APPENDIX M

Water Quality Technical Memorandums

Disinfection Byproducts Study

PREPARED FOR: Sammamish Plateau Water and Sewer District

PREPARED BY: Kim Ervin, Cathy Hood

DATE: December 29, 1999

Introduction

The Sammamish Plateau Water and Sewer District (District) is currently evaluating regional water supply options. The Seattle Public Utilities (SPU) Tolt River Supply (Tolt) has been identified as the most likely source of regional water for the District. There are two possible connections to this source; the first is located to the north near Northridge and Redmond Ridge, and the second is a south connection in Bellevue near the Eastside Reservoir, which would also supply the City of Issaquah and new developments in the area. It is also possible that the District would periodically receive water from SPU's Cedar River Supply (Cedar) at the southern connection.

The 1992 South Fork Tolt Pilot Study for SPU indicated that compliance with disinfection byproducts (DBPs) regulations in the distribution system may be a concern for customers located far from the source. In 1999, CH2M HILL performed independent testing for the District to determine the potential for DBP formation based on proposed connections to the Tolt supply because the Tolt filtration plant is not yet on line. The raw water underwent simulated filtration and ozone treatment to mimic the upcoming Tolt filtration plant process prior to performing the simulated distribution system tests. Samples were also rechlorinated to simulate conditions in the distribution system. DBP levels are quantified and compared to present and future DBP regulations.

Test Protocol

A Testing Plan and Protocol Memorandum was developed, dated October 15, 1999, for review by the District and for guidance for the CH2M HILL Laboratory. It outlined the purpose, sampling location, sampling procedures, schedule, and protocol for the DBP study. The following sections detail the activities resulting from the study.

Sample Collection

The raw water sample (SP-Raw) was collected from the Tolt Regulating Basin, prior to treatment, in October 1999.

Treatment Simulation

Treatment facilities are currently under construction for the Tolt supply. The planned treatment facilities include coagulation, filtration, and ozone treatment. Since these facilities are not on-line, treatment was simulated in the laboratory using the raw water sample (SP-Raw). Table 1 summarizes the treatment simulation, which is similar to SPU's pilot testing performed in 1992. The treatment conditions used were provided by SPU and are based on the anticipated performance of facilities currently under construction.

TABLE 1
Treatment Simulation Parameters

Treatment	Parameters
Pre-Ozone	2.8 mg/L (typical residual 1.5 mg/L)
Coagulant (Ferric Chloride)	0.4 mg/L
Cationic Polymer (Nalco 8100)	1.0 mg/L
Anionic/Nonionic Polymer	0.4 mg/K
Proposed Filtration	8 gpm/sf

Water quality parameters were measured before (Raw Water) and after (Treated Water) simulated treatment, as shown in Table 2. The laboratory simulation did not result in the turbidity and TOC removal that would be expected from full-scale treatment. The operating agreement for the Tolt plant requires a filtration effluent turbidity of less than 0.1 NTU, 95% of the time and always less than 0.2 NTU; the simulated treatment turbidity was 0.33 NTU. The higher concentration of organics in the simulated treated water resulted in somewhat conservative estimates of DBP formation, as discussed below under Testing Results. However, the actual distribution system would also have more organics than the simulated system. Despite these variations from actual conditions, the resultant DBP formation is representative of potential DBP formation and is useful in evaluation of potential future alternatives and likely treatment requirements.

TABLE 2
Water Quality

Analyte	Raw Water	Treated Water
Alkalinity (as $CaCO_3$)	7.5 mg/L	---
pH	6.41	---
DOC	---	1.08 mg/L
TOC	1.42 mg/L	1.23 mg/L
Turbidity	0.86 NTU	0.33 NTU
UV-254	0.058 abs/cm	0.013 abs/cm

Detention Time

Analysis was dependent on the estimated travel time from the Tolt source to the customer. The north connection was assumed to be near the City of Redmond's connection to the new Tolt Pipeline 2. Based on hydraulic modeling of near-future average day conditions, the travel time from the source to this connection point was approximated at 1-2 hours. The detention time in the District's distribution system was modeled assuming buildout conditions, and the detention time was 3-4 days. Therefore, analysis at 3-4 days simulated average flow at buildout conditions through the north connection.

A southern connection was assumed to occur in Bellevue, in the vicinity of the Eastside Reservoir. Current travel time from the source to this connection point was estimated to be 12 hours during average day conditions in the near future. Another factor that must be accounted for is the shared use of a future pipeline between Bellevue's system and Issaquah's. The connection to communities east of Bellevue (the District and Issaquah) was assumed to be a 24-inch diameter pipe. The Issaquah Highlands near-term water demands are expected to average 150,000 gallons per day or (110 gpm), and the District's demands from this source were estimated as 1500 gpm. This results in an average day travel time of approximately 1 day through this pipeline to the District. These factors resulted in a total travel time from the Tolt to the District's system of approximately 5-6 days through the south connection.

The travel time assumptions combine current day and buildout travel times. Actual travel time as the District's system develops may be longer if new facilities are brought on line prior to connection of new customers.

Simulated Distribution System

Time and temperature are the most influential factors for DBP formation. Two tests were performed on the samples which would simulate maximum and normal conditions. Test A was conducted at 15°C, which is the highest estimated temperature in the distribution system. This was also the temperature at which SPU's pilot testing was performed in 1992. Test B was conducted at 7°C, the approximate average temperature in the region.

Table 3 summarizes the Simulated Distribution System (SDS) test conditions.

TABLE 3
Simulated Distribution System Test Conditions

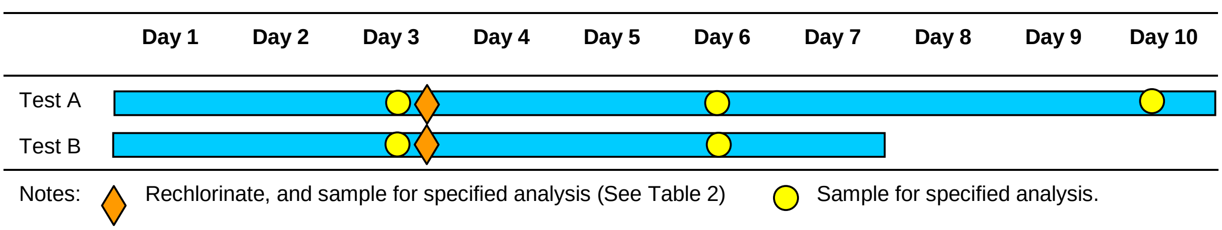
Test	Test A	Test B
Initial Test Conditions		
Initial Chlorine Dose	2.0 mg/L	2.0 mg/L
Total Chlorine Residual at Day 3 (after initial 2.0 mg/L dose)	0.39 mg/L	0.61 mg/L
Minimum Chlorine at End of Time [A]	0.2 mg/L	0.2 mg/L
pH [B]	8.11	8.13
Temperature	15°C	7°C
Total Test Duration	10 days	7 days
Rechlorination		
Rechlorination Time	Day 3	Day 3
Rechlorination Dose	0.8 mg/L	0.8 mg/L
Analysis		
Analysis	Temperature, pH, chlorine residual, total trihalomethanes (TTHMs), and total haloacetic acids (5) (HAA5) at 3 contact times: 3 days (72 hrs), 6 days, 10 days.	Temperature, pH, chlorine residual, total trihalomethanes (TTHMs), and total haloacetic acids (5) (HAA5) at 3 contact times: 3 days (72 hrs).

[A] Minimum chlorine residual based on Surface Water Treatment Rule requirements for 0.2 mg/L in distribution system.

[B] pH is normally elevated to 8.2 using lime and CO_2. Phosphate buffer was used in lieu of CO_2.

Table 4 illustrates the analysis schedule that was based on the estimated detention times.

TABLE 4
Simulated Distribution System Analysis

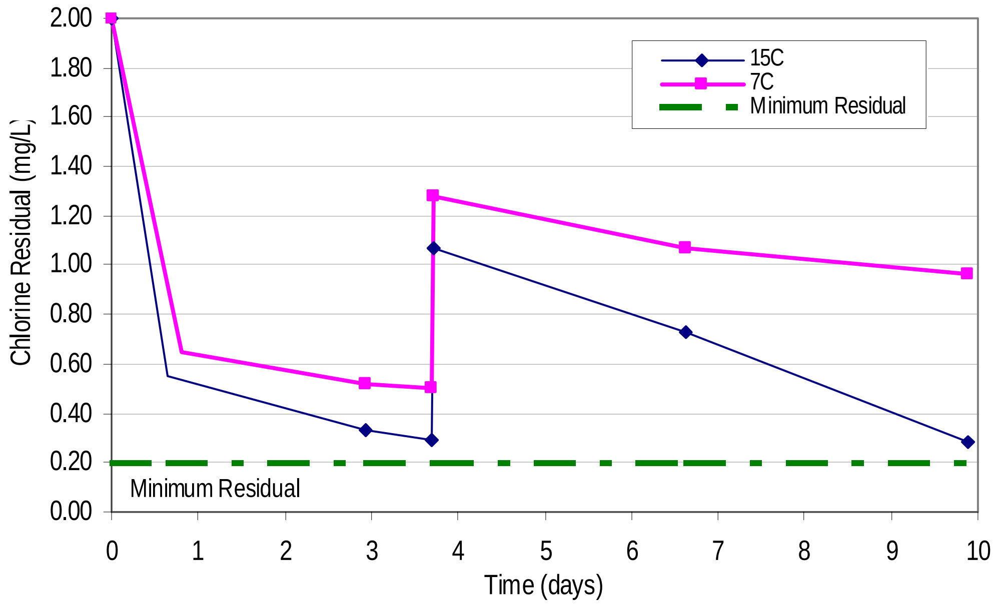


Testing Results

Chlorine Demand and Decay

Figure 1 shows a predictable chlorine decay of an initial 2.0 mg/L dose of chlorine. The average chlorine consumption was 1.48 and 1.67 mg/L over 3 days for the 7°C and the 15°C tests, respectively. No intermediate chlorine residuals were collected. The decay rates between the chlorine dose and Day 3 have been interpolated. In general, the greatest chlorine demand is consumed within the first few hours. As expected, the test conducted at the higher temperature, 15°C, decayed at a faster rate than the test conducted at 7°C. The chlorine residuals approach the minimum residual at the end of Day 3, and were rechlorinated with 0.8 mg/L chlorine. The test conducted at 15°C approached a minimum residual after an additional 6 days of simulated travel time. The test conducted at 7°C displayed minimal chlorine decay after rechlorination with 0.8 mg/L chlorine.

Figure 1
Chlorine Decay



DBP Formation

Figure 2 illustrates the formation of Total Trihalomethanes (TTHMs) which include chloroform, bromodichloromethane, dibromochloromethane, and bromoform. TTHM formation occurs at the fastest rate during the first couple of days in the distribution system, with the system at 15°C having the faster rate. After 3 days, the TTHM levels were below 40 µg/L, the proposed Stage 2 MCL. Even after rechlorination on the third day, TTHM formation slowed, and the TTHM formation rate was similar for both simulations, regardless of the temperature. There was no clear relationship between chlorine consumption and disinfection byproduct formation. The test at 15°C exceeded 40 µg/L after 4 days, and the test at 7°C exceeded 40 µg/L after 7 days.

Figure 2
Total Trihalomethanes

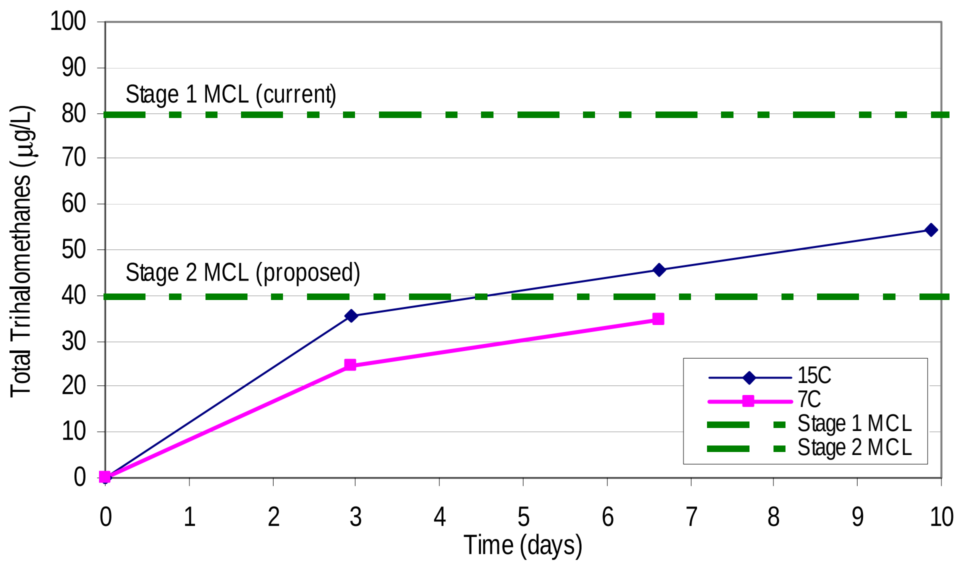
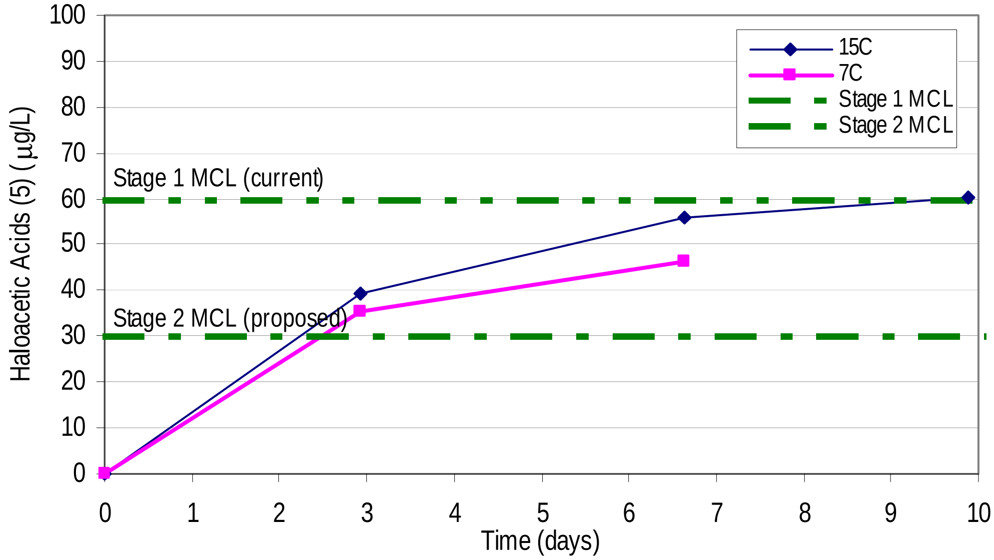


Figure 3 illustrates the formation of Haloacetic Acids (five) (HAA5), which includes monochloroacetic acid, monobromoacetic acid, dichloroacetic acid, trichloroacetic acid, and dibromoacetic acid. Like TTHMs, HAA5 formation occurred at the highest rate during the first few days in the distribution system, with the 15°C having the faster rate. Both tests exceeded 30 µg/L, the proposed Stage 2 MCL, around Day 3 of simulated travel time. Even after rechlorination on the third day, HAA5 formation continued to slow. The test conducted at 15°C exceeded 60 ug/L, the Stage 1 MCL, after 10 days. The test at 7°C appeared to remain below 60 µg/L after 7 days, and most likely 10 days. Laboratory data sheets for both tests are provided as Attachments.

Figure 3
Total Haloacetic Acids (5)



Comparison with SPU 1992 Pilot Study

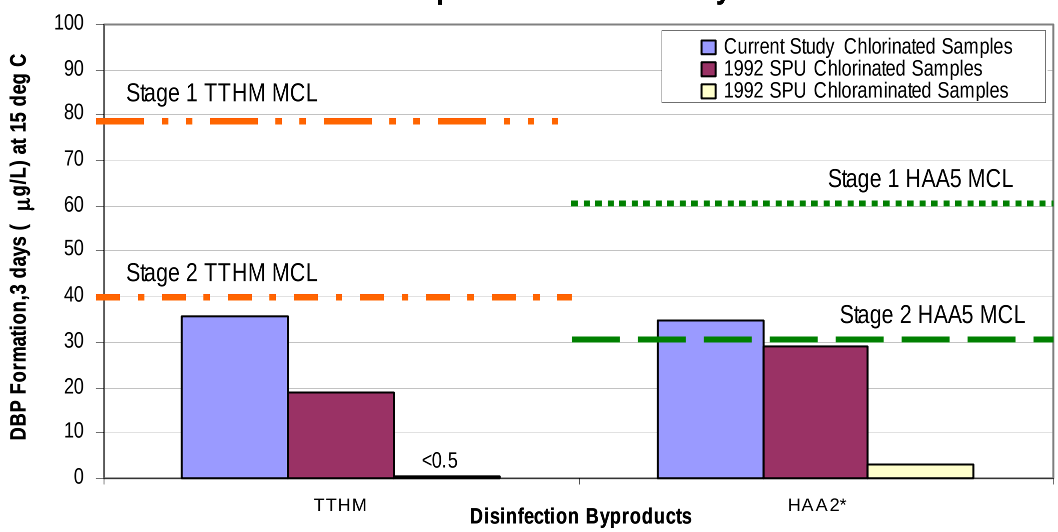
SPU's DBP testing was performed on water samples which received similar pretreatment prior to disinfection, and then incubated for a 3-day period at 15°C. The simulated treatment conditions included 1.5 mg/L ozone, 2.0 mg/L ferric chloride, and 3.0 mg/L cationic polymer (Nalco 8100). Separate simulated distribution system tests were run using chlorine and chloramine as the residual disinfectant. A comparison of the water quality and chlorine demand between these two tests is provided in Table 5.

TABLE 5
Comparison of Water Quality for current study and 1992 SPU Pilot Study

Water Quality Parameter (@ 15C)	Current Study (1999)	SPU Pilot Study (1992)	
Raw Water Quality			
UV254	0.058/cm	0.081/cm	
TOC	1.42 mg/L	1.8 mg/L	
Treated Water Quality			
UV254	0.013/cm	0.013/cm	
TOC	1.23 mg/L	1.3 mg/L	
Disinfectant	Chlorine	Chlorine	Chloramine
Chlorine Dose	2.0 mg/L	3.0 mg/L	2.0 mg/L
Chlorine Utilized (3 days)	1.67 mg/L (free)	0.85 mg/L (free)	0.35 mg/L (total)

Chlorinated samples resulted in a TTHM level of 19 μg/L. Chloraminated samples at 15°C had TTHM levels below 5 μg/L, a reduction of 74%. SPU did not sample for HAA5, but did produce results for some HAA5 constituents, dichloroacetic acid (DCAA) and trichloroacetic acid (TCAA). The DCAA level was 14 μg/L, and the TCAA levels were 15 mg/L. Chloraminated samples had a DCAA level of 2.8 μg/L, and TCAA levels less than 2 μg/L. The use of chloramines resulted in a substantial reduction of HAA formation. Figure 4 compares the results from this study and the SPU pilot study.

Figure 4
Comparison with SPU Study



*HAA2 includes DCAA and TCAA. SPU study did not measure for other HAAs. Current study also measured 5μg/L MCAA.

The DBP formation during this study is consistently higher than the previous SPU pilot study, most notably for TTHMs. Some of this variation may be due to the simulated treatment performance. The filtered water turbidity during the current study had a turbidity of 0.33 NTU which is higher than anticipated for full-scale treatment. However, as shown in Table 5 previously, the TOC and UV 254 levels for both the current study and SPU study are similar. The difference in DBP formation may also be due to improved laboratory techniques for detecting and measuring these compounds. Regardless of the differences in the results, both tests support the same conclusions discussed below.

Conclusions

The Stage 1 Disinfectant/Disinfection Byproducts Rule, promulgated in December 1998 with required compliance by December 2001, set maximum contaminant levels for DBPs. The maximum contaminant level (MCLs) for TTHMs was set at 80 μg/L and haloacetic acids (Five) (HAA5) at 60 μg/L. All MCLs are based on annual averages of quarterly samples. The Stage 2 Rule (expected May 2002) will supercede the Stage 1 Rule and is expected to reduce the MCL's for TTHMs and HAA5s as much as 50%. The DBP test results were evaluated using both current and future MCLs. A summary of the test's conclusions is presented in Table 6.

Current Stage 1 DBP Rules

Based on this DBP study, either a northern or southern connection to SPU's Tolt supply will not result in exceedance of the Stage 1 DBP Rule, regardless of normal or high temperature. Rechlorination at the connection point or at reservoirs may be required to maintain a system residual greater than 0.2 mg/L chlorine, but should not result in excess TTHM or HAA5 formation.

Future Stage 2 DBP Rules

The proposed northern connection has an adequately short travel time, and the proposed Stage 2 Rule for TTHM MCLs will most likely be met at normal temperatures. The proposed southern connection, has a longer travel time, therefore creating favorable conditions for DBP formation. At high temperatures, this connection may potentially result in periodic exceedance of the proposed Stage 2 Rule for TTHMs, though the yearly average TTHM levels may meet the standard.

This DBP study showed that it is not likely that the HAA5 MCL would be met, regardless of the location of the connection. This conclusion is supported by SPU's pilot test as well. Meeting the Stage 2 Rule may prove challenging for SPU as well as the District. SPU's prior testing with chloramines demonstrated a potential treatment alternative to meet the Stage 2 Rule.

TABLE 6
Simulated Distribution System Testing Results Summary

	North Connection	South Connection
Estimated Average Day Travel Time	3 - 4 days	5 - 6 days
Rechlorination	Possible rechlorination at tanks. None at connection point.	Likely seasonal or permanent rechlorination at tanks and/or connection point.
Compliance with Total Trihalomethanes		
Current Stage 1 MCL (80mg/L)	Yes at all temperatures	Yes at all temperatures
Proposed Stage 2 MCL (40mg/L)	Likely at all temperatures	Potentially not at high temperatures. Yearly average may comply.
Compliance with Total Haloacetic Acids		
Current Stage 1 MCL (60mg/L)	Yes at all temperatures	Yes at all temperatures
Proposed Stage 2 MCL (30mg/L)	Not likely at average or high temperatures.	Not likely at average or high temperatures.

ATTACHMENTS

Laboratory Data Sheets

DBP Formation Potential at Maximum Temperature Conditions (15°C)

Formation Potential (FP) Test Conditions

Client ID	Lab ID	Cl_2 Dose	Free Cl_2 Residual	Free Cl_2 Demand	Total Cl_2 Residual	Temp. (°C)	Measured pH	FP Start	FP Take-Off	FP Time H:M	FP Time (Hour)
15 C SDS		2.00	0.33	1.67	0.38	15.0	8.12	10/18/99 18:30	10/21/99 17:00	70:30	70.50
			0.29	1.71	0.39	15.0	8.10		10/22/99 11:15	88:45	88.75
		0.78 Re-chlor	1.07	1.71	NA	15	8.10		10/22/99 11:45	89:15	89.25
			0.73	2.05	0.80	15.2	8.02		10/25/99 9:37	159:07	159.1
			0.28	2.50	0.69	15.0	8.15		10/28/99 15:30	237:00	237.0

Formation Potential Trihalomethanes (THMs) Disinfection By-Products, (ug/L)

Client ID	Lab ID	FP CHCl3	FP BDCM	FP DBCM	FP CHBr3	FP TTHM
15 C 70.5 hr	326402	32.8	2.9	<1	<1	**35.7**
15 C Re chlor 159.1 hr	328301	41.3	3.3	<1	<1	**44.6**
15 C Re chlor 237.0 hr	330001	50.8	3.7	<1	<1	**54.5**

Notes: *CHCl3 = Chloroform*
BDCM = Bromodichloromethane
DBCM = Dibromochloromethane
CHBr3 = Bromoform

EPA TTHM Stage 1 MCL = 80 ug/L
EPA TTHM Stage 2 MCL = 40 ug/L

Formation Potential Haloacetic Acids (HAAs) Disinfection By-Products (ug/L)

Client ID	Lab ID	FP MCAA *	FP MBAA *	FP DCAA *	FP TCAA *	FP BCAA	FP DBAA *	FP HAA5	FP HAA6
15 C 70.5 hr	326402	4.8	<1	21.9	12.7	<1	<1	**39.4**	**39.4**
15 C Re chlor 159.1 hr	328301	7.0	<1	31.0	17.9	1.3	<1	**55.9**	**57.2**
15 C Re chlor 237.0 hr	330001	7.6	<1	33.3	19.3	1.4	<1	**60.2**	**61.6**

*Notes: * These compounds make up the HAA5*
MCAA = Monochloroacetic acid
MBAA = Monobromoacetic acid
DCAA = Dichloroacetic acid
TCAA = Trichloroacetic acid
BCAA = Bromochloroacetic acid
DBAA = Dibromoacetic acid

EPA HAA5 Stage 2 MCL = 30 ug/L
EPA HAA5 Stage 1 MCL = 60 ug/L

DBP Formation Potential at Normal Temperature Conditions (7°C)

Formation Potential (FP) Test Conditions

Client ID	Lab ID	Cl_2 Dose	Free Cl_2 Residual	Free Cl_2 Demand	Total Cl_2 Residual	Temp. (°C)	Measured pH	FP Start	FP Take-Off	FP Time H:M	FP Time (Hour)
7 C SDS		2.00	0.52	1.48	0.59	7.8	8.14	10/18/99 18:30	10/21/99 17:00	70:30	70.50
			0.50	1.50	0.62	7.0	8.12		10/22/99 11:35	89:05	89.08
		0.78 Re-chlor	1.28	1.50	NA	7.0	8.12		10/22/99 11:40	89:10	89.17
			1.07	1.71	NA	7.0	8.09		10/25/99 9:45	159:15	159.3
			0.96	1.82	1.03	7.0	8.09		10/28/99 15:30	237:00	237.0

Formation Potential Trihalomethanes (THMs) Disinfection By-Products, (ug/L)

Client ID	Lab ID	FP CHCl3	FP BDCM	FP DBCM	FP CHBr3	FP TTHM
7 C 70.5 hr	326401	22.4	2.2	<1	<1	**24.6**
7 C Rechlor 159.3 hr	328302	31.3	2.6	<1	<1	**33.9**

Notes: *CHCl3 = Chloroform*
BDCM = Bromodichloromethane
DBCM = Dibromochloromethane
CHBr3 = Bromoform

EPA TTHM Stage 1 MCL = 80 ug/L
EPA TTHM Stage 2 MCL = 40 ug/L

Formation Potential Haloacetic Acids (HAAs) Disinfection By-Products (ug/L)

Client ID	Lab ID	FP MCAA *	FP MBAA *	FP DCAA *	FP TCAA *	FP BCAA	FP DBAA *	FP HAA5	FP HAA6
7 C 70.5 hr	326401	4.6	<1	18.5	12.2	<1	<1	**35.3**	**35.3**
7 C Re chlor 159.3 hr	328302	6.1	<1	23.6	16.5	1.3	<1	**46.2**	**47.5**

Notes: ** These compounds make up the HAA5*
MCAA = Monochloroacetic acid
MBAA = Monobromoacetic acid
DCAA = Dichloroacetic acid
TCAA = Trichloroacetic acid
BCAA = Bromochloroacetic acid
DBAA = Dibromoacetic acid

EPA HAA5 Stage 2 MCL = 30 ug/L
EPA HAA5 Stage 1 MCL = 60 ug/L

ATTACHMENT M2

Blending of District Well Water with New Supplies

Blending of District Well Water with New Supplies

PREPARED FOR: Sammamish Plateau Water and Sewer District

PREPARED BY: Kim Ervin
Mark Carlson

DATE: October 6, 1999

Background

Currently, the Sammamish Plateau Water and Sewer District (District) obtains its water supply from 13 wells located in the Plateau and Issaquah Valley aquifers. Future supply options to meet projected water demands include supplementing existing groundwater with surface water supplied from either Seattle Public Utilities' (SPU) Tolt River supply or from SPU's Cedar River supply, depending on the connection location. Water supplied from the Union Hill Water District may also be used. Blending multiple water sources would occur within the distribution system and any end products from mixing would be distributed to the customer without treatment. The purpose of this technical memorandum is to identify potential effects of source water blending. Table 1 presents the potential blending scenarios that are proposed and have been evaluated.

TABLE 1
Blending Scenarios

Well 7 or 8 with Tolt	Well 12 with Tolt	Well 4 or 11 with Cedar
Well 7 or 8 with Cedar	Well 13 with Tolt	Well 4 or 11 with Tolt
Well 1, 2, or 10 with Tolt	Well 12 with Union Hill	Well 14 with Tolt
Well 1, 2, or 10 with Cedar	Well 13 with Union Hill	Well 14 with Union Hill

Source Water Quality

The District groundwater is untreated and unchlorinated. The SPU surface water sources are chlorinated, fluoridated, and the pH is adjusted at the source prior to distribution. Future filtration for the Tolt and ozonation of the Cedar supplies are imminent. A filtration and ozone plant is currently under construction on the Tolt supply and scheduled to be on line in 2000. An ozone plant is planned for the Cedar supply with a likely service date of 2004. These treatment facilities will improve the water quality of the two sources and reduce disinfection byproduct formation; however, chlorination residuals in the distribution system will likely remain the same. Union Hill Water District (Union Hill) is primarily served by two untreated wells. Union Hill also receives approximately 1 to 10% of their water supply from the City of Redmond. Redmond's water is comprised of chlorinated well water and Tolt water from SPU. Characteristics for all water sources are listed in Table 2.

TABLE 2
Source Water Quality (after treatment)

Source Water	Manganese Concentration (µg/L)	pH	Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)	Disinfection Byproducts	
					TTHM	HAA-5
District Well 1	ND	6.9	82	N/A	ND	ND
District Well 2	34	7.6	96	N/A	ND	ND
District Well 4	46	7.8	61	74	ND	ND
District Well 7	ND	6.5	75	72	ND	ND
District Well 8	ND	7.4	75	N/A	ND	ND
District Well 9	ND	N/A	68	N/A	ND	ND
District Well 10	ND	8.3	60	N/A	ND	ND
District Well 11.2	33	8.4	58	N/A	ND	ND
District Well 12	135	7.6	99	N/A	ND	ND
District Well 13	ND	7.8	67	N/A	ND	ND
District Well 14	*	*	*	*	ND	ND
Tolt River	3	7.7-8.5	12	13	63	
Cedar River	ND	7.4-8.6	26	19	24	
Union Hill Well 1	74	7.2	**	**	N/A	N/A

Secondary Maximum Contaminant Level for Manganese is 0.05 mg/L.

* *Data not yet available for Well 14. Sample collected mid September 1999. Prior to 1999, this was an emergency only source. Source is now planned for permanent operation. Chlorine is added to control hydrogen sulfide odor.*

** *Data not available*

N/A – Not analyzed

ND – Not disinfected

The primary issues associated with blending surface and groundwaters are manganese precipitation, pH, hardness, and disinfection byproduct formation. A summary of water quality issues resulting from the blending scenarios is presented in Table 3 at the end of this section.

Manganese Precipitation

Manganese (Mn) is typically present in groundwater in low concentrations. However, concentrations as low 20 to 40 µg/L can result in discoloration of fixtures and staining of laundry. Higher concentrations can also contribute to microbial growth in the distribution system. In waters with low to neutral pHs, manganese remains dissolved. However, oxidation, such as by addition of chlorine, results in oxidation of the dissolved manganese, Mn^{2+}, to solid forms, MnOOH and MnO_2. Oxidation is accelerated at pHs greater than 8.5. The oxidized (solid) form of manganese then precipitates out of the water in the distribution system and in customer's homes causing staining and deposits on plumbing fixtures. For these reasons, the drinking water secondary maximum contaminant level for manganese has been set at 50 µg/L.

Blending with Surface Water

The primary concern for blending the District's well water with SPU surface water is the potential for oxidation of manganese by chlorine. Although the District's wells are not currently chlorinated, blending with surface water supplies from SPU would require chlorination to maintain a minimum chlorine residual of 0.2 mg/L throughout the chlorinated zone of the distribution system as required by the Total Coliform Rule for chlorinated supplies. Wells 2, 4, and 11.2 have exhibited historical manganese concentrations close to the secondary maximum contaminant level (SMCL), and Well 11.2 has a high pH of 8.4, which may accelerate the oxidation reaction. Cedar River water has a non-detectable concentration of manganese and the Tolt River has small amounts. Both rivers have neutral to slightly basic pHs. Since both the groundwater and surface water supplies in the blended zone would be chlorinated, manganese precipitation can occur from chlorination of the well water, even when the well water does not come into contact with the surface water.

Although the manganese concentration may be below the SMCL of 50 µg/L most of the time, the precipitate that forms often accumulates in areas of low flow. The deposits often remain there undisturbed until the flow pattern in the distribution system changes. When the flow is increased or the direction of flow is reversed, the particulate matter is re-suspended, and the problem is immediately noticed by consumers. Utilities typically respond by sampling the source. Often the source concentrations are below detection and the problem is never resolved. As a consequence, extra vigilance in the areas receiving water from Well 12 and Well 4 is recommended because some manganese precipitation can be anticipated in these areas.

The molecular balance between soluble manganese and free chlorine shows that 1.3 mg of chlorine can precipitate 1.0 mg of manganese. The required minimum chlorine residual in the distribution system for chlorinated waters is 0.2 mg/L; typical chlorine doses range from 0.5 to 1.0 mg/L. This level of chlorination is sufficient to precipitate the manganese in any of the source waters. Based on an adequate chlorine concentration and the greater than neutral pH of the Tolt and Cedar River supplies and many of the wells, precipitation of manganese is likely to occur if waters containing manganese are chlorinated. While there are no known health impacts related to manganese at these concentrations, the manganese precipitation is an aesthetic issue and is likely to generate customer complaints.

Blending with Union Hill Water

The Union Hill groundwater sources contain manganese at concentrations greater than the SMCL of 50 µg/L, similar to several of the District's wells. If this water is blended unchlorinated with the District's wells, the District is likely to experience issues similar to those associated with delivering water from the high manganese sources in the District, primarily Wells 2, 4, 11.2, and 12. In these cases, the District may receive complaints of staining and deposits on fixtures when customers add oxidizing agents to their water at home, such as chlorine for cleaning.

As noted earlier, Union Hill also receives some water from Redmond, 1 to 10% of their supply per year based on discussions with Union Hill staff. The water supplied from Redmond is chlorinated and may result in some manganese precipitation. Union Hill reports that they periodically receive complaints from their customers of manganese staining. The Draft Union Hill Water Comprehensive Plan does not indicate where the complaints occur and if they can be correlated to use of chlorinated water.

If the Union Hill water is blended with the surface water supplies in the District, the manganese issues will be similar to those discussed above for the District's wells.

pH

Most of the blending scenarios would have little to no effect on pH because the groundwater and surface waters have similar pHs ranging from 7.4 to 8.6. The wells also have higher alkalinity than the surface water. This alkalinity will tend to buffer against changes in the pH. Wells 1 and 7 have less than neutral pH. Depending on the mixing proportions of well water and surface water, a slight pH increase of the well water may result in the blended water. The higher pH will tend to reduce corrosion of the distribution system, which has been an area of some concern in the past. The District is currently pursuing pH adjustment projects for wells with low pH. These projects will likely be on-line prior to development of a new source. The proposed blending approaches will nto negate the need for these facilities. The blended water may also result in a slight decrease in pH of water from high pH wells such as 10 and 11.2. The resulting decrease is not expected to negatively impact corrosion in the distribution system.

Hardness

Blending surface water with well water will result in softer water in the blended areas. Well waters generally have higher alkalinity and more hardness than surface waters. Analysis of the District's wells indicates a hardness ranging from 60 to 100 mg/L as $CaCO_3$. The Tolt and Cedar supplies are generally soft waters with hardness of 26 and 12 mg/L as $CaCO_3$, respectively. Depending on the mixing proportions, the well waters may be softened to varying degrees. Soft water is less prone to scaling and causing precipitation on bathroom and kitchen fixtures. The hardness effects of blending are considered to be beneficial.

Disinfection Byproducts

Disinfection byproducts are currently monitored in the SPU sources since they are treated with chlorine. As discussed above, blending of the District's wells with a chlorinated surface water source will require chlorination of the wells to maintain the minimum required chlorine residual of 0.2 mg/L in the distribution system.

SPU's annual water quality report indicates that SPU complies with the Disinfectant/Disinfection Byproduct Rule (DBP). However, travel times to the District may be quite long, depending on the point of connection to the SPU supply. With longer contact time, rechlorination upon arrival at the District may be required, and the disinfection byproduct residuals may increase to unacceptable levels. Also, new DBP regulations are expected to decrease the DBP limits in 2002.

The District does not currently monitor for disinfection byproducts since the well sources are not chlorinated. Therefore, information is not currently available regarding the formation potential of these sources. Groundwater generally has lower concentrations of

DBP precursors than surface water, resulting in acceptable concentrations of disinfection byproducts.

Given the uncertainties and lack of applicable data, bench scale testing is recommended to estimate the DBP levels. The recommended testing would include collection of water samples and simulation of distribution system conditions to estimate the potential levels of DBP. This task would evaluate disinfection byproduct formation by both simulating one point of application (re-chlorination not required) and two points of application in case re-chlorination is required. Testing is proposed for blending with the Tolt surface water source only because it is the most likely and more conservative of the surface water alternatives. The task would include the following laboratory study elements:

1. Measure chlorine decay and DBP formation under a “base set” of conditions -- typical temperature, pH, chlorine residual -- at four contact times
2. Measure DBP formation at one contact time and under the same conditions as in #1, but at maximum temperature to answer the question -- how high might DBPs go?
3. Measure the above using a lower chlorine dose and simulating a “boost” at an appropriate time.

This laboratory information would provide information to assess the potential for disinfection byproduct formation to aid in source selection and address issues raised by the Department of Health.

Fluoride

Fluoride is added to the SPU sources for dental benefits. This will result in increased fluoride in areas receiving surface water. It is recommended that customers in this area be notified of the change in water quality so that they may adjust dental supplements if desired. If blending patters change seasonally or daily, it may be difficult for customers to anticipate the fluoride level in their water. The District may want to evaluate this issue further and consider District-wide or zone-wide fluoridation of the wells.

Other Water Quality Parameters

Other water quality parameters monitored and recorded for the water sources do not indicate any areas of concerns. All sources evaluated have low levels of inorganics and organic contaminants, with the exception of those discussed above.

TABLE 3
Summary of Water Quality Issues Resulting from Source Water Blending Scenarios

Blending Scenarios			Water Quality Issues
Well		Blending Water	
7	+	Tolt	Well 7 has a low pH (6.5). The blended water would tend to be more neutral and reduce corrosion. No significant manganese is present in these sources. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
7	+	Cedar	Well 7 has a low pH (6.5). The blended water would tend to be more neutral and reduce corrosion. No manganese is present in these sources. Level of DPB formation is uncertain.

TABLE 3
Summary of Water Quality Issues Resulting from Source Water Blending Scenarios

Blending Scenarios			Water Quality Issues
Well		**Blending Water**	
8	+	Tolt	The blended water would have a neutral pH and no significant manganese. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
8	+	Cedar	The blended water would have a neutral pH and no significant manganese. Level of DPB formation is uncertain.
1	+	Tolt	Well 1 has a low pH (6.9). The blended water would tend to be more neutral and reduce corrosion. No significant manganese is present in these sources. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
1	+	Cedar	Well 1 has a low pH (6.9). The blended water would tend to be more neutral and reduce corrosion. No manganese is present in these sources. Level of DPB formation is uncertain.
2	+	Tolt	Chlorination of Well 2 may result in oxidation of manganese causing precipitation and potential accumulation in the distribution system. The blended water will tend to have a pH slightly above neutral. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
2	+	Cedar	Chlorination of Well 2 may result in oxidation of manganese causing precipitation and potential accumulation in the distribution system. The blended water will tend to have a pH slightly above neutral. Level of DPB formation is uncertain.
10	+	Tolt	Well 10 has a relatively high pH and no manganese. The blended water will be have a lower pH and therefore be somewhat more corrosive. No significant manganese is present in these sources. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
10	+	Cedar	Well 10 has a relatively high pH and no manganese. The blended water will be have a lower pH and therefore be somewhat more corrosive. No significant manganese is present in these sources. Level of DPB formation is uncertain.
12	+	Tolt	Well 12 has a relatively high concentration of manganese (0.135 mg/L). Chlorination of this source will likely result in oxidation and precipitation of manganese in the distribution system. Treatment may be required to mitigate this reaction. The blended water pH will be slightly above neutral. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
12	+	Union Hill	Well 12 has a relatively high concentration of manganese (0.135 mg/L) as does Union Hill (actual data not yet available). Treatment may be required for these sources.
13	+	Tolt	The blended water would have a neutral pH and no significant manganese. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
13	+	Union Hill	The Union Hill wells have relatively high concentrations of manganese (data not yet available). Treatment may be required for this source.
14	+	Tolt	Data is not currently available for Well 14 due to its change in status from emergency to permanent source this year. Data anticipated in 1 month. This

TABLE 3
Summary of Water Quality Issues Resulting from Source Water Blending Scenarios

Blending Scenarios			Water Quality Issues
Well		**Blending Water**	
			source is reported to have hydrogen sulfide and chlorine is currently added for treatment. Mixing with chlorinated Tolt water is not anticipated to alter the treatment issues related to this well.
14	+	Union Hill	Data is not currently available for Well 14 due to its change in status from emergency to permanent source this year. Data anticipated in 1 month. This source is reported to have hydrogen sulfide and chlorine is currently added for treatment. The Union Hill wells have relatively high concentrations of manganese (data not yet available). Treatment may be required for this source.
4	+	Tolt	Well 4 has relatively high concentrations of manganese (0.046 mg/L). Chlorination of Well 4 may result in oxidation of manganese causing precipitation and potential accumulation in the distribution system. The blended water will tend to have a pH slightly above neutral. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
4	+	Cedar	Well 4 has relatively high concentrations of manganese (0.046 mg/L). Chlorination of Well 4 may result in oxidation of manganese causing precipitation and potential accumulation in the distribution system. The blended water will tend to have a pH slightly above neutral. Level of DPB formation is uncertain.
11.2	+	Tolt	Well 11.2 has manganese concentrations of 0.033 mg/L. Chlorination of Well 11.2 may result in oxidation of manganese causing precipitation and potential accumulation in the distribution system. The blended water will tend to have a pH slightly above neutral. The Tolt system has DBP concentrations near the MCLs. A connection point far from the source could result in elevated DBPs.
11.2	+	Cedar	Well 11.2 has manganese concentrations of 0.033 mg/L. Chlorination of Well 11.2 may result in oxidation of manganese causing precipitation and potential accumulation in the distribution system. The blended water will tend to have a pH slightly above neutral. Level of DPB formation is uncertain.

Conclusions and Recommendations

The primary consideration for blending of surface water with the District's groundwater is chlorination. Addition of chlorine to a previously unchlorinated system will result in a re-equalization period in the distribution system and long-term water quality impacts with regard to manganese precipitation and disinfection byproduct formation. Based on available data, the District has one well with manganese in excess of the secondary maximum contaminant level, Well 12. Chlorination of this well is likely to result in unacceptable water quality conditions and treatment would likely be required. Several other wells in the distribution system have notable manganese residuals, including Wells 2, 4, and 11.2. These wells may or may not require treatment.

Other groundwater systems in the state have also considered or currently practice chlorination for regional distribution and "wheeling" of water. Lakehaven Utility District (LUD), as an example, is in the process of installing well chlorination and surface water blending in an isolated zone of their system to pilot the approach before complete system implementation. LUD has on the order of 20 wells and purchases chlorinated water from

Tacoma Water. In the past, LUD isolated a zone dedicated solely to Tacoma Water. Their modified system will provide chlorination of the wells in this zone for use in combination with the surface water. LUD also has manganese in several of their well sources. They are in the process of installing a manganese sequestering system at their wells to help control the program. If this initial treatment is not completely effective, they will implement manganese removal through a filtration system at problem wells. They have previously piloted three manganese removal systems, all of which successfully removed manganese.

In reviewing LUD's treatment plans, the Department of Health concluded that sequestering may be used where the manganese concentration does not exceed twice the SMCL or 100 µg/L. Based on this guideline, it is likely that manganese removal would be required at Well 12. If manganese is problematic at the other wells with manganese below the SMCL, it may be appropriate to treat these wells with sequestering.

Disinfection byproducts in the surface water source may present a compliance issue. Two important unknowns exist with regard to this issue: travel time (related to point of connection) and maximum or likely disinfection byproduct formation potential. Simulated distribution system testing conducted by SPU does not adequately address the travel time of the water to the District, especially if a southern connection is selected. Bench-scale testing is recommended as discussed earlier in the memorandum. This testing has been authorized as part of the Contract Supplement No. 2 to the Water System Plan project, dated September 1999.

It is recommended that the District gain a better understanding of the flow pattern in the distribution system and where the water from the problem wells and the surface water is likely to accumulate to assess the extent of manganese and disinfection byproduct issues. These areas should then be monitored for manganese and DBPs if the sources are to be blended in the future. This monitoring is typically done at dead ends, fire hydrants, and storage tanks. The District's hydraulic model can be used to simulate blended water flows to identify potential trouble locations. A preliminary assessment will be performed as part of the Water Quality Modeling task in the current contract.

As discussed above, chlorination of a previously unchlorinated system generally results in an equalization period, while the system adjusts to the new conditions of the water. There is likely to be accumulated demand for chlorine in the distribution system which could lead to corrosion related problems such as red water (iron corrosion). A monitoring and flushing program is recommended for startup of any water quality change that has the potential to impact the existing balance in the distribution system. Hydraulic modeling can be used to identify areas that may be of concern for corrosion. A review of pipe conditions including age and material is recommended. Detailed information collected during pipe replacement would also be useful in assessing the condition of the distribution system prior to changing the system water quality through blending or treatment. This would allow the District to evaluate the condition of the distribution system in these areas to help anticipate where water quality issues may arise.

Besides chlorination, blending with surface waters will also alter the fluoride concentration in the system. Since the District currently does not fluoridate the system, residents may use fluoride supplements. If this water quality condition is changed, residents should be informed. The District may also want to consider fluoridation of the well sources for District-wide consistency.

Blending with Union Hill water and remaining unchlorinated will likely not result in new water quality issues for the District. Conditions would be similar to those now existing in the vicinity of Wells 2, 4, 11.2, and 12. Union Hill water does exceed the SMCL for manganese and also receives small amounts of chlorinated water from Redmond. Union Hill reports periodic complaints from customers due to fixture staining. The District may want to consider manganese removal or sequestering for this source.

In summary, the five tasks are recommended to further clarify the water quality issues and impacts from blending of new supplies with the District's groundwater system. Those currently in our scope of work include:

1. Determine flow patters for blending scenarios, focusing on high manganese wells and surface water distribution. This task will be completed in conjunction with the hydraulic modeling of future source alternatives.
2. Conduct bench-scale testing of simulated distribution system conditions for formation of disinfection byproducts.

The following tasks are not currently in our scope of work. Much of the effort associated with these tasks involves data collection and review which could be accomplished by the District. Some additional evaluation may be required by a consultant or specialist. These tasks will be specific to the selected source alternative and can be considered for addition to the Capital Improvements Program related to source and treatment improvements.

3. Review the condition of the distribution system, including age and pipe material. Identify high-risk areas likely to result in water quality issues during startup of a new source and treatment process.
4. Evaluate fluoridation of District sources. This may require a policy decision by the Board of Commissioners.
5. Monitor manganese and DBPs following startup of any new treatment systems or implementation of a new source.