TECHNICAL REPORT

Whole-of-Life Cost Comparison:

Vacuum, Gravity and Pressure Sewer Systems

Case Study: Fishermans Bay Vacuum Sewer System, South Australia

Flovac Vacuum Sewerage Systems Pty Ltd | June 2026 | 400 Dwellings | 30-Year Analysis | 7% Discount Rate

$38	$287	$433	$6.2M
Vacuum per connection/yr *Confirmed from SCADA + FMS data*	**Gravity per connection/yr** *Modelled — see Appendix A for assumptions*	**Grinder Pumps per conn/yr** *Modelled — see Appendix A for assumptions*	**30-yr NPV saving vs grinder pumps** *At 7% discount rate*

Executive Summary

This report presents a 30-year whole-of-life cost comparison for vacuum sewerage, gravity sewerage with pump stations, and pressure sewer (grinder pump) systems, based on confirmed operational data from the Fishermans Bay Vacuum Sewer System in South Australia and modelled alternatives for the same site. Fishermans Bay serves 400 dwellings on a flat coastal peninsula via 101 Flovac collection chambers, commissioned in 2022, and monitored in real time by the Flovac FMS platform.

Vacuum system costs are based on confirmed operational data: eleven months of SCADA energy data, manufacturer-verified motor ratings, and twelve months of per-pit FMS alarm records. Gravity and grinder pump costs are modelled using standard engineering practice and published industry benchmarks. The assumptions and sources for modelled costs are set out in Appendix A.

Vacuum sewerage is the lowest-cost technology for this class of site at every time horizon assessed. The confirmed annual operating cost of $38 per connection per year compares with a modelled gravity figure of $287 and a modelled grinder pump figure of $433. Over 30 years at a 7 percent discount rate, vacuum produces an NPV of $5.52 million, compared with $5.74 million for gravity and $11.72 million for grinder pumps.

> *The vacuum cost is confirmed from a real system in its fourth year of operation. The gravity and grinder pump figures are modelled on the same site. Readers should note that the gravity NPV does not account for the cost escalation that typically occurs in coastal gravity systems as infiltration increases and infrastructure ages — this is discussed in Section 4.*

Site and System Description

Fishermans Bay is a coastal holiday community on the Yorke Peninsula, South Australia. The site is a flat sandy peninsula, elevation 2.1 to 3.5 m AHD, with a high seasonal water table and water on three sides. The community is primarily a holiday destination, with population and sewage flows that vary significantly through the year — peak January flows are substantially higher than mid-winter flows, with weekend averages approximately 31 percent above weekday averages year-round.

The vacuum pump station houses two Busch MINK MV 0502B vacuum pumps (7.5 kW each) and two Grundfos SEV sewage pumps (11 kW each), all in duty/assist configuration, discharging via a 7 km rising main to the Barunga West Sewage Treatment Plant at Port Broughton.

Annual Operating Cost Analysis

Annual operating cost covers genuine recurring cash expenditure: energy, routine labour, scheduled maintenance, alarm response, and parts provisions. Capital events — pump rebuilds and replacements, panel renewals — are treated as discrete cashflows in the 30-year NPV model. All modelled gravity and grinder pump assumptions are sourced and documented in Appendix A.

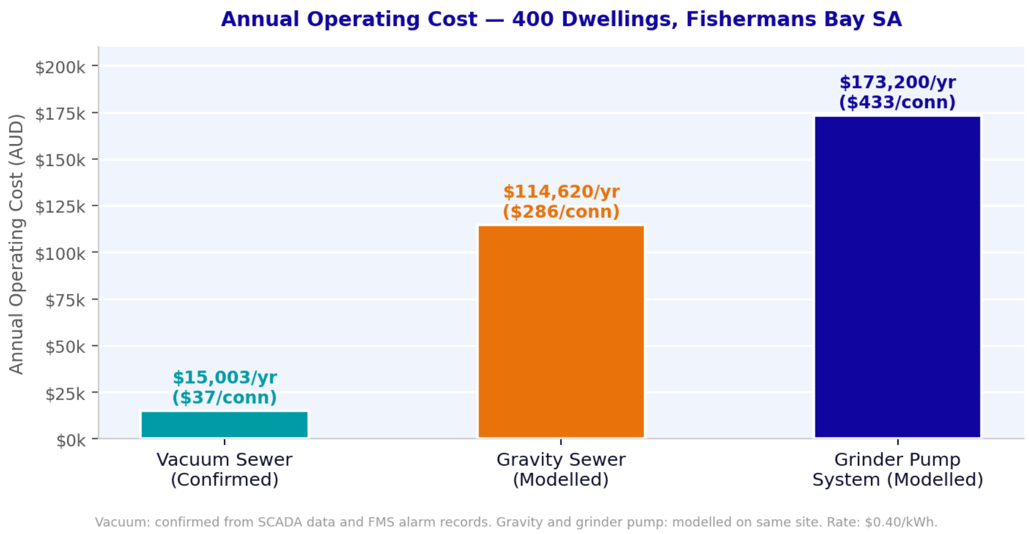

Figure 1: Annual operating cost comparison. Vacuum confirmed from SCADA and FMS data. Gravity and grinder pump modelled — see Appendix A for all assumptions and sources.

Cost Component	Vacuum Sewer (Confirmed)	Gravity Sewer (Modelled)	Grinder Pump System (Modelled)
Annual energy cost	$2,958	$3,900	$19,200
Annual O&M labour	$5,520	$37,440	—
Station maintenance	$3,000	$54,000	—
Alarm response cost	$960	$17,280	$72,000
Per-property maintenance	—	—	$80,000
Asset lifecycle provision	$2,525	$7,200	$320,000†
TOTAL ANNUAL OPEX	**$15,003**	**$114,620**	**$173,200**
Per connection per year	**$38**	**$287**	**$433**
30-Year NPV (7%)	**$5.52M**	**$5.74M***	**$11.72M**

** Gravity NPV does not include cost escalation from infiltration progression — see Section 4.*

† Grinder pump lifecycle cost annualised: 400 units x $8,000 replacement on a 10 to 15 year cycle, utility borne. See Appendix A.

Energy

Vacuum energy consumption is confirmed at 7,396 kWh per year from SCADA run hour data applied to manufacturer-verified motor ratings. At $0.40 per kWh this costs $2,958 per year — $7.40 per connection. A grinder pump system for 400 dwellings consumes approximately 48,000 kWh per year at $19,200 — 6.5 times higher. This energy is charged to individual property electricity accounts and does not appear in the utility's central energy bill. It is a real cost to the scheme; it is simply not visible in a central energy account unless specifically aggregated across all properties.

The gravity alternative at wet-weather design flows consumes an estimated 9,750 kWh per year. Gravity pump stations on high water table coastal sites are required to be sized for peak wet-weather flows incorporating groundwater infiltration, which can substantially increase the volume pumped compared with dry-weather sewage flow alone.

Maintenance and Alarm Response

The FMS alarm methodology requires explanation. The analysis uses alarms lasting more than 30 minutes as the threshold for potential site attendance, excluding connection-lost alarms which are telemetry events rather than system failures. Over the twelve-month analysis period from June 2025 to June 2026, 314 operational alarms were recorded across 101 pits. Of these, seven lasted more than 30 minutes. All seven were High Level type. All seven resolved without recorded manual intervention. The analysis assumes four precautionary site visits per year — 50 percent of the seven qualifying alarms — at a confirmed cost of $960.

> *Seven alarms lasting more than 30 minutes over twelve months across 101 pits. All self-cleared. This equates to 0.07 qualifying alarms per pit per year, consistent with the best-practice international benchmark of 0.08 per pit per year from a large, well-maintained US system with dedicated operators and quarterly tuning.*

Gravity and grinder pump callout figures are modelled from industry benchmarks. Gravity pump station attendance rates vary with station size, age, and monitoring capability. Industry data suggests a range of 15 to 35 callouts per station per year for small to medium stations without telemetry; 24 per station per year is used here as a mid-range figure. Grinder pump callout rates of 0.5 to 1.5 per unit per year are reported in published literature; 0.75 per unit is used as a conservative mid-range assumption. These figures and their sources are documented in Appendix A.

The Holiday Community Factor: Low Flows and Their Consequences

The seasonal flow pattern at Fishermans Bay has structural implications for two of the three technologies under comparison. For extended periods outside the holiday season, sewage generation from this community is low — a characteristic confirmed by the SCADA flow record. For pressure sewer and gravity systems, low-flow periods create specific operational challenges in coastal sandy environments.

Pressure Sewer Systems: Retention Time and Sand Management

Pressure sewer systems rely on regular flow through the pressure main to keep the pipe swept and oxygenated. At low-flow periods, sewage retention time in the main increases. Two operational issues are commonly reported in coastal pressure systems operating at intermittent or low flows.

Retention Time and H2S

- Extended retention time allows sewage to septicise, generating hydrogen sulphide at concentrations that can attack infrastructure, corrode metal components, and produce odour events at air release points and properties.
- When a holiday property reopens after an extended period, accumulated septic sewage can produce noticeable odour events. At a coastal holiday destination this is a community amenity issue as well as a maintenance consideration.
- H2S corrosion reduces the effective service life of pressure main components and associated infrastructure over time. These costs are difficult to predict at the design stage and tend to appear as reactive maintenance items.

Sand Management in Coastal Soils

- In sandy coastal soils, any imperfection in pressure main joints or fittings can allow fine sand to migrate into the pipe during low-pressure or transient conditions. Sand accumulates at low points and, at low flow velocities, is not effectively transported to the pump station.
- Sand blockages in pressure mains require flushing and, in some cases, excavation. This has been reported as an operational issue in coastal pressure systems in Australia and the United States, particularly in areas with fine mobile sands.
- Sand entering the wet well or pump intake in a gravity system causes accelerated impeller wear. In coastal gravity systems this can reduce the effective pump service life below the nominal design interval.

These issues are not universal to all pressure or gravity installations. Their significance depends on soil type, pipe joint quality, flow variability, and maintenance practice. They are noted here because Fishermans Bay — flat, sandy coastal terrain, highly variable seasonal flows — presents conditions where both risks are relevant to an options assessment.

> *Both grinder pump systems and gravity sewers can face sand management and retention time issues in coastal sandy environments with variable flows. The significance of these issues should be assessed on a site-specific basis as part of any formal options study.*

Vacuum Sewerage: Largely Resistant to Both Mechanisms

The vacuum system largely avoids the retention time and sand management issues described above. These characteristics follow from the operating principle of the technology rather than from design choices specific to this installation.

On retention time: the vacuum reticulation operates under continuous negative pressure. Once sufficient wastewater accumulates in the collection chamber sump to trigger the interface valve, sewage is transported through the vacuum network to the pump station regardless of ambient flow conditions. The system does not rely on hydraulic head to move sewage, so low seasonal flows do not extend retention time in the reticulation in the same way as a gravity or pressure system.

On sand: the FV80 interface valve opens in response to sewage accumulation in the collection chamber sump only. The sealed reticulation under negative pressure does not provide a pathway for external material to enter. High-velocity slug flow in the vacuum main — typically 4 to 6 metres per second during a valve event — provides a self-cleansing action that does not depend on minimum daily flow volumes.

> *The vacuum system largely avoids the retention time and sand management issues commonly encountered in coastal pressure and gravity systems. This is a consequence of operating principle rather than site-specific design, and should be considered in any options assessment for coastal or low-flow sites.*

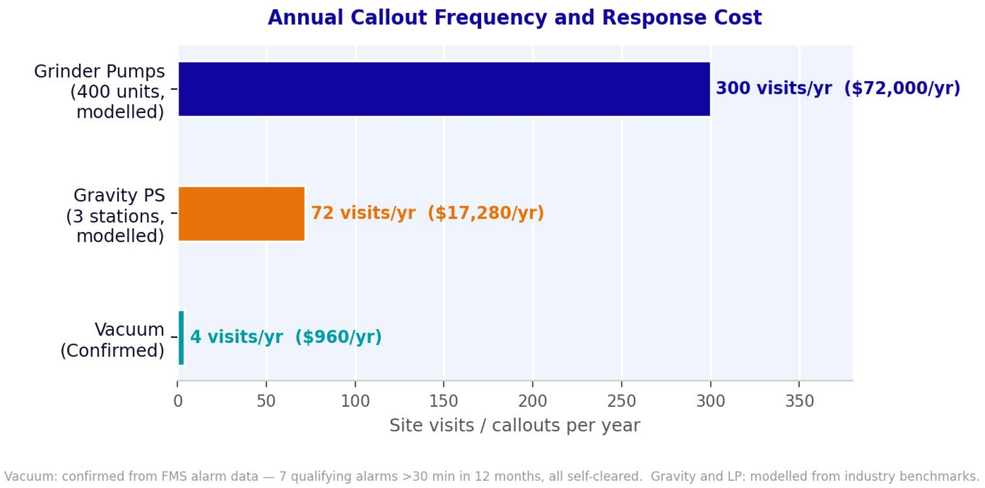

Figure 2: Annual callout frequency and response cost. Vacuum confirmed from FMS alarm data, June 2025 to June 2026. Gravity and grinder pump modelled from industry benchmarks — see Appendix A.

Why Gravity Costs Tend to Increase Over Time

The modelled gravity NPV of $5.74 million is close to the vacuum figure of $5.52 million. This proximity is real within the scope of the model. However, the gravity model uses a flat annual cost assumption. Operational experience and published data on gravity systems in coastal environments suggest that annual costs for gravity sewerage tend to increase over the asset life for reasons that are not captured in a flat-rate model.

The following section sets out the mechanisms behind this tendency. It draws on published data and operational observations rather than site-specific modelling for Fishermans Bay, and should be read as engineering context rather than a quantitative projection.

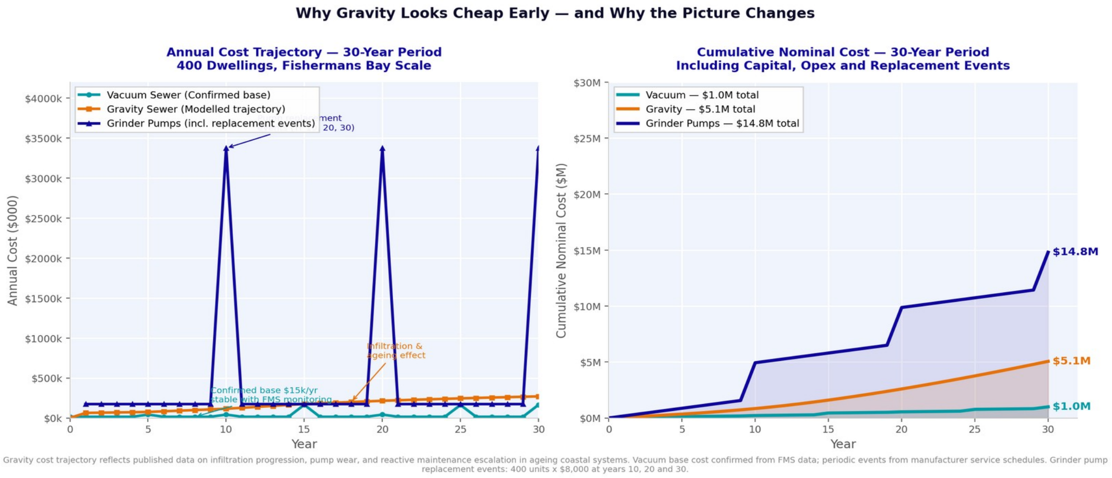

Figure 3: Illustrative annual cost trajectory and cumulative nominal cost. The gravity escalation curve is qualitative, based on published data from comparable coastal systems. The vacuum base cost is confirmed; periodic events follow manufacturer service schedules. This chart is illustrative — actual gravity cost escalation will depend on site conditions and maintenance practice.

Infiltration Tends to Increase Over Time

New gravity sewers typically exhibit low infiltration rates. Joints are intact, pipes are undistorted, and groundwater pathways are minimal. Over time, ground movement, root intrusion, and the cumulative effect of pressure cycling open pathways through pipe joints and minor construction defects. In high water table coastal soils this process is generally more pronounced than in drier inland conditions.

As infiltration increases, pump station hydraulic loads rise above the design sewage flow. Pump cycling frequency increases. Energy consumption rises. At the extreme, infiltration in an ageing coastal gravity system can approach or exceed the sewage flow volume, meaning pumps are handling a diluted mix of sewage and groundwater rather than sewage alone. The additional hydraulic load also passes through to the treatment plant, where it increases processing energy and reduces effective capacity.

Wet Well Environments and Pump Service Life

Gravity pump wet wells are inherently corrosive environments. Hydrogen sulphide generated by septicising sewage attacks concrete structures, pump housings, and electrical conduit. Submersible pump mechanical seals and bearings operate under vibration and thermal cycling that is more demanding than manufacturer design-life calculations may assume. In coastal systems handling septic or partially anaerobic sewage, pump components can reach end of service life earlier than the nominal design interval.

Many operators of gravity systems in coastal environments report pump replacement cycles shorter than the nominal ten-year design life. This is consistent with published data on wet well pump service life in H_2S-generating conditions. The gravity model uses a ten-year replacement interval; actual intervals in challenging coastal conditions are sometimes shorter.

Reactive Operations and Deferred Maintenance

Gravity pump stations tend to be operated reactively — attend when an alarm fires or a fault is reported. In the early years of a well-constructed system this approach produces low visible costs. As infrastructure ages and the reactive burden grows, the cost structure shifts. Deferred maintenance items compound: a pump overdue for replacement that fails unexpectedly produces a wet well overflow event, the cost of which typically exceeds the planned replacement cost by a significant margin.

Vacuum systems with real-time per-pit monitoring are structurally oriented toward preventive rather than reactive operations. Abnormal valve activation patterns, rising sewage levels, and changed alarm frequencies are visible before they produce failures. The Fishermans Bay operational record — seven qualifying alarms in twelve months, all resolved without intervention — reflects this characteristic.

> *Operators commonly observe that gravity sewerage appears lower cost in the early years but that maintenance costs tend to grow as the system ages. This reflects the progressive nature of infiltration, H2S corrosion, and reactive maintenance escalation rather than poor practice. It is a characteristic of the technology in this class of operating environment. The flat-rate gravity model used in this report does not capture this trajectory.*

The Kurnell Reference

The 2013 Kurnell crisis provides a documented case study in gravity cost escalation at its most severe, though it should be noted that the Kurnell system is an Airvac vacuum system, not a Flovac system, and that the failures at Kurnell were specifically attributable to 24 years of deferred maintenance rather than to any inherent technology limitation.

According to Flovac benchmarking records drawing on Sydney Water Maximo maintenance data, the crisis cost at Kurnell in 2013 included approximately $1.25 million in emergency operations and equipment, client rebates totalling approximately $553,000, and an estimated $3 million in valve and controller upgrades required as a consequence of the event. The root cause was the repeated deferral of standard ten-year maintenance — specifically, requests for $40,000 in valve and controller servicing that had been declined in preceding years.

The Kurnell case is cited not as a typical outcome but as a documented illustration of what compound deferred maintenance produces in a vacuum system, and by analogy what progressive deferred gravity maintenance can produce in a gravity system. Maintaining scheduled preventive maintenance — for any technology — is the primary determinant of long-term whole-of-life cost.

30-Year Whole-of-Life Analysis

Capital Costs and the Grinder Pump Replacement Liability

The supply and install cost of one grinder pump unit in the current Australian market is comparable to the supply and install cost of one Flovac collection pit — confirmed at approximately $15,000 per unit for both technologies. At 400 units, grinder pump collection infrastructure costs approximately $6,000,000, compared with approximately $1,515,000 for 101 Flovac collection chambers. Including the vacuum pump station (approximately $715,000), total vacuum capital is approximately $5,230,000 versus approximately $6,700,000 for the grinder pump alternative including pressure mains.

The more significant whole-of-life capital consideration for grinder pump systems is pump mechanism replacement. Many utilities budget on a 10 to 15 year replacement cycle for grinder pump mechanisms, with actual intervals depending on solids loading, maintenance practice, and unit type. Utilities in several jurisdictions — including JEA in Jacksonville Florida, Watercare in Auckland, and a number of Victorian water corporations — have found that the replacement cost tends to fall on the utility regardless of the original maintenance agreement between the authority and the property owner. At $8,000 per mechanism across 400 units, each replacement cycle represents a $3,200,000 liability. Over 30 years with two to three replacement cycles, the total utility replacement cost in nominal terms is between $6,400,000 and $9,600,000 depending on the cycle assumed.

> *The grinder pump replacement liability is the largest single driver of the whole-of-life cost difference between vacuum and grinder pump systems. Flovac collection chambers are rated to a 50-year design life; the principal recurring cost is $250 in valve parts per chamber on a 10-year service interval.*

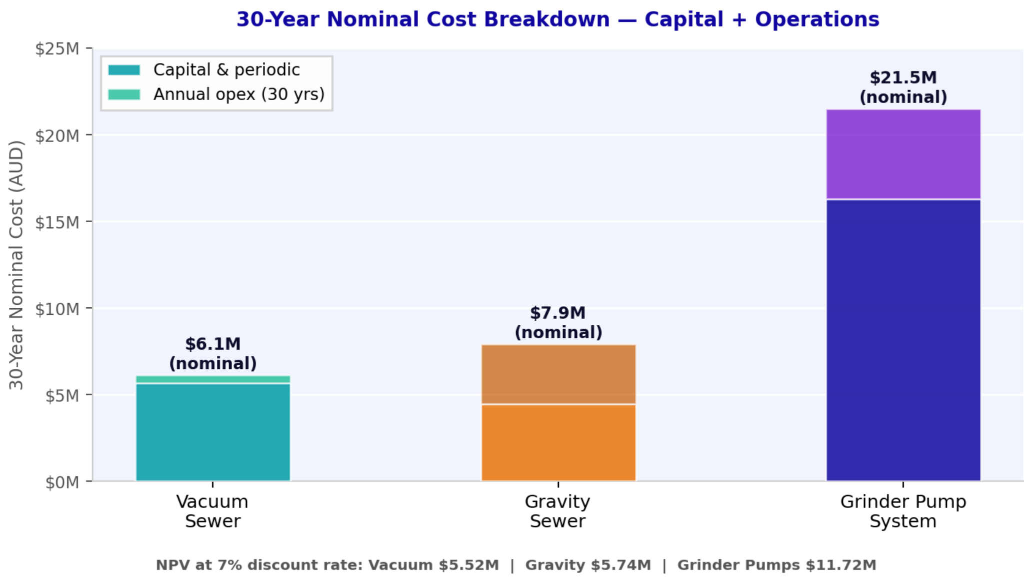

Figure 4: 30-year nominal cost breakdown. Grinder pump replacement events at years 10, 20 and 30 are the dominant cost driver for that technology. Capital costs shown at year 0.

30-Year NPV Results

$5.52M	$5.74M	$11.72M
Vacuum Sewer — 30-Year NPV	Gravity Sewer — 30-Year NPV	Grinder Pump — 30-Year NPV

7% discount rate | confirmed operating cost base	*Modelled | flat-rate opex | excludes infiltration escalation*	*Modelled | includes utility replacement liability*

The gravity NPV of $5.74 million is close to vacuum at $5.52 million on a modelled flat-rate basis. As noted throughout this report, this comparison does not capture the cost escalation tendency of gravity systems in coastal environments as infiltration increases and infrastructure ages. Engineers using this report for options assessment purposes should apply a site-specific sensitivity analysis to the gravity opex assumption, particularly for years 15 to 30.

Conclusions

- Vacuum sewerage produced a confirmed annual operating cost of $38 per connection per year at Fishermans Bay, based on twelve months of SCADA energy data and FMS alarm records. This figure is at the lower end of the published Australian benchmark range of $31 to $86 per connection per year and reflects the operational benefit of real-time FMS monitoring.
- Gravity sewerage is modelled at $287 per connection per year on a flat-rate basis. The actual gravity cost trajectory on this site is likely to increase over time as infiltration builds and infrastructure ages — a characteristic of coastal gravity systems documented in published operational data. The modelled NPV of $5.74 million should be treated as a lower-bound estimate.
- Grinder pump systems carry a replacement liability of between $6.4 million and $9.6 million (nominal) depending on the replacement cycle assumed. At the 10 to 15 year mid-point the 30-year NPV is $11.72 million — more than double the vacuum figure.
- At a coastal holiday community with highly variable seasonal flows, pressure sewer systems may experience operational issues related to retention time and sand management. Gravity systems at sub-cleansing velocities face similar sand settling challenges in coastal soils. Vacuum systems are largely resistant to both mechanisms by virtue of operating principle.
- The vacuum alarm record at Fishermans Bay — seven qualifying alarms over 30 minutes in twelve months, all self-cleared, at a confirmed alarm response cost of $960 per year — is consistent with best-practice international benchmarks and supports a preventive rather than reactive operational model.
- These findings are consistent with the independent Arup 2011 options analysis of Greenhills Beach (Kurnell), which found vacuum to be the lowest-cost option on both capital and 30-year NPV at 5 percent discount rate, and with the Wallbridge and Gilbert 2006 comparative study for LGA South Australia, which identified vacuum as cost-competitive with pressure sewerage above 75 to 100 connections.

> *This report is based on confirmed operational data for the vacuum system and modelled estimates for gravity and grinder pump alternatives. Modelled figures use industry benchmarks and standard engineering practice. All assumptions and sources are documented in Appendix A. These figures should be independently verified for any formal options assessment or procurement process.*

Appendix A — Modelled Cost Assumptions and Sources

The following tables document all assumptions used for the modelled gravity and grinder pump cost estimates. Vacuum system figures are drawn from confirmed SCADA and FMS data and are not modelled.

A1. Gravity Sewer — Annual Operating Cost Assumptions

Parameter	Value Used	Basis / Range	Source
Number of pump stations	3	Minimum for flat coastal peninsula — 3 in cascade to 7 km rising main	Engineering judgement based on site topography (O&M Manual, Flovac 2024)
Annual energy — wet weather design	9,750 kWh/yr	Range 9,000–10,500 kWh/yr. Infiltration uplift 1.5x–3x dry-weather sewage flow	Modelled from site flow data. Vacuum SCADA base of 9,700 kL/yr adjusted for infiltration
Station maintenance (per station)	$18,000/yr	Wet well cleaning, pump maintenance, electrical, odour management	Industry benchmark range $12,000–$25,000/station/yr. Mid-range used.
Annual callouts (per station)	24/yr	Range 15–35 for small-medium stations without telemetry	Published industry benchmark. Source: Flovac operational benchmarking data
Hours per callout	2 hrs	Travel, wet well access, pump inspection	Standard assumption
Labour rate	$120/hr	SA contractor rate 2026	Consistent with vacuum model
Pump replacement interval	10 years	Nominal design life. Coastal conditions may reduce this	Manufacturer specification. Actual range 7–12 years in coastal/H2S conditions
Pump unit cost	$12,000 per pump	Submersible sewage pump, 2–4 kW range, duty/assist per station	Market rate 2026
Gravity reticulation	4,000m at $800/m	Deeper trench required for grade on flat coastal terrain	W&G 2006 escalated to 2026 AUD using ABS construction cost indices

A2. Grinder Pump System — Annual Operating Cost Assumptions

Parameter	Value Used	Basis / Range	Source
Number of units	400	One per dwelling	Site design basis
Supply and install cost per unit	$15,000	CONFIRMED: equal to Flovac pit supply and install cost	Australian market 2026. Confirmed by Flovac supply pricing.
Annual energy per unit	120 kWh/yr	Published range 60–240 kWh/yr. Midpoint used.	E/One Sentry grinder pump published specifications
Callout rate per unit	0.75/yr	Published range 0.5–1.5/unit/yr. Conservative mid-range used.	Published literature on grinder pump maintenance rates
Hours per callout	2 hrs	Travel to private property, pit access, householder liaison, repair	Standard assumption. Property-level callouts typically longer than centralised
Annual maintenance per unit	$200/yr	Property-level service,	Industry benchmark —

		check valve, electrical. Published mid-range.	Australian and US published data
Pump mechanism replacement interval	10–15 years	Many utilities budget on this cycle; actual depends on loading and practice	E/One published design life 15 yrs. Mechanism replacement 10–15 yrs in practice.
Replacement cost per mechanism	$8,000	Components only — not full unit replacement	Market rate 2026. Utility borne per JEA, Watercare and Victorian utility precedent.
Replacement liability	Utility	Replacement cost assumed to fall on utility	JEA (Jacksonville FL), Watercare (Auckland NZ), Victorian water corporation precedents
Pressure main cost	$350/m (2,000m)	W&G 2006 escalated to 2026 AUD	W&G 2006 comparative study, LGA South Australia

A3. Vacuum System — Confirmed Data Sources

Parameter	Value	Status	Source
Annual energy — vacuum pumps	4,283 kWh/yr	CONFIRMED	FMS SCADA cumulative run hours Jul 2025–Jun 2026. Busch MINK MV0502B 7.5 kW motor rating from manufacturer datasheet.
Annual energy — sewage pumps	3,113 kWh/yr	CONFIRMED	FMS SCADA cumulative run hours. Grundfos SEV.80.80.110 11 kW motor rating from manufacturer datasheet.
Total annual energy	7,396 kWh/yr	CONFIRMED	Sum of VP and SP from SCADA run hours x nameplate motor ratings.
Annual flow volume	9,700 kL/yr	CONFIRMED	FMS SCADA Jul 2025–Jun 2026.
Total operational alarms (>30 min)	7 per year	CONFIRMED	FMS alarm data Jun 2025–Jun 2026. All High Level type. All self-cleared. Connection lost alarms (1,760 total) excluded as telemetry events.
Precautionary site visits from alarms	4 per year	Assumption	50% of 7 qualifying alarms. All alarms self-cleared without recorded intervention — 50% is conservative.
Alarm response cost	$960/yr	Calculated	4 visits x 2 hrs x $120/hr.
Collection chambers	101 pits	CONFIRMED	FMS system, June 2026.
Electricity rate	$0.40/kWh	Current	SA commercial rate 2026.
Valve parts cost	$250/valve/10yr	CONFIRMED	Flovac FV80 current parts pricing. 50-year valve design life.

A4. Supporting Published References

Reference	Key Finding Cited
Wallbridge and Gilbert (2006). Wastewater Collection Systems — Comparative Merits. LGA South Australia.	Breakeven point where vacuum becomes cost-competitive with pressure: 75–100 connections. Generic annualised costs: vacuum $265/conn/yr, pressure $320/conn/yr, gravity $190/conn/yr (gravity assuming 4 pump stations, flat ground).
Arup (2011). Greenhills Beach (Kurnell) Options Report. Australand/Sydney Water.	30-year NPV comparison: vacuum (Flovac) $5.66M, pressure $8.15M at 5% discount rate over 983 lots. Vacuum had lowest capital cost of four options assessed.

Flovac benchmarking study (Maximo 2009 source data).	Australian vacuum system O&M costs (excl electricity, VPS maintenance, pipe leaks): normal range $31–$86 per connection per year. Problem systems (deferred maintenance): $556–$784 per connection per year.
E/One (Environment One) Sentry grinder pump published specifications.	Motor rating: 0.75 kW. Annual energy consumption: 60–240 kWh per dwelling per year. Midpoint 120 kWh/yr used in this analysis.
Flovac FMS SCADA data, Fishermans Bay, Jul 2025 to Jun 2026.	Primary data source for all vacuum energy and alarm statistics in this report.