Beenyup Advanced Water Recycling Plant
The Perth, Australia Groundwater Replenishment Scheme

Jim Lozier, CH2M
Acknowledgements

- Co-authors (with Water Corporation)
  - Kevin Guppy, Delivery Manager
  - Stacey Hamilton, Senior Process & Framework Specialist
• Climate change, impact to Perth’s water supply and response by the Water Corporation to achieve sustainability
• The Groundwater Replenishment Trial as a key element of Perth’s water supply scheme
  – Treatment process
  – Treatment objectives
  – Regulatory aspects
• Full-scale advanced water recycling plant (at Beenyup)
  – Process/equipment selection
  – Regulatory compliance pertaining to pathogen removal
  – Implementation schedule
Perth, Australia

- Capital and largest city of Western Australia
- Fourth most populous city in Australia
- ~2 million residents in Greater Perth
- Mediterranean climate
- **Historical** average rainfall of 33 in/yr
Why Groundwater Replenishment?

30-40% reduction in rainfall over 50-year period
Inflow to Metropolitan Dams

- 103 billion gals/yr
- 47 billion gals/yr
- 24 billion gals/yr
- 20 billion gals/yr

= 13 summer days demand!
Integrated Water Supply Scheme 1993
Integrated Water Supply Scheme 2013

16 BGAL/YR
40 BGAL/YR
32 BGAL/YR

Desalination
Dams and lower security Groundwater
Secure Groundwater

Goldfields & Agricultural WS
Neerabup Wanneroo Mirrabooka
South Whitfords Lexia Mirrabooka
Gwelup Mundaring
Perth Victoria
Jandakot Canning Wungong
Serpentine North Dandalup
South Dandalup Samson Pipehead
Harvey Dam and Wokalup
Stirling Harris Pumpback

PSDP
SSDP
• Reduce demand by additional 15%
• Recycle 30% of wastewater by 2030
Groundwater Replenishment Trial (GWRT)

Trial Objectives

- Technical feasibility
- Policy and regulation
- Community engagement and discussion
- Conducted from 2009 through 2012
- Evaluated by regulatory agencies
- Endorsed by Government as next major source in 2013
The Groundwater Replenishment Trial was managed under the Wastewater Quality Framework.

This is a risk based quality management system aligned to the principals of the Australian Guidelines for Water Recycling and the Australian Drinking Water Guidelines.

The same type of approach is used by companies such as Coca Cola to ensure the quality of their products.
Demonstration AWRP

- Visitors Centre
- Recharge Bore
- Monitoring Bores
**Treatment Train**

**Wastewater Treatment**
- Effluent suitable for discharge to ocean

**Ultrafiltration – Removes:**
- All suspended solids
- Crypto, giardia, all bacteria
- Viruses (pore size dependent)

**Reverse Osmosis – Removes:**
- All viruses
- Inorganics, including nitrogen
- Bulk and trace organics

**Ultraviolet Treatment**
- Final disinfection step
- Inactivation of bacteria, crypto, giardia and viruses
Assurance through Critical Control Points

Breach of any Critical Limit for a Critical Control Point causes automatic diversion of the AWRP.

1. Turbidity: From ocean outfall (ex. Beenyup)
   - Storage tank
   - Ultra filtration barrier
     - Pressure Decay
     - Turbidity
   - Two - stage reverse osmosis barrier
     - Conductivity (3)
     - Total Organic Carbon
   - De-gassing (removing bubbles)
   - Flow
   - UV Intensity
   - Ultra violet disinfection barrier
   - Water suitable for recharge

Total Critical Control Points: 13
Recycled Water Quality Indicators

18 Recycled Water Quality Indicators

292 Recycled Water Quality Parameters
## Recycled Water Quality Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Group Represented</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Boron</td>
<td>Metals and metalloids</td>
</tr>
<tr>
<td>2 Nitrate as N</td>
<td>Inorganic anions</td>
</tr>
<tr>
<td>3 NDMA</td>
<td>N-nitrosamine DBPs</td>
</tr>
<tr>
<td>4 Chlorate</td>
<td>DBP anions</td>
</tr>
<tr>
<td>5 1,4-Dioxane</td>
<td>Miscellaneous organics</td>
</tr>
<tr>
<td>6 Chloroform</td>
<td>DBPs</td>
</tr>
<tr>
<td>7 1,4-dichlorobenzene</td>
<td>Volatile organics</td>
</tr>
<tr>
<td>8 Fluorene</td>
<td>Polycyclic aromatic compounds</td>
</tr>
<tr>
<td>9 2,4,6-trichlorophenol</td>
<td>Phenols</td>
</tr>
</tbody>
</table>
## Recycled Water Quality Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Group Represented</th>
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<tbody>
<tr>
<td>10 Carbamazepine</td>
<td>Persistent pharmaceuticals</td>
</tr>
<tr>
<td>11 Estrone</td>
<td>Hormones</td>
</tr>
<tr>
<td>12 EDTA</td>
<td>Complexing Agents</td>
</tr>
<tr>
<td>13 Diclofenac</td>
<td>Acidic Pharmaceuticals</td>
</tr>
<tr>
<td>14 Trifluralin</td>
<td>Pesticides</td>
</tr>
<tr>
<td>15 Octadioxin</td>
<td>Dioxins, furans &amp; dioxin like PCBs</td>
</tr>
<tr>
<td>16 MS2 Coliphage</td>
<td>Microbial pathogens including virus</td>
</tr>
<tr>
<td>17 Alpha Particle Activity</td>
<td>Radioisotopes</td>
</tr>
<tr>
<td>18 Beta Particle Activity</td>
<td>Radioisotopes</td>
</tr>
</tbody>
</table>
## Microbial Log Reduction Credits

<table>
<thead>
<tr>
<th></th>
<th>Equivalent Log Reduction Credits</th>
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<tbody>
<tr>
<td></td>
<td>Bacteria</td>
</tr>
<tr>
<td>Wastewater Treatment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>BAWRP Process Unit</td>
<td></td>
</tr>
<tr>
<td>UF with chloramination &gt;1.5 mg/L</td>
<td>3</td>
</tr>
<tr>
<td>Reverse Osmosis</td>
<td>3</td>
</tr>
<tr>
<td>UV Disinfection at &gt;186 mJ/cm²</td>
<td>4</td>
</tr>
<tr>
<td>Total AWRP ELRC</td>
<td>10</td>
</tr>
<tr>
<td>Total (WWTP &amp; BAAWRP)</td>
<td>11</td>
</tr>
<tr>
<td>DoH Requirement</td>
<td>8.5</td>
</tr>
<tr>
<td>Excess credits (safety factor)</td>
<td>2.5</td>
</tr>
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Timeframes for the GWR Scheme

**Stage One & Two**
14 gigalitres/yr (10 mgd)
Jun 2014: Planning & Construction
Jun 2016: Recharge & abstraction

**Stage Three**
Additional 14 GL/yr (10 mgd)
Aug 2020: Construction start
Jun 2022: Recharge & abstraction
In August 2013 the WA Government approves groundwater replenishment as a next major water source for Perth.

In November 2013 Water Corporation selects two teams to develop preliminary design and total outturn cost (TOC) for three separate replenishment stages (capacities).

In July 2014 Water Corporation selects the Joint Venture of CH2M HILL and Thiess (aka CHTJV) to design, construct and commission the 14 GL/yr Beenyup AWRP, incorporating both Stages 1 and 2.
Ultrafiltration

- 2,989 m³/hr (17.3 mgd) gross filtrate flow
- 8+1 Skids (manufactured by Hager + Elsasser)
- Dow SFD-2880 UF modules (Toray)
- 104 modules per skid
- 49 LMH (29.5 gfd) max inst. flux
- 92% recovery
- Key performance requirement:
  - 3-log removal of MS-2 phage to comply with ELRC
  - Demonstration via:
    - Full-scale system if sufficient MS-2 in UF feed
    - Test rig if insufficient level through seeded challenge test
- SFD-2880 module selected based on NSF ETV MS-2 phage results
MS-2 Phage Challenge Testing – Dow SFD2880 Module

- Testing conducted by NSF Int’l (EPA ETV program)
- 50% LRV of 3.5
Reverse Osmosis

- 2042 m³/d (13 mgd) permeate flow
- 4+0 skids (manufactured by Hager + Elsasser)
- Hydranautics ESPA2-LD elements (Toray TMD-20)
- 70:35 vessel array using 7M vessels
- Average flux: 19.2 LMH (11.3 gfd)
- Recovery: 75% initial (80% ultimate)
- FEDCO ERD for Stage 2 pressure boost
- Key performance requirement:
  - 3-log virus/bacteria/protozoa removal
    - Demonstrated through challenge testing with Rhodamine-WT (ASTM D6908-06) and sulfate
  - Compliance with ASTM D3923-08 (vacuum testing)
    - <10 kPa/min (1.4 psi/min) decay rate
Log Removals – ESPA2-LD
Rhodamine WT & Conductivity

![Graph showing log removals for ESPA2-LD process stages and training stages over time.]
Weekly SO4 Log Removal

Sulphate Monitoring Across RO - Weekly Analysis

- **Sufficient Feed**
- **Insufficient Feed**
- **Target**
Ultraviolet (Light) Disinfection

- 1999 m³/hr (12.7 mgd) flow
- 2+0 trains
- Calgon Sentinel 9L24 (UV AOP specific)
- Medium pressure, polychromatic
- MS2 phage RED = 186 mJ/cm²
- 94% UVT
- Key Performance Requirement
  - 4-log virus inactivation
### BAWRP Stages 1&2 Project Schedule

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
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<tbody>
<tr>
<td>Project Award</td>
<td>July 2014</td>
</tr>
<tr>
<td>Start of Design</td>
<td>Aug 2014</td>
</tr>
<tr>
<td>Design Completion</td>
<td>Feb 2015</td>
</tr>
<tr>
<td>UF/RO/UV Systems Delivery</td>
<td>Jun 2015</td>
</tr>
<tr>
<td>Construction Completion</td>
<td>Mar 2016</td>
</tr>
<tr>
<td>Validation &amp; Verification Completion</td>
<td>Nov 2016</td>
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</tbody>
</table>
Looking Ahead – Water Forever

% IWSS Sources - 2012

- Dams & Lower Security Groundwater
- Desalination
- Secure Groundwater

% IWSS Sources - 2022

- Desalination
- Secure Deep Groundwater
Questions?

- jlozier@ch2m.com
Plant Design
Overall Facility
RO Trains