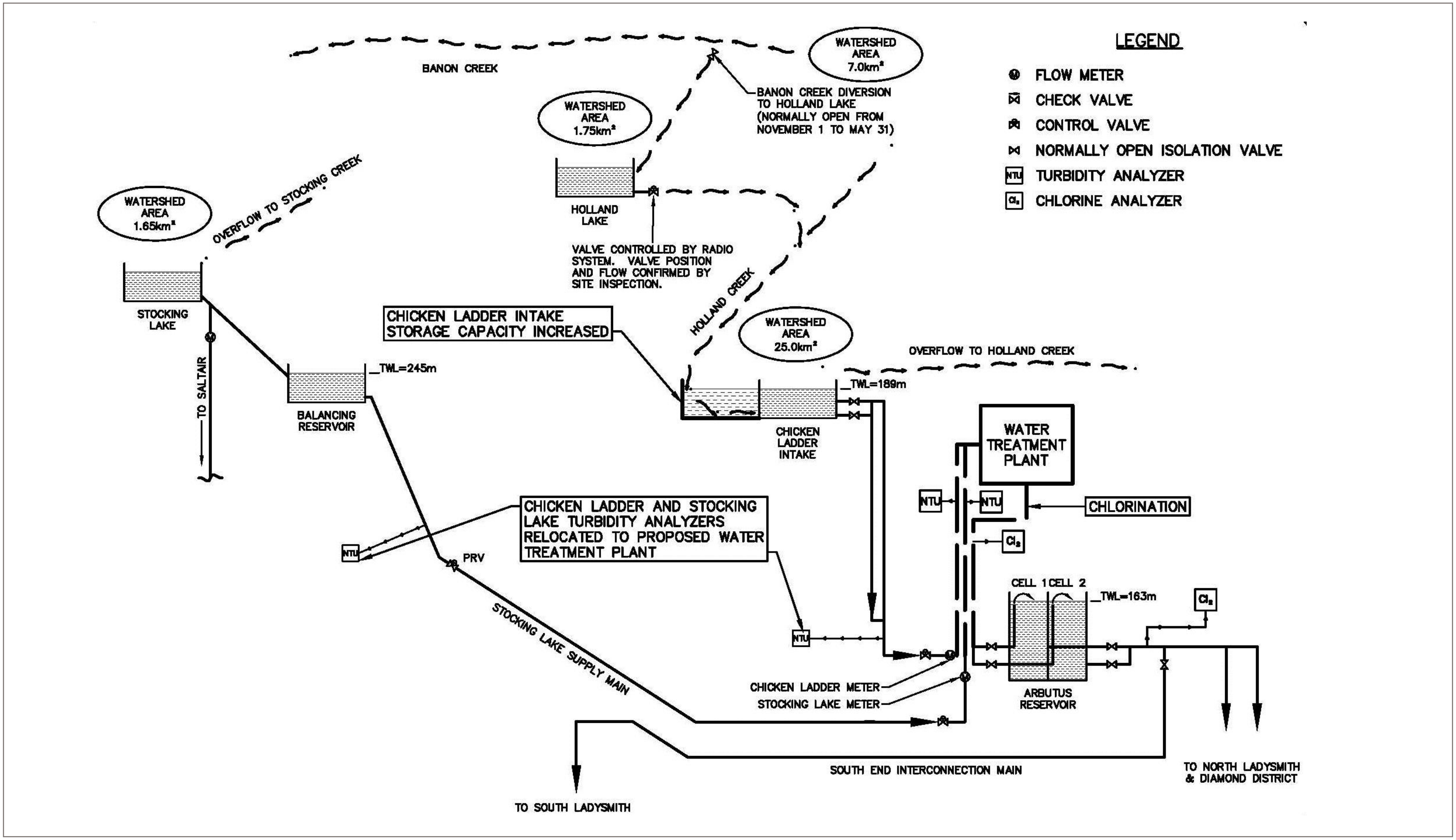

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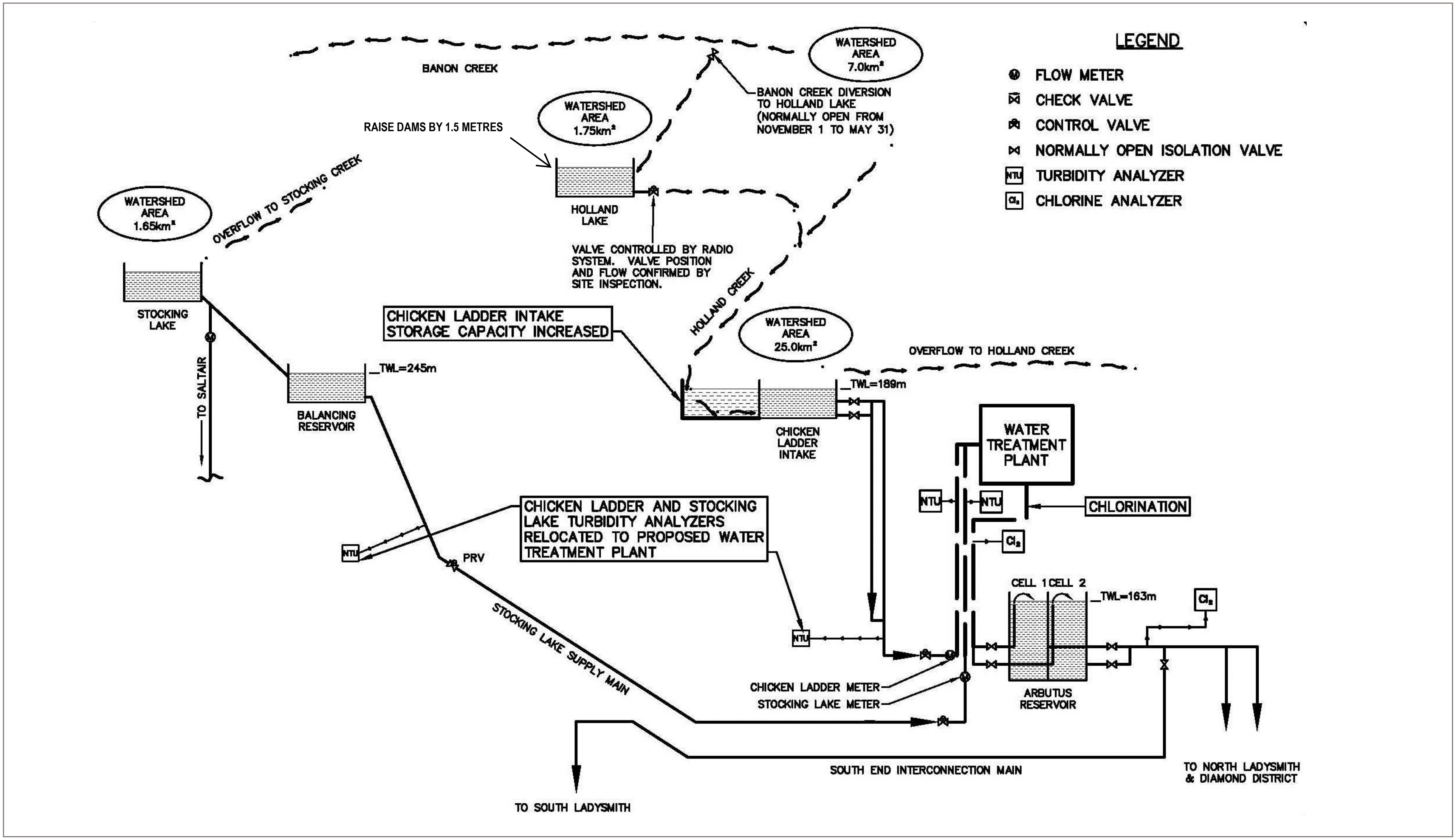
HOLLAND & STOCKING LAKES HYDROLOGY UPDATE

WATER SUPPLY OPTION 4

PROJECT NO.	DWN	CKD	APVD	REV
V13203036-01	ML	ML	MH	0

OFFICE	DATE
EBA-VANC	Sep, 2014

Figure 4



LEGEND

NOTES

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STATUS

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TETRA TECH EBA

HOLLAND & STOCKING LAKES HYDROLOGY UPDATE

WATER SUPPLY OPTION 5

PROJECT NO.	DWN	CKD	APVD	REV
V13203036-01	ML	ML	MH	0

OFFICE	DATE
EBA-VANC	Sep, 2014

Figure 5