Water Reclamation, Reuse and Public Health

Ian B Law

Principal, IBL Solutions

Australia

Presentation at SIWW 2022 Hot Issues Workshop
20th April 2022

Why Recycle Water?

- Increase availability through substitution.

Others:

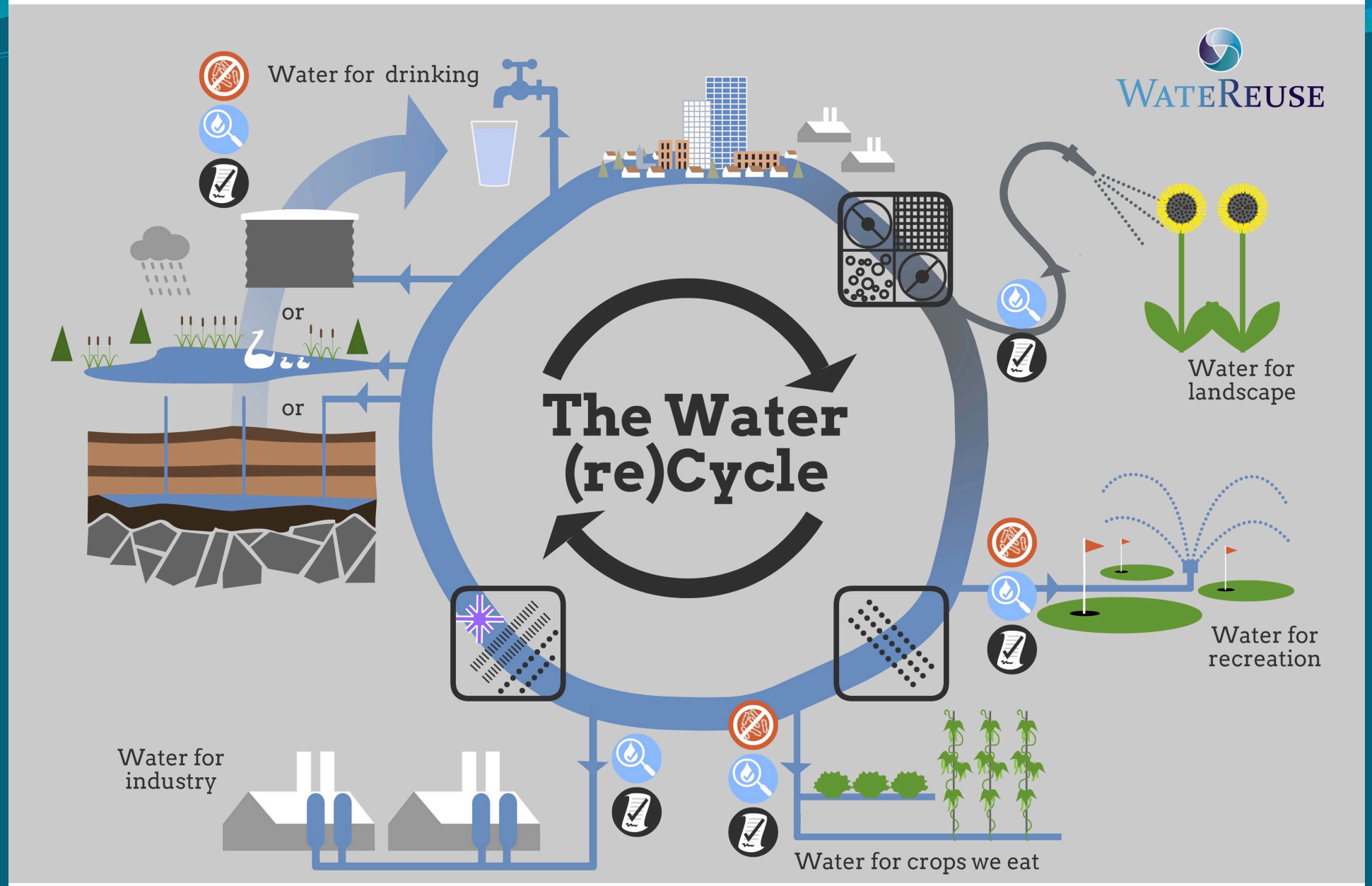
- ??
- ??
- ??

All Reasons should support the aim of achieving a sustainable management framework for our fresh water supplies as our demands for water increase.

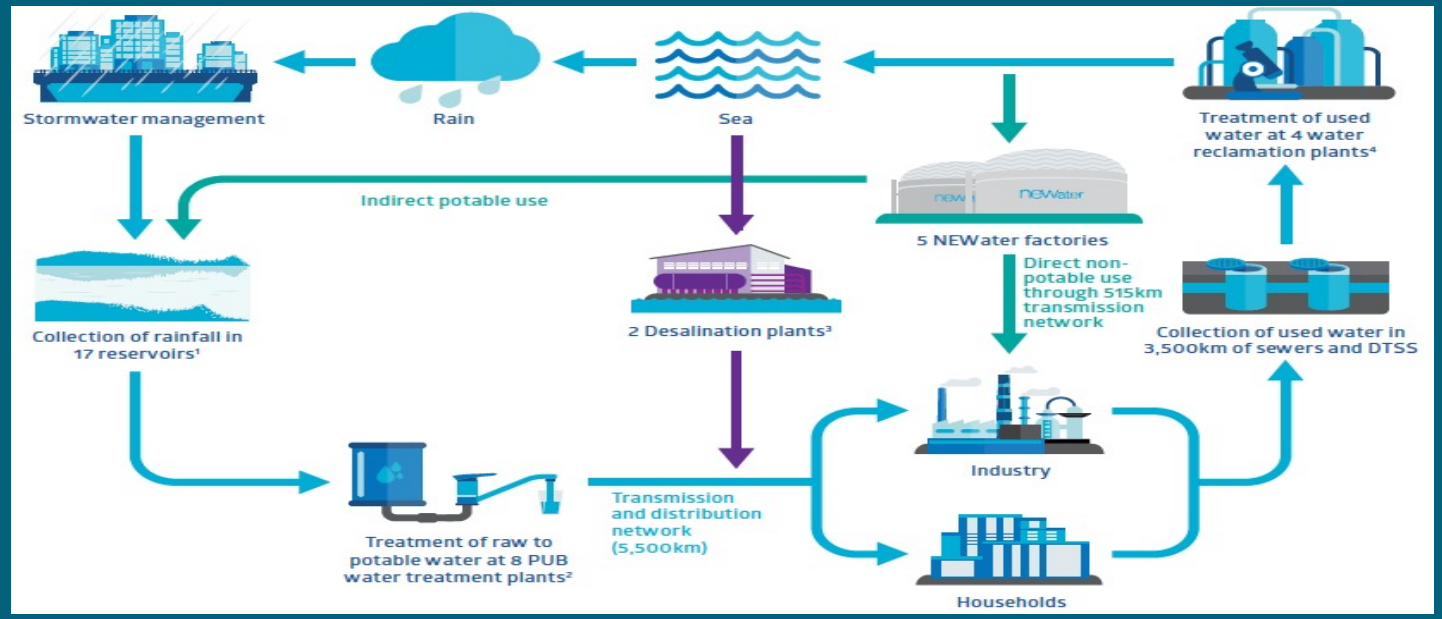
How to Diversify our Water Supplies??

- New dams;
- Inter-basin transfers;
- Stormwater Harvesting
- Seawater Desalination;
- Recycling for non-potable uses (domestic & industrial);
- Using reclaimed water for environmental flows.
- Recycling for Drinking Water (Potable Reuse);

Note: Demand Management in place for all options.


WateReuse
Water for drinking
or
or
The Water (re)Cycle
Water for landscape
Water for recreation
Water for industry
Water for crops we eat

Using Technology to Close the Water Loop – the Singapore expereince



- Sources of Water Supply

Regulations and Quality Requiremetns Depend on the form of End Use

Purified Recycled Water (PRW)

Domestic non-potable Reuse

Agricultural Reuse on Food Crops

Environmental Flows

Unrestricted Recreational Reuse

Unrestricted Urban Irrigation Reuse

Restricted Urban Irrigation Reuse

Restricted Recreational Reuse

Industrial Reuse

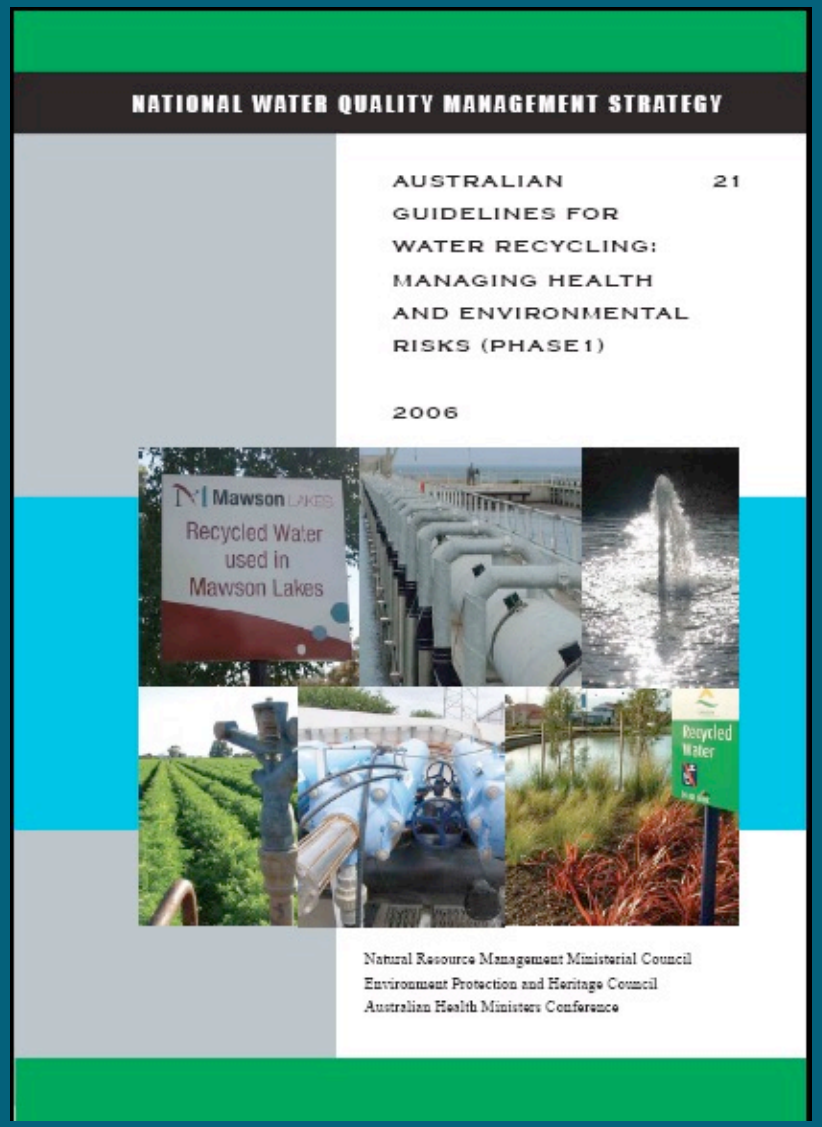
Environmental Reuse

Agricultural Reuse on Non-food Crops

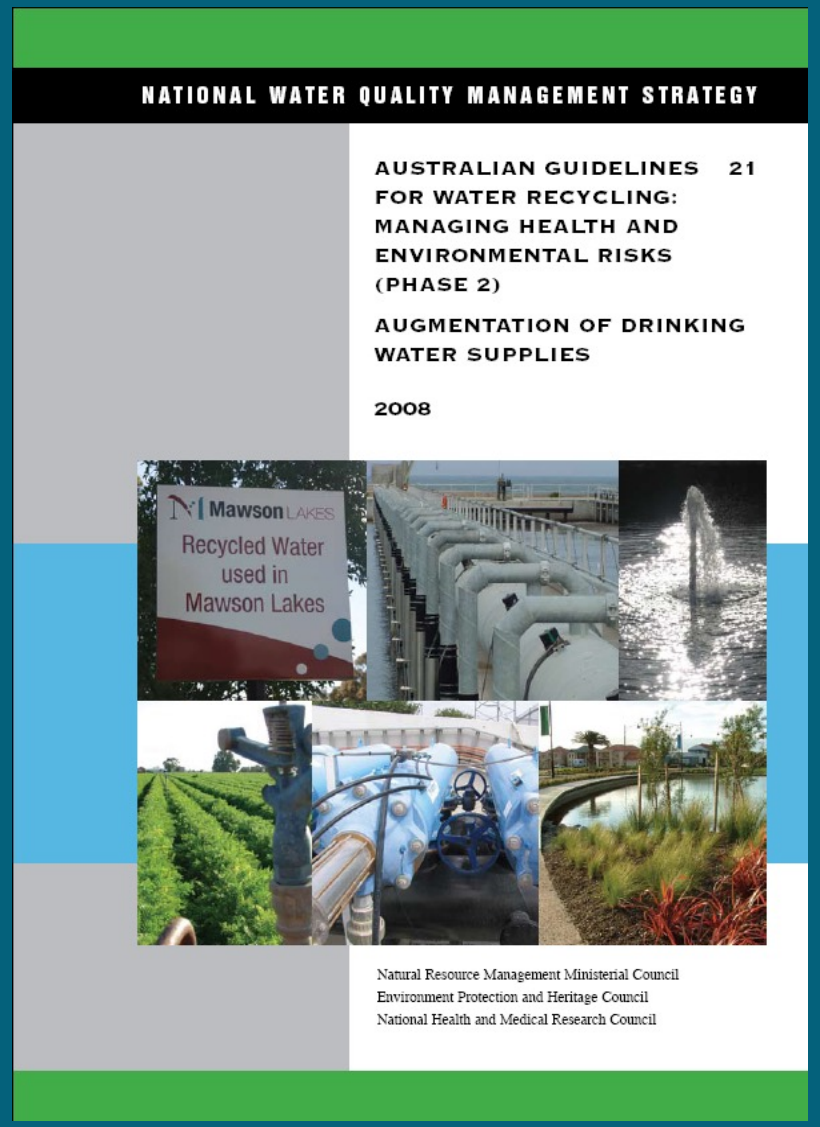
Most Stringent Regulations

Less Stringent Regulations

2006



2008

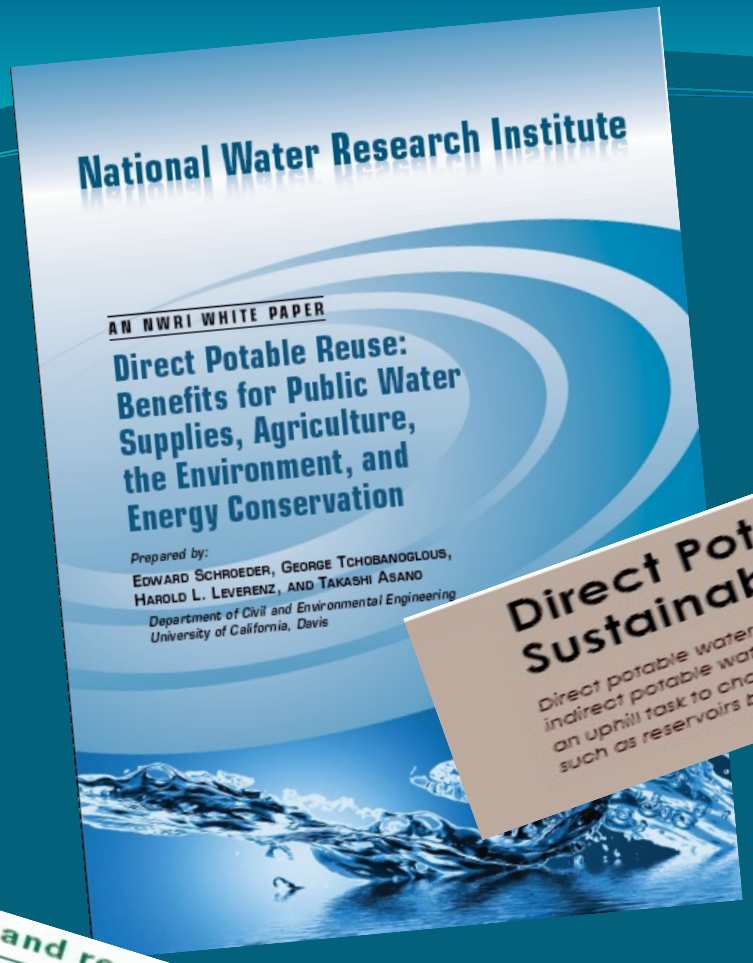


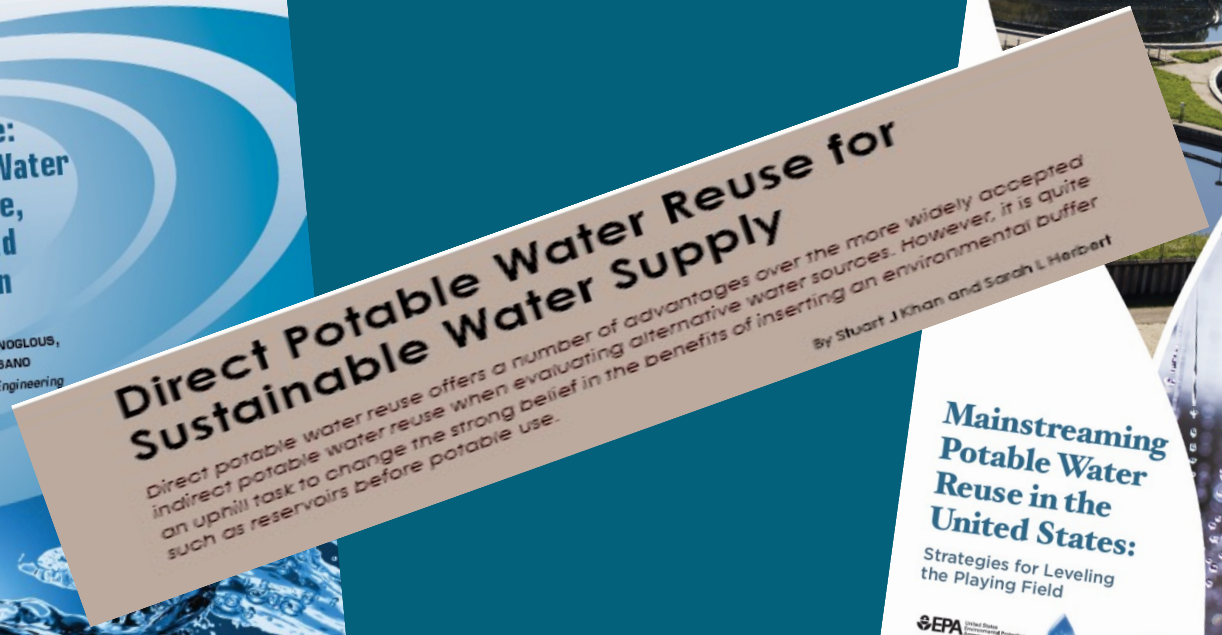
2017

The ‘Key Principles’ of the AGWR & the WHO Documents

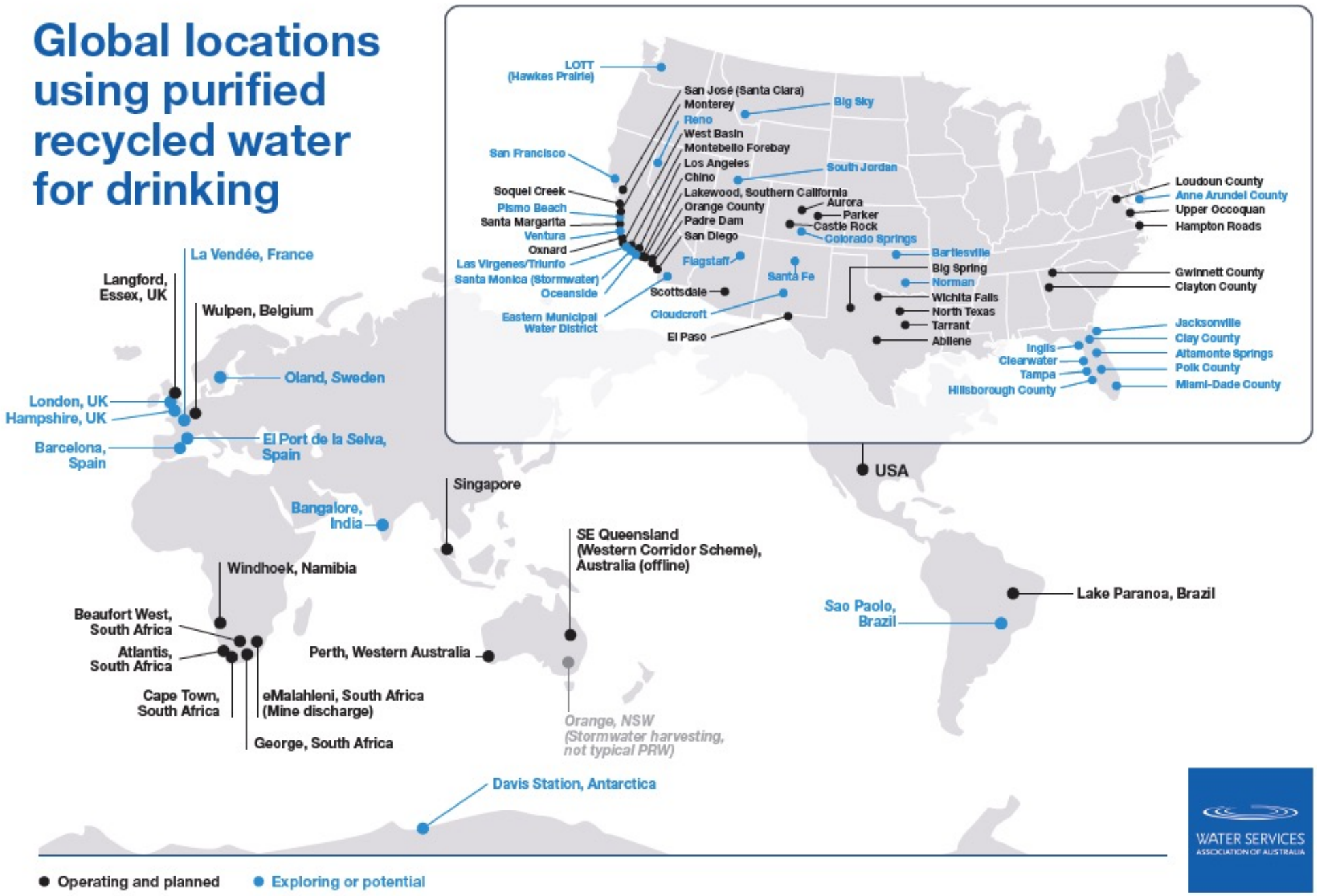
- Protection of public health remains paramount;
- Community engagement and support is essential;
- Institutional capacity must be in place;
- Effective trade waste (or source control) programs must be in place
- Robust and reliable *multiple barriers* must be installed to ensure reliable operation of all treatment stages;
- On-going operational & verification monitoring
- Personnel skills, training and accountability essential;
- Regulatory surveillance and independent auditing.

Sundry Reports & Papers



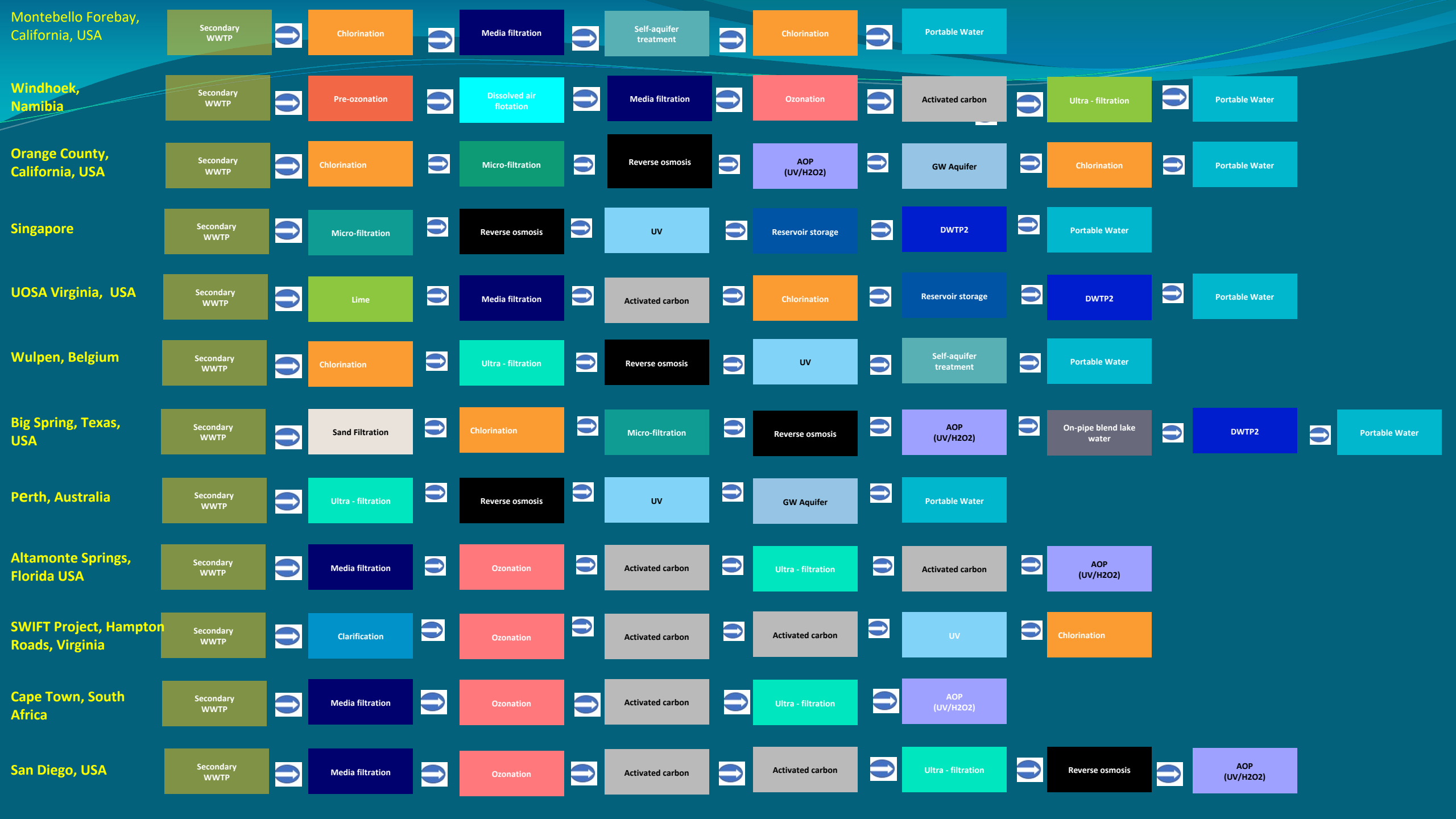


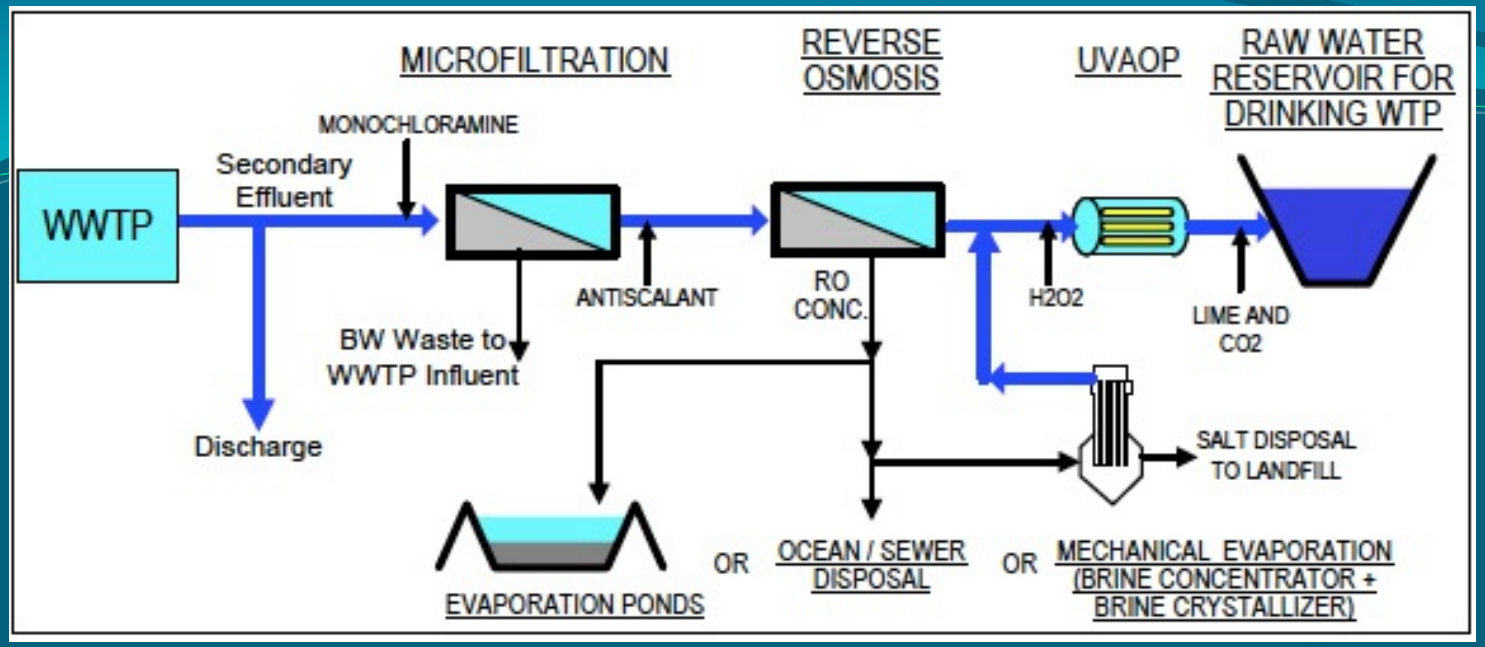
Global locations using purified recycled water for drinking



WATER SERVICES ASSOCIATION OF AUSTRALIA

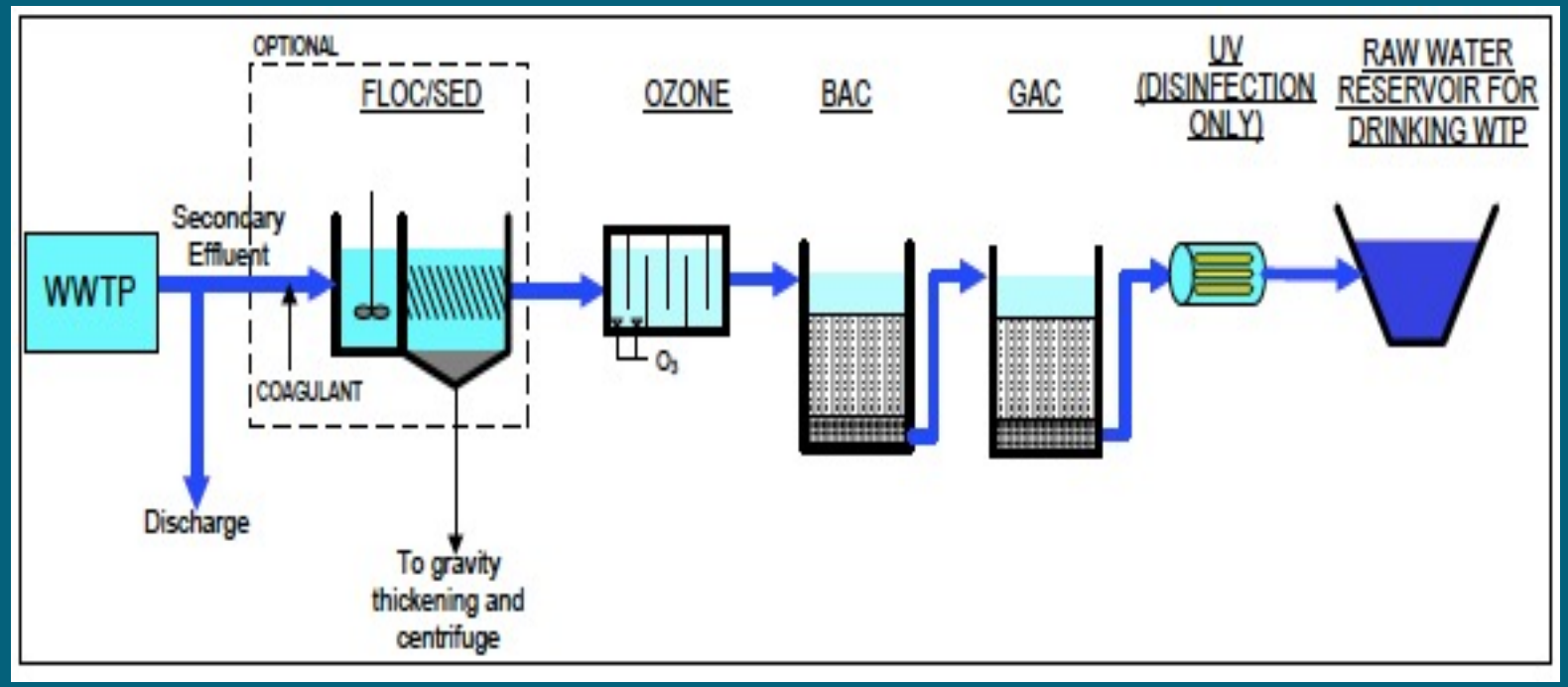
Examples of Adopted Treatment Technologies


Montebello Forebay, California, USA
Secondary WWTP
Chlorination
Media filtration
Self-aquifer treatment
Chlorination
Portable Water
Windhoek, Namibia
Secondary WWTP
Pre-ozonation
Dissolved air flotation
Media filtration
Ozonation
Activated carbon
Ultra - filtration
Portable Water
Orange County, California, USA
Secondary WWTP
Chlorination
Micro-filtration
Reverse osmosis
AOP (UV/H2O2)
GW Aquifer
Chlorination
Portable Water
Singapore
Secondary WWTP
Micro-filtration
Reverse osmosis
UV
Reservoir storage
DWTP2
Portable Water
UOSA Virginia, USA
Secondary WWTP
Lime
Media filtration
Activated carbon
Chlorination
Reservoir storage
DWTP2
Portable Water
Wulpen, Belgium
Secondary WWTP
Chlorination
Ultra - filtration
Reverse osmosis
UV
Self-aquifer treatment
Portable Water
Big Spring, Texas, USA
Secondary WWTP
Sand Filtration
Chlorination
Micro-filtration
Reverse osmosis
AOP (UV/H2O2)
On-pipe blend lake water
DWTP2
Portable Water
Perth, Australia
Secondary WWTP
Ultra - filtration
Reverse osmosis
UV
GW Aquifer
Portable Water
Altamonte Springs, Florida USA
Secondary WWTP
Media filtration
Ozonation
Activated carbon
Ultra - filtration
Activated carbon
AOP (UV/H2O2)
SWIFT Project, Hampton Roads, Virginia
Secondary WWTP
Clarification
Ozonation
Activated carbon
Activated carbon
UV
Chlorination
Cape Town, South Africa
Secondary WWTP
Media filtration
Ozonation
Activated carbon
Ultra - filtration
AOP (UV/H2O2)
San Diego, USA
Secondary WWTP
Media filtration
Ozonation
Activated carbon
Activated carbon
Ultra - filtration
Reverse osmosis
AOP (UV/H2O2)



The Californian *FAT* ('Full Advanced Treatment ') train

The *Ozone/GAC train* – gaining acceptance in inland areas; no brine & significant energy savings over the FAT train.



Public Health Considerations

Examples of Pathogen Removal LRVs for *Potable Reuse* – based on default concentrations in wastewater

	Australia[1]	California[2]	Texas[3]	WHO
Viruses	9.5	12	8	9.5
Protozoa	8.0	10/10	5.5/6	8.5
Bacteria	8.1	9	n/s	8.5

Notes:

1. Between wastewater and finished drinking water
2. Between wastewater and finished drinking water
3. Between secondary effluent and finished drinking water

The Differences

- *Australia* & WHO - Risk is defined in terms of *Disability Adjusted Life Year* (DALY's), based on approach by WHO;
- *Tolerable risk* for reclaimed water is a DALY of 10^{-6} per person per year – *approximately 1 illness (diarrhoea) per 1,000 people*;
- *US* - Tolerable or *de minimis* level of risk is *1 illness (diarrhoea) per 10,000 people*[1]

Is this difference justified ? Can we achieve consistency in approach to 'acceptable' levels of risk .....

1. Reference: *Trussell, R. R. et al (2013). Potable Reuse: State of the Science Report and Equivalency Criteria for Treatment Trains. WRRF Report 11-02, ISBN 978-1-934183-83-0.*

Indicative Log Reductions for Other Uses

(Ref: AGWR, 2006)

Water use	Exposure (L/year)	LRV Required		
		Virus	Bacteria	Protozoa
Irrigation of gardens	0.66	6	5	4.9
Irrigation of Food crops	0.5	5.9	4.9	4.8
Toilet flushing	0.05	4.8	3.8	3.7
Drinking	700	9.5	8.1	8.0

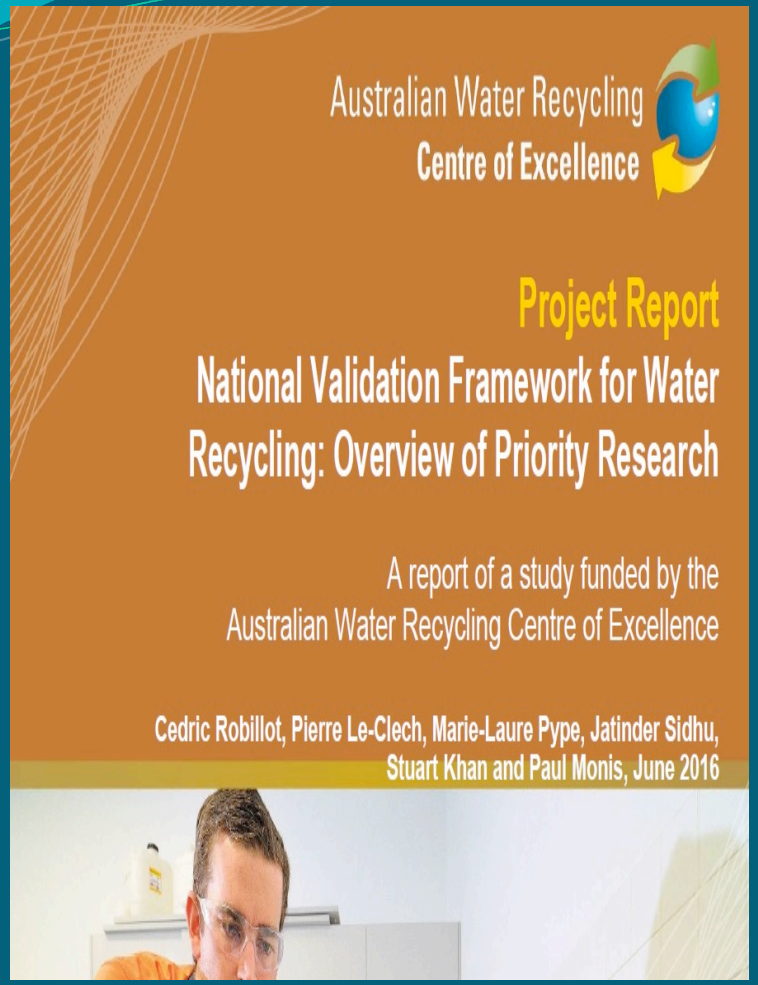
Caveats on Treatment Efficacy

- Treatment processes must be *validated* to demonstrate that they provide the claimed pathogen reductions (published data, pilot plants, challenge testing …);
- Maximum log removal credit per unit process for reference pathogens not greater than 4 in Australia (6 in the US) – *multiple barriers* required;
- Log Removal Values can only be claimed if they can be *operationally monitored*;
- Implications for membrane systems – MF, UF, NF & RO.

What is ‘Treatment Validation’ ?

Demonstrating the capability of treatment processes to remove or inactivate target pathogens and correlating performance with operational monitoring

National Validation Protocols



Work initiated by the *Australian Water Recycling Centre of Excellence (AWRCE)* and led to the development of *National Validation Protocols* in 2016 for the validation of :

- **Membrane Bioreactors (MBRs);**
- **Ultraviolet Disinfection;**
- **Reverse Osmosis (RO);**
- **Chlorination;**
- **Activated Sludge process.**

The protocols are accepted across all jurisdictions within Australia and that for MBRs is finding application in the US.

https://www.waterra.com.au/research/waterval/

Validation of the Goreangab Reclamation Plant in Windhoek, Namibia against the 2008 Australian Guidelines for Water Recycling

Ian B. Law, Jurgen Menge and David Cunliffe

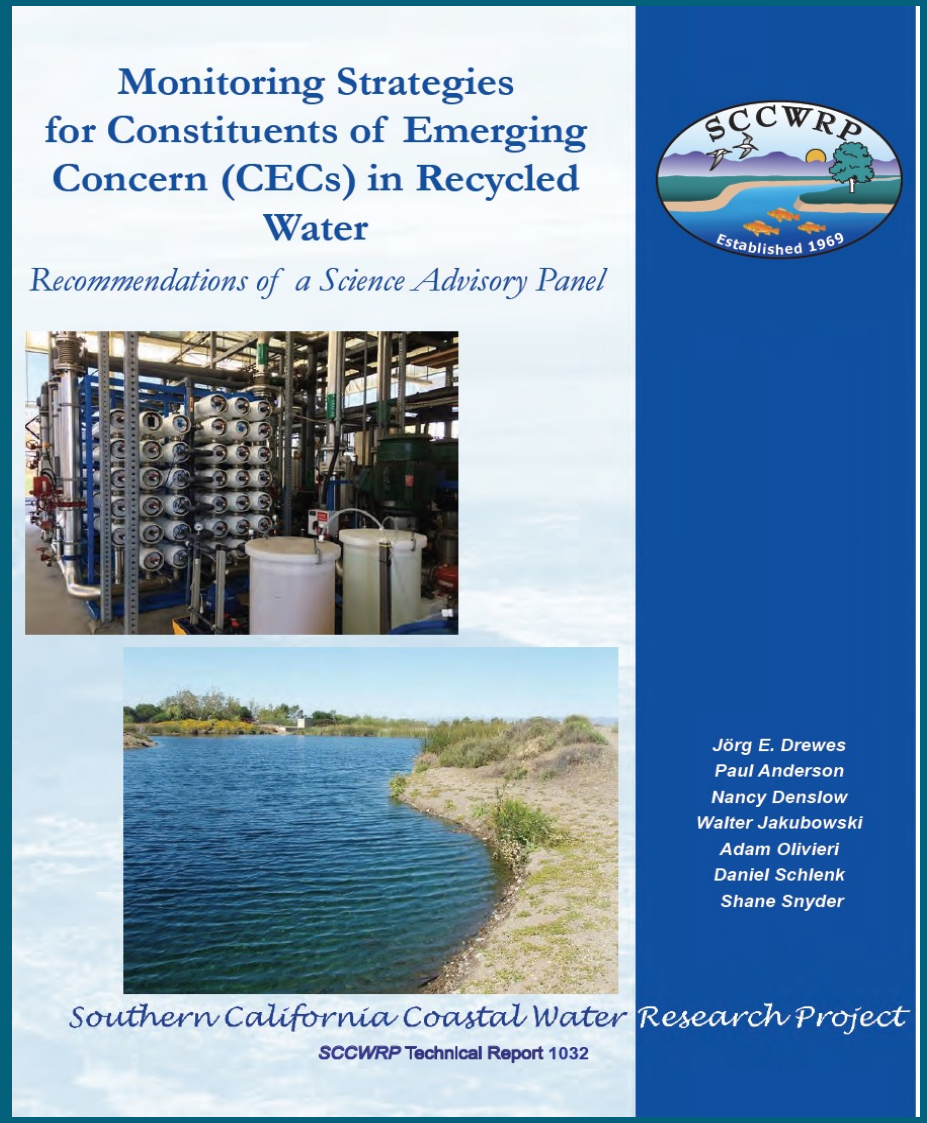
Unit Process	Process Design Parameters	*Virus LRV Credit*	*Bacteria LRV Credit*	*Protozoa LRV Credit*
Gammams WWTP	BNR (long SRT)	**0.5-1.0**	**1.0**	**0.5**
Pre O_3 and Coag/DAF	Pre-O3 dose: 3 mg/L Contact Time: 3 min Coag Chem's: $FeCl_3$, HCl, polyelectrolyte DAF SLR: 4 $m^3/m^2/hr$	**Included in DMF**	**Included in DMF**	**Included in DMF**
Dual Media Filtration (DMF)	Rate: 6m/hr Anthracite: 0.7m (ES 1.3) Sand: 0.7m (ES 0.7)	**1.5**	**1.5**	**2.0**
Ozone	Dose: 12mg/L mg O_3/mg DOC: 1.1 Contact Time: 24 mins CT: 12-20 mg/L/min	**4.0**	**4.0**	**(>0.6) 1.5-2.0**
BAC	EBCT: 10 min minimum Bed Depth: 1.5m	**Included in GAC**	**Included in GAC**	**Included in GAC**

Once Validated ..then need on-going *Operational Monitoring* with Critical Control Points (CCPs) developed through a HACCP process

Barrier	On-Line Operational Monitoring*	Laboratory Monitoring	Contingency
1 – Source Control in Collection System	• pH • VOC analysers at nodal points & at WWTP • *Microbial Fuel Cells* • *Real-time sensors (pH, Temp, ORP, Conduct'y, Turbidity) in collection system*	• Regular monitoring of individual trade waste discharges – compliance monitoring • WWTP influent	• Communication/Liaison Plan - media • Trade Waste Regulations • Trade Waste Agreements
2 – WWTP, including MBR, Effluent	• TOC • pH, Temperature • Turbidity • Conductivity • Ammonia	• Routine operational monitoring tests, e.g. MLSS, MLVSS, SRT, effluent SS & DOC • EEM Fluoresence	• All excursions communicated to Source Control & Collection System Managers as well as downstream AWTP operators • Divert effluent away from AWTP?
RO Based AWTP:			
3 – MF/UF	• Filtrate Turbidity • Filtrate Particle Count • Filtrate pH & Combined Chlorine Weekly Membrane Integrity Test (MIT, PDT, PHT)	• On-line instrument verification • EEM Fluoresence	• Feedback to WWTP • Redundant process units • AWTP shutdown – last resort
4 - RO	• Combined/Free Chlorine • Feed ORP/UVT • Permeate Conductivity • Permeate TOC (ppb) • Permeate pH & Flow • Brine Flow & Conductivity	• On-line instrument verification • EEM Fluoresence • Selected RW parameters – SAMP compliance	• Feedback to WWTP • Redundant process units on-line • AWTP shutdown
5 – UV & UV/AOP	• H_2O_2 and/or NaOCl dose (AOP only)	• SAMP Compliance • EEM Fluoresence	• AWTP shutdown – last resort.

Verification Monitoring

- Verifying compliance of reclaimed water quality with relevant quality standards;
- Sampling and Monitoring Program (SAMP) – chemical and microbiological tests; living document, extensive and surrogates
- Bioanalytical tests to verify 'safety' of the water - *ER-a* and *AhR* bioassay data should be collected on the product water in PR applications on a quarterly basis.



Water Corporation's 18 Surrogates

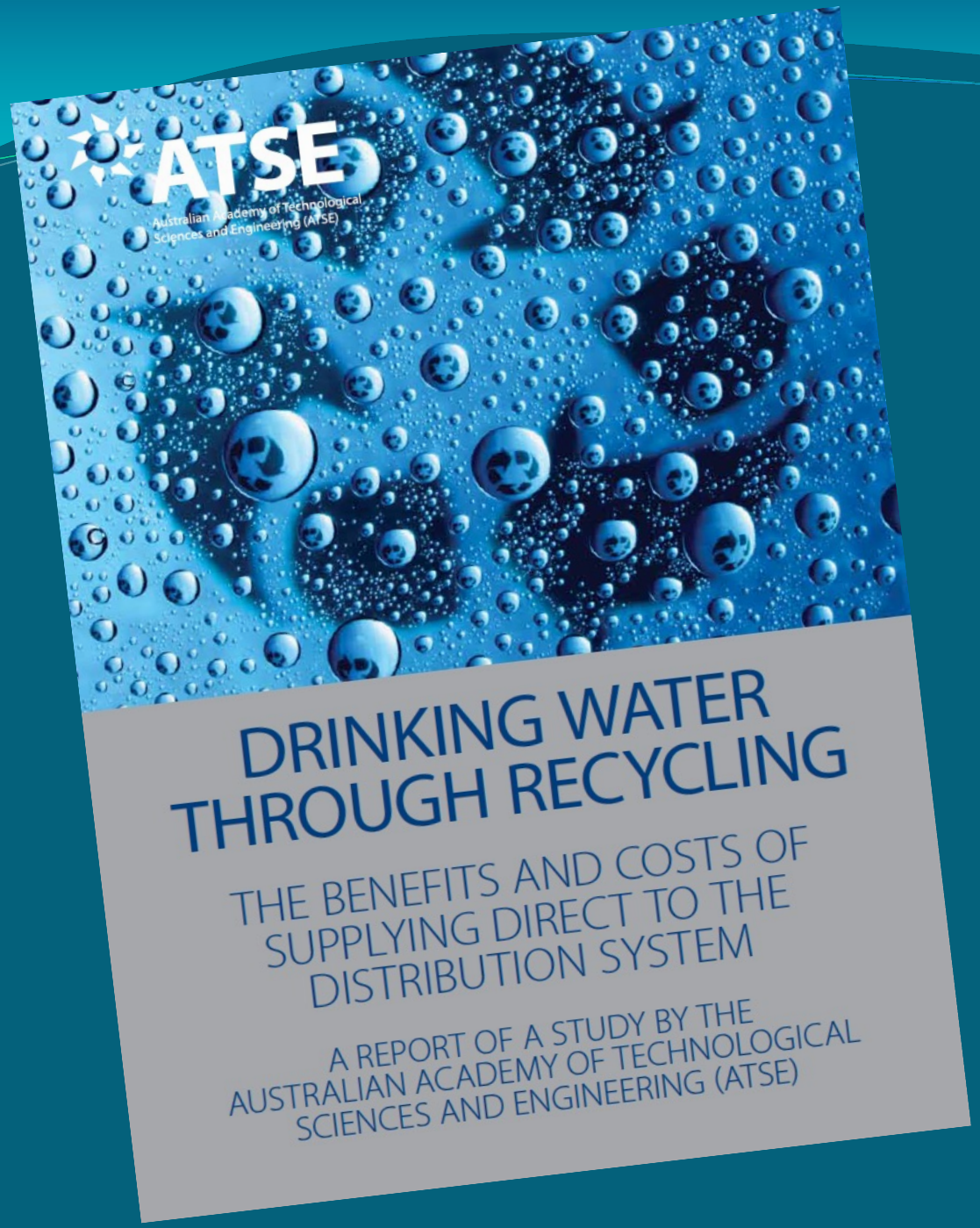
Surrogates selected as indicators of UF/RO treatment performance

Table 7: RWQI for groundwater replenishment in the Beenyup wastewater catchment

RWQI	Unit	Guideline Value(1)	Limit of reporting	Chemical Group that they represent
Boron	mg/L	4	0.02	Inorganic chemicals
N-nitrosodimethylamine (NDMA)	ng/L	100	1	Nitrosamines
Nitrate as nitrogen	mg/L	11	0.01	Inorganic chemicals
Chlorate	mg/L	0.7	0.01	Inorganic disinfection by-products
1,4-Dioxane	ug/L	50	0.1	Organic chemicals
Chloroform	ug/L	200	0.05	Other disinfection by-products
Fluorene	ug/L	140	0.1	Organic chemicals
1,4-dichlorobenzene	ug/L	40	0.05	Organic chemicals
2,4,6-trichlorophenol	ug/L	20	1	Phenols
Carbamazepine	ug/L	100	0.05	Pharmaceuticals and personal care products
Estrone	ng/L	30	1	Hormones
EDTA	ug/L	250	10	Organic chemicals
Trifluralin	ng/L	50000	1	Pesticides and herbicides
Diclofenac	ug/L	1.8	0.05	Pharmaceuticals and personal care products
Octadioxin	pg/L	9000	2	Organic chemicals
MS2 Coliphage	pfu/L	<1	0.6	Microorganisms / Pathogens
Alpha particle activity	mBq/L	500	10	Radioactive compounds
Beta particle activity (-K40)	mBq/L	500	10	Radioactive compounds

(1) Sampled results should be equal to or less than the guideline value.

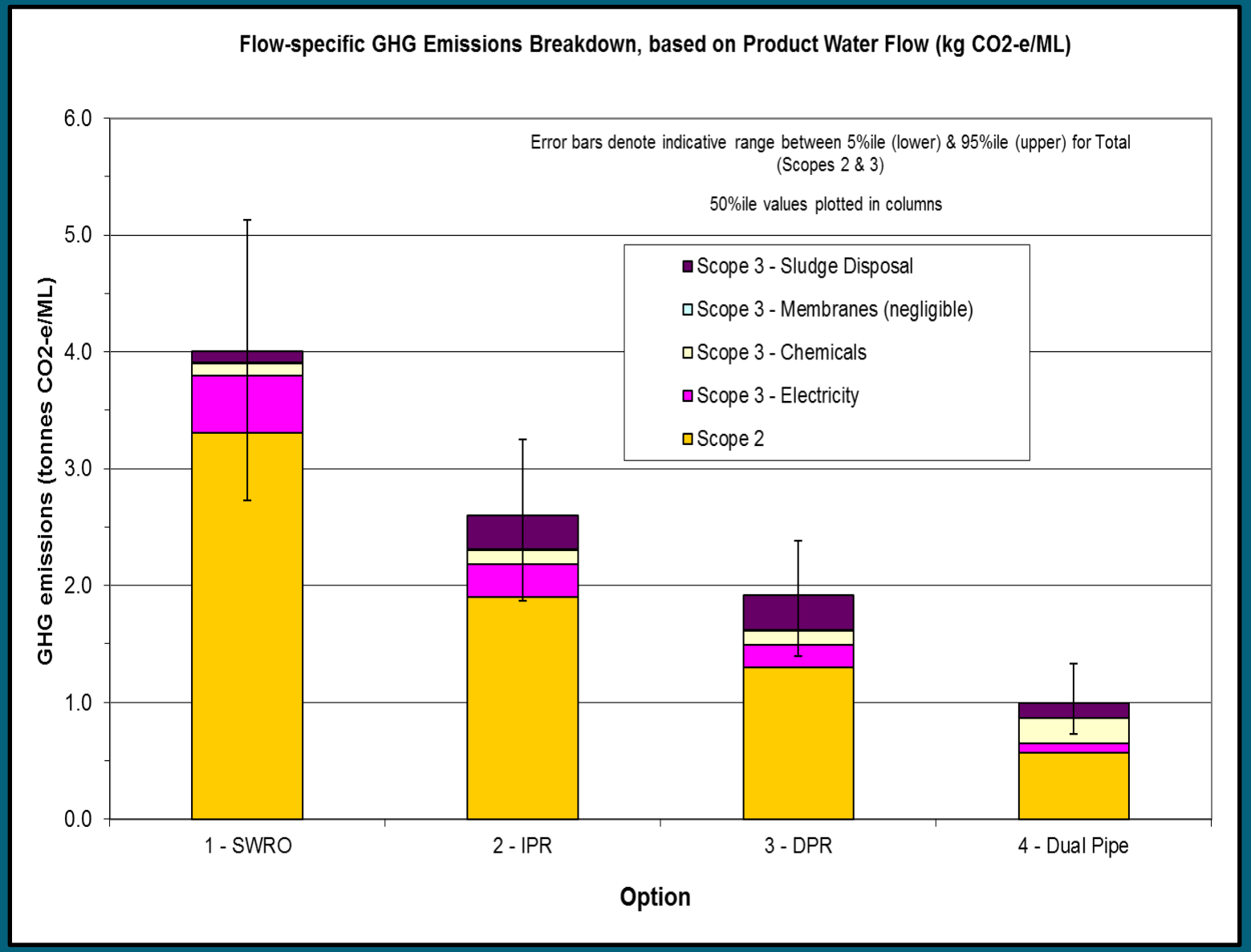
Sustainability – considering the future



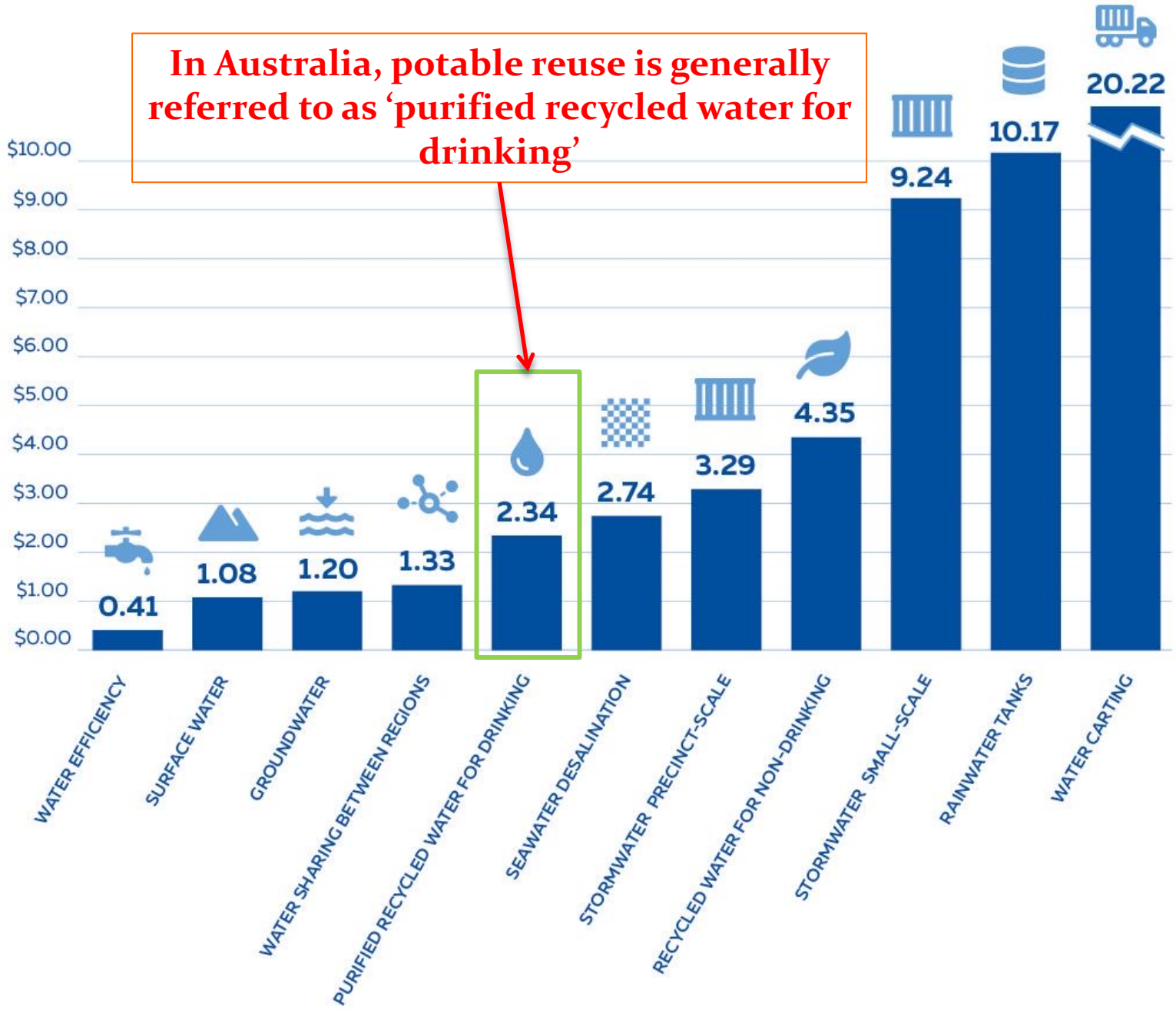
Report funded by the *Australian Water Recycling Centre of Excellence* (AWRCE) and released in October 2013

Extols benefits of the DPR option – and motivates for its consideration in any assessment of future water supply options.

Greenhouse Gas Emissions



In Australia, potable reuse is generally referred to as 'purified recycled water for drinking'



Communicating with the Public & Politicians on Potable Reuse

We do have some hurdles to overcome .....

We now know how to engage communities

October 2019

Lessons from the journeys of others

1

It can be done

Communities around the world have implemented purified recycled water schemes for decades. It could be successfully implemented in Australia, if circumstances warrant.

The three 'T's:
Trust • Transparency • Time

2

Trust is critical for securing support for purified recycled water

Transparency and open information sharing will help to develop and maintain this trust.

3

Establishing purified recycled water is complex and takes time

It takes time – up to a decade. People need to be taken on a journey to be comfortable with it. Rushing or imposing deadlines increases the risk of rejection or backlash.

4

Seeing is believing

Investing in a demonstration plant, visitor centre and tour program for 'place based learning' will greatly improve community understanding and support. It can showcase and prove the reliability of the technology, and pre-empt stigma reactions through calm, engaging learning environments.

The experience should be carefully crafted with sequenced messaging to build overall awareness and understanding, and may include sampling the water.

5

Wording and imagery are critical

This will be somewhat specific for each community, so local research is important. Choose words and branding that resonate and do not alienate. Technical jargon confuses people and doesn't build trust.

6

News media coverage has a profound impact on public acceptance

It can make or break a scheme. Proactively engaging key influencers and the media, leveraging social media, and using expert testimony and third party advocacy can help build trust and transparency.

7

Political support is essential

Political cycles can polarise an issue, and force people to take a side. Good engagement across the full political spectrum, to gain and keep support, is critical.

8

Grass roots education and engagement

Can be more effective than high profile marketing activity or 'above the line' presence.

'Water should be judged by its quality and not its history'
LUCAS VAN VUUREN, SOUTH AFRICA

9

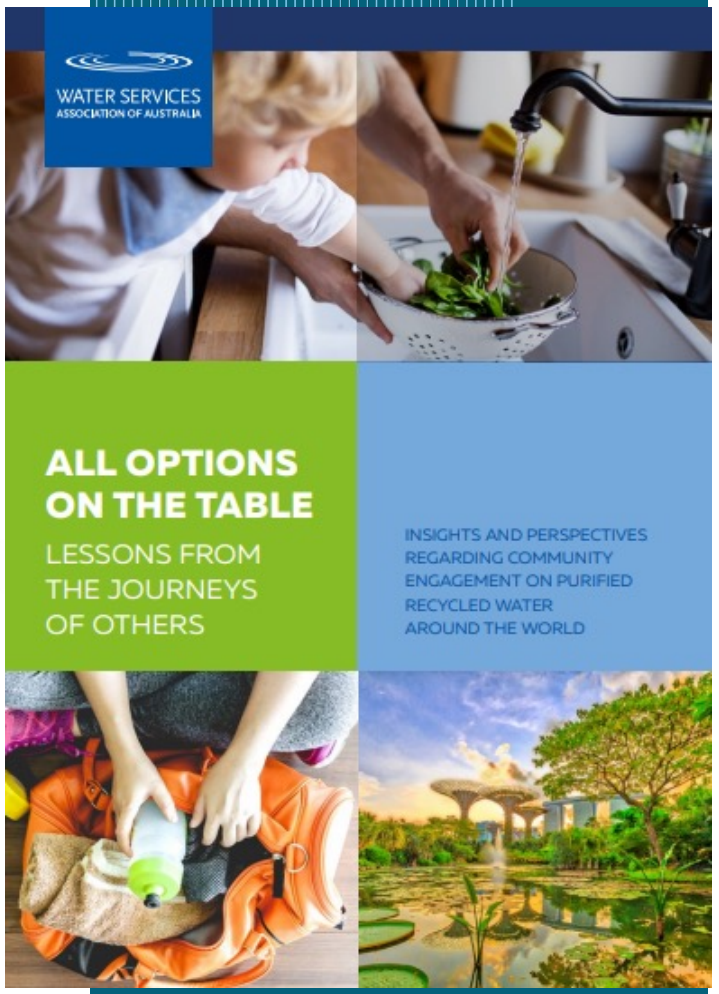
General education around the urban water cycle and context

Will help prevent stigma and encourage acceptance. Provide information on the range of long-term supply options, climate trends and cost.

10

Regulators play a powerful role

They will lead government and community perception, and have the authority to determine whether purified recycled water can proceed. It is their role to take a conservative approach to risk management, so it may take a long time for them to become comfortable and produce a regulatory framework. Good regulatory engagement, and high



NEWater, Singapore

One Example of the Demonstration Plant impact

Demonstration Plant, May 2000

Visitor Centre, Feb 2003

Some additional reading ….

Water Services Association of Australia (WSAA) - PRW toolkit, 2022
https://www.wsaa.asn.au/all-options-table-toolkit-purified-recycled-water-drinking

Closure

- The uptake of Purified Water for Drinking (PRW) (aka Potable Reuse) will continue to increase in many countries of the world as the search for reliable climate resilient water supplies intensifies … and the world's population grows;
- We must continue to investigate and develop technologies that produce a safe purified recycled water with reduced environmental footprint and at affordable cost;
- Co-operation/communication between water practitioners around the world is of paramount importance as we move forward in this important quest.

Thank YOU !

I wish you all good health and stay safe !!

Email: iblaw@bigpond.com
Mobile/Cell: +61 416034106