OPTIMISATION OF MEMBRANE BIOREACTOR NUTRIENT REMOVAL PERFORMANCE – PRACTICAL EXAMPLES

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Optimised MBR Operation for Nutrient Removal

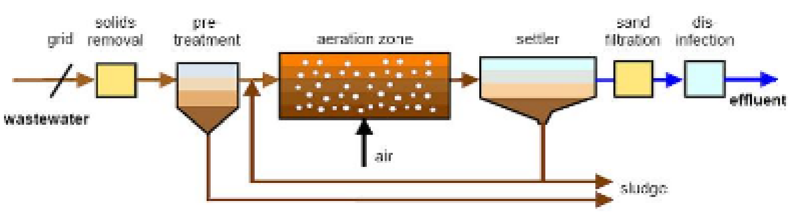
- Tightening Nutrient Consents
- What is MBR?
- MBR Design and Operation - Lessons Learnt
- MBR Facility Examples
- Nitrogen Removal Optimisation Using Ammonia Based Aeration Control (ABAC)
- Phosphorus Removal Control Optimisation
- Wet Weather Impacts to Phosphorus Removal
- MBR Train Phosphorus Release
- Conclusions & Questions

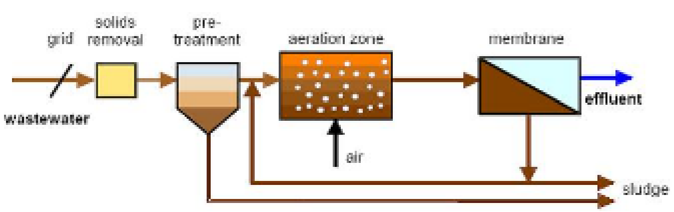
Tightening Nutrient Consents in Australia

- 1990s – TN<10, NH3<2, SS<20
  - Primary Settling, Extended Aeration, Oxidation Ditches, Nitrifying Trickling Filters, Aerated Lagoons
  - **MBRs regarded as an Emerging Technology**
- 2000s - TN<5, NH3<1, TP<2
  - MLE, A2O, UCT and Bardenpho variants, Oxidation Ditches, no Primary Settling, Anaerobic Zones, Fermenters
  - **First Major MBR in Australia. Gippsland Water Factory, Cleaner Seas**
- 2010s – TN<3, NH3<0.5, TP<1, Class A, No Chlorine to Discharge
  - Advanced process controls; Aeration, supplementary COD and metal salts (Alum) dosing
  - Simultaneous Nitrification Denitrification (SND)
  - **MBR refined for nutrient removal and energy efficiency**
- 2020s – NH3<2, TP<0.5, Energy & Resource Recovery
  - Carbon redirection, Enhanced Primary Treatment
  - MABR, Short cut N removal, Deammonification
  - Nutrient and residuals recovery
  - **Next Gen MBR integration with new technologies**

What is MBR?

- **MBR – Membrane Bioreactor**
  - Activated sludge process with an integrated filtration device
  - Replaces Final Clarification
  - Submerged or pressurised membrane systems
  - Micro and Ultra Filtration membrane pore size options
  - Hollow fibre or flat sheet configurations
  - Reinforced and unreinforced hollow fibre options
  - Pumped too and pumped configuration options

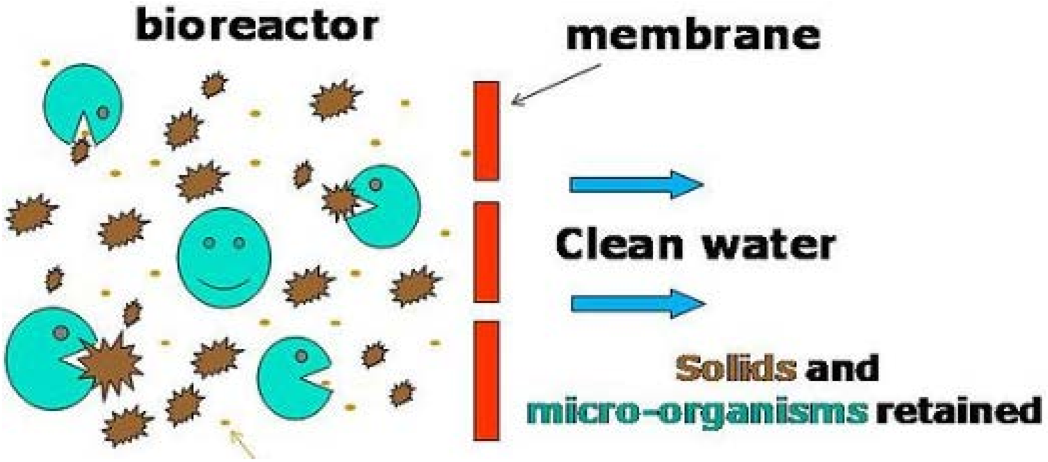




What is MBR?

- **Benefits of MBR**

  - Allows higher MLSS, process intensification and reduced volume and footprint
  - MBR Train volume can be included as bioreactor biomass fraction
  - Provides superior effluent filtration (inc N and P part. Fractions)
  - Bacteria and micro-organisms rejection, partial virus rejection. Ideal as part of a recycled water treatment process
  - Tertiary Treatment (Media Filtration and UV) may not be needed
  - Guaranteed pro rata service life now typically 7 - 10 years, initially 5 – 7 years. Proven service life now up to 15+ years



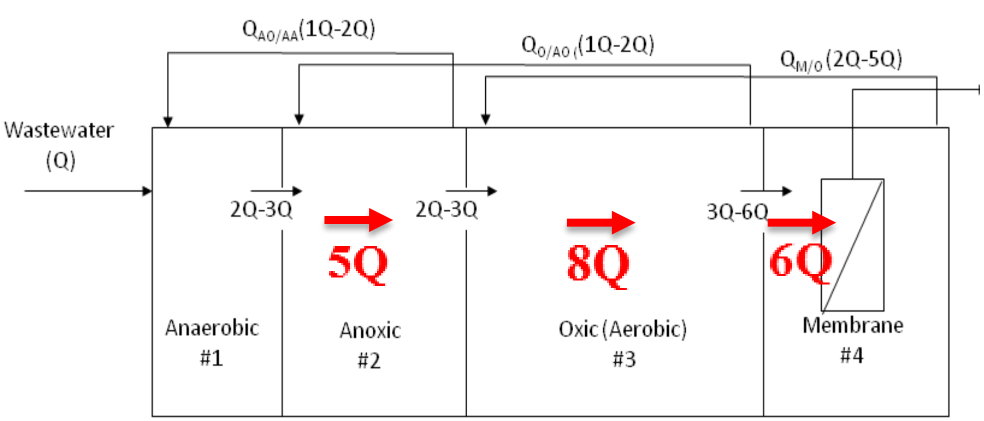
MBR Design and Operation – Lessons Learned

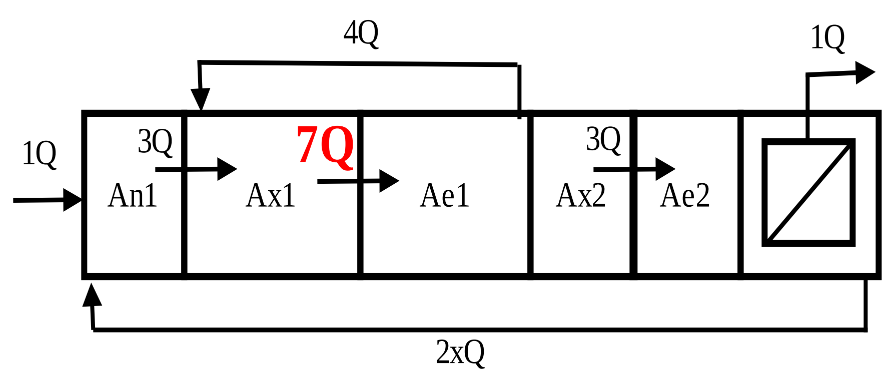
- **Influent Screening**
  - Important for membrane integrity and service life expectancy
  - 2mm punch hole without screens bypass to the MBR
  - Screen failure has been experienced:
    - Loss of seal integrity caused by incorrect installation,
    - Membranes accumulated screenings; cleaned,
    - Minimum damage, minor repair only
  - Improved Drum Screen Design:
    - Double screen seals

MBR Design and Operation – Lessons Learned

Reactor Configuration for MBR Integration

- Are high and multiple internal recycles necessary?:
  - Ammonia breakthrough, DO carry-over and poor Anaerobic Zone function
  - High pumping energy and very high alpha, poor aeration efficiency
- Pump to vs Pumped from MBR, which one?:
  - Pumped from = lower flow, higher head loss, difficult MRAS control
  - Pumped to = higher flow, lower head loss, easier MRAS control
  - Consider layout an pumping power





MBR Design and Operation – Lessons Learned

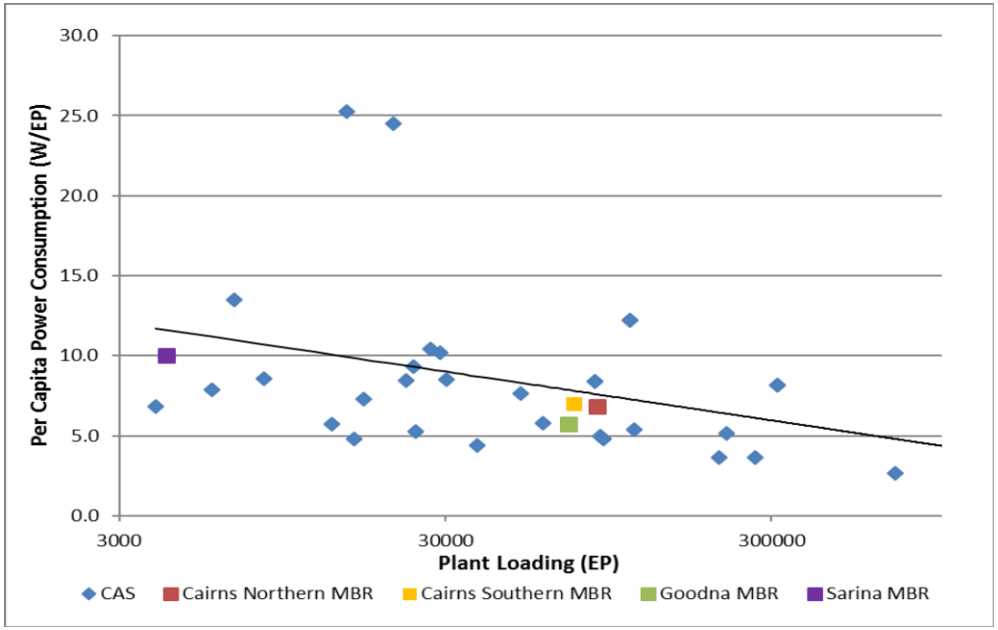
- **Pushing Hard… Solids and Hydraulic Flux**
  - More capacity, but high flux can cause increased rate of / or premature fouling
  - Requires more CIPs, reducing service life, chlorine age
- **Insufficient CIP or Scour Air**
  - CIP and/or Scour air reduced to save operating costs
  - May cause increased rate of fouling and solids settlement in trains
  - More CIPs and less effective
  - May reduces service life
- **MBR Capacity and CIP**
  - Membranes capacity may be time varied
  - MCIP restores full capacity
  - Design for redundancy including MCIP

MBR Design and Operation – Lessons Learned

- **BioP Difficulties**
  - High recirculation and high RAS DO impact BioP – some early challenges
  - Improved configurations protect Anaerobic Zones and prevent secondary P release
- **Access and O&M Provisions**
  - Typically annual inspections undertaken
  - Access for cassette removal and insertion
  - Enables safe and efficient O&M operations
  - Gantry Crane for large facilities
  - Mobile Cranes for small facilities
  - Provide laydown and washdown bunds

MBR Design and Operation – Lessons Learnt 3

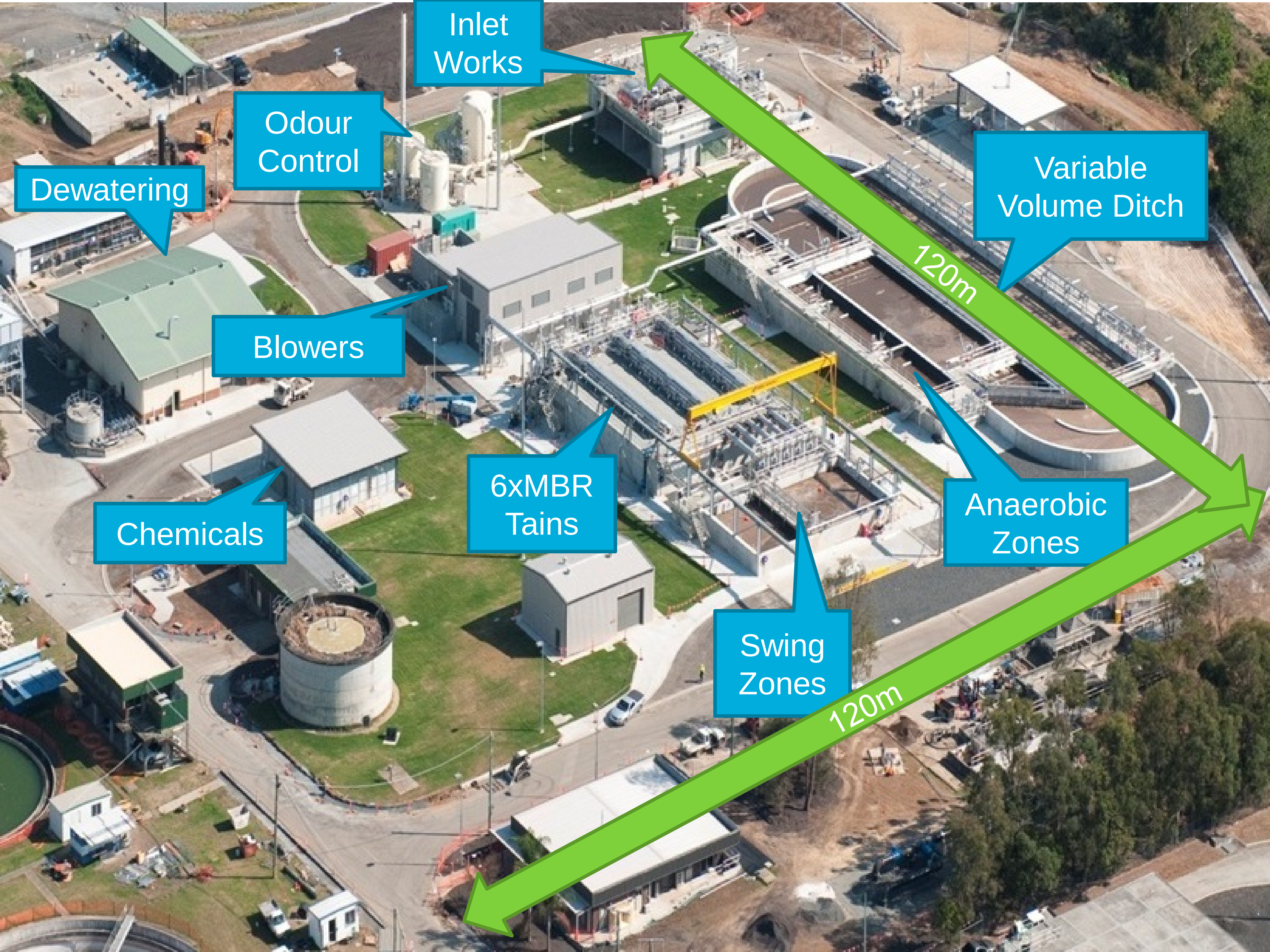
- **EPS Fouling**
  - Extracellular Polymeric Substances
  - Increased fouling, UK examples.
  - Minimum sludge age criteria, eg +8 days
- **Energy Efficiency**
  - Often thought to be high energy processes
  - Improved design provides significant energy reductions
  - Hydraulics – consider internal recycle and hydraulic losses
  - Aeration - consider design MLSS and scour aeration for biological demand



MBR vs Conventional Activated Sludge Power Demand per Equivalent Person Load

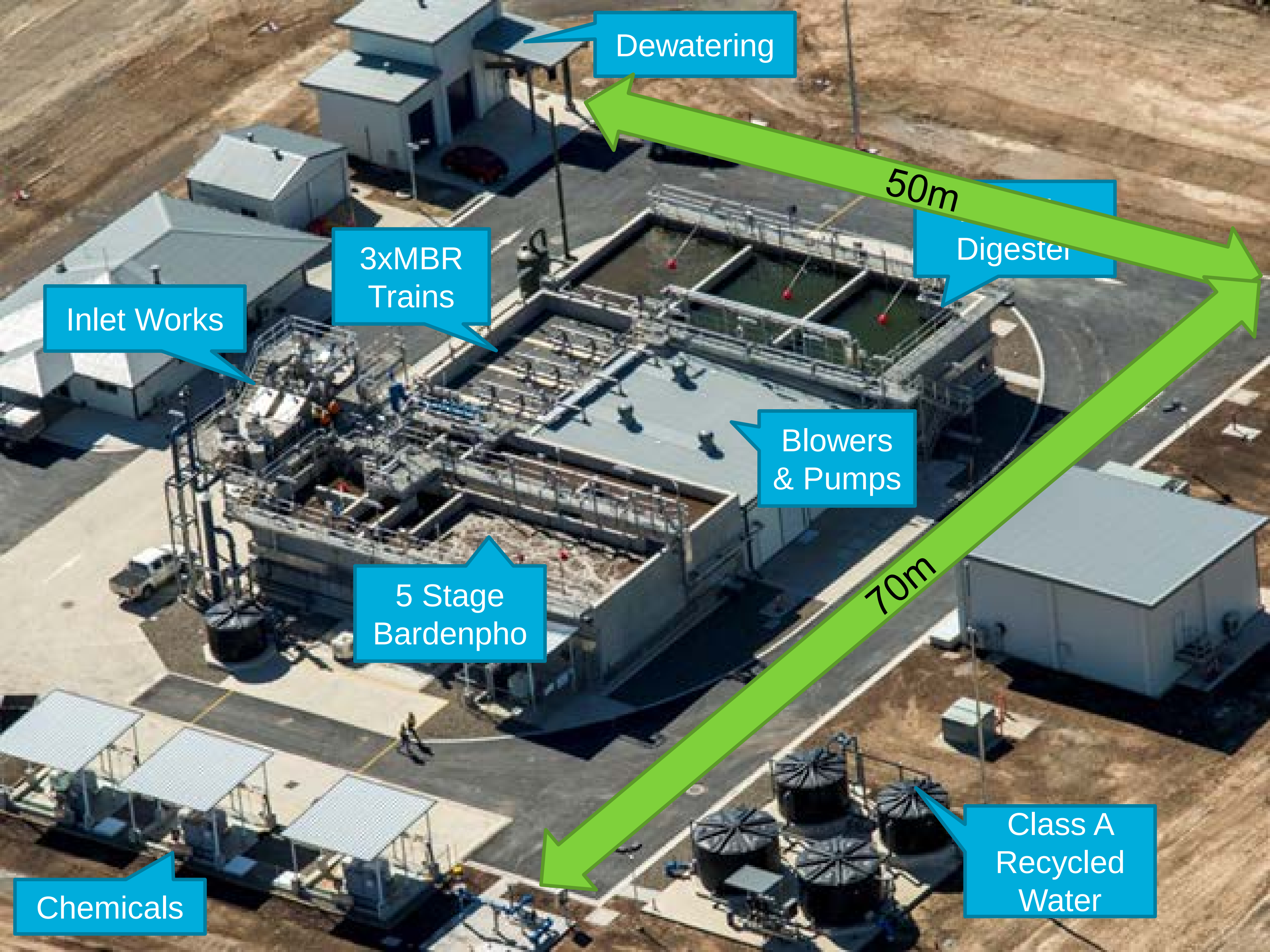
MBR Facility Example – Goodna STP

- **Goodna STP (QUU 2012)**
  - 90kEP, TN 2.2, TP 0.5
  - Low influent C:N ratios ≈8:1
  - Novel BNR MBR integrated configuration
  - Ammonia based aeration control (ABAC)
  - Analyser based Alum and methanol dosing control
  - Benchmark energy efficient (5.4W/EP)
  - Variable Tank volume
  - 42 x Suez 500D Membranes
  - Class A Recycled Water
  - Aerobic Digester
  - Multi-award winning design


Inlet Works
Odour Control
Dewatering
Variable Volume Ditch
120m
Blowers
6xMBR Tains
Anaerobic Zones
Chemicals
Swing Zones
120m

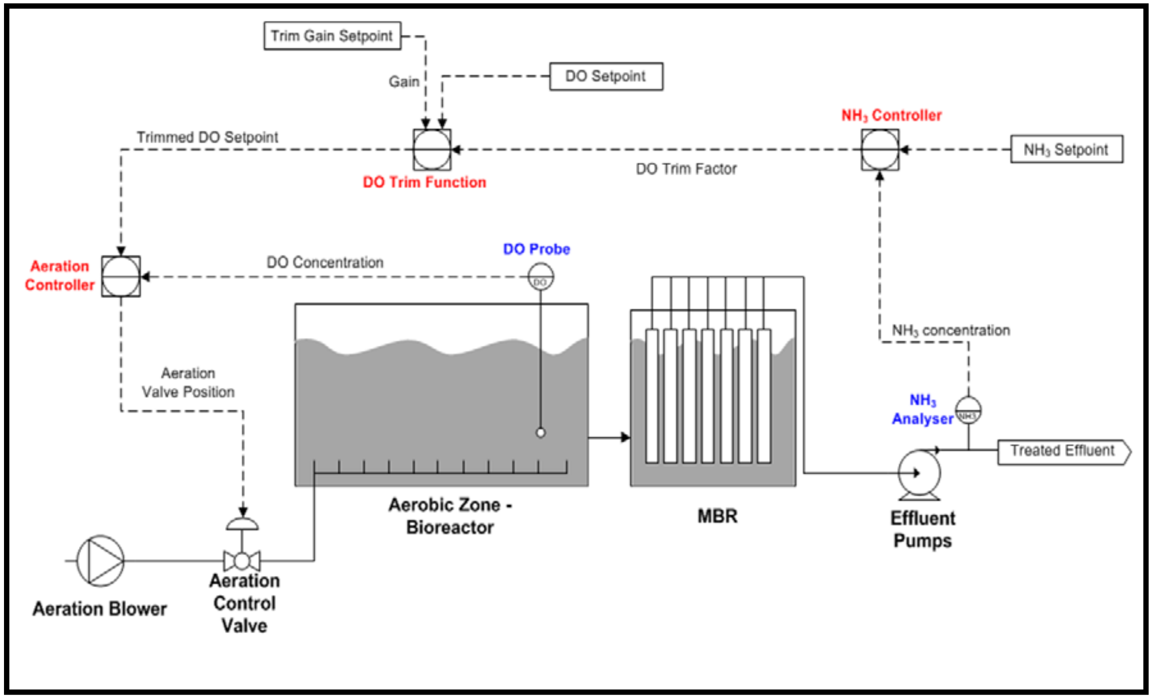
MBR Facility Example – Sarina WRF

- **Sarina WRF (Mackay Regional Council 2015)**
  - 8kEP, TN 3.4, TP 0.3
  - Compact 5 Stage Bardenpho
  - Ammonia based aeration control (ABAC)
  - Analyser (OP) based Alum dosing control
  - 4.5 x Suez LEAP500D Membranes
  - Energy efficient (10W/EP)
  - Class A Recycled Water
  - Aerobic Digester
  - Robust and Cost effective


Dewatering
50m
Digester
3xMBR Trains
Inlet Works
Blowers & Pumps
70m
5 Stage Bardenpho
Class A Recycled Water
Chemicals

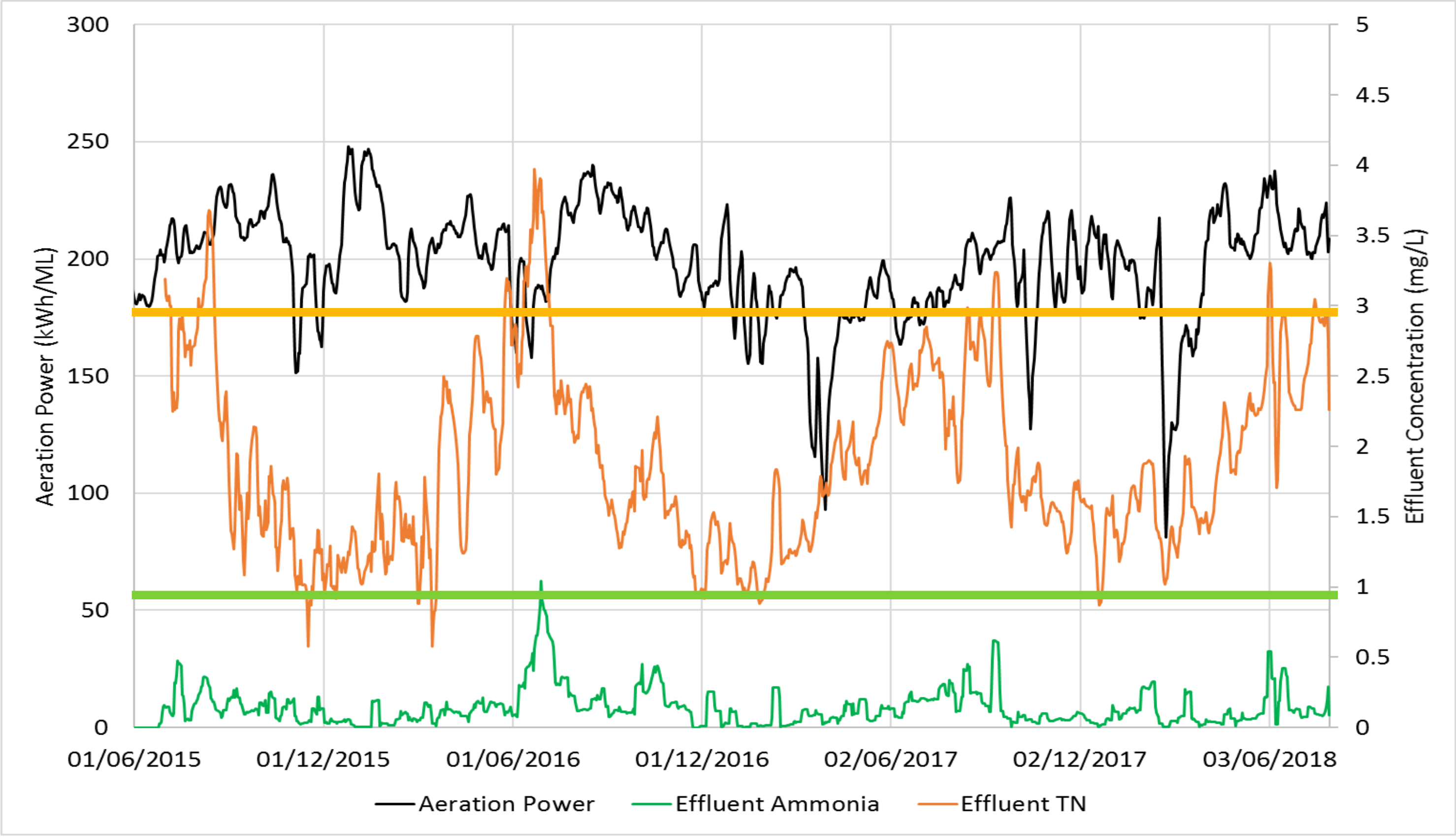
Ammonia Based Aeration Control

- **What is ABAC ?**
  - Aeration control methodology that meets aeration demand to achieve a desired ammonia concentration in the bioreactor or effluent
  - DO setpoint is trimmed based on NH3 Effluent relative to setpoint
  - Avoids over and under aeration and tighter effluent NH3 compliance
- **An ABAC Resurgence?**
  - Proven Technology
  - Improved analyser reliability
  - Increased energy saving
  - SND and N-Shunt
  - Helpful in MBR (short HRT)



ABAC Performance - Goodna STP

- Robust nutrient removal performance since plant commissioning
  - Ease of compliance with TN 3 mg/L and NH3 of 1.0 mg/L at respective medians of 2.2mg/L and 0.2mg/L.



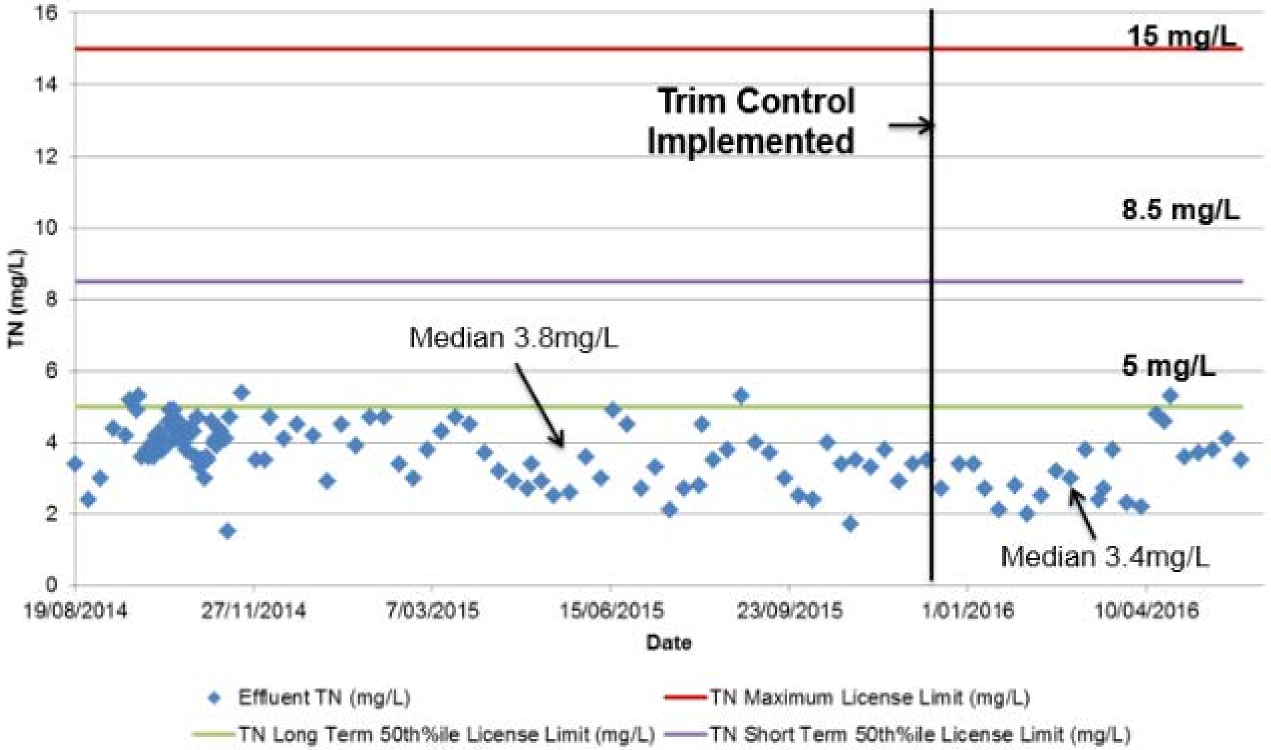
ABAC Optimisation Results - Sarina WRF

- ABAC initially hampered by ammonia analyser failure
- Improved analyser and ABAC in late 2017, resulted in an improvement in energy efficiency over previous years

Year	Aeration Control	Power (kWh/d)	Load (EP)	Efficiency (W/EP)
2014	DO	1253	3900	13.4
2015	DO	1278	3900	13.7
2016	DO	1259	4000	13.1
2017	DO	1230	4100	12.5
2018	ABAC	1012	4200	10.0

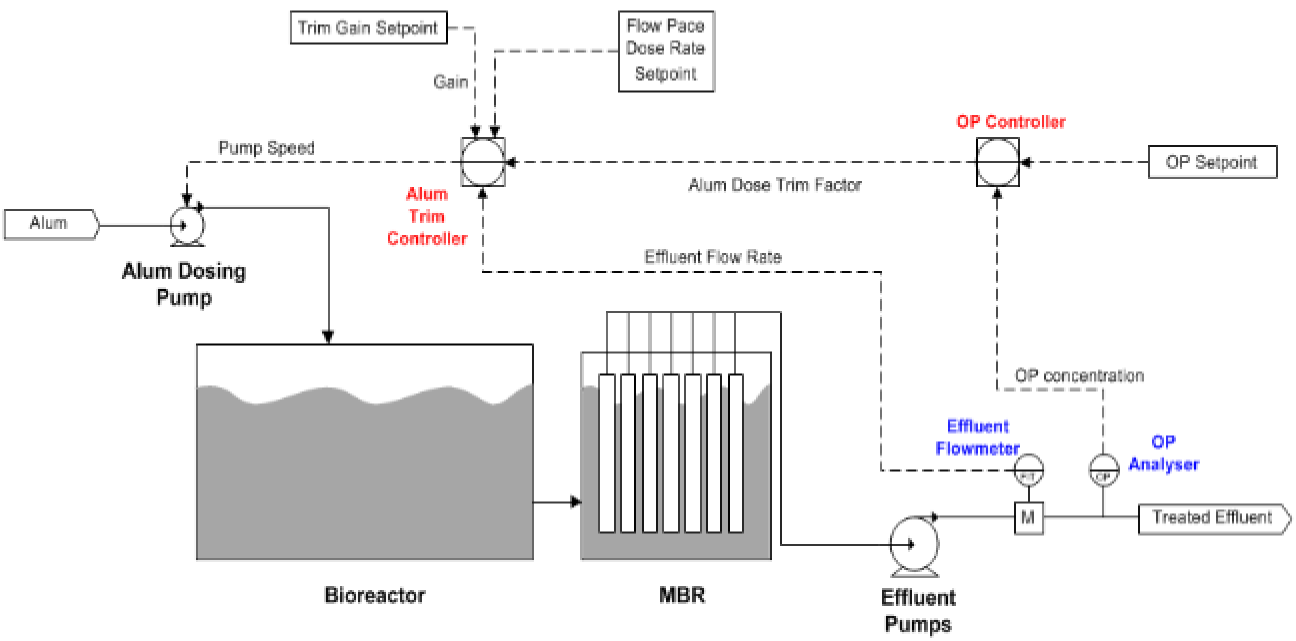
ABAC Optimisation Results - Sarina WRF

- Earlier attempts using ABAC also showed improved process performance and reliability:
  - Median TN reduced from 3.8mg/L to 3.4mg/L



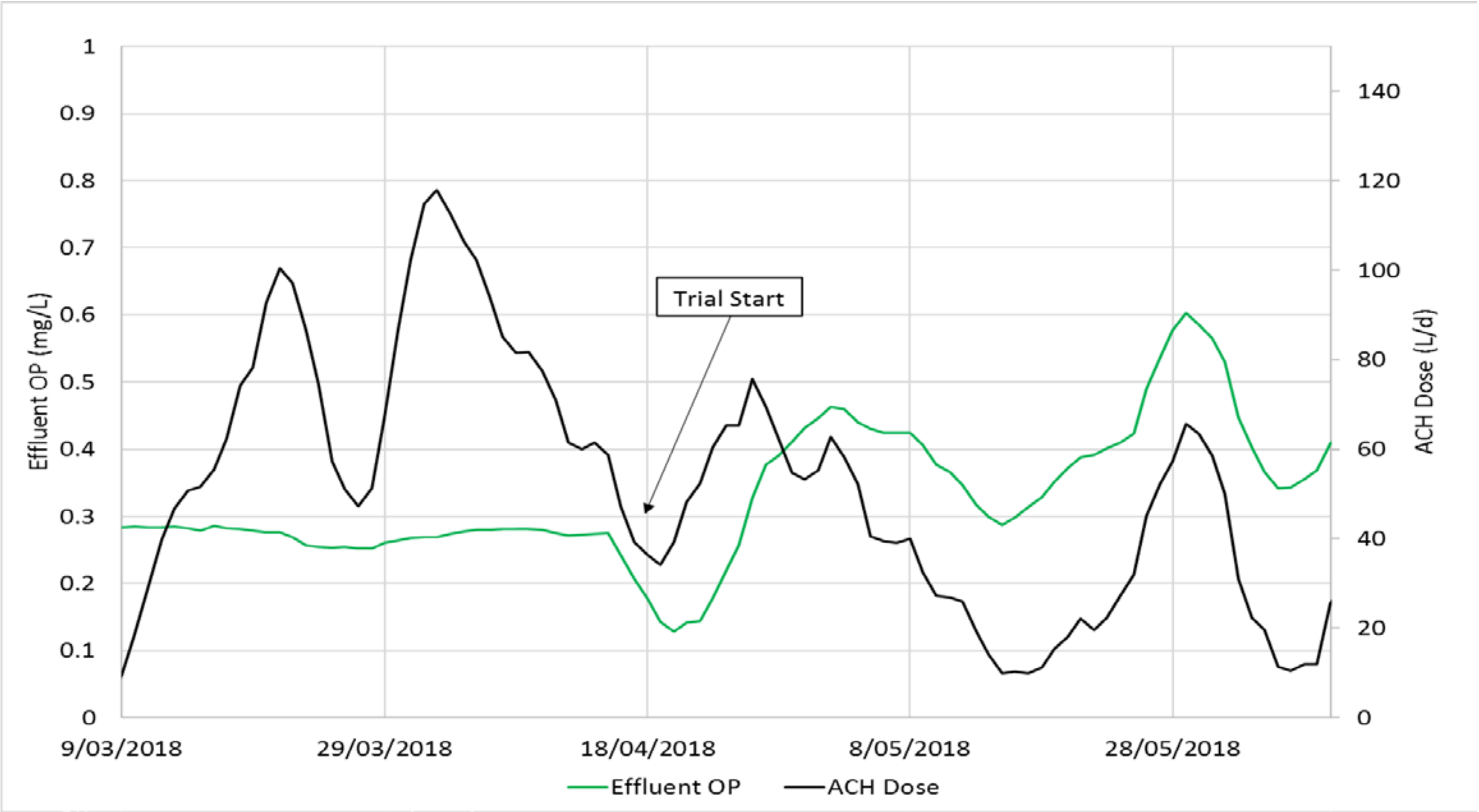
MBR Phosphorus Removal Optimisation Control

- ❑ Enhanced Biological Phosphorus Removal (EBPR) has been challenging in development of MBR systems:
  - o To achieve reliable effluent TP below 1 - 2mg/L, metal salt dosing is required.
  - o Chemical dosing requirements are variable depending on environmental conditions
  - o An advanced analyser based controller improves dosing efficiency and reliability.



Phosphorus Removal Optimisation - Sarina WRF

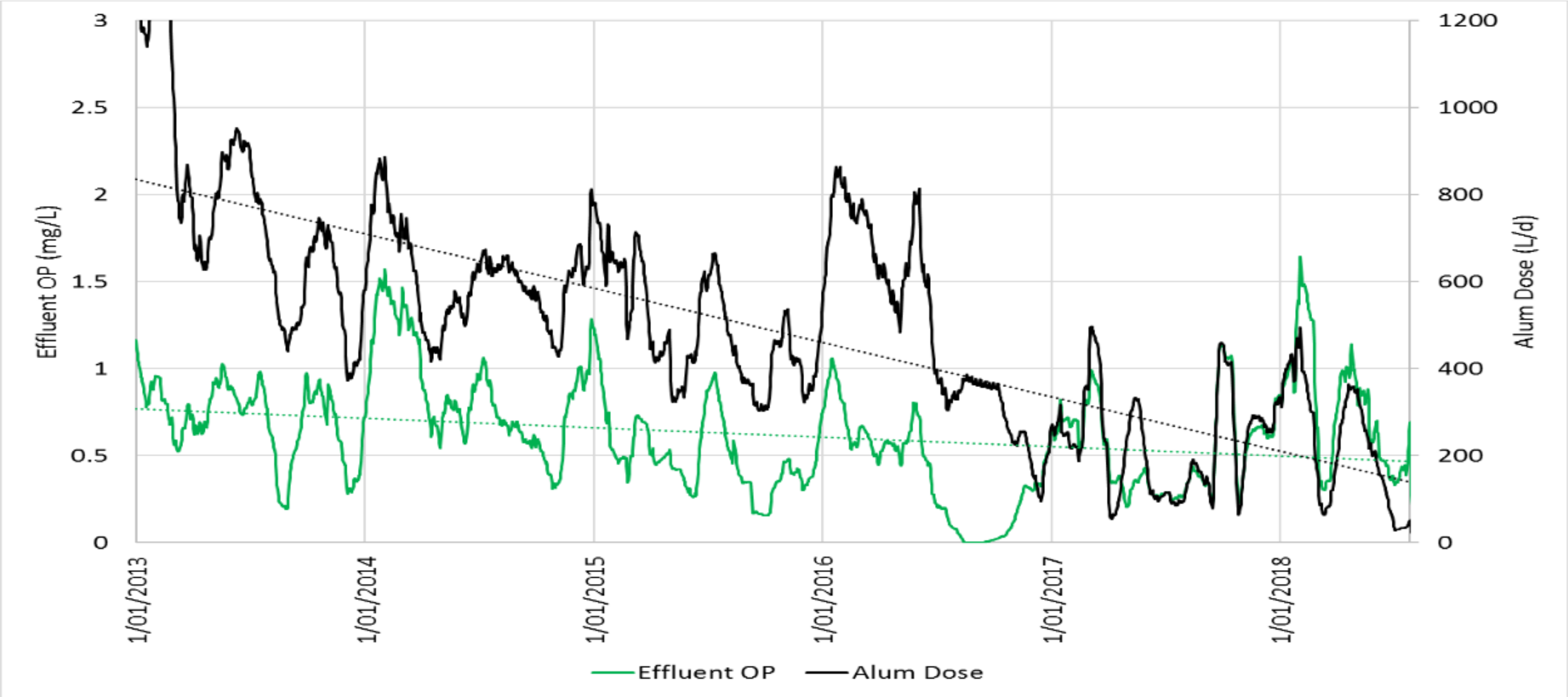
- ❑ Effluent TP increase from 0.28 to 0.45 mg/L, based on a selected set point of 0.5 mg/L and improved control.
- ❑ ACH dosing rate were reduced from 59.3 L/d to 34.6 L/d



Sarina Advanced Controls Trial: Effluent OP vs ACH Dosing

Phosphorus Removal Optimisation – Goodna STP

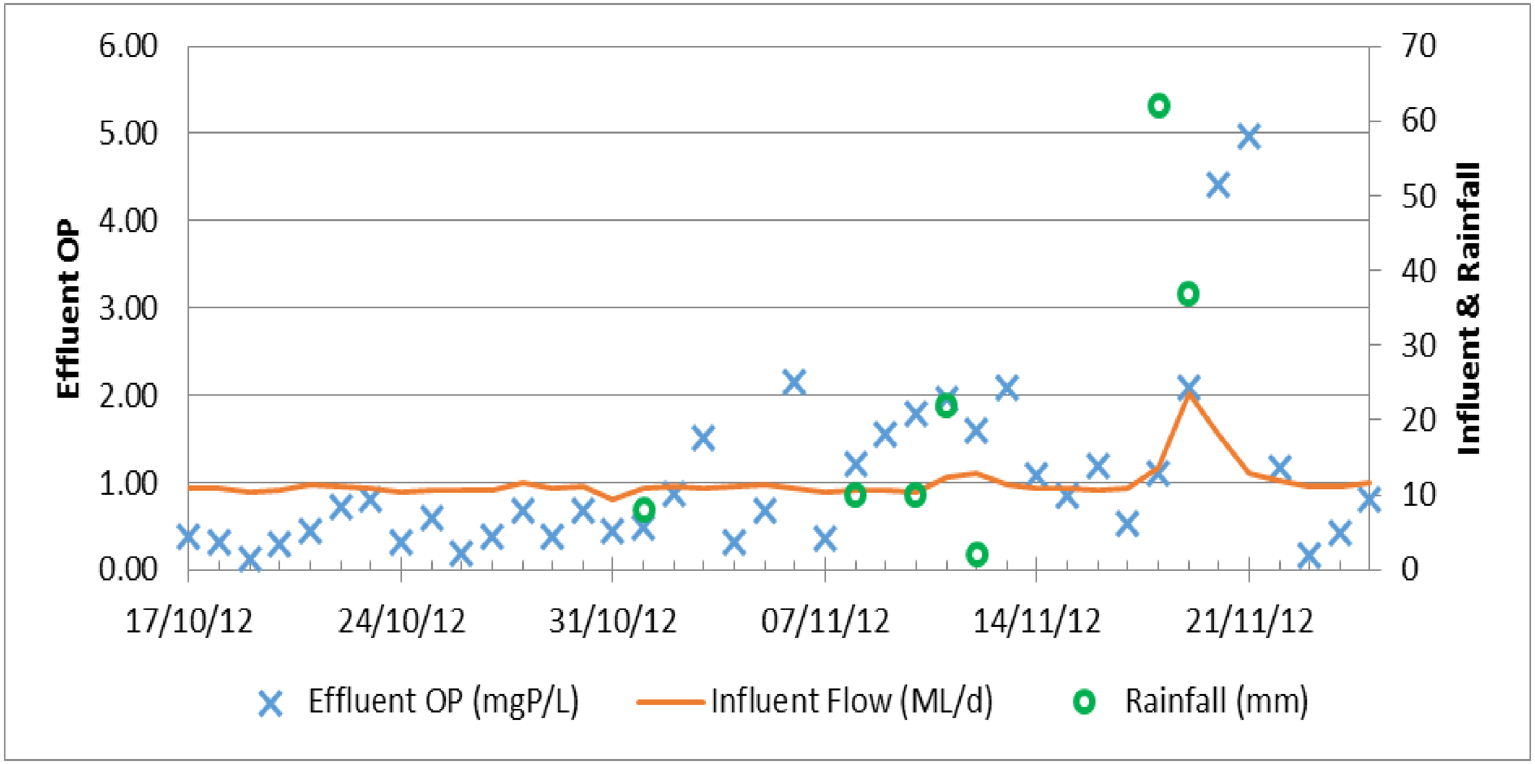
- ❑ Goodna STP conducted long term implementation and refinement of OP analyser based dosing control
- ❑ Alum dosing has been gradually reduced while meeting the licence consent of TP 1 mg/L



Goodna STP OP Analyser Based Control Performance

Phosphorus Removal for Wet Weather Resilience

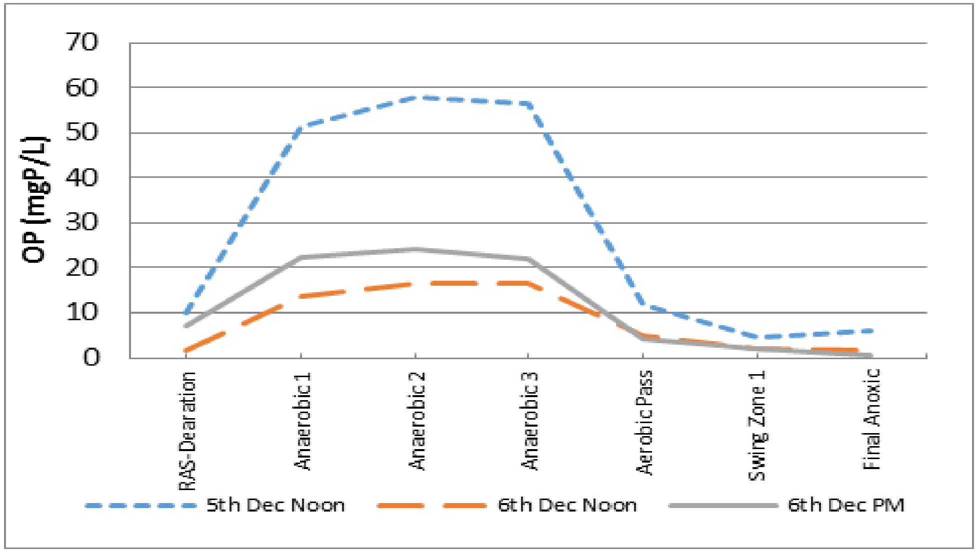
- During Goodna STP commissioning, the EBPR process suffered of a reduction in performance upon wet weather events
- Increased alum dosing was necessary to lower effluent TP below the license maxima of 3 mgP/L



Phosphorus Removal for Wet Weather Resilience

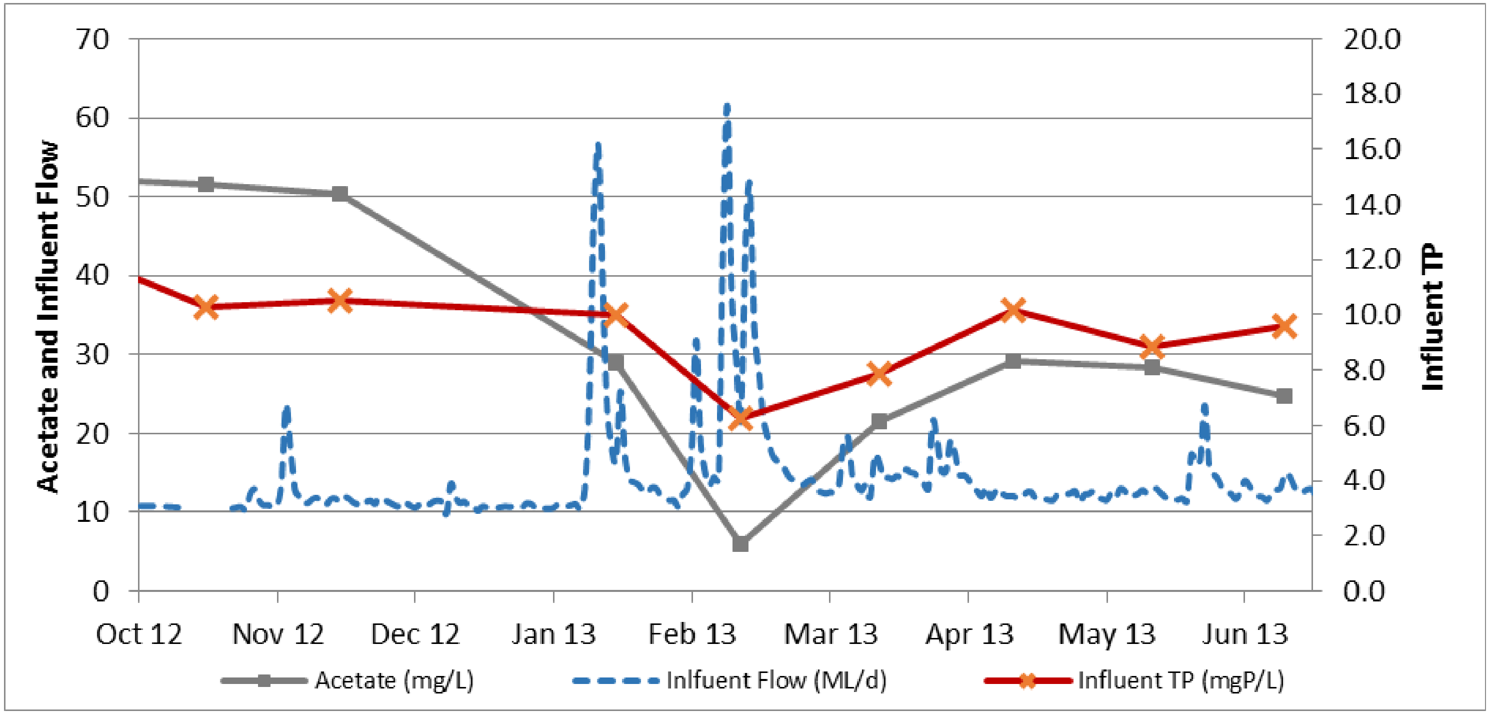
- Analysis identified possible causes of reduced EPBR:
  - Nutrient ‘slug’ at the start of the wet weather event
  - High DO and/or NO_3 in RAS impacting anaerobic zones
  - Reduced Anaerobic Zone HRT, impacting VFA uptake
  - Reduced VFA upon wet weather
  - Reduced sewage temperature and high DO impacting anaerobic reactions
  - Insufficient alum dosing control response to meet the EBPR short fall

- Recovery Steps:
  - Reduced SRT from 16 to 13 days
  - Increased RAS reaeration fraction
  - RAS NO_3 reduced <0.5 mg/L by adopting lower DO setpoints



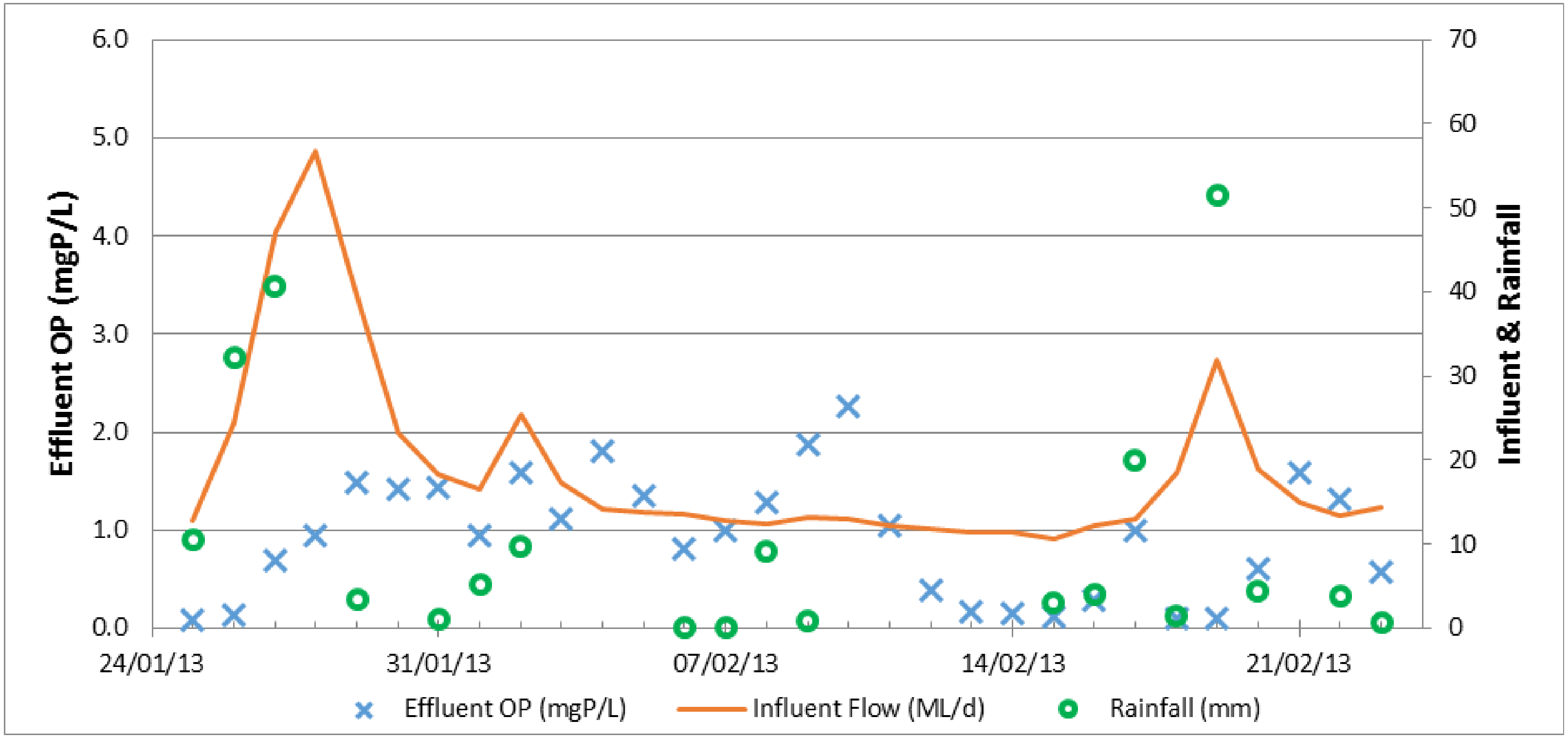
Phosphorus Removal for Wet Weather Resilience

- Longer term analysis of sewage VFA was considered
  - Acetate is an important VFA for PAOs
  - EBPR requires an acetate:TP ratio >7 – 9
  - Acetate is derived via fermentation processes in the sewer
  - Reduced sewage temperatures during winter result in acetate:TP ratio of ≈3:1
  - During significant wet weather the acetate:TP ratio reduces to ≈1:1



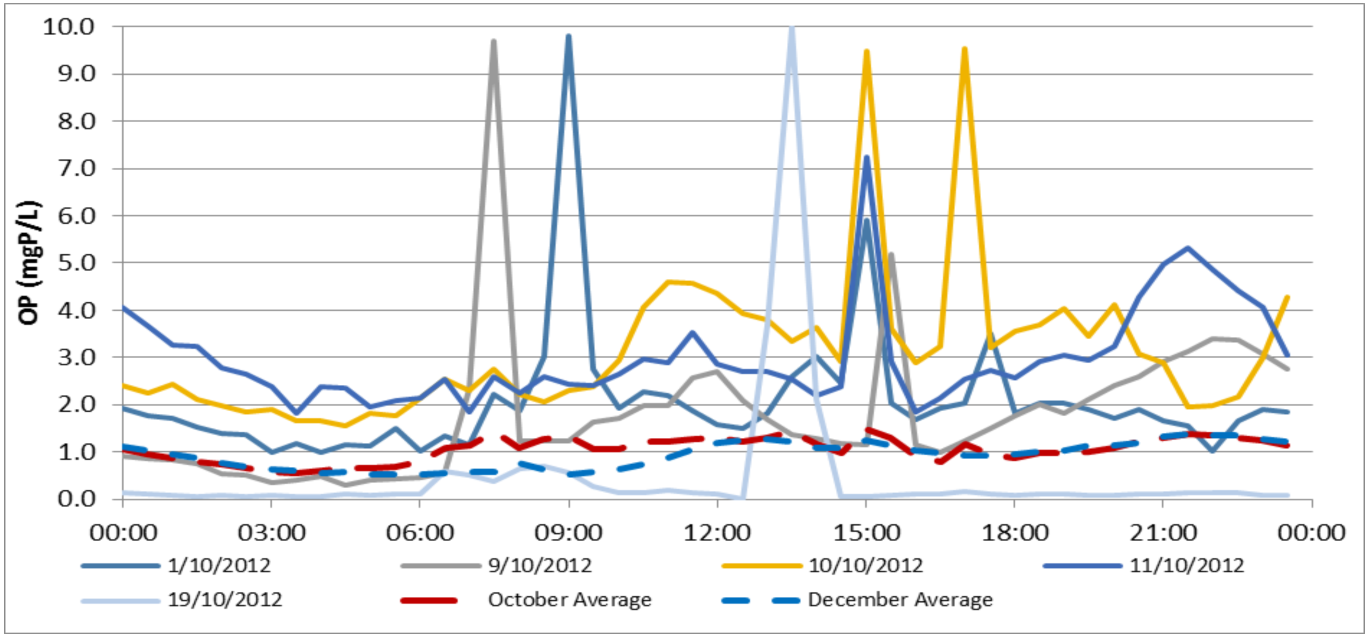
Phosphorus Removal for Wet Weather Resilience

- Optimised Alum dosing to reduce wet weather impacts:
  - Flow paced Alum dosing adjusted by trim factor proportional to measured OP.
  - Effluent TP was successfully reduced below the license maxima of 3 mgP/L during wet weather events.



MBR Train Phosphorous Release Elimination

- During Goodna STP commissioning effluent OP spikes were observed.
- Spikes occurred upon initiation of train production after standby periods.
- The Spikes were eliminated by:
  - Increasing train flushing frequency
  - Increased standby aeration frequency
  - Extended MBR train initiation flush



Effluent OP Showing MBR OP Spikes (October) and Rectification (November)

Conclusions

- The lessons learned and strategies presented provide practical refinements for design of integrated MBR systems to achieve:
  - Benchmark nutrient removal performance
  - Highly reliable facility operation
  - Optimised energy efficiency
  - Reduced chemical supplementation costs
- Adoption and further refinement of these MBR integration strategies provide community and environmental benefit through lower cost to serve and improved environmental outcomes.

Question Time

Acknowledgments:

- Janice Wilson: Mackay Regional Council
- Peter Bailey: Queensland Urban Utilities

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