WINZLER & KELLY
CONSULTING ENGINEERS
CH2MHILL

TECHNICAL MEMORANDUM

Water Quality and Treatment

PREPARED FOR:	City of Santa Rosa
PREPARED BY:	Anne Kernkamp/CH2M HILL
REVIEWED BY:	Marc Solomon/Winzler & Kelly Ted Whiton/Winzler & Kelly Dave Coleman/Winzler & Kelly
COPIES:	Dave Smith/Merritt SmithConsulting Mark Millan/Data Instincts Pat Collins/Winzler & Kelly
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Background and Purpose

The Laguna Subregional Water Reclamation Facility (Laguna Plant or Plant) currently produces disinfected tertiary recycled water as defined by Title 22 of the California Code of Regulations (Title 22). This water is suitable for the following uses outlined in Title 22:

- **Urban Landscape** – Parks and playgrounds, schoolyards, unrestricted access golf courses, residential landscaping, freeway and roadway landscaping, cemeteries, ornamental nurseries, and sod farms.
- **Agriculture** – Food crops for human consumption; orchards; vineyards; fodder, fiber, and seed crops; non-fruit bearing trees; pasture for milking animals; and water supply for livestock.
- **Impoundments** – Restricted and unrestricted (full-body contact) recreational impoundments, decorative lakes and fountains, and fish hatcheries.
- **Industrial**[1] – Industrial processes (e.g., paper manufacturing, carpet and textile dyeing, boiler feed; cooling towers and air conditioning; non-residential toilet, urinal, and floor drains; structural and non-structural fire fighting; commercial laundries; commercial car washes; concrete mixing; construction (dust control, soil compaction, backfill consolidation around pipelines, including potable); street and sidewalk cleaning; flushing sanitary sewers, and snowmaking.

Many other permitted uses require less treatment.

[1] Some of these uses require additional treatment.

The goal of the Santa Rosa Urban Reuse Project is for the quality of water delivered to the Subregional System's urban irrigation customers to be suitable for convenient operation of drip irrigation systems. Drip irrigation emitters have the smallest size opening of any type of irrigation equipment.

The purposes of this technical memorandum (TM) are as follows:

- Characterize the recycled water quality required for reliable use in drip irrigation systems
- Describe the water quality available from the Laguna Plant and storage ponds
- Evaluate the treatment and other system management measures recommended to achieve and maintain a suitable level of quality
- Optimize the location, size, and cost of recycled water storage, treatment, and distribution
- Recommend any additional water quality measures that are needed to achieve the City's recycled water quality requirements

This TM does not address the use of recycled water in misters or foggers, which is not recommended because of the potential for inhalation.

Conclusions and Recommendations

- Deleterious effects to plants can occur at pH greater than 9. Stored recycled water often approaches pH of 10. If any of the future irrigation system serves stored recycled water to sensitive plants, pH adjustment with acid should be considered if aeration alone proves to be insufficient.
- Recycled water is not recommended for use in mister/fogger systems because of the inhalation risk.
- Recycled water from the Laguna Plant via the Geysers Pipeline will need the addition of chlorine (assumed to be in the form of liquid sodium hypochlorite) to inhibit biological growth at a minimum, and could also require filtration if sloughing of biological growth from the pipeline is a problem.
- To date, the City has not experienced adverse effects from algae at the Rohnert Park Pump Station filters. However, the Rohnert Park system will be served increasing amounts of stored recycled water in the future. The City may elect to monitor operations and phase in aerators/mixers as needed as a maintenance measure.
- Chlorine will need to be added to the distribution system to control biological growth. The industry recommendation is to maintain a minimum chlorine residual of at least 1 milligram per liter (mg/L) throughout the distribution system at all times. Filtered, undisinfected water downstream of the Rohnert Park Pump Station should be sampled during the 2007 irrigation season so that chlorine demand/decay curves can be

developed on the stored recycled water in the distribution system. Using these data, the distribution system model can be used to predict chlorine residual throughout the system for a given chlorine dose. The data will also help determine whether re-chlorination stations are needed in the system.

- An important management tool in any recycled water system is the ability to flush mains. Flushed water must be directed to a sanitary sewer only.
- Strainers should be provided at each irrigation customer connection or control valve.
- With a total volume of 12.8 million gallons in the existing Laguna Plant equalization basins, storage is adequate to equalize future summertime flows.
- The ability to separate recycled water from the Laguna Plant from stored recycled water returned from the Meadowlane Ponds will be desirable. The easiest method for accomplishing this separation is to construct a weir in the common wetwell for the Llano Pump Station (serving the Geysers Pipeline) and the E Pump Station (serving the agricultural reuse system).
- Four alternatives were evaluated for optimizing the location, size, and cost of treatment, storage, and distribution facilities. Alternative 2 – Maximize System Storage (provide some peaking from the Laguna Plant) is the recommended alternative. This alternative consists of the following maximum flow scenario:
  - 19 million gallons per day (mgd) to the Geysers Pipeline
  - 14 mgd to West Santa Rosa
  - 10 mgd to Rohnert Park

  This alternative includes the following facilities:
  - Two 1.5-million gallon (MG) storage tanks in the Santa Rosa hills
  - 2.5 MG of storage tanks in Rohnert Park
  - Chlorination, and possibly filtration facilities at the Ludwig turnout from the Geysers Pipeline (a separate TM addresses the possible addition of a turbine generator at the same site)
  - A 2-mgd expansion of the Rohnert Park Pump Station, filters, and chlorination
  - A 14-mgd expansion of the Llano Pump Station
- Return of filter backwash water to an irrigation pond is recommended. At the Rohnert Park Pump Station, backwash water can continue to be discharged to a local sewer. If filters are added at the E Pump Station, the Meadowlane ponds could be used for backwash water disposal. Backwash water constitutes less than 1 percent of the filter throughput.

Required Water Quality

Drip systems are susceptible to clogging. Clogging is usually the result of algae, agglomeration of fine particulates by microbial byproducts, and biofilm growth on distribution piping that can slough off. Some form of treatment is typically required to prevent clogging of drip systems, whether they are served recycled water or stored recycled water, because of the potential for biological growth in both storage and the recycled water distribution system.

Most existing recycled water systems typically serve larger customers for uses such as agriculture, golf courses, parks, schools, and cemeteries. These users employ large-scale irrigation equipment that is not as susceptible to clogging as drip systems, so actual experience with drip systems is limited. Utilities in Florida indicate that water having a total suspended solids (TSS) content of less than 5 mg/L is sufficient to protect drip systems, and it is the Florida recycled water standard.

The pH of the recycled water is also important to landscape irrigation. At pH above 9, deleterious effects can occur, depending on the sensitivity of the plant. Stunting may occur and, as pH increases, foliage can burn. Algae growth in storage ponds elevates pH.

Some ions present in recycled water can be toxic to plants. The most common of these are sodium, chloride, and boron. However, these ions are not present in the Subregional System at concentrations high enough to be of concern.

Existing Water Quality

Water delivered to customers can be either recycled water served directly from the Laguna Plant or recycled water that has been stored in ponds. Recycled water quality leaving the Laguna Plant is described in Table 1. Table 1 summarizes analytical data from grab samples collected during the discharge seasons as part of the Subregional System's Self Monitoring Program from January 2000 through July 2006.

Table 2 presents water quality data for stored recycled water from Delta Pond and Meadowlane Pond D. These data are from grab samples collected during the discharge seasons from January 2000 through the end of the discharge season in 2006 as part of the Self Monitoring Program. Summertime sampling at Meadowlane Ponds B, C, and D has been conducted since June 2006. These ponds have been sampled for chlorophyll *a*, TSS, and fecal coliform. The results of those analyses are included graphically in Attachment 1.

Recycled water leaving the Plant is consistently in the range of 1 mg/L TSS and pH 7.4. However, stored recycled water consistently exceeds 10 mg/L TSS and is usually in the range of 50 to 150 mg/L TSS during the summer. This high TSS concentration generally correlates with an increase in chlorophyll *a*, representative of algal growth. Algae growth also elevates pH to close to 10 at times.

Because the storage ponds are open, they are exposed to wildlife. Therefore, fecal coliform is present in the ponds.

TABLE 1
Final Effluent and Quarterly Data Summary – 2000 – 2006
Santa Rosa Incremental Recycled Water Program – Water Quality and Treatment

Constituent	Unit	Number of Samples	Average	Median	Minimum	Maximum	95th Percentile
Alkalinity (Bicarbonate)	mg/L	25	168.17	175	0.125	200	190.00
Alkalinity (Total)	mg/L	2,460	168.52	170	72	222	190.00
BOD, 5 Day	mg/L	974	1.96	1	1	266	4.00
Boron, ICP – Total	mg/L	26	0.39	0.405	0.23	0.53	0.53
Calcium, ICP – Total	mg/L	27	31.06	30	25	39.6	35.40
Chloride	mg/L	25	62.95	65	31	120	80.60
Chlorine Residual – DPD	mg/L	37	0.06	0.05	0.05	0.25	0.09
Total Coliform 15 Tube	MPN/100ml	4,242	2.37	1	1	1600	4.00
Diss. Organic Carbon	mg/L	18	11.07	11	5	16	16.00
Electrical Conductivity	µmhos/cm	720	694.31	710	7.7	1030	804.00
Total Hardness by Calculation - mg/L	mg $CaCO_3$/L	18	160.72	162	128	195	184.80
Iron, ICP – Total	mg/L	25	0.09	0.072	0.025	0.48	0.15
Iron, ICP – Dissolved	mg/L	9	0.05	0.05	0.025	0.087	0.08
Magnesium, ICP - Dissolved	mg/L	10	19.10	19	16	21	21.00
Magnesium, ICP - Total	mg/L	25	19.35	19.9	15.6	23.9	23.00
Manganese, ICP/MS - Total	µg/L	21	29.57	20	6.8	120	92.00
Sodium	mg/L	25	76.20	77	45	108	95.40
Nitrate as N	mg/L	294	11.30	11	5.7	18	16.00
Nitrite as N	mg/L	1,000	0.20	0.12	0.005	3.6	0.70
Ammonia as N	mg/L	1,332	0.23	0.05	0.05	9	1.00
Phosphate, Ortho as P	mg/L	25	2.07	2.1	0.85	3.7	3.38
pH	pH	2,457	7.46	7.5	6.4	8.1	7.70
Potassium	mg/L	25	13.30	13	7.5	26	17.00
Settleable Solids	ml/L	24	0.05	0.05	0.05	0.1	0.05
Silica, ICP - Total (as SiO2)	mg/L	19	29.89	31	25	34	34.00
Silicon, ICP - Diss. (as SiO2)	mg/L	10	26.06	27.00	5.60	33.00	32.55
Sulfate	mg/L	25	33.96	32.4	27	61	44.80
Sulfur, ICP – Total	mg/L	10	12.11	12	8.5	16	15.10
Temperature (Field)	°C	4	23.25	24	19	26	26.00
Total Dissolved Solids	mg/L	640	442.91	450	210	790	493.05
Total Kjeldahl Nitrogen	mg/L	25	1.25	1.2	0.2	2	1.92
Total Organic Carbon	mg/L	310	13.67	13	2.5	56	20.00
Organic Nitrogen	mg/L	19	1.09	1.3	0.1	1.8	1.71
Total Phosphorus	mg/L	372	2.47	2.4	0.3	17	3.90
Tot. Suspended Solids	mg/L	2,466	2.35	0.5	0.5	3590	1.90
Turbidity	NTU	2,429	0.59	0.5	0.1	16	1.10
Volatile Suspended Solids	mg/L	347	1.32	0.5	0.5	100	1.60
Vanadium, ICP – Total	mg/L						
b-BHC[a]	µg/L	31	<.066	<.06	ND	ND	0.05
Endosulfan Sulfate[a]	µg/L	31	<0.13	<0.10	ND	ND	0.33
Bromodichloromethane (Dichlorobromomethane)	µg/L	32	0.29	0.25	0.25	0.63	0.545

TABLE 1
Final Effluent and Quarterly Data Summary – 2000 – 2006
Santa Rosa Incremental Recycled Water Program – Water Quality and Treatment

Constituent	Unit	Number of Samples	Average	Median	Minimum	Maximum	95th Percentile
Chloroform	µg/L	32	0.54	0.25	0.25	2.5	1.98
1,4-Dichlorobenzene	µg/L	32	0.32	0.25	0.25	1.3	0.6
Methylene Chloride	µg/L	32	0.28	0.25	0.25	0.6	0.5
Methyl-tertButyl Ether	µg/L	31	0.96	0.25	0.25	8.7	3.15
Toluene	µg/L	32	0.30	0.25	0.25	1.4	0.5
Di-n-Butyl Phthalate	µg/L	31	<11.2	<10	ND	ND	12.5
Naphthalene	µg/L	31	4.4	2.5	0.25	7.5	12.5
n-Nitrosodimethylamine	µg/L	33	5.0	2.5	0.00095	0.012	12.5
n-Nitrosodi-n-Propylamine	µg/L	33	4.2	2.5	0.00095	0.013	12.5
Methomyl	µg/L	5	1.8	1	1	5	4.2
1,4-Dioxane	µg/L	5	0.52	0.5	0.25	0.7	0.696
Perchlorate	µg/L	5	0.84	0.5	0.5	1.4	1.38
Antimony	µg/L	29	0.92	1.0	0.25	0.55	1.0
Arsenic	µg/L	29	1.2	1.0	1.0	3.0	2.7
Beryllium	µg/L	29	<0.48	<0.50	ND	ND	0.25
Cadmium	µg/L	29	<0.48	<0.50	ND	ND	0.25
Chromium	µg/L	29	1.4	1.0	0.8	12	2.3
Chromium VI	µg/L	5	0.52	0.40	0.2	0.8	0.96
Copper[a,b]	µg/L	11	3.24	3.53	1.7	4.37	4.07
Cyanide	µg/L	29	4.8	1.5	1.5	51	14.6
Lead[a]	µg/L	33	0.89	1.0	0.072	1.5	1.5
Mercury	µg/L	30	0.041	0.025	ND	ND	0.1
Nickel	µg/L	33	3.4	3.7	ND	5.5	5.2
Selenium	µg/L	29	<4.4	<5.0	ND	ND	2.5
Silver	µg/L	29	<0.44	<0.50	ND	ND	0.25
Thallium	µg/L	29	<1.8	<2.0	ND	ND	1.0
Zinc	µg/L	29	27.5	27	19	42	36
Dissolved Antimony	µg/L	29	0.91	1.0	0.25	0.6	1.0
Dissolved Arsenic	µg/L	29	1.1	1.0	0.77	2.86	1.9
Dissolved Beryllium	µg/L	29	<0.48	<0.50	ND	ND	0.25
Dissolved Cadmium	µg/L	29	<0.48	<0.50	ND	ND	0.25
Dissolved Chromium	µg/L	29	1.09	1.0	0.69	3	1.9
Dissolved Copper	µg/L	33	7.7	9.3	ND	14.0	12.4
Dissolved Lead	µg/L	33	0.85	1.0	0.06	1.1	1.1
Dissolved Mercury	µg/L	29	<0.08	<0.050	ND	ND	0.1
Dissolved Nickel	µg/L	33	3.2	3.6	ND	5.3	5.1
Dissolved Selenium	µg/L	29	<4.4	<5.0	ND	ND	2.5
Dissolved Silver	µg/L	29	<0.44	<0.50	ND	ND	0.25
Dissolved Thallium	µg/L	29	<1.8	<2.0	ND	ND	1
Dissolved Zinc	µg/L	29	26.7	25	17	44	40.4

[a]Shaded rows indicate constituents found to have reasonable potential to require effluent limits.

[b]Data are October 2005 to January 2007; sampling technique changed in October 2005.

TABLE 2
Stored Recycled Water Summary – 2000 – 2006
Santa Rosa Incremental Recycled Water Program – Water Quality and Treatment

Constituent	Units	Average[a]	Median[a]	Minimum	Maximum Detected	Number of Samples
Inorganic Constituents						
Alkalinity – Total	mg/L	156	160	120	190	22
Aluminum – Total	mg/L	1.25	0.52	ND	5.86	29
Aluminum – Dissolved	mg/L	0.23	0.17	0.02	1.33	29
Ammonia as N	mg/L	0.66	0.50	ND	4.30	293
Antimony – Dissolved	µg/L	<1.8	<2.0	0.25	ND	24
Antimony – Total	µg/L	<1.7	<2.0	ND	ND	26
Arsenic – Dissolved	µg/L	1.85	1	1	3.8	24
Arsenic – Total	µg/L	1.8	1.5	1	4.0	26
Asbestos	million fibers/L	<4.73	<2.1	ND	ND	3
Barium Total	mg/L	0.039	0.037	0.032	0.051	4
Beryllium – Dissolved	µg/L	<0.50	<0.50	ND	ND	24
Beryllium – Total	µg/L	<0.48	<0.50	ND	ND	26
Boron – Total	mg/L	0.32	0.30	0.17	0.50	23
Cadmium – Dissolved	µg/L	<0.50	<0.50	ND	ND	24
Cadmium – Total	µg/L	<0.54	<0.50	ND	ND	26
Calcium – Total	mg/L	29.73	30.60	2.91	48.00	106
Chlorate	mg/L	0.057	0.053	0.051	0.072	4
Chloride	mg/L	73.71	66.00	44.00	190.00	22
Chlorine Residual	mg/L	<0.1	<0.1	ND	ND	139
Chromium – Dissolved	µg/L	1.10	1	0.25	3.4	24
Chromium – Total	µg/L	4.07	2.05	0.43	21	26
Chromium – Total Hexavalent	µg/L	<0.96	<0.40	ND	ND	12
Copper – Dissolved	µg/L	2.8	2.6	1.2	4.9	18
Copper – Total[c]	µg/L	3.5	3.6	1.7	4.9	32
Cyanide	µg/L	<3	<3	ND	ND	9
Dissolved Organic Carbon	mg/L	10.09	7.60	4.50	42.00	18
Fluoride	mg/L	0.2	0.2	0.2	0.2	4
Iron – Total	mg/L	1.71	0.91	0.06	8.90	21
Iron – Dissolved	mg/L	0.10	0.057	0.025	0.28	6
Lead – Dissolved	µg/L	0.69	1	0.044	0.6	32
Lead – Total[c]	µg/L	0.80	1.0	ND	2.5	34
Magnesium – Total	mg/L	19.28	20.00	1.80	33.00	106
Manganese – Total	mg/L	0.05	0.03	0.01	0.23	22
Mercury – Dissolved	µg/L	<0.060	<0.050	ND	ND	24
Mercury – Total	µg/L	0.04	0.025	ND	0.0032	26
Nickel – Dissolved	µg/L	6.45	5.25	ND	15.5	32
Nickel – Total	µg/L	9.4	6.74	3.3	32	34
Nitrate as N	mg/L	8.02	8.25	0.90	16.00	294
Nitrite as N	mg/L	0.18	0.17	ND	0.50	22
Organic Nitrogen	mg/L	1.23	1.20	ND	9.00	290
Orthophosphate as P	mg/L	1.56	1.30	0.20	2.70	22
Potassium	mg/L	10.68	11.10	5.60	15.60	20
Selenium – Dissolved	µg/L	<4.4	<5.0	ND	ND	24
Selenium – Total	µg/L	<4.6	<5.0	ND	ND	26
Silica – Total (as SiO_2)	mg/L	36.81	31.00	1.10	81.00	19
Silver – Dissolved	µg/L	<0.46	<0.50	ND	ND	24
Silver – Total	µg/L	<0.52	<0.50	ND	ND	26

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Constituent	Units	Average[a]	Median[a]	Minimum	Maximum Detected	Number of Samples
Sodium	mg/L	65.01	66.50	35.00	89.00	22
Sulfate	mg/L	33.86	32.00	26.00	67.00	22
Thallium – Dissolved	µg/L	<1.8	<2.0	ND	ND	24
Thallium – Total	µg/L	<1.6	<2.0	ND	ND	26
Total Kjeldahl Nitrogen	mg/L	1.54	1.50	ND	4.80	63
Total Organic Carbon	mg/L	10.61	9.40	5.40	19.00	21
Total Phosphorus	mg/L	2.01	2.00	0.24	4.00	300
Vanadium Total	mg/L	<0.05	<0.05	ND	ND	4
Zinc – Dissolved	µg/L	17.5	17.5	0.5	28	24
Zinc – Total	µg/L	23.3	23	10	38	26
Organic Constituents Detected in Recycled Water or Stored Recycled Water						
b-BHC[c]	µg/L	0.050	0.04	0.001925	0.07	27
Endosulfan Sulfate[c]	µg/L	0.10	0.05	0.00425	0.08	27
Bromodichloromethane	µg/L	0.27	0.25	0.15	0.6	29
Chloroform	µg/L	0.43	0.25	0.225	1.5	29
1,4-Dichlorobenzene	µg/L	0.28	0.25	0.23	0.62	29
Methylene Chloride	µg/L	<0.58	<0.50	ND	ND	29
Methyl-tertButyl Ether	µg/L	0.43	0.25	0.25	1.2	28
Toluene	µg/L	<0.52	<0.50	0.1525	ND	29
Di-n-Butyl Phthalate	µg/L	4.4	2.65	2.5	5.7	31
Naphthalene	µg/L	<7.4	<5.0	ND	ND	31
n-Nitrosodimethylamine	µg/L	<8.6	<5.0	ND	ND	33
n-Nitrosodi-n-Propylamine	µg/L	<7.8	<5.0	ND	ND	33
Methomyl	µg/L	1.4	1	1	2.2	3
1,4-Dioxane	µg/L	0.34	0.24	0.235	0.53	3
Perchlorate	µg/L	<1.0	<1.0	ND	ND	3
Radionuclides						
Gross Alpha	pCi/L	<3	<3	ND	ND	4
Gross Beta	pCi/L	8.2	8.3	7.6	8.7	4
Sum Radium 226 & 228	pCi/L	1.78	1.82	ND	2.808	4
Strontium 90	pCi/L	<0.87	<0.92	ND	ND	4
Uranium	pCi/L	<2	<2	ND	ND	4
Tritium	pCi/L	<361	<361	ND	ND	4
Physical Parameters						
Color	CU	35	35	30	40	4
Electrical Conductivity	µmhos/cm	582.36	561	430	754.	22
Hardness	mg $CaCO_3$/L	156.56	158.00	69.70	256	105
Odor	T.O.N.	2	1	ND	5.5	4
Turbidity	NTU	16.63	5.50	0.60	410.00	297
Settleable Solids	ml/L	<0.1	<0.1	ND	ND	22
Total Dissolved Solids	mg/L	382.43	395.00	260.00	456.00	21
Total Suspended Solids	mg/L	22.31	7.00	ND	530.00	205
pH	pH	7.79	7.85	7.20	8.70	22
Surfactants	mg/L	<0.1	<0.1	ND	ND	4
Volatile Suspended Solids	mg/L	-	-	-	-	0

TABLE 2
Stored Recycled Water Summary – 2000 – 2006
Santa Rosa Incremental Recycled Water Program – Water Quality and Treatment

Constituent	Units	Average[a]	Median[a]	Minimum	Maximum Detected	Number of Samples
Biological Constituents						
Bioassay 96 hour	% Survival	99.7	100	95	100	86
Chronic Lethal Toxicity (Fathead Minnow)[b]	NOEC	100	100	100	100	24
BOD 5 Day	mg/L	2.6	2.0	ND	13.0	299
Chlorophyll a	mg/m³	13.2	5.5	ND	45.4	14
Pheophytin	mg/m³	14.2	6.4	ND	41.0	18

[a]When values were below detection, half the reporting limit used to calculate averages and medians except when all values were below detection. If all values were below detection the values shown are the average and median of the reporting limits.

[b]For chronic lethal toxicity, the minimum No Observable Effects Concentration was 100 percent stored recycled water which occurred in all 24 toxicity tests. One toxicity test showed extreme bacterial/fungal coverage of the fish and extreme variability in mortality between replicates (no dose response curve). Therefore, these data are not included here

[c]Shaded rows indicate constituents found to have reasonable potential to require effluent limits.

Notes:
μg/L = micrograms per liter
ml/L = milliliters per liter
mg/m³ = milligrams per cubic meter

Source: Merritt Smith Consulting Draft TM, *Discharge to Surface Water Impacts*, May 2007.

Water Quality Management

Once recycled water is designated for urban reuse, its quality will continue to change throughout the urban reuse distribution system. The distribution system will include open ponds, enclosed steel tanks, pump stations, and pipelines. The goal is to deliver water that reliably meets customer needs for irrigation and other uses.

Treatment

One possibility to ensure high quality water in the distribution system would be to add treatment processes to the Laguna Plant to remove additional nutrients that contribute to downstream biological growth. This would entail additional processes, primarily to remove nitrogen and/or phosphorus. Treatment could be accomplished physically, biologically, or chemically. However, this would be a relatively expensive approach that would not totally eliminate biological activity in the recycled water.

A more effective and efficient approach would be to add only the amount of treatment needed where it is needed. When recycled water leaves the Laguna Plant, it is pumped either north through the Geysers Pipeline or north and south through the Santa Rosa Subregional Water Reuse System (Subregional System). This will hold true in the future. Currently, customers close to the Laguna Plant along the Subregional System are served recycled water or stored recycled water without any additional treatment.

Customers downstream of the Rohnert Park Pump Station (which includes customers on drip systems) in the existing Subregional System receive water that has been filtered using screen-type automatic backwash filters and chlorination with sodium hypochlorite addition (Figure 1). The sodium hypochlorite feed facilities were added last year in response to a snail infestation (Figure 2) that caused clogging in customer systems. The location of the larval snail entry point is unknown. Chlorination is expected to control snail and biofilm growth in the distribution system downstream of the pump station. The experience of other recycled water utilities indicates that a chlorine residual of at least 1 mg/L is desirable throughout the system. The hypochlorite system began operating during the 2007 irrigation season.

FIGURE 1
ROHNERT PART PUMP STATION FILTERS

The Rohnert Park reuse system does not currently adjust for pH. If any of the future irrigation system serves sensitive plants, pH adjustment with acid should be considered if aeration alone is insufficient (refer to section, Storage Pond Management).

Because no residual disinfectant is maintained in the Geysers Pipeline, biofilm grows on the pipe walls and could slough off. If the Llano Pump Station serving the Geysers Pipeline draws from storage, larger organisms could be present. Therefore, for urban reuse customers served from the Geysers Pipeline, the recycled water will need the addition of chlorine (in the form of liquid sodium hypochlorite) at a minimum, and could also require filtration.

FIGURE 2
SNAIL INFESTATION IN ROHNERT PARK RECYCLED WATER DISTRUCTION SYSTEM

Filtration is commonly provided by screen-type filters with automatic backwash when pumping out of open ponds into drip irrigation systems (Figure 3). Drip system equipment manufacturers recommend filter opening size in the range of 100 to 150 microns to protect systems they manufacture. The backwash supply is filtered recycled water. Backwash is typically initiated based upon pressure differential, and can either be motor-operated or operate off of system pressure. Backwash water constitutes less than 1 percent of filter throughput.

Strainers should be provided at each irrigation customer connection or control valve. This is common practice for commercial or residential irrigation systems, even on potable water systems.

FIGURE 3
130-MICRON FILTERS AT MONDAVI VINEYARDS DRIP SYSTEM, OAKVILLE (COURTSEY AMIAD USA)

Storage Pond Management

Because the existing storage ponds currently grow algae and other microorganisms that are prone to clogging drip systems, any storage ponds constructed in the future are assumed to be biologically active in the absence of control measures. These organisms need to be prevented from forming, removed before entering the distribution system, or a combination of both.

Additional nutrient removal could occur at the Laguna Plant to prevent algal growth, but this is an expensive and incomplete solution with respect to storage pond algal growth control. Chemical addition to ponds is a potential method (typically copper sulfate), but could have adverse effects on landscaping and result in accumulations at the bottom of the ponds, and would be toxic to aquatic life. A partial solution would be to install surface aerators on the ponds, which control, but do not eliminate, algal growth. Reducing algal growth is also possible using ultrasound.

Another method to control biological growth in storage ponds would be to prevent sunlight needed for algal growth from reaching the water by installing pond covers. This provides the most complete solution, but does not eliminate algae completely.

Pond Covers

Flexible membrane pond covers became more common in the late 1980s after the U.S. Environmental Protection Agency (EPA) mandated in the 1986 Safe Drinking Water Act Amendments that all drinking water reservoirs be covered. The American Water Works Association manual M25, *Flexible-Membrane Covers and Linings for Potable-Water Reservoirs*, was first published in 1987 and updated again in 1996 and 2000. Utilities, scientists, consultants, and manufacturers participated in writing M25. Membrane material is typically polyethylene or polypropylene.

According to M25, the principal advantages of flexible covers are reduced algal growth and prevention of evaporative losses. The primary disadvantages of flexible covers are susceptibility to damage by vandalism and the need for regularly scheduled maintenance to inspect the membrane and system integrity, remove surface water and debris, and make repairs.

M25 also states that wind stability needs to be considered in cover design, and a rainwater removal system should be included. A floating cover is usually attached to the top of a reservoir above the maximum overflow level by means of corrosion-resistant batten bars, fasteners, and a vulcanized rubber cushion strip. Figure 4 illustrates a typical floating cover installation.

The largest flexible membrane pond cover installed to date is 44 acres in surface area (personal conversation with Doug Hilts, Hilts Consulting, AWWA M25 committee member). Installed costs ranged between $3 and $6 per square foot. The main variable in cost is the extent of facilities needed to remove stormwater from the cover.

FIGURE 4
FLOATING RESERVOIR COVER
(COURTESY MPC CONTAINMENT)

A potential additional advantage to pond covers would be the space available for installation of flexible solar panels. The cost and operational challenges associated with such a system are beyond the scope of this evaluation, but may be considered as an alternative means of renewable energy supply in the future.

Pond Aerators/Mixers

Another method of controlling algae is to provide aerators and mixers. Surface aerators both entrain air in the pond and provide mixing. The circulatory action reduces the time that any given surface area is exposed to sunlight of sufficient intensity to promote algal growth. As a result, less algal growth occurs. A reservoir shown before and after aeration/mixing is illustrated on Figures 5a and 5b. Note that solar-powered aerators are available (Figure 6).

FIGURE 5A
RESERVOIR BEFORE AERATION/MIXING
(COURTESY SOLARBEE)

Ultrasound

The National Sanitation Foundation has recently approved an ultrasonic device for algae control. However, ultrasound is not being considered further here because of its limited documented record of performance.

Case Study

The Pebble Beach Community Services District (District) brought an open earthen 105-million-gallon recycled water reservoir online during winter 2006 (Figure 7). The

FIGURE 5B
RESERVOIR AFTER AERATION
(COURTESY SOLARBEE)

reservoir is equipped with separate aeration and mixing systems and is lined with Hypalon. The District equipped the reservoir discharge with automatic backwash screen-type filters, chlorine addition, and pH adjustment (acid).

As the reservoir filled, algae began to grow until water clarity, as measured with a Secchi disc, reached less than 1 foot. After operating the aeration and mixing systems, clarity increased, although algae growth continued to alternately increase and decrease throughout the summer. District Engineer, Michael Nissum, reports that algae never reached a level that became an operational problem. Moreover, conditions never became favorable for growth of blue-green algae, which is more difficult to control. Mr. Nissum said that his District determined that they need to run mixing all of the time during the irrigation season, and aeration at least half of the time. Reservoir pH exceeded 10 and pond effluent was treated with acid to reduce pH to approximately 7.

FIGURE 6
SOLAR-POWERED AERATOR/MIXER (COURTESY SOLARBEE)

FIGURE 7
FOREST LAKE RESERVOIR, PEBBLE BEACH COMMUNITY SERVICES DISTRICT

Recommendation

Several measures are available to control algae growth in reservoirs. Covers range in cost between approximately $3 and $6 per square foot, installed. Aerator/mixers cost about $1 per square foot. Because of the large difference in cost and the acceptable track record of aerator/mixers, aerator/mixers are preferable to covers.

To date, the City has not experienced adverse effects from algae at the Rohnert Park Pump Station filters. However, the Rohnert Park system will be served increasing amounts of stored recycled water in the future. The City may elect to monitor operations and phase in aerators/mixers as needed as a maintenance measure.

Distribution System Management

Because the recycled water in the distribution system is biologically active, chlorine will need to be added to control biological growth. The industry recommendation is to provide a minimum chlorine residual of 1 mg/L throughout the distribution system at all times. However, a means is not currently available to determine the application dose needed to meet this requirement. The City should obtain a sample of filtered, undisinfected water downstream of the Rohnert Park Pump Station during the 2007 irrigation season and run chlorine demand/decay curves on the stored recycled water. Using these data, the distribution system model can be used to predict chlorine residual throughout the system for a given chlorine dose. The data will also help determine whether re-chlorination stations are needed in the system.

An important management tool in any recycled water system is the ability to flush mains. Flushing can refresh dead ends and prevent anaerobic conditions from forming. The urban reuse distribution system will likely include blowoffs to the adjacent sanitary sewers, allowing this flushing to be part of the regular maintenance of the system.

Optimizing Storage, Treatment, and Distribution

This section describes a range of alternatives developed to determine the optimal combination of treatment, storage, and distribution main sizing and location at the lowest overall system cost. Many of the optimization alternatives rely on relatively constant production from the Laguna Plant. Therefore, equalization basins were evaluated for capacity to equalize flow during the irrigation season when future average dry weather flow is 25.9 mgd.

Flow Equalization

The Plant currently employs two equalization basins with a capacity of 6.4 million gallons each to equalize flow downstream of primary treatment. Primary effluent flows are equalized during as much of the year as possible.

A typical irrigation season day diurnal flow from the 2006 curve (Figure 8) was used as a baseline for a flow equalization analysis. Total flow on that particular day was 17.5 MG. This curve was scaled up to 25.9 mgd (a ratio of 25.9 to 17.5, or 1.47) to project a corresponding diurnal curve. These data were analyzed to determine the amount of storage needed to equalize flow (see Table 3). The result was 3.2 million gallons. Allowing a 25 percent contingency to account for flow variations and downtime for cleaning, this translates to a volume of 4 million gallons. With a total volume of 12.8 million gallons in the existing equalization basins, adequate storage is currently available to equalize future summertime flows.

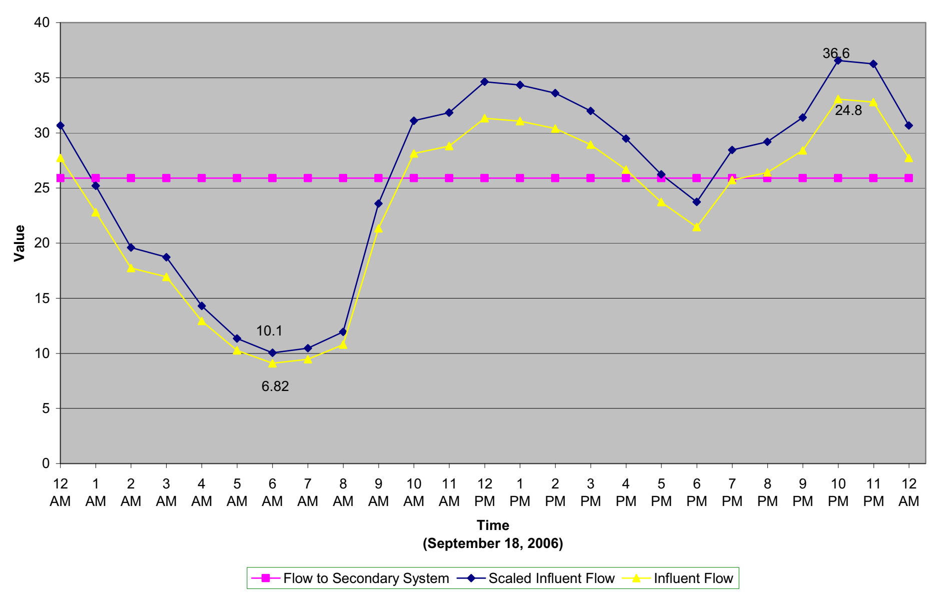

FIGURE 8
TYPICAL DIURNAL FLOW CURVE SCALED TO 25.9 MGD

Flow Separation

Separating recycled water originating at the Laguna Plant from stored recycled water returned from the Meadowlane Ponds to the Subregional System is desirable for at least two reasons. First, delivering recycled water to the Geysers Pipeline to meet the existing water quality agreement with Calpine is desirable. Second, any urban reuse turnout from the Geysers Pipeline could require less treatment if the recycled water comes directly from the Laguna Plant rather than from storage. The easiest method for accomplishing this separation is to construct a weir in the common wetwell for the Llano Pump Station (serving the Geysers Pipeline) and the E Pump Station (serving the Subregional System), as illustrated on Figure 9.

TABLE 3
Flow Equalization Analysis
Santa Rosa Incremental Recycled Water Program – Water Quality and Treatment

1.47 (scaling factor=25.9/17.5) Scaled Influent Flows (mgd)	Average Hourly Influent IN (I) (mgd)	Flow to Secondary System OUT (O) (mgd)	Average Hourly Flow Rate (I/O) (mgd)	Volume into (+) or out of (-) Storage (I-O) (MG)	Required Storage Sum (I-O) (MG)
30.7		25.9			
25.2	27.9	25.9	2.0	0.1	0.1
19.6	22.4	25.9	-3.5	-0.1	0.0
18.7	19.2	25.9	-6.7	-0.3	0.0
14.3	16.5	25.9	-9.4	-0.4	0.0
11.4	12.8	25.9	-13.1	-0.5	0.0
10.1	10.7	25.9	-15.2	-0.6	0.0
10.5	10.3	25.9	-15.6	-0.7	0.0
11.9	11.2	25.9	-14.7	-0.6	0.0
23.6	17.8	25.9	-8.1	-0.3	0.0
31.1	27.3	25.9	1.4	0.1	0.1
31.8	31.5	25.9	5.6	0.2	0.3
34.6	33.2	25.9	7.3	0.3	0.6
34.3	34.5	25.9	8.6	0.4	1.0
33.6	34.0	25.9	8.1	0.3	1.3
32.0	32.8	25.9	6.9	0.3	1.6
29.5	30.7	25.9	4.8	0.2	1.8
26.2	27.9	25.9	2.0	0.1	1.9
23.7	25.0	25.9	-0.9	0.0	1.8
28.5	26.1	25.9	0.2	0.0	1.8
29.2	28.8	25.9	2.9	0.1	2.0
31.4	30.3	25.9	4.4	0.2	2.1
36.6	34.0	25.9	8.1	0.3	2.5
36.3	36.4	25.9	10.5	0.4	2.9
30.7	33.5	25.9	7.6	0.3	3.2
					Maximum = 3.2

The Laguna Plant may not be able to supply the Geysers Pipeline demand at all times. This condition would require makeup water to be returned from the Meadowlane ponds. This water could be supplied by filtering water discharged from the E Pump Station and returning it to the Llano Pump Station wetwell.

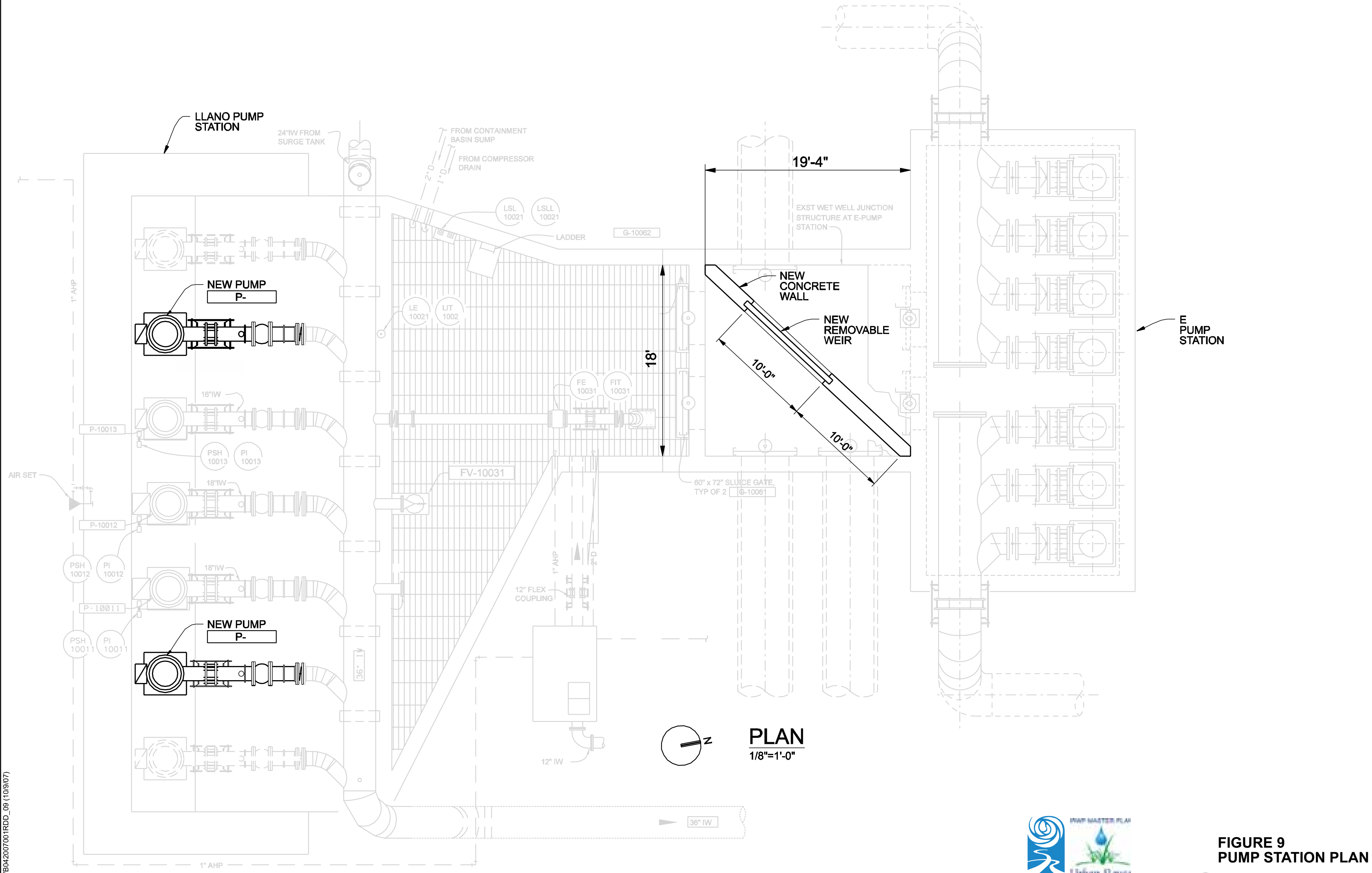

FIGURE 9
PUMP STATION PLAN

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WB042007001RDD_09 (10/9/07)

Optimization Alternatives

Two pairs of alternatives were developed for treatment, storage, and distribution to determine the combination resulting in the lowest overall capital cost. The first pair of optimization alternatives minimizes storage in the distribution system and meets a considerable portion of peak irrigation demand from the Laguna Plant. The second pair of alternatives maximizes storage in the distribution system and provides little peaking from the Laguna Plant. These alternatives are described as follows.

Alternative 1 – Minimize Distribution System Storage (locate storage at the Laguna Plant)

- 19 mgd to the Geysers Pipeline
- 14 mgd to West Santa Rosa
- 17 mgd to Rohnert Park

This alternative is illustrated schematically on Figure 10.

Alternative 1a – Minimize System Storage (locate storage at the Rohnert Park Pump Station)

- 19 mgd to the Geysers Pipeline
- 14 mgd to West Santa Rosa
- 17 mgd to Rohnert Park

This alternative is illustrated schematically on Figure 11.

Alternative 2 – Maximize System Storage (provide some peaking from the Laguna Plant)

- 19 mgd to the Geysers Pipeline
- 14 mgd to West Santa Rosa
- 10 mgd to Rohnert Park

This alternative is illustrated schematically on Figure 12.

Alternative 2a – Maximize System Storage (no peaking from the Laguna Plant)

- 19 mgd to the Geysers Pipeline
- 3 mgd to West Santa Rosa
- 12 mgd to Rohnert Park

This alternative is illustrated schematically on Figure 13.

Under Alternatives 1a and 2, demand for flow to the Geysers could exceed Plant production at times. Therefore, Figures 11 and 12 show filtration of return flow for the E Pump Station to ensure acceptable water quality.

Other alternatives were considered but resulted in larger transmission mains that would be more costly than the four main alternatives presented above.

Table 4 summarizes the analysis. Although the alternatives fall within a relatively narrow cost range of $10 million, Alternative 2 provides the least-cost solution.

The filters will generate backwash water that is high in algae content. The Laguna Plant has previously experienced difficulty removing algae when the West College Ponds are drained to the Plant at the end of the irrigation season. Therefore, disposal to the sanitary sewer is not recommended. Returning the backwash water to an irrigation pond is recommended. At the Rohnert Park Pump Station, backwash water can continue to be discharged to a nearby sewer. If filters are added at the turnout from the Geysers Pipeline near Ludwig Road, backwash water could be piped to the nearby Alpha Ponds.

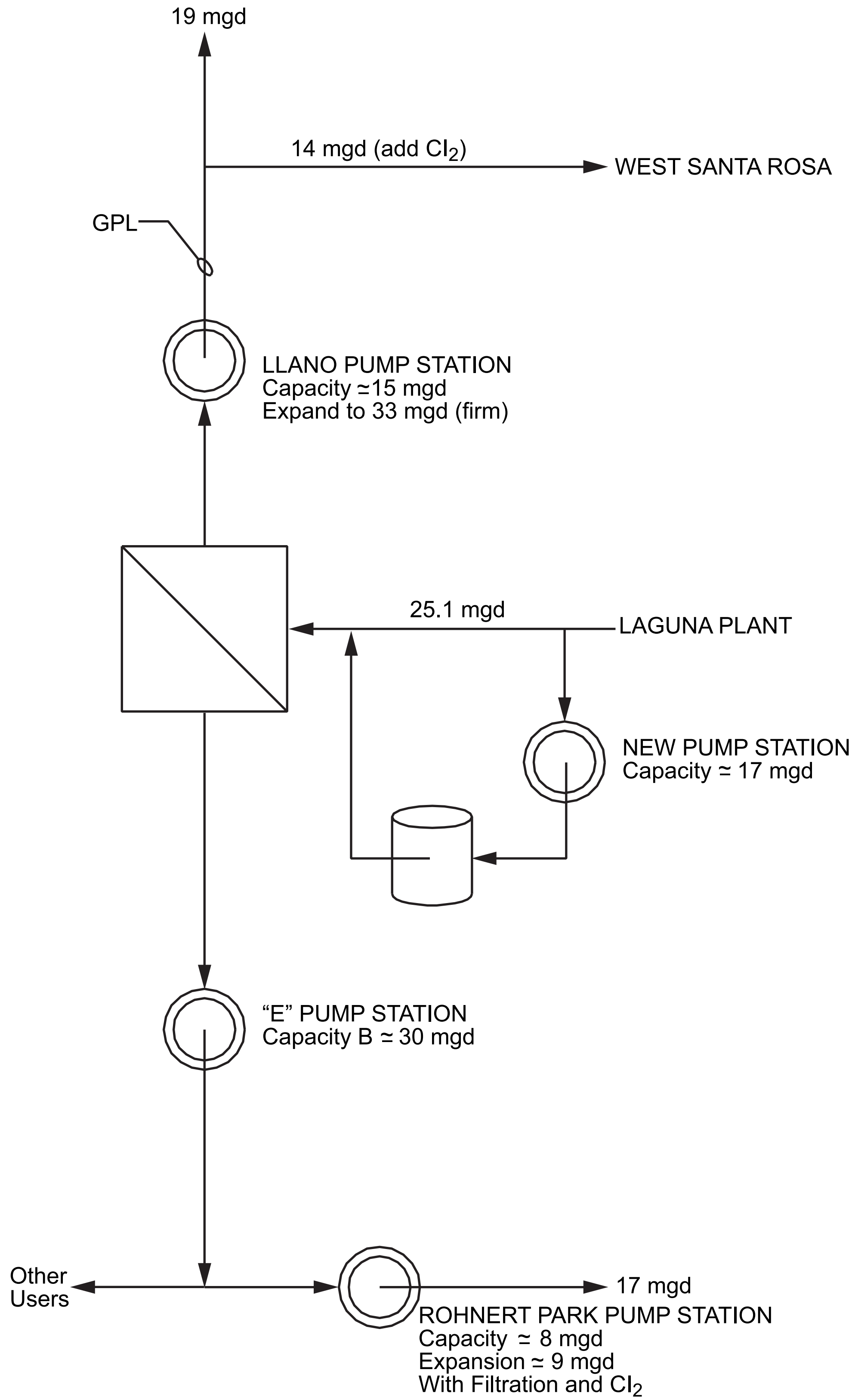

FIGURE 10
ALTERNATIVE 1
STORAGE, TREATMENT, AND DISTRIBUTION

WB042007001RDD_10 (10/9/07)

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Urban Reuse
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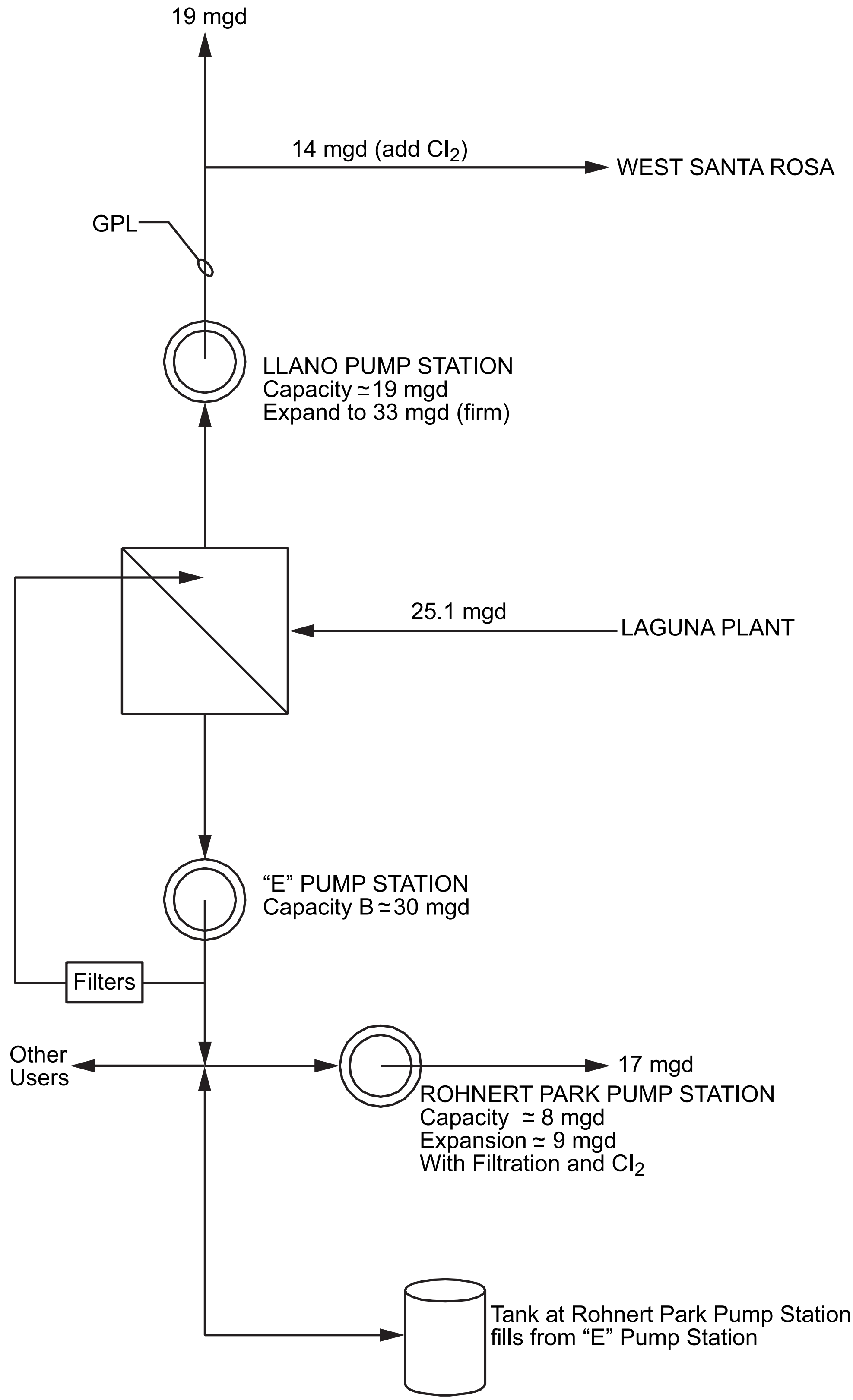

FIGURE 11
ALTERNATIVE 1a
STORAGE, TREATMENT, AND DISTRIBUTION

WB042007001RDD_11 (10/9/07)

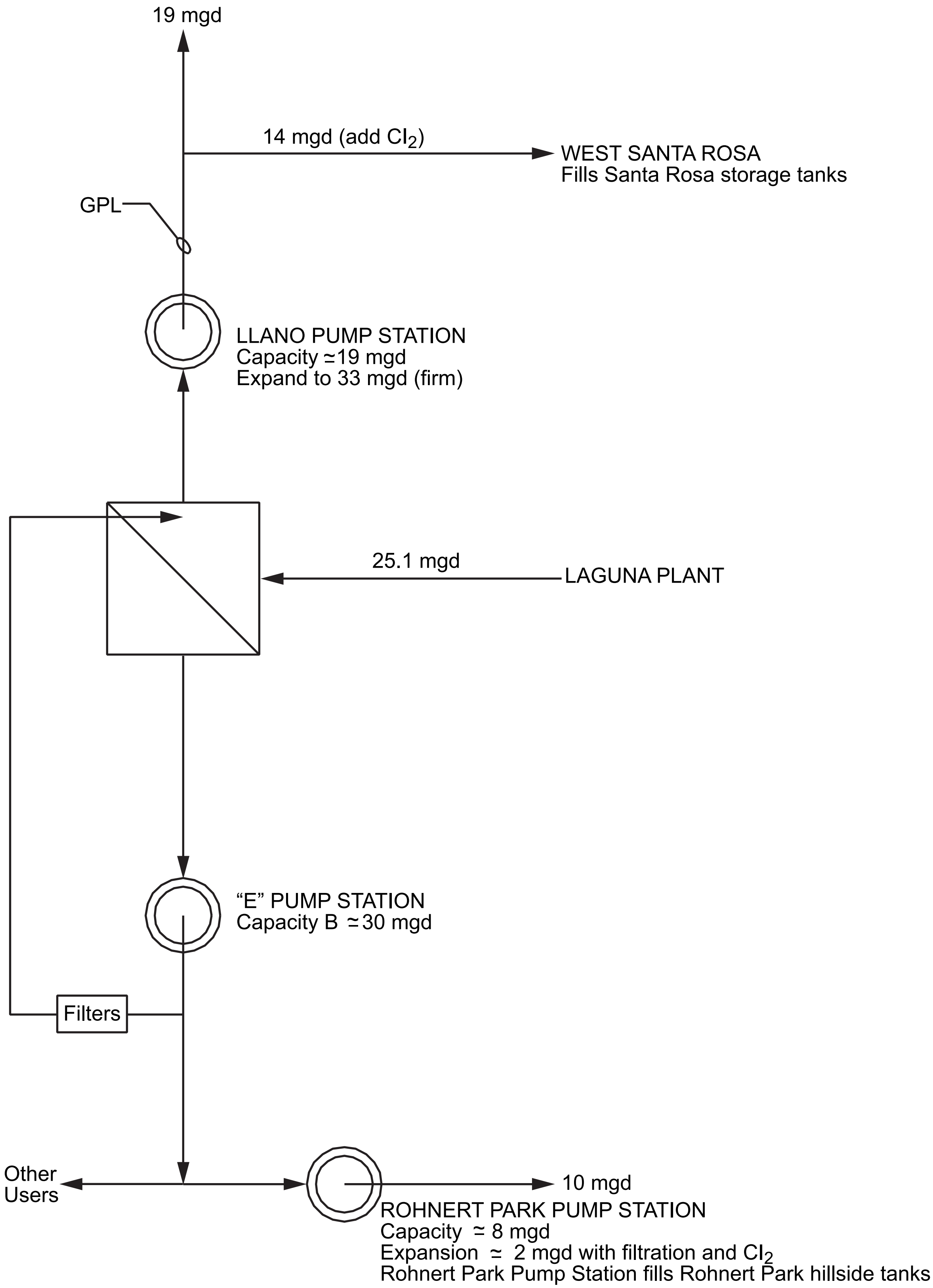

FIGURE 12
ALTERNATIVE 2
STORAGE, TREATMENT, AND DISTRIBUTION

WB042007001RDD_12 (10/9/07)

IRWP MASTER PLAN Urban Reuse

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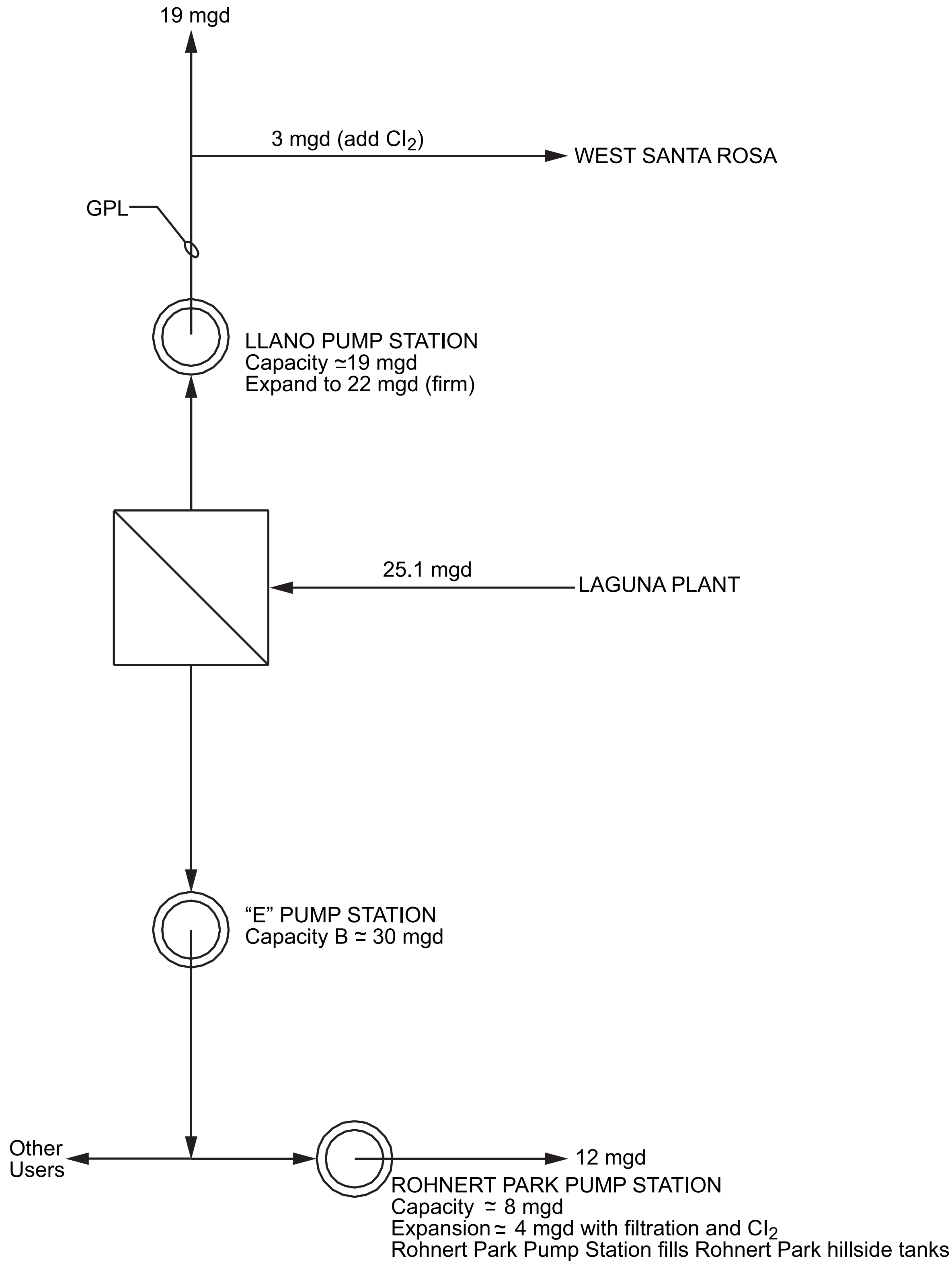

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FIGURE 13
ALTERNATIVE 2a
STORAGE, TREATMENT, AND DISTRIBUTION

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Urban Reuse
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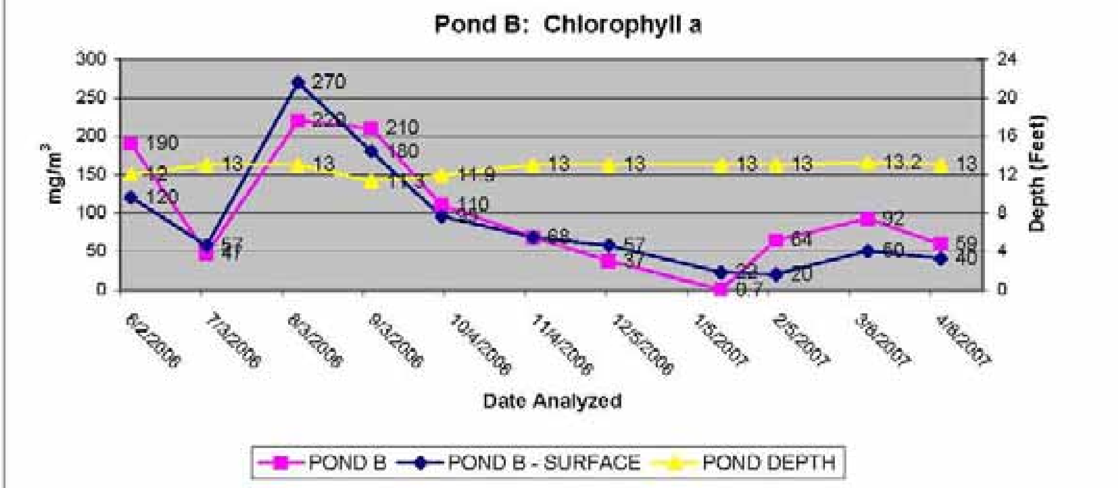
TABLE 4
Storage, Treatment, and Distribution Optimization
Santa Rosa Incremental Recycled Water Program – Water Quality and Treatment

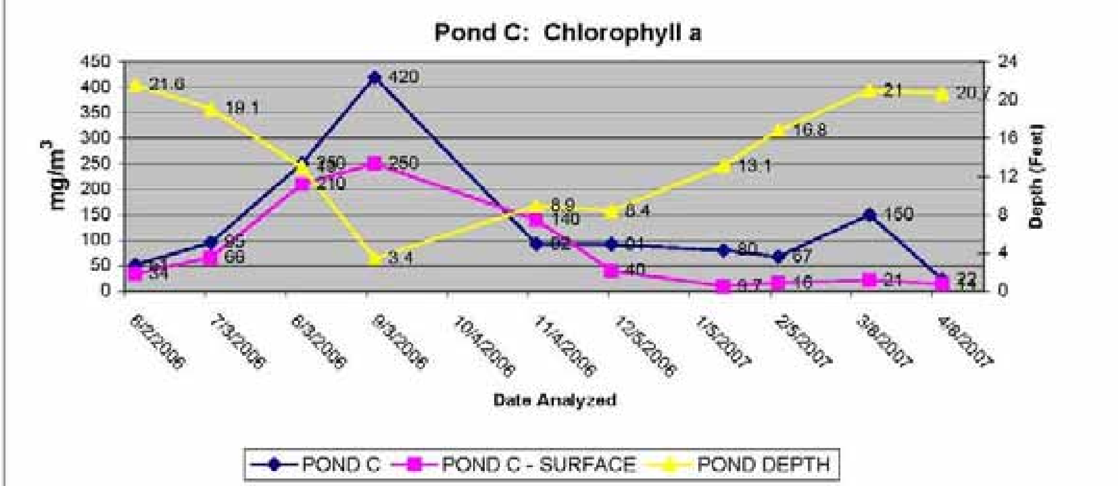
	Components/Cost																							
	Storage Volume, Location, and Cost								Treatment Type, Location, and Cost								Additional Pumping, Location, and Cost						Distribution	
Alternative/Peak Hour Scenario	**Laguna Plant**	**Cost ($M)**	**Rohnert Park Pump Station**	**Cost ($M)**	**Santa Rosa Hills**	**Cost ($M)**	**Rohnert Park Hills**	**Cost ($M)**	**Cl_2 at Ludwig**	**Cost ($M)**	**Filters at Laguna**	**Cost ($M)**	**Filters at Rohnert Park Pump Station**	**Cost ($M)**	**Cl_2 at Rohnert Park Pump Station**	**Cost ($M)**	**Laguna In-plant**	**Cost, ($M)**	**Llano Pump Station Expansion**	**Cost ($M)**	**Rohnert Park Pump Station**	**Cost ($M)**	**Cost ($M)**	**Grand Total Cost ($M)**
1. Minimize System Storage (Storage at Laguna Plant) 11 mgd to Geysers Pipeline 14 mgd to West Santa Rosa 17 mgd to Rohnert Park (Task 2)	2 tanks at 2.5 MG	5			2 tanks at 1.5 MG	3			14 mgd (2.4-mgd maximum month)	0.3			17 mgd (9-mgd expansion)	1.0	17 mgd (7-mgd maximum month)	0.7	17 mgd	0.4	14 mgd	3.5	17 mgd (9-mgd expansion)	2.3	28	**44.2**
1a. Minimize System Storage (Storage at Rohnert Park Pump Station) 11 mgd to Geysers Pipeline 14 mgd to West Santa Rosa 17 mgd to Rohnert Park (Task 3)			2 tanks at 2.5 MG	5	2 tanks at 1.5 MG	3			14 mgd (2.4-mgd maximum month)	0.3	5 mgd	0.5	17 mgd (9-mgd expansion)	1.0	17 mgd (7-mgd maximum month)	0.7			14 mgd	3.5	17 mgd (9-mgd expansion)	2.3	28	**44.3**
2. Maximize System Storage (some peaking at Laguna) 11 mgd to Geysers Pipeline 14 mgd to West Santa Rosa 10 mgd to Rohnert Park (Task 4)					2 tanks at 1.5 MG	3	2.5 MG	2.5	14 mgd (2.4-mgd maximum month)	0.3	5 mgd	0.5	10 mgd (2-mgd expansion)	0.3	14 mgd (7-mgd maximum month)	0.7			14 mgd	3.5	10 mgd (2-mgd expansion)	0.4	29	**40.4**
2a. Maximize System Storage (no peaking at Laguna) 11 mgd to Geysers Pipeline 3 mgd to West Santa Rosa 12 mgd to Rohnert Park (Task 5)					2 tanks at 3.25 MG	6.5	1.5 MG	1.5	3 mgd (2.4-mgd maximum month)	0.3			12 mgd (4-mgd expansion)	0.5	12 mgd (7-mgd maximum month)	0.7			3 mgd	0.8	12 mgd (4-mgd expansion)	0.8	37	**48.1**

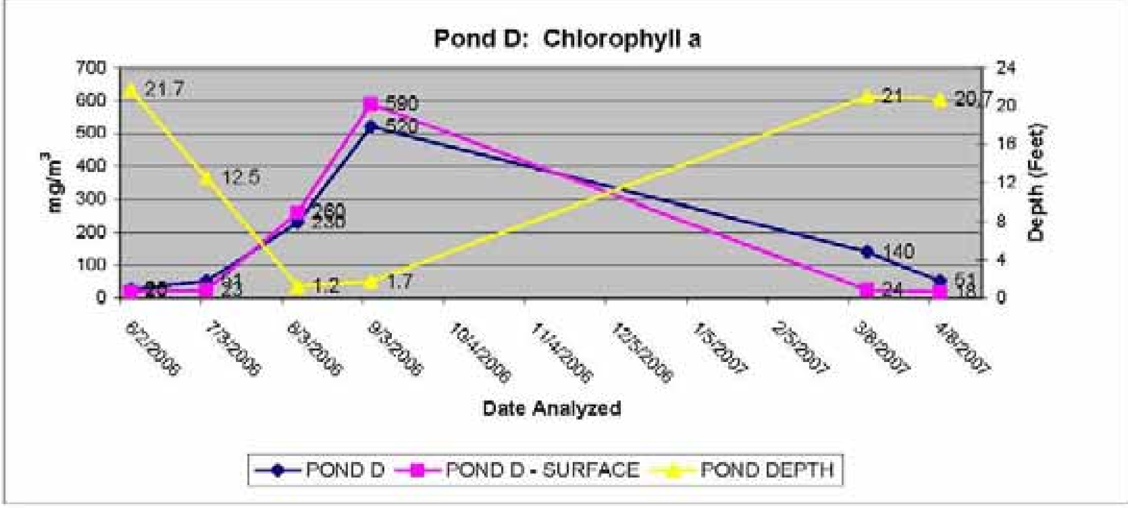
Attachment 1
Sampling Data – Ponds B, C, and D

Santa Rosa Urban Reuse - Ponds: Chlorophyll a

Comment: When Pond B reaches a depth of 13', it overflows into Pond C.

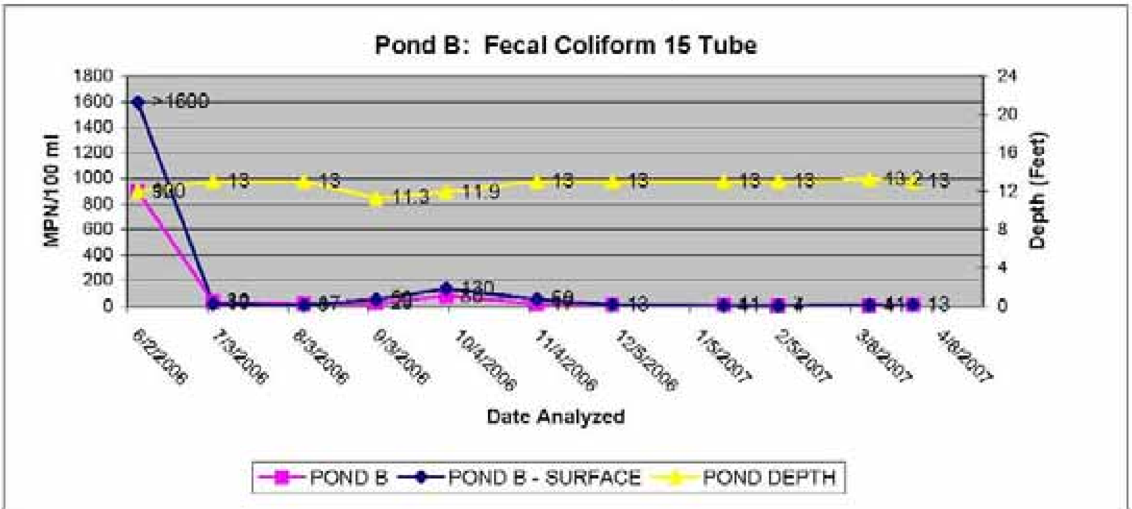


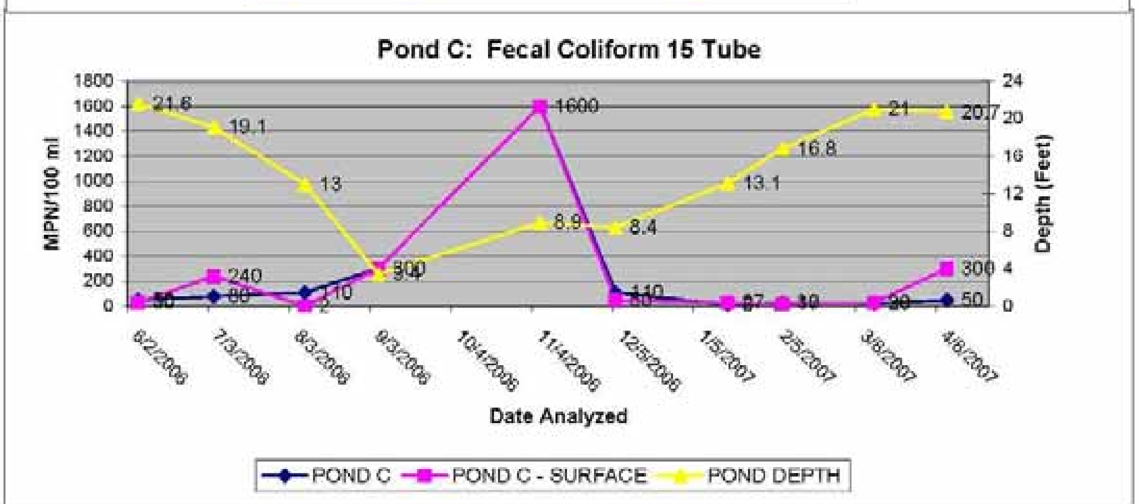


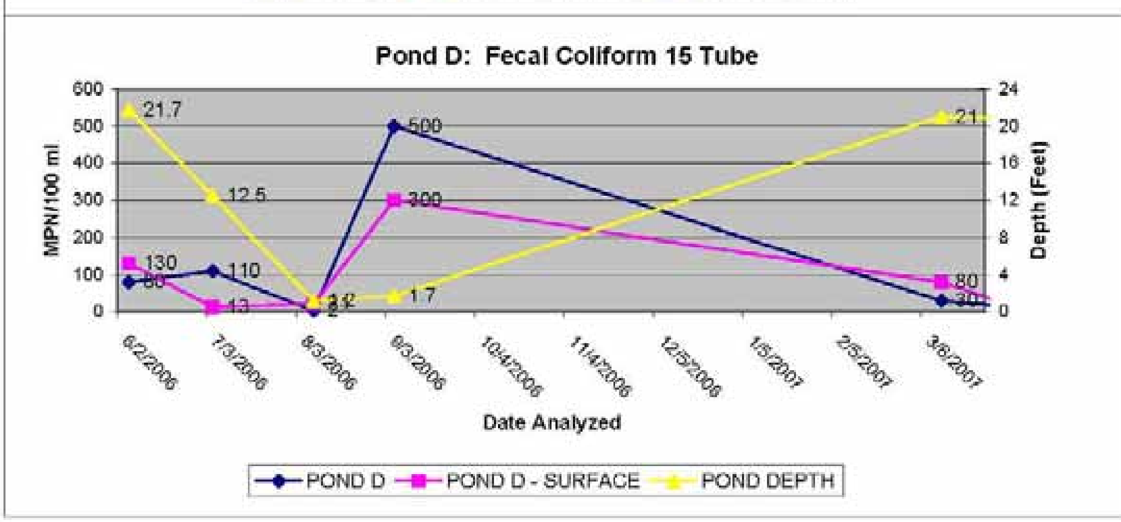


Santa Rosa Urban Reuse - Ponds: Fecal Coliform

Comment: When Pond B reaches a depth of 13', it overflows into Pond C.







Santa Rosa Urban Reuse - Ponds: Total Suspended Solids

Comment: When Pond B reaches a depth of 13', it overflows into Pond C.