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PROJECT MEMORANDUM

Subject:	Estimation of Additional Reliability Added by Equipping Second UV Channel
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Date:	February 10, 2016
Project Number:	8347G.00

BACKGROUND

The City of Watsonville, in partnership with the Pajaro Valley Water Management Agency (PVWMA), operates a Trojan UV3000-Plus UV disinfection system as part of the Recycled Water Treatment Facility which produces disinfected tertiary recycled water for distribution to PVWMA customers in the Pajaro Valley. The UV disinfection system consists of five banks of low-pressure high-output (LPHO) UV lamps operated in series in one channel. A second channel is available for expansion, which currently contains no UV lamps or equipment. Each bank contains 15 modules of lamps and 8 lamps per module, for a total of 120 lamps per bank. The total UV system size is 600 lamps.

The UV disinfection system was approved for operation by the California Department of Public Health, Regional Water Quality Control Board, Central Coast Region, in a letter dated March 11, 2009. According to the approval letter, the UV system is limited to the following operational parameter ranges.

a. "Permit flow up to 7.7 million gallons per day (mgd). The actual capacity of the Trojan UV system for the design conditions of 55 % UVT, 100 mJ/cm^2 dose, end-of-lamp-life (EOLL) of 0.98, and fouling factor (FF) of 0.95, results in a capacity of 6.09 mgd (4231 gpm). If the design capacity is to be based on 58.2 percent UVT, the system capacity meets the 7.70 mgd design objective with a delivered dose of 100.0 mJ/cm^2."

b. " Flow should be maintained at or below 6.09 mgd (4231 gpm), unless the UVT is at or above 55 percent. This will maintain one redundant bank of UV lamps out of service. If flow is greater than 6.09 mgd and the UVT is less than 58 percent, the redundant bank may be utilized temporarily."

The UV disinfection system occasionally has not been able to meet the required UV dose and has had to bypass or reduce flow. The Pajaro Valley Water Management Agency (PVWMA) and

the City of Watsonville wish to evaluate the added reliability that would be provided by equipping the second UV channel with UV lamps. The cost of equipping the second UV channel and associated electrical infrastructure is estimated at $2.8 million (Recycled Water Treatment, Storage, and Distribution System Pipeline Improvements, Facilities Planning Report, prepared by Carollo for PVWMA, May 2015).

OPERATIONAL REQUIREMENTS

Under the current operation, UV dose delivery is defined by the March 11, 2009 permit letter, as shown in Equation 1.

$$RED = (0.79) \times (FF) \times (LHF) \times 10^{(A+B \times \log(Flow) + C \times \log(UVT) + D \times \log(P))} \quad \text{Equation 1}$$

Where RED is the MS2 Reduction Equivalent UV Dose (mJ/cm^2) per operating lamp bank, 0.79 is a correction factor, FF is a sleeve fouling factor (0.95), LHF is a lamp aging factor (defined as 0.98 at the end of lamp life of 9000 hours), Flow is the water flow in gpm/lamp in one bank, UVT is the water UV transmittance(%), P is the lamp ballast power setting (%) and A (-4.63), B (-0.70), C (2.91) and D (1.09) are coefficients determined by linear regression of validation data.

Based on guidance outlined in the 2012 National Water Research Institute UV Disinfection Guidelines, the equations defining UV dose delivery by UV systems validated prior to 2012 have been modified. These changes have significant impact on UV system sizing and treatment plant capacity for the PVWMA and the City of Watsonville should the existing system be expanded.

According to the NWRI 2012 criteria, the modified UV dose delivery is defined by Equation 2.

$$RED = (0.906) \times (FF) \times (LHF) \times 10^{(A+B \times \log(Flow) + C \times \log(UVT) + D \times \log(P))} \quad \text{Equation 2}$$

Where RED is the MS2 Reduction Equivalent UV Dose (mJ/cm^2) per operating lamp bank, 0.906 is a confidence ratio, FF is a sleeve fouling factor (0.95), LHF is a lamp aging factor (defined as 0.98 at the end of lamp life of 9000 hours), Flow is the water flow in gpm/lamp in one bank, UVT is the water UV transmittance(%), P is the lamp ballast power setting (%) and A (-6.3439), B (-0.8655), C (3.709) and D (1.2909) are coefficients determined by linear regression of validation data.

DATA ANALYSIS

We performed a detailed analysis of plant data obtained from the City of Watsonville from October 1, 2013 through September 30, 2014, and January 1 through December 31, 2015. The data included a total of 11,746 hourly readings from the plant's SCADA system. The analysis was performed to evaluate the UV system reliability at meeting the minimum UV dose of 100 mJ/cm^2 under the existing operation, as defined by the current UV dose delivery equation, compared to the projected operation under the 2012 NWRI dose delivery equation if the UV system expansion described above were carried out.

The analysis, summarized in Table 1, indicates that under the current permit letter with UV dose calculated using equation 1, and based on the historical operating period described above, the UV system is unable to meet the minimum UV dose of 100 mJ/cm^2 0.9 percent of the time, which is equivalent to 79 hours per year. If the UV system were expanded to include a second channel with 5 banks of lamps (a doubling of the current UV system size), with UV dose calculated using Equation 2, the system reliability would increase such that the UV system would be unable to meet the minimum UV dose of 100 mJ/cm^2 0.06 percent of the time, which is equivalent to 5 hours per year.

Table 1 UV System Reliability at Meeting Minimum UV Dose Criteria

Number of Channels	Operating UV Banks/ Channel	Minimum UV Dose Required (mJ/cm^2)	UV Dose Calculation Basis	Percent of Points Not Meeting Minimum UV Dose (%)	Estimated Time Not Meeting Minimum UV Dose (Hrs/Yr)
1	5	100	Existing Permit	0.90	79
2	5	100	2012 NWRI	0.06	5