SULTAN CITY COUNCIL RETREAT
AGENDA COVER SHEET

ITEM: D - 3

DATE: May 13, 2010

SUBJECT: Water Treatment Plant Evaluation and Optimization

CONTACT PERSON: Connie Dunn, Public Works Director
Bill Ferry, Water Treatment Plant Operator
Mike Williams, Water Distribution Manager

ISSUE:
For the council to review the Water Treatment Plant (WTP) Evaluation and Optimization Report prepared by Crazy Mountain Services for the Cadmus Group, Inc. hired by Washington State Department of Health (DOH). Attachment A is the report that was submitted to the City and DOH for review, there are many suggestions and recommendations included in the report.

STAFF RECOMMENDATION:
Provide staff with direction to move forward regarding changes that require low to no impact on the 2010 budget. Items that require additional fund expenditures will be in the 2011 and 2012 budget requests.

SUMMARY:
Crazy Mountain Services, LLC (Joe Steiner) and South Hills Consulting, LLP (Dan Fraser) were at the Sultan WTP on March 17-19, 2010 conducting a comprehensive performance evaluation of Sultan's plant. The evaluation was done at no cost to the city through a DOH program.

The purpose of the evaluation is to improve the performance of surface water filtration plants and achieve optimization by identifying and correcting the unique combination of factors in the areas of design, operation, maintenance, and administration that limit performance of the filtration plant.

DISCUSSION:
The City of Sultan owns, operates and maintains a municipal owned water treatment facility providing water to the citizens of Sultan from Lake 16, a Surface Water Source.

<u>Sultan Filtration Plant Performance Evaluation Report:</u>
The report provided for review is divided into sections:

- A - Major effect on a long-term, repetitive basis,
- B – Moderate effect on a routine basis or major effect on a periodic basis
- C – Minor Effect

Report Recommendations

A-1 Administration Policies: The City of Sultan has not adopted clear objective and measureable goals for finished water quality. The plant operators are working to protect public health goals that are clearly more stringent and protective of public health than the current drinking water regulation. However, measureable optimization goals have not been formally adopted.

Recommendation: Copies of goals and recommendations were given to the city at the exit interview. Key point goals should be established to maximize public health protection, then communicated to all involved parties, posted for viewing and strived for with a coordinated effort.

A-2 Design: Filter to Waste: The design at the WTP is such that a severe flow surge through the filters appears to be unavoidable with minor design changes.

Recommendation: Correction to the design to ensure that there is not an immediate increase in the filtration rate when converting from filter to waste to production. This correction would dampen the shear forces which causes turbidity spikes. Also, the operators should experiment with alternative coagulants, coagulant aids and filter aids to produce stronger floc particles, which will be more resistant to flow changes.

A-3 Operations: Technical Guidance: Staff could benefit from expert outside technical assistance (e.g., performance based training) that would be very helpful to achieve optimization.

Recommendation: DOH could be a source of performance based training and potential for receiving technical assistance.

A-4 Operations: Application of Water Treatment Concepts: Five items are listed (Attachment A) are recommended be put in place for day to day operations.

Recommendation: Jar Testing; effluent turbidity from the adsorption clarifier measured and recorded; Using water storage to balance water production with water use; use smaller chemical feed pumps; and maintain consistency in numbers reported to DOH monthly reports.

B-1 Design: Minor Design Problems: Minor design/instrumentation problems make optimization difficult. Flow measurement, continuous turbidity monitoring of the Adsorption Clarifier effluent, record filter-to-waste turbidity, over-sized chemical feed pumps and filter media size.

Recommendation: Have an engineering firm investigate and suggest changes to better ensure equal proportioning of flow through the three filters. Additional monitoring of filters and the clarifier, installing speed control valves where appropriate, modifications to the SCADA system, smaller chemical feed pumps, and media replacement.

B-2 Administration: Number of Staff: Staffing may be inadequate to ensure optimization for holidays, weekends, vacations, water distribution emergencies.

Recommendation Optimization is typically achieved through step-by-step experimentation over six months to years, which are time consuming. Additional staff, perhaps part time, may be helpful.

FISCAL IMPACT:

For the 2010 Budget, staff recommends to make low to no cost adjustments within current budget restraints, as follows:

- Recommend to City Council to adopt Washington Department of Health's optimization goals.
- Contact DOH for technical assistance from their staff of experts.
- Jar testing completed by the operators, the city owns the testing equipment.
- Using the computer and adjust the reservoir levels before the plant is called to start.
- Maintain consistency with turbidity numbers being reported.
- Add filter media to the one filter that was identified to be low on media.

RECOMMENDED ACTION:

Provide staff with direction to move forward regarding changes that require low to no impact on the 2010 budget. Items that require additional fund expenditures will be in the 2011 and 2012 budget requests.

ATTACHMENTS:

A – Memo to City of Sultan from Crazy Mountain services and South Hills Consulting
B – Results of the City of Sultan Water Treatment Plant Evaluation

Crazy Mountain Services, LLC
6 Crazy Mountain Road, Clancy, MT 59634
406-449-6153 406-461-8361 (cellular)

South Hills Consulting, LLP
1224 South Hills Drive, Helena, MT 59601
406-422-5244 406-434-7984 (cellular)

Memo

To: Connie Dunn, Public Works Director
Deborah Knight, City Administrator
Mike Williams, Water System Manager
Bill Ferry, Operator

From: Joe Steiner
Dan Fraser, P.E

Date: April 5, 2010

Re: Sultan Filtration Plant Recommendations

Thank you for allowing us to spend a few days with you while performing an evaluation of your water treatment plant. Your cooperation and participation made the process a pleasure as well as a learning experience for us. We again want to congratulate you for providing your users with high quality drinking water. Enclosed is a copy of our report that includes items we discussed during the exit meeting. If there are errors, please let us know so we can correct them.

This memo is intended to provide recommendations we hope you find useful in your efforts to improve the plant's performance in terms of finished water quality. Also, as we mentioned during the exit meeting, we are enclosing a CD with copies of several references we think may be of use to you. They include:

- An American Water Works Association article, *Effect of Washwater Chemistry and Delayed Start on Filter Ripening*, that addresses some techniques for reducing after-backwash turbidity spikes. We briefly discussed some of the techniques while on site.
- Two papers presented by Logsdon and Hess, *An International Survey of Filter O & M Practices* and *Turbidity Monitoring and Compliance for the Interim Enhanced Surface Water Treatment Rule*, cover a host of things to consider to improve finished water quality.
- Copies of relevant pages from two engineering design books outlining how filter media are selected and matched.
- Electronic copies of three training manuals we developed for the Washington Department of Health (WADOH) and EPA. (Electronic copies of these documents were left with Bill while we were on site.)
- An electronic copy of *Drinking Water Coagulation with Polyaluminum Coagulants – Mechanisms and Selection Guidelines.*
- *Potable Organic Polymers – Types and Applications.*
- *A Review of Cryptosporidium Removal by Granular Filtration.*

We also suggest you get a copy of a manual produced by the American Water Works Association Research Foundation entitled "*Filter Maintenance and Operation.*" Logsdon and Hess are the primary authors and we believe this to be the best single reference book we've come across for operators. It explains the logic behind our current recommendations and is specifically designed to be used as a problem-solving tool by operators.

SULTAN WTP'S PERFORMANCE LIMITING FACTORS

As discussed in the exit meeting of March 20, 2010, we evaluated the areas of design, operation, maintenance, and administration to identify factors that limit performance. Our evaluations were based on information obtained from the plant tour, interviews, performance and design assessments, special studies, and the judgment of the evaluation team. Each of the identified performance limiting factors was classified as A, B, or C according to the following guidelines:

A - Major effect on a long-term, repetitive basis.
B - Moderate effect on a routine basis or major effect on a periodic basis.
C - Minor effect.

We then prioritized the performance limiting factors as to their relative impact on performance and listed them in order of importance. In developing this list of factors limiting performance, 50 potential factors were reviewed and their impact on the performance of the city of Sultan Water Treatment Plant was assessed. Four A factors and two B factors were identified and are summarized below. We determined the remaining 44 factors were not having a significant impact on plant performance.

A-1 ADMINISTRATION: Policies

The city of Sultan has not adopted clear, objective and measurable goals for finished water quality. Plant operators are working toward public health goals that are clearly more stringent and protective of public health than the current drinking water regulations. However, measurable optimization goals have not been formally adopted.

RECOMMENDATION: The administration and plant staff should jointly develop a written policy stating their goals for high quality water and the commitment of resources to achieve these goals. We believe that these goals should be established first and foremost for the quality of each individual filter's effluent. We suggest the Washington Department of Health's optimization goals be formally adopted. A copy of the WADOH Treatment Optimization Program goals was given to Deborah Knight during the exit meeting. Our key point is that goals should be established to maximize public health protection. They should then be communicated to all involved parties, posted for viewing, and strived for with a coordinated effort. Although the water treatment plant is judged to be adequate to meet current demands in terms of its major unit processes (i.e., contact adsorption clarifier, filters and disinfection), it is important to recognize there are minor design problems as discussed below. These issues should be corrected to ensure optimization.

Based on the competence and interest we found in the plant operators, we believe they are capable of operating around the plant's design limitations most of the time.

A-2 DESIGN: Filter-to-Waste

The filter-to-waste design is such that a severe flow surge through the filters appears to be unavoidable without minor design changes. The surge in flow occurs when the filters are switched from the filter-to-waste mode into production. When this change is made, the pressure the filters are working against is abruptly and significantly reduced, causing a nearly instantaneous flow rate change through the filters. This change in rate is estimated to be a 60-100 percent increase.[1] Figure 1 is an enlarged photo of a filter's grains of sand covered with chemical floc particles containing pathogens and other contaminants that are removed in the treatment process. The increase in velocity of the water flowing through the pores in the granular media dramatically increases the shear forces exerted on attached contaminants, causing them to pass through the filter and be released into the finished water. This results in measureable turbidity spikes and risks to public health.

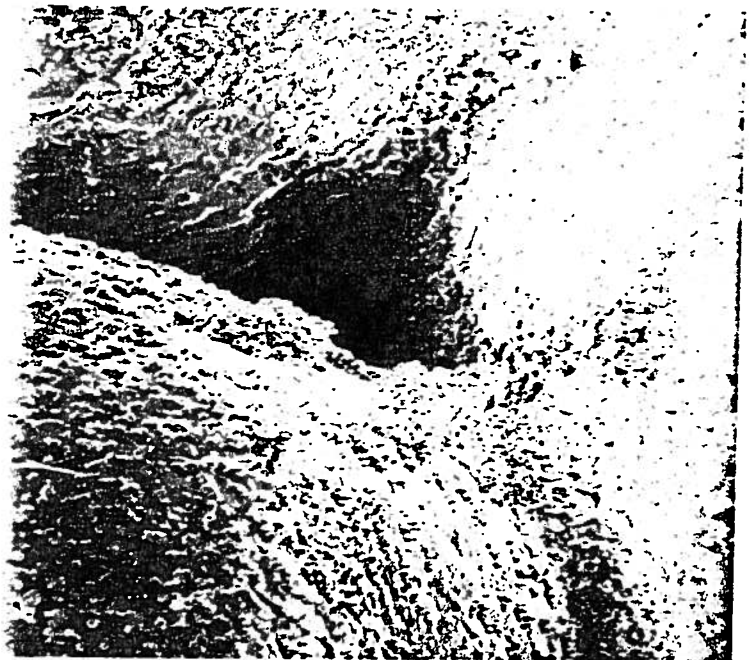

Figure 1 – Electron Photomicrograph of Filter Sand Grains with Attached Floc Particles

RECOMMENDATION: In our judgment, the flow through the filters is dramatically increased when the filters are switched from filter-to-waste into production because the downstream head (pressure) is near instantaneously reduced. This causes the flow through the filter to increase from a rate less than they receive during steady plant flow to a level beyond the steady plant flow rate. This occurs until such time as the filter effluent valves sense the falling water level and begin to close. We suggest you have your consulting engineers confirm our conclusions and, assuming they agree, correct the problem.

Corrective actions should be designed to ensure that there is not an immediate increase in the filtration rate when converting from filter-to-waste to production. After production begins, any necessary rate increase should be accomplished slowly over several minutes in order to dampen the shear forces which will cause turbidity spikes. This could likely be accomplished with a slow-opening flow control valve placed on the CFE line immediately downstream of the filters. There may be other and better solutions.

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[1] While on site, the evaluation team observed the filters while filtering-to-waste. With the influent flow held constant at 750 GPM, the filters overflowed into the backwash water troughs while in filter-to-waste mode. When put into production, the overflow immediately ceased and the filter water levels dropped as much as 2 ½ inches in less than 30 seconds. This surge in flow, estimated to be at least a 70 percent increase, caused turbidity spikes in the filtered water.

In addition to the above corrective action, operators should experiment with alternative coagulants, coagulant aids and filter aids to produce stronger floc particles, which will be more resistant to flow changes. This approach appears to be promising because the operators report the polyaluminum chloride (PACl) coagulant used in the winter has proven to be more resistant to the turbidity spikes.

A-3 OPERATIONS: Technical Guidance

The water treatment plant has unusual problems that may prove to be difficult to correct. Expert outside technical assistance (e.g., performance based training) is likely to be very helpful to operators in achieving optimization.

RECOMMENDATION: We suggest that you contact the WADOH to learn about the potential for receiving technical assistance. Performance based training provided by WADOH may be a possibility. If so, we think your operators would find it very useful.

A-4 OPERATIONS: Application of Water Treatment Concepts

- Jar testing is not used to experiment with coagulants, coagulant and flocculant aids, and variable pH conditions in order to improve removal of turbidity and/or color.
- The contact adsorption clarifier (CAC) effluent turbidity is measured but not recorded and trended for use in ensuring the barrier is optimized.
- Storage isn't used to balance water production with water use.
- Chemical feed pumps are generally over-sized.
- The wrong daily maximum turbidity is reported on the state form[2].

RECOMMENDATION: Based upon our experience with other water treatment plants, we believe there are modifications that could improve your finished water quality. This is likely to be particularly true when the raw water is turbid and difficult to treat. For example:

- Jar testing can be used to experiment with various dosages, combinations of dosages, and pHs using the plant's raw water. If operators become proficient in jar testing (preparation of stock solutions, etc.) they can, through experience, learn how to best perform the test and apply the test findings to the plant for improvement of water quality. We suggest that operators practice the procedures of preparation of stock solutions and jar testing until they develop a level of expertise and comfort with them. Then, work with modifications of the testing process (mixing times, mixing energy, etc.) to "calibrate" the jar test to the plant. As noted above, we are enclosing an electronic copy of a manual we prepared for the USEPA and WADOH that addresses jar testing and calibration of the jar test. Some things you might try in jar tests and, perhaps, with full-scale trials include:
    - Alternative primary coagulants such as ferric chloride, ferric sulfate, PACls, aluminum chlorohydrates (ACH), and polyaluminum silica sulfate (PASS). In theory, the chemical processes of coagulation require alkalinity and happen very quickly. Some PACls and ACHs are designed to react more quickly and use less alkalinity. Also, iron based coagulants are often more effective in terms of the removal of color, taste, odor and disinfection byproduct precursors (i.e. TOC).
    - Coagulant aid polymers.
    - Flocculant aid polymers.
    - Filter aid polymers.

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[2] This problem is likely because the state hasn't adequately communicated what they really want on the form.

- A constant monitoring and recording turbidimeter should be placed on the effluent of the CAC and tied into your supervisory control and data access (SCADA) system. The turbidity of the CAC effluent should regularly be trended to determine the effectiveness of the unit in turbidity removal.
- It appeared that the operators were unclear on the use and "calibration" of the streaming current meter (SCM). The use of the zero offset is confusing when more than one operator sets the zero value. We believe that operating the SCM in the true value mode would be better in Sultan's WTP. This, coupled with the monitoring of the CAC turbidity discussed above, would provide the operators a better understanding of the coagulation process occurring at the WTP. Electronic copies of references on the use and understanding of the SCM were left with Bill while we were on site.
- Storage should be used to meet the system's peak daily demands, and the plant's production rate should be throttled to run for a complete filter run without stopping and re-starting. After the filter run, the three filters should be backwashed and the plant left off-line until it becomes necessary to produce water again. This method of operation will reduce the surges that cause turbidity spikes and, more importantly, will eliminate re-starting dirty filters.
- Chemical feed pumps should be sized to ensure a regular and rapid injection of chemical.
- The state report has been completed by using the maximum 4-hour CFE turbidity reading as the maximum daily CFE turbidity. As discussed, the WADOH wants you to record the maximum daily CFE turbidity that occurs at any time the filters are in production (not including filter-to-waste).

<u>B-1 DESIGN: Minor Design Problems</u>

Minor design/instrumentation problems make optimization difficult.

- Flow measurement/proportioning to filters.
- Lack of continuous turbidity monitoring of CAC effluent.
- Inability to record filter-to-waste turbidity.
- CFE turbidity measurement is not representative of "real" turbidity. The measurements are influenced by chemical additions and pumping.
- Over-sized chemical feed pumps.
- Filter media size.

RECOMMENDATION: We suggest the following:

- Have your engineering firm investigate the practicality of making changes to better ensure equal proportioning of the flow of water through the three filters. While equal flow proportioning is desirable, we don't think it is essential to optimization and don't think this is a high priority improvement that should be made regardless of cost.
- As noted above, the turbidity of the CAC effluent should be monitored to ensure the effectiveness of the clarification process.
- You should change your controls and SCADA system so you can monitor the turbidity of each filter effluent during the filter-to-waste process. This should include the ability to "filter" the IFE data so only water entering the clearwells is reported on the WADOH monitoring forms.
- You should work with the WADOH to come up with a better methodology for measuring or otherwise determining the CFE effluent turbidity. Perhaps an average of the IFE measurements would be appropriate. Also, the use of the maximum IFE could be reported in addition to the average IFE to ensure that the average value does not mask a bad performing filter.

- As noted above, chemical feed pumps should be sized such that chemicals are injected in rapid pulses (i.e., near continuous rather than intermittently).
- As we discussed, the anthracite appears to be smaller than the specifications indicate it should be. This could cause short filter runs and make it difficult to filter at the high loading rates you have applied. We suggest you have your engineers collect samples and conduct sieve analyses of each filter's sand and anthracite to see if media change-out is necessary.

  If it is determined that media replacement is necessary, we suggest you have your engineers investigate the condition of the filter boxes and under drains to see if recoating or replacements are desirable. Also, the subsurface washing system is unusual and your engineers may find it appropriate to modify it to a more typical surface wash system.

B-2 ADMINISTRATION: Number of Staff

- Staffing may be inadequate to ensure optimization.
  - Back-ups, holidays, weekends, vacations, etc.

RECOMMENDATION: Optimization is typically achieved through step-by-step experimentation over six months to years. Some of the necessary activities (e.g., jar testing of coagulants, full scale testing, etc.) are time consuming. Additional staff, perhaps part time, may be helpful.

Again, thank you for your cooperation and if we can be of any help do not hesitate to call us at 406.431.7984 (Dan) or 406.461.8361 (Joe). Our email addresses are:

dan.fraser@bresnan.net (Dan)
crazymountainservices@bresnan.net (Joe)

Copies to: Stephen Baker, WADOH
Jolyn Leslie, P.E., WADOH

Results of the
City of Sultan
Water Treatment Plant

319 Main Street, Suite 200
P.O. Box 1199
Sultan, WA 98294

March 17-19, 2010

Prepared By:
Joe Steiner, Crazy Mountain Services, LLC
Dan L. Fraser, PE, South Hills Consulting, LLP

For
The Cadmus Group, Inc.
2620 Colonial Dr., Suite A
Helena, MT 59601

For

The Washington Department of Health

SITE VISIT INFORMATION

Mailing Address:

Connie Dunn, Public Works Director
319 Main Street, Suite 200
P.O. Box 1199
Sultan, WA 98294

Date of Site Visit:

March 17-19, 2010

Water Treatment Plant Personnel:

Mike Williams, Water System Manager
Bill Ferry, Water Plant Operator

Other City Personnel:
Deborah Knight, City Administrator
Connie Dunn, Public Works Director

CPE Team:

Completed for The Washington Department of Health by:

Joe Steiner, Crazy Mountain Services, LLC – 406.461.8361
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Dan L. Fraser, P.E., South Hills Consulting, LLP – 406.422.5244
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Washington Department of Health Personnel in Attendance:
Jolyn Leslie, P.E., – WADOH Regional Engineer

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CAC	contact adsorption clarifier
CCP	Composite Correction Program
CFE	combined filter effluent
CPE	Comprehensive Performance Evaluation
CTA	Comprehensive Technical Assistance
CT	residual disinfectant concentration (mg/L) x time (minutes)
DBP	disinfectant byproduct
DBPP	disinfectant byproduct precursor
gpm/sf	gallons per minute per square foot
GPM	gallons per minute
HAA5	haloacetic acids
HOA	Homeowners' Association
HP	horsepower
IESWTR	Interim Enhanced Surface Water Treatment Rule
IFE	individual filter effluent
LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MGD	million gallons per day
mg/L	milligrams per liter
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
PPM	parts per million
PWS	public water supply
Stage 1DDBPR	Stage 1 Disinfectants and Disinfection Byproducts Rule
Stage 2DDBPR	Stage 2 Disinfectants and Disinfection Byproducts Rule
SCM	Streaming Current Meter
SOP	standard operating procedure
SRF	State Revolving Loan Fund
SCADA	supervisory control and data acquisition
SWTP	surface water treatment plant
SWTR	Surface Water Treatment Rule
TA	technical assistance
THDT	theoretical hydraulic detention time
TOC	total organic carbon
TOP	Treatment Optimization Program
WADOH	Washington Department of Health
WTP	water treatment plant

INTRODUCTION

Rules regarding surface water treatment have been modified over the past 12 years to provide additional public health protection. Among other requirements, such modifications establish more stringent turbidity performance standards for conventional and direct filtration plants and require systems with individual filter performance problems to have a Comprehensive Performance Evaluation (CPE) performed by the state or a third party approved by the state.

The requirements of these rules clearly provide additional measures of public health protection against pathogens such as *Giardia* and *Cryptosporidium*; however, many plants will not be able to maintain compliance if they use a "business as usual" approach. The Washington Department of Health (WADOH) is making proactive technical assistance efforts to ensure surface water treatment plants are capable of meeting and exceeding the requirements of these rules. One of these efforts is providing CPEs to identify factors that may limit plant performance.

This CPE was conducted as a part of WADOH's technical assistance program. The CPE was performed at the city of Sultan water treatment plant (WTP). It was conducted for technical assistance purposes and not in response to any known or anticipated compliance problems. The CPE evaluated the plant's performance against WADOH optimization goals (Table 1) that are even more stringent and protective of public health than existing federal and WADOH regulatory requirements.

EVALUATION PROTOCOL

The CPE is the first phase of EPA's Composite Correction Program (CCP), which is an approach developed to improve the performance of filtration plants and achieve optimization. The CPE is a systematic, comprehensive procedure to identify and correct the unique combination of factors in the areas of design, operation, maintenance, and administration that limit performance of the treatment plant.

The CCP consists of two components, a CPE, which is an evaluation of the existing treatment plant, and a follow-up Comprehensive Technical Assistance (CTA). The CTA is a facilitated procedure to address issues identified in the CPE and help improve performance of the plant. Each CPE report will discuss whether a CTA is advisable for the particular surface water treatment plant (SWTP).

The CPE process focuses on the fundamental relationships among four key areas: plant design, plant operation, plant maintenance and administrative support. The CPE assesses each of these four areas. The goal is to evaluate the impact of each element on the performance of the plant and its ability to provide safe and reliable drinking water. The objective of the CPE is a prioritized list of factors limiting optimized performance of the water plant. This list is then provided to the plant staff and administrators at an exit meeting and, at a later date, in a written report. Additionally, the evaluation team will provide written guidance on how to address the performance limiting factors and improve finished water quality. With performance limiting factors identified and guidance provided, the plant staff can often accomplish the needed improvements without further assistance. In the case of difficult-to-address factors, the WADOH may provide follow-up technical assistance.

It is important to note that the CPE process is designed to ensure that, when possible, optimization is achieved without high-cost capital improvements. This is because, too often, capital improvements are seen as a quick and easy answer for performance problems that have root causes related to operation, maintenance and/or administrative factors. Unfortunately, major capital improvements are expensive and often do not solve performance problems.

In recent years, the CCP has gained prominence as a mechanism that can be used to optimize the performance of existing surface water treatment plants. This can result in production of high quality treated water that exceeds WADOH regulatory requirements. Optimizing water treatment plant performance to improve disinfection and the physical removal of particles is an important strategy against the public health risks posed by pathogenic microorganisms. Waterborne disease outbreaks emphasize the importance of producing the highest quality water possible. Producing filtered water with a turbidity of less than 0.10 NTU has been shown to increase the removal of pathogens such as *Cryptosporidium*, the microorganism responsible for a large outbreak of cryptosporidiosis in Milwaukee in April 1993.

The WADOH Treatment Optimization Program (TOP) Goals

The CPE for the state of Washington's plants utilizes the TOP optimization performance goals when assessing a water plant's operation. The plant's current performance is measured against these goals to determine what corrections will be necessary. Water plants that operate within these performance goals meet WADOH requirements and ultimately make high quality, safe water. These performance goals include:

1. Filtration performance goals.
2. Disinfection performance criteria.
3. Minimum data monitoring requirements.

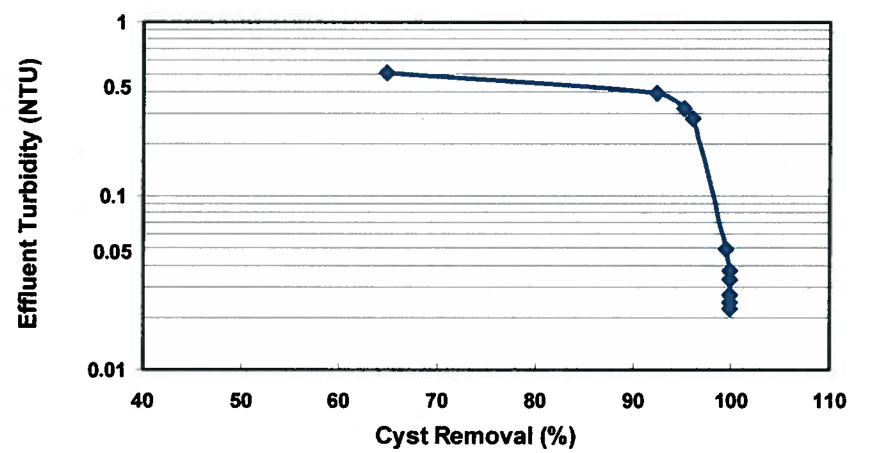
Table 1 provides greater detail for each goal.

Table 1. Summary of WADOH TOP Goals
Filtration Performance Goals[1] • Filtered water turbidity less than 0.10 NTU 95 percent of the time based upon maximum daily values recorded (systems without filter-to-waste may exclude the first 15 minutes after filter backwash). • Filtered water is below 0.10 NTU within 15 minutes of the filter being in production.[2] • Maximum filtered water measurement of 0.3 NTU. • Filters are backwashed before breakthrough. • Raw water turbidity changes do not affect filtered water turbidity.
Disinfection Performance Criteria • Required CT values are achieved at all times.
Minimum Data Monitoring Requirements • Raw water turbidity is monitored at least every 4 hours. • Effluent turbidity is continuously recorded for each filter. • Combined filter effluent turbidity is continuously recorded.

[1]WADOH uses the highest combined filter effluent turbidity (CFE) recorded at any time the plant is operated during the day for this evaluation.

[2]Production begins when the effluent is being discharged into the system (clearwell or distribution system).

Figure 1 shows the relationship between filter effluent turbidity and *Giardia* cyst removal efficiency by filtration as demonstrated in a 1990 study. At effluent turbidity levels of 0.3 NTU (i.e., the regulatory requirement for combined filter effluent turbidity), a high percentage of cysts were removed. However, at this turbidity level, high numbers of cysts can still potentially be found in the finished water. This is of particular concern with cysts of *Cryptosporidium* because they are unlikely to be inactivated by normal disinfection processes. The graph shows that removal of cysts approaches 100 percent as filtered effluent turbidities of 0.10 NTU or less are achieved. Based upon this and similar research, it is likely that significant additional public health protection is provided by achieving high quality, low turbidity filtered water.



Source: Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities, EPA, 1990.

Figure 1 – Percent Cyst Removal vs. Filtered Water Turbidity

FACILITY INFORMATION

Administration

The Sultan WTP is owned and operated by the city of Sultan. The city is organized using the Mayor and City Council form of government. The city's web site describes this form of government as follows:

> *Under this form the independently-elected mayor has powers of appointment and removal of subordinates, administrative control over departments, and the power to veto council legislation.*
>
> *The resulting government structure limits the council's role to policy making and oversight, and reserves administrative power and responsibility for the mayor.*

There are seven council members and two student council representatives. The city hires a city administrator who assists the mayor with administrative and policy duties. The water system is operated within the Public Works Department of the city. Figure 2 shows the city organization chart.

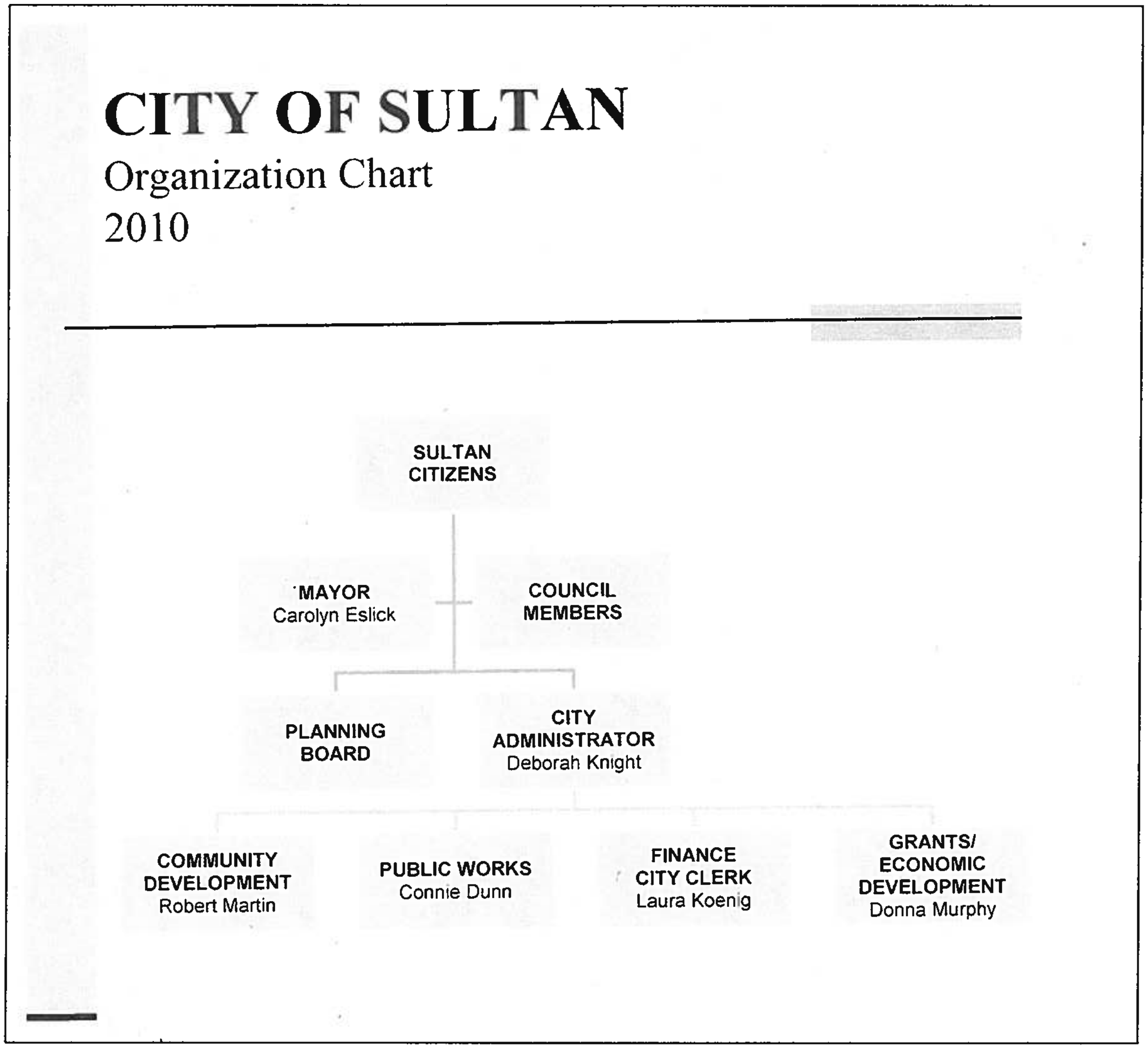


Figure 2 – Sultan Organization Chart

The water system is a self-supported enterprise fund. The water rates include a base rate and a fixed volume charge. The city has a connection fee for new connections. The city has one-year budget and capital improvement plans. It also has 6-year and 20-year capital improvement plans.

The public works director manages the water system (see Figure 3). The water system has two certified operators who provide 24-7 operation and oversight of the water treatment plant. The city is reorganizing the public works department to include a field supervisor that will add an additional "part" of an employee to assist in coverage of the water treatment plant.

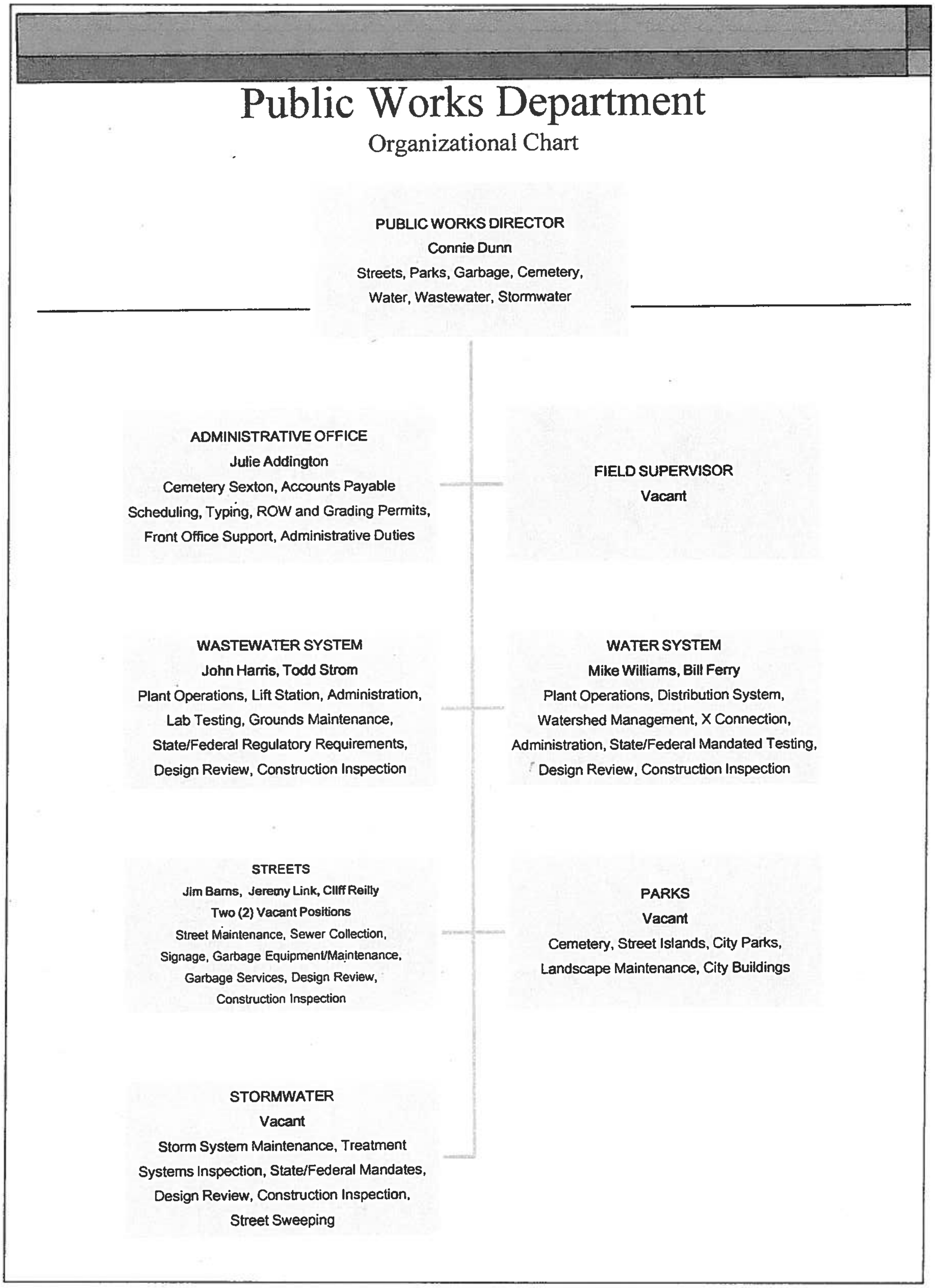


Figure 3 – Public Works Organization Chart

Water Treatment Plant Overview
As shown in the schematic in Figure 4, the WTP has a single contact-adsorption clarifier (CAC) followed by three dual-media filters. The plant treats up to 900 GPM.

Raw water is provided by a 12-foot deep intake located in Lake 16, a small surface water impoundment located approximately 2.5 miles upgradient from the WTP. Treated water is discharged to two ground-level storage tanks which provide contact time.

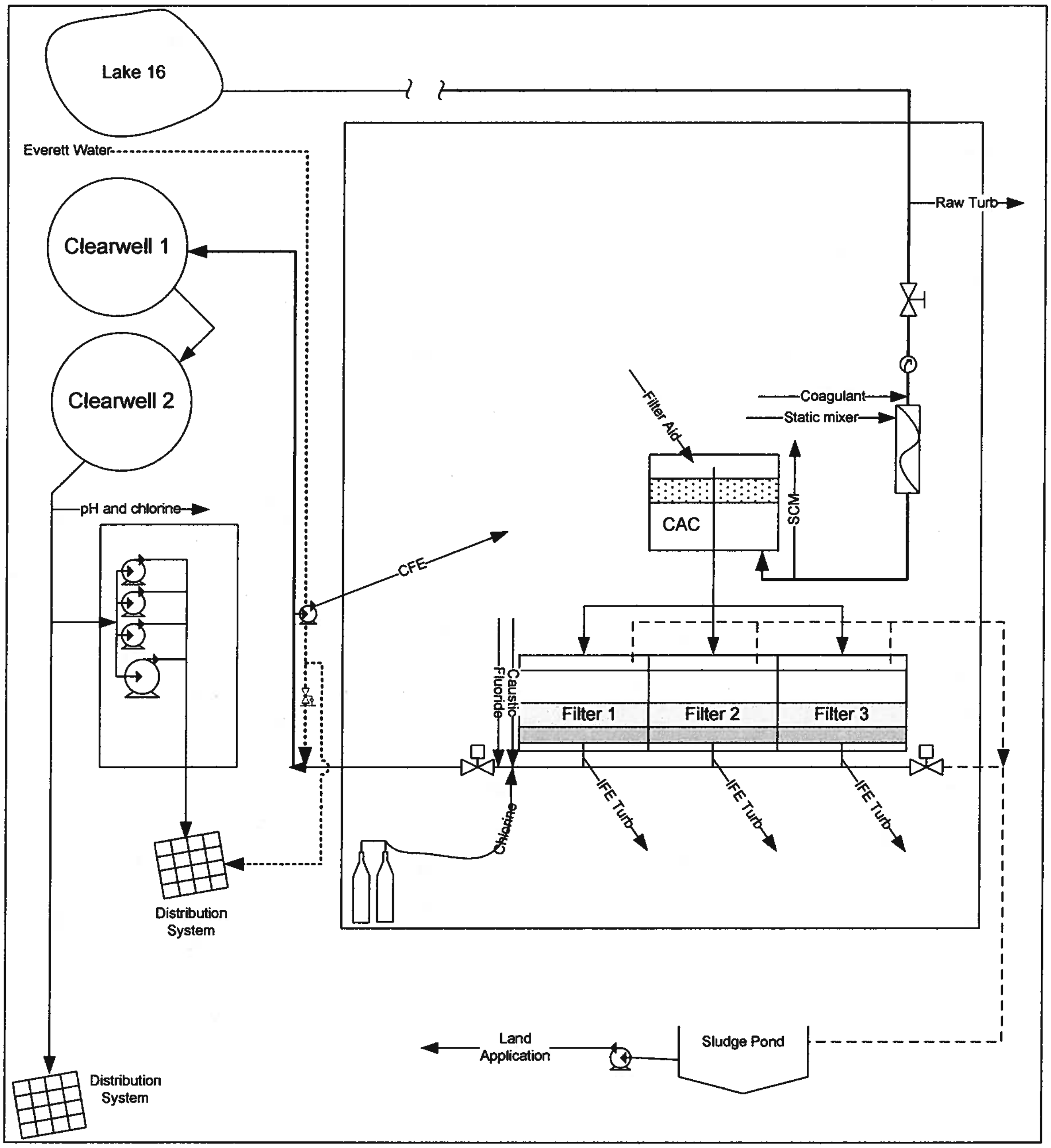


Figure 4 – City of Sultan WTP

The filters are backwashed using a fire pump located in a pump house adjacent to the two ground-level finished water storage tanks. A control valve is used to control the backwash water flow rate.

Source Water and Intake
As noted above, the source water for the WTP comes from a small surface water impoundment located near the plant. The intake is about 12 feet deep in the middle of the impoundment. The impoundment is fed by both surface water and springs. See Figure 5.

Figure 5 – Lake 16

Rapid Mix and Contact Adsorption Clarifier (CAC)
As the raw water enters the WTP building, the primary coagulant polymer (SumalChlor 50) is injected immediately upstream of an inline static mixer. After the static mixer, the water passes through a pipeline with two 90-degree elbows prior to entering the bottom of the CAC. The CAC contains 1-mm polyethylene floating media. The coagulated water flows upward through the plastic beads where flocculation and particle removal by attachment occur. The clarified water is discharged to the dual-media filters. The CAC unit is periodically cleaned, based on either time or headloss, by introduction of air combined with the coagulated water. The wastewater from this flushing action flows by gravity to the backwash water basin located in the WTP yard.

The coagulated water is continuously monitored using a streaming current meter (SCM). Jar testing equipment is available but coagulant control is primarily based upon past experience. The raw water quality is relatively consistent but is impacted by organic compounds that produce elevated color.

Filtration
The clarified water passes into a flow-proportioning discharge trough intended to evenly distribute the water to the three dual-media filters. The filters are each one-third of a common steel tank separated by two common walls. Each filter has its own individual control valve, but they have to be backwashed sequentially and essentially operate as a single unit. After the water passes through the filters, it flows by gravity to the two ground-level storage tanks operated in series. The flow to the filters is controlled by a single influent flow control valve. The head over each filter, and the effluent flow rate, is controlled by automatic effluent valves.

Chlorine solution, caustic soda and fluoride are injected into the filtered water immediately after filtration in the combined filter effluent (CFE) pipeline. During backwash and WTP shutdowns, most of the CFE gravity pipeline to the storage tanks drains to the same level as the water in the clearwells.

Backwash water is provided from a fire pump that is located in the pump station near the two storage tanks. The three filters are sequentially backwashed during every backwash cycle. The backwash water flow is adequate to fully fluidize the media. At the time of the evaluation, the media expansion was measured at 18-23 percent. The filter is equipped with subsurface wash.

After all three filters are backwashed, the combined filter effluent flows against roughly four feet of head to waste for ten minutes. At the end of the ten-minute filter-to-waste period, the combined filter effluent flows downgradient to the clearwells.

Backwash Water and Sludge
Spent filter backwash water, filter-to-waste and flush water from the CAC flow by gravity to a sedimentation basin (sludge basin) downgradient from the plant. The water is pumped from the basin to the adjacent forested area for land application. Sludge is removed as necessary from the basin.

Disinfection
Chlorine solution is injected into the filtered water for disinfection. The WTP is required by WADOH to provide 1.0-log *Giardia lamblia* inactivation. Adequate contact time to meet the WADOH requirements for inactivation is met by the storage tanks. Thus, the finished water has several hours contact time before it reaches the consumers.

MAJOR UNIT PROCESS EVALUATION

The purpose of the major unit process evaluation is to determine if each step in the treatment process (meaning the unit processes of flocculation, sedimentation, filtration, and disinfection) is of adequate size to treat the current peak instantaneous flow while producing water that meets water quality optimization goals as described in Table 1. The WTP's peak instantaneous flow is used because it represents the highest overflow and loading rates to which the WTP will be subjected and its point of greatest vulnerability to passage of pathogens.

The major unit process evaluation assesses the adequacy of existing facilities in terms of basin size (i.e., existing concrete and steel). The assumption is that if the basins are not of adequate size, then optimization goals often cannot be met without major construction. Because the effectiveness of each step in the treatment process is dependent on the adequacy of prior steps, if any one of the major unit processes is undersized, the plant may not be capable of meeting optimization goals at peak instantaneous flow.

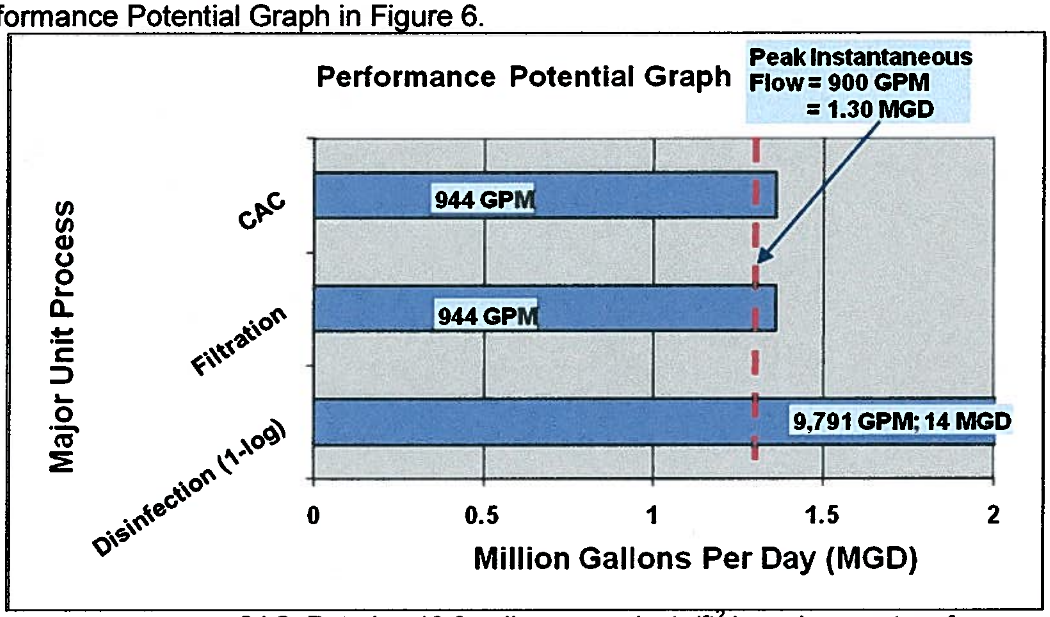
The major unit process evaluation does not include an assessment of the condition of existing mechanical equipment or the operational practices applied to the facility. The evaluators assume mechanical equipment can be repaired or replaced, minor improvements can be made, and process control requirements implemented to meet optimization goals without the need for major capital improvements. Performance limitations caused by mechanical equipment or operational practices are addressed as factors limiting performance, which are presented later in this report.

Peak Instantaneous Flow

Since the plant's treatment processes must provide an effective barrier at all times, a peak instantaneous operating flow is determined. As noted previously, the peak flow represents the maximum flow rate to which the unit processes are subjected. It is the hydraulic condition under which the treatment processes are likely to be the most vulnerable to the passage of contaminants. If the treatment processes are adequate at the peak instantaneous flow, then they should be capable of providing the necessary effective barriers at lower flow rates. The peak instantaneous operating flow of the WTP was established at 900 GPM because this is the maximum flow rate at which the plant has been operated.

Performance Potential Graph

The results of the major unit process evaluation for the plant are shown as a Performance Potential Graph in Figure 6.



- CAC: Rated at 13.3 gallons per minute/ft^2 based on past performance.
- Filtration: Rated at 6 gallons per minute/ft^2.
- Disinfection:
    - ≥1.0 mg/L free chlorine.
    - pH ≤ 7.5.
    - Water temperature of ≥ 0.5 C°.
    - 1-log *Giardia lamblia* inactivation required.
    - 20 feet of water in baffled tank.

Figure 6 – Sultan Performance Potential Graph

The adequacy of each major unit process was assessed by comparing its treatment capability to the peak instantaneous flow rate through the plant (the red vertical line at 900 GPM).

Criteria and assumptions used to assess each major unit process are described in the notes below the performance potential graph. The evaluated unit processes are shown on the graph (y-axis). The flow rates at which the processes were assessed are shown on the bottom of the graph (x-axis). The lengths of the top two horizontal bars on the graph represent the projected water production capability of each unit process while meeting optimization goals. The bottom bar represents the plant's disinfection capability and it's length does not fully represent the plant's capacity in order to maintain an appropriate scale for the performance potential graph. The capability of each major unit process was projected based on its physical size and configuration, the CPE team's experience with similar processes, industry guidelines, raw water quality, the plant's past performance, and generally accepted design standards. The shortest bar(s) represents the unit process that is most limiting to the plant's ability to achieve optimized performance.

Contact Adsorption Clarifier
The plant is equipped with an "add-on" Microfloc floating media contact adsorption clarifier which provides the first removal barrier in the treatment process. The coagulated water flows upward through buoyant plastic beads where flocculation and particle removal by attachment occur. The clarified water is discharged to a flow-proportioning trough before entering the three filters.

The CAC has a surface area of 71 square feet. The CAC unit is designed to be flushed with a combination of air and raw water at the normal flow rate. Air is introduced while the raw water continues to flow at the plant flow rate[1]. The flush water is wasted to the sludge basins. Flushing is typically based on time but the CAC will also flush on headloss. The operator has the CAC set to flush after 180 minutes during times when the raw water quality is poor and 300 minutes during good raw water quality. The flush lasts about 12 minutes and uses a combination of water and air flows.

Based upon a surface overflow rate of 13.3 gpm/f^2, the CAC unit is judged to have a maximum capacity of 944 GPM or 1.36 million gallons per day (MGD). This overflow rate was established for the CAC based on industry guidelines and past performance. The CAC is not expected to be a limiting factor.

Filtration
Following the CAC, the water goes to the constant rate dual-media filters, which is the plant's second barrier for particle removal. The evaluation team rated the filter with a surface loading rate of 6.0 gpm/f^2 and a capacity of 944 GPM (1.36 MGD), assuming the filter media meet appropriate design specifications and the subsurface wash is shown to be effective. Therefore, the WTP's filters are not expected to be limiting factors.

Disinfection
Disinfection provides the third and final barrier in the multiple barrier concept of surface water treatment by inactivating microbial contaminants that escape the removal processes provided by flocculation and filtration. The disinfection process was assessed based on Surface Water Treatment Rule requirements for 3-log removal/inactivation of

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[1] The raw water flow is manually adjusted by the operator.

Giardia lamblia cysts and 4-log removal/inactivation of viruses. The *Giardia* removal/inactivation is the more stringent criterion when free chlorine is used as a primary disinfectant. In the case of Sultan's plant, the WADOH requires 1.0-log inactivation to be achieved by meeting specified disinfection requirements as measured by CT[2].

For the evaluation, it was assumed that only one of the clearwells is operated and the tank will be maintained at least at a 20-foot level. The baffling factor was assumed to be 0.7. Using these assumptions, the total effective volume usable for contact time was calculated to be 822,469 gallons. Assuming near worst-case conditions (pH ≤ 7.5 and temperature ≥ 0.5° C) and a free chlorine residual ≥ 1.0 mg/L, the WTP can provide 1.0-log *Giardia lamblia* inactivation at flows up to 9,791 GPM or 14 MGD. Therefore, the plant's disinfection capacity is not a limiting factor.

Major Unit Process Evaluation Summary
As shown by the Performance Potential Graph (Figure 6), the contact clarification, filtration and disinfection processes are considered to be adequate to produce water achieving the optimization performance goals. It should be noted, however, the plant does exhibit minor design problems that can likely be corrected without major capital improvements.

PERFORMANCE ASSESSMENT

A component of the CPE is the assessment of the WTP's ability to meet the relevant optimized performance goals provided in Table 1. Optimized performance goals, for purposes of this CPE, represent performance that exceeds the current regulatory requirements. Optimized performance requires a facility that treats a source water of variable quality to consistently produce high quality finished water (i.e., less than 0.10 NTU).

Multiple treatment processes (i.e., CAC, filtration and disinfection) are provided in series to remove and inactivate microbial pathogens. Each of the available processes represents a barrier to prevent the passage and survival of these microbial pathogens through the plant. By providing multiple barriers, the potential of pathogens passing through the entire plant and surviving to cause waterborne disease is minimized.

An assessment of the past 12 months' (March 2009 - February 2010) performance at the WTP was conducted to identify whether specific treatment unit processes were performing as intended.

Performance Assessment Turbidity Profile
Figure 7 is a graphical representation of the raw and maximum CFE water turbidities for the last 12-month period. Unfortunately, it was determined that much of the data was inaccurate because the operators record the highest four-hour CFE turbidity and not the highest CFE of the day. In short, the records indicate the finished water quality is better than it actually is.

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[2] CT is defined as the disinfectant concentration (C) in mg/L multiplied by the time (T) in minutes that the water is in contact with the disinfectant.

Performance Assessment Summary
In summary, the performance assessment data cannot be used, but the evaluation team can state the plant does not meet WADOH optimized performance goals.

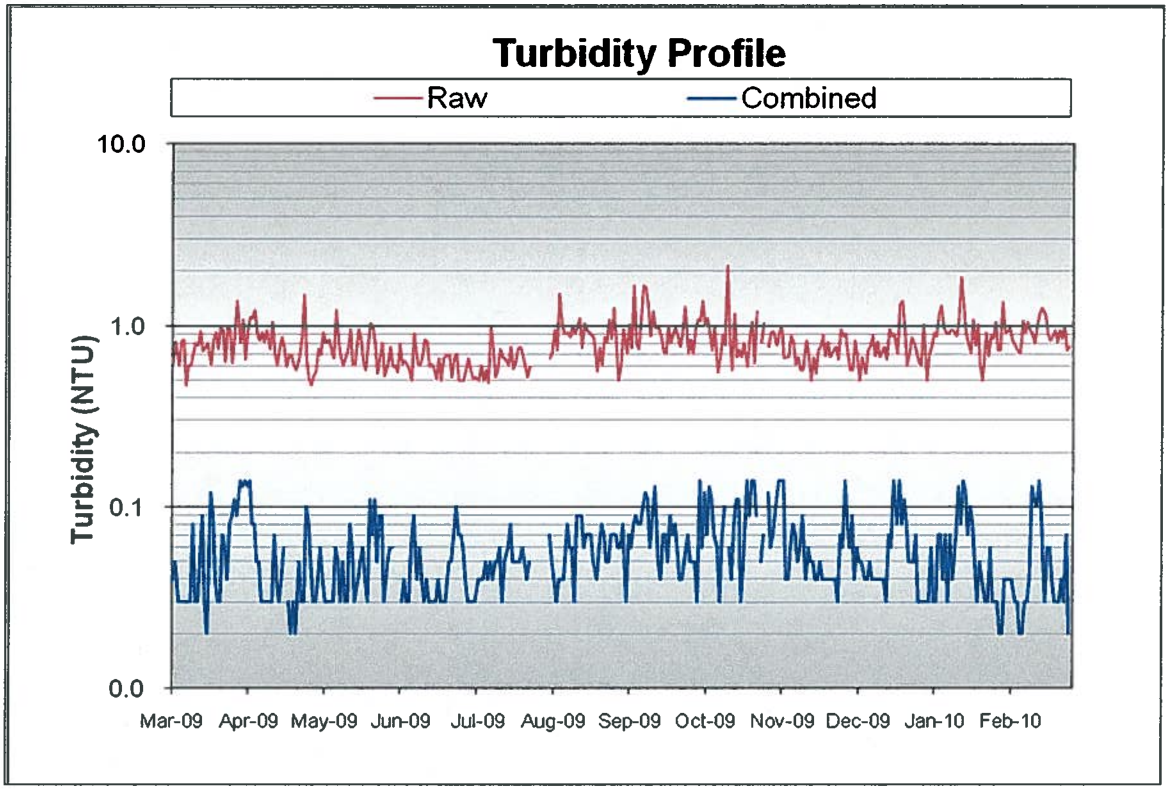

Figure 7 – Sultan Performance Assessment

SPECIAL STUDIES

Plant turbidimeter calibration procedures and frequency were reviewed by the team. The plant operators are properly calibrating the plant turbidimeters, and the plant turbidimeter for Filter 2 closely matched the team's installed turbidimeter.

The water plant operators reported that they had completed a filter inspection recently, and the evaluation team had previously completed a filter evaluation during a prior visit, so a complete filter evaluation was not conducted. However, a quick evaluation of the filters was completed, in addition to the observation of a backwash.

A backwash sequence was initiated even though the filters had only been in service for slightly more than three hours. The results are shown in Table 2:

Table 2

	Filter 1	Filter 2	Filter 3
Subsurface wash functional	Yes	Yes	Yes
Top of filter wall to resting media	45"	44"	47"
Depth of media	28"	30"	26"
Expansion of media during backwash	5" (18%)	6" (20%)	6" (20%)

A spent filter backwash turbidity profile was not completed since the filters were prematurely forced to backwash.

The operators indicated that the filters experienced turbidity spikes during several events. They reported turbidity spikes from the individual filter effluent (IFE) and CFE when the filters were placed back in service after plant shutdown and after backwash. However, the spikes only occurred, or at least were amplified, when using the coagulant SumalChlor 50.

Currently, the plant's supervisory control and data acquisition (SCADA) system is unable to measure, record and trend IFE turbidity during the filter-to-waste period. The evaluation team determined that it is essential to monitor the IFE turbidities during the filter-to-waste cycle in order to track the filters' performance. While on site, the evaluation team installed a HACH 1720D turbidimeter on the effluent line from Filter 2. The turbidimeter recorded turbidities at one-minute intervals for the duration of the CPE including when the filter was in service, being backwashed, being filtered-to-waste or out of service. Figure 8 shows the turbidity of the filter's IFE graphed against time (a filter profile).

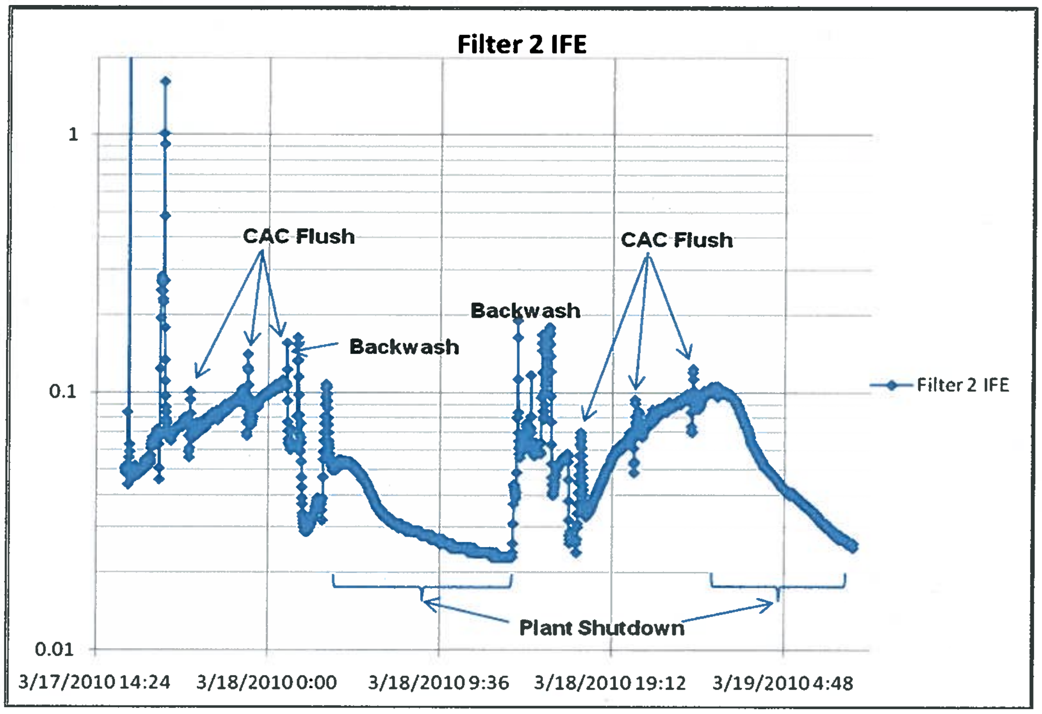

Figure 8 – Sultan Filter 2 Profile

The IFE shows significant turbidity spikes each time the filter is subjected to an increase in flow. For example, when the flow through the filters is stopped so the CAC unit can be flushed, a turbidity spike is triggered by restarting the filter. Also, the startup after each backwash causes a turbidity spike. As expected, when the plant is shutdown without first backwashing the filters, the most significant turbidity spike occurs when startup occurs and the filter effluent is switched from filter-to-waste to production. In addition, the filter never reaches a steady state where the effluent turbidity is stable. The effluent turbidity shows a continual turbidity increase. All these trends and events are indicators of inadequate chemical treatment and inadequate flow rate control through the filter.

Figure 9 shows a typical filter profile for a properly conditioned filter. After backwash the filter may spike but the turbidity spike is less than 0.3 NTU and lasts less than 15 minutes. This spike is captured during the filter-to-waste cycle and the elevated turbidity water is wasted. The filter then enters a steady state where the turbidity remains low and even. This stage of the filter run is important because it typically lasts the longest time of any stage of the filter run. The concentration of particles measured as turbidity in the filtered water during this stage, if elevated as seen in Sultan's Filter 2, indicates a significant increased risk for passing pathogenic microorganisms.

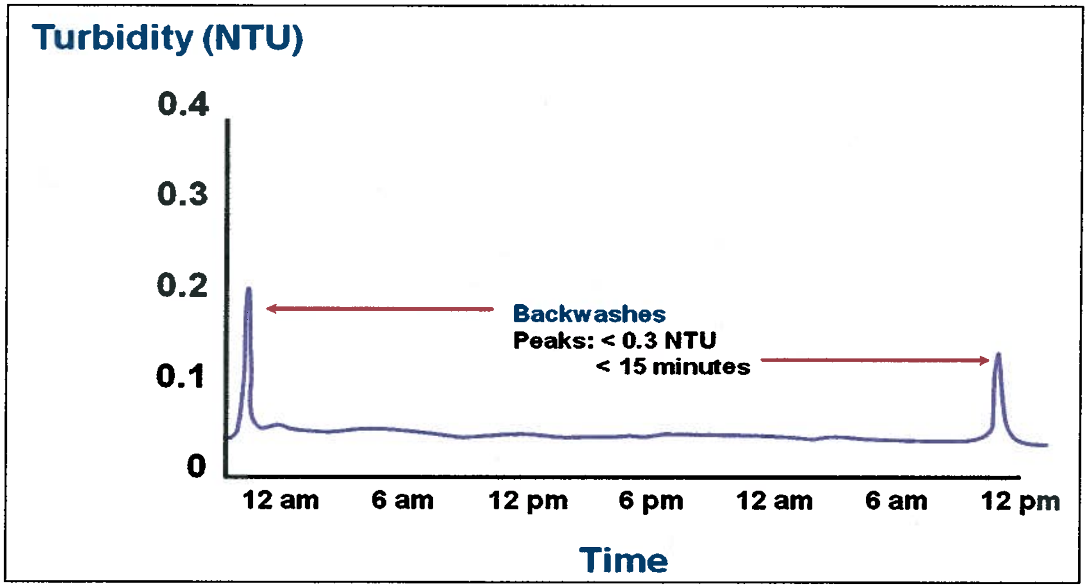

Figure 9 – Typical Filter Profile

PERFORMANCE LIMITING FACTORS

The areas of design, operation, maintenance, and administration were evaluated in order to identify factors that limit performance. These evaluations were based on information obtained from the plant tour, interviews, performance and design assessments, special studies, and the judgment of the evaluation team. Each of the factors was classified as A, B, or C according to the following guidelines:

A - Major effect on a long-term, repetitive basis.
B - Moderate effect on a routine basis or major effect on a periodic basis.
C - Minor effect.

The performance limiting factors were prioritized as to their relative impact on performance and are summarized below. In developing this list of factors limiting performance, 50 potential factors were reviewed and their impact on the performance of the Sultan Water Treatment Plant was assessed. There were four A factors and one B factor for the Water Treatment Plant. We determined that the remaining 45 factors were not having a significant impact on plant performance.

<u>A-1 ADMINISTRATION: Policies</u>

The city of Sultan has not adopted clear, objective and measurable goals for finished water quality. Plant operators are working toward public health goals that are clearly more stringent and protective of public health than the current drinking water regulations. However, measurable optimization goals have not been formally adopted.

A-2 DESIGN: Filter-to-Waste

The filter-to-waste design is such that a severe flow surge appears to be unavoidable without first making minor design changes. The surge in flow occurs when the filters are switched from the filter-to-waste mode into production. When this change is made, the pressure (head) the filters are working against is abruptly and significantly reduced, causing a nearly instantaneous flow rate change estimated to be a 60-100 percent increase.

While on site, the evaluation team observed the filters while filtering-to-waste. With the influent flow held constant at 750 GPM, the filters overflowed into the backwash water troughs while in the filter-to-waste mode. When the filters were put into production, the overflow immediately ceased and the filter water levels dropped as much as 2.5 inches in less than 30 seconds. This surge in flow, estimated to be at least a 70 percent increase, caused turbidity spikes in all IFEs and the CFE.

This surge in flow dramatically increases the shear forces exerted on contaminants stored in the filter media (as shown in Figure 10), causing them to be released into the finished water. This results in turbidity spikes and risks to public health.

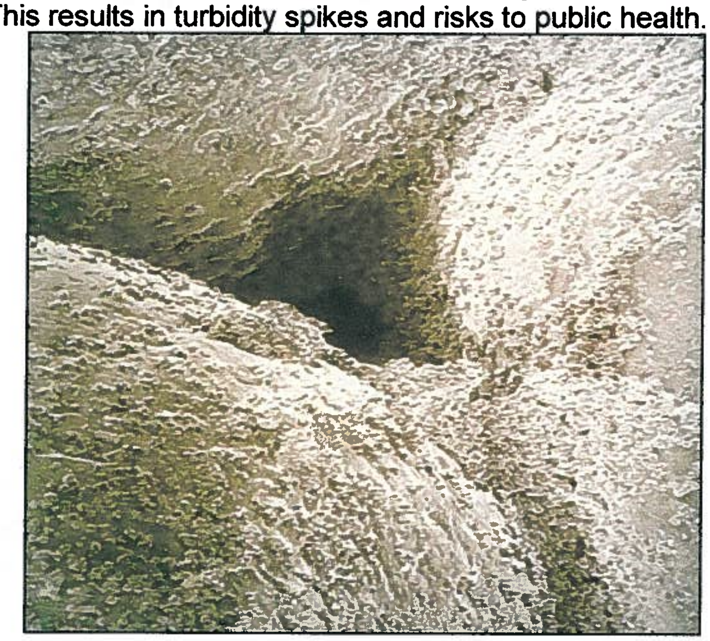

Figure 10 – Electron Photomicrograph of Filter Sand Grains with Attached Floc Particles

A-3 OPERATIONS: Technical Guidance

The water treatment plant has unusual problems that may prove to be difficult to correct. Expert outside technical assistance (e.g., performance based training) is likely to be very helpful to operators in achieving optimization.

A-4 OPERATIONS: Application of Water Treatment Concepts

- Jar testing is not used to experiment with coagulants, coagulant and flocculant aids, and variable pH conditions in order to improve removal of turbidity and/or color.
- CAC turbidity is measured but not trended for use in ensuring the barrier is

optimized.

- Storage isn't used to balance water production with water use.
- Chemical feed pumps are generally over-sized.
- The wrong daily maximum turbidity is reported on the state form.

B-1 DESIGN: Minor Design Problems

Minor design/instrumentation problems make optimization difficult.

- Flow measurement/proportioning to filters.
- Lack of continuous turbidity monitoring of CAC effluent.
- Inability to record filter-to-waste turbidity.
- CFE turbidity measurement is not representative of "real" turbidity.
- Over-sized chemical feed pumps.
- Filter media size.

B-2 ADMINISTRATION: Number of Staff

- Staffing may be inadequate to ensure optimization.
    - Back-ups, holidays, weekends, vacations, etc.

PROJECTED IMPACT OF COMPREHENSIVE TECHNICAL ASSISTANCE

Comprehensive Technical Assistance is a formal and comprehensive program that systematically addresses the factors identified as limiting the plant's performance during the CPE. A CTA is typically initiated when significant performance problems are identified during the CPE. It normally focuses on improved performance through operator training and improved process control. Administrative factors are also addressed as they relate to their impact on performance problems. All changes are implemented by local personnel under the guidance of a facilitator external to the plant staff. The facilitator can be a consultant, a WADOH employee or other qualified person.

The evaluation team believes that the Sultan WTP can benefit from comprehensive technical assistance.

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