DIRECT POTABLE REUSE: THE TIME IS NOW

III Conferencia Panamericana de Sistemas de Humedales para el Tratamiento y Mejoramiento de la Calidad del Agua

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DISCUSSION TOPICS

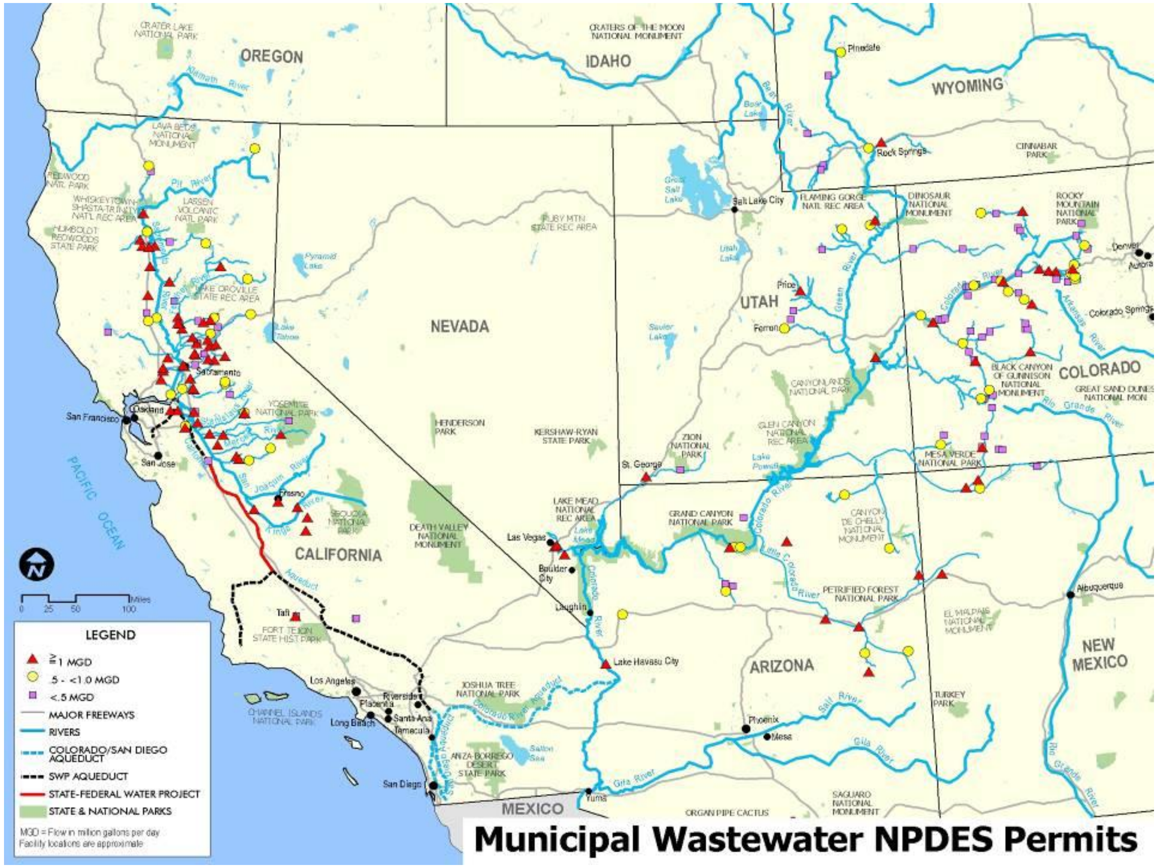
What is direct potable reuse
Key elements of a DPR program
Information sources for DPR
A historical perspective
Some issues that may impact IPR and DPR
Trends in advanced treatment technologies
A case study in DPR
The future

WHAT IS POTABLE REUSE?

- What are the different types of potable reuse?
  - ✓ *de facto* indirect potable reuse (*df*-IPR)
  - ✓ Indirect potable reuse (IPR)
  - ✓ Direct potable reuse (DPR)
- Technologies for IPR and DPR?
- What are the cost and energy implications?
- What are the driving forces for IPR and DPR
- Where does potable reuse fit in the water portfolio

OVERVIEW: DE FACTO INDIRECT POTABLE REUSE

The downstream use of surface water as a source of drinking water that is subject to upstream wastewater discharges.

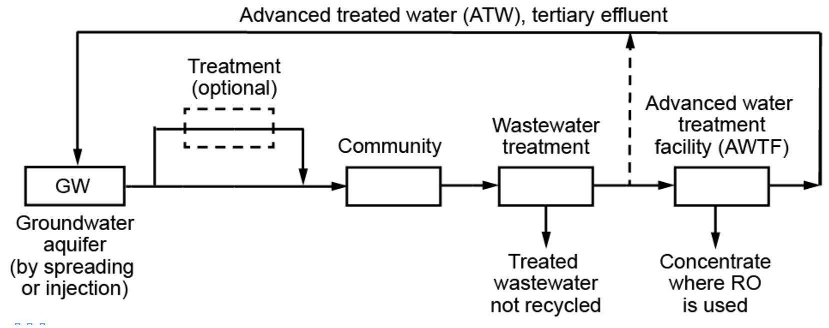


Courtesy City of San Diego

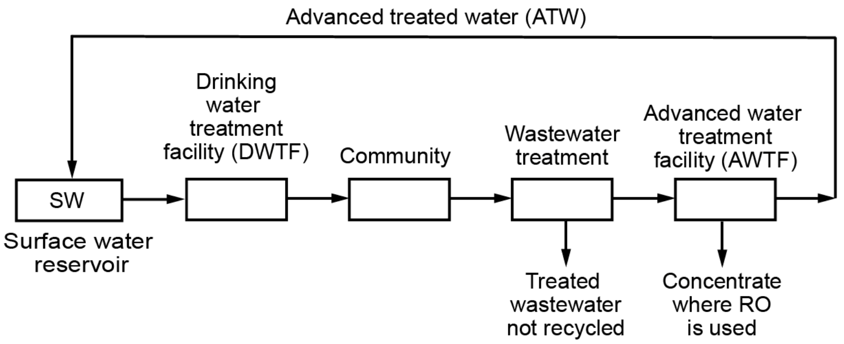
ALLEN HAZEN (1914)
"CLEAN WATER AND HOW TO GET IT"

"Looking at the whole matter as one great engineering problem, it is clear and unmistakably better to purify the water supplies taken from rivers than to purify the sewage before it is discharged into them. It is very much cheaper to do it this way. The volume to be handled is less and the per million gallons the cost of purifying water is much less than the cost of purifying sewage."

OVERVIEW: INDIRECT POTABLE REUSE

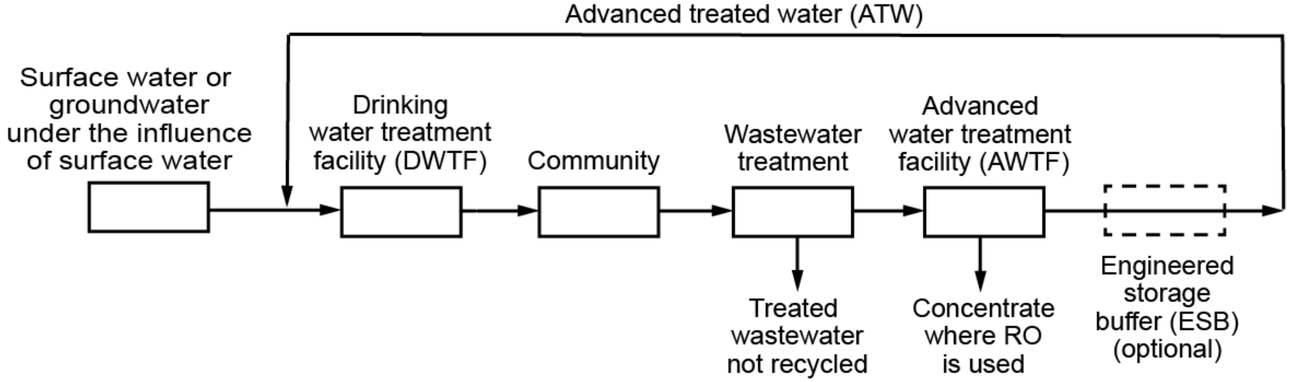


Typical injection well - OCWD

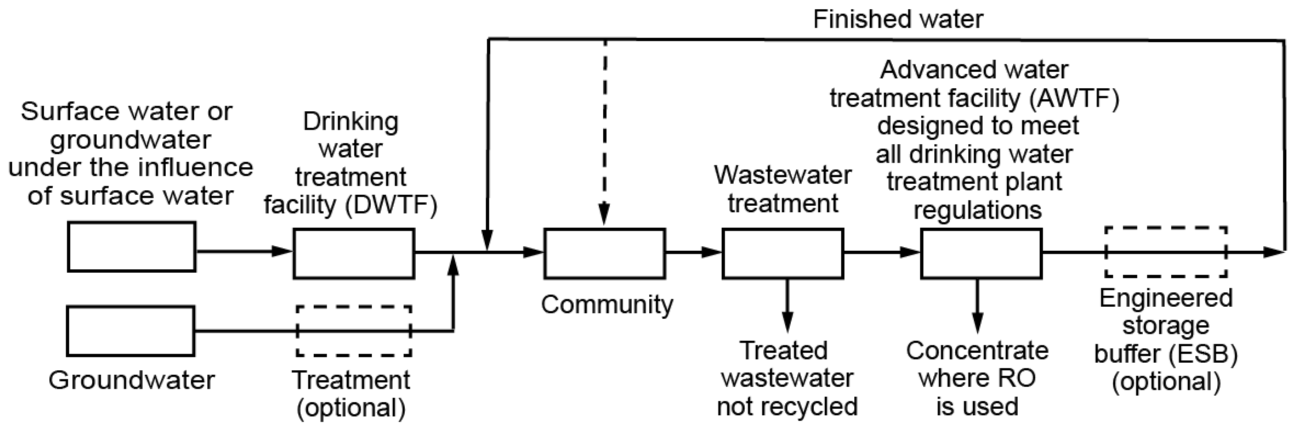


San Vicente reservoir, San Diego, CA

OVERVIEW: DIRECT POTABLE REUSE

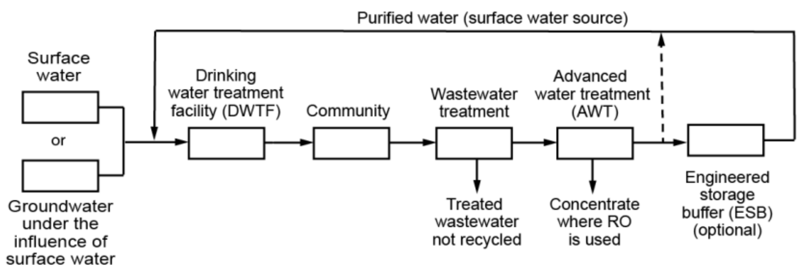


DPR with *Advanced Treated Water (ATW)*

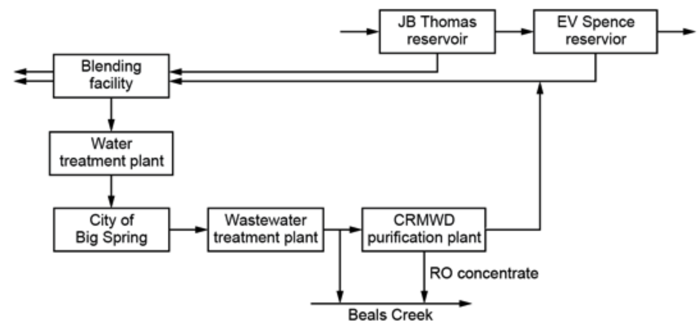


DPR with *Finished Water*

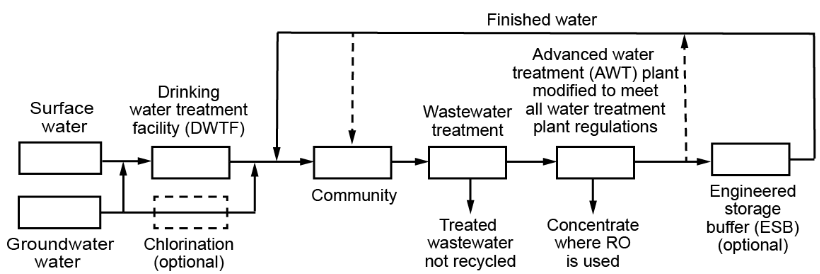
OVERVIEW: DIRECT POTABLE REUSE



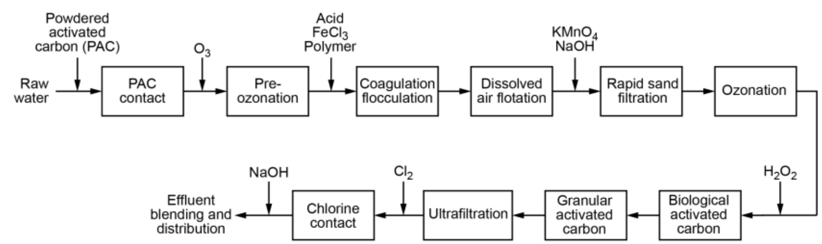
DPR with *purified* water



Big Spring, Texas

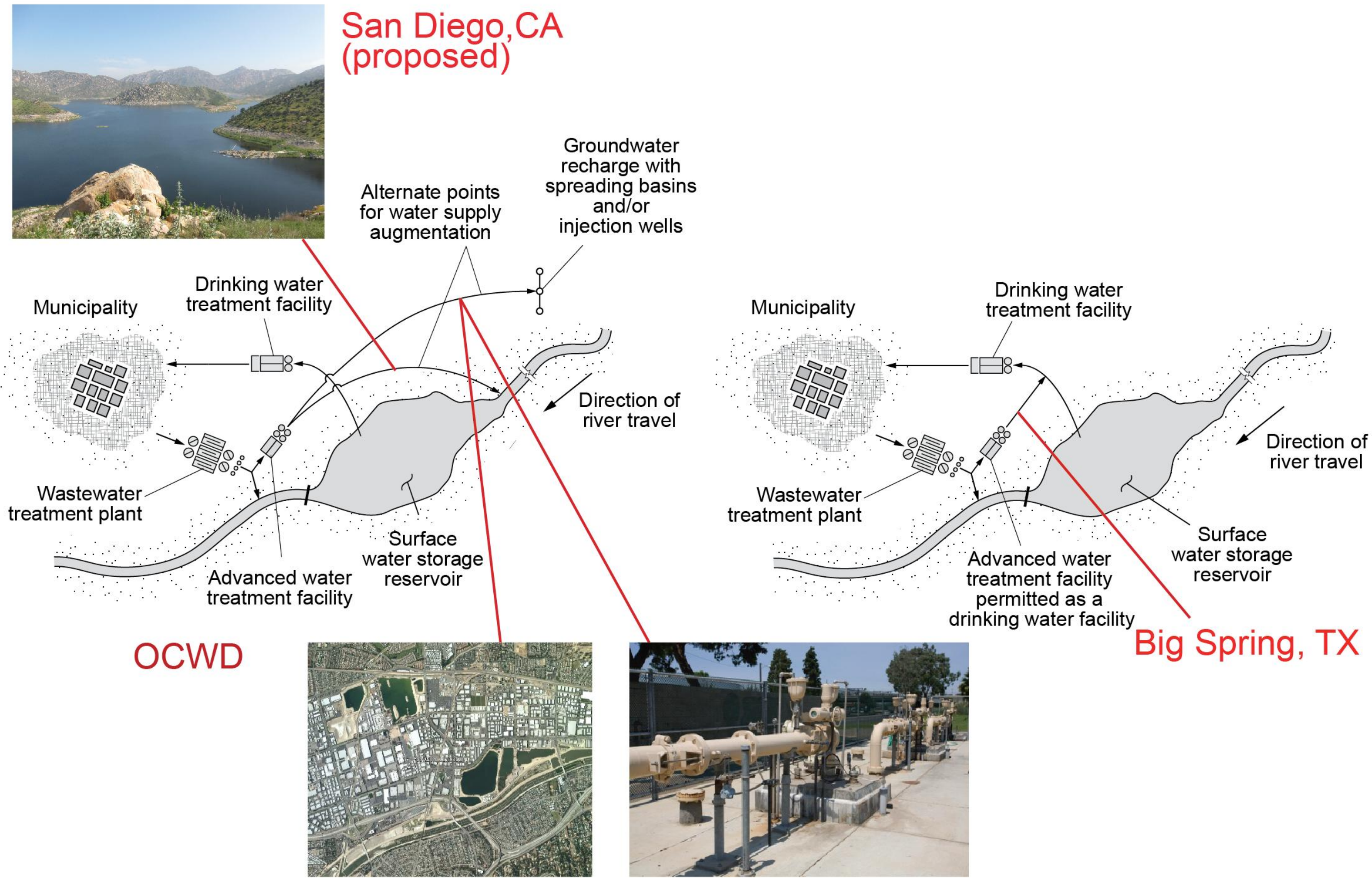


DPR with *finished* water

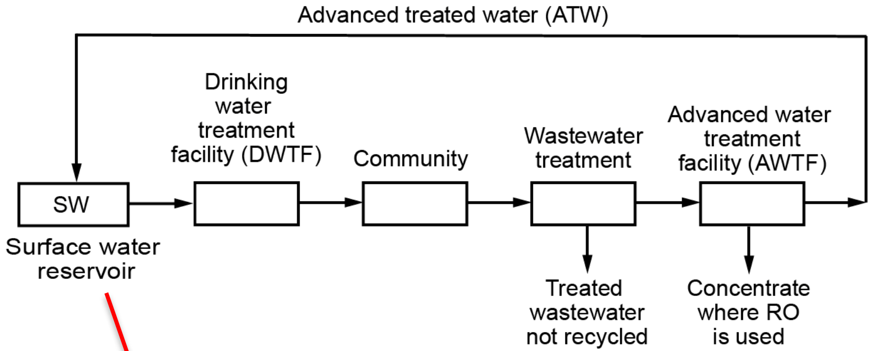


Windhoek, Namibia

PICTORIAL VIEW OF IPR AND DPR

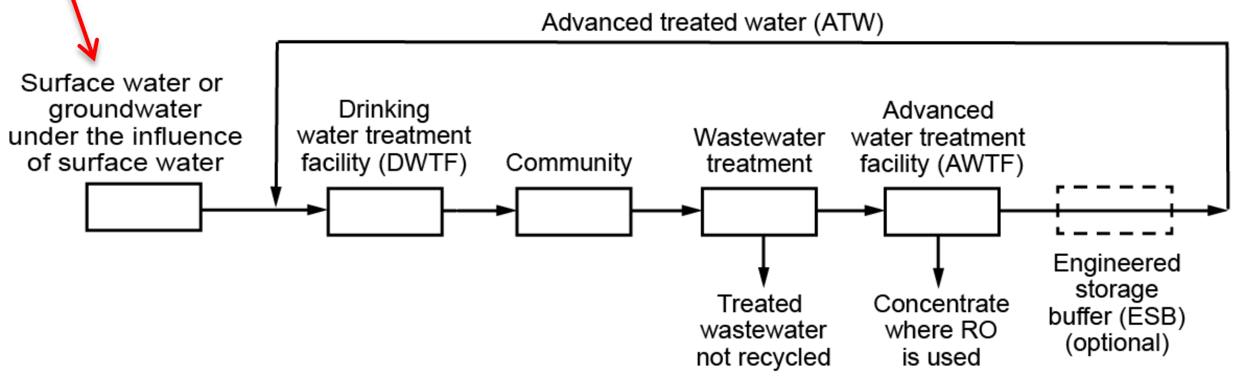


INDIRECT VERSUS DIRECT POTABLE REUSE



Indirect potable reuse (IPR)

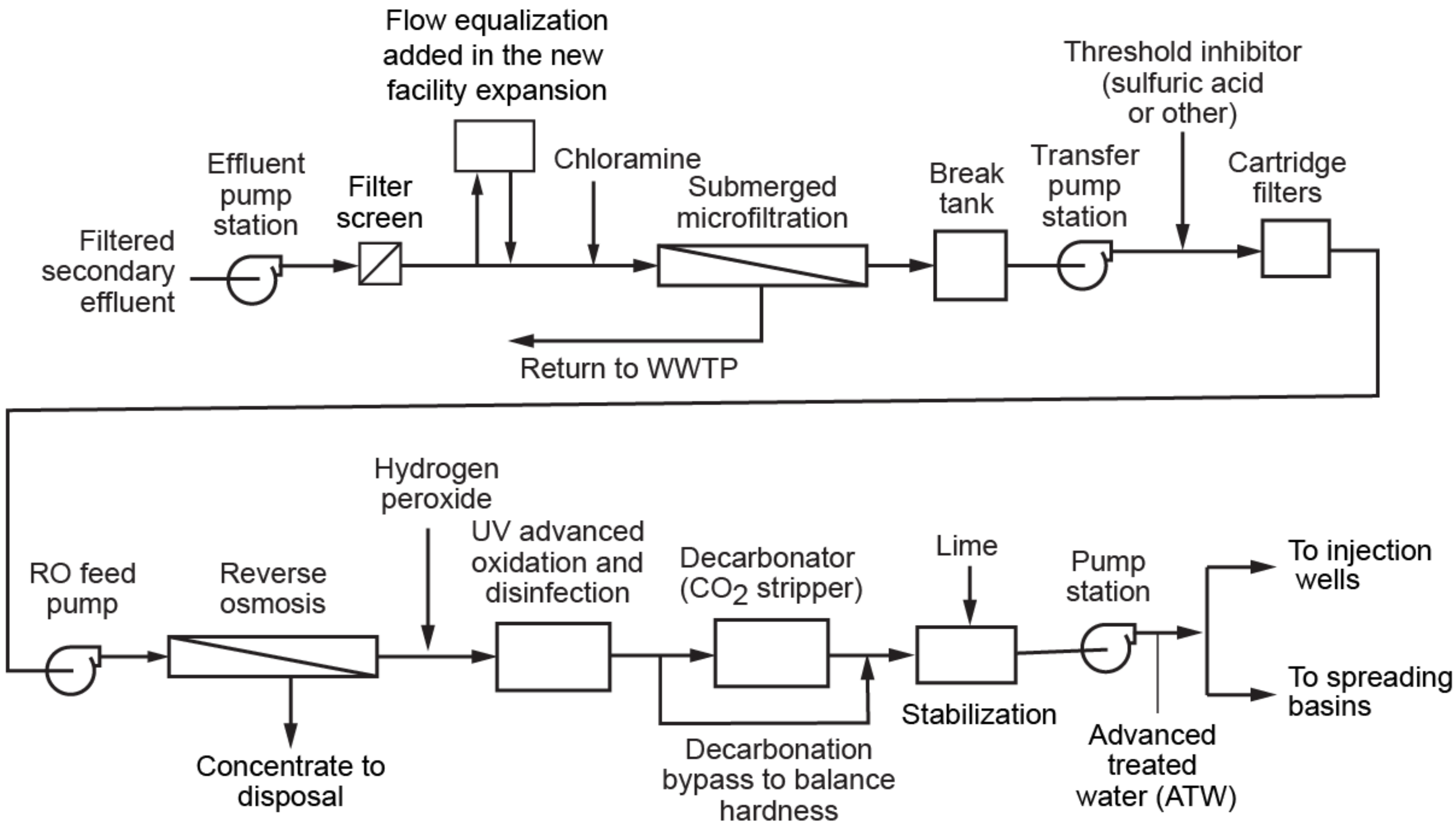
San Vicente reservoir, San Diego, CA



Direct potable reuse (DPR)

At what point does IPR becomes DPR, as the reservoir becomes smaller

TECHNOLOGIES FOR THE INDIRECT AND DIRECT POTABLE REUSE



Adapted from OCWD

WHAT DOES DPR COST?

Supply option	Cost, $/10³ gal ($/AF) Treatment	Residuals management	RO concentrate management	Conveyance facilities
ATW with RO	2.10 – 2.76 (685 – 900)	0.03 – 0.15 (10 – 50)	0.21 – 2.38 (70 – 775)	0.31 – 3.07 (100 – 1,000)
ATW without RO	1.23 – 2.15 (400 –700)	0.03 – 0.15 (10 – 50)	n.a.	0.31 – 3.07 (100 – 1,000)
Brackish groundwater desalination (inland)	2.76 – 3.84 (900 – 1,250)	0.06 – 0.31 (20 – 100)	0.21 – 2.15 (70 – 700)	0.92 – 6.14 (300 – 2,000)
Seawater desalination	5.52 – 6.44 (1,800 – 2,100)	0.06 – 0.31 (20 – 100)	0.31 – 0.61 (100 – 200)	1.23 – 9.21 (400 – 3,000)
Retail cost of treated imported surface water	1.23 – 3.99 (400 – 1,300)		n.a.	0.31 – 1.84 (100 – 600)
Water use efficiency, conservation, and use restrictions	1.38 – 2.92 (450 – 950)			0.31 – 1 .23 (100 – 400)

Note: $/10³ gal x 325.89 = $/AF

DPR ENERGY USAGE

Technology/water source	Energy required: Range, kWh/10^3 gal	Energy required: Typical kWh/10^3 gal	Energy required: Typical kWh/m^3	Carbon footprint kg $CO_{2e}/10^3$ gal
Secondary treatment without nutrient removal	1.35 – 1.05	1.25	0.33	0.63
Tertiary treatment with nutrient removal effluent filtration	1.95 – 1.60	1.85	0.49	0.93
Advanced water treatment	3.25 – 3.50	3.30	0.87	1.65
Ocean desalination	9.50 – 14.75	12.00	3.17	6.00
Brackish water desalination	3.10 – 6.20	5.85	1.55	2.93
Interbasin transfer of water, California State Water Project	7.92 – 9.92	9.20	2.43	4.60
Interbasin transfer of water, Colorado River water	6.15 – 7.40	6.15	1.62	3.07
Conventional water treatment	0.30 – 0.40	0.37	0.10	0.19
Membrane-based water treatment	1.00 -1.50	1.25	0.33	0.63

Note: kWh/10^3 gal x 325.89 = kWh/AF

DRIVING FORCES FOR IPR AND DPR

- The value of water will increase significantly in the future (and dramatically in some locations)
- De facto indirect potable reuse is largely unregulated (e.g., secondary effluent, ag runoff, urban stormwater, highway runoff, etc.)
- Population growth and global warming will lead to severe water shortages in many locations. A reliable alternative supply should be developed
- Existing and new technologies can meet the water quality challenge
- Infrastructure requirements limit reuse opportunities
- Stringent environmental regulations

WHERE DOES POTABLE REUSE FIT IN THE WATER PORTFOLIO?

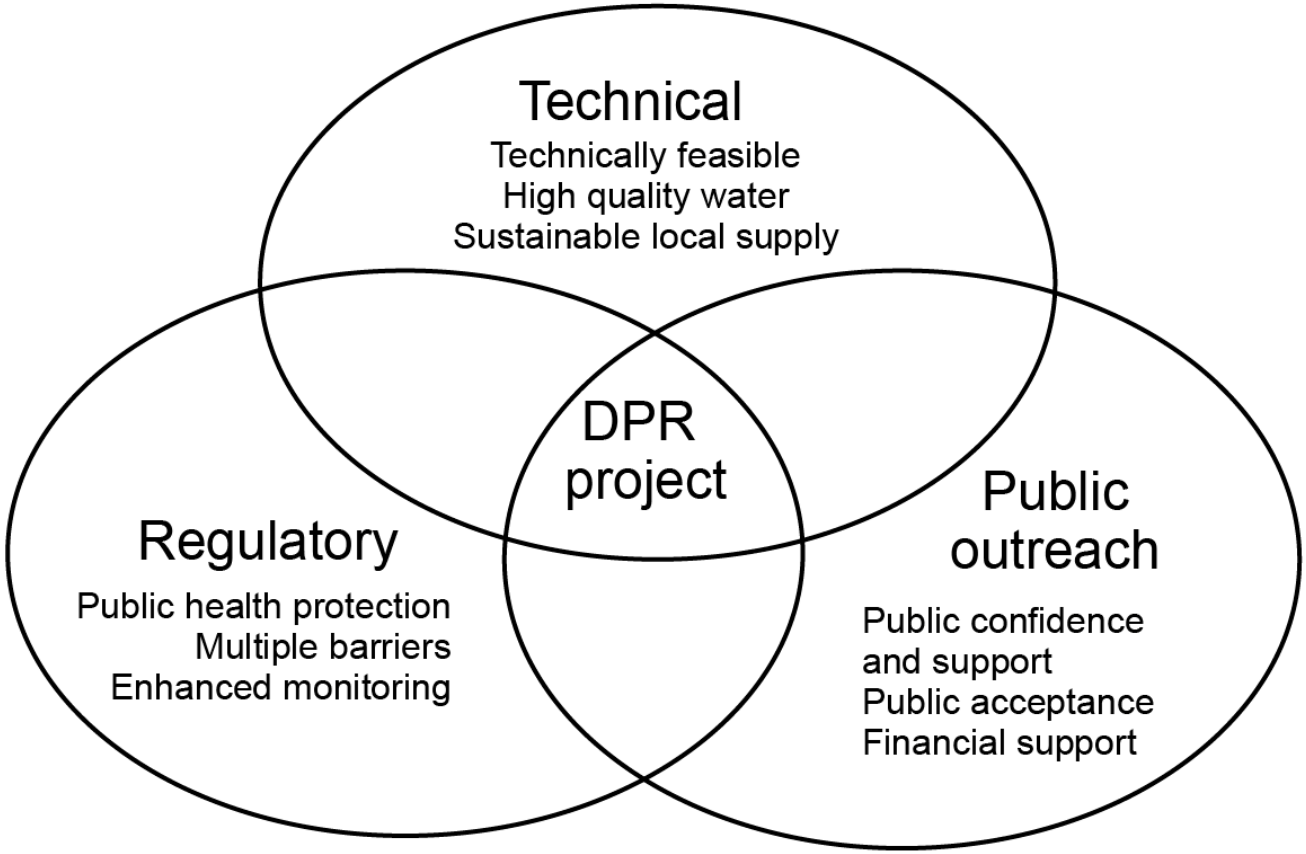
WATER SOURCES

- Local surface water
- Local groundwater
- Imported water
- Potable reuse (DPR and IPR)
- Desalination (brackish and sea water)
- Stormwater (?)

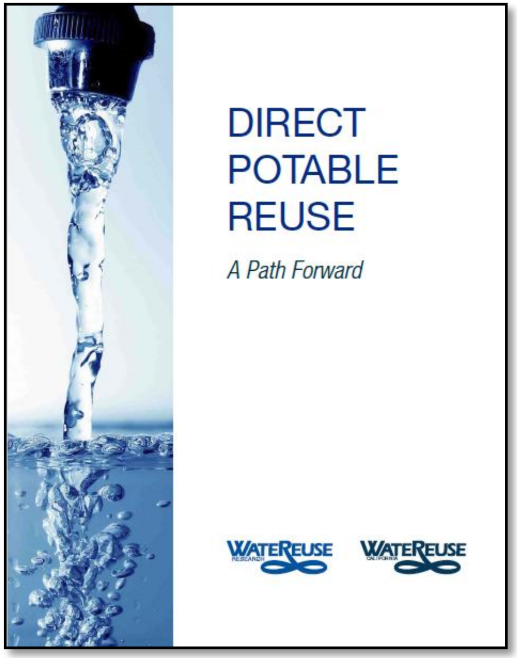
OTHER MEASURES

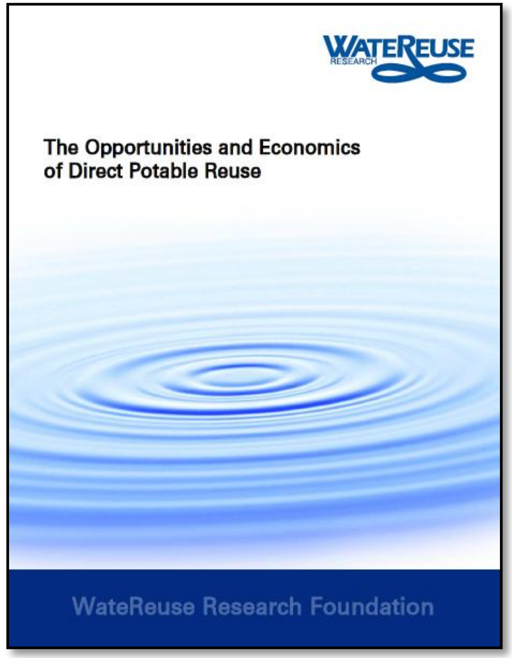
- Centralized non-potable reuse (e.g., purple pipe)
- Decentralized non-potable reuse (e.g.,greywater)
- Conservation and curtailments

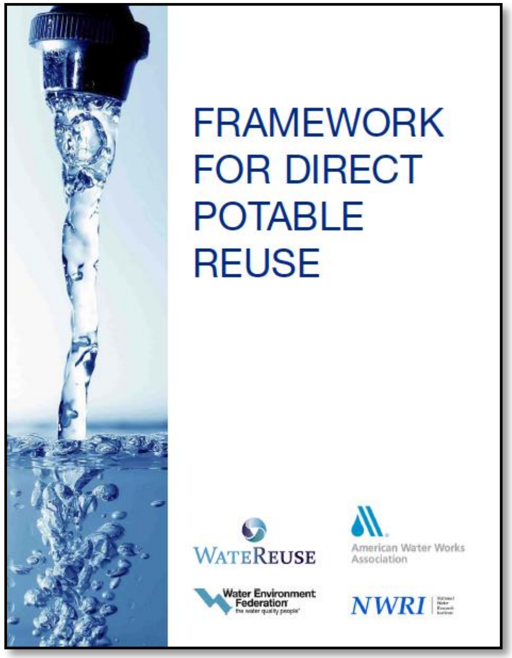
KEY COMPONENTS OF A DPR PROGRAM: TECHNICAL, REGULATORY, AND PUBLIC OUTREACH



SOME USEFUL INFORMATION SOURCES FOR DPR







*PURPOSE OF FRAMEWORK DOCUMENT**

To provide an overview of the key elements that make up a DPR program and a framework for assessing the specific topics and issues that need to be addressed in the development of a DPR program and future DPR Guidelines.

*Available at WateReuse and NWRI web sites

A HISTORICAL PERSPECTIVE:

"RECLAMATION OF TREATED SEWAGE"

TALK GIVEN BY R. F. GOUDEY ON October 30, 1930*

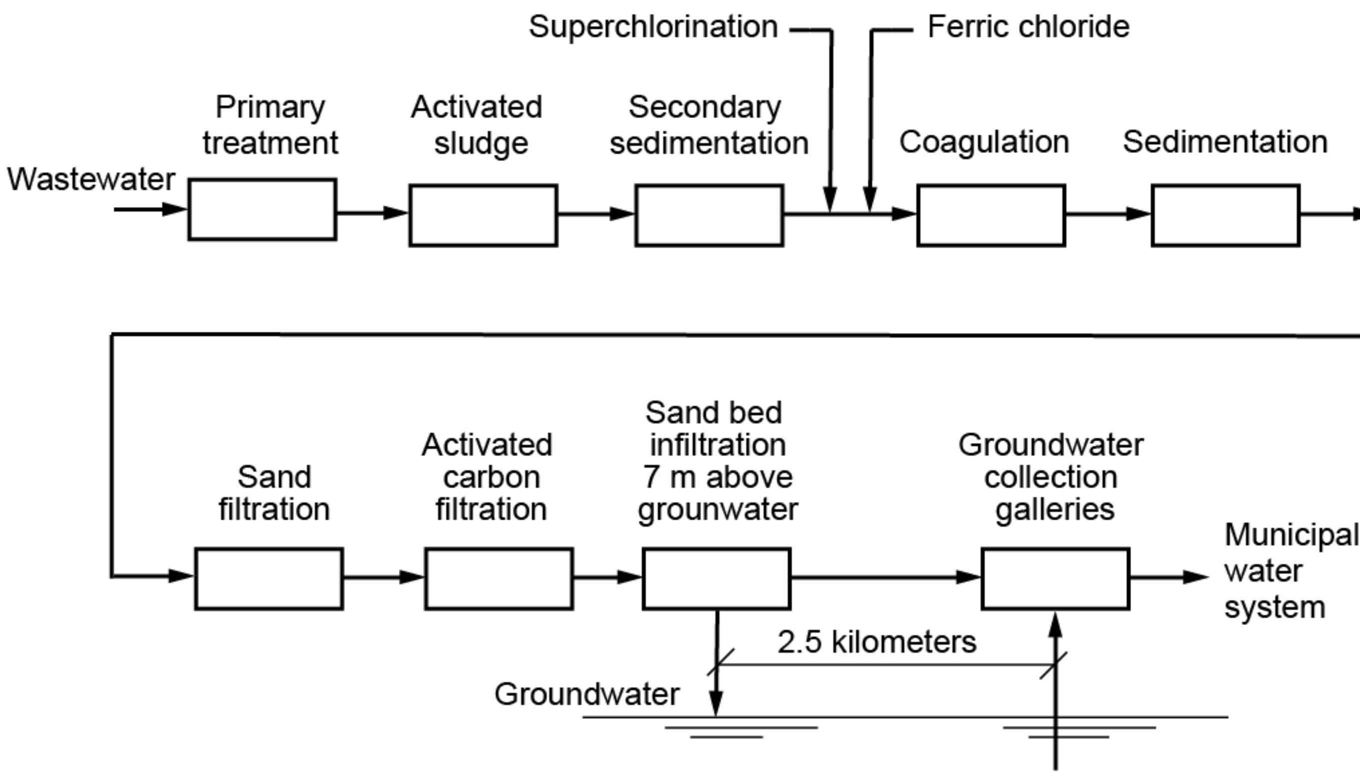
"Reclamation of sewage in Southern California, is coming whether we like it or not. It is not a. question of sewage disposal, but one directly related to a legitimate increase in water supply."

*Sanitary Engineer, Department of Water and Power, Los Angeles, CA. Formally, with the Bureau of Sanitary Engineering, Department of Public Health.

R. F. GOUDEY (October 30, 1930)
RECLAMATION OF TREATED SEWAGE

"California likewise need have no fear of eastern criticism, for it is in the east where one finds the most primitive methods of reclamation being practiced with no thought of their being questionable or repulsive. What else is it than reclamation where city after city discharges crude sewage into streams used by cities below for water supply intakes. But it is uncontrolled and unreliable reclamation."

GOUDEY'S TREATMENT SYSTEM

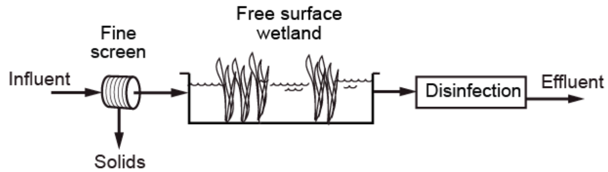


Politicians noted that Los Angeles would have to drink sewage if the bond issue to bring Colorado River water to Los Angeles did not pass

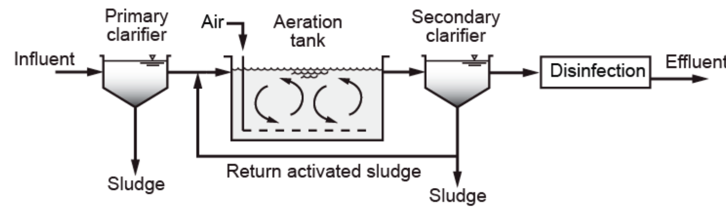
ISSUES THAT MAY IMPACT DPR AND IPR

- Suitability of typical wastewater treatment process
- Impact of climate change (discussed previously)
- Impact of conservation

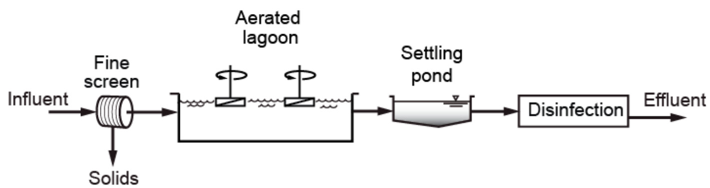
NOT ALL WASTEWATER EFFLUENTS ARE CREATED EQUAL



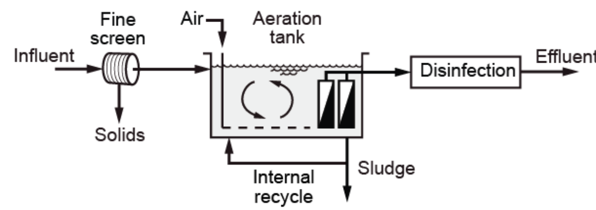
Free Suface Wetland



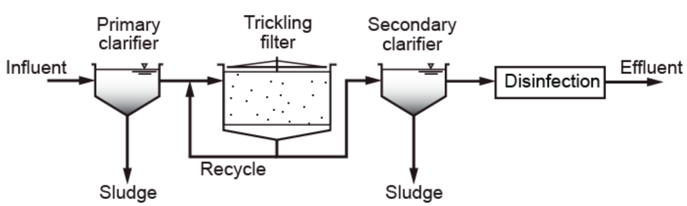
Conventional Activated Sludge



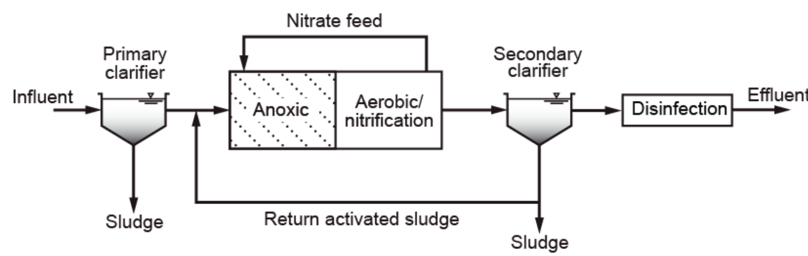
Aerated Lagoon



Membrane Bioreactor Activated Sludge

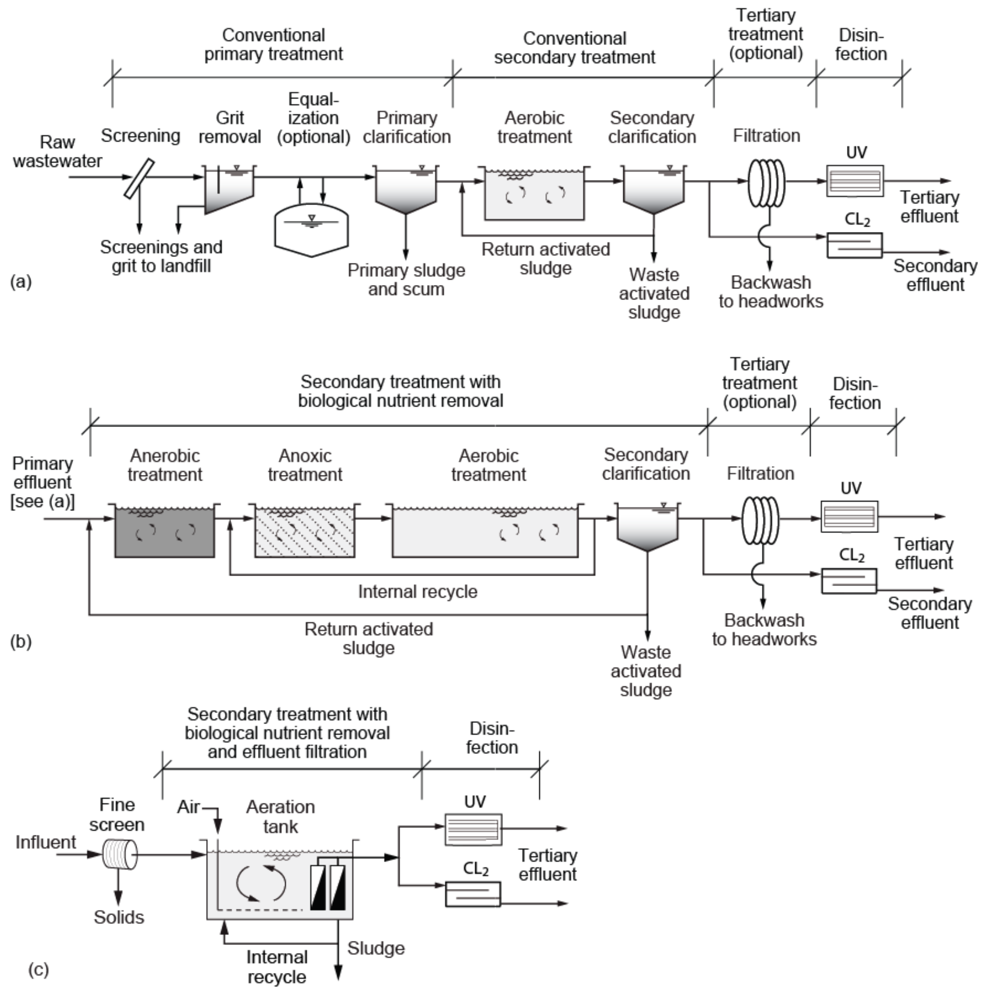


Tricklig Filter



Preanoxic Nitrogen Removal

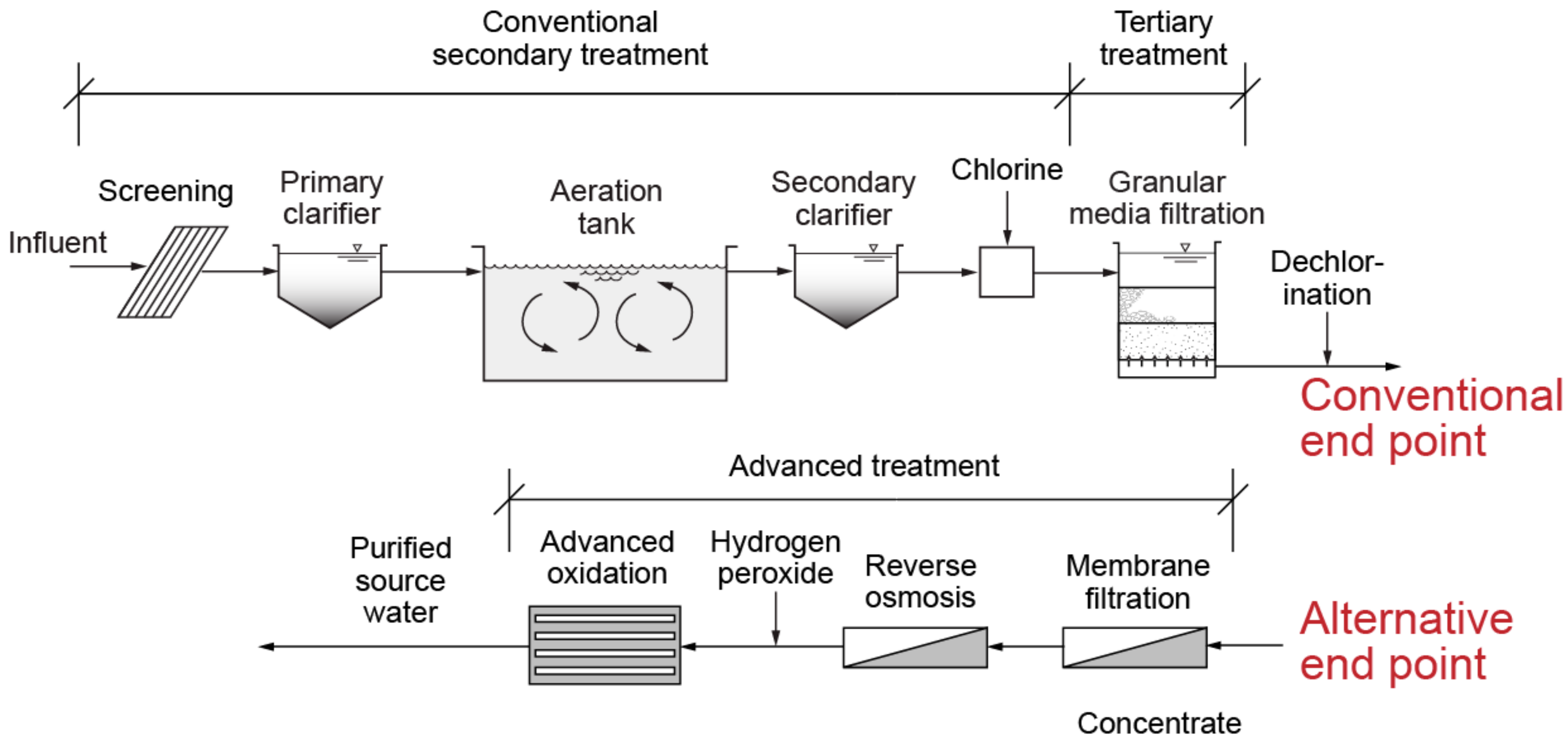
ARE ALL SECONDARY WASTEWATER TREATMENT PROCESSES SUITABLE FOR DPR?



DIFFERENCES IN EFFLUENT QUALITY BETWEEN ACCEPTED SECONDARY TREATMENT PROCESSES

Constituent	Unit	Untreated wastewater	Range of effluent quality after indicated treatment				
			Conventional activated sludge	Conventional activated sludge with filtration	Activated sludge with BNR	Activated sludge with BNR and filtration	Membrane bioreactor
Total suspended solids (TSS)	mg/L	130 – 389	5 – 25	2 – 8	5 – 20	1 – 4	<1 – 5
Turbidity	NTU	80 – 150	2 –15	1 –5	1 – 5	1 – 5	<1 – 2
Biochemical oxygen demand (BOD)	mg/L	133 – 400	5 – 25	< 5 – 20	5 – 15	1 – 5	<1 – 5
Chemical oxygen demand (COD)	mg/L	339 – 1016	40 – 80	30 – 70	20 – 40	20 – 30	<10 – 30
Total organic carbon (TOC)	mg/L	109 – 328	20 – 40	15 – 30	10 – 20	1 – 5	<0.5 – 5
Ammonia nitrogen	mg N/L	14 – 41	1 – 10	1 – 6	1 – 3	1 – 2	<1 – 5
Nitrate nitrogen	mg N/L	0 – trace	5 – 30	5 – 30	<2 - 8	1 - 8	<8
Nitrite nitrogen	mg N/L	0 – trace	0 – trace	0 – trace	0 – trace	0.001 – 0.1	0 – trace
Total nitrogen	mg N/L	23 – 69	15 – 35	15 – 35	3 – 8	2 – 5	<10
Total phosphorus	mg P/L	3.7 – 11	3 – 10	3 – 8	1 – 2	≤2	<0.3 – 5
Volatile organic compounds (VOCs)	µg/L	<100 – >400	10 – 40	10 – 40	10 – 20	10 – 20	10 – 20
Iron and manganese	mg/L	1 – 2.5	1 – 1.5	1 – 1.4	1 – 1.5	1 – 1.5	trace
Surfactants	mg/L	4 – 10	0.5 – 2	0.5 – 1.5	0.1 – 1	0.1 – 1	0.1 – 0.5
Totals dissolved solids (TDS)	mg/L	374 – 1121	374 – 1121	374 – 1121	374 – 1121	374 – 1121	374 – 1121
Trace constituents	µg/L	10 – 50	5 – 40	5 – 30	5 – 30	5 – 30	0.5 – 20
Total coliform	No./100 mL	$10^6 – 10^{10}$	$10^4 – 10^5$	$10^3 – 10^5$	$10^4 – 10^5$	$10^4 – 10^5$	<100
Protozoan cysts and oocysts	No./100 mL	$10^1 – 10^5$	$10^1 – 10^2$	0 –10	0 –10	0 – 1	0 – 1
Viruses	PFU/100 mL	$10^1 – 10^8$	$10^1 – 10^4$	$10^1 – 10^3$	$10^1 – 10^3$	$10^1 – 10^3$	$10^0 – 10^3$

DESIGN OF BIOLOGICAL TREATMENT PROCESS FOR ALTERNATIVE END POINT



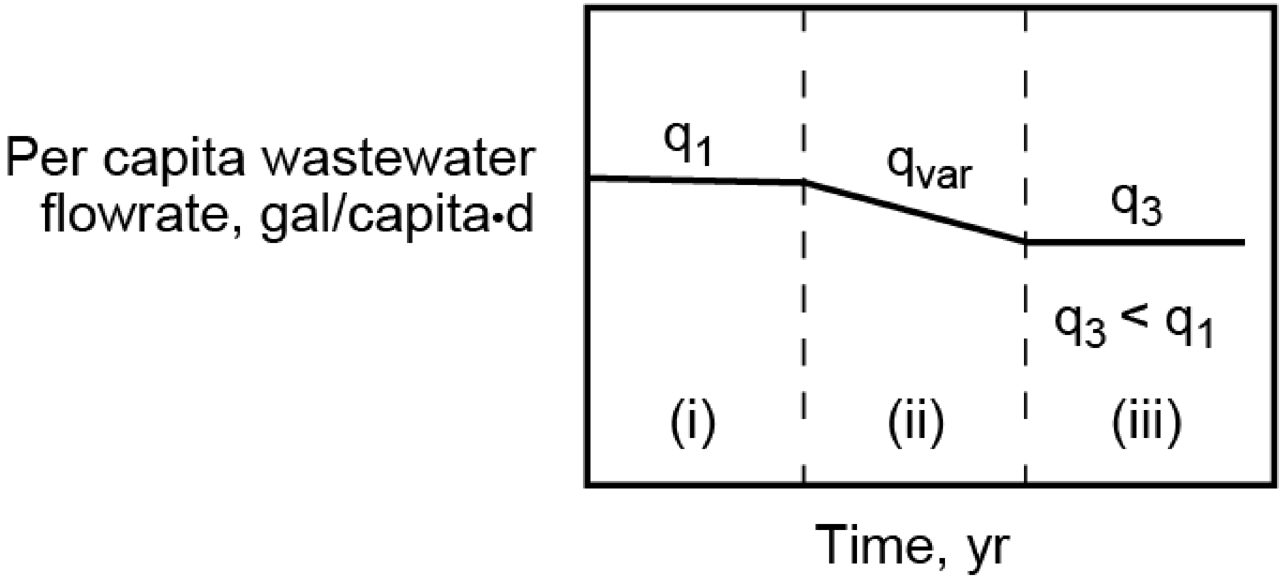
Must think differently about secondary treatment

MEASURES TO IMPROVE PERFORMANCE AND ENHANCE RELIABILITY OF EXISTING WWTPs

Measure	Value of each measure[a]
Enhanced screening process and possibly fine screening (2 to 6 mm)	Efficiency, reliability
Influent flow and load equalization	Efficiency, water quality, reliability
Elimination (or equalization) of untreated return flows	Water quality, reliability
Operational mode for biological treatment process	Water quality, reliability
Effluent filtration and disinfection	Water quality, reliability
Improved process monitoring	Water quality, reliability

[a]*Efficiency* – increases the overall cost efficiency of operation. *Water quality* – increases the final potable water quality. *Reliability* – increases the overall stability and performance of the treatment train.

IMPACT OF CONSERVATION ON OPERATION OF COLLECTION SYSTEMS, WWTPS, AND POTABLE REUSE



(i) Pre-1992

(ii) Improved water conservation

(iii) Maximum water conservation

CURRENT AND PROJECTED PER CAPITA WATER USE IN THE UNITED STATES

	Flow, gal/capita•d					
	2013		2020		2030	
Use	Range	Typical	Range	Typical	Range	Typical
Domestic						
Indoor use	40 - 80	60	35 - 65	55	30 - 60	45
Outdoor use	16 - 50	35	16 - 50	35	16 - 50	35
Commercial	10 - 75	40	10 - 70	35	10 - 65	30
Public	15 - 25	20	15 - 25	18	15 - 25	15
Loss and waste	15 - 25	20	15 - 25	18	15 - 25	15
Total	96 - 255	175		161		138

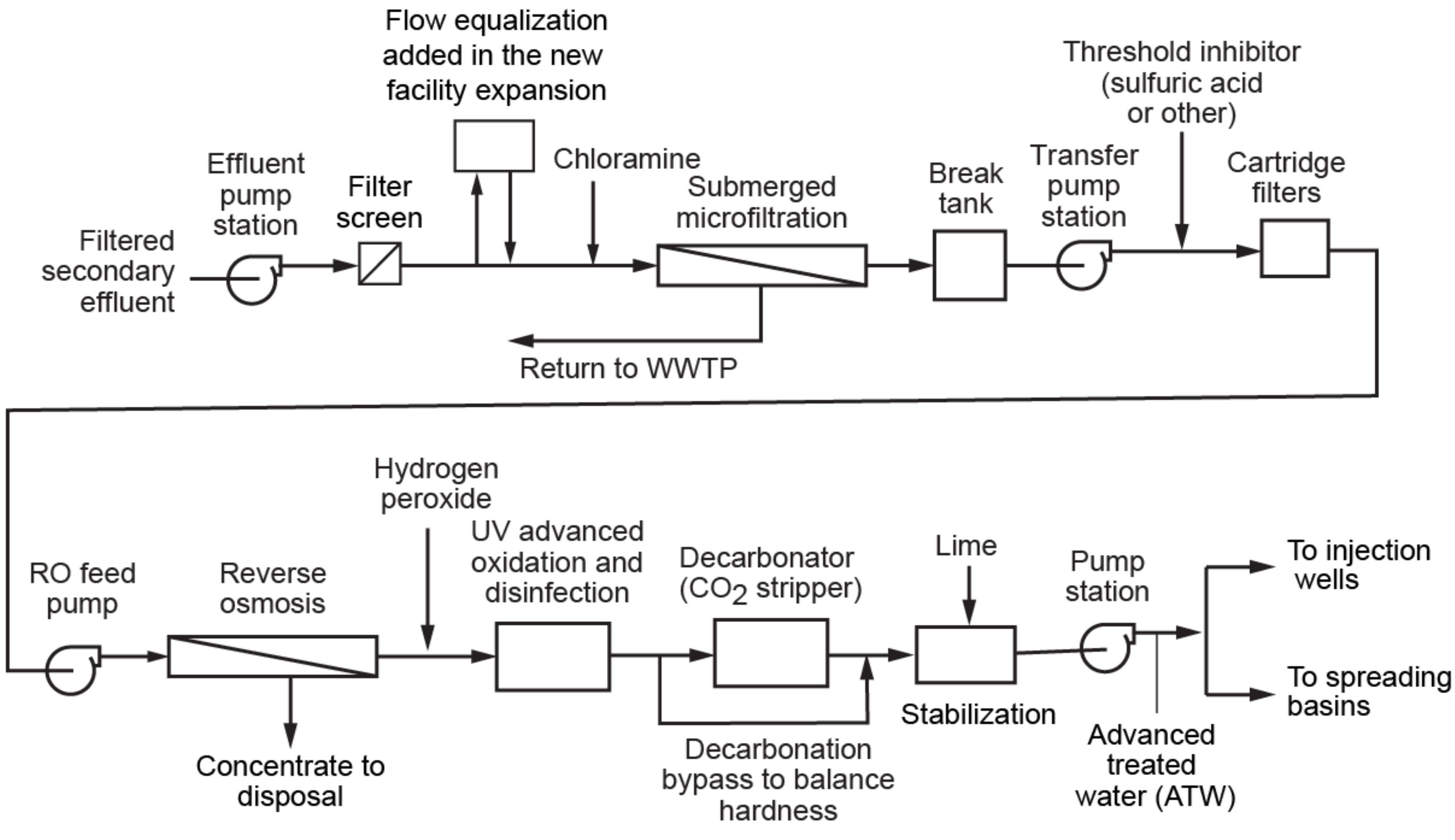
84 gal/capita•d in Bay Area to 584 gal/capita•d Northern San Diego

TRENDS IN ADVANCED TREATMENT TECHNOLOGIES

LOG-REDUCTION VALUES FOR DPR

Microbial Group	Criterion ($\log_{10}$ reduction)	Possible surrogates	Source used to develop criteria
Enteric virus	12	MS2 bacteriophage	SWTR (U.S. EPA, 1989a); CDPH (2011); NRC (2012); NRMMC–EPHC–NHMRC (2008)
Cryptosporidium spp.	10	Latex microspheres, AC Fine Dust, inactivated *Cryptosporidium* oocysts, aerobic spores	Interim ESWTR (U.S. EPA, 1998); LT2 ESWTR (U.S. EPA, 2006); CDPH (2011); NRC (2012); NRMMC–EPHC–NHMRC (2008)
Total coliform bacteria	9	NA[c]	Total Coliform Rule (U.S. EPA, 1989b); NRC (2012) risk assessment for salmonella

TECHNOLOGIES FOR THE INDIRECT AND DIRECT POTABLE REUSE



Adapted from OCWD

Microfiltration, Cartridge Filters, Reverse Osmosis, and Advanced Oxidation (UV) Technologies at OCWD

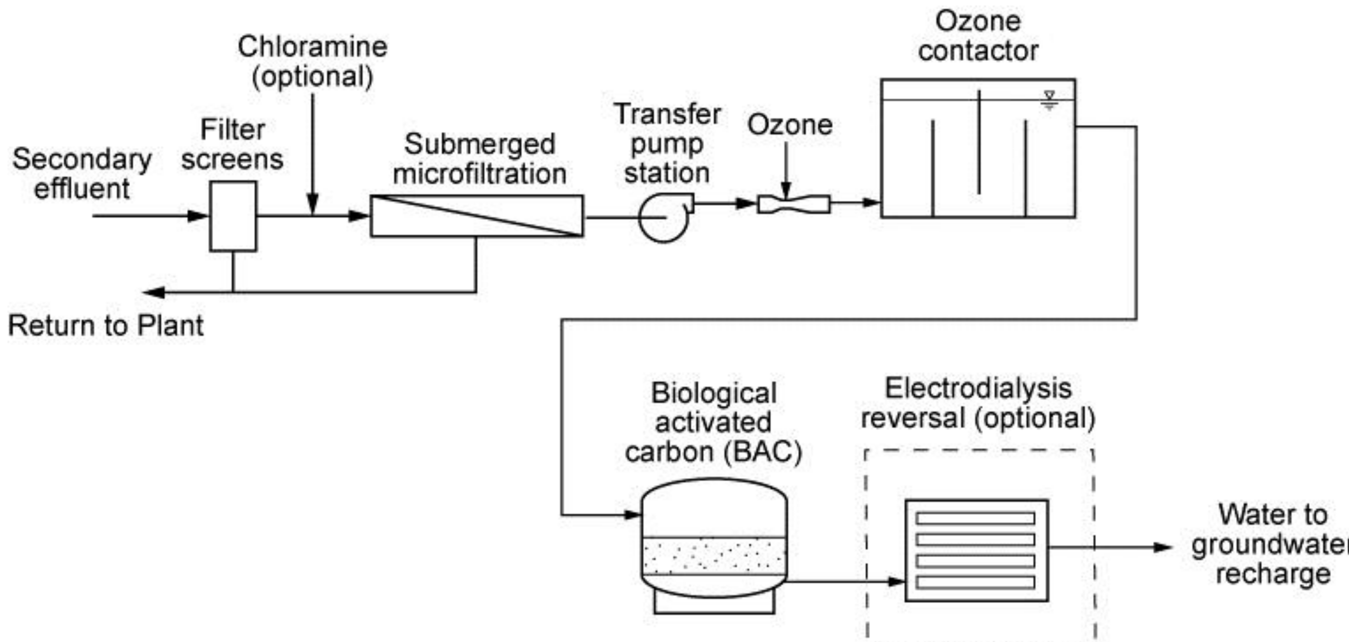
ONGOING RESEARCH AT OCWD
TESTING OF NEW MEMBRANE MODULES

ORANGE COUNTY WATER DISTRICT, OCWD

Decarbonator
(CO_2 Stripping)

Lime Saturator
(pH adjustment)

TECHNOLOGIES FOR THE REMOVAL OF TRACE CONSTITUENTS AND UNKNOWNS



Adapted from Sundaram et al., 2009

COMPARISON OF TECHNOLOGIES FOR THE REMOVAL OF TRACE CONSTITUENTS & UNKNOWNS

Item	MF-Ozone-BAC	MF-RO-UV/Peroxide
Fate of trace organics	Degraded	Removed and degraded
Reject/side streams	Minor (periodic backwash water)	Major (up to 20%)
Salinity	Unchanged	Decreased significantly
Corrosivity	Unchanged	Increased (requires buffering)
Energy consumption without MF	0.03 - 1.0 kWh/m^3	8 - 10 kWh/m^3

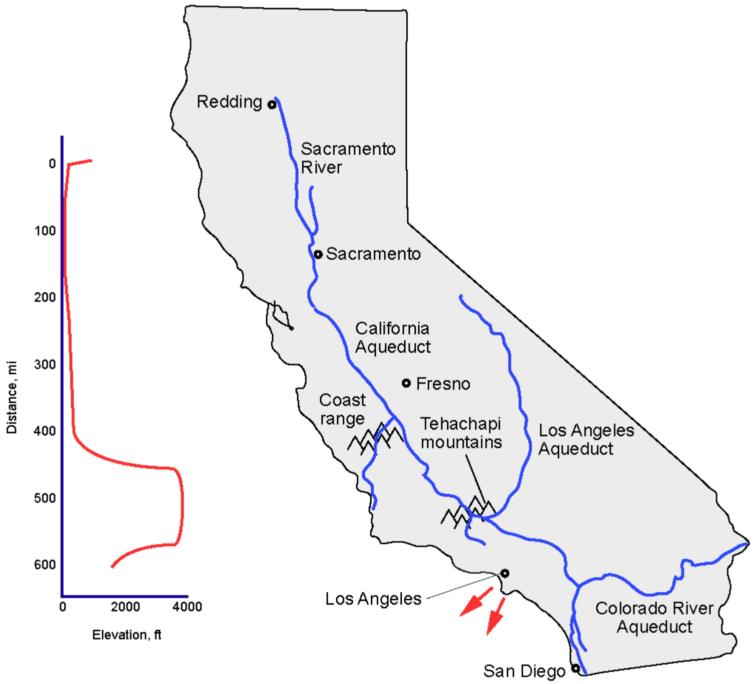
Adapted from Sundaram et al., 2009

MANAGEMENT OPTIONS FOR RO CONCENTRATE

1. Surface water discharge
2. Discharge to wastewater collection system
3. Deep-well injection
4. Evaporation ponds (without and with greenhouse)
5. Land application
6. Zero liquid discharge (ZLD)
7. RO concentrate discharged through existing wastewater effluent ocean outfall
8. RO concentrate discharged through separate ocean outfall

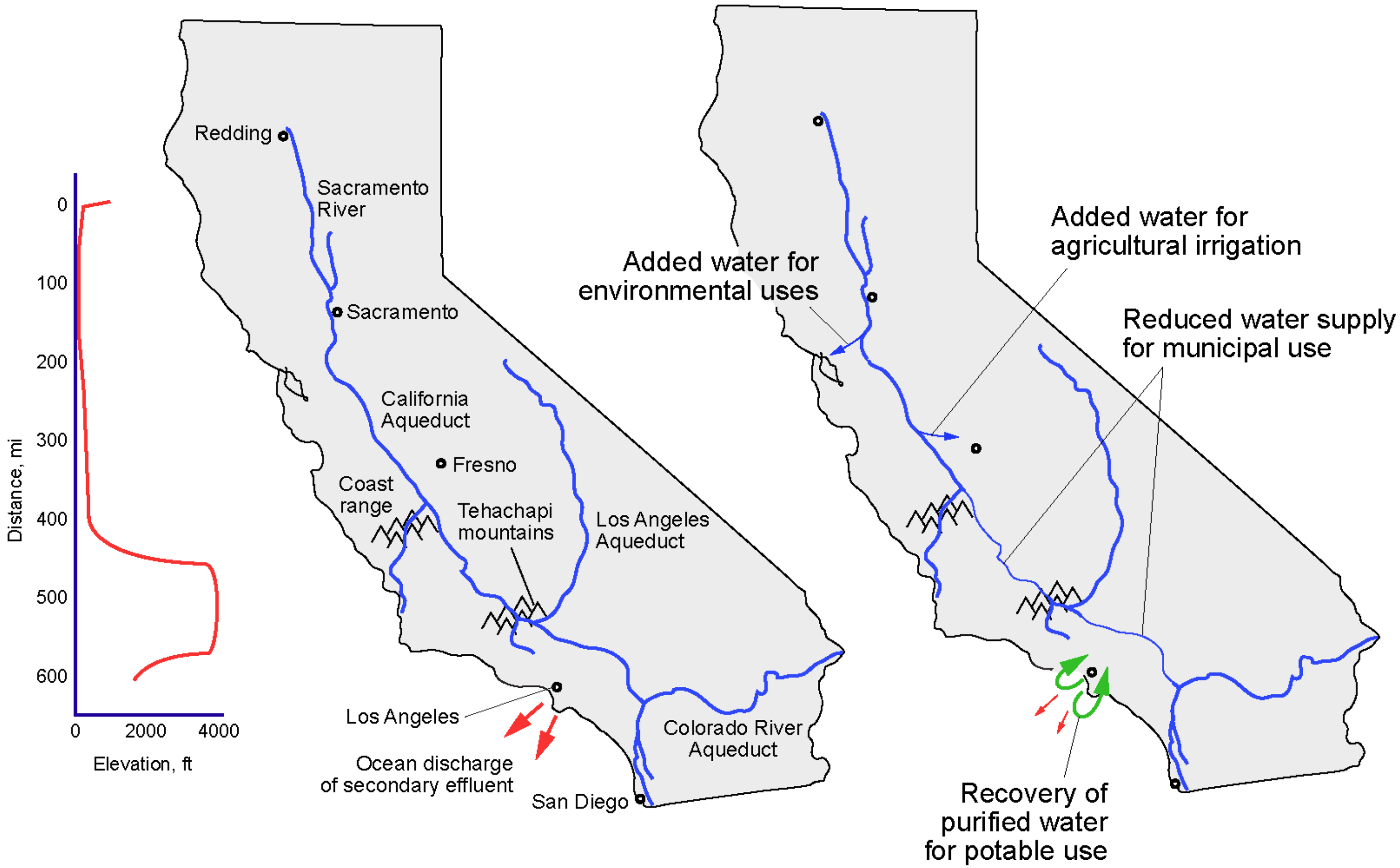
A DPR CASE STUDY: SOUTHERN CALIFORNIA

Electric Power Consumption for Urban Water Systems in Northern and Southern CA

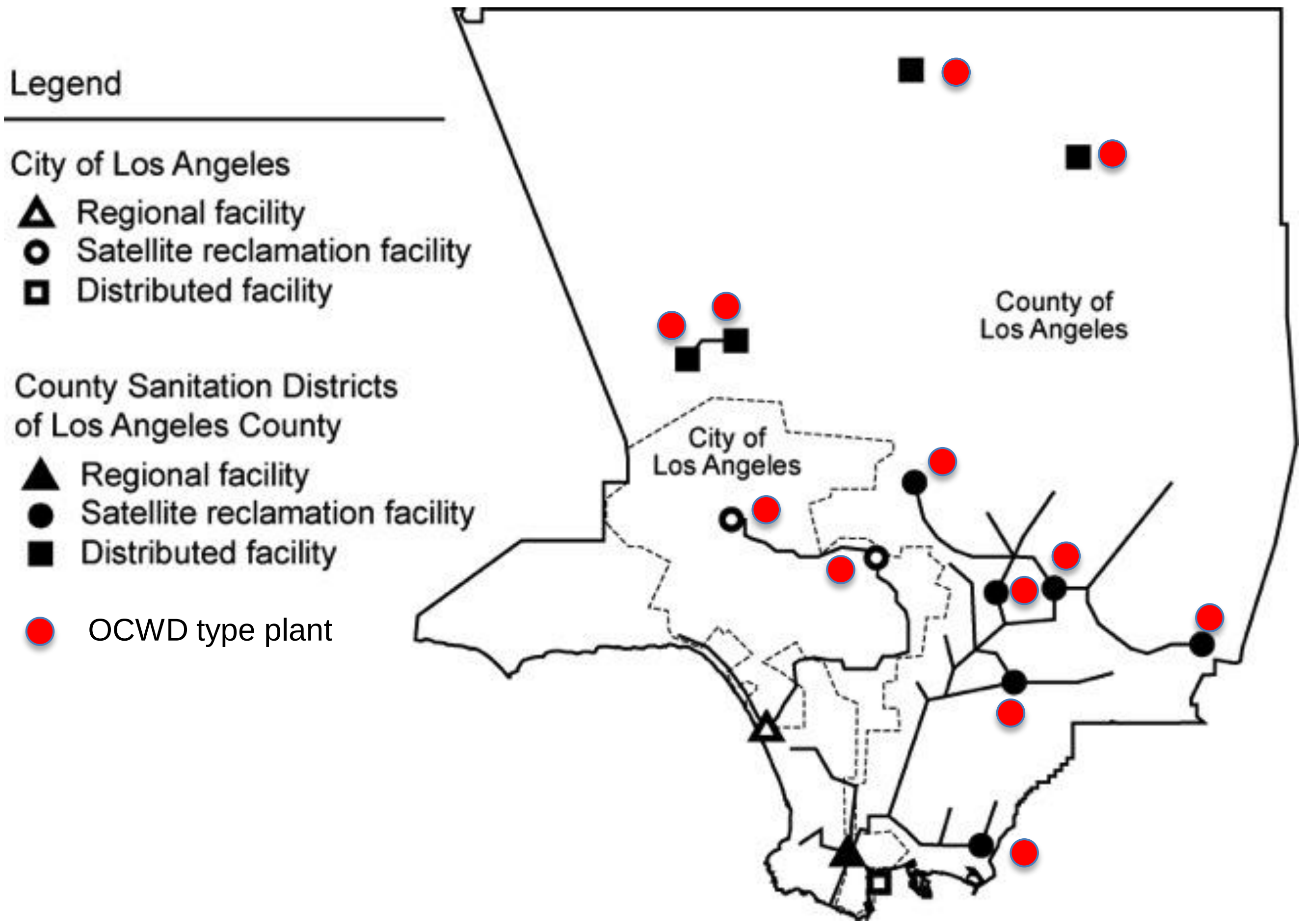


System	Power consumption, kWh/Mgal	
	Northern California	**Southern California**
Supply and conveyance	150	8,900
Water treatment	100	100
Distribution	1200	1200
Wastewater treatment	2,500	2,500
TOTAL	**3,950**	**12,700**

Opportunities for the Future: The Southern California Example



Wastewater Management Infrastructure - Potential Locations for Water Plants



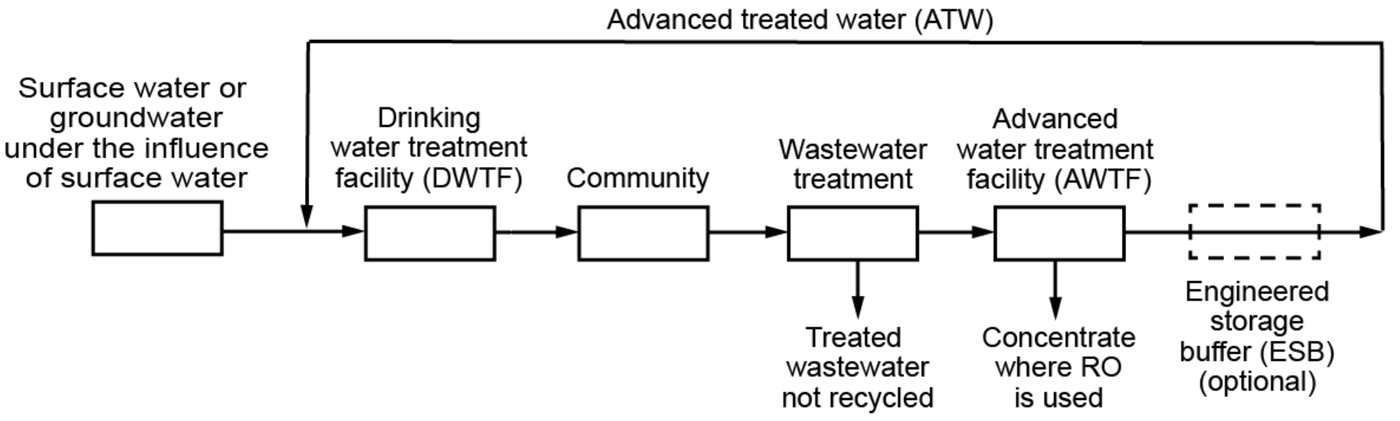
BENEFITS OF SOUTHERN CALIFORNIA EXAMPLE

- Reliable alternative source of supply, more secure from natural disasters
- Lower cost and reduced energy usage
- More water available for agricultural and other uses, especially during drought periods
- Environmental benefits for bay delta habitat restoration

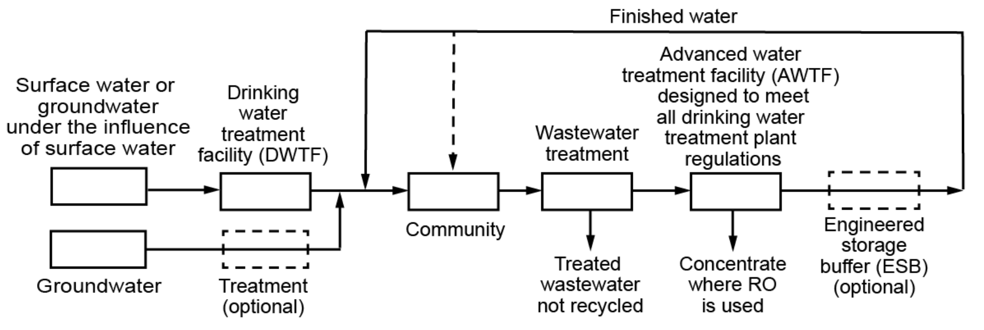
THE FUTURE

- Let’s move ahead with DPR now
- Needs identified in framework document to enhance the implementation of DPR
  - ✓ Regulatory
  - ✓ Technology
  - ✓ Public outreach
- Wastewater management in the 21^{st} Century

LETS MOVE AHEAD WITH DPR



Focus on DPR with *advanced treated water (ATW)*



Continue to work on DPR with *finished water*

FUTURE REGULATORY NEEDS

- National guidelines and regulations
- National framework for integrating the CWA and SDWA for permitting DPR projects
- Consideration of advanced treated water (ATW) as a third water source (i.e., surface water, groundwater, and ATW)
- Development of consistent training programs
- Operator training and certification?

FUTURE TECHNOLOGY NEEDS

- Better understanding of treatment processes to reduce overly conservative designs
- Improved understanding of relationship between multiple barriers
- Improved monitoring methods to capture failure and other events of interest
- Full-scale demonstration of advanced water treatment facility without reverse osmosis
- Development of technologies for satellite and decentralized AWTFs

FUTURE PUBLIC OUTREACH

- We already have a lot of tools
- Develop appropriate and consistent terminology
- Clear message about potable reuse– what it is and what it is not.

CLOSING THOUGHTS

Ultimately, implementation of DPR and/or IPR is inevitable in urban and other areas, and will represent an essential element of a sustainable water future

- Must think of wastewater differently
- Technology is not an issue
- The public is supportive
- To make it a reality, bold new planning must begin now!!

THE FUTURE OF DPR AND IPR

Rather than regulations driving wastewater management as in the past, **THE VALUE OF POTABLE WATER, RESOURCES, and ENERGY** will propel developments in the 21st century.

THANK YOU
FOR LISTENING