Final Report

Ceramic Membrane Technology to Remove Persistent Solids from Wastewater

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1.0 Abstract

Dardanup Butchering Company (DBC), a multi-species abattoir near Picton in Western Australia, produces large volumes of wastewater that must be treated to an acceptable level before it can be reused to irrigate land or sent to sewer. The site's existing treatment removed phosphorus well but left behind a build-up of chemical sludge that fouled the irrigation pond over a period, causing water-quality problems. This project set out to test whether new treatment technology could remove residual suspended solids and phosphorus more to the required levels, while also turning the leftover sludge into a useful, reusable product.

The project installed and operated a ceramic membrane filter — a fine barrier that strains solids out of water — and dewatering equipment, then compared it against a simpler gravity-based settling tank (a radial flow settler). Treated water and sludge were sampled regularly and analysed by an accredited laboratory over more than three years.

The ceramic membrane produced very clean water, removing about 90% of phosphorus using aluminium chlorohydrate (ACH) addition, but it clogged repeatedly and could not be run reliably on this wastewater.

The settling tank achieved phosphorus removal performance comparable to the membrane system, while operating continuously at a much lower cost. The system is expected to deliver annual savings of approximately $47,000. The resulting sludge also has the potential to be reused on land, subject to further testing.

The project demonstrates that, for many Australian red-meat processors, a well-designed settling tank may offer a simpler, more reliable and lower cost alternative to membrane filtration, especially where wastewater quality is highly variable.

2.0 Executive summary

Dardanup Butchering Company (DBC) is a multi-species processing facility at Picton, Western Australia, that generates a high-strength, nutrient-rich wastewater stream which must be treated before reuse for irrigation or discharge to sewer under Department of Water and Environmental Regulation (DWER) Licence L5177. Prior to this project, DBC's tertiary treatment relied on ferric-chloride coagulant dosing followed by pond sedimentation. While this removed a high proportion of phosphorus, it produced a persistent ferric-phosphate sludge that accumulated in the irrigation pond, drove anaerobic conditions, and elevated ammonia in the irrigation stream. An earlier trial (PIP 2020-1046, geo-bag desludging) had been unsuccessful, and DBC had already invested substantial capital in alternative technologies before this project began.

AMPC Project 2023-1060 installed and evaluated a submerged silicon-carbide (SiC) ceramic-membrane ultrafiltration plant (the "Cembrane" unit, supplied by Amiad) rated at 21 $m^3/h \approx 250$ kL/day), filtering to 0.1 µm, with a Trident MD screw press for sludge dewatering. The aim was to remove persistent suspended solids and phosphorus so the treated stream could be reused or discharged in compliance with the site licence, while producing a spadable, beneficially reusable solid waste year-round.

The ceramic-membrane plant was installed and commissioned in late 2023 and operated through to early 2025. During commissioning the coagulant was switched from ferric chloride to aluminium chlorohydrate (ACH) to reduce membrane fouling. Assessed against its true pump feed — the Sedimentation Area, behind the sedimentation curtain — the membrane performed strongly as a phosphorus-removal and solids-polishing process, achieving approximately 90% total phosphorus removal (feed ≈19 mg/L to permeate ≈1.4 mg/L) and a consistently low-turbidity permeate with total suspended solids in the single-digit mg/L range, largely independent of feed quality. Over the project the plant processed in excess of 40 ML of wastewater.

The difficulty encountered was operational rather than a limitation of the membrane material. As installed and configured for this duty, the plant could not sustain filtration against DBC's particular wastewater: it cut out repeatedly on rising differential pressure, required frequent chemically-enhanced cleaning, and ultimately sustained damage to the primary filtration layer that forced extended offline periods for manual cleaning. A documented sequence of operational trials in March–April 2025 — including running the membrane in series behind a radial flow settler and reverting between ACH and ferric dosing — could not restore sustainable filtration, and the unit was taken offline in early April 2025. The ceramic membrane delivered to specification when in service; the constraint was the operability of the as-installed configuration for this feed.

In its place, a Radial Flow Settler (RFS) was installed — first as pre-treatment to the membrane, and subsequently as the sole tertiary stage. As a coagulation-assisted settling process the RFS targets the same solids-bound phosphorus fraction as the membrane and achieved a treated-discharge total phosphorus of approximately 1.1 mg/L with full operational reliability and lower operating cost.

An important methodological point underpins the comparison: The two technologies were not assessed against an identical feed sampling point. The membrane was assessed against the Sedimentation Area (the true pump feed, behind the sedimentation curtain), whereas during the RFS era the feed was sampled at the Aeration Pond — at the request of the project's environmental engineer, to tune the upstream nitrogen-removal lagoon system rather than to characterise the unit's feed. A direct, single-figure removal comparison between the two units is therefore not presented; instead, the membrane's measured performance against its true feed and the RFS's measured discharge quality are reported, with the technology behaviour explained qualitatively.

Neither technology is a nitrogen-removal process. Both coagulation-assisted settling and 0.1 μm filtration act on particles, not dissolved species: they remove suspended solids and the phosphorus and particulate organic nitrogen bound to those solids, but not dissolved nitrogen (ammonia, nitrate, soluble organic nitrogen). This is borne out by the speciation data — across the membrane, dissolved ammonia and NO_x pass through essentially unchanged while particulate organic nitrogen falls sharply. Nitrogen removal at DBC is achieved by the upstream anaerobic and aeration lagoon system using a combination of The MLE (Modified Ludzack-Ettinger) and anammox process, not by the RFS or membrane, and is correctly attributed accordingly in this report.

The project concludes that, for this site and feed, radial flow settling provided the more operable and economically sustainable phosphorus/solids-removal solution, while the ceramic membrane demonstrated superior — but, as installed, operationally unsustainable — polishing performance. DWER Licence L5177 limits are load-based (Total N 250 kg/ha per annual period; Total P 20 kg/ha per annual period; BOD 30 kg/ha/day), and the RFS-treated stream supports continued compliant irrigation reuse. Sludge characterisation confirmed a beneficially reusable product, and the Radial Flow Business Case projects annual operating savings of approximately $45,000 (chemical costs) with a payback of around three years. The findings are directly transferable to other red-meat processors evaluating membrane versus settling-based tertiary treatment.

Future research and recommendations: DBC recommends retaining the radial flow settler as the principal tertiary treatment stage due to its reliable performance and lower operating costs. Further monitoring would allow a more direct comparison of treatment options such as reinstating pump-feed (Sedimentation Area) sampling to enable a quantified like-for-like removal comparison. For any processor considering ceramic-membrane ultrafiltration, careful design and sizing of the system is essential to suit the specific wastewater characteristics of the site, together with effective upstream solids management before the membrane system to ensure reliable operation and control costs.

3.0 Introduction

3.1 The participant and the wastewater challenge

Dardanup Butchering Company, operated by Cutting Cart Pty Ltd, is a Category 15 abattoir licensed to process up to 30,000 tonnes liveweight per annum under DWER Licence L5177/1989/13. Like all red-meat processing facilities, the site converts a large fraction of its incoming fresh water into wastewater — of the order of 85% of fresh water used in a processing facility ends up as wastewater requiring treatment prior to disposal (AMPC n.d.). This wastewater is high in organic load, suspended solids, nitrogen and phosphorus, and the required treatment standard is dictated by its end use: where treated wastewater is reused for irrigation, removal of salt as well as nutrients can be important (AMPC n.d.).

At DBC, treated wastewater is reused for irrigation, with approximately 100 m³/day is discharged to the to the Water Corporation sewer system. Both disposal routes are governed by licence conditions. As a result, the reliable removal of nutrients and suspended solids is essential to maintaining compliance and avoiding potential environmental and operational risks.

3.2 The pre-project baseline

Before this project, DBC's tertiary treatment relied on dosing ferric chloride to remove phosphorus, with the resulting solids settling in the irrigation pond. While this approach was effective for phosphorus removal, it created an ongoing sludge build-up problem, i.e. the residual ferric-phosphate sludge accumulated in the irrigation pond, generating anaerobic conditions and elevating ammonia levels. Over three years of baseline monitoring, ammonia-nitrogen in the irrigation stream averaged approximately 2.4 times that of the sedimentation stream. A prior AMPC PIP (2020-1046) trialling geo-bag desludging had not resolved the sludge-handling problem, and DBC had independently invested significant capital evaluating alternative technologies. The persistent-solids and sludge-accumulation problem — and the need to reserve the irrigation pond for winter storage rather than as a de-facto settling basin — provided the rationale for this project.

4.0 Project objectives

4.1 Technical objectives

The project pursued four technical objectives:

1. Daily filtration of aeration-pond-derived wastewater ≈ 250 kL/day, coagulant-dosed) to remove suspended solids and phosphorus prior to irrigation or sewer discharge;
2. Filtration of the existing irrigation pond to reserve it for winter storage rather than settling duty;
3. Cessation of geo-bag desludging to reduce chemical and labour cost; and
4. Development of beneficial-use cases for the sludge produced by the filtration plant and the Trident MD screw press.

4.2 Contracted deliverables

Per the executed Variation 1 agreement, the project carried five formal deliverables:

#	Deliverable
1	Ongoing DWER licence conditions met
2	Ongoing Water Corporation sewer-connection licence conditions met

#	Deliverable
3	Reduced Total Nitrogen, suspended solids and phosphorus in all post-filtration discharge
4	Spadable solid waste (sludge) removable year-round
5	Potential of the filter for adoption by other red-meat processors (added in Variation 1)

5.0 Methodology

5.1 Technology Overview

This section outlines the two solids-separation technologies addressed in this study: ceramic membrane filtration and radial flow settling. For the purpose of this report, both technologies are classified as tertiary treatment process. This section describes their operating principles, performance characteristics, and typical roles in meat-processing wastewater treatment, to provide the technical basis for the. evaluation methodology and discussion of results.

5.1.1 Ceramic (silicon-carbide) membrane ultrafiltration

Ceramic membranes separate solids from water by size exclusion through a rigid inorganic membrane wall. The DBC plant uses submerged flat-plate membranes manufactured from silicon carbide (SiC) with a nominal surface pore size of 0.1 µm, placing it in the ultrafiltration / fine-microfiltration range. Operating outside-in under a slight vacuum, the membrane draws water through its pores while suspended solids, colloids, bacteria and other contaminants larger than the pores are physically rejected and accumulate as a cake on the membrane face (Figure 2). Because separation is purely physical, permeate quality is highly consistent and largely independent of upstream biological variability — the basis for the plant's near-complete solids removal (permeate TSS in the single-digit mg/L range).

SiC is particularly well suited to abattoir wastewater because it is one of the few membrane materials that is naturally and permanently hydrophilic: water is strongly drawn into the membrane while hydrophobic organic foulants — including the fats, oils and greases, characteristic of meat-processing streams — are repelled rather than adsorbed. SiC also offers high mechanical strength, chemical inertness across a wide pH range, abrasion resistance and tolerance of aggressive cleaning chemistries, giving long service life relative to polymeric membranes (Eray et al. 2021).

The principal trade-off associated with membrane filtration is fouling. As solids accumulate on the membrane face, the differential pressure (DP) required to maintain a given flux increases, reducing permeability and necessitating cleaning. Membrane cleaning typically involves a combination of backwashing, sprinkler washing and air scourging, supplemented by chemically enhanced cleaning using agents such as sodium hypochlorite and citric acid.

Each cleaning cycle consumes filtered (treated) permeate and temporarily takes the plant offline. As a result, cleaning frequency has a direct impact on net recovery, defined as the volume of filtrate produced after accounting for losses associated with backwashing, sprinkler washing and clean-in-place (CIP) operations, expressed as a percentage of total filtrate production.

Where feed solids concentrations are high or highly variable, fouling rates generally increase, resulting in more frequent cleaning and lower net recovery. Under such conditions, sustainable membrane performance depends on appropriate process design, correct equipment sizing and effective upstream solids management.

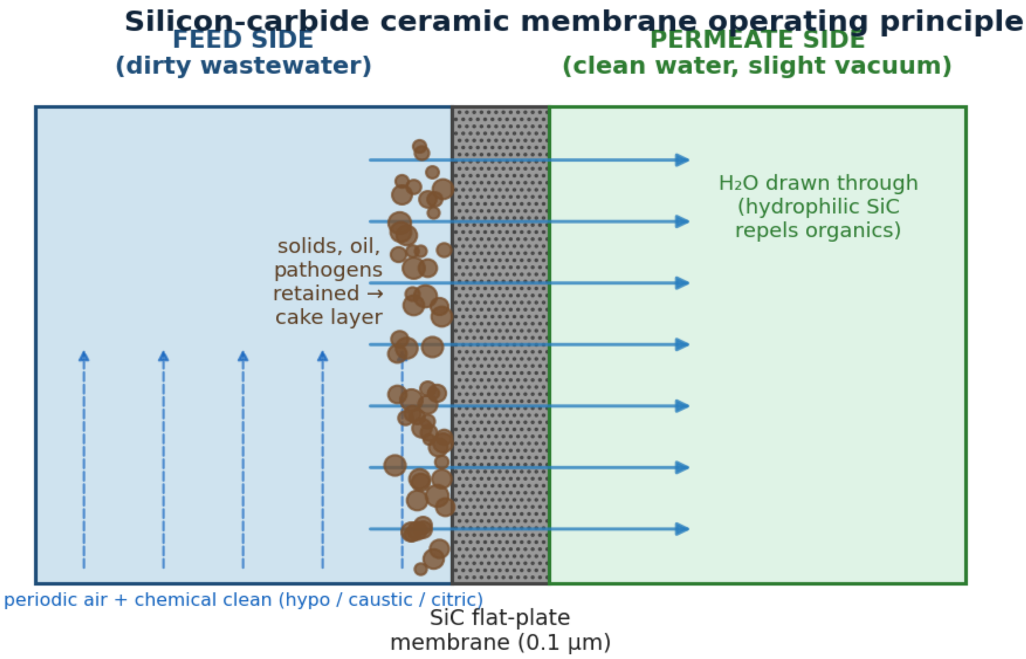

Figure 1. Operating principle of the silicon-carbide flat-plate ceramic membrane: vacuum-driven permeate flux, surface rejection of solids/oil/pathogens, and periodic air + chemical cleaning.

5.1.2 Radial flow settling

A radial flow settler (RFS), or circular centre-feed sedimentation basin, removes suspended solids by gravity rather than by a physical barrier. Wastewater enters through a central feed-well — a turbulence-damping cylinder — which dissipates the incoming flow energy and distributes it evenly. Water then travels outward, radially, toward a weir around the full circumference of the tank (Figure 2). Because the cross-sectional area available to the flow increases with radius, horizontal velocity falls progressively toward the perimeter, and the long circumferential weir produces a very low weir-loading rate — together creating the quiescent conditions needed for particles to settle. At DBC the settling is coagulant-aided, so the process targets the same solids-bound phosphorus fraction as the membrane.

Settled solids concentrate in the conical bottom and are periodically drawn off to the MD press, while clarified water overflows the perimeter weir to the next stage. Radial flow settlers are the standard clarifier geometry in municipal wastewater treatment because they perform well on the low-specific-gravity, slow-settling biological solids that dominate this kind of effluent, and they are robust to feed variability: in controlled trials a radial flow settler removed of the order of 78% of influent TSS per pass — roughly twice the efficiency of a comparable swirl/tangential separator — consistently across a wide range of inlet solids concentrations (Davidson & Summerfelt 2005). Critically for this duty, mechanical settling consumes neither cleaning chemicals nor permeate, so it carries no membrane-cleaning bottleneck.

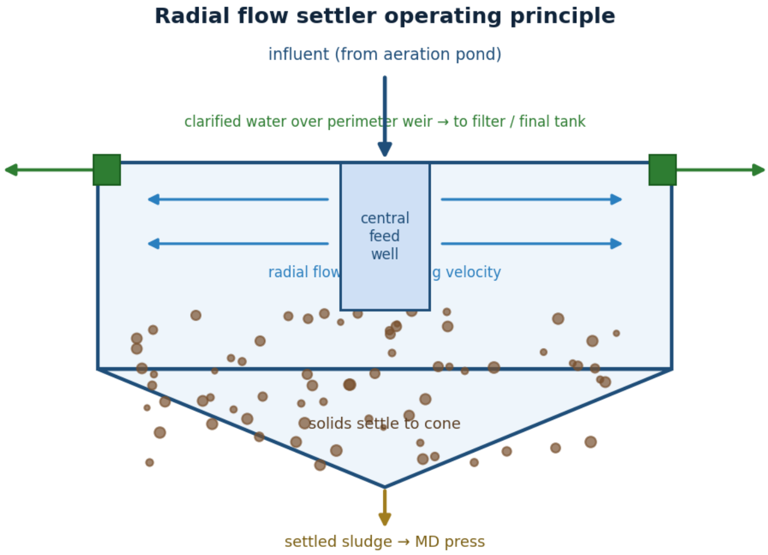

Figure 2. Operating principle of the radial flow settler: central feed-well, outward radial flow with decreasing velocity, gravity settling to the cone, and clarified-water collection over the perimeter weir.

5.1.3 Comparative suitability

Both technologies are fundamentally phosphorus- and solids-removal processes, and neither removes dissolved nitrogen.

The 0.1 µm membrane barrier captures more fine colloidal material than a gravity settler, which provides higher effluent quality, particularly for suspended solids. However, this improved performance comes at the cost of higher operating costs and complexity, more maintenance and periodic shutdowns for cleaning.

The radial flow settler produces water quality that is only slightly lower for most applications, but it offers significant advantages in reliability, throughput and operating cost. It can operate cautiously without the downtime associate with the membrane filtration system and is less sensitive to changes in wastewater quality.

The project demonstrated that this membrane filtration system may be more suitable where very high-water quality is required and the system is specifically design for the site’s wastewater characteristics. In contrast, the radial flow settler is well suited to sites where wastewater varies significantly and where reliability, simplicity and lower operating costs are more important considerations.

5.2 Treatment train and sampling points

DBC's wastewater passes sequentially through a dissolved air flotation (DAF) stage, anaerobic and aerobic (aeration pond) biological treatment, and then the tertiary treatment stage that is the subject of this project. Treated water reports to the irrigation tank/pond for reuse, and sewer-discharge pathway. Figure 3 shows the full train, the two tertiary configurations evaluated, and the sampling points.

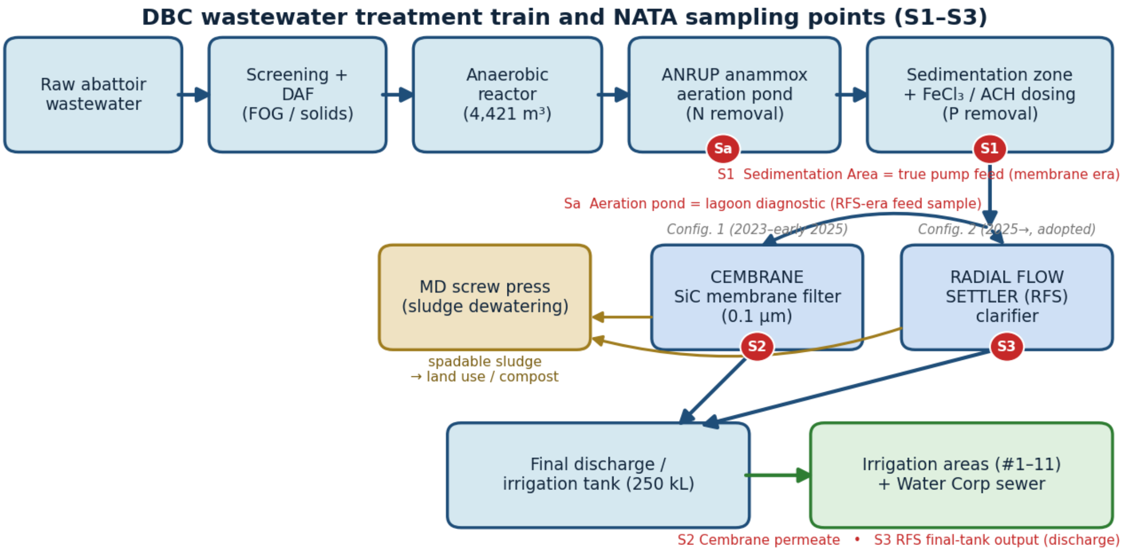

Figure 3. DBC treatment train, the two tertiary-treatment configurations evaluated, and NATA sampling points. Note the distinction between the Sedimentation-Area pump feed (S1) and the Aeration-Pond lagoon-diagnostic point (Sa).

Two feed sampling points are relevant, and the distinction is central to interpreting this report:

- **Sedimentation Area (pump feed).** The pump that feeds the RFS or the membrane draws from behind a sedimentation curtain, where a substantial portion of the suspended solids has already settled out. The Sedimentation-Area sample is therefore the true influent to the treatment unit and is the correct basis for assessing unit performance.
- **Aeration Pond.** During the RFS operating period, the feed was sampled at the Aeration Pond, at the request of the project's environmental engineer, to tune the upstream nitrogen-removal lagoon system — not to characterise the feed to the RFS or membrane. The aeration pond is sampled under active aeration, when biosolids are suspended throughout the water column, producing a solids-rich nutrient profile considerably stronger than the actual pump feed behind the curtain.

Because the ceramic-membrane period was assessed against the Sedimentation Area, while much of the RFS period was assessed against the Aeration Pond, a single-figure removal comparison between the two units against an identical feed point is not available. This report therefore presents the membrane's measured performance against its true pump feed, the RFS's measured discharge quality, and a qualitative interpretation of the two technologies' behaviour (Section 7).

Performance was assessed by NATA-accredited laboratory analysis of grab samples, with sampling and handling following the AS/NZS 5667 series specified in the site's DWER licence (Standards Australia 1998). The full sample register is provided in Appendix A.

EEI commentary (Dr R. Kurup, EEI): All wastewater samples were collected as grab samples and analysed by a NATA-accredited laboratory in accordance with the AS/NZS 5667 series specified in Licence L5177. Sampling was undertaken weekly for project benchmarking, supplemented by the quarterly compliance monitoring required at the discharge tank.

The membrane era was assessed against the Sedimentation-Area pump feed, while the RFS era was sampled at the Aeration Pond to support lagoon-system tuning for nitrogen removal. The project sample register contains no Sedimentation-Area (pump-feed) results during the RFS era; therefore, a direct like-for-like quantitative assessment of RFS removal performance cannot be derived from the existing dataset. Reinstating pump-feed sampling is recommended to enable this comparison in the future.

5.3 Baseline benchmarking (Milestone 1)

Prior to plant installation, baseline wastewater quality was benchmarked across the existing treatment train to characterise the persistent-solids and nutrient-accumulation problem and establish the reference against which the new plant would be assessed. This confirmed that solids accumulation in the irrigation lagoon — not the dosing chemistry — was the dominant driver of compliance risk, with irrigation-stream ammonia averaging ≈2.4 times the upstream sedimentation stream over three years.

5.4 Ceramic membrane plant (Cembrane)

The Cembrane plant (Amiad, Functional Specification Ref 4643) was installed and commissioned in 2023, with commissioning concluded on 30 October 2023. It is a 21 m^3/h ≈ 250 kL/day) submerged SiC ceramic-membrane system filtering to 0.1 µm. It comprises two stacks of seven membrane modules (14 modules in total), operated in an outside-in configuration.

Membrane fouling and solids accumulation are managed through a combination of backwashing, sprinkler cleaning, air-scouring and chemically enhanced cleaning using sodium hypochlorite and citric acid. Coagulant is dosed upstream in proportion to the flow rate to improve treatment performance. During commissioning, the coagulant was changed from ferric chloride to aluminium chlorohydrate (ACH) to reduce membrane fouling.

The plant was operated at approximately 80% recovery and achieved treatment rates of up to ≈ 253 kL/day. The principal installed equipment is summarised in Table 1.

Table 1. Principal installed equipment (Amiad Cembrane filtration & MD-press plant).

Equipment item	Qty	Function
Cembrane SiC membrane modules	14	0.1 µm flat-plate ultrafiltration (2 stacks × 7)
Cembrane header/base sets & feed tank	2 / 1	Membrane housing and feed tank
Trident MD screw press	1	Sludge thickening / dewatering
Flocculation & conical sludge tanks	1 / 1	Polymer conditioning and buffering
Hypochlorite / citric acid dosing	1 / 1	Membrane CIP cleaning chemistry
Polymer & coagulant dosing equipment	set	Sludge flocculation; flow-paced coagulant
Blower, pumps, valves, flow meters	set	Air scour, transfer and control
24 VDC control & motor-control cabinets	2	Automation, VSD drives, SCADA

5.5 Sludge dewatering (Trident MD screw press)

Filter and pond sludge was directed to a Trident MD screw press (0.25–1.3 m³/h), fitted with an upstream polymer-dosed flocculation tank and a manually adjustable end plate to control sludge-cake dryness. The screw press was rated well below the sludge-generation rate of the membrane plant under its cleaning regime and was placed in maintenance mode from June 2024 when its throughput (≈ 7.2 m³/day) proved a constraint.

5.6 Radial flow settler (RFS)

Following operational difficulties with the membrane plant, a coagulant-aided radial flow settler was retrofitted into an existing large conical tank. Initially, the RFS was operated as a pre-treatment stage upstream of the membrane plant. Following the decision to take the membrane plant offline, the RFS was subsequently used as the sole tertiary treatment and solids separation system, treating wastewater prior to discharge to the irrigation storage tank.

5.7 Coagulant chemistry

Phosphorus is precipitated by coagulant dosing. Ferric chloride was originally used at DBC; however, during commissioning of the membrane plant, it was replaced with aluminium chlorohydrate (ACH) to help reduce membrane fouling. Following installation of the radial flow settler (RFS), DBC progressively transitioned back to ferric chloride, as the mechanical removal of solids was expected to minimise previous fouling while also taking advantage of ferric chloride's generally stronger phosphorus removal performance through the formation of denser, faster-settling flocs (Li et al. 2017).

Table 2 compares the performance and characteristics of the two coagulants at DBC.

Table 2. Coagulant comparison — aluminium chlorohydrate (ACH) vs ferric chloride ($FeCl_3$) at DBC.

Parameter	ACH	Ferric chloride
Indicative cost per IBC	$1,850	$1,536
Typical dose rate	~494 mL/kL	~253 mL/kL
Indicative annual chemical cost	~$37,000	~$15,360
Phosphorus removal	effective	stronger (denser floc)
Status at DBC	Cembrane era	adopted with RFS

6.0 Results

6.1 Ceramic membrane performance

When assessed against its actual pump-feed source (the Sedimentation Area), the ceramic membrane plant performed strongly in removing phosphorus (total phosphorus) and fine suspended solids (Table 3, Figures 4–5). The system consistently produced low-turbidity permeate with suspended solids concentrations typically in the single-digit mg/L range, largely independent of variations in feed water quality. This reflects the defining advantage of a membrane filtration system (0.1 µm barrier) than conventional settling/sedimentation process,

During the project, the membrane plant processed more than 40 ML of wastewater. Total phosphorus removal averaged approximately 90%, demonstrating that the system was highly effective at removing phosphorus and suspended solids when operating as intended.

Table 3. Ceramic membrane performance against its true pump feed (membrane operating era, means).

Parameter	Pump feed (Sedimentation)	Cembrane permeate	Removal
Total Phosphorus	≈ 19 mg/L	≈ 1.4 mg/L	≈90%
Total Suspended Solids	≈ 48 mg/L	≈ 6 mg/L	≈87% (single digit permeate)
Total Nitrogen	≈ 33 mg/L	≈ 26 mg/L	limited (see 6.4)

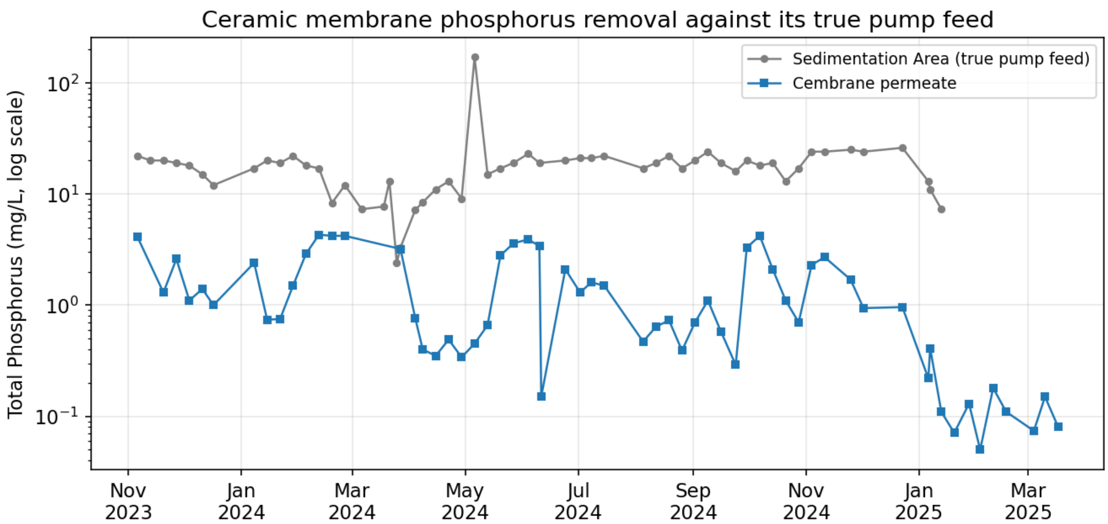

Figure 4. Ceramic-membrane phosphorus removal against its true pump feed (Sedimentation Area) over the membrane operating era. Permeate phosphorus is consistently low regardless of feed variability.

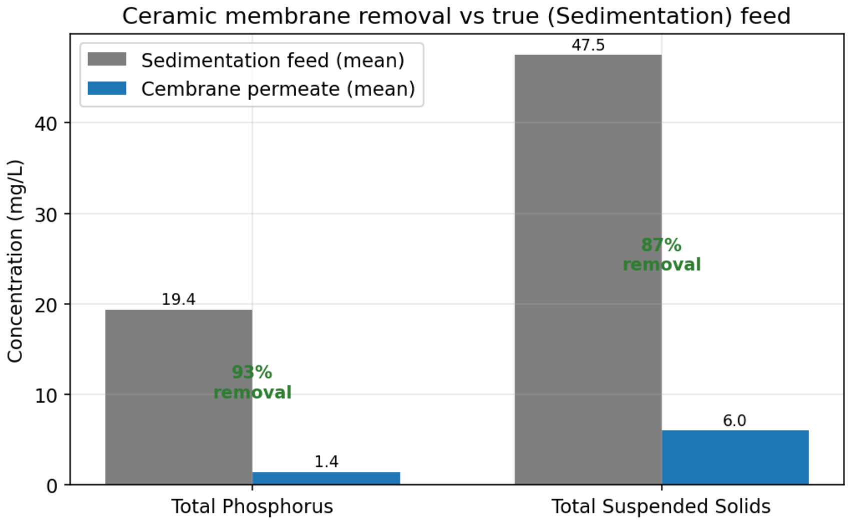

Figure 5. Mean ceramic-membrane removal against the true (Sedimentation) feed: ~ 90% total phosphorus and a near-complete reduction in suspended solids to single-digit mg/L.

6.2 Operational challenges and the transition to radial flow settling

The limitations encountered during the project were primarily related to how the membrane plant was configured and sized for DBC's wastewater treatment requirements, rather than to the ceramic membrane technology itself.

In practice, the as-installed system was unable to sustain stable operation when treating DBC's wastewater. The plant experienced repeated shutdowns due to increasing differential pressure (DP), required frequent chemically enhanced cleaning to restore performance, and eventually suffered damage to the primary filtration layer. This resulted in extended periods offline for maintenance and manual cleaning.

To address these issues, a series of operational trials and optimisation measures were undertaken during March and April 2025. The outcomes of these investigations are summarised in Table 4 and documented in the project's WWT field records.

Table 4. March–April 2025 operational trial sequence (WWT field notes).

Date (2025)	Configuration and observation
17 Mar	RFS running with ACH
19 Mar	RFS → Cembrane in series, dosing ferric chloride to reduce load on the membrane
21 Mar	RFS straight to product tank, bypassing Cembrane (discharge sample taken)
25 Mar	Cembrane + ACH, no RFS — cut out immediately on DP
27 Mar	RFS + Cembrane in series with ferric; incremental ferric dosing trialled; cleaning delta improved from 0.05 to 0.1 days
≈ 3 Apr	Reverted to RFS-only — long-term membrane buildup continued to take the filter offline for extended manual cleaning

Despite a series of configuration changes and coagulant-dosing trials that marginally extended the cleaning interval, persistent long-term membrane fouling could not be satisfactorily resolved. As a result, the membrane plant was taken offline in early April 2025, after which the RFS operated as the sole tertiary treatment and solids removal stage.

6.3 Radial flow settler performance

Operating as the sole tertiary treatment stage from April 2025 to April 2026, the RFS treated the wastewater before discharge to the irrigation tank. During this period, the treated wastewater achieved a mean total phosphorus concentration of approximately 1.1 mg/L, based on 48 NATA accredited laboratory samples with a median concentration of 0.6 mg/L.

As noted in Section 5.1, the RFS-era feed was sampled at the Aeration Pond, which was used as a lagoon-system diagnostic point rather than at the Sedimentation Area, which represents the actual pump feed to the RFS. Consequently, a direct like-for-like phosphorus removal efficiency cannot be calculated for the RFS using the available dataset. For this reason, the performance of the RFS is reported based on the quality of its treated discharge.

Figure 6 compares the treated-discharge phosphorus concentrations achieved by the membrane plant and the RFS. This comparison is valid because both systems discharged to the same final irrigation tank and were assessed using the same downstream monitoring point.

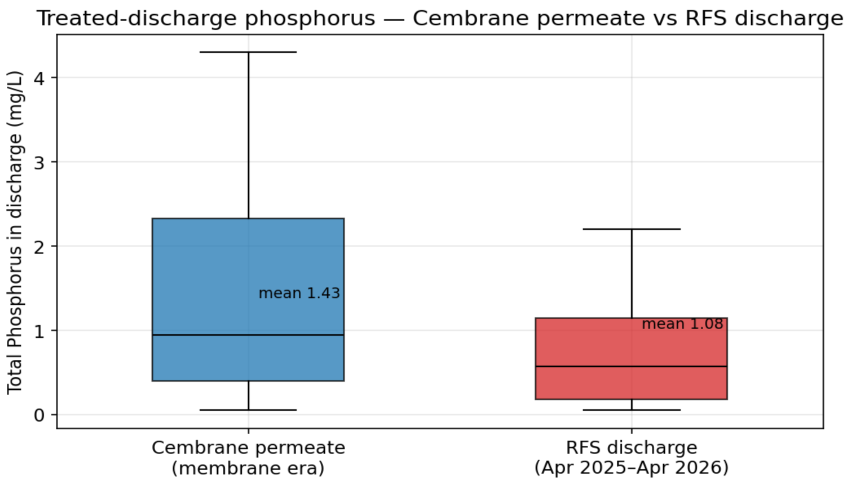

Figure 6. Treated-discharge phosphorus — Cembrane permeate (membrane era) vs RFS discharge (2025–26). Both report to the same final tank; the membrane gives the lower absolute concentration, the RFS a strong, reliable discharge.

6.4 Nitrogen: what these technologies can and cannot do

Total nitrogen in this wastewater consists of several forms, including dissolved inorganic nitrogen (ammonia, nitrate, nitrite), dissolved organic nitrogen, and particulate organic nitrogen bound to suspended solids.

Neither coagulation-assisted settling (RFS) nor 0.1 µm ceramic-membrane filtration system is designed to remove dissolved nitrogen. As a results, dissolved forms of nitrogen, including ammonia, nitrate and soluble organic nitrogen, pass through both treatment processes.

However, both systems can remove the particulate organic-nitrogen fraction bound to suspended solids. This occurs as part of their normal solids-removal function, with nitrogen removed together with the captured solids.

The nitrogen speciation data clearly demonstrate this behaviour (Figure 7). Across the membrane plant, dissolved ammonia (≈ 6.1 to ≈ 6.4 mg/L) and NO_x (≈ 11.4 to ≈ 15.8 mg/L) remained largely unchanged, indicating that these dissolved forms of nitrogen passed through both treatment processes. In contrast, organic nitrogen decreased from ≈ 14.3 to ≈ 3.5 mg/L, reflecting the removal of the particulate fraction of nitrogen captured with suspended solids.

The modest reduction in total nitrogen (TN) achieved by the membrane plant is therefore attributable to primarily to the removal of particulate-N attached to suspended solids, rather than to the removal of dissolved nitrogen. The bulk of nitrogen removal at DBC is achieved by the upstream anaerobic and aeration lagoon system, using a combination of The MLE (Modified Ludzack-Ettinger) and anammox process and not by the RFS or membrane plant.

This also explains why Aeration-Pond samples (taken under active aeration, biomass /MLSS in suspension) show a much stronger nutrient profile than the pump feed: those samples characterise the lagoon system, not the unit feed, and should not be used to credit either technology with nitrogen removal.

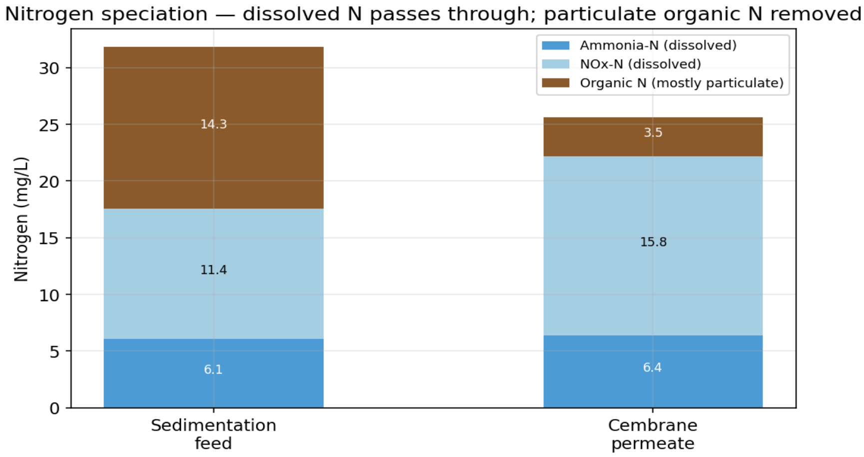

Figure 7. Nitrogen speciation at the pump feed vs Cembrane permeate. Dissolved ammonia and NOx pass through essentially unchanged; particulate organic nitrogen is removed — confirming the units do not remove dissolved nitrogen.

EEI commentary (Dr R. Kurup, EEI): At the Sedimentation Area pump feed, the measured total nitrogen concentration of ≈ 33 mg/L comprises ≈ 6 mg/L ammonia-N and ≈ 11 mg/L oxidised nitrogen (NO_x-N) giving a dissolved inorganic nitrogen concentration of ≈ 17 mg/L. The remaining ≈ 14 mg/L is present as organic nitrogen.

As the pump feed is drawn from behind the sedimentation curtain, it already contains relatively low levels of suspended solids, and, consequently, relatively low levels of particulate organic nitrogen. The limited TN reduction observed across the membrane plant (and, by the same mechanism, the RFS) is therefore consistent with removal of the particulate organic-nitrogen fraction only. This is reflected by the reduction in organic N from ≈ 14 to ≈ 3.5 mg/L across the membrane, while ammonia-N and No_x-N concentrations remained essentially unchanged.

Accordingly, the modest TN reduction should not be interpreted as process underperformance. The removal of dissolved nitrogen remains the function of the upstream anaerobic/aeration lagoon system, which provides the majority of nitrogen treatment at DBC.

6.5 Sludge characterisation and beneficial-use cases

Project objective 4 — developing beneficial-use cases for the sludge — was assessed by NATA-accredited analysis of solids collected from each sludge stream. Four laboratory certificates from EATS / MPL Laboratories (NATA accreditation 2901),were reviewed, with the results summarised in Appendix B.

The key finding is that the sludge cannot be considered a single uniform product. Its characteristics, quality and potential reuse options vary significantly depending on the source stream from which it is collected and the type of coagulant used in the treatment process.

6.5.1 Anaerobic-tank sludge — the premium stream (no coagulant)

The anaerobic reactor sludge (sampled 29 April 2024) receives no coagulant dosing and was found to be the highest-quality solid stream assessed in the project. It contained ≈ 45,000 mg/kg total nitrogen and ≈ 16,000 mg/kg total phosphorus, making it a nutrient-rich biosolid with significant potential value to agricultural reuse. Hexavalent chromium was below detection (<1 mg/kg), while organochlorine and organophosphorus pesticides were not detected.

The sludge was classified Contaminant Category C2 and is suitable for application to agricultural land, subject to agronomic application rates. The laboratory noted that its very high nitrogen and phosphorus content, together with elevated sodium levels, would need to be considered when determining application rates to manage risks such as nutrient leaching and soil sodicity.

Importantly, because no aluminium or iron coagulants are added to the anaerobic reactor, this sludge does not contain the elevated metal concentrations associated with the chemically dosed treatment streams (Figure 8). As a result, it represents the most valuable and readily reusable sludge product generated at the site.

6.5.2 Coagulant-dosed solids — the chemistry sets the reuse pathway

The solids removed downstream of phosphorus dosing carry a chemical fingerprint of the coagulant used, and this dominates their metals profile (Figure 8, left):

- **ACH (aluminium chlorohydrate) dosing:** samples MD1 and MD2 (13 May 2024) contain ≈ 190,000–230,000 mg/kg aluminium with only ≈ 740–870 mg/kg iron. MD1 met Category C2; MD2 was classified C3 because hexavalent chromium reached 1.7 mg/kg (above the 1 mg/kg C2 limit), making it unsuitable for direct land application and directing it to composting.
- **Ferric chloride dosing —** the RFS underflow (7 May 2025, a largely liquid sludge) and the MD-press cake (16 June 2025) are iron-dominated: ≈ 1,100 mg/L iron in the liquid RFS sludge and ≈ 130,000 mg/kg iron in the dewatered MD-press cake, with low aluminium and an acidic pH (4.6). The ferric MD-press cake met contaminant Category C2 but pathogen Category P2 (E. coli and coliphages present), so it is suitable for land application only after composting or heat treatment, with blending recommended given high chloride, sodium, phosphorus and nitrogen.

All dosed streams are phosphorus-rich (total phosphorus ≈ 43,000 – 57,000 mg/kg) because the coagulant precipitates phosphate, whereas the un-dosed anaerobic stream is comparatively nitrogen-rich (Figure 8, right). The iron in the ferric-dosed cake is itself a useful plant micronutrient, which may add value to that stream once composted. Table 5 compares the streams.

Table 5. Solid-stream comparison from the four NATA sludge analyses (mg/kg dry unless marked *).

Stream / sample (date)	Coagulant	Total N	Total P	Aluminium	Iron	Category & reuse
		mg/kg				
Anaerobic tank (29/4/24)	none	45,000	16,000	not tested	not tested	C2 — direct land application
MD1 (13/5/24)	ACH	10,000	43,000	230,000	740	C2 — direct, rate-limited
MD2 (13/5/24)	ACH	16,000	53,000	190,000	870	C3 (Cr(VI) 1.7) — compost only
RFS sludge (7/5/25)*	Ferric	160*	320*	20*	1,100*	Liquid — dewater then reuse
MD Press (16/6/25)	Ferric	48,000	57,000	4,300	130,000	C2 / P2 — compost or heat-treat

** RFS sludge was substantially liquid and is reported in mg/L. Hexavalent chromium: anaerobic <1, MD1 <1, MD2 1.7, RFS <0.005, MD-press <1 mg/kg.*

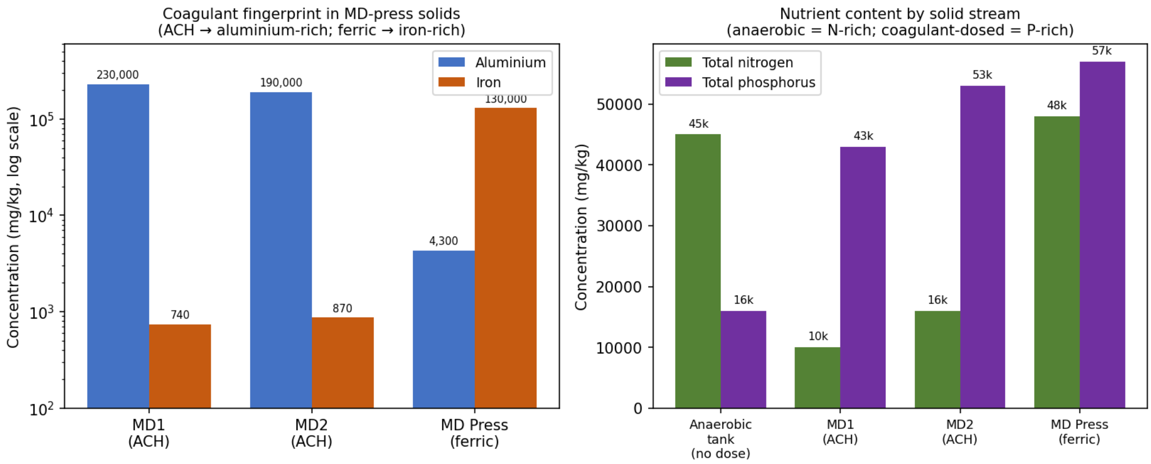

Figure 8. Left: coagulant fingerprint in MD-press solids — ACH dosing yields aluminium-rich sludge, ferric dosing iron-rich sludge (note log scale). Right: nutrient content by stream — the un-dosed anaerobic sludge is nitrogen-rich while coagulant-dosed solids are phosphorus-rich.

6.5.3 A two-stream dewatering strategy

This characterisation, combined with the MD-press capacity constraint identified earlier (the existing 0.25–1.3 m³/h press, ≈ 7.2 m³/day, was undersized for the coagulant dosed solids load and was placed in maintenance mode in June 2024), points to a clear handling strategy. Rather than simply replacing the existing press, DBC proposes to operate two dewatering streams in parallel:

- **A larger, purpose sized dewatering unit** dedicated to the main coagulant-dosed solids stream (the RFS / filter underflow), sized for the actual sludge generation rate so it is no longer the system bottleneck; and

- **the existing smaller MD press redeployed** to dewater the clean anaerobic-tank sludge, displacing the geo-bag desludging of that stream and recovering the premium, directly land-applicable, coagulant-free biosolid as a separate product.

Separating the high value anaerobic biosolid (no aluminium or iron, C2, direct reuse) from the coagulant-dosed solids (compost / blend pathway) maximises the beneficial-use value of each stream and reduces reliance on geo-bags — directly advancing project objectives 3 (cease geo-bag desludging) and 4 (sludge use cases). It also de-risks the dosed-solids pathway, as the iron-bearing ferric cake can be developed as a composted soil amendment independently of the premium anaerobic biosolids.

6.6 DWER licence load-based compliance

DWER Licence L5177 sets load-based emission-to-land limits, not concentration limits: 250 kg/ha per annual period of Total N, 20 kg/ha per annual period of Total P, and 30 kg/ha/day of BOD. Because irrigation load is the product of concentration and applied volume over an irrigation area, the discharge concentrations do not, in themselves, breach the licence — the governing quantity is annual nutrient load per hectare. At realistic application rates, total nitrogen is the binding constraint; managing irrigation area and applied volume to the nitrogen load keeps both nitrogen and phosphorus loads within their respective limits. This confirms that the treated stream supports continued compliant irrigation reuse.

DBC operates a second, separately licensed disposal pathway: a Water Corporation sewer connection, in service for approximately two years, through which a portion of the treated stream (of the order of 100 m^3/day) is discharged to sewer rather than applied to land. This connection is governed by its own Water Corporation sewer-connection licence conditions (Deliverable 2), which are distinct from the load-based emission-to-land limits that govern irrigation reuse. By diverting a portion of the treated flow away from land irrigation, the sewer pathway reduces the volume — and therefore the nutrient load — applied per hectare across the licensed irrigation areas, providing additional operational flexibility in managing the binding nitrogen constraint. Together, the two pathways allow DBC to balance treated-water disposal between compliant irrigation reuse and licensed sewer discharge, maintaining compliance under both sets of conditions

6.7 Economics

The Radial Flow Settler Business Case projects annual operating savings of approximately $47,400, comprising a coagulant saving (ferric chloride vs ACH, ≈ $21,640/yr) and a substantial reduction in membrane-cleaning cost (Amiad cleaning cost ≈ $32,193/yr reduced to ≈ $6,440/yr once the membrane was removed from service, ≈ $25,753/yr). The RFS installation total cost, including a 10% contingency, was approximately $141,200, giving a payback of around three years. Removing the membrane from service also eliminated the recurring cost and production interruption associated with its frequent chemically enhanced cleaning and manual de-fouling. Figures 9–10 summarise the throughput/recovery and cost positions; detailed expenses are in Appendix D.

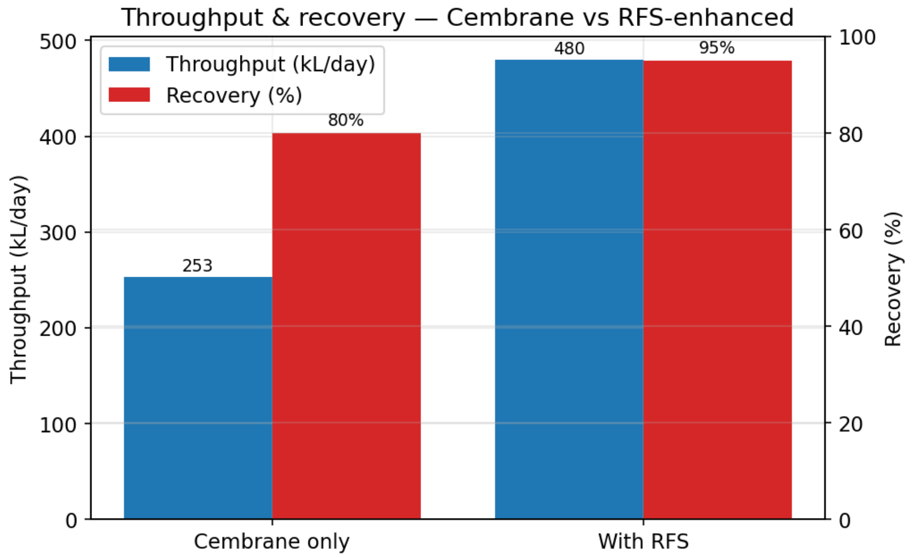

Figure 9. Throughput and recovery — Cembrane-only (~253 kL/day, 80% recovery) vs RFS operation (projected ~480 kL/day, >95% recovery), reflecting the elimination of cleaning-driven downtime.

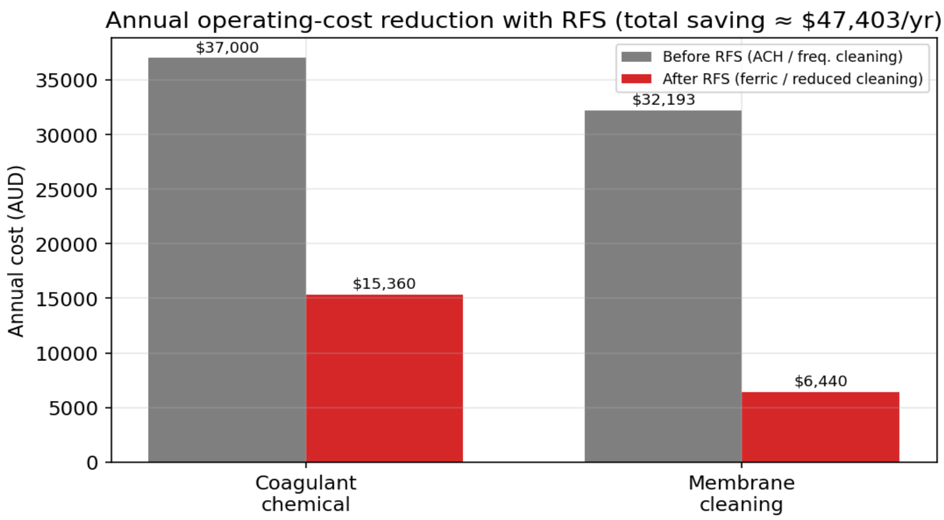

Figure 10. Annual operating-cost reduction enabled by the RFS — lower coagulant cost (ferric vs ACH) and reduced membrane-cleaning chemical cost, totalling ~$47,400/yr.

7.0 Discussion

7.1 Comparing the two technologies on a fair basis

The central question of this project — whether radial flow settling is a viable alternative to ceramic-membrane ultrafiltration for this duty — must be interpreted in light of the sampling-point change between the two operating eras (Section 5.2). The membrane was assessed against its true pump feed (Sedimentation Area) and achieved approximately 90% phosphorus removal. The RFS, as a coagulation-assisted settling process, targets the same solids-bound phosphorus fraction and achieved a strong treated-discharge phosphorus of ≈ 1.1 mg/L. Both are fundamentally phosphorus- and solids-removal processes, and both performed that function well. The finer 0.1 µm membrane barrier would be expected to capture more fine colloidal material than a gravity settler, giving the membrane an edge on absolute solids consistency — which the permeate TSS data (single-digit mg/L) bear out. A single-figure head-to-head removal comparison is deliberately not presented, because the two units were not measured against the same feed point.

7.2 Nitrogen

While neither unit removes dissolved nitrogen directly, both have nonetheless delivered a meaningful reduction in the nitrogen burden carried into the irrigation system relative to the pre-project baseline. Under the former arrangement, residual ferric-phosphate sludge accumulated in the irrigation pond and drove anaerobic conditions, which in turn generated ammonia — over three years of baseline monitoring, ammonia-nitrogen in the irrigation stream averaged approximately 2.4 times that of the sedimentation stream. By reliably removing the solids and phosphorus that previously settled and decomposed in the pond, both the ceramic membrane and the radial flow settler prevent this secondary, in-pond generation of ammonia and allow the irrigation pond to be reserved for its intended winter-storage duty rather than acting as a de-facto anaerobic settling basin. The nitrogen benefit of the two technologies is therefore best understood as one of avoidance — eliminating a downstream ammonia source — rather than direct dissolved-nitrogen removal across the unit, and it complements the dissolved-nitrogen removal achieved by the upstream anaerobic and aeration lagoon system.

7.3 Deliverables assessment

Deliverable 1 (DWER licence conditions met): supported by the load-based compliance position established in Section 6.6 — the treated stream supports continued compliant irrigation reuse under the load-based emission-to-land limits, with total nitrogen the binding constraint managed through irrigation area and applied volume.

Deliverable 2 (Water Corporation sewer-connection licence conditions met): met and ongoing. DBC operates a licensed Water Corporation sewer connection (in service for approximately two years), discharging a portion of the treated stream to sewer under its own sewer-connection licence conditions, as described in Section 6.6.

Deliverable 3 (reduced TN, suspended solids and total phosphorus in post-filtration discharge): both technologies demonstrably reduced phosphorus and suspended solids. Neither unit removes dissolved nitrogen directly — that is delivered by the upstream anaerobic and aeration lagoon system, which is stated transparently — but both units also reduce the overall nitrogen burden carried into the irrigation system by removing the solids and phosphorus that previously accumulated in the irrigation pond and generated ammonia under anaerobic conditions (Section 7.2). The nitrogen element of this deliverable is therefore met through a combination of upstream lagoon treatment and this downstream avoidance mechanism.

Deliverable 4 (beneficial sludge reuse): addressed in Section 6.5 — NATA-accredited characterisation confirmed a beneficially reusable solid product across the streams, subject to the chromium and pathogen caveats noted.

Deliverable 5 (industry adoption potential): addressed in Section 8 — the project provides a field-based comparison of ceramic-membrane ultrafiltration and radial flow settling directly transferable to other red-meat processors

7.4 Interpretation

The data supports a clear and honest conclusion: the ceramic membrane delivered the higher absolute effluent quality, particularly for solids, but could not be operated sustainably as installed for this feed; the radial flow settler delivered strong phosphorus removal with full operational reliability. For DBC's purpose — producing a treated stream that reliably meets load-based land-application limits without an unsustainable cleaning and maintenance burden — the RFS is the more fit-for-purpose solution. This is a finding about implementation and operability for this site, not a verdict against ceramic-membrane technology, which performed to specification when in service.

8.0 Conclusions

- The ceramic-membrane technology met the project's phosphorus and solids treatment-quality objectives — ~90% total phosphorus removal against its true pump feed and a consistently low-solids permeate (single-digit mg/L TSS), processing in excess of 40 ML.
- The as-installed membrane plant was not operationally sustainable for this duty. Persistent DP-driven cut-outs, frequent cleaning and damage to the primary filtration layer rendered continuous operation impractical for this feed; the membrane performed to specification when in service.
- The radial flow settler is a viable, more operable alternative for this site, delivering strong phosphorus removal (discharge ~1.1 mg/L) with full operational reliability and lower operating cost.
- The radial flow settler delivered a substantial economic benefit, with the business case projecting annual operating savings of approximately $47,400 (reduced coagulant and membrane-cleaning costs) against an installed cost of approximately $141,200 — a payback of around three years.
- Neither technology removes dissolved nitrogen directly; dissolved-nitrogen removal is achieved by the upstream anaerobic and aeration lagoon system and is correctly attributed accordingly. Both technologies nonetheless reduce the overall nitrogen burden on the irrigation system by removing the solids and phosphorus that previously accumulated in the irrigation pond and generated ammonia under anaerobic conditions.
- The treated wastewater supports compliant irrigation reuse under the load-based DWER limits and is complemented by a licensed Water Corporation sewer connection that provides a second, separately licensed disposal pathway. The project also produced a beneficially reusable sludge, subject to the chromium, pathogen and site-irrigation-data caveats noted.

This project provides the Australian red-meat processing industry with a practical, real-world comparison of two tertiary / solids separation technologies operating on the same high-strength abattoir wastewater stream, addressing the fifth deliverable added under Variation 1.

The project demonstrated that ceramic membrane ultrafiltration can produce excellent and highly consistent treated-water quality. However, successful operation depends heavily on correct engineering and sizing for the specific feed.

The project also demonstrated that well designed, coagulant-aided radial flow settler can deliver comparable phosphorus removal performance with far greater operational resilience and lower operating cost where feed variability is high.

The findings have broader relevance to the Australian red-meat processing industry because the level of treatment required depends on the intended wastewater disposal or reuse pathway. Where treated wastewater is reused for irrigation, factors such as salt levels and nutrient loads can be just as important as treatment performance. Similarly, the project's findings relating to the load-based regulatory compliance and sludge suitability for land application provide useful guidance for other processors considering wastewater reuse and resource recover opportunities.

Practical application

- Retain the RFS as the primary tertiary treatment stage for DBC, managing irrigation application to the nitrogen load to maintain DWER compliance, and optimising the disposal split between irrigation reuse and the licensed Water Corporation sewer discharge to manage the binding nitrogen constraint across both pathways.
- Implement the two-stream dewatering strategy: install a larger, purpose-sized dewatering unit for the coagulant-dosed solids stream (sized to the actual sludge-generation rate) and redeploy the existing MD press to dewater the clean anaerobic-tank sludge — displacing geo-bag desludging and recovering premium, directly land-applicable biosolids.
- Separate and beneficially reuse the solid streams per their chemistry: route the clean anaerobic-tank sludge to direct land application, and compost/blend the aluminium- or iron-rich coagulant-dosed solids.
- Continue to monitor and optimise the upstream lagoon system, which is the primary driver of nitrogen removal; both tertiary units complement this by removing the solids and phosphorus that previously generated in-pond ammonia.

Future research, development and extension

- Undertake RFS-era pump-feed (Sedimentation Area) sampling to enable a quantified like-for-like RFS removal figure and capture additional TSS/turbidity data.
- Optimise RFS operation — coagulant type and dose and settling performance — to improve removal and further reduce chemical cost.
- Address the sludge caveats — undertake pathogen testing to confirm biosolids grade and verify the chromium result — to fully unlock the beneficial-reuse pathway.
- Where ceramic-membrane ultrafiltration is considered by other processors, ensure the plant is engineered and sized for the specific feed variability and composition, with realistic cleaning-regime provisions and effective upstream solids management.

Adoption and extension

- Disseminate the comparative findings of this project to the broader red-meat processing industry through AMPC communication channels, to support evidence-based selection between membrane and settling-based tertiary treatment.

9.0 Project outputs

The project was delivered as an on-site research and demonstration installation at the Dardanup Butchering Company (DBC) facility, Picton WA. As the work was conducted at operational scale on a working abattoir wastewater stream rather than as a public extension program, the outputs of the project are the physical treatment assets, the engineering and performance datasets, and the reporting deliverables produced over its course. These are listed below.

Physical assets and demonstration installation

- A commissioned 21 m^3/h (≈250 kL/day) submerged silicon-carbide ceramic-membrane ultrafiltration plant (Amiad "Cembrane"), with an associated Trident MD screw-press sludge-dewatering plant, installed and operated at DBC.
- A coagulant-aided radial flow settler (RFS) retrofitted into an existing conical tank, operated first as membrane pre-treatment and subsequently as the sole tertiary treatment stage.
- The installation remains in service at DBC as a working demonstration of coagulant-assisted radial flow settling for tertiary treatment of red-meat processing wastewater, available to inform other processors.

Engineering and design deliverables

- Plant functional specification and process design (Amiad Functional Specification Ref 4643), developed collaboratively with the membrane supplier (Amiad).
- Radial Flow Settler design and the supporting Radial Flow Settler Business Case.

Data and knowledge deliverables

- A multi-year NATA-accredited monitoring dataset characterising baseline, membrane-era and RFS-era wastewater quality (full sample register, Appendix A).
- Four NATA-accredited sludge characterisation certificates establishing the beneficial-reuse classification of each solids stream (Appendix B).
- A documented operational-trial record of the March–April 2025 membrane/RFS configuration testing.

Reporting and communications deliverables

- Milestone Reports 1–8 submitted to AMPC over the project term, maintaining ongoing reporting against the agreed milestones.
- This Final Report and its appendices, which provide the Australian red-meat processing industry with a field-based comparison of ceramic-membrane ultrafiltration system and radial flow settling system (delivering the industry-adoption deliverable added under Variation 1).

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11.0 Appendices

Internal project documents (milestone reports, applications, the executed agreement, functional specification, business case and cost workbooks) are held by DBC and listed in Appendix F.

Appendix A – NATA-accredited sample data

Table A-1. Membrane-era performance against the true (Sedimentation) feed, and summary statistics (mg/L).

Stream / parameter	n	Mean	Median	Min–Max
Sedimentation feed – TP	56	19.4	–	–
Cembrane permeate – TP	60	1.43	0.95	0.05–4.3
Cembrane permeate – TSS	5	6.0	5	5–10
Sedimentation feed – TN	56	32.6	–	–
Cembrane permeate – TN	60	25.8	25.5	1.6–47
Cembrane permeate – NH_3-N	60	6.4	2.25	0.005–34

Stream / parameter	n	Mean	Median	Min–Max
RFS discharge – TP	48	1.08	0.57	0.05–5.7
RFS discharge – TN	48	46.9	46.5	12–97

Note: RFS-era values are discharge quality; the RFS feed was sampled at the Aeration Pond (lagoon diagnostic), not the pump feed, so no like-for-like RFS removal figure is computed (Section 5.1).

Table A-2. RFS-era discharge dataset — final-tank output with aeration-pond context (mg/L), 24 Mar 2025 – 15 Apr 2026.

Date	Aeration TP (context)	RFS disch. TP	Aeration TN (context)	RFS disch. TN	RFS NH_3-N
2025-03-24	46	0.05	180	29	0.12
2025-03-31	65	0.05	140	32	0.81
2025-04-07	66	0.11	170	37	0.39
2025-04-14	88	0.3	230	38	3.1
2025-04-22	6.6	0.18	34	33	3.4
2025-04-30	77	0.3	240	22	3.7
2025-05-14	83	0.17	240	47	2
2025-05-21	78	0.25	190	52	5.9
2025-05-28	54	0.12	190	70	10
2025-06-04	54	0.55	160	62	3.4
2025-06-11	57	0.33	180	62	3.9
2025-06-18	36	2	90	54	4.7
2025-06-26	35	2.7	130	47	2
2025-07-02	34	4.6	100	97	2.5
2025-07-09	57	5.5	190	45	0.74
2025-07-15	85	2	250	59	1.9

Date	Aeration TP (context)	RFS disch. TP	Aeration TN (context)	RFS disch. TN	RFS NH_3-N
2025-07-22	94	0.45	220	47	9.8
2025-07-29	36	0.59	120	57	9.5
2025-08-06	66	0.56	47	30	1.9
2025-08-13	9.6	1.1	91	80	2.1
2025-08-20	155	1.3	72	70	6.1
2025-08-27	47	3.7	68	62	1.7
2025-09-03	60	3.6	190	54	4.3
2025-09-10	41	0.34	120	28	15
2025-09-17	15	0.39	49	46	24
2025-09-24	55	0.12	140	25	8.8
2025-10-01	74	0.2	200	26	5.6
2025-10-08	69	0.13	160	40	32
2025-10-22	54	1.3	230	45	3.9
2025-10-29	85	0.16	150	56	15
2025-11-05	91	0.16	160	53	13
2025-11-12	95	2.2	200	48	12
2025-11-19	83	0.074	160	39	3.9
2025-11-26	93	1.1	210	36	3.7
2025-12-03	98	5.7	150	38	5.4
2025-12-10	46	0.052	180	57	12
2025-12-17	36	0.16	220	54	13

Date	Aeration TP (context)	RFS disch. TP	Aeration TN (context)	RFS disch. TN	RFS NH_3-N
2026-01-07	84	0.67	190	84	38
2026-01-14	73	0.64	140	75	43
2026-01-28	85	0.62	210	55	28
2026-02-04	77	0.75	180	36	21
2026-02-11	60	1	220	28	10
2026-02-18	64	0.78	170	39	0.76
2026-02-25	25	0.76	160	46	0.48
2026-03-01	79	1.1	180	19	3.2
2026-03-11	52	1.4	110	12	1.6
2026-03-25	57	0.33	170	22	5.3
2026-04-15	55	1	140	60	2.1

Aeration-pond columns are lagoon-diagnostic context only and must not be read as the RFS feed.

Appendix B – Sludge laboratory analyses (NATA)

Four NATA-accredited sludge analyses (EATS, Bunbury WA; analysed by MPL Laboratories, NATA accreditation 2901) characterise the site's solid streams. Key results are reproduced below; the original laboratory certificates are attached separately (provided with this report).

Table B-1. Anaerobic-tank sludge — 29 April 2024 (Lab PFD1949). Un-dosed; Category C2.

Analyte	Result (mg/kg unless noted)
pH / Electrical conductivity	7.0 / 1,800 µS/cm
Moisture	85%
Total nitrogen / Organic N	45,000 / 44,000
Ammonia-N / NOx-N	320 / 110
Total phosphorus	16,000

Analyte	Result (mg/kg unless noted)
Calcium / Magnesium / Sodium / Potassium	30,000 / 2,200 / 2,900 / 1,600
Chromium / Chromium VI	22 / <1.0
Copper / Zinc / Lead / Nickel / Arsenic	210 / 1,000 / 8.9 / 12 / 4.6
Pesticides (OCP / OPP)	Not detected
Classification	Contaminant Category C2 — direct land application

Table B-2. MD-press solids (ACH-dosed) — 13 May 2024 (Lab PFE0884).

Analyte (mg/kg)	MD1	MD2
pH	8.0	7.6
Total nitrogen	10,000	16,000
Organic nitrogen	10,000	15,000
Total phosphorus	43,000	53,000
Aluminium	230,000	190,000
Iron	740	870
Chromium / Chromium VI	13 / <1.0	22 / 1.7
Sodium / Calcium / Magnesium	5,100 / 12,000 / 2,900	2,900 / 16,000 / 3,800
Classification	C2 (direct)	C3 (compost only)

Table B-3. RFS sludge (ferric-dosed, liquid) — 7 May 2025 (Lab PGE0513). Reported in mg/L.

Analyte	Result (mg/L)
pH / Electrical conductivity	6.5 / 2,600 µS/cm
Total nitrogen / Organic N	160 / 140
Ammonia-N / NOx-N	1.9 / 17
Total phosphorus / Phosphate-P	320 / 0.41

Analyte	Result (mg/L)
Iron / Aluminium	1,100 / 20
Chromium / Chromium VI	2.1 / <0.005
Sodium / Calcium / Magnesium	370 / 69 / 53
Note	Substantially liquid (RFS underflow); ferric fingerprint

Table B-4. MD-press cake (ferric-dosed) — 16 June 2025 (Lab PGF1072).

Analyte	Result (mg/kg unless noted)
pH / Electrical conductivity	4.6 / 1,900 µS/cm
Moisture	87%
Total nitrogen / Organic N	48,000 / 47,000
Ammonia-N	470
Total phosphorus	57,000
Iron / Aluminium	130,000 / 4,300
Chromium / Chromium VI	62 / <1.0
Sodium / Chloride / Calcium / Magnesium	2,300 / 2,100 / 2,400 / 3,100
Microbiology (E. coli)	20 CFU/g
Classification	Contaminant C2 / Pathogen P2 — compost or heat-treat before use

Appendix D – Operating-cost analysis

Cost item	Before RFS	After RFS
Coagulant (ACH → ferric chloride)	$37,000	$15,360

Cost item	Before RFS	After RFS
Membrane cleaning chemicals	$32,193	$6,440
Indicative annual saving	–	~$47,403

Appendix E – Instrument records

Continuous filtration-rate and differential-pressure instrument logs (e.g. the Amiad filtration-rate export, 16 September 2024) are retained by DBC and available to AMPC on request; these document the cleaning-cycle frequency and recovery behaviour discussed in Section 6.2.

Appendix F – Internal source documents referenced

- AMPC Application (2022) and AMPC PIP Application (funded, detailed version).
- Executed Variation Agreement #1 (28 January 2025) — added 5th deliverable; extended reporting deadline.
- Milestone Reports 1, 3, 4 and combined 5/6/7 (2023–2024).
- Amiad Cembrane Filtration Plant Functional Specification (Ref 4643, Rev 1).
- Radial Flow Business Case; Strategy and throughput notes; Wastewater Costs and DBC Cembrane Filter Expenses workbooks.
- Samples Timeline workbook (master NATA dataset); sludge laboratory reports; WWT and Filter Resolution field notes.
- DWER Licence L5177/1989/13 (21 May 2025).