Industry Discussion Paper

qldwater

Sewage treatment plants in Great Barrier Reef catchments

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Contents

1. Executive Summary

In catchments of the Great Barrier Reef (GBR), sewage discharges contribute only a small fraction of nutrients that are a key concern for reef health. Given the high cost of sewage treatment plant (STP) upgrades it is prudent to determine if greater benefit could be derived from alternative investments. This paper reviews the contribution of sewage treatment to pollution of the GBR and the costs of further STP upgrades.

Existing data was used to establish the attributes of the 129 local government sewage treatment sites within catchments of the GBR and new data was collected on the costs and benefits of recent upgrades. A simple relationship between volume treated and capital and operational expenditure for STPs built or upgraded in the last decade indicated that a further $719 million in new infrastructure and ongoing operational costs of $33 million per year would be needed to upgrade all remaining plants within 50 km of the coast. The high cost of achieving best practice treatment standards was most telling in small communities where lack of economies of scale make achieving high standards very expensive relative to larger communities. These communities are also least able to bear ongoing cost increases.

Given the decreasing rate of return on investment to upgrade small STPs and their relatively small contributions to pollutant loads, greater benefit for the GBR would be derived from alternative investments including offsets to improve water quality. Economic modelling has shown that reef targets can be achieved by addressing diffuse sources at much lower cost than that estimated for further STP upgrades. Crucially, investments in STPs and other point sources to date, although beneficial for local environments, have contributed only to slowing decline in GBR health. To halt and reverse decline requires a focus on high risks such as diffuse catchment sources and climate change. Addressing such issues will require significant public investment and a reassessment of the opportunity cost of expensive STP upgrades is essential.

2. Impacts of discharges to the Great Barrier Reef

Waterways in catchments of the Great Barrier Reef (GBR) require protection from discharges both for their own environmental value and to protect downstream environments including the reef itself. The recent Reef Water Quality Protection Plan Report Card showed that the GBR is not recovering from land-based impacts.[1] Nutrients (particularly nitrogen), sediments and pesticides in runoff have been identified as key causes of reef deterioration second only to climate change.[2] Discharges from sewage treatment plants (STPs) have been considered an important source of nitrogen and phosphorus in the past but are known to contribute negligible volumes of sediments and pesticides.

The contribution of STPs to loads of nitrogen and phosphorus reaching the GBR is actually very small compared with those of other sources. In 2003, the Productivity Commission[3] found the total discharge from all GBR STPs accounted for less than 3% of the entire nutrient load. The Great Barrier Reef Marine Park Authority (GBRMPA) confirmed this estimate in 2014 reporting that "sewage discharge contributes only between three and four per cent of the total nitrogen load and less than one per cent of the total phosphorus load discharged annually into the Great Barrier Reef". [4] In 2014, the Queensland Government undertook detailed modelling of loads from 18 large STPs which showed total loads of nitrogen and of phosphorus from all STPs are in the order of 4% (see Appendix 1).

One reason for the minor contribution from STPs has been past State policy focus resulting in significant investment in STP upgrades over the last two decades. Responding to a series of studies highlighting the impacts of sewage discharges,[5] policy frameworks were put in place which led to upgrades of many large STPs near the coast (see policy review in Appendix 2). In 2014, the GBRMPA noted that "the total cost of these upgrades has been between $600 and $700 million since the early 2000s, with investment from all levels of government and the community." [6] Some upgrades are still underway: the "Reef 2050 Long-Term Sustainability Plan" noted that in "2014–15, local councils in Queensland invested around $230 million in protecting and managing the Great Barrier Reef, including improving sewage treatment and water quality".[7] However, while some STPs are now operating at the current limit of technology, others have not been upgraded and the emergence of new

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[1] Reef Water Quality Report Card 2014 http://www.reefplan.qld.gov.au/measuring-success/report-cards/2014/

[2] Great barrier Reef Water Science Taskforce, May 2016. Department of Environment and Heritage Protection, State of Queensland.

[3] Productivity Commission 2003, Industries, land use and water quality in the Great Barrier Reef catchment: research report. Department of Communications, IT and the Arts, Canberra, Australia.

[4] Great Barrier Reef Marine Park Authority 2009, Great Barrier Reef Outlook Report 2009, GBRMPA.

[5] This progression is reflected in the following three scientific papers (1) Brodie, J.E., 1994. Management of sewage discharges in the Great Barrier Reef Marine Park. In: Bellwood, O., et al., (Eds.), Recent advances in Marine Science and Technology, vol. 94. James Cook University, Townsville, pp. 457–465, (2) Waterhouse, J., Johnson, J., 2002. Sewage Discharges in the Great Barrier Reef Region. Water 29 (5), 43–49, and (3) Brodie, J., Waterhouse, J., Schaffelke, B., Kroon, F., Thorburn, P., Rolfe, J., Johnson, J., Fabricius, K., Lewis, S., Devlin, M., Warne, M. and McKenzie, L.J. 2013, 2013 Scientific Consensus Statement: Land use impacts on Great Barrier Reef water quality and ecosystem conditions, Reef Water Quality Protection Plan Secretariat, Brisbane.

[6] Great Barrier Reef Marine Park Authority 2014, Great Barrier Reef Outlook Report 2014, GBRMPA, Townsville, p. 171.

[7] Reef 2050 Long-Term Sustainability Plan, Commonwealth of Australia 2015 at p. 56.

technologies often raises expectations that further upgrade should be pursued especially where population growth is increasing the loads treated. These expectations are considered in the next section.

3. Expectations for management of STP discharges

Current and emerging expectations about the capacity of STPs in GBR catchments can be understood only in light of changes over the past decades. In 2015, the Reef 2050 Long-Term Sustainability Plan summarised this history as follows: [8]

> *Throughout the 1980s and early 1990s the focus was strongly on minimising rubbish and sewage disposal within the Marine Park, particularly from coastal communities, island resorts, tourism infrastructure and vessels. By 2002 the sewage facilities of island resorts were improved to tertiary level treatment standards. In parallel, the Queensland Government supported the upgrade of sewage treatment plants discharging into coastal waters that enter the Marine Park, with the aim of achieving a tertiary treatment standard by 2010. Almost $620 million has been invested in upgrading sewage treatment plants in the three largest coastal communities adjacent to the Reef— Townsville, Cairns and Mackay."*

Policies put in place from 2001 (see Appendix B) were effective and by 2009, the GBR Outlook Report noted that "an increasing proportion of sewage is tertiary treated or recycled [...because...] under Queensland Government policy, all coastal sewage treatment plants that discharge into the marine environment must meet the most stringent treatment standards (i.e. tertiary treatment) by 2010." The report noted that STP discharges were by then a relatively minor contributor to total loads, but warned that "as populations grow, so will the need to address increases in sewage outputs."[11]

> **Box 1. What is tertiary treatment?**
> Although used regularly in the documents quoted in this paper, a strict definition of 'tertiary treatment' does not exist. Licence conditions imposed by the regulator for GBR STPs over the past decade suggest that this standard is being interpreted as long-term median reduction of total nitrogen to 5 mg/L and total phosphorus of 1-2 mg/L. This accords with the understanding presented by Brodie (1995), Waterhouse and Johnson (2002),[9] and the GBRMPA policy for island STPs[10].

In 2013, the Reef Water Quality Scientific Consensus Statement confirmed these trends noting "the main source of excess nutrients, fine sediments and pesticides from Great Barrier Reef catchments is diffuse source pollution from agriculture." [12] However, it was also noted that although STPs were relatively minor contributors, they "could be locally, and over short-time periods, highly significant […and...] are the major sources of pollutants such

[8] Note 7 at p. 24.
[9] Note 5.
[10] The Great Barrier Reef Marine Park Authority Sewage Discharge Policy, March 2005 requires "tertiary equivalent nutrient concentrations of 5 mg/L Total Nitrogen and 1 mg/L Total Phosphorus".
[11] Note 4 at p. 102.
[12] Brodie, *et al.* 2013, note 5 at p. 1.

as metals, industrial chemicals and pharmaceuticals".[13] These findings were reflected in the Reef Water Quality Protection Plan released in the same year:[14]

> *The latest modelling and monitoring supports previous research which indicates that the vast majority of loads of sediment, nutrients and herbicides are derived from diffuse agricultural sources, in particular dryland grazing and sugarcane. [...] Major improvements have also been made to minimise water quality impacts from urban areas, for example through major investments to upgrade sewage treatment plants, which now contribute less than four per cent of the total nutrients to the reef.*

Similarly, the most recent Outlook Report (2014) noted "most of the major population centres adjacent to the Great Barrier Reef, with the exception of Rockhampton, now have upgraded sewage treatment plants"[15] and "as regulations require sewage to be tertiary treated, sewage discharge is likely to be only a small component of the nutrient load entering the marine environment and have only minor effects."[16] This report also warned that population growth could increase future risk, rating the likelihood of this occurring as 'almost certain'. However, the overall risk to the reef was low as the analysis rated the consequence of population growth as 'minor' probably reflecting the small relative contribution of STPs from such increases. It was concluded that:[17]

> *While inputs of nutrients from sewage treatment plants accounted for only a small percentage of the overall load entering the Region from the catchment, the reductions gained through upgrades can be quite significant at a local scale*

Taken together, these successive reports reiterate the minor contribution of STPs in comparison with other catchment loads but warn of local impacts particularly over short periods. The concern for future increases in risk are small, but this is based on an expectation that STPs will continue to meet 'tertiary' treatment standards with continuous improvement as required by current environmental legislation. There is also broad concern for potential future contamination by metals, industrial chemicals and pharmaceuticals as these have not been well studied in the past.

The Queensland Government policy direction for STPs in reef catchments appears to support these findings and supports consolidating the nutrient reductions achieved in past decades and keeping pace with population growth to protect the broader GBR (see Appendix B). There is also a strong regulatory focus on reducing local impacts on the local environment near STPs where discharges may be significant, particularly during dry periods. For these reasons, there is an expectation of 'tertiary' treatment and an increasing focus on introducing environmental monitoring (e.g. Receiving Environment Monitoring Programs) to counter concerns about local impacts and the effects of contaminants (e.g. pharmaceuticals) that are not well understood. Given these expectations, the following section examines the current state of STP treatment in GBR catchments.

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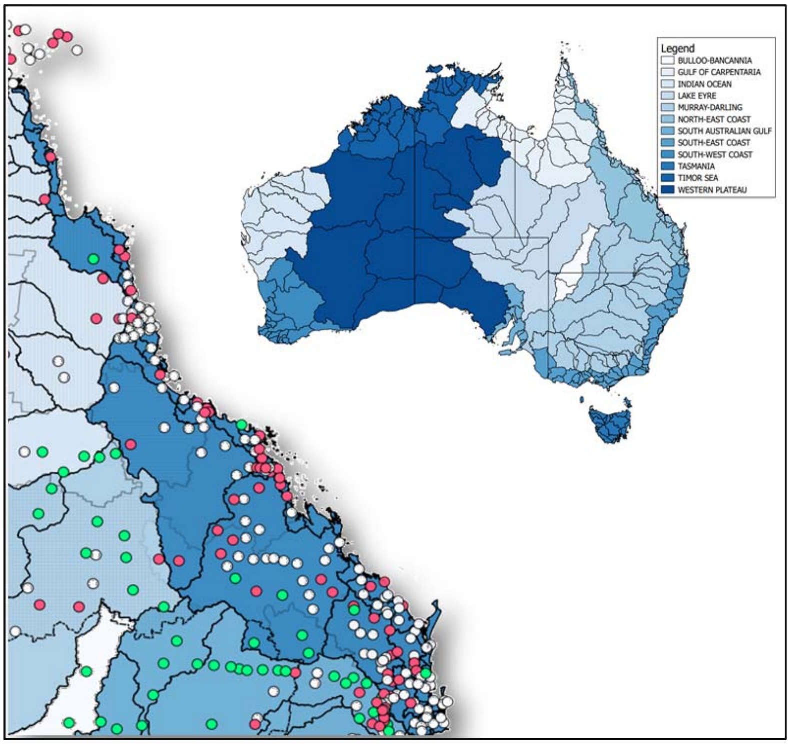
[13] Ibid at p. 7.
[14] Reef Water Quality Protection Plan 2013 at p. 11.
[15] Note 6 at p. 171.
[16] Ibid at p. 291.
[17] Ibid at p. 171.

4. STPs and sewage treatment capacity in GBR catchments

There are 129 STPs in GBR catchments (Figure 1) which vary significantly in terms of population served, volume of sewage treated, treatment types, degree of recycling, and volumes discharged. The available data for each of these attributes is not comprehensive, but analysis of available information from the State-wide Water Information Management (SWIM) system and other sources for this report indicated that 'tertiary' treatment is achieved at 33 of these sites (Appendix C).

Figure 1. There are 129 STP sites located in catchments that drain to the GBR.



Within the largest 15 STPs, there are five sites that do not treat to a 'tertiary' standard. Two of these sites (Hervey Bay and Gladstone) have a significant proportion of wastewater reused in recycling schemes. However, wastewater from the Rockhampton North and Bundaberg East schemes are only partially recycled with the majority being discharged directly to coastal waters (though the Bundaberg scheme is currently being upgraded). Similarly, more than half of the wastewater from the Maryborough STP is discharged close to the coast. The GBR Outlook Report 2014 singled out Rockhampton as one of the few remaining schemes not to have been upgraded to tertiary treatment.[18] This variation was included in the modelling undertaken in 2014 which nevertheless showed that the STPs were relatively small contributors of nutrients. Recycling is also common (Appendix C) but larger plants must always have at least some level of discharge, particularly during wet weather when there are high flows and little demand for recycled water.

Despite the large number of STPs in the catchments and the small proportion that have 'tertiary treatment', the contribution of STPs to the GBR is minor. While continuous improvement and local environment protection are critical, the expectation that more STPs should have full tertiary treatment in order to protect the GBR is questionable, particularly when social impacts and the costs of upgrades are considered.

[18] See note 6 at p. 171.

5. Costs of treatment

To explore costs of sewage treatment, 15 service providers were asked to provide capital (CAPEX) and operational (OPEX) expenses for recently upgraded STPs. Six councils responded, providing information from the past ten years (see summary in Table 1) and Queensland Urban Utilities (QUU) provided a useful comparison of operational costs across the broad range of STPs they operate.

Table 1: CAPEX/EP and OPEX/EP from recent tertiary treatment STPs from GBR catchments (“-” means no data were available).

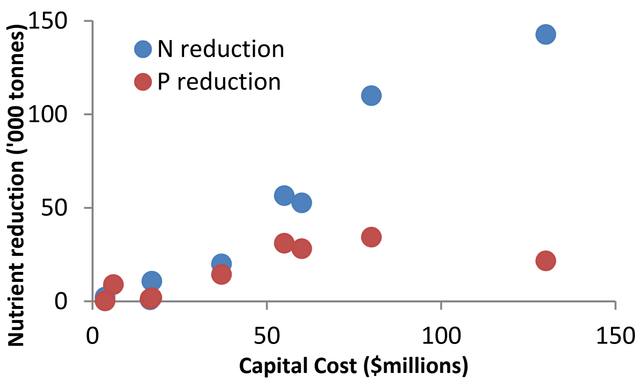
14/15 load (EP)	Year of upgrade	Licence limit	CAPEX/EP ($)	OPEX/EP ($-14/15)	OPEX increase*
840	2006	5N/1P	11,905	714.29	-
1250	2012	5N/1P	-	256.00	-
2100	2002	3N/0.1P	2,857	285.71	-
3600	2013	5N/1P	11,111	166.00	-
4000	2014	5N/1P	-	247.28	-
4100	2011	5N/1P	537	139.00	-
4500	2015	5N/2P	3,667	86.44	2.1
10000	2016	5N/2P	1,700	50.00	-
10000	2015	5N/1P	-	68.18	-
16200	2015	5N/1P	-	91.85	-
18000	2009	5N/1P	333	17.17	2.3
24800	2009	5N/1P	1,492	17.14	2.0
58800	2009	5N/1P	935	9.47	1.8
65000	2011	5N/1P	2,000	53.85	-
68000	2009	5N/1P	882	10.62	1.7
105000	2008	5N/1P	762	52.38	-

* multiplier for 2014/15 OPEX over the pre-upgrade OPEX. Note this incorporates a period of optimisation in most of the plants.

The data included capital costs to achieve nutrient reductions through STP upgrades, replacement, and new plants of a range of sizes, and varied in total cost from $2.2 to $130 million. These capital figures are not directly comparable because they were collected over several years and represent a range of technological solutions at plants with a range of projected maximum loads. The total capital expenditure at 15 of the STPs reported was $500 million in the last ten years.

The relative cost for reduction of nutrients was consistent (Figure 2) showing CAPEX is correlated with the reduction in total nitrogen. In contrast, total phosphorus reductions did not maintain a linear relationship in larger plants probably because plants are designed specifically to decrease the more difficult-to-manage nitrogen (as phosphorus can be controlled through chemical dosing if required).

Figure 2. Relationship between cost of STPs and the reduction in the annual load of nitrogen and phosphorus.



These data were analysed further to explore the operational and capital costs of tertiary treatment.

Operating costs of GBR STPs

Relative operating costs (OPEX) for STPs scale with size so that larger plants are less expensive per unit load which is often measures in 'equivalent persons' (EP) to operate.[19] Queensland Government Guidelines indicate that OPEX decreases regularly with increasing size (Figure 3).

When compared with recent data, this relationship for STPs below 10,000 EP is either conservative or based on less stringent treatment standards than are expected today. For example, analysis by Queensland Urban Utilities comparing 27 STPs across a range of treatment standards showed that OPEX/EP had a non-linear relationship with EP and was 1.5 to 8 times higher for 500 EP plants than for plants with 10,000 EP or more.

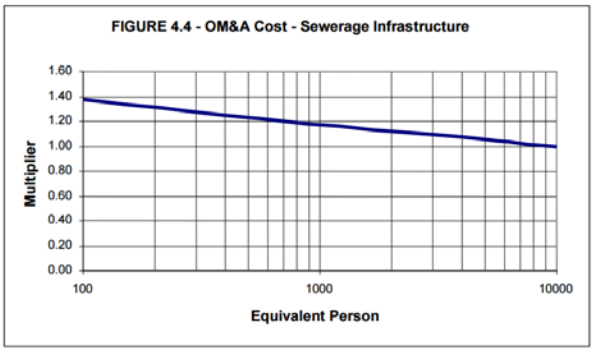


Figure 3. Relationship of operational costs to STP size (Source: DEWS, 2014[20]).

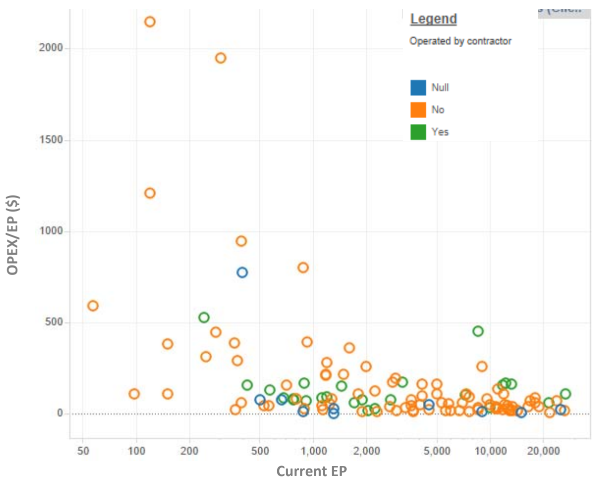


Figure 4. Relationship between operational cost per EP and STP load (EP). Source: WSAA unpublished data (2015).

A similar comparison using unpublished national data from the Water Services Association of Australia (WSAA) closely reflects the relationship demonstrated by QUU (Figure 4). The relationship of OPEX/EP to EP is non-linear although there is significant variation for small plants. In general, small STPs have OPEX/EP that is larger than that for large STPs and the multiplier is much greater for small plants than that predicted in the government guidelines represented in Figure 3.

[19] See e.g. review by Lequerica, M. and McInnes, R. 2016 Evaluation of upgrade effects in four sewage treatment plants in NSW. Analysing the consequences of qualitative and quantitative upgrades in sewage treatment. Water e-journal 1(2), 2016.

[20] Planning Guidelines for Water Supply and Sewerage (2014).

This same trend was also apparent in the recent data from STPs in GBR catchments which maps well to the national and QUU figures (Figure 5). Although the projected trend-line fits the data reasonably well (R^2 = 0.677) further data are needed to fully characterise this relationship. This relationship uses the equivalent population (EP) treated at the STP, a similar and slightly better fit (R^2 = 0.757) is obtained using annual volume of sewage collected as a normaliser rather than EP (Figure 6). The data also closely matches those obtained from numerous national STPs (Figure 7) suggesting that the relationship is representative. It is clear that operational costs per ML increase as a power function of decreasing STP size.

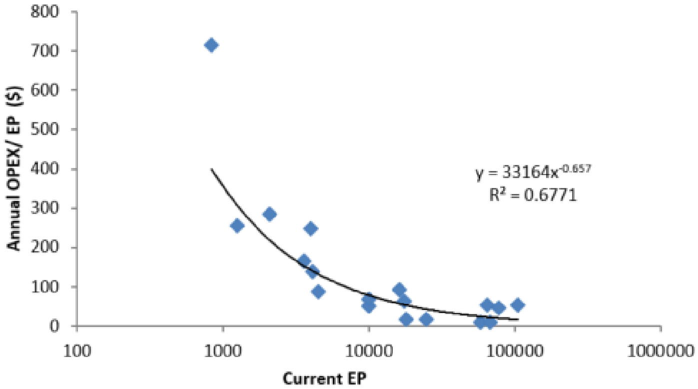


Figure 5. Relationship between operational cost per EP and sewage load (EP) for STPs in GBR catchments.

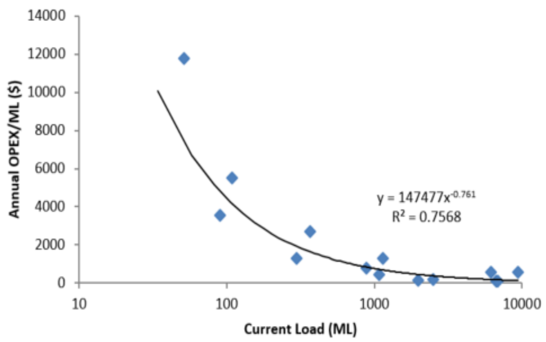


Figure 6. Relationship between operational cost per ML and sewage volume for the STPs in GBR catchments also represented in Figure 3.

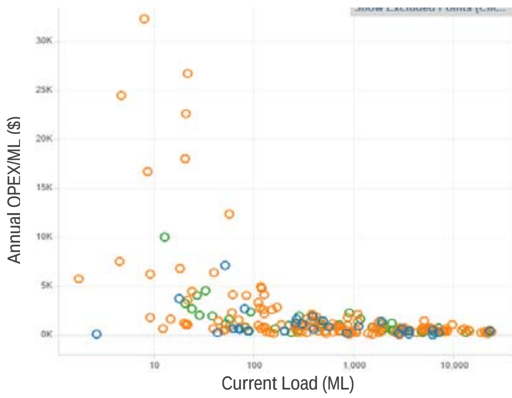


Figure 7. Relationship between operational cost per ML and sewage volume. Source: WSAA (unpublished data, 2015).

This data does not compare OPEX before and after an upgrade to tertiary treatment which is an important factor to consider as any additional costs must be borne by the local community. The OPEX displayed in the national data (Figure 7) includes both secondary and tertiary plants but these are separately displayed in Figure 8 further demonstrating higher OPEX at tertiary plants than other plants of the same size. Detailed comparison is difficult between STPs because of yearly variation in costs, optimisation processes over time and the complexities of third-party operation and commissioning (e.g. Design-Build-Operate schemes). However, relative costs immediately before and after upgrading to tertiary treatment were provided for five STPs. In every case, OPEX more than doubled following the upgrade. Although this ratio sometimes decreased in subsequent years (e.g. following optimisation), the operational costs were always around twice as high (see Table 1).

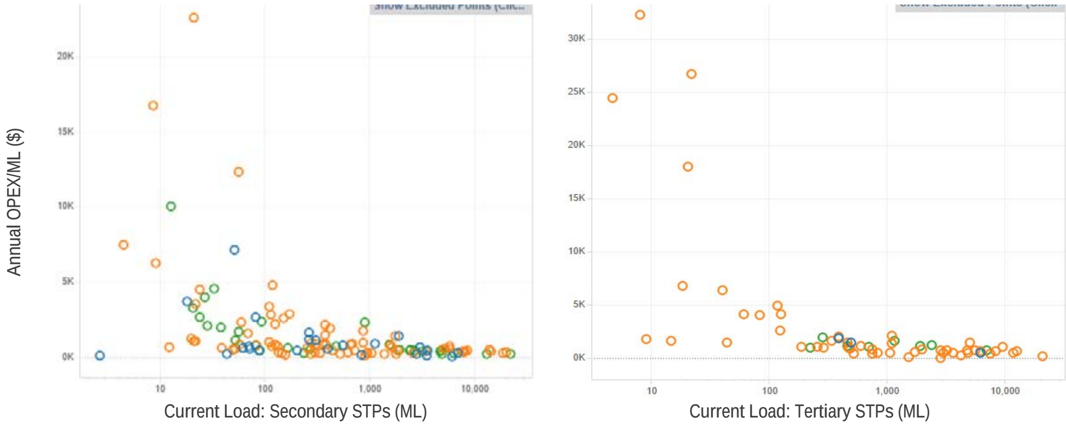


Figure 8. Relationship between operational cost per ML and sewage volume in secondary (left) and tertiary (right) STPs (note greater scale for tertiary OPEX). Source: WSAA (unpub, 2015).

The causes of increased OPEX are complex. For four STPs, a break-down of OPEX unit costs were provided showing that some chemical costs actually decreased following an upgrade. In contrast, energy costs more than doubled in all plants and even after optimisation in subsequent years energy costs never fell below 1.6 times the original value. QUU analysis showed similar increases in energy costs for advanced treatment compared with lower treatment levels across similar sized STPs. Specialised professional and operator skill sets are also required to maintain tertiary STPs (especially for the increasingly common membrane bioreactor plants). This can have a large impact on OPEX depending on whether operations are outsourced and on the operational and maintenance policies of the organisations. Costs to manage biosolids can also form a large proportion of OPEX and vary dramatically depending on moisture content (i.e. process type) and distance to the disposal or reuse site. Increased OPEX at tertiary plants is a result of a combination of these drivers which can vary dramatically from plant to plant.

National, QUU and GBR data all confirm that there are diminishing returns in terms of OPEX for small STPs. This is primarily because of economies of scale and the nature of the technologies available to treat small volumes of sewage and achieve tertiary standards. This means that OPEX/EP increases rapidly with decreasing STP size despite the smaller volumes of sewage treated. There was good agreement among the three data sets indicating that the data from GBR STPs is representative of the broader population of STPs in Queensland and Australia. Costs for electricity, biosolids treatment and appropriate skills are key drivers and are likely to increase over the next decade thus further increasing OPEX which will be particularly expensive for small communities. Increased energy use is of particular concern in the context of reef protection given that climate change is the primary threat to the health of the GBR.[21] Regardless of the drivers, ongoing operational expenses must be factored into any analysis of total return on investment for small STPs.

[21] See Note 1 and Note 2.

Capital Costs

Relative capital costs (CAPEX) also increase with decreasing STP size. Queensland Guidelines[22] indicate that CAPEX decreases non-linearly with increasing STP capacity (Figure 9). This trend was also reflected in the data collected from STPs in the GBR catchments (Figure 10). As with the OPEX data, CAPEX appears to rise more rapidly with decreasing STP size than was predicted in the guidelines. However, this limited data must be interpreted cautiously because of the different types of treatment technology used, the different 'design EP' for each of the plants, the mixture of new and upgraded plants and the time period over which the infrastructure was built (which included both intense and light periods of state-wide growth and thus relative design and construction costs). There will be significant variation and the data has not been normalised to take account of inflation over time.

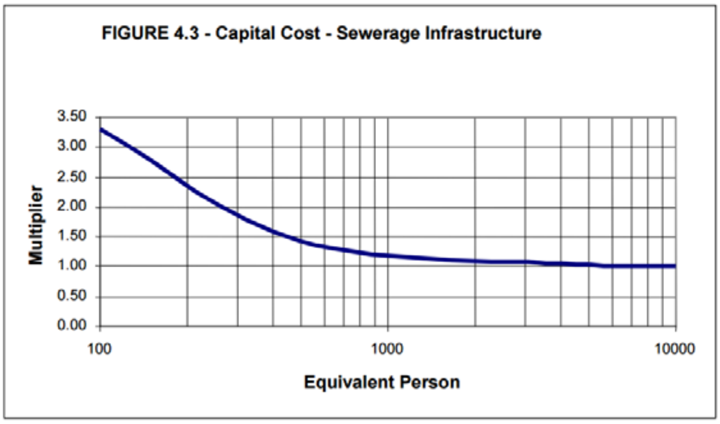


Figure 9. Relationship of capital cost/EP to STP size (EP). Source DEWS (2014).

This variability is reflected in the weak relationship of the trendline in Figure 10 (R^2 = 0.497). Further data are needed to better understand capital costs of different types of 'tertiary' STPs but it is clear from the available data that capital costs are relatively large at small STPs, likely reflecting economies of scale for large plants and indivisibilities of factor inputs at small scales.

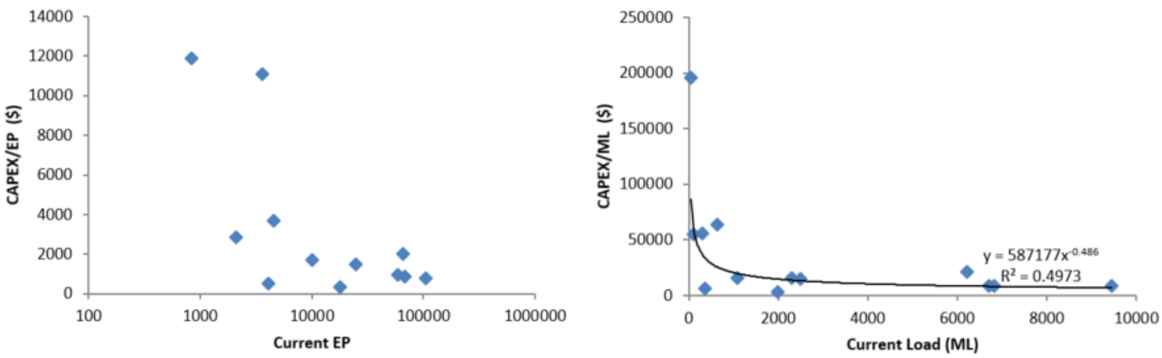


Figure 10. Relationship of capital costs with Current EP and with ML treated in STPs from GBR catchments that were recently upgraded to tertiary treatment.

[22] Note 19.

6. Estimated cost of upgrading all STPs in GBR catchments

The costs for design, construction and commissioning of STPs varies based on many factors but an approximate order of magnitude cost to upgrade current STPs to a ‘tertiary’ standard can be estimated using the costs of recent upgrades. Similarly, operational costs for new plants can be projected based on the costs of running existing plants of a similar size. A formula using the preliminary relationships of OPEX and CAPEX to volume treated (see Figures 6 and 10) provided an initial estimate for the 96 STPs that are not already at a ‘tertiary’ level of treatment (Table 2). These STPs represent just over a third (34.2%) of the total volume of sewage collected annually in GBR catchments.

Table 2. Total capital and ongoing annual operational costs projected to upgrade current non-tertiary STPs within 50 km of the coast in GBR catchments based on costs of for existing STPs over the past 10 years.

Non-‘tertiary’ STPs in GBR catchments*	Number of STPs	Annual sewage collected (ML)	% of GBR total	Est Total CAPEX ($mill)	Est Annual OPEX ($mill)
All < 50 km from coast	61	34,937	34.2%	719	33
All > 50 km from coast	35	7,362	7.2%	279	17
Total	**96**	**42,298**	**41.4%**	**998**	**50**

*50 km straight-line distance was chosen for comparisons for the reasons described in Appendix A.

This heuristic approach could be improved by matching similar technologies, climates, operational standards and allowing for variation, particularly in capital costs over time. It would also be better to compare nitrogen and phosphorus loads directly rather than volumes (which vary dramatically between communities depending on inflow and infiltration into the sewer network). For the purposes of this initial analysis, the estimated capital cost to upgrade all non-tertiary plants that are within 50 km of the coast would be in the order of $719 million. The estimated operational costs for these upgraded STPs would be in the order of $33 million annually. The total OPEX is an absolute figure rather than an additional cost to that for existing treatment. Further data specific to STP OPEX (i.e. rather than that for the entire sewerage network and treatment OPEX which is all that is currently reported) is needed to confirm the actual increase but it is likely to be around twice the current total for non-tertiary operations and maintenance.

7. Discussion

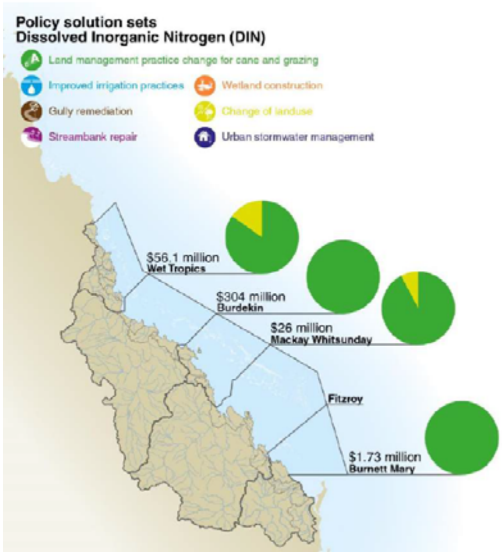
Total costs to upgrade the remaining STPs within 50 km of the GBR coastline would exceed $719 million in CAPEX and require ongoing annual OPEX in the order of $33 million. These initial estimates could be impacted by many factors (e.g. the contract delivery method for design, construction and operation) but are indicative of high costs to achieve ‘tertiary’ standards in small plants. This is particularly telling for small communities where the relative costs are much higher and there is little capacity to absorb ongoing operational costs.

The actual reduction in nitrogen loads from these upgrades would be relatively small. The reduction of nitrogen from the nine new and upgraded reef STPs for which data was provided in this study totalled more than 400 tonnes per year (Figure 2) which was a 77% improvement. In 2013 it was calculated that all STP improvements up to that time had removed “an estimated 834 tonnes of nutrients annually (approximately 80 per cent of the original total nutrient load from this source) that would have otherwise entered the World Heritage Area".[23] As a comparison, "the total modelled TN baseline load exported to the GBR is 36,699 t/yr".[24] The remaining coastal STPs collect around one third of the total sewage volume of all GBR STPs which together represent only 4% of the total nitrogen load from all catchment sources. Even conservatively assuming that the non-tertiary STPs contribute half of the total nutrient load from all STPs and could be upgraded to achieve an 80% reduction, this would represent only a 1.6% reduction of the total catchment load.

Despite being a small proportion of the total load, nutrient reductions from past STP improvements represent significant gains, particularly for local habitats near the discharges. However, they do come at a high cost. The capital expenditure between 2000 and 2013 alone was estimated at between $600 and 700 million[25] and this did not include all STPs nor factor in increases in OPEX. The estimate in this paper indicates that the remaining secondary STPs within 50 km of the coast require a similar level of investment even though they treat around one third the volume.

More important than total nitrogen loads are the anthropogenic loads if dissolved inorganic nitrogen (DIN) reaching the GBR. DIN is the component of nitrogen that is most damaging to the reef and is the subject of targets set in the Reef 2050 Plan.[27] The costs to achieve the DIN target were modelled in a 2016 study commissioned by the Queensland Government which determined an optimal combination of solutions (excluded STP improvements as they were considered minimal, see Figure 11). The modelling showed the target could be achieved with a combination of solutions addressing high-risk diffuse loads at a total cost of $390.6 million.[28] This estimate included CAPEX, OPEX and maintenance meaning the cost to reach the target by addressing diffuse loads is well less than half the total cost to upgrade non-tertiary STPs, which would reduce only a small fraction of anthropogenic DIN loads.

Figure 11: Estimated costs to reduce the nitrogen loads to meet the Reef 2050 Plan targets. Source: Alluvium, 2016[26].



The high relative costs and the small relative contribution of the remaining STPs mean that tertiary upgrades are difficult to justify in terms of impacts on the reef itself and better return on investment would be achieved by focussing on diffuse catchment inputs. Indeed, the nitrogen targets of the Reef 2050 Plan can be achieved at half the cost of the STP upgrades meaning that STP upgrades should be assessed based on a broader social,

[23] Reef 2050 Long-Term Sustainability Plan, 2013. See note 7 at p. 24.
[24] Waters *et al.*, 2014 at p. 68 and see Appendix 1.
[25] See note 6
[26] Alluvium (2016). Costs of achieving the water quality targets for the Great Barrier Reef by Alluvium Consulting Australia for Department of Environment and Heritage Protection, Brisbane. July 2016, p. 44.
[27] Ibid at pp 65-67.
[28] Ibid at p. 61.

economic and ecological outcomes and arbitrary adherence to a 'tertiary' standard of treatment no longer provides optimal outcomes for the reef. This is particularly pertinent if climate impacts are considered in addition to water quality because the significant additional energy demands of tertiary treatment add to climate change risks. Offset approaches in particular may provide better outcomes for reef health by focussing on diffuse sources while also considering energy efficiency. In general, tertiary upgrades to protect reef health become less appropriate with decreasing STP size and increasing distance from the coast.

In contrast, tertiary treatment standards are justified to protect the values of the local environment near the point of a discharge, particularly during dry periods when they may comprise a large proportion of the flow in small streams. Indeed, zero-discharge is the ideal though seldom possible aim because of technical and financial limitations. If discharge is required, 'tertiary' standards are desirable because they represent best practice for the reduction of nitrogen and phosphorous. However, this standard itself is not economically feasible for some (particularly small) STPs. Recycling and land application are common alternatives but seldom eliminate all discharges and can also be costly. Another useful approach could be to modify licence requirements to encourage best practice at a reduced standard, for example by excluding from licence limits the fraction of nitrogen that is resistant to decay and which STPs cannot remove. Licence requirements that have a reduced focus on nitrogen are less costly to maintain and can still protect the receiving environment so long as biological oxygen demand and the unionised fraction of ammonia (which have acute impacts) have sensible discharge limits.[29] The point is, although tertiary treatment can be justified on a local scale, greater flexibility may permit optimisation of social, economic and ecological outcomes to better meet local environmental values.

A focus on STP improvements through upgrades to 'tertiary' treatment has reduced nutrient inputs to the GBR over recent decades and has become a default expectation. There is a need to maintain and build on the hard-won improvements that were gained through expensive public investment in the past and also to maintain a focus on protection of the local environment near discharge points. However, the return on investment for tertiary treatment diminishes rapidly with decreasing STP size and it is increasingly difficult to justify the expense of achieving this standard on the grounds of protection of the GBR. Most importantly, investments in STPs and other point sources have served only to slow the decline in GBR health. To halt and reverse decline, a different approach is needed and the focus needs to be redirected to the greatest risks, namely diffuse pollution and climate impacts. Addressing such issues will likely require large public investment and necessitates an immediate reassessment of the opportunity cost of expensive STP upgrades.

[29] BOD limits vary but typically ammonia has a 50^{th} percentile limit of 1 mg/L and 2 or 3 mg/L as a maximum.

8. Appendix A: Modelling catchment contributions to the GBR.

In 2014, a series of papers was published based on modelling undertaken by the Queensland Government on the catchment inputs to the Great Barrier Reef (Box A1). The modelling considered both 'urban' and 'point sources' with the latter being estimated using data on discharges from 18 large STPs in 2010. Table A1 shows the combined contribution of these sources modelled for the whole GBR catchment.

Box A1. Reports on modelling by the Queensland Government on loads from GBR catchments.
Waters, DK, Carroll, C, Ellis, R, Hateley, L, McCloskey, GL, Packett, R, Dougall, C, Fentie, B 2014, Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Whole of GBR, Technical Report, Volume 1, Queensland Department of Natural Resources and Mines, Toowoomba. McCloskey, GL, Ellis, R, Waters, DK, Carroll, C 2014, Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Cape York NRM Region, Technical Report, Volume 2, Queensland Department of Natural Resources and Mines, Cairns. Hateley, L, Ellis, R, Shaw, M, Waters, D, Carroll, C 2014, Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Wet Tropics NRM region, Technical Report, Volume 3, Queensland Department of Natural Resources and Mines, Cairns. Dougall, C, Ellis, R, Shaw, M, Waters, D, Carroll, C 2014, Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Burdekin NRM region, Technical Report, Volume 4, Queensland Department of Natural Resources and Mines, Rockhampton. Packett, R, Dougall, C, Ellis, R, Waters, D, Carroll, C 2014, Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Mackay Whitsunday NRM region, Technical Report, Volume 5, Queensland Department of Natural Resources and Mines, Rockhampton. Dougall, C, McCloskey, GL, Ellis, R, Shaw, M, Waters, D, Carroll, C 2014, Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Fitzroy NRM region, Technical Report, Volume 6, Queensland Department of Natural Resources and Mines, Rockhampton. Fentie, B, Ellis, R, Waters, D, Carroll, C 2014, Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Burnett Mary NRM region, Technical Report, Volume 7, Queensland Department of Natural Resources and Mines, Brisbane, Queensland (ISBN: 978-0-7345-0445-6).

It is not possible to distinguish the STP load from other urban sources in most of the reports but where data was available, STPs contributed less than half of the total urban load of nutrients and none of the sediments[30]. This means that contributions from the 18 large STPs were likely well below 4% for both nitrogen and phosphorus.

Table A1. Total modelled nitrogen, phosphorus and suspended solid loads from urban and all sources each year.[31] The urban contribution includes 18 large STPs and other urban sources.

	Urban Load (kt/yr)	Total load (kt/yr)	% Urban contribution
Total nitrogen	1,393	36,702	3.80%
Total phosphorus	237	6,295	3.76%
Total suspended solids	79	8,545	0.92%

[30] e.g. Hateley *et al.* (2014) – see Box A1.
[31] Waters *et al.* (2014) – see Box A1.

However, the modelling reports considered only "STPs with an arbitrary criterion of a minimum 10,000 equivalent person's (EP) capacity"[33] which included 18 of the 129 STPs located in GBR catchments (see Appendix 2). It is not possible to determine the contribution of the smaller STPs with available data but annual volume collected can provide a rough approximation. Using volume collected tends to exaggerate the volumes of nutrient contributed because it is strongly affected by rainfall meaning that annual totals are increased by rain although nutrient volumes remain constant. The period over which data was collected included some of the wettest years in the last decades and dilution would be considerable in some small towns particularly in tropical areas. Nevertheless, Figure A1 shows that most STPs collect volumes that are more than 10 times smaller than the STPs included in the modelling.

Box A2. Available data on annual volume of sewage collected at STPs in GBR catchments between 2008/09 to 2014/15 was extracted from SWIM[32] and mean annual loads over this period were calculated. For 15 small STPs no data was available and annual flows were estimated from QGSO population figures based on flows in similar sized councils.

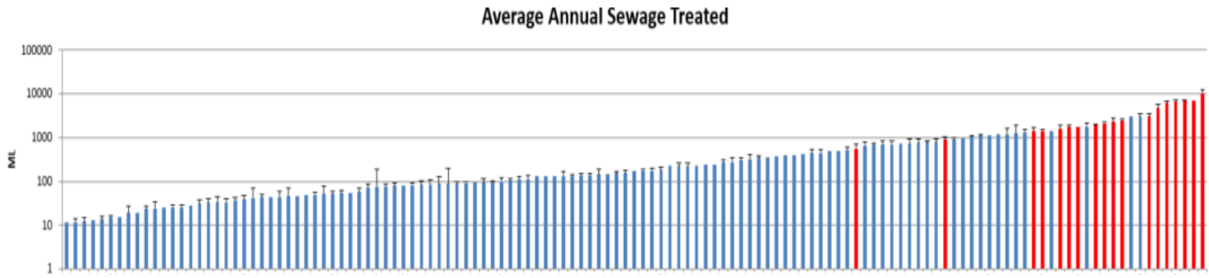


Figure A1. Average annual volume treated at STPs in GBR catchments indicating plants included in the reef modelling studies (red). Error bars are one standard deviation of the mean where 4 or more data points were reported between 2009 and 2015 (note logarithmic scale).

In fact, STPs that were not included in the reef modelling treat just over a third of the total volume of sewage collected in GBR catchments (Figure A2). Some are too distant from the coast to affect the reef and although it is not possible to estimate true contributions without modelling for the purposes of this report an arbitrary distance of 50 km from the coast[34] was selected encompassing 72 'unmodelled' STPs. This left 39 STPs that are greater than 50 km from the coast. In fact, all 39 were greater than 60 km and most (22) were between 100-300 km distant (Table A2). The 18 modelled STPs were all within 44 km of the coastline.

Table A2. Number of STPs in 2014 modelling studies at two distances from the coast.

Distance to coast	Number of STPs (number that are 'tertiary')		
	modelled	unmodelled	Tot.
< 50 km	18 (10)	72 (19)	90 (29)
> 50 km	0	39 (4)	39 (4)
All	18 (10)	111 (21)	129 (33)

[32] SWIM is the Statewide Water Information Management system which assists Queensland service providers in KPI reporting and data management.

[33] See individual catchment reports (Volumes 2-7) in Box A1.

[34] The distances quoted are straight-line distance meaning the actual distance along a waterway would be considerably larger.

The total of the average annual volumes collected at these 72 STPs between 2009 and 2015 was 29,400 ML which was just under half the volume collected at the 18 modelled STPs during the same period. Around three quarters (74.0%) of the modelled volume is treated to a tertiary level compared to 37.2% at the unmodeled STPs which will thus discharge a relatively higher concentration of nutrients. However, the majority of these STPs recycle or irrigate at least a component of their treated wastewater (see Table C1) meaning the entire volume treated is not released thus reducing the mass of nutrients reaching waterways (and the GBR).

This reduction through recycling and the fact that the volume of sewage collected exaggerates the actual mass of nutrients (see above), means the total mass of actual nutrients collected at unmodeled STPs within 50 km of the coast are likely less than half that collected at the 18 modelled STPs. The modelled STPs contribute only one component of the modelled 'urban load' and as little as half of the estimated 4% from urban inputs. Therefore, the total contribution of all STPs within 50 km of the reef is likely to be between 3% and 5% of the total catchment inputs thus confirming the figures reported in previous studies[35].

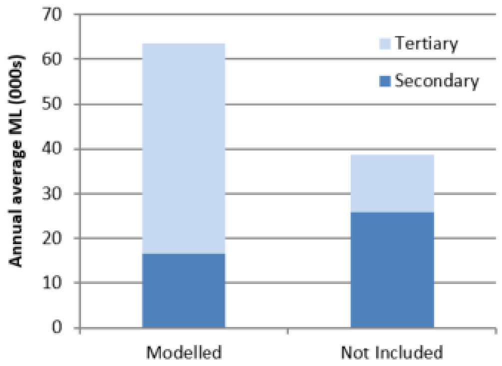


Figure A2. Total of average annual volumes of sewage collected annually at 18 STPs modelled in 2014 compared with those not modelled.

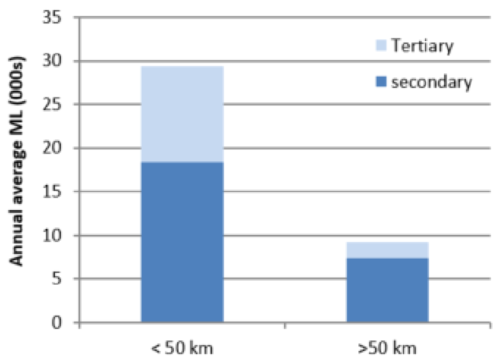


Figure A3. Total of average volumes of sewage collected annually at 'unmodeled' STPs, comparing 72 STPs within 50 km of the coast and 39 that are > 50 km distant.

[35] See note 3 and note 2.

9. Appendix B: Policy and regulation governing public STPs in GBR catchments.

In a comprehensive review of the management of water quality impacts of the reef, Brodie and Waterhouse[36] noted coastal (i.e. not island) STPs were upgraded in the first decade of the 2000s driven by the State Coastal Plan, often with Commonwealth assistance through Coast and Clean Seas funding. The original State Coastal Management Plan (2001) required that "sewage treatment works are designed and managed to enable appropriate nutrient removal within the following periods: (a) for discharge of effluent from islands into coastal waters — by 2005; and (b) for discharge of effluent from the mainland into coastal waters — by 2010."[37]

GBRMPA's Sewage Discharge Policy[38] still requires specific treatment levels[39] for discharge directly into the Marine Park (e.g. island and resorts) but does not have jurisdiction over most public STPs because they are not located within the Marine Park. Brodie and Waterhouse (2012)[40] noted "close cooperation has been required with the Queensland Government to gather further support to improve coastal discharges through the State Coastal Management Plan".

The State Coastal Management Plan under which change was initiated was in operation between February 2002 and February 2012, then replaced by the Queensland Coastal Plan and subsequently the Coastal Protection State Planning Regulatory Provision in October 2012. The current policy is the Coastal Management Plan[41] which recognises sewage as a potential contributor of pollution (p.3) and describes the process under which discharges must be managed under the State Planning Policy and the State Development Assessment Provisions. The Plan also notes: "the Environmental Protection (Water) Policy 2009 and the Reef Water Quality Protection Plan (Reef Plan) both play a role in addressing water pollution in coastal areas. Potentially polluting industries are regulated through licensing waste outputs into waterways" (p.4).

In summary, these documents include the following references to discharges from STPs:

- *State Planning Policy*: indicates maximising "recovery and reuse and avoiding or minimising impacts of stormwater and wastewater discharge to receiving water" [42],
- *State Development Assessment Provisions SDAP*: requires discharges to be "(1) treated to the quality of the receiving waters prior to discharge, or (2) reclaimed or re-used such that there is no export of pollutants to receiving waters" [43]

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[36] Brodie, J. and Waterhouse, J. Estuarine, Coastal and Shelf Science 104-105 (2012), p 1- 22 and p. 16.
[37] Queensland State Coastal Management Plan 2001, s 2.4.2, p. 33.
[38] Sewage Discharges from Marine Outfalls to the Great Barrier Reef Marine Park, 2005
[39] See note 10.
[40] See note 5.
[41] Coastal Management Plan 2013
[42] State Planning Policy 2014, p.17
[43] State Development Assessment Provisions Version 1.7, effective 23 November 2015 (see Module 4, Table 4.1.2, AO6.2).

- *Reef Plan* : recognises STP discharges are managed in environmental legislation and "remains predominantly focused on working with landholders to address diffuse sources of pollution from broad-scale land use" (p.11).
- *Environmental Protection Regulations*: define "sewage and sewage residues, whether treated or untreated" as prescribed water contaminants[44] and sewage (wastewater) treatment as an Environmentally Relevant Activity.[45]
- *Environmental Protection (Water) Policy*: defines 'sewerage service' and sewage (wastewater) treatment plant.[46]
- *Model Operating Conditions*: provide guidance on what aspects of a STP will be regulated (without setting default discharge limits) and require receiving environment monitoring programs (REMPS).[47]

Read together, this framework requires that any new or material change to an existing STP is rigorously assessed with respect to the quality of water discharged and the values of the receiving environment. There appears to be no "tertiary equivalent concentration" mandated which means the requirements may be more or less stringent than the 5N and 1P limits indicated by the GBRMPA policy, depending on the 'Water Quality Objectives' of the receiving waters. In practice, most recently new or upgraded STPs in GBR catchments have been required to meet 5N/1P, long-term median discharge requirements. In short, there is widespread expectation that STPs in GBR catchments will achieve similar 'tertiary equivalent' treatment standards.

[44] Environmental Protection Regulation 2008, Schedule 9, s17.
[45] s 147 and see Schedule 2, Part 13, s 63.
[46] Environmental Protection (Water) Policy, Schedule 2.
[47] Model Operating Conditions. ERA63 – Sewage Treatment.

10. Appendix C: Identification of public STPs in GBR catchments

For this review, lists of publicly owned STPs were sought through review of online information and enquiries to the following agencies:

- regional and central offices of the Department of Environment and Heritage Protection (EHP),
- the Office of the Great Barrier Reef (EHP),
- the Commonwealth (Department of Environment and Spatial Layers database), and
- the Department of Science, Information Technology and Innovation.

While it was clear that there is no currently coordinated list, reef policy documents and some academic articles refer to "a preliminary desktop review of the coastal sewage facilities adjacent to the GBRWHA, including documentation of 42 major facilities" referenced by Waterhouse and Johnson in 2002.[48] This study mapped, but did not list the STPs. Other papers have reported different numbers and part of the problem is defining the scope of "discharges to GBR catchments". To determine the scope of possibly affected STPs, four sources were accessed:

1. A list of STPs provided by the Office of the Great Barrier Reef from a recent report being compiled on 'major STPs' (35 STPs),
2. A list of sites that report to the DSITI 'WaTERS' database, discharge to coastal waters and undertake mandatory environmental monitoring (42 STPs),
3. The national spatial dataset of wastewater treatment plants[49] (106 STPs),
4. Modelling undertaken by Reef Plan, 'Paddock to Reef Assessments'[50] which used "an arbitrary criterion of a minimum 10,000 equivalent person's (EP) capacity" (18 STPs), and
5. ***qldwater*** databases which include all Queensland sewage treatment sites (~300 sites).

The location of all STPs was compared spatially with publicly available GIS layers representing catchments discharging to the GBR. Table C1 lists the 129 public sewage treatment sites (STPs and simple pond/lagoon systems) in catchments that drain eastward from the north of Fraser Island to the Torres Strait. The size, extent of discharge, treatment process and distance from the coast varies significantly among the listed sites.

[48] See note 5. The authors included only near-shore STPs between Bundaberg and Cairns.
[49] Available at https://data.gov.au/dataset/national-wastewater-treatment-plants-database
[50] See Appendix A.

Table C1. List of Sewage treatment sites within catchments draining to the Great Barrier Reef.

Council	Sewage treatment sites within GBR catchments	'Tertiary'*?	Average annual volume	Modelled in 2014?	Recycling?
Banana	Biloela STP		500-2000 ML		✓
Banana	Moura STP	✓	100-500 ML		✓
Banana	Taroom STP		50-100 ML		✓
Banana	Theodore STP		50-100 ML		✓
Bundaberg	Bargara Wastewater Treatment Plant		500-2000 ML		✓
Bundaberg	Bundaberg East STP		>2000 ML	✓	✓
Bundaberg	Bundaberg North STP		100-500 ML		
Bundaberg	Childers STP		100-500 ML		✓
Bundaberg	Coral Cove STP		50-100 ML		✓
Bundaberg	Gin Gin STP		100-500 ML		✓
Bundaberg	Millbank STP		500-2000 ML		✓
Bundaberg	Thabeban STP	✓	100-500 ML		✓
Bundaberg	Woodgate STP		50-100 ML		✓
Burdekin	Ayr/Brandon STP		500-2000 ML	✓	
Burdekin	Home Hill STP		100-500 ML		
Cairns	Babinda STP		500-2000 ML		
Cairns	Cairns North STP	✓	>2000 ML	✓	✓
Cairns	Cairns South STP	✓	>2000 ML	✓	✓
Cairns	Edmonton Sewage Treatment	✓	500-2000 ML	✓	
Cairns	Gordonvale STP	✓	500-2000 ML		
Cairns	Marlin STP	✓	>2000 ML	✓	✓
Cassowary	Innisfail STP	✓	>2000 ML		
Cassowary	Tully STP	✓	500-2000 ML		
Central Highlands	Black Gully (Emerald) STP		100-500 ML		✓
Central Highlands	Blackwater STP		500-2000 ML		✓
Central Highlands	Capella STP		50-100 ML		✓
Central Highlands	Park Avenue (Emerald) STP		500-2000 ML		✓
Central Highlands	Rolleston STP		< 50 ML		
Central Highlands	Springsure STP		50-100 ML		
Central Highlands	Tieri STP		100-500 ML		✓
Charters Towers	Charters Towers STP		500-2000 ML		✓
Charters Towers	Greenvale STP		< 50 ML		
Charters Towers	Ravenswood STP		< 50 ML		
Cherbourg	Cherbourg STP		100-500 ML		
Cook	Coen STP		< 50 ML		✓
Cook	Cooktown STP	✓	100-500 ML		✓
Douglas	Mossman STP		100-500 ML		
Douglas	Port Douglas Sewage Treatment	✓	500-2000 ML		✓
Gladstone RC	Agnes/1770 Sewage Treatment		100-500 ML		✓
Gladstone RC	Boyne Island STP		100-500 ML		✓
Gladstone RC	Calliope STP		100-500 ML		✓
Gladstone RC	Gladstone (Calliope River) STP		>2000 ML		✓
Gladstone RC	South Trees STP		50-100 ML		
Gladstone RC	Tannum Sands STP		100-500 ML		✓

Gympie	Goomeri STP		50-100 ML		✓
Gympie	Gympie STP	✓	500-2000 ML	✓	✓
Gympie	Imbil STP	✓	< 50 ML		✓
Gympie	Kilkivan Sewage Treatment		< 50 ML		✓
Hinchinbrook	Ingham STP		500-2000 ML		✓
Hinchinbrook	Lucinda STP		< 50 ML		✓
Hope Vale	Hope Vale Sewage Treatment		100-500 ML		
Isaac	Clermont Sewage Treatment		100-500 ML		✓
Isaac	Dysart STP		100-500 ML		✓
Isaac	Glenden STP		100-500 ML		✓
Isaac	Middlemount STP		100-500 ML		✓
Isaac	Moranbah STP	✓	500-2000 ML		✓
Isaac	Nebo STP		50-100 ML		✓
Livingstone	Emu Park STP	✓	100-500 ML		✓
Livingstone	Yeppoon STP	✓	500-2000 ML	✓	✓
Lockhart River	Lockhart River Sewage Treatment		< 50 ML		
Mackay	Mackay Nth (Bucasia) STP	✓	500-2000 ML	✓	✓
Mackay	Mackay Sth (Baker's Creek) STP	✓	>2000 ML	✓	✓
Mackay	Mirani Water Recycling Facility	✓	100-500 ML		✓
Mackay	Sarina STP	✓	100-500 ML		✓
Maranoa	Injune Sewage Treatment		50-100 ML		
Mareeba	Kuranda STP		50-100 ML		
Mareeba	Mareeba STP		500-2000 ML		
North Burnett	Biggenden STP		< 50 ML		✓
North Burnett	Eidsvold STP		50-100 ML		
North Burnett	Gayndah STP		100-500 ML		✓
North Burnett	Monto STP		50-100 ML		✓
North Burnett	Mundubbera Sewage Treatment		100-500 ML		✓
NPA	Bamaga Sewage Treatment		100-500 ML		
NPA	Injinoo Sewage Treatment		< 50 ML		
NPA	New Mapoon Sewage Treatment		< 50 ML		
Palm Island	Palm Island STP		500-2000 ML		
Rockhampton	Gracemere STP		500-2000 ML		✓
Rockhampton	Mt Morgan STP		50-100 ML		✓
Rockhampton	Rockhampton North STP		>2000 ML	✓	✓
Rockhampton	Rockhampton South STP		>2000 ML	✓	
Rockhampton	Rockhampton West STP		500-2000 ML	✓	
South Burnett	Blackbutt & Benarkin		< 50 ML		✓
South Burnett	Kingaroy STP	✓	500-2000 ML		✓
South Burnett	Murgon STP		100-500 ML		✓
South Burnett	Nanago STP		100-500 ML		✓
South Burnett	Proston STP		< 50 ML		✓
South Burnett	Wondai STP		100-500 ML		✓
Tablelands	Atherton STP	✓	500-2000 ML		✓
Tablelands	Malanda STP	✓	50-100 ML		
Tablelands	Ravenshoe STP		100-500 ML		
Tablelands	Tinaroo STP		< 50 ML		✓

Tablelands	Yungaburra STP	✓	50-100 ML		✓
Torres	Thursday Island STP		100-500 ML		
Townsville	Condon STP		500-2000 ML	✓	✓
Townsville	Horseshoe Bay STP	✓	50-100 ML		✓
Townsville	Magnetic Island (Picnic Bay) STP	✓	100-500 ML		✓
Townsville	Mt St John STP	✓	>2000 ML	✓	✓
Townsville	Toomulla STP		< 50 ML		
Townsville	Townsville (Cleveland Bay) STP	✓	>2000 ML	✓	✓
TSIRC	Badu STP		100-500 ML		
TSIRC	Boigu STP		< 50 ML		
TSIRC	Erub STP		< 50 ML		
TSIRC	Iama STP		< 50 ML		
TSIRC	Kubin STP		< 50 ML		
TSIRC	Mabuiag STP		< 50 ML		
TSIRC	Masig STP		< 50 ML		
TSIRC	Mer STP		< 50 ML		
TSIRC	Poruma STP		< 50 ML		
TSIRC	Saibai STP		50-100 ML		
TSIRC	St Pauls STP		< 50 ML		
TSIRC	Warrber STP		< 50 ML		
Unity Water	Cooroy STP	✓	100-500 ML		
Unity Water	Kenilworth STP		< 50 ML		
Unity Water	Maleny STP		100-500 ML		✓
Western Downs	Wandoan Sewage Treatment	✓	50-100 ML		✓
Whitsunday	Bowen STP		500-2000 ML		✓
Whitsunday	Cannonvale STP	✓	500-2000 ML		✓
Whitsunday	Collinsville STP		100-500 ML		✓
Whitsunday	Proserpine STP	✓	500-2000 ML		✓
Wide Bay Water	Burrum Heads WWTP		50-100 ML		✓
Wide Bay Water	Eli Creek (Hervey Bay) STP		500-2000 ML	✓	✓
Wide Bay Water	Howard Sewage Treatment		< 50 ML		✓
Wide Bay Water	Maryborough Sewage Treatment		500-2000 ML		✓
Wide Bay Water	Nikenbah (Hervey Bay) STP		500-2000 ML		✓
Wide Bay Water	Pulgul (Hervey Bay) STP		>2000 ML	✓	✓
Wide Bay Water	Toogoom STP		50-100 ML		✓
Woorabinda	Woorabinda Sewage Treatment		100-500 ML		✓
Wujal Wujal	Wujal Wujal STP	✓	< 50 ML		
Yarrabah	Yarrabah Sewage Treatment		100-500 ML		

* see Box 1 for a definition of 'tertiary' treatment.