Agua Consulting Inc.
"Engineered Water Solutions"
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July 8, 2008

Regional District of North Okanagan
9848 Aberdeen Road
Coldstream, BC
V1V 1Z6

Attention: Mr. Bob Campbell
Infrastructure Services Manager

Dear Bob:

RE: SILVER STAR MOUNTAIN WATER SYSTEM
VANCE CREEK RESERVOIR AND WELL 13
DISINFECTION EFFECTIVENESS ASSESSMENT

1.0 INTRODUCTION

This letter provides our assessment of the disinfection effectiveness for the existing water system at Silver Star Mountain. The analysis comes at your request of June 2, 2008. It is understood that modifications are underway for the addition of Well 13 and the Vance Creek Reservoir and pump station to increase the raw water supply capacity for the mountain.

With these proposed additions, the Interior Health Authority (regulator) has requested an assessment of the disinfection systems with the proposed additional infrastructure. Agua Consulting Inc. is to analyze the water system disinfection effectiveness for the following conditions:

1. Existing water distribution system;
2. Existing system with the addition of UV disinfection;
3. Determination of disinfection effectiveness with the increased pump capacity head from Vance Creek Reservoir pump station;
4. Determination of the disinfection effectiveness with the increased capacity from Vance Creek plus the addition of UV disinfection.

Water treatment processes are assessed in terms of log removal or inactivation credits. One log credits means the process is able to achieve removal or inactivation of 90% of the specified organism. Two log means 99 %, and three log means 99.9% inactivation/removal. This report is consistent with this terminology.

2.0 CRITERIA

The following criterion was utilized in this analysis. The analysis follows the requirements of the IHA and where standards are not available, the criteria set out by Health Canada and the USEPA were followed. The key documents considered during this assessment include:

1. IHA, 43210 Protocol for water supply.
2. Guidelines for Canadian Drinking Water Quality, May, 2008 update;
3. UV Guidance Manual, USEPA, November, 2006;
4. Long Term Enhanced Surface Water Treatment Rule, Disinfection Profiling and Benchmarking, Technical Guidance Manual, May, 2003;

The effectiveness of the present chlorination disinfection system was assessed utilizing the CT concept. The CT concept is a standard industry practice of assessing disinfection of various chemicals and water system conditions. CT is the Concentration x Time as defined below:

CT calc.(minutes-mg/L) = C x T
C = residual disinfection concentration during peak hour flow in mg/L at the first user
T = time in minutes that chlorine is in contact with the water before the first user

The CT concept is an assessment of the ability of the disinfection system to act as a reliable barrier in protecting the public water supply from risks that may be present in the raw water. A primary objective is to minimize the risks challenging the water system treatment and disinfection systems through source protection. Disinfection is essential to the protection of public health. Additional treatment supports the critical barrier of disinfection.

There are three groups of microbial risks that typically challenge drinking water systems, viruses, bacteria and protozoa. Viruses and bacteria are effectively dealt with using chlorine. Protozoa are more challenging for chlorination with either very long contact times required to inactivate them or being relatively ineffective for specific ones such as *Cryptosporidium*.

Table 2.1 - CT Values for 4 log Inactivation of Viruses with Free Chlorine

	pH	
Temperature (°C)	6-9	10
0.5	12	90
5	8	60
10	6	45
15	4	30
20	3	22
25	2	15

Source: 2003 USEPA Disinfection Profiling Manual

Table 2.1 provides the chlorine CT in minutes-mg/L for 4 log inactivation of viruses. Table 2.2 that follows provides the chlorine CT for 3 log inactivation for *Giardia*. The *Giardia* inactivation is an order of magnitude longer than the levels required for viruses.

Table 2.2 - CT Values for 3 log Inactivation of *Giardia* with Free Chlorine

Chlorine Concentration (mg/L)	Temperature <=0.5°C							Temperature =5°C						
	pH							pH						
	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0
<=0.4	137	163	195	237	277	329	390	97	117	139	166	198	236	279
0.6	141	168	200	239	286	342	407	100	120	143	171	204	244	291
0.8	145	172	205	246	295	354	422	103	122	146	175	210	252	301
1.0	148	176	210	253	304	365	437	105	125	149	179	216	260	312
1.2	152	180	215	259	313	376	451	107	127	152	183	221	267	320
1.4	155	184	221	266	321	387	464	109	130	155	187	227	274	329
1.6	157	189	226	273	329	397	477	111	132	158	192	232	281	337
1.8	162	193	231	279	338	407	489	114	135	162	196	238	287	345
2.0	165	197	236	286	346	417	500	116	138	165	200	243	294	353
2.2	169	201	242	297	353	426	511	118	140	169	204	248	300	361
2.4	172	205	247	298	361	435	522	120	143	172	209	253	306	368
2.6	175	209	252	304	368	444	533	122	146	175	213	258	312	375
2.8	178	213	257	310	375	452	543	124	148	178	217	263	318	382
3.0	181	217	261	316	382	460	552	126	151	182	221	268	324	389

Source: 2003 USEPA Disinfection Profiling Manual

An updated summary of the Guidelines for Canadian Drinking Water Quality was recently made available in May of 2008. Both Health Canada and the IHA require 3 log inactivation of protozoa. No tables have been developed for chlorine to inactivate Cryptosporidium as the CT values are too large and have not been defined. Fortunately UV disinfection has proven to be effective for the inactivation of protozoa. Provided the source water transmissivity is adequate (>80%), UV and chlorination disinfection together provide an effective barrier for all known viruses, bacteria and protozoa.

Table 2.3 - UV dose requirements (mJ/cm^2) to achieve log inactivation

Target Pathogens	Log Inactivation							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

Source: 2007 USEPA UV Guidance Manual

3.0 CT ANALYSIS

The intent of the CT analysis in this section is to provide guidance to the water utility and regulator with regards to contact times required to achieve inactivation of viruses, bacteria and protozoa, specifically *Giardia Lamblia*. Chlorination is the only disinfectant currently installed, the assessment is based on achieving 4 log inactivation of viruses, 3 log inactivation of bacteria, and 3 log inactivation of *Giardia*. Inactivation of *Cryptosporidium* protozoa is not possible by chlorine with typical contact times or municipal water supply chlorine dose levels.

As presented in Table 2.1, inactivation of viruses is achieved in relatively short contact times with chlorination. Table 2.1 presents the criteria for disinfection by chlorine to achieve 3 log inactivation of *Giardia*. The numbers in Table 2.3 are CT values in units of minutes-mg/L.

Raw Water Parameters

The critical time for disinfection is during water demand at Silver Star Mountain which is during the Christmas break. During this time the physical water parameters for Silver Star are estimated to be as follows:

- pH 7.0
- Temperature 2.5 degrees C
- Residual Chlorine level at first user during high flow times 1.0 mg/L

An interpolation between the 0.5 degree and 5.0 degree temperatures was made. To provide 3 log inactivation of *Giardia*, a CT value of 180 must be achieved.

Inlet versus Outlet Flows

The key to the assignment is not to assess the inlet lines or pumping rates from Vance Creek or Paradise as those numbers are to replace water that leaves the Upper Tee Reservoir. Provided that the primary location for chlorination is maintained at the Mid-Tee location, the critical flow rate is the rate by which water leaves the Mid-Tee facility. This is totally dependant on water demands by the utility.

Figure 3.1 provides an illustration of the watermains to and from the Mid-Tee Disinfection facility and Upper-Tee Reservoir. A 150mm supply main feeds water to the disinfection facility. From there the water is routed by gravity up through a 200mm main to the Upper-Tee Reservoir. From the reservoir, water is distributed back to the village via 250mm and 300mm diameter watermains. The computer model indicates that each of these distribution mains conveys approximately half of the total demand to the village.

Water from several of the wells is also routed through the mid-tee facility. This does not impact on the CT calculation as under high demand conditions, the majority of water is obtained from the surface water sources.

Figure 3.1 - Mains to and From Upper-Tee Reservoir

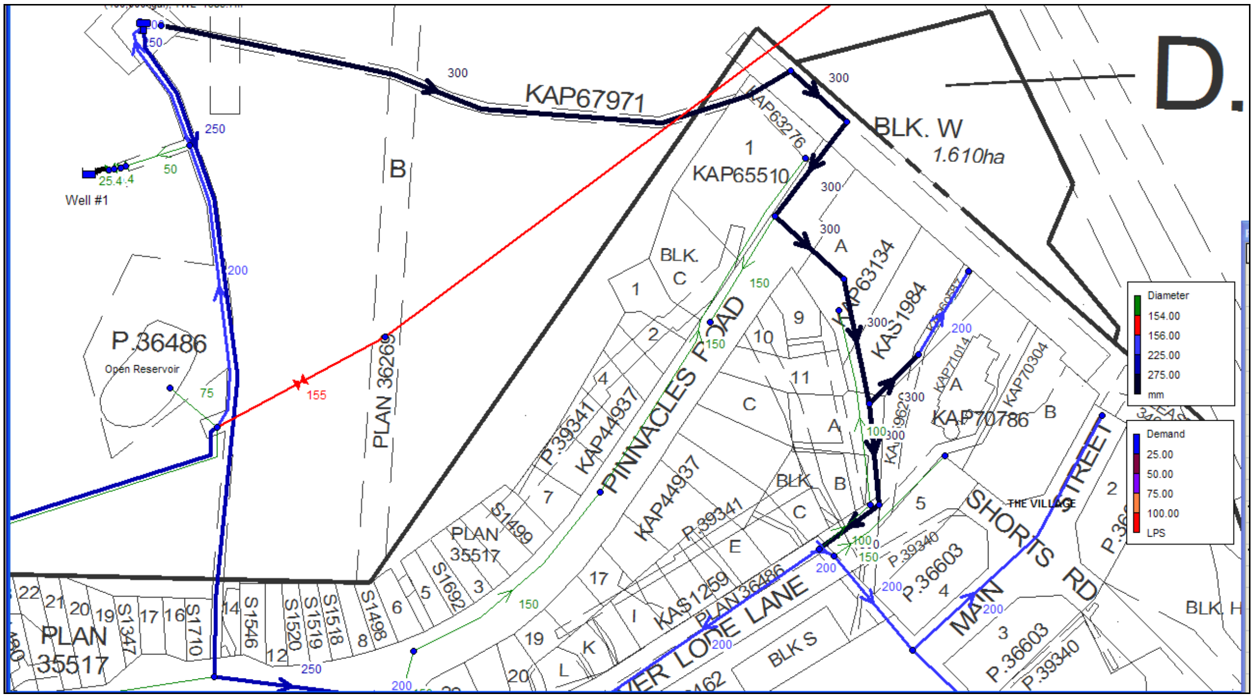


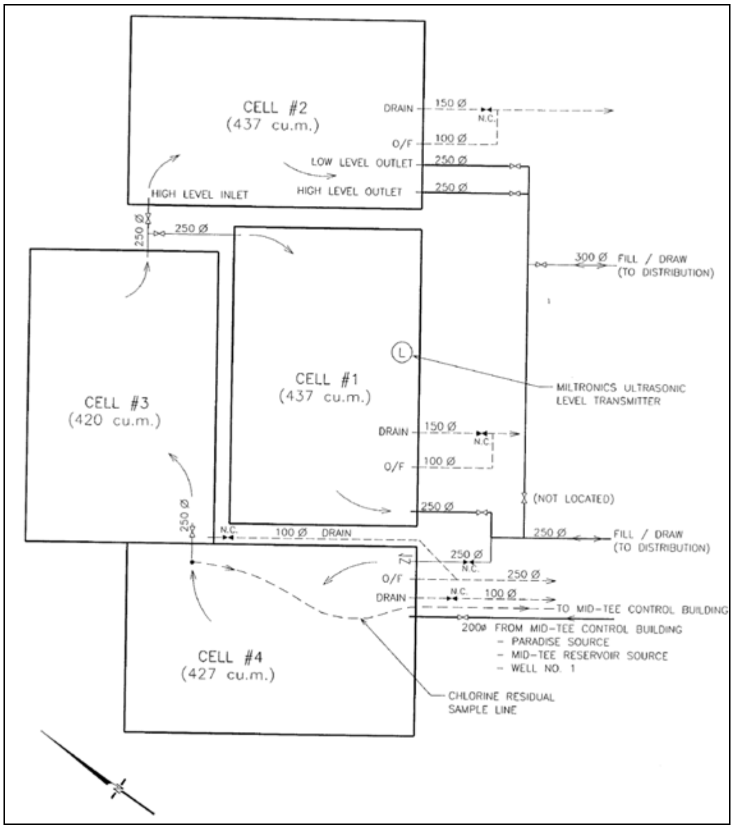
Figure 3.1 shows the supply main in red, the 200mm feed from the Mid-Tee to the Reservoir and a 250 and 300mm main from the reservoir to the first users.

Reservoir Baffling

The Upper-Tee Reservoir provides the majority of contact time for chlorination. Some smaller retention volumes are obtained through the watermains, but the majority of contact time is in the reservoir cells. The USEPA Disinfection Profiling and Benchmarking, Technical Guidance Manual was utilized as the guide for assessing the effectiveness of the reservoir to baffle flow and create improved contact time for chlorination. The total reservoir size is 1720 m^3. Figure 3.2 provides a schematic layout of the inflow and outflow through the reservoir cells.

With maximum day demands for the current utility in the range of 1,035 m^3/day, the time for water to pass through the 1,720 m^3 reservoir takes approximately 39.8 hours. This effective contact time through the reservoir is reduced due to the fact that the flow is not perfectly baffled.

Figure 3.2 - Upper-Tee Reservoir



Based on the reservoir configuration and the limited baffling, a baffling factor of 0.30 is recommended to assess the effectiveness of the contact time through the four reservoir cells. This reduces the effective contact volume from $1720m^3$ down to $516m^3$. The second condition on Table 3.1 best reflects the current reservoir baffling characteristics.

Table 3.1 - Reservoir Baffling Factors

Baffling Condition	Baffling Factor	Baffling Description
Unbaffled (mixed flow)	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities.
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles.
Average	0.5	Baffled inlet or outlet with some intra-basin baffles.
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders.
Perfect (plug flow)	1.0	Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles.

Source: 2003 USEPA Disinfection Profiling Manual

Flow for existing critical condition, 2007 demand condition:

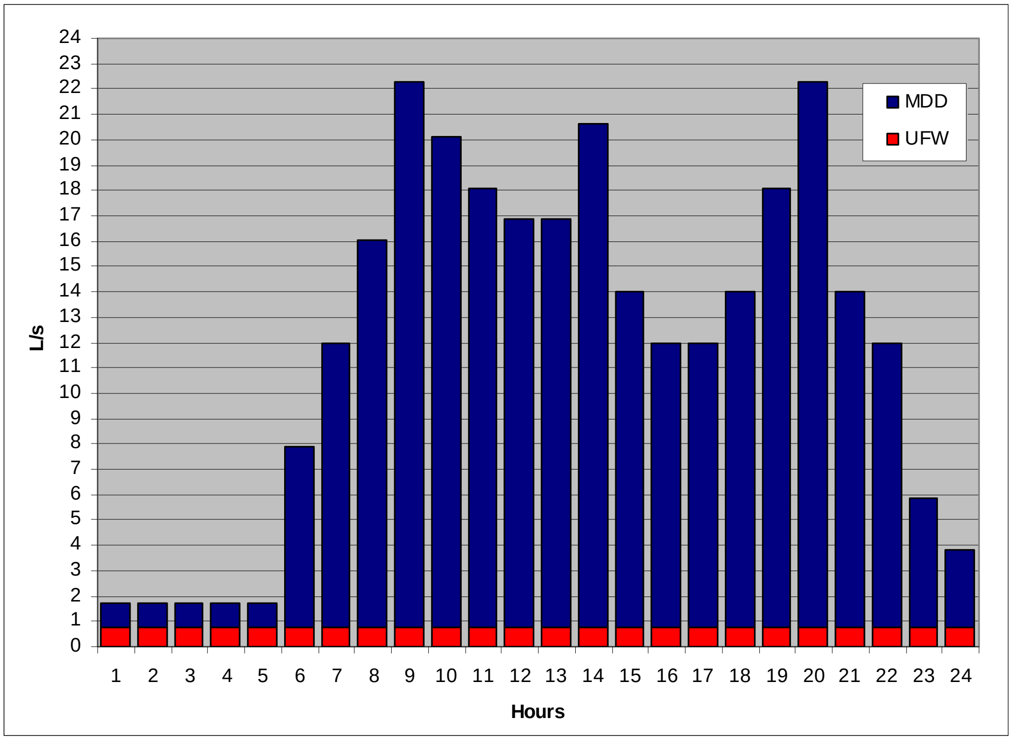
Maximum Day Demand (measured)	= 11.98 L/s
Peak Hour Demand (est.)	= 22.28 L/s

There are two ways to calculate the baffling factor.

1. Based on strictly volumes, the 0.30 baffling factor applied to the 1720 m^3 reservoir volume works out to an effective volume of 516 m^3. This simplistic calculation does not account for the fact that the water will take many hours to pass through the reservoir, even if the there is short circuiting.

2. A more detailed method for assessing contact time is provided below. If the baffling is considered to be 30% effective, the time to pass through the reservoir would be 30% of the full detention time of the reservoir. Due to the larger size and relatively low flow rate from the reservoir, the 30% detention time extends over many hours. The 2007 flow rate for a MDD condition is set out in Figure 3.3. The MDD rate was measured at 11.98 L/s and the PHD was estimated to be 22.28 L/s. Utilizing a reservoir flow through rate of 30% of the full detention volume, the flow rate to pass through the reservoir was estimated over that time and calculated to be 17.67 L/s. This method was used to calculate the peak flow rate (over a representative number of hours).

Figure 3.3 - Daily Diurnal Pattern of Flow



The diurnal (24 hour) pattern in Figure 3.3 was extended into the future to estimate the daily patterns and peak flows for increased demands with addition bed units.

Table 3.2 provides a summary of the critical watermain and reservoir components considered in the CT calculations.

Table 3.2 - System Component Parameters

No.	Description	Size	Length (m)	Volume (m^3)	Effective Volume (m^3)
1a	Transmission main – Vance to Paradise				[1] 0
1b	Transmission main – Paradise to Vance Int.				[1] 0
2	Transmission main – Paradise-Vance Int. to mid-Tee				[1] 0
3	Transmission main – Mid tee to Reservoir	200 mm	225 m	7.1 m^3	7 m^3
4	Reservoir	1720 m^3	n/a	1720 m^3	Dependant on flow
5a	Distribution main to First User (north main)	300 mm	346 m	24.4 m^3	South main governs
5b	Distribution main to First User (south main)	250 mm	355 m	17.4 m^3	[3] 35 m^3
	TOTAL AVAILABLE CONTACT VOLUME				

Notes:

1. Length and contact time for mains above disinfection are not included.
2. Half of the total flow moves through the south distribution main, therefore a volume two times the 250mm main amount was used to allow for consistent minutes of contact time.

Table 3.2 - CT Values – Chlorination only for *Giardia*

Condition	Bed Units	Resid. Conc.	pH	Temp	Effective Pk Flow (L/s)	Total Res. Volume (m3)	Total Det.Time (min)	Baffling Factor	Reservoir Contact Time (min)	Total Contact Time (min)	CT calc.= (min-mg/L)	CT Req'd	Inact. Ratio
Jan. 2007 Condition	5454	1.0	7.0	2.5	17.27	1720	1660	0.3	498	538	538	180	2.99
Present Full Allocation	7579	1.0	7.0	2.5	25.18	1720	1138	0.3	342	369	369	180	2.05
Additional units	8000	1.0	7.0	2.5	26.58	1720	1079	0.3	324	350	350	180	1.94
	9000	1.0	7.0	2.5	30.87	1720	929	0.3	279	301	301	180	1.67
	10000	1.0	7.0	2.5	35.11	1720	817	0.3	245	265	265	180	1.47
	12500	1.0	7.0	2.5	43.22	1720	663	0.3	199	215	215	180	1.20
	15000	1.0	7.0	2.5	51.86	1720	553	0.3	166	179	179	180	1.00
	17500	1.0	7.0	2.5	60.50	1720	474	0.3	142	154	154	180	0.85
	20000	1.0	7.0	2.5	73.95	1720	388	0.3	116	126	126	180	0.70
	22500	1.0	7.0	2.5	83.19	1720	345	0.3	103	112	112	180	0.62

To achieve 3 log inactivation of *Giardia* using only chlorination, a CT value of 180 must be achieved. If UV disinfection is provided, then chlorination must produce only 1 log inactivation of *Giardia*. This results in a reduced required CT of only 58 min-mg/L.

Calculation Notes:

1 Effective Bed units assume 80% occupancy of all rated bed units during maximum day demand conditions which matches historical water usage and occupancy.
2 Peak hour demand based on 1.86 x Maximum Daily Demands
3 Peak demand rate for calculation is based on longer period of time than one hour.
4 7579 build out number includes Ridge 1535 BU and Alpine Meadows 585 BU plus 2 BU for maintenance facility
5 Reservoir is not completely full but drawn down which is accounted for during daily CT Calculations

4.0 SUMMARY

In review of the information provided, we have the following conclusions:

- The maximum recorded demand in 2007 for Silver Star Mountain was 11.98 L/s which was for an occupied development of 5454 bed units;
- The Upper-Tee Reservoir is unbaffled and a baffling factor of 0.30 (30% effective) is utilized in the calculations. There is opportunity for improvement of the baffling through static baffles and/or inlet and outlet manifold configurations. The baffling factor can be upgrades to 70% effective through these means and as stated on Table 3.1;
- There is 42 cubic meters of watermain with 100% effective contact time included in the calculations;
- For the CT calculation, the flow rate through the Upper-Tee Reservoir was estimated to be the highest flow rate that would occur over a period of time equivalent to 30% of the total reservoir detention time;
- In total there are 7579 bed units currently allocated on the mountain. This works out to an estimated maximum daily water demand of 16.65 L/s. The peak hour demand is estimated to be 30.96 L/s however with 30% reservoir effectiveness, the reservoir retention reduces this design peak demand number to 25.2 L/s (max. average flow over a period of 8 hours);
- The CT calculation was estimated based on a free residual chlorine level at the first user of 1.00 mg/L, pH of 7.0 and a water temperature of $2.5^{o}C$. Chlorine dosage is higher during peak times due to higher reliance on Paradise Reservoir source water;
- Based on winter physical water parameters, the CT value to achieve 3 log (99.9%) inactivation of *Giardia* is 180 min-mg/L;
- Currently the CT value for all allocated development at Silver Star Mountain (7579 bed units) is estimated to be 368 min-mg/L. This exceeds the requirement of 180 min-mg/L;
- The maximum number of units that can be developed while still achieving 3 log inactivation of *Giardia* (CT = 180 min-mg/L) is estimated to be 14,900 bed units;
- Based on winter physical water parameters, the CT value to achieve 1 log (90%) inactivation of *Giardia* is 58 min-mg/L;
- If UV disinfection is added, then only one log inactivation by chlorine is required. The CT rate is sufficient with chlorination and UV to allow development of over 25,000 bed units;
- Proposed Well 13 has no impact on the CT calculation as it is to provide raw water to Paradise Reservoir;
- The proposed pump at Vance Creek has no effect on the CT calculation as the flow rate is dependant on water demand (reservoir outflow) and not reservoir filling;

Please call me directly at 212-3266 if you wish to discuss any aspects of this letter.

Yours truly,
Agua Consulting Inc.

Bob Hrasko, P.Eng.
Principal
RJH/rh