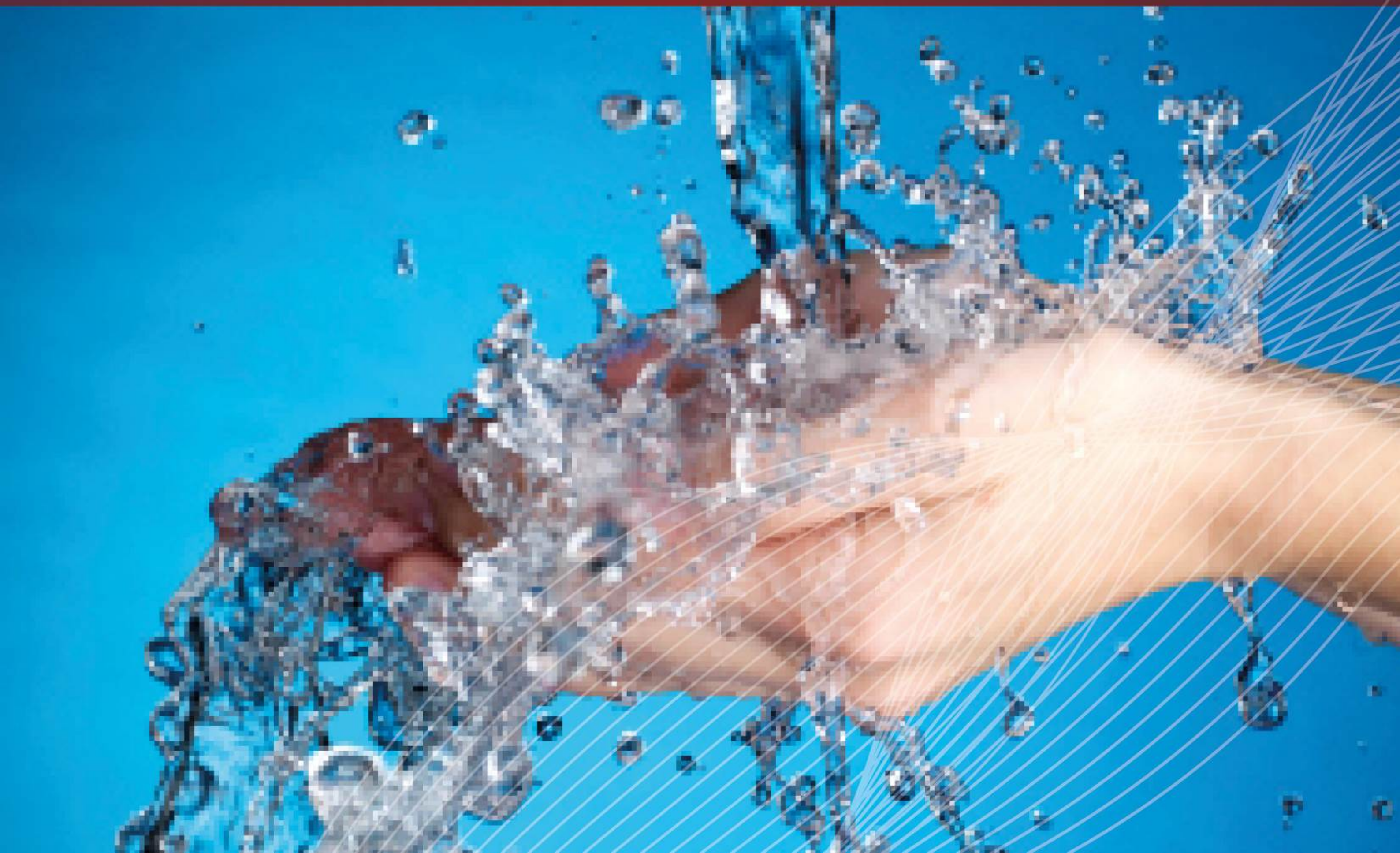
Australian Water Recycling
Centre of Excellence

Project Report
Global Potable Reuse Case Study 1: Orange County GWRS

A report of a study funded by the
Australian Water Recycling Centre of Excellence

University of New South Wales, November, 2014



Global Potable Reuse Case Study 1: Orange County GWRS

This report has been prepared as part of the National Demonstration Education and Engagement Program (NDEEP). This Program has developed a suite of high quality, evidence-based information, tools and engagement strategies that can be used by the water industry when considering water recycling for drinking purposes. The products are fully integrated and can be used at different phases of project development commencing at "just thinking about water recycling for drinking water purposes as an option" to "nearly implemented". The information contained in this Case Study was first published on the Public Health pages of a University of New South Wales Wiki website in 2012.

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About the Australian Water Recycling Centre of Excellence

The mission of the Australian Water Recycling Centre of Excellence is to enhance management and use of water recycling through industry partnerships, build capacity and capability within the recycled water industry, and promote water recycling as a socially, environmentally and economically sustainable option for future water security.

The Australian Government has provided $20 million to the Centre through its National Urban Water and Desalination Plan to support applied research and development projects which meet water recycling challenges for Australia's irrigation, urban development, food processing, heavy industry and water utility sectors. This funding has levered an additional $40 million investment from more than 80 private and public organisations, in Australia and overseas.

ISBN: 978-1-922202-37-6

Citation:

Onyango, L., Leslie, G. and Wood, J.G. (2014). *Global Potable Reuse Case Study 1: Orange County GWRS*, Australian Water Recycling Centre of Excellence, Brisbane, Australia.

Date of publication: November, 2014

Publisher:
Australian Water Recycling Centre of Excellence
Level 5, 200 Creek St, Brisbane, Queensland 4000

www.australianwaterrecycling.com.au

This report was funded by the Australian Water Recycling Centre of Excellence through the Australian Government's National Urban Water and Desalination Plan.

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1. Scheme overview

Background

Around 1965, the Orange County Sanitation District (OCSD) began operating its first secondary treatment process unit - a trickling filter - to treat municipal wastewater. Initial studies assessing the post-injection water quality, using a pilot injection well and secondary effluent, quickly revealed that additional (tertiary) treatment would be necessary to avoid septic conditions in the aquifer, plus the dispersion and mixing in the subsurface alone was insufficient to dilute the mineral content of the reclaimed water.

Figure 1: Orange County is located close to Los Angeles, California, USA.

Pilot testing

OCSD and the Orange County Water District (OCWD) partnered to fund the **Water Factory 21** (WF 21) project. Various combinations of treatments were tested during the pilot testing phase that lasted ~5 years. In 1971, the district committed to build WF 21 which went **online in 1976** with the purified water being used as a seawater intrusion barrier. At the same time, a flash-distillation ocean desalination unit was constructed with federal government assistance to provide demineralized blend water prior to injection. However, the federal government pulled funding for the desalination facility in 1976, after less than a year in operation. In 1977, WF 21 incorporated RO in its water purification system as the blend water alternative to the cancelled desalination project. Deep-well groundwater was blended to the purified water prior to injection into the seawater barrier. WF 21 operated three major treatment components following tertiary pre-treatment: RO, GAC, and deep wells, each with 5 million gallons per day (mgd) capacity.

The operations at WF 21 helped pave the way for future developments and expansion of the Ground Water Replenishment System (GWRS) by functioning as the long-term pilot testing plant. The following analyses were performed over the years:

- In the 1980s, chemical and pathogen removal associated with carbon adsorption and RO was tested as well as various tests on new types of membranes;
- In the 1990s, MF pilot testing performed to replace lime clarification / recarbonation / filtration process before RO or carbon treatment; and
- In the early 2000s, carbon treatment was ended, and UV and AOX treatments were added post RO to WF 21.

Ground Water Replenishment System (GWRS)

During the mid-1990s, OCWD faced several challenges that prompted thought into the expansion of the WF 21 plant. These drivers included:

- **Severe drought** and projected future droughts for the region;
- Threat of **seawater intrusion;**
- Rising **population growth and demand;** and
- Increased **costs** associated with **water transportation.**

During 2004-2006, a 5 mgd demonstration plant using advanced treatments was instituted at WF 21. In **2008**, over 30 years after WF 21 began operation, the GWRS took its place as the **largest advanced water purification facility** of its kind with an estimated design and expanded barrier and pipeline cost of **US$481 million**. The plant produces **70 million gallons** of purified water per day, whose quality exceeds both state and federal drinking water standards for its **planned IPR**. This capacity provides enough drinking water for **600,000** residents in OCWD service region, injected into the subsurface to protect the basin from seawater intrusion, provides water for industrial consumers, and is used for aquifer recharge (Kraemer-Miller-Miraloma-La Palma Basins). The plant has received 36 international, national, and state awards. [1] [2]

Further information on the Orange County GWRS can be found on the Global Connections Map on the *Water360* website.

2. Scheme infrastructure

Operational Monitoring

The GWRS's operational permit is based on USEPA and State of California standards. To manage the operations at the GWRS, there are operators every 12hr shift, instrument and electrical technicians, maintenance technicians and process and control experts. Operations at the GWRS are monitored by an online Supervisory Control and Data Acquisition (SCADA) system that tracks the operational performance of each process unit, an Operation, Monitoring and Maintenance Plan (OMMP) which incorporates the use of critical control points (CCP), and automated sampling. For maintenance, the GWRS utilizes a Computerised Maintenance Management System (CMMS) to automatically schedule and track progress of all maintenance work which is performed during scheduled plant shutdown. Additionally, the scheme also monitors for flow changes that would affect processes for which there have been **no significant seasonal variations** to impact the GWRS operations so far.

GWRS is regularly **audited by the California Regional Water Quality Control Board** (CRWQCB) regulatory staff who perform random inspections (on average **3/yr**). Additionally, the operations of the GWRS are independently monitored by an **advisory panel** appointed and administered by the National Water Research Institute (NWRI). This panel consists of a range of experts in the water industry who provide ongoing advice and guidance to the operations of the GWRS.

Treatment & Multiple Barriers

The GWRS project receives highly treated **domestic and commercial** wastewater as its source water. Source control standards are dictated by their operational permit and approved by the CRWQCB. The GWRS adapts a comprehensive **13-step multiple barrier system** from source to tap. These include: source control, enhanced primary treatment, secondary treatment, low-level chlorination (combined), advanced treatment, decarbonation, lime addition, injection or surface recharge, subsurface retention (3 months minimum) with groundwater water quality monitoring, disinfection post well-extraction, and periodic water quality monitoring at potable supply wells.

Industrial waste is collected and treated separately at OCSD's **Plant No.2**. Most industrial dischargers in the service area are approved and issued permits by OCSD which they must comply with as part of a National Pretreatment Program (NPP). As such, these dischargers are required to have best available technology installed to treat their industrial wastes before discharging into the sewer. The dischargers must meet federal, state, and local requirements before discharge. Effluent is released as ocean outfall.

At the OCWD's GWRS Advanced Water Purification Facility (AWPF), secondary treated wastewater is strained and sodium hypochlorite added to prevent biofouling on the MF membranes. This process is then followed by advanced treatment steps: MF; RO; UV disinfection with hydrogen peroxide (AOX); and Decarbonation and lime stabilization (Figure 2).

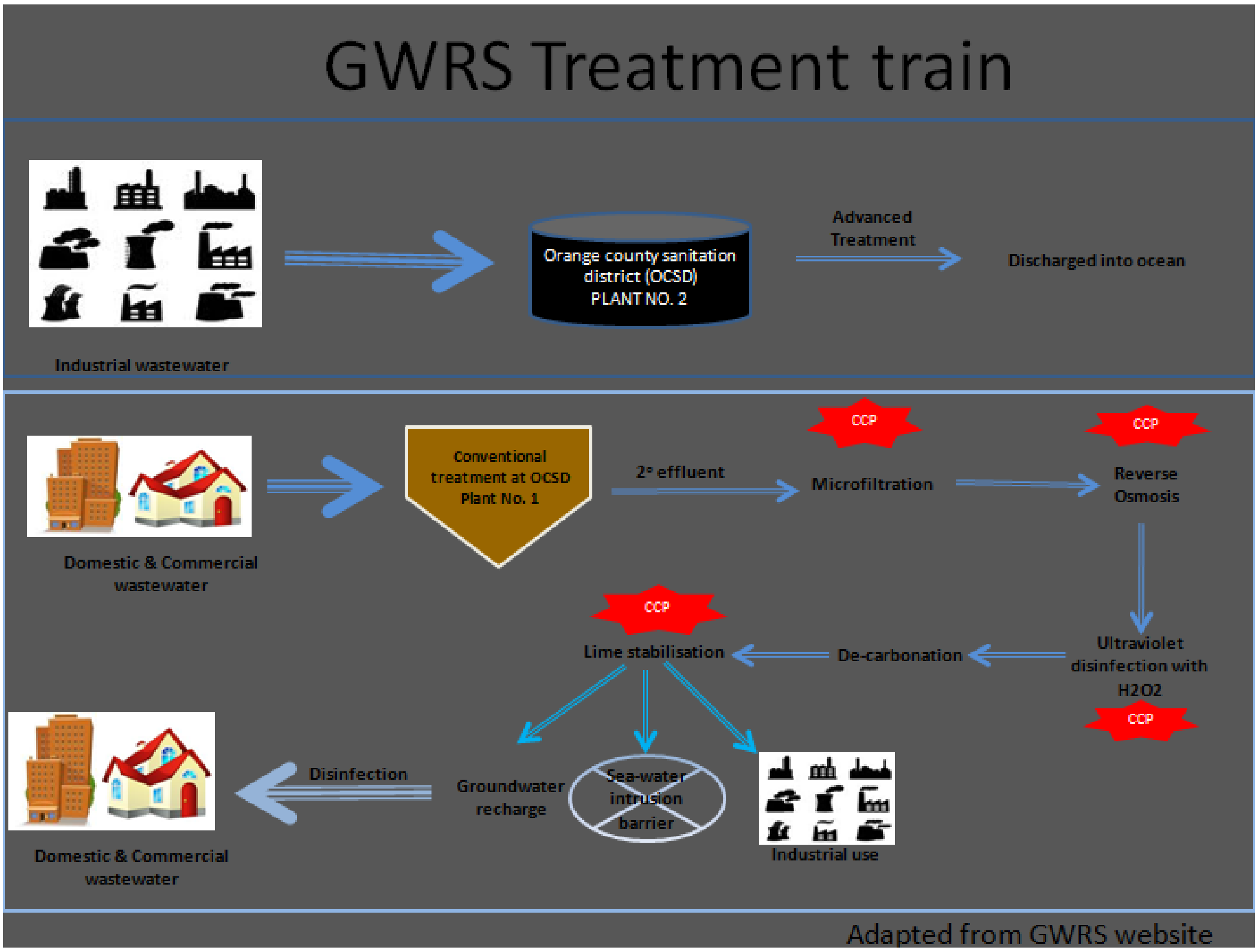

Figure 2: Ground Water Replenishment System treatment train.

3. Water Quality & Public Health

The GWRS was approved using the draft regulations (at the time) and a review by an independent advisory panel which was a requirement by the California Department of Public Health (CDPH). The panel continues to advise operations of the GWRS. Currently, the GWRS collaborates with the State Water Resources Control Board (Division of Drinking Water (DDW)) in assessing and preventing health risks associated with potable reuse.

The GWRS has a number of continuously-monitored, **online CCPs** that help ensure water quality and reliability. The operating permit also has a number of water quality limits and monitoring requirements which help mitigate risks and protect public health. A selected list of CCP and laboratory WQ parameters are monitored to ensure the GWRS does not violate its permit requirements. If these aren't met, the GWRS is permitted to confirm the result before the plant can go into shutdown. Processes resume only after parameters are met. These incidents are all reported to the CRWQCB in summary reports. In the event water quality is compromised post-injection, the GWRS has a comprehensive contingency plan to protect consumers' health. The steps include:

Well owners informed if monitoring wells indicate a threat to public health;

- Affected wells shut off and alternative water supply used (e.g., imported surface water or another unaffected well) at the expense of the OCWD;
- Well-head treatments are implemented (for prolonged incidents of water quality interruptions).

Assessments of Water Quality

Additionally, the on-site laboratory monitors samples collected from intermediate points within the scheme, final product water (FPW), as well as the receiving groundwater which is also reviewed to ensure the scheme is meeting the water quality requirements contained within their permit. Water produced at the GWRS is approved by two institutions:

- California Department of Public Health; and
- California Regional Water Quality Control Board.

The GWRS is monitored for **>500** individual parameters for the FPW. A summary of some of their key parameters and those of public health relevance is presented in Table 1.

Table 1: Summary of key parameters monitored at the Orange County Groundwater Replenishment System.

Water Quality Category	Parameter
Aesthetic characteristics	Turbidity
	Colour
	Conductivity
	pH
	Total hardness
Chemical components	Fluoride
	Nitrate
	Sulphate
	Total trihalomethanes
	EDTA
	NDMA
Metals	Aluminium
	Iron
	Manganese
	Zinc
Microbiological indicators	Total Coliform (Mult. Tube Fermentation)
	Fecal Coliform (Mult. Tube Fermentation

More detailed WQ data for the GWRS for the past 5 years (2008-2012) has also been captured (Table 2).

Table 2: Orange County Groundwater Replenishment System (GWRS) water quality data 2008-2012.

Parameter	Unit	Secondary Effluent †					Finished Product Water					Permit Limit
		2008	2009	2010	2011	2012	2008	2009	2010	2011	2012	
Microbiological indicators												
Total Coliform (Mult. Tube Fermentation)	MPN/100 mL	1,387,959	1,633,010	857,048	335,657	252,165	<2	<2	<2	<2	0.20[4]	2.2
Fecal Coliform (Mult. Tube Fermentation)	MPN/100 mL	514,694	532,663	355,962	108.771	107,455	<2	<2	<2	<2	0.20[4]	N/A
Aesthetic characteristics												
Electrical Conductivity	um/cm	1660.71	1649.83	1,559.24	1,502.53[1]	1,476.96	80.96	88.72[1]	81.91[1]	79.89[1]	82.41[1]	900
Total Dissolved Solids	mg/L	919.7	949.77	1,015.57	955.19	901.18	40.01	45.37	42.93	43.24	44.55	500[2]
Suspended Solids	mg/L	6.41	8.94	9.84	7.32	7.96	na	na	na	na	na	N/A
Turbidity	NTU	2.94	3.43	2.84	2.27	2.28	0.18	0.156[1]	0.101[1]	0.070[1]	0.085[1]	≤0.2/≤0.5
Ultraviolet percent transmittance @254nm	%	na	na	na	na	na	98.8	99.4	na	na	na	>90
pH	Units	7.69	7.63	7.39	7.45	7.34	8.22	8.59[1]	8.36[1]	7.64[1]	7.78[1]	6 - 9
Total Hardness (as CaCO3)	mg/L	289.75	317.17	315.17	312.75	300.5	22.92	24.61	22.8	21.42	20.92	240[2]
Nutrients												
Nitrate Nitrogen	mg/L	1.08	2.79	9.69	9.21	9.01	0.18	0.35	0.93	0.99	1.22	3[2]
Nitrite Nitrogen	mg/L	0.3	0.57	0.37	0.52	0.59	0.06	0.06	0.03	0.03	0.04	1[2]
Ammonia Nitrogen	mg/L	24.71	20.53	2.22	2.36	3.62	1.35	1.24	0.3	0.33	0.43	N/A
Organic Nitrogen	mg/L	1.98	2.26	0.92	0.73	0.51	<0.1	0.08	<0.1	0.02	0.05	N/A
Total Nitrogen	mg/L	27.94	25.79	12.8	12.35	13.59	1.67	1.75	1.26	1.36	1.74	5
Phosphate Phosphorus	mg/L	0.79	0.57	0.3	0.32	0.7	<0.01	<0.01	<0.01	<0.01	<0.01	N/A
Macroelements												
Calcium	mg/L	78.41	84.64	82.2	78.69	76.85	8.86	9.69	9.42	8.73	8.08	N/A
Magnesium	mg/L	22.83	25.88	26.68	28.23	26.43	<1	<1	<0.1	<0.1	<0.1	N/A
Sodium	mg/L	207.92	217.83	215.42	203.33	197.08	6.18	6.48	6.55	6.5	8.06	45
Potassium	mg/L	16.99	17.34	16.93	16.8	17	0.4	0.36	0.43	0.38	0.64	N/A
Bromide	mg/L	na	na	na	na	na	<0.1	<1	<0.1	<0.1	0.01	N/A
Chloride	mg/L	241.08	258.08	237.92	230.33	246.58	3.62	4.75	4.41	5.23	6.65	55
Sulfate	mg/L	226.33	231.42	240.83	213	205.75	<0.5	<0.5	<0.5	0.33	0.46	100
Hydrogen Peroxide	mg/L	na	na	na	na	na	1.99	2.51	2.42	2.29	2.3	N/A
Bicarbonate (as CaCO3)	mg/L	na	na	na	na	na	31.02	34.73	28.06	26.25	25.6	N/A
Iron	µg/L	247.89	451.25	508.92	276	415.08	7.24	2.98	<1	0.65	0.76	300

Manganese	µg/L	47.38	42.13	35.63	34.22	47.46	<1	<1	<1	<1	<1	50
Aluminum	µg/L	18.52	18.55	17.56	11.87	23.31	4.6	7.27	1.78	2.6	2.5	200[2]
Arsenic	µg/L	1.35	1.58	<1	0.18	1.23	<1	<1	<1	<1	<1	10
Barium	µg/L	22.92	27.21	32.69	29.66	30.98	<1	<1	<1	<1	<1	1,000
Boron	µg/L	0.39	0.37	0.4	0.37	0.38	0.25	0.23	0.23	0.22	0.26	N/A
Cadmium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	5
Chromium	µg/L	<1	<1	<1	0.34	0.26	<1	<1	<1	<1	<1	50
Copper	µg/L	6.78	5.88	4.94	4.14	5.83	<1	<1	<1	<1	<1	1,000[2]
Cyanide	µg/L	9.03	9.3[3]	1.8	0.91	<5	<5	<5	<5	<5	<5	150
Fluoride	µg/L	0.83	0.93	0.92	0.93	0.89	<0.1	<0.1	<0.1	,0.1	<0.1	2
Lead	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	15
Mercury	µg/L	0.33	0.35	0.28	0.16	0.18	<0.1	<0.1	<0.1	<0.1	<0.1	2
Nickel	µg/L	8	6.94	4.58	5	8.51	<1	<1	<1	<1	<1	100
Perchlorate	µg/L	na	na	na	na	na	na	na	<2.5	<2.5	<2.5	6
Selenium	µg/L	2.39	2.58	2.23	1.6	1.86	<1	<1	<1	<1	<1	50
Silica	µg/L	21.29	22.18	21.13	21.21	21.43	<1	<1	<1	0.4	0.56	N/A
Silver	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	100
Zinc	µg/L	24.08	20.07	28.23	23.1	25.28	1.13	0.78	<1	<1	0.98	5,000
Disinfection by products											
N-nitrosodimethylamine	ng/L	31.1	49.42	18.97	11.95	99.66	<2	<2	2.31	0.66	2.17	N/A
1,4-Dioxane	µg/L	1.42	2.19	2.27	3.47	5.63	<1	<1	<1	<1	0.12	N/A
Total Trihalomethanes	µg/L	na	na	na	na	na	0.18	0.14	1.62	0.7	1.27	80
Dibromoacetic Acid	µg/L	na	na	na	na	na	<1	<1	<1	<1	<1	60,total HAA5
Dichloroacetic Acid	µg/L	na	na	na	na	na	<1	<1	<1	<1	<1	60,total HAA5
Monobromoacetic Acid	µg/L	na	na	na	na	na	<1	<1	<1	<1	<1	60,total HAA5
Monochloroacetic Acid	µg/L	na	na	na	na	na	<1	<1	<1	<1	<1	60,total HAA5
Trichloroacetic Acid	µg/L	na	na	na	na	na	<1	<1	<1	<1	<1	60,total HAA5
Other compounds											
Apparent Color (unfiltered)	Units	na	na	na	na	na	<3	<3	<3	<3	<3	15
Total Organic Carbon (unfiltered)	mg/L	14.08	13.59	10.63	9.96	9.48	0.19	0.19	0.16	0.16	0.14	0.5[2]
Surfactants (MBAS)	mg/L	0.23	0.2	0.27	0.23	0.19	<0.02	<0.02	<0.02	<0.02	<0.02	0.5

Note:

† Secondary Effluent figures refer to the untreated inflow to the potable reuse system.

4. Health effects of potable reuse

In the mid 1990's the CDPH and the panel considered conducting an epidemiological study for the GWRS to investigate health effects of potable reuse in the population based on a recommendation in the National Academy of Science report [3]. Despite these discussions, the study was never performed. It was decided that such a study would not have been sensitive enough to identify health effects from the groundwater recharge project due to **population mobility** and **complexities of groundwater movement** [4].

Other epidemiological studies performed in the Los Angeles County area (Montebello Forebay studies) showed no correlation between reclaimed water use and increase in birth defects, cancer reports, mortality, infectious disease or any other significant health effects. Use of reclaimed water was considered as safe as other traditional water sources for the parameters tested [5] [6] [7] [8]. Nonetheless, the GWRS has reported **no water-borne outbreaks** in the region from potable reuse and no consumer complaints impacting wells or incidents requiring consumer notification.

5. Public Education & Engagement

- Initial public outreach implemented 10 years prior to implementation of WF 21
- Target audience included local, state and federal elected officials; business and civic leaders; health experts; environmental advocates; regulatory agencies; media and the general public
- The OCWD manages the ongoing outreach campaign for the GWRS
- Public access to facility via guided tours
- On-going public education on water issues via online 'H20 university'
- Multilingual website includes interactive forms
- Monthly corporate newsletters sent out
- The GWRS follows media coverage of other proposed water reclamation facilities and engages with agencies to provide assistance
- On-going research and laboratory water quality data reports are made publicly available
- Panel's peer review reports are also made publicly available
- Monthly, quarterly and yearly audit reports available
- The GWRS has a crisis management protocol in place to handle consumer complaints, but has not had any consumer complaints impacting wells or adverse incidents requiring consumer notification.

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