Selectable Ammonia Injection Point Feasibility Analysis

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TASK NUMBER: Task 7.0: Evaluation of Selectable Ammonia Injection Points for Compliance with Stage 1 Disinfection By-Products Rules

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Executive Summary

New Drinking Water Regulations

Two new drinking water regulations were promulgated by the US Environment Protection Agency (EPA) in January 2006. They are the Stage 2 Disinfectant and Disinfection Byproducts Rule (Stage 2 DBPR) and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Each of these new regulations has treatment, testing, and new compliance requirements for Ketchikan Public Utilities (KPU) and associated compliance time tables.

Need to Quickly Come into Compliance with Previous Regulations

Currently KPU is not in compliance with the Stage 1 DBPR because of high levels of five haloacetic acids (HAA5) that form after chlorine is added to KPU's raw water supply. KPU is under a compliance order from the Alaska Department of Environmental Conservation (ADEC) to quickly come into compliance, or KPU will be ordered to design and construct a water filtration treatment facility.

Adding Ammonia to KPU's Water Will Form Chloramines

Many community water systems that have high DBPs add both chlorine and ammonia to their water to form chloramines. Chloramines form DBPs at a much reduced rate compared to chlorine alone.

Selectable Ammonia Injection Points – Not Recommended

To comply with the Stage 1 DPBR requirements, it is technically feasible to form chloramines using three selectable ammonia injection points located immediately upstream and within the Bear Valley CT reservoir. However, since ammonia injection points may have to be changed on a daily basis due to system flow rate changes, we believe such a system will be too operationally complex to operate successfully. And, if not operated correctly, this could result in DBP violations under the existing Stage 1 DBPR or failure to meet disinfection requirements. For these reasons, we do not recommend KPU proceed with implementing selectable ammonia injection points.

Primary and Secondary Process Recommendations

Therefore, we have a primary and a secondary recommendation for regulatory compliance:

1) Our primary recommendation is to proceed with the design, construction, and operation of a new facility that will provide UV light disinfection and a single ammonia injection point to form chloramines. This new water treatment facility will bring KPU into compliance with both the Stage 1 and Stage 2 DBPRs and the LT2ESWTR. Stage 2 DBPR and LT2ESWTR compliance for community water systems serving less than 10,000 people is not required at this time, but doing so will provide higher quality water to KPU's customers in a facility that will be relatively simple to operate. This facility will not have to be expanded in just a few short years after it is constructed. The total capital cost is estimated at $6.2 million and annual O&M costs at $148,000. The 25-year life cycle cost is estimated to be $8.5 million.

2) If KPU elects not to proceed with UV at this time, our secondary recommendation is to construct a new facility that houses a new onsite sodium hypochlorite generation system and ammonia storage and injection system. Chlorine would continue to be injected at its current location, at a much lower dose, and the second dose of chlorine, along with ammonia, would be injected at the mid-point of the CT reservoir. This facility would have to be expanded with a major project and injection points would be moved in a few short years, when the LT2ESWTR will require that a second disinfectant be in place and operating. This second disinfectant will be UV light. The initial capital cost is estimated at $2.8 million dollars and annual O&M at $52,000. About four to six years after the initial project is completed and put into operation, KPU will need to begin a second capital improvement project to add UV disinfection at an estimated cost of $6.8 million. The 25-year life cycle cost is estimated to be $8.4 million.

Timely Decisions Are Needed

It is up to KPU and other decision makers to decide between moving forward with: 1) our primary recommendation for one large design and construction project that addresses all previous drinking water rules regulations and the two newly promulgated regulations or 2) our secondary recommendation which commits KPU to two design and construction projects, the first of which needs to start this year and the second project would need to start in about five years.

1. Introduction and Background

Ketchikan Public Utilities (KPU), a filtration avoidance utility, currently uses free chlorine for primary and residual disinfection. KPU began testing for disinfection by-products (DBPs) in 2004 under the Stage 1 DBP Rule. After the first full year of monitoring, KPU had a running annual average (RAA) for five haloacetic acids (HAA5) of 69.9 μg/L against a regulatory maximum contaminant level of 60 μg/L. This means KPU's delivered water was out of compliance with the Stage 1 DBP Rule. During the second year of monitoring (2005), the HAA5 RAA was 74.2 μg/L. In other words, the 2005 DBP levels were further out of compliance than the 2004 DBP levels. The organic materials and other contaminants in KPU's surface water source react with free chlorine and form DBPs in concentrations greater than allowed by the Stage 1 DBP Rule.

Based on the results of the first year of monitoring, KPU was issued a compliance order from the Alaska Department of Environmental Conservation (ADEC) dated January 4, 2005 to come into compliance with the requirements of the Stage 1 DBP Rule. With the January 2006 promulgation of the new Stage 2 Disinfectant and Disinfection By-Products Rule (Stage 2 DBPR) and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), the requirements for DBPs and disinfection will become even more stringent. Therefore KPU must make changes to its water treatment process.

In 2004, CH2M HILL completed an evaluation of disinfection alternatives for KPU to reduce the formation of DBPs, primarily HAA5. One of the alternatives identified for further consideration was the use of ammonia injection to convert free chlorine to chloramines for residual disinfection to halt the formation of HAA5. It is common water industry practice to use chloramines to control the formation of DPBs when the formation potential with free chlorine is high.

The initial alternative evaluation concluded that two or more selectable ammonia injection points would be required because no one location could meet all expected flow and temperature conditions in the KPU system. This is because winter cold water and low flow conditions, for example, have very different DBP formation dynamics as compared to summer warm weather, high flow conditions.

Further analysis was required to review actual operational variations and complete more detailed analysis of KPU water's HAA5 formation rates. The City Council opted to pursue this evaluation in July 2005 in an effort to potentially defer additional capital improvements for compliance with the Long Term 2 Enhanced Surface Water Treatment Rule and remain an unfiltered water system. Compliance with that rule will require additional microbial inactivation with a second disinfectant or the addition of a filtration treatment facility. Compliance is required by October 2013 for small systems (<10,000 customers). Systems are also eligible to apply for a 2 year extension if capital improvements are required to come into compliance.

This memorandum discusses the feasibility of using ammonia injection to convert free chlorine into chloramines after primary disinfection has achieved adequate CT for *Giardia* and virus inactivation.. Ammonia injection is required over a wide range of flow rates, temperatures, and other water quality parameters. To best address the range of operating conditions, three alternatives are considered in this memorandum. Two of the alternatives considered allow KPU to come into compliance with the Stage 1 DBP Rule without constructing and operating the UV light disinfection facility until required for the LT2ESWTR by 2013.

Alternative 1: Selectable Ammonia Injection Points. This alternative involves injecting ammonia at one of three injection points immediately upstream and within the Bear Valley CT reservoir. The injection point is selected based on compliance with the minimum disinfection requirements and acceptable HAA5 levels. The optimum injection point will vary during the day based on the water quality, temperature, and flow rate.

Alternative 2: One-point Ammonia and Booster Chlorination Injection. This alternative uses lower initial chlorine doses to limit the formation of HAA5 and then adds additional chlorine along with the ammonia at one injection point to achieve the desired chloramine residual for the distribution system. This new injection point would be located at the mid-point of the CT reservoir.

Alternative 3: UV Disinfection and Ammonia Injection. This final alternative includes installation of a UV system for disinfection. Ammonia is injected into the water near the UV disinfection point to form chloramines for residual disinfection in the distribution system to limit HAA5 formation. This alternative provides a higher level of assurance of microbial disinfection, meeting the LT2 ESWTR disinfection requirements, while coming into compliance with both Stage 1 and Stage 2 DBPR and maintaining filtration avoidance status.

1.1. Water Quality

Onsite water quality sampling began in September of 2003. Since that time samples have been collected daily for the following parameters for the initial (raw) water quality, at the CT reservoir entrance, and at the CT reservoir exit.

- Chlorine Residual (initial chlorine residual is measured immediately after chlorine injection)
- Temperature
- pH
- Turbidity
- UV Absorbance

A monthly summary of this sampling is shown in Table 1.

TABLE 1
On-site Sampling Results - Monthly Averages (2003 - 2005)

Month	Temp		pH*			Cl_2 Residual (mg/L)			Turbidity (NTU)			UV Absorbance (cm^{-1})		
	Initial	CT	Initial	Pre -CT	Post -CT	Initial	Pre -CT	Post -CT	Initial	Pre-CT	Post -CT	Initial	Pre-CT	Post-CT
Jan	3.8	4.2	6.1	7.0	6.9	1.80	1.76	1.31	0.40	0.22	0.21	0.071	0.058	0.055
Feb	3.4	3.9	6.1	7.0	6.8	1.72	1.64	1.20	0.27	0.22	0.21	0.069	0.061	0.055
Mar	3.6	4.1	6.1	7.0	6.6	1.65	1.63	1.19	0.30	0.24	0.21	0.067	0.054	0.050
Apr	5.3	5.6	6.1	6.9	6.9	1.69	1.57	1.07	0.21	0.22	0.20	0.063	0.051	0.050
May	10.2	10.3	6.2	7.1	7.3	1.96	1.86	1.36	0.16	0.15	0.15	0.053	0.044	0.036
Jun	13.4	13.7	6.2	7.1	7.2	1.63	1.77	1.22	0.16	0.14	0.15	0.040	0.030	0.028
Jul	16.4	16.6	6.2	7.1	7.2	1.89	1.56	1.19	0.20	0.17	0.15	0.041	0.032	0.033
Aug	16.7	17.0	6.2	7.1	7.1	1.94	1.72	1.26	0.17	0.23	0.20	0.066	0.051	0.047
Sep	10.3	11.1	6.1	7.1	6.9	2.21	1.85	1.33	0.21	0.28	0.25	0.068	0.052	0.049
Oct	9.2	10.0	6.1	7.1	6.9	1.95	1.84	1.27	0.20	0.24	0.24	0.068	0.057	0.049
Nov	6.7	6.8	6.0	7.0	6.8	2.09	1.74	1.30	0.20	0.19	0.18	0.068	0.058	0.051
Dec	5.3	5.4	6.0	6.9	6.8	1.85	1.72	1.28	0.34	0.17	0.18	0.063	0.054	0.051

* The post CT sample results are prior to the addition of soda ash.

In addition to daily sampling for the parameters above, raw water characterization tests were conducted as a part of the laboratory tests completed as a part of this project. Table 2 summarizes KPU's average raw water characteristics.

TABLE 2
KPU's Raw Water Characterization Summary

Constituent	Detection Limit	Average	Range
TOC (mg/L)	0.5	1.52	0.5-1.9
Iron (ug/L)	100	ND	ND
Manganese (ug/L)	10	ND	ND
Hardness (mg/L as $CaCO_3$)	0.66	2.60	2.3-3.4
Nitrate (mg/L as N)	0.1	ND	ND
Bromide (mg/L)	0.02	0.03	NA
Ammonia (mg/L)	0.1	ND	ND
Turbidity (NTU)*	--	0.25	NA
pH *	--	6.3	NA

NA – Range not available, only one sample taken.
ND – No Detection Reported in Samples Tested

* Results from laboratory testing only. KPU monitors these parameters regularly.

Typically, a water source is considered to have a high likelihood of producing DBPs if the total organic carbon (TOC) in the water is above 3.0 mg/L. Raw water characterization test results show that the TOC in KPU's water is typically in the neighborhood of 1.5 mg/L and based on TOC content alone would not be considered to have a high probability of producing DBPs. However, another common indicator for the likelihood of DBP formation is high SUVA (Specific Ultraviolet Absorbance). SUVA is calculated by dividing the UV254 by the DOC (Dissolved Organic Carbon). No DOC values are available for KPU water at this time, but based on an estimation of the DOC from the known values of TOC, the SUVA for KPU water may be near 5.0 $m^{-1}/(mg/L)$, considered an indicator of increased potential for DBP formation.

1.2. History of DBPs in KPU Water

KPU's water system is a long and linear system because Ketchikan extends along the coastline. The furthest sampling point in the distribution system is at Carlanna Plant. The travel time of water from the CT reservoir to Carlanna Plant may be as great as 9 days during low water demand periods, based on the distribution system model. This causes two problems. The first problem created by a long travel time is that the residual disinfectant decays 1.0 to 1.5 mg/L after it leaves the CT reservoir. Based on the chlorine decay rate in KPU water, high chlorine doses are typically provided by KPU in order to provide a regulatory required disinfectant residual throughout the distribution system. The need for a high initial disinfection residual results in much more disinfectant contact time than necessary for disinfection and subsequent high DBP formation. The second problem that comes with the long travel time in the Ketchikan system is that the lengthy time the water is in contact with free chlorine greatly increases the overall DBP formation. DBP formation would be over the regulatory limit even with lower initial chlorine doses due to the extended time that the water remains in the distribution system. Based on the lowest chlorine doses tested in the lab (1.5 mg/L), free chlorine can be left in contact with KPU water for about 1 day before exceeding the MCL for HAA_5; far less than the 9 days of retention that occurs in the Ketchikan system. This indicates that reducing the travel time in the distribution system by water wasting will not resolve the DBP issues.

KPU has been testing distribution system samples for compliance with the Stage 1 DBPR since 2004. KPU has collected additional water samples prior to the compliance monitoring from Carlanna Plant in the distribution system to better define DBP concentrations. In addition, KPU water samples have been collected and analyzed to determine the formation potential of DBPs under various scenarios of disinfectant dosing. These results are discussed in detail in the memorandum entitled *"Water Quality Evaluation for Ketchikan Public Utilities Water System"* dated October 27, 2004.

KPU has collected samples for distribution system monitoring as required under the Stage 1 DBPR. Monitoring results from 2004 and 2005 for HAA_5 are presented in Table 3 and Table 4, respectively.

TABLE 3
KPU 2004 Stage 1 DBPR Compliance Monitoring – HAA5 (μg/L)[1,2]

Date Sampled	Site 1 pH Facility	Site 2 The Mat	Site 3 Public Works	Site 4 Carlanna Plant	Average
First Quarter (March 2, 2004)	55.3	54.0	**65.3**	**86.1**	**65.2**
Second Quarter (June 16, 2004)	**72.6**	**78.9**	**79.0**	**105.2**	**83.9**
Third Quarter (September 21, 2004)	50.3	49.5	**75.1**	**84.7**	**64.9**
Fourth Quarter (November 2, 2004)	55.5	**65.5**	**65.6**	**76.2**	**65.7**
Locational Running Annual Average (LRAA) Stage 2 DBPR	58.4	**62.0**	**71.3**	**88.1**	
Running Annual Average (RAA) Stage 1 DBPR					**69.9**

[1] Sample site 1 is closest to the CT reservoir and site 4 is the most distant in KPU's distribution system.
[2] The MCL is 60 μg/L. Samples that exceed the MCL are shown in bold.

TABLE 4
KPU 2005 Stage 1 DBPR Compliance Monitoring – HAA5 (μg/L)[1,2]

Date Sampled	Site 1 pH Facility	Site 2 The Mat	Site 3 Public Works	Site 4 Carlanna Plant	Average
First Quarter (March 3, 2005)	49.9	59.6	**62.4**	**83.0**	**63.7**
Second Quarter (May 6, 2005)	57	**68**	**65**	**89**	**69.8**
Third Quarter (September 14, 2005)	**84.9**	**95.7**	**105.7**	**99.9**	**96.6**
Fourth Quarter (November 11, 2005)	52.7	**63.6**	58.1	**93.2**	**66.9**
Locational Running Annual Average (LRAA) Stage 2 DBPR	**61.1**	**71.7**	**72.8**	**91.3**	
Running Annual Average (RAA) Stage 1 DBPR					**74.2**

[1] Sample site 1 is closest to the CT reservoir and site 4 is the most distant in KPU's distribution system.
[2] The MCL is 60 μg/L. Samples that exceed the MCL are shown in bold.

Running Annual Average HAA5 levels exceed the established MCL in both 2004 and 2005. The system-wide running annual average (RAA) and locational running annual averages (LRAA) were reviewed (as indicated by the average values provided in Table 3 and Table 4). The RAA for HAA5 was determined to be 69.9 μg/L in 2004 and 74.2 μg/L in 2005, which are above the current MCL of 60 μg/L. Based on the 2004 RAA monitoring results for HAA5, ADEC issued a compliance order to KPU for the Stage 1 DBPR. Although the original compliance order required filtration, subsequent communication with ADEC has resulted in the potential for alternative methods of compliance, including the use of chloramines in lieu of free chlorine in the distribution system.

HAA5 values also surpassed the Stage 2 LRAA requirements at all samplings sites in one or both years. Stage 2 sample sites will be based on the Initial Distribution System Evaluation (IDSE) and thus may be different than those currently used for Stage 1. The IDSE must be completed by March 31, 2010. It is assumed that Carlanna Plant will be one of the required sample points for DBP monitoring since the KPU system is linear and Carlanna Plant is the furthest point in the distribution system, making it the most likely location to exceed DBP regulations. This means that by the time KPU is required to come into compliance under the Stage 2 DBPR, compliance with the 60 μg/L MCL will be required at each sample location, including Carlanna Plant. Stage 2 compliance begins October 1, 2013.

2. Existing Facilities

KPU takes water from Fawn Lake which is fed by the Ketchikan Lakes and Granite Basin. The water is chlorinated at the Ketchikan Chlorination Plant. After the chlorination plant, the water is conveyed through approximately 4,000 feet of 36-inch transmission main to the 3 MG Bear Valley CT Reservoir. Downstream of the reservoir, soda ash is added to raise the pH and alkalinity to help limit corrosion in the distribution system. No additional treatment is provided in the distribution system. A schematic of the water supply and treatment system is shown in Figure 1. A discussion of these system components is provided below.

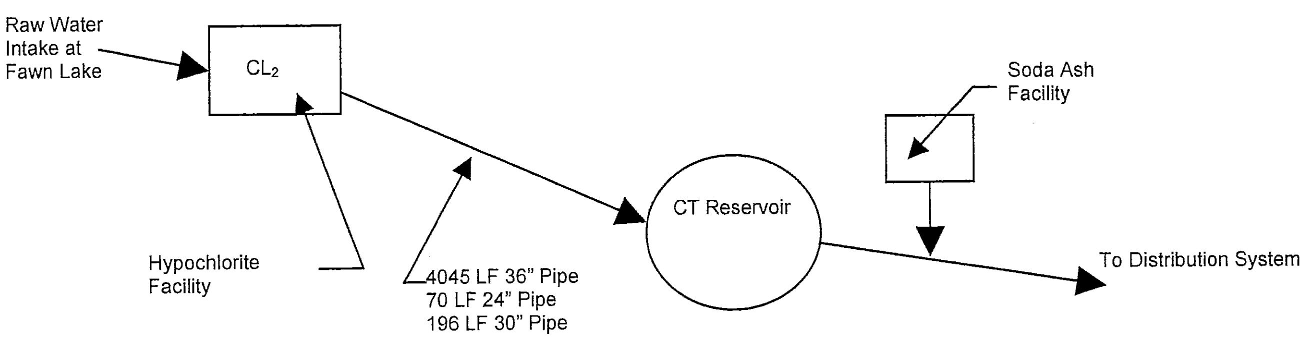


FIGURE 1
KPU Water Treatment System Schematic Diagram

2.1. On-site Sodium Hypochlorite Generation Facility

Immediately after entering the water system sodium hypochlorite is injected into the water to provide primary and residual disinfection. The chlorine dose is determined by the need to meet regulatory required disinfection CT and to maintain a disinfection residual at the end of the distribution system. The operator adjusts the dosing set point either up or down based on the need for more or less residual at the end of the system, as this is the controlling factor.

The current hypochlorite generation and injection system has a capacity of 420 lbs/day of chlorine gas equivalent using two generators, each with a capacity of 210 lbs/day. This corresponds to a maximum dosing rate of 4.44 mg/L at a peak flow of 11.3 mgd. A chlorine dose this high would make DBPs unmanageable and so the current chlorine system is more than adequate for the current system and operating conditions, along with the selectable ammonia injection point alternative.

Another alternative proposes a small initial chlorine dose using the current generation system, and the addition of a second chlorine generation and injection system near the CT reservoir. The second chlorine injection points boosts the chlorine residual and establish the necessary chloramines concentration so that the chloramines residual at the end of the distribution system is in the range of 0.5-0.6 mg/L total chlorine. This second chlorine injection point alternative is discussed in further detail in section 4 below, including the estimated capacity of this second chlorine injection system.

2.2. Bear Valley CT Reservoir

After sodium hypochlorite is injected into the water, it travels through a 4311 foot long pipeline to the Bear Valley CT reservoir. The total volume of this pipeline is 222,600 gallons.

The CT reservoir is a two story serpentine reservoir with spiral baffles at both stories. Plan and section views of the reservoir are shown in Figure 2 and Figure 3, respectively. The reservoir is credited with 75 percent hydraulic efficiency (T_{10}/T). Although short-circuiting is less of a concern with this type of baffled tank design, it is still possible for water to short-circuit through the tank by moving along the shortest wall length. A flow model has not been performed and is not part of this scope. The travel time through the tank for the formation of disinfection by-products has been assumed to be equal to the theoretical detention time. If there are pockets of water that remain in the tank longer, then the actual HAA_5 concentration may be higher than estimated in this analysis.

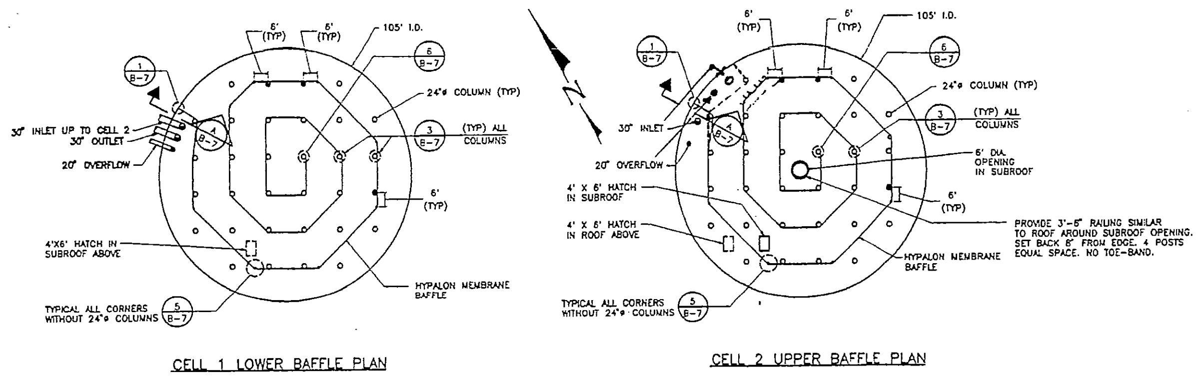


FIGURE 2
Bear Valley CT Reservoir – Plan View

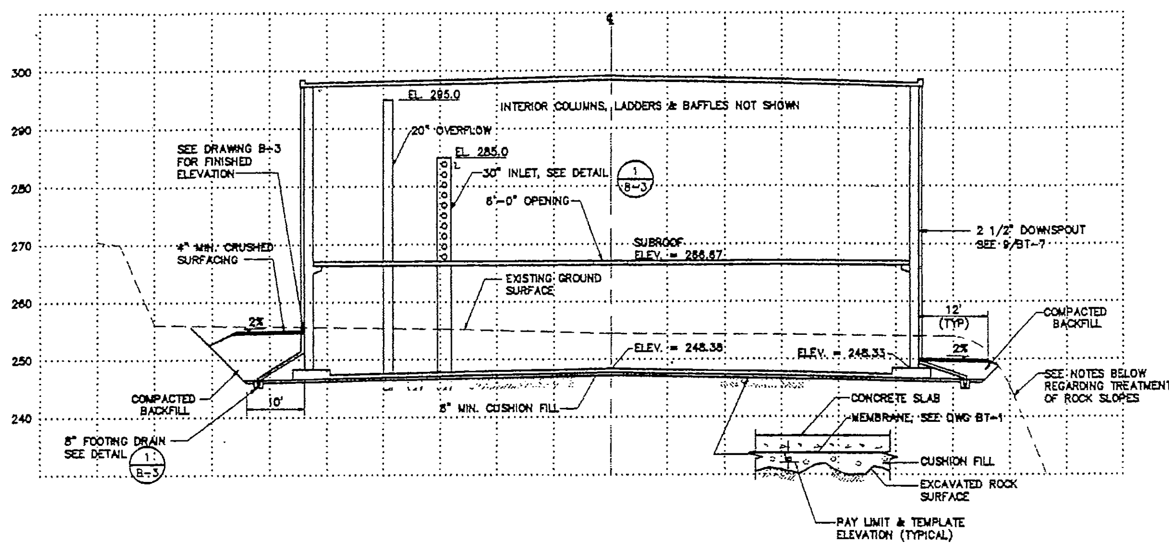


FIGURE 3
Bear Valley CT Reservoir – Section View

2.3. Soda Ash Facilities

At the outlet of the CT reservoir, soda ash is injected into the water in order to increase the pH of the water entering the distribution system. The target pH of KPU water is currently 8.5 pH units; however, the typical measured pH entering the distribution system is around 8.3. The soda ash system is housed in an 800 square foot metal building. The soda ash system itself (pumps, feeder, hopper, and solution tanks) takes up less than half of the floor space in the building. The rest of the space is used to store pallets of soda ash and to park the forklift used to unload palletized soda ash. It may be possible to optimize the efficiency of storage space for soda ash and develop an alternative parking space for the forklift in order to create space for additional treatment processes in the soda ash building; however, the space is fairly tight.

One important aspect of the existing soda ash system is its capacity. With the addition of ammonia into the water to form chloramines, the target pH in the distribution system may be increased to as high as 9.0 in order to further optimize the control of lead corrosion in the distribution system. In order to maintain the desired pH in the distribution system, additional soda ash will need to be added to the water.

The system as it currently exists was designed to feed up to 9.0 mg/L of soda ash in order to raise the pH to a target value of 8.5. However, after the conversion to sodium hypochlorite for disinfection, the required soda ash to meet target pH conditions was reduced to an average of approximately 2.2 mg/L (based on annual soda ash consumption). Based on current calculations, this dose would need to be increased to a dose between 4.0-5.0 mg/L in order to raise the pH to 9.0. This reflects a significant increase as compared to current dosing rates, but should still be possible to meet with the current soda ash feed and dosing system. It is assumed that the soda ash hopper is large enough to hold sufficient soda ash so as not to require refilling on extended weekends, but this detail should be confirmed during final design.

The capacity of the soda ash facility in its present state is based on the 94 lbs/hr capacity of the soda ash feeder and the 70 gph capacity of the metering pump.

3. Evaluation Criteria

In order to determine the feasibility of using multiple ammonia injection points to convert free chlorine into chloramines, the following historical and predicted future conditions were analyzed.

- HAA5 formation rate and formation potential
- Disinfection CT requirements for Giardia and virus inactivation
- Temperature, maximum/average/minimum flows, pH, and chlorine demand and decay

Using the data compiled from this research, we were able to predict the free chlorine contact time that would be required to meet CT for disinfection and the maximum allowable free chlorine contact time before HAA5 formation has exceeded the allowable limit, or our desired target limit. After determining the various seasonal minimum and maximum chlorine contact times based on temperature and chlorine dose, we were able to use the flow data to determine the ammonia injection points to meet our design criteria.

3.1. Disinfection By-Product Formation

Disinfection by-product formation was analyzed using two data sources. The first data source is the result of the distribution system monitoring that is currently conducted to report the DBP levels to ADEC. The second data source is the results of multiple rounds of simulated distribution system bench scale tests that were performed by CH2M HILL's Applied Sciences Laboratory (ASL) in Corvallis, Oregon.

3.1.1. Distribution System Monitoring

In 2004 KPU began conducting distribution system monitoring for DBPs and reporting them to ADEC. This testing gives valuable information regarding the total formation potential of DBPs in the water system, but does not reveal how rapidly DBPs form. These data, shown previously in Table 3 and Table 4, confirm that the HAA5 concentration is regularly greater than the regulatory limit even early in the distribution system. Additional laboratory simulations were needed to estimate the rate at which these DBPs are formed.

3.1.2. Simulated Distribution System (Lab Analysis)

CH2M HILL conducted simulated distribution system (SDS) modeling using KPU's raw water to further define the DBP formation rate in the early hours after chlorine injection. This testing involved adding a specific chlorine dose to a raw water sample and measuring DBPs and chlorine residual at specific time intervals. Based on the results of this test, we were able to predict DBP concentrations with time after chlorine injection for various water temperatures and chlorine doses. The test results are included in Appendix A.

Based on the results of the SDS testing, the maximum chlorine contact time that can be allowed due to HAA5 formation, and the minimum chlorine contact required to meet CT for primary disinfection were determined for each of the test conditions. The test conditions, and contact times are shown in Table 5 and Figure 4. Figure 4 provides a graphical comparison of the minimum free chlorine contact time for CT and the maximum free chlorine contact time for three different levels of HAA5 formation. To provide a factor of safety, our analysis targets a maximum of 80 percent of the HAA5 limit, or 48 μg/L. Therefore, for the first set of data at 4 °C and 1.5 mg/L chlorine dose, a minimum of 4 hours is required to meet CT and a maximum of 12 hours is allowable before exceeding 80 percent of the HAA5 MCL (48 μg/L).

TABLE 5
Predicted CT and HAA5 Allowable Free Chlorine Contact Times for SDS Test Runs

Test Date	Test Parameters			Max. time for HAA5 formation			Min. CT retention required (hr)
	Temp (°C)	Cl_2 Dose (mg/L)	pH	HAA5= 60 μg/L (hr)	HAA5= 54 μg/L (hr)	HAA5= 48 μg/L (hr)	
1/28/2004	4	1.5	7	30	24	12	3.5
1/28/2004	4	2	6.95	12	10	9	2.3
1/28/2004	4	3	7.16	8[1]	7	5	1.5
1/22/2005	4	3.25	7.3	9	7.5	5	1.6
6/2/2004	5.9	1.5	6.7	26	15	10	3.0
6/2/2004	5.9	2	6.8	12	10.5	8	2.2
10/18/2005	10.5	3.75	7.5	2	1.7	1.5	1.5
8/18/2004	13.5	1.5	7.2	28	22	11	1.6
8/18/2004	13.5	2	7.3	14	11	9	1.2
8/18/2004	13.5	3	7.8	10[1]	9	8	1.0
1/22/2005	17	4.5	7.6	1.9	1.7	1.5	0.6

([1]) – Estimated value, ammonia added before HAA5 reached 60 μg/L

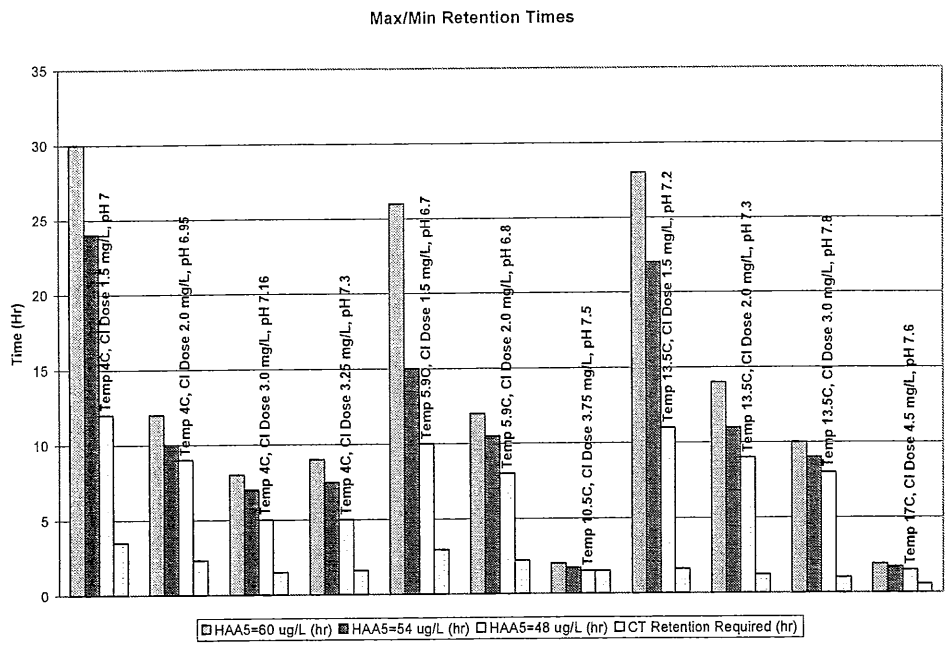


FIGURE 4
Max Allowable/Min Required Retention Times for SDS Tests

3.2. Seasonal and Critical Conditions

To determine the operating parameters under which a new treatment system will need to operate, seasonal and critical conditions were determined and analyzed. The most significant natural conditions that play a role in the formation rate of DBPs and the required CT retention times are minimum and maximum flow rates, pH, and temperature.

Potential ammonia injection points must be located in the system in order to allow enough free chlorine contact time before ammonia addition to satisfy CT requirements (based on temperature, chlorine residual, pH) and to keep the chlorine contact time short enough that DBP formation (based on chlorine dose and temperature) is kept below the regulatory limit. Both CT requirements and DBP formation rates vary based on water temperature, so the most important factors to determine and evaluate are temperature (to determine retention time allowed/required) and reservoir level and flow rate (to determine actual retention time in system).

3.2.1. Historical Flow Conditions

KPU historical records were analyzed to determine system operational conditions. Water quality parameters were determined from on-site sampling (see Section 1.1, Water Quality). Average flow conditions were taken from total water usage reports generated by KPU. Maximum hourly flows were taken from CT reports compiled by KPU and sent to ADEC. Minimum hourly flows were determined by analyzing graphs of flows experienced in the KPU system. Minimum and maximum flows are based on records from 1997 and 2004-2005. These two years were suggested by KPU as representative samples of cold (1997) and warm (2005) years. Generally, the temperatures experienced in Ketchikan inversely influence the maximum and minimum flows with greater water consumptions occurring during colder years. Table 6 shows the historical flow conditions that were collected and used along with the water quality parameters shown in Table 1 to assess the feasibility of selectable ammonia injection points within the CT reservoir.

TABLE 6
Historical Flow Conditions

Month (Avg. Temp)	Average Temp Degrees C	Average Monthly Flow (gpm)	Peak 1-Hour Flow (gpm)	4-Hour Minimum Flow (gpm)
January	3.8	2923	5300	1300
February	3.4	2825	4600	1182
March	3.6	2707	4100	1100
April	5.3	2356	4300	850
May	10.2	2381	5800	650
June	13.4	2675	6300	650
July	16.4	3916	8300	800
August	16.7	4346	8900	560
September	10.3	2918	6200	800
October	9.2	2346	5100	800[1]
November	6.7	2487	4300	950[1]
December	5.3	2629	5300	1100[1]

([1]) – Estimated minimum flow, no historical data provided.

KPU experiences a wide range of variations in flows on both a seasonal and daily basis. This is mainly due to the two predominant industries in the area, fish processing and cruise ships. Cruise ships dock in the city throughout the summer months and fill their potable water tanks from KPU's water system. This puts high spikes (4,000+ gpm) on the water system for short periods of time. In addition to the cruise industry, the fish processors located in the area use KPU water at many different times throughout the year. This increases the flow on a more regular basis throughout the time the fish processors are in operation and creates a significant drop off during times when the fish processors are not working.

Based on the available historical flow conditions, we have determined that any treatment system proposed must be able to treat the winter and summer minimum and maximum flow rates shown in Table 7.

TABLE 7
Seasonal Design Flow Conditions

Season	Min 4-hour Flow (gpm)	Min 8-hour Flow (gpm)	Max 1-hour Flow (gpm)	Temp (°C)	Reservoir Level (ft)
Winter	800	1450	5300	4-10	Variable
Summer	600	1250	8900	10-19	Variable

3.2.2. Future Predicted Flows

The flows in Ketchikan over the past ten years have no apparent trends either up or down. The average daily water consumption from 1993 to 2005 is shown in Figure 5.

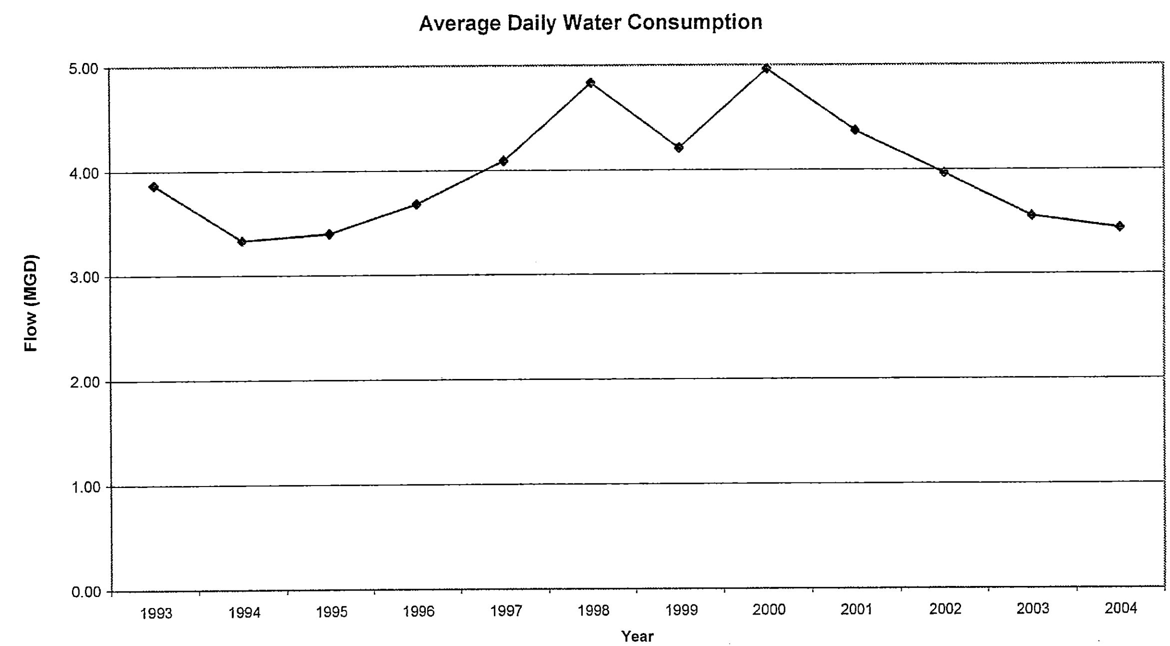


FIGURE 5
Average Daily Water Consumption (1993-2004)

As can be seen in this figure, the average flows have changed during the past 11 years, but with no consistent trend. The data suggests that overall changes to KPU's water demand in the next 10 years will only be impacted as a result of a major development. Major developments could include construction of a new cruise ship terminal or addition or deletion of fish processors. As these kinds of changes take several years to implement, time should be available to address required modifications before the changes are implemented.

Since using selectable ammonia injection points is considered to be an interim solution, to be effective up to 10 years, historical flows are assumed to represent future flows without significant increases or decreases. In actuality, the system should be robust enough to handle gradual variations in flows over the next 10 years.

Based on these factors we have determined that the flows shown in Table 7 can be used to design a temporary system that would be used prior to implementation of a new disinfection system designed to meet the requirements of LT2ESWTR.

3.3. Chlorine Dose/Chloramines Residual Requirements

Currently, the chlorine dose in the KPU water system is controlled by the amount of chlorine needed to maintain a residual at the end of the distribution system. The new regulations still require a detectable residual at the end of the distribution system. With the use of chloramines for residual disinfection, the suggested target for total chlorine residual at the end of the distribution system is 0.5-0.6 mg/L. Total chlorine residuals less than this are more subject to nitrification. Based on lab testing conducted on KPU's water, the corresponding free chlorine dose required to maintain this residual over the 9-day retention time in the KPU system would be in the range of 2.5-3.0 mg/L.

The second factor that controls the chlorine dose is the CT requirement. The primary disinfection process must achieve 3-log Giardia and 4-log virus inactivation under current regulations. This can be done in KPU's system under fairly low doses due to the long contact time that is provided in the CT reservoir.

Based on the results of lab testing, the maximum chlorine dose in KPU water will need to be less than 3.75 mg/L to meet CT requirements but avoid rapid DBP formation.

4. DBP Control Strategies

Based on the analysis of the design criteria and parameters that are given in Section 3, we have identified three possible alternatives for the control of disinfection by-products. Two of these alternatives use the chlorine-chloramines approach. The third alternative uses UV-chlorine/chloramines. UV light disinfection may be required if multiple selectable ammonia addition points are either not possible or operationally too complex to meet all regulatory requirements for CT and DBPs.

4.1. Selectable Ammonia Injection Points

The selectable ammonia injection point chlorine-chloramines disinfection approach is the main focus of this memorandum. This approach uses selectable ammonia injection points to control DBP formation while achieving the required chlorine CT needed for primary disinfection. The wide range of seasonal and daily flows in the KPU water system necessitates selectable ammonia injection locations within the CT reservoir. In CH2M HILL's preliminary disinfection alternatives study (Technical Memorandum 6), we determined that the addition of only one ammonia injection point would not be adequate. To meet the required CT retention times necessary for free chlorine while simultaneously keeping the DBP formation below the regulated maximum contaminant level (MCL), it was determined that at least two selectable ammonia injection locations would be required.

This memorandum determines if two or more injection points can successfully bring KPU into compliance for the historical flow conditions. The initial goal was to determine if two injection points could selectively be used to meet the disinfection requirements for a particular season without needing to switch between injection points more than a few times per season. After evaluating the range of flows experienced on a day to day basis in each season, it was determined that it would not be possible to maintain the chloramines residual at the end of the distribution system, meet CT for primary disinfection and limit HAA_5 formation with less than three ammonia injection points; and without using more than one injection point each day. This makes this alternative operationally complex, from the programming, monitoring and operating perspectives.

The worksheet in Figure 6 shows the input parameters and the associated range of flows that could be treated with three injection points at locations at the tank entrance and 10% and 30% of the way through the CT Reservoir. The 1-hour maximum and 4-hour minimum historical flows have been used for the 2.5-3.0 mg/L dose analysis based on the HAA_5 maximum retention times ranging from 5-10 hours. These maximum and minimum flows are shown by the red lines on each chart.

The worksheet shows the range of flows that can be treated by a set of injection points based on the minimum and maximum allowable retention times. The minimum retention time required for adequate disinfection is calculated using equations developed by CH2M HILL based on published CT tables. For the calculations of the CT required retention time in the system, T_{10}/T is assumed to be 0.75 for the CT reservoir and 1.0 for the pipeline. An inactivation ratio (IR), which is the actual CT divided by the required CT, of 1.25 is assumed to provide a factor of safety for disinfection. The minimum retention time required corresponds to the maximum flow that can be handled by a specific injection point. The maximum chlorine contact time that can be allowed based on HAA_5 formation rate is estimated based on the laboratory testing discussed above. The flows that can be treated by a particular injection point are broken down into two ranges. These ranges are based on the maximum allowable contact time to reach 80% of the HAA_5 MCL (48 μg/L) and the additional range that could be treated if the DBP formation were allowed to reach 100% of the HAA_5 MCL (60 μg/L). The target goal in designing a new treatment process is to limit the predicted HAA_5 formation to 80% of the MCL. However, by allowing for higher formation of HAA_5 in the system, the same injection point could be used to treat a wider range of flows. For the calculations of the HAA_5 retention time in the system, contact time is assumed to be equal to the theoretical detention time (Volume/Flow) for both the pipeline and the CT reservoir.

In the winter months, it is not possible to cover the entire range of flow predicted in the KPU water system with three injection points while simultaneously meeting CT requirements for disinfection and remaining below 80% of the MCL for HAA_5. All of the flows predicted can be covered by allowing the formation of HAA5 to increase to 100% of the MCL. This alternative does not provide significant overlap at different injection points.

Range of Flow Treated by Three Selectable Ammonia Injection Points

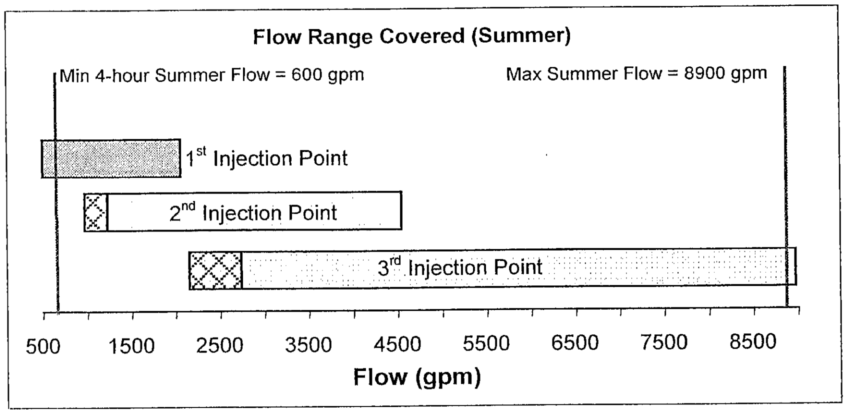
with 2.5-3.0 mg/L Initial Chlorine Dose

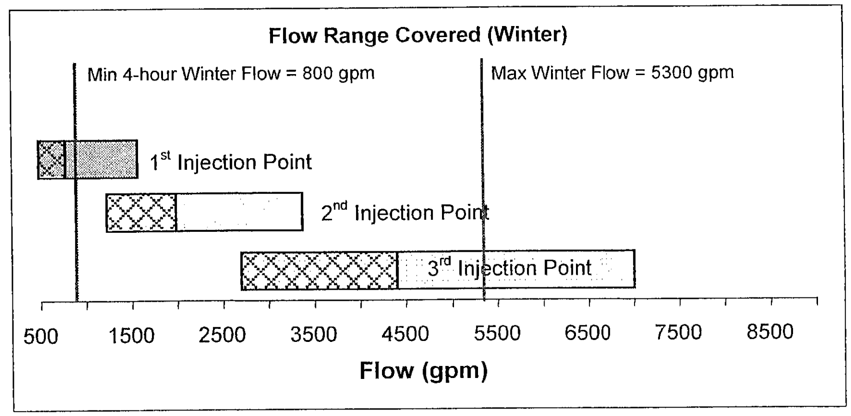
Summer

Temp	12-17	Degrees C	
Cl2 Dose	2.5-3.0	mg/L	
Min Retention Time	1.9	hr	IR= 1.25
Max Retention Time (HAA5 = 48 ug/L = 80% MCL)	8	hr	
Max Retention Time (HAA5 = 60 ug/L= MCL)	10	hr	
1st Injection Point Location	Tank Entrance		
2nd Injection Point Location	10%	of the distance through the tank	
3rd Injection Point Location	30%	of the distance through the tank	
Tank Level	46	ft	

Winter

Temp	4-8	Degrees C	
Cl2 Dose	2.5-3.0	mg/L	
Min Retention Time	2.5	hr	IR= 1.25
Max Retention Time (HAA5 = 48 ug/L = 80% MCL)	5	hr	
Max Retention Time (HAA5 = 60 ug/L = MCL)	8	hr	
1st Injection Point Location	Tank Entrance		
2nd Injection Point Location	10%	of the distance through the tank	
3rd Injection Point Location	30%	of the distance through the tank	
Tank Level	46	ft	





Flow treated by 1st injection point (HAA5 < 80% MCL)	Flow treated by 2nd injection point (HAA5 < 80% MCL)	Flow treated by 3rd injection point (HAA5 < 80% MCL)
Additional flow treated by 1st injection point if HAA5 < 100% MCL	Additional flow treated by 2nd injection point if HAA5 < 100% MCL	Additional flow treated by 3rd injection point if HAA5 < 100% MCL

FIGURE 6
Selectable Ammonia Injection Points Worksheet
Figure 6 shows the range of flows that could be treated at each of the three selectable ammonia injection points based on minimum and maximum regulatory retention times. It also compares those ranges to the design flows expected in the KPU water system. This worksheet shows that summer conditions could be met without exceeding the goal of 80% of the HAA5 MCL. On the other hand, winter conditions could only be met by exceeding the target of 80% of the HAA5 MCL but without exceeding the MCL.

Daily switching between multiple ammonia injection points as a DBP control strategy is complicated. The first concern is the difficulty of programming a control system that can properly handle the transitions from one ammonia injection point to another. Using multiple ammonia injection points to meet the range of flows that occur in the KPU water system each day would require an intensive operational scheme to maintain adequate chlorine and ammonia ratios at all times. This requires the control system to know the exact amount of time that would pass between the moment one ammonia injection point is turned on and another turned off. Alternatively, the control system could control the ammonia based on a sampled concentration of ammonia in the water. However, this is also challenging due to the delay in response time between the water sample point, the analyzer, and the injection system. With this much time delay between the time a change in ammonia concentration occurred and the time the control system adjusted the ammonia dose at that point, there would be a great deal of room for error in the ammonia dose.

If the timing of changes in the injection points is not properly executed, the chlorine to ammonia ratio will not be correct. The concerns associated with the conversion of free chlorine to chloramines for disinfection begin with the need to maintain the appropriate chlorine to ammonia ratio. The preferred ratio is 4 parts chlorine to 1 part ammonia, with an acceptable range of 3 to 5 parts chlorine per part ammonia. In the event that the ammonia concentration drops below this value, free chlorine would be present in the water. This free chlorine would interact with the organics in the water as it does now and continue to form disinfection by-products. If the ammonia ratio becomes too high, nitrification can be a concern. As a result of nitrification, a system may experience an increase in chloramines demand or growth of numerous biological organisms. Both of these concerns can be mitigated by maintaining the appropriate chlorine to ammonia ratio. Maintaining the chlorine - ammonia ratio is normally not a problem, but there are concerns with this challenge due to the complicated injection and control system that would be required for the KPU water system. In addition to the issue of complex programming, this alternative would also require frequent calibration and back-checking to ensure that the system is operating properly. This greatly increases the complexity of the operation of the water system and increases the risk of errors.

An additional concern with the use of injection points located at any point inside the CT reservoir is associated with the need to obtain complete mixing in an extremely short period of time in a large volume of slow moving water. This is an issue that must be addressed in more detail should for any alternative requiring injection points within the CT reservoir.. Possible options to obtain adequate mixing include using side stream injection and incorporating a static mixer, using some sort of mixing baffles in the CT reservoir, using high pressure jets to inject the ammonia, or any combination of these or other commonly used mixing techniques.

Finally, an ammonia system likely cannot be located inside the existing soda ash facility. Therefore, an ammonia storage and pumping facility has to be located on the adjacent property owned by KPU. This increases the time required for conveying the ammonia solution to the point of injection and complicates the delivery of the chemical. Since running the chemical lines under Schoenbar Road is not desirable, the lines are shown routed behind the mini storage facility. The run is fairly long for chemical lines which will delay the response time to dose changes, but it can be done. The ammonia facility location should be incorporated into the site considering the long term plan for UV or filtration to meet the LT2ESWTR.

4.2. Low Initial Chlorine Dose with One Ammonia Injection Point and Second Chlorine Injection Point

Another alternative for the implementation of a combination of chlorine/chloramines for disinfection would be to reduce the initial chlorine dose for primary disinfection to approximately 1.5 mg/L (as compared to the 2.5-3.0 mg/L required to maintain residual in the distribution system). Based on the lab testing results, the window of chlorine contact time between when disinfection CT requirements are achieved and when HAA_5 limits are reached is greatly increased with a lower initial chlorine dose. The required retention time is only slightly increased in order to meet disinfection CT requirements as compared to the increase in the allowable retention time for HAA_5 formation at lower chlorine doses. This increase in available "window" would allow a single ammonia injection point to handle a much wider range of flows. This alternative would be easier to operate and control compared to the alternative with multiple, selectable ammonia injection points.

Figure 7 shows the same worksheet as the one that was used previously, except the minimum and maximum chlorine contact times have been adjusted to reflect the test results conducted at low chlorine doses. The results show that with a single ammonia injection point half way through the CT reservoir, the design parameters can be met for minimum and maximum flow conditions in both the summer and winter. The 8-hour historical minimum flows have been used for this 1.5 mg/L chlorine dose analysis since the HAA maximum retention times at this low dose range from 10-30 hours.

The drawback with this alternative is that this low chlorine dose will not provide sufficient disinfectant concentration to maintain the required residual throughout the distribution system. To meet residual disinfection requirements, additional chlorine must be added to boost the chlorine concentrations to the required level. This additional chlorine booster injection would likely be in the range of 1.5 - 2.0 mg/L. To accomplish this, an on-site hypochlorite generation facility must be installed near the CT Reservoir. It may be possible to relocate one of the existing 210 ppd on-site generation units to the new site; however, this would need to be approved by ADEC since it impacts the redundancy of the treatment system. For the purpose of this analysis, we assumed a new 150 ppd on-site generation unit would be installed near the CT reservoir.

This low chlorine dose combined chlorine/chloramines alternative also includes the same concern regarding adequate mixing at the proposed injection points as the previous alternative.

Range of Flow Treated by Single Ammonia Injection Point

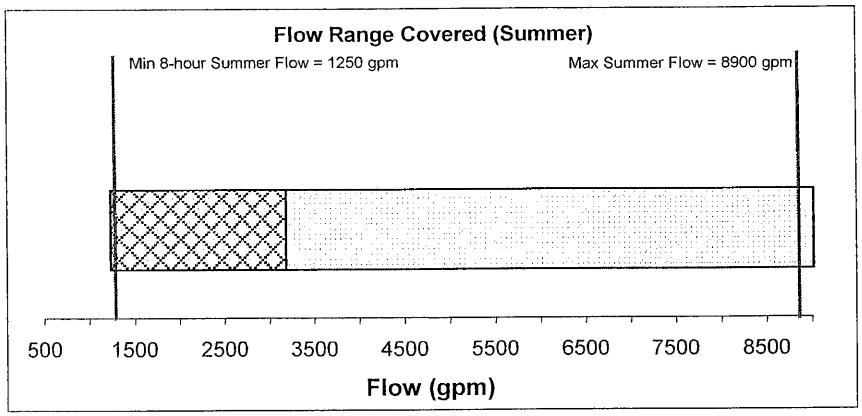
with 1.5 mg/L Initial Chlorine Dose

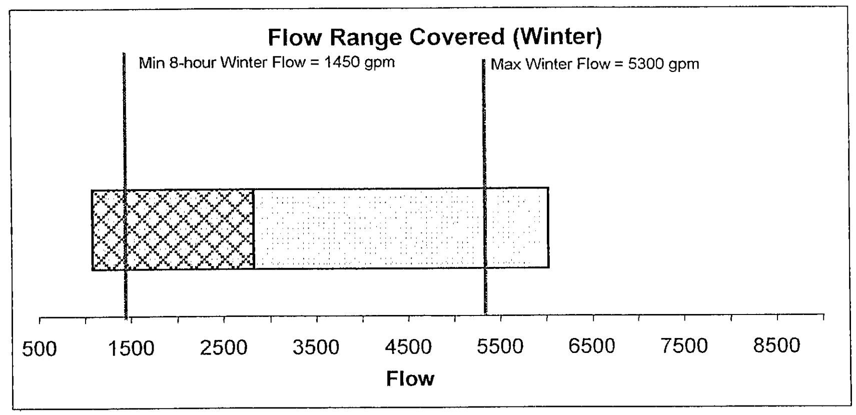
Summer

Temp	12-17	Degrees C	
Cl2 Dose	1.5	mg/L	
Min Retention Time	2.5	hr	IR= 1.25
Max Retention Time (HAA5 = 48 ug/L = 80% MCL)	10	hr	
Max Retention Time (HAA5 = 60 ug/L= MCL)	26	hr	
Injection Point Location	50%	of the distance through the tank	
Tank Level	44	ft	

Winter

Temp	4-8	Degrees C	
Cl2 Dose	1.5	mg/L	
Min Retention Time	4.4	hr	IR= 1.25
Max Retention Time (HAA5 = 48 ug/L = 80% MCL)	12	hr	
Max Retention Time (HAA5 = 60 ug/L = MCL)	30	hr	
Injection Point Location	50%	of the distance through the tank	
Tank Level	46	ft	





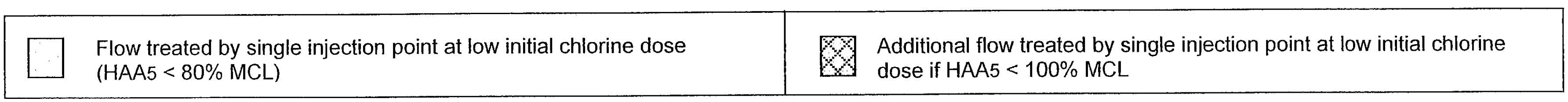


FIGURE 7

Single Ammonia Injection Point Worksheet

Figure 7 shows the range of flows that could be treated by a single ammonia injection point based on minimum and maximum regulatory retention times. It also compares those ranges to the design flows expected in the KPU water system. This worksheet shows that both summer and winter conditions would exceed the target maximum of 80% of the HAA5 MCL but will not exceed the total HAA5 MCL.

4.3. UV and Chloramines

This alternative includes implementation of UV light in combination with chlorine for primary disinfection and chloramines for residual disinfection to address DBP formation. The new facility would house 2 UV reactors and associated piping for 100% redundancy and be sized to treat the maximum hour flow rate of 8,900 gpm. It was previously discussed in CH2M HILL's Technical Memorandum 6: Disinfection Alternatives. Due to the inherent concerns with the two chlorine/chloramines alternatives for meeting disinfection requirements in the Ketchikan water system, it was reevaluated. This alternative reduces the required chlorine contact time prior to ammonia addition to roughly 5% to 10% (from 1.5 to 2 hrs down to 6-12 minutes) of the amount of free chlorine contact time necessary to receive credit for virus inactivation. UV can be used to meet the inactivation requirements for Giardia and Cryptosporidium (future), and free chlorine will only be used to meet CT requirements for viruses. After the short contact time to obtain credit for virus inactivation, ammonia is injected in to the flow stream to convert chlorine to chloramines to minimize DBP formation.

An additional benefit of UV-chlorine/chloramines is that within 10 years KPU will be required to add a second disinfectant to meet the requirements of the recently promulgated LT2ESWTR. The preferred disinfection alternative for KPU is UV, so this alternative simply accelerates the implementation of UV and does not add a process that would not be required in the future. The UV Facility would be constructed with two reactors for disinfection redundancy. The building itself will be large enough to house a third reactor in case it is needed to meet future demand.

This alternative is preferred because the injection points for ammonia are different in the other two temporary chloramines alternatives than the long term solution. The optimal location to add ammonia if free chlorine is only being used for virus inactivation is at a point less than half of the way through transmission main between the chlorine injection point and the CT Reservoir. However, the most likely location to add ammonia would be just after to UV disinfection. This would mean that in order to obtain the most effective possible operation scheme, the ammonia injection point would need to be moved when the UV system was added and the injection point or points developed for a combined chlorine/chloramines alternative would be abandoned. In order to ensure that HAA_5 formation is limited in the UV-chlorine/chloramines alternative, ammonia would be added at the earliest possible location where inactivation of viruses has been met for all seasonal conditions and flow ranges. A possible solution to this concern is to place the ammonia system on the adjacent property owned by KPU and pipe the ammonia to the reservoir for injection under one of the proposed chlorine/chloramines alternatives. Then when the UV system is put in place, the ammonia injection points themselves could be moved to the UV building, while leaving the existing ammonia system unchanged.

For further information on the UV/chloramines alternative, see TM 6: Disinfection Alternatives (CH2M HILL, 2005).

5. Site Layout

The site layouts shown in Figures 8 and 9 at the end of this memorandum depict possible options for the layout of the UV and ammonia injection system on KPU's property adjacent to the CT reservoir. Figure 8 shows Phase 1 of construction in which ammonia (and hypochlorite) would be added to temporarily control the DBP problem. Figure 9 shows Phase 2 of construction where UV disinfection would then be placed on the same site. The layouts show proposed buildings, access, and pipeline locations. A more detailed master plan should be created for the site to make sure that space is provided in a logical manner for all future facilities.

6. Updated Cost Opinions

Conceptual level cost opinions were provided for two of these alternatives during the City Council meeting in July 2005. Costs were provided for selectable ammonia injection (alternative 1) and for UV disinfection (alternative 3). Since that time, some market prices have changed and the ammonia system has been better defined. In this section, we provide an update to those cost estimates based on currently available information and provide an estimate for alternative 2 including ammonia injection with booster chlorine. A brief discussion of the assumptions for each of these systems is discussed below.

Alternative 1: Selectable Ammonia Injection. The costs for this alternative assume three ammonia injection points in the CT Reservoir. The ammonia building is located on the newly purchased Tract D. Chemical lines are run from the ammonia building to the CT reservoir in the access road behind the mini storage facility. The cost estimate assumes a more complicated injection and control system than originally considered.

Alternative 2: One-point Ammonia Injection and Booster Chlorination. The costs for this alternative assume a new chlorine and ammonia facility constructed on Tract D. Booster water is taken off the 36-inch line in Schoenbar Road. Both chlorine and ammonia are injected at a point approximately 50% of the way into the CT Reservoir. Although it may be possible to relocate one of the existing 210 ppd hypochlorite generation systems, we have assumed that two new 150 ppd units (one active and one standby) are purchased and installed. A holding tank is also provided at the new chlorination facility to provide several days of chlorination while the dose is adjusted at the upstream facility.

Alternative 3: UV Disinfection and Ammonia Injection. This alternative includes a UV and ammonia facility on Tract D. The full pipeline flow of water from the 36-inch line in Schoenbar Road is diverted to the UV facility, through the UV reactors and back out to the road to connect to the existing pipeline. Ammonia is injected at the UV building.

The cost estimates also include the following general assumptions:

Mobilization, bonds, insurance, temporary facilities, health and safety, and demobilization	15%
Location adjustment factor	40%
Contingency	30%
Escalation to mid-point of construction (Assumed to be July 2007)	13%
Sales Tax	0%
Engineering/Construction Management	30%
Legal/Administration	9%

Operations and Maintenance costs include additional funds required for staffing needed to operate and maintain the proposed facilities.

Life cycle costs are based on 25 years at 4 percent. For alternatives 1 and 2, UV is assumed to be installed and operational by 2015, assuming Alaska grants a two-year time extension, as allowed by the regulations for capital improvement projects.

Project and operating and maintenance costs for the three alternatives are presented in Table 8. These are conceptual level cost opinions have been escalated to the mid point of construction, assumed to be July 2007, and do not include financing costs. The cost opinion shown has been prepared for guidance in project evaluation from the information available at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets. Conceptual level costs are generally accurate to +50 and -30 percent of the estimate.

TABLE 8
Alternatives Cost Summary

Alternative	Initial Capital Cost	Annual O&M Cost
Ammonia (Not Recommended Due to Operational Complexity)	$1,700,000	$61,000
Ammonia + Hypochlorite	$3,100,000	$78,000
UV + Ammonia (Recommended)	$6,500,000	$174,000

Table 9 shows the total cost of each of the three alternatives over the next 25 years. The total capital costs include the cost of any current improvements now, and the cost of adding UV facilities in 10 years (for the two alternatives that postpone construction of UV facilities).

TABLE 9
25-Year Life Cycle Costs in 2006 dollars

Alternative	Total Capital Costs	25-Year O&M Cost	Total
Ammonia Now + UV in 10 Years (Not Recommended Due to Operational Complexity)	$6,000,000	$1,900,000	$7,900,000
Ammonia/Hypochlorite + UV in 10 Years	$7,400,000	$2,000,000	$9,400,000
UV/Ammonia Now (Recommended)	$6,500,000	$2,800,000	$9,300,000

7. Conclusions and Recommendations

The purpose of this evaluation was to consider the feasibility of implementing an intermediate ammonia injection system to bring KPU into compliance with the Stage 1 DBP rule. Ultimate compliance with the Stage 2 DBP rule and the Long Term 2 ESWTR will require UV with chloramines (ammonia) or filtration by 2016. This evaluation included three alternatives. A brief summary of the conclusions from this evaluation are provided below.

Alternative 1: Selectable Ammonia Injection. This alternative is operationally complex and higher risk due to the need to switch between ammonia injection points daily. A miscalculation or equipment failure could result in failure to comply with either disinfection requirements or disinfection byproduct limits. Due to the inherent concerns and operational complexity of this alternative, it is not recommended.

Alternative 2: One-point Ammonia Injection and Booster Chlorination. This second alternative is easier to operate and control but requires construction of a booster chlorination facility along with the ammonia facility. This chlorination facility is not needed in the ultimate UV/chloramine system. If KPU determines that the immediate costs for UV facilities are too great at the present time, we would then recommend that KPU chose to implement the Ammonia/Hypochlorite alternative as a temporary solution to the DBP problem.

Alternative 3: UV Disinfection and Ammonia Injection. The final alternative considered is early construction of the UV/chloramine facility. This alternative provides additional treatment and protection against Cryptosporidium and other resistant microbes as well as simplified operation of the ammonia system.

As shown in Table 8, the costs increase with the increased flexibility, reliability, and microbial inactivation. However, the total difference in the life cycle costs over the next 25 years (Table 9) show a small overall cost decrease for implementation of the UV-chloramines option now. With this in mind, and considering

- the ultimate need to install UV,
- the higher level of public protection, and
- operational simplicity,

we recommend that KPU consider installation of the UV/chloramine facility as the first and final step for compliance with these three regulations.

If KPU is unable to address the immediate funding need associated with the early implementation of UV and chloramines, then we recommend proceeding with the intermediate ammonia and hypochlorite facilities described as alternative 2. This facility is more reliable and lower risk than Alternative 1.

Whichever alternative is chosen, it is important that KPU make the selection and proceed with the preliminary design phase as soon as possible as implementation will require 24 months to 36 months depending on the alternative implemented.