Attachment 4

PHG Cost Estimate

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Table 1

Reference: 2012 ACWA PHG Survey

COST ESTIMATES FOR TREATMENT TECHNOLOGIES

(INCLUDES ANNUALIZED CAPITAL AND O&M COSTS)

No.	Treatment Technology	Source of Information	Estimated Unit Cost 2012 ACWA Survey ($/1,000 gallons treated)
1	Ion Exchange	Coachella Valley WD, for GW, to reduce Arsenic concentrations. 2011 costs.	1.84
2	Ion Exchange	City of Riverside Public Utilities, for GW, for Perchlorate treatment.	0.89
3	Ion Exchange	Carollo Engineers, anonymous utility, 2012 costs for treating GW source for Nitrates. Design souce water concentration: 88 mg/L NO_3. Design finished water concentration: 45 mg/L NO_3. Does not include concentrate disposal or land cost.	0.67
4	Granular Activated Carbon	City of Riverside Public Utilities, GW sources, for TCE, DBCP (VOC, SOC) treatment.	0.45
5	Granular Activated Carbon	Carollo Engineers, anonymous utility, 2012 costs for treating SW source for TTHMs. Design souce water concentration: 0.135 mg/L. Design finished water concentration: 0.07 mg/L. Does not include concentrate disposal or land cost.	0.32
6	Granular Activated Carbon, Liquid Phase	LADWP, Liquid Phase GAC treatment at Tujunga Well field. Costs for treating 2 wells. Treament for 1,1 DCE (VOC). 2011-2012 costs.	1.36
7	Reverse Osmosis	Carollo Engineers, anonymous utility, 2012 costs for treating GW source for Nitrates. Design souce water concentration: 88 mg/L NO_3. Design finished water concentration: 45 mg/L NO_3. Does not include concentrate disposal or land cost.	0.72
8	Packed Tower Aeration	City of Monrovia, treatment to reduce TCE, PCE concentrations. 2011-12 costs.	0.39
9	Ozonation+ Chemical addition	SCVWD, STWTP treatment plant includes chemical addition + ozone generation costs to reduce THM/HAAs concentrations. 2009-2012 costs.	0.08
10	Ozonation+ Chemical addition	SCVWD, PWTP treatment plant includes chemical addition + ozone generation costs to reduce THM/HAAs concentrations, 2009-2012 costs.	0.18

COST ESTIMATES FOR TREATMENT TECHNOLOGIES

(INCLUDES ANNUALIZED CAPITAL AND O&M COSTS)

No.	Treatment Technology	Source of Information	Estimated Unit Cost 2012 ACWA Survey ($/1,000 gallons treated)
11	Coagulation/Filtration	Soquel WD, treatment to reduce manganese concentrations in GW. 2011 costs.	0.68
12	Coagulation/Filtration Optimization	San Diego WA, costs to reduce THM/Bromate, Turbidity concentrations, raw SW a blend of State Water Project water and Colorado River water, treated at Twin Oaks Valley WTP.	0.77
13	Blending (Well)	Rancho California WD, GW blending well, 1150 gpm, to reduce fluoride concentrations.	0.64
14	Blending (Wells)	Rancho California WD, GW blending wells, to reduce arsenic concentrations, 2012 costs.	0.52
15	Blending	Rancho California WD, using MWD water to blend with GW to reduce arsenic concentrations. 2012 costs.	0.62
16	Corrosion Inhibition	Atascadero Mutual WC, corrosion inhibitor addition to control aggressive water. 2011 costs.	0.08

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Table 2

Reference: Other Agencies

COST ESTIMATES FOR TREATMENT TECHNOLOGIES

(INCLUDES ANNUALIZED CAPITAL AND O&M COSTS)

No.	Treatment Technology	Source of Information	Estimated Unit Cost 2012 Other References ($/1,000 gallons treated)
1	Reduction - Coagulation-Filtration	Reference: February 28, 2013, Final Report Chromium Removal Research, City of Glendale, CA. 100-2000 gpm. Reduce Hexavalent Chromium to 1 ppb.	$1.47 - $9.23
2	IX - Weak Base Anion Resin	Reference: February 28, 2013, Final Report Chromium Removal Research, City of Glendale, CA. 100-2000 gpm. Reduce Hexavalent Chromium to 1 ppb.	$1.50 - $6.29
3	IX	Golden State Water Co., IX w/disposable resin, 1 MGD, Perchlorate removal, built in 2010.	$0.46
4	IX	Golden State Water Co., IX w/disposable resin, 1000 gpm, perchlorate removal (Proposed; O&M estimated).	$1.00
5	IX	Golden State Water Co., IX with brine regeneration, 500 gpm for Selenium removal, built in 2007.	$6.57
6	GFO/Adsorption	Golden State Water Co., Granular Ferric Oxide Resin, Arsenic removal, 600 gpm, 2 facilities, built in 2006.	$1.72 -$1.84
7	RO	Reference: Inland Empire Utilities Agency : Chino Basin Desalter. RO cost to reduce 800 ppm TDS, 150 ppm Nitrate (as NO3); approx. 7 mgd.	$2.25
8	IX	Reference: Inland Empire Utilities Agency : Chino Basin Desalter. IX cost to reduce 150 ppm Nitrate (as NO3); approx. 2.6 mgd.	$1.25
9	Packed Tower Aeration	Reference: Inland Empire Utilities Agency : Chino Basin Desalter. PTA-VOC air stripping, typical treated flow of approx. 1.6 mgd.	$0.38

10	IX	Reference: West Valley WD Report, for Water Recycling Funding Program, for 2.88 mgd treatment facility. IX to remove Perchlorate, Perchlorate levels 6-10 ppb. 2008 costs.	$0.52 - $0.74
11	Coagulation Filtration	Reference: West Valley WD, includes capital, O&M costs for 2.88 mgd treatment facility- Layne Christensen packaged coagulation Arsenic removal system. 2009-2012 costs.	$0.34
12	FBR	Reference: West Valley WD/Envirogen design data for the O&M + actual capitol costs, 2.88 mgd fluidized bed reactor (FBR) treatment system, Perchlorate and Nitrate removal, followed by multimedia filtration & chlorination, 2012. NOTE: The capitol cost for the treatment facility for the first 2,000 gpm is $23 million annualized over 20 years with ability to expand to 4,000 gpm with minimal costs in the future. $17 million funded through state and federal grants with the remainder funded by WVWD and the City of Rialto.	$1.55 - $1.63

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Table 3

Reference: 2010 ACWA Cost of Treatment Table, Costs Revised for 2012

COST ESTIMATES FOR TREATMENT TECHNOLOGIES

(INCLUDES ANNUALIZED CAPITAL AND O&M COSTS)

No.	Treatment Technology	Source of Information	Estimated 2012* Unit Cost ($/1,000 gallons treated)
1	Granular Activated Carbon	Reference: Malcolm Pirnie estimate for California Urban Water Agencies, large surface water treatment plants treating water from the State Water Project to meet Stage 2 D/DBP and bromate regulation, 1998	0.53-1.00
2	Granular Activated Carbon	Reference: Carollo Engineers, estimate for VOC treatment (PCE), 95% removal of PCE, Oct. 1994,1900 gpm design capacity	0.24
3	Granular Activated Carbon	Reference: Carollo Engineers, est. for a large No. Calif. surf. water treatment plant (90 mgd capacity) treating water from the State Water Project, to reduce THM precursors, ENR construction cost index = 6262 (San Francisco area) - 1992	1.16
4	Granular Activated Carbon	Reference: CH2M Hill study on San Gabriel Basin, for 135 mgd central treatment facility for VOC and SOC removal by GAC, 1990	0.45-0.66
5	Granular Activated Carbon	Reference: Southern California Water Co. - actual data for "rented" GAC to remove VOCs (1,1-DCE), 1.5 mgd capacity facility, 1998	2.08
6	Granular Activated Carbon	Reference: Southern California Water Co. - actual data for permanent GAC to remove VOCs (TCE), 2.16 mgd plant capacity, 1998	1.35
7	Reverse Osmosis	Reference: Malcolm Pirnie estimate for California Urban Water Agencies, large surface water treatment plants treating water from the State Water Project to meet Stage 2 D/DBP and bromate regulation, 1998	1.56-2.99
8	Reverse Osmosis	Reference: Boyle Engineering, RO cost to reduce 1000 ppm TDS in brackish groundwater in So. Calif., 1.0 mgd plant operated at 40% of design flow, high brine line cost, May 1991	3.69
9	Reverse Osmosis	Reference: Boyle Engineering, RO cost to reduce 1000 ppm TDS in brackish groundwater in So. Calif., 1.0 mgd plant operated at 100% of design flow, high brine line cost, May 1991	2.27
10	Reverse Osmosis	Reference: Boyle Engineering, RO cost to reduce 1000 ppm TDS in brackish groundwater in So. Calif., 10.0 mgd plant operated at 40% of design flow, high brine line cost, May 1991	2.46
11	Reverse Osmosis	Reference: Boyle Engineering, RO cost to reduce 1000 ppm TDS in brackish groundwater in So. Calif., 10.0 mgd plant operated at 100% of design flow, high brine line cost, May 1991	1.90
12	Reverse Osmosis	Reference: Arsenic Removal Study, City of Scottsdale, AZ - CH2M Hill, for a 1.0 mgd plant operated at 40% of design capacity, Oct. 1991	6.17

COST ESTIMATES FOR TREATMENT TECHNOLOGIES

(INCLUDES ANNUALIZED CAPITAL AND O&M COSTS)

No.	Treatment Technology	Source of Information	Estimated 2012* Unit Cost ($/1,000 gallons treated)
13	Reverse Osmosis	Reference: Arsenic Removal Study, City of Scottsdale, AZ - CH2M Hill, for a 1.0 mgd plant operated at 100% of design capacity, Oct. 1991	3.64
14	Reverse Osmosis	Reference: Arsenic Removal Study, City of Scottsdale, AZ - CH2M Hill, for a 10.0 mgd plant operated at 40% of design capacity, Oct. 1991	2.73
15	Reverse Osmosis	Reference: Arsenic Removal Study, City of Scottsdale, AZ - CH2M Hill, for a 10.0 mgd plant operated at 100% of design capacity, Oct. 1991	1.69
16	Reverse Osmosis	Reference: CH2M Hill study on San Gabriel Basin, for 135 mgd central treatment facility with RO to remove nitrate, 1990	1.70-2.99
17	Packed Tower Aeration	Reference: Analysis of Costs for Radon Removal... (AWWARF publication), Kennedy/Jenks, for a 1.4 mgd facility operating at 40% of design capacity, Oct. 1991	0.98
18	Packed Tower Aeration	Reference: Analysis of Costs for Radon Removal... (AWWARF publication), Kennedy/Jenks, for a 14.0 mgd facility operating at 40% of design capacity, Oct. 1991	0.52
19	Packed Tower Aeration	Reference: Carollo Engineers, estimate for VOC treatment (PCE) by packed tower aeration, without off-gas treatment, O&M costs based on operation during 329 days/year at 10% downtime, 16 hr/day air stripping operation, 1900 gpm design capacity, Oct. 1994	0.26
20	Packed Tower Aeration	Reference: Carollo Engineers, for PCE treatment by Ecolo-Flo Enviro-Tower air stripping, without off-gas treatment, O&M costs based on operation during 329 days/year at 10% downtime, 16 hr/day air stripping operation, 1900 gpm design capacity, Oct. 1994	0.27
21	Packed Tower Aeration	Reference: CH2M Hill study on San Gabriel Basin, for 135 mgd central treatment facility - packed tower aeration for VOC and radon removal, 1990	0.42-0.69
22	Advanced Oxidation Processes	Reference: Carollo Engineers, estimate for VOC treatment (PCE) by UV Light, Ozone, Hydrogen Peroxide, O&M costs based on operation during 329 days/year at 10% downtime, 24 hr/day AOP operation, 1900 gpm capacity, Oct. 1994	0.51
23	Ozonation	Reference: Malcolm Pirnie estimate for CUWA, large surface water treatment plants using ozone to treat water from the State Water Project to meet Stage 2 D/DBP and bromate regulation, *Cryptosporidium* inactivation requirements,1998	0.12-0.24
24	Ion Exchange	Reference: CH2M Hill study on San Gabriel Basin, for 135 mgd central treatment facility - ion exchange to remove nitrate, 1990	0.57-0.74

Note: *Costs were adjusted from date of original estimates to present, where appropriate, using Engineering News Record (ENR) building costs index (20-city average) from Dec 2012.

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Table 4

Reference: Technical Report 6: Drinking Water Treatment for Nitrate

Nitrate Treatment Costs for California Utilities

This information was extracted from Chapter 6 of *Technical Report 6: Drinking Water Treatment for Nitrate (July 2012)*, part of a series of reports from the State Water Resources Control Board to the California Legislature. The report was prepared by Chad Seidel and Craig Gorman of Jacobs Engineering and by Vivien Jensen and Jeannie Darby of the Center for Watershed Services, University of California, Davis, and was derived from their June 2011 report to AWWA, *An Assessment of the State of Nitrate Treatment Alternatives.* The tables were created using information taken directly from *Technical Report 6*.

Treatment Cost Analysis

Cost details presented here were derived from literature, vendors, surveys, and water utilities with a specific focus on California. Factors affecting the different cost categories are as follows:

- Costs unique to each system - flow rate, source water quality, temperature, and target effluent concentration
- Waste brine disposal
- Capital costs for treatment - land, housing, piping, storage tanks, O&M equipment, process equipment, preliminary testing, permits, and training
- O&M costs - resin, media, or membrane replacement and disposal; waste residuals disposal or treatment; chemical use; repair and maintenance; power; and labor.

Costs by Treatment Type

Average total annualized costs across all system sizes surveyed were estimated for the following treatment processes:

- Reverse Osmosis (RO) – Capital $0.70/kgal; O&M $2.10/kgal – much higher for <0.5MGD
- Ion Exchange (IX) – Capital $0.50/kgal; O&M $1.35/kgal – much higher for systems <0.5MGD
- Biological Denitrification (BD) – Capital $0.60/kgal; O&M $0.50/kgal – little variation w/capacity
- Electrodialysis Reversal (EDR) – Capital $0.75/kgal; O&M $0.80/kgal

Treatment costs generally increase if multiple contaminants are treated. Higher contaminant concentrations can also increase O&M costs.

Costs by System Size

System size greatly affects treatment costs. Larger systems generally have higher capital and O&M costs, but the cost per gallon typically decreases. Treatment cost estimates by system size are shown below for IX and RO. RO treatment is usually higher than IX.

IX and RO Costs by System Size

System Size (persons served)	MGD Range	Treatment Type	Capital Cost		O&M Cost		Total Cost	
			Range	Average	Range	Average	Range	Average
Very Small (25-500)	0.009-0.17	IX	0.05-1.53	0.75	0.28-3.81	1.22	0.62-4.60	1.97
		RO	0.47-4.40	2.43	0.22-16.16	4.22	0.69-19.16	6.64
Small (501-3300)	0.17-1.09	IX	0.08-0.25	0.15	0.15-2.63	0.87	0.34-2.73	1.05
		RO	0.19-1.13	0.47	0.23-1.15	0.57	0.58-1.34	0.93
Medium (3300-10,000)	1.09-3.21	IX	0.06-0.52	0.19	0.12-1.69	0.84	0.36-2.04	1.06
		RO	0.44-0.63	0.53	0.91-2.76	1.89	1.35-3.39	2.59
Large (10,001-100,000)	3.21-30.45	IX	0.09-0.41	0.26	0.13-1.39	0.66	0.22-1.81	0.97
		RO	0.33-1.46	0.97	0.40-2.21	1.48	0.73-3.67	2.38

Disposal Costs

Disposal costs can be a significant part of O&M costs. IX uses salt for resin regeneration and produces a waste stream of spent brine solution as well as nitrate and other contaminants. RO and EDR produce concentrates of contaminants.

Brine and Concentrate Disposal

Brine and concentrate disposal can be a significant part of the O&M cost, and costs are influenced by proximity to a coastal brine line, waste brine volume, and water quality characteristics of waste brine. The presence of other contaminants can also increase disposal costs. Disposal to a hazardous waste facility may be required.

Brine or concentrate disposal methods include discharge to septic tanks and leach fields, to wastewater treatment plants through sewers or by trucking, to irrigation ponds (RO), and to a brine line. For this study, trucking and disposal costs for IX brine were approximately $0.15/gallon. O&M costs for the disposal range from $0.015 to $ 0.05/1000 gallons of treated water or from $3 to $11/1000 gallons of waste brine (high efficiency of 99.5%). The table shows costs by several brine disposal methods from a study in Arizona, but costs in California could differ because of location-specific characteristics.

	Avg. Cost by Waste or Treated Volume ($/1000 gallons)			
Disposal Method	**Annualized Capital**	**O&M**	**Total Annualized**	**Total Range**
Evaporation Ponds				
Waste	10.23	5.62	15.85	7-27
Treated	0.046	0.015	0.061	0.03–0.14
Solar Ponds				
Waste	20.48	18.80	39.27	8-80
Treated	0.063	0.047	0.110	0.07-0.20
Well Injection				
Waste	12.00	18.52	30.52	13-111
Treated	0.051	0.077	0.128	13-111
Sewer				
Waste	2.40	5.51	7.91	6-11
Treated	0.007	0.034	0.041	0.02-0.12

Resin Disposal

Because IX resin removes other contaminants, disposal at hazardous waste facilities may be required. Non-hazardous resin can be disposed in landfills. The use of regenerable resin can result in significantly lower disposal costs than brines or concentrates.

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Table 5

Reference: Final Report for Water Research Foundation Project #4359:
State-of-Science on Perchlorate Treatment Technologies and Regulations*

Table ES.1
Comparison of removal technologies for treatment of perchlorate.

Technology	Typical Influent Concentration	Pros	Cons	Water Production Costs
Ion Exchange	• 6 – 100 µg/L • >300 µg/L (bifunctional resins)	• Proven technology • Most effective and commonly used	• Generates concentrated brine stream • Performance impacted by competing anions	• $100 – 450/acre foot
Carbon Adsorption	• 60 – 80 µg/L	• Existing facilities can be used • No waste brine is generated	• Tailoring necessary for high efficiency • Limited full-scale installations	• $60 – 120/acre foot
Nanofiltration/ Reverse Osmosis	• 100 – 800 µg/L	• Multicontaminant removal	• Generates large quantity of brine • High energy consumption	• >$450/acre foot
Electrodialysis/ Electrodialysis Reversal	• 10 – 130 µg/L	• Multicontaminant removal	• Generates large quantity of brine • High energy consumption	• >$350/acre foot

- While the report contains many references and is essentially a literature review, specific references for these costs are not provided in the report
- The report does not specify a target treatment level, system size, or other assumptions for these costs.
- The report does not state whether these costs include both capital and operation and maintenance costs in total annualized costs.

* Extracted from Final Report for Water Research Foundation Project #4359:
State-of-Science on Perchlorate Treatment Technologies and Regulations

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Table 5

Reference: Final Report for Water Research Foundation Project #4359:
State-of-Science on Perchlorate Treatment Technologies and Regulations*

Table ES.2
Comparison of reduction technologies for treatment of perchlorate.

Technology	Typical Influent Concentration	Pros	Cons	Water Production Costs
Fluidized Bed Reactor (FBR)/Packed Bed Reactor (PBR)	• 8 – 10.000 µg/L	• Proven technology • Can be cost effective compared to ion exchange when influent concentration is high	• Acclimation of microorganisms • Public acceptance	• $90 – 360/acre foot
Membrane Biofilm Reactor (MBfR)	• 50 – 1.000 µg/L	• No waste brine is generated	• Reactor efficiency • Still under development	• $300 – 1.000/acre foot
In situ Bioremediation (ISB)	• < 500.000 µg/L	• Treats high levels of perchlorate	• Time consuming • Efficiency depends on nutrient availability	• <$2500/acre foot
Permeable Reactive Barrier (PRB)	• <10.000 µg/L	• Treats high levels of perchlorate	• Time consuming • Efficiency depends on nutrient availability	• $130 – 210 /acre foot

* Extracted from Final Report for Water Research Foundation Project #4359:
State-of-Science on Perchlorate Treatment Technologies and Regulations

Attachment 5

PHG Acronyms

Public Health Goal Report Acronyms:

ACWA	Association of California Water Agencies
BAT	Best Available Technology
CCR	Consumer Confidence Report on Water Quality
CDPH	California Department of Public Health
Cr (VI)	Chromium VI
cis-1,2-DCE	cis-1,2-Dichloroethylene
CTC	Carbon Tetrachloride
DLR	Detection Level for the Purposes of Reporting
GA	Gross Alpha
GAC	Granular Activated Carbon
IX	Ion Exchange
LCR	Lead and Copper Rule
LGAC	Liquefied Granular Activated Carbon
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg/L	milligrams per liter
MHTS	Monk Hill Treatment System
MWD	Metropolitan Water District of Southern California
OEHHA	California EPA Office of Environmental Health Hazard Assessment
O&M	Operation and Maintenance
PCE	Tetrachloroethylene
PHG	Public Health Goal
pCi/L	picoCuries per liter
PAT	Packed Aeration Tower
RO	Reverse Osmosis
TCE	Trichloroethylene
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound