



**Terranora Broadwater Sustainability Assessment
Report
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EXECUTIVE SUMMARY

This Sustainability Assessment report is based on results from the Coastal Lake Assessment and Management (CLAM) tool for Terranora Broadwater. This tool was developed as part of the Northern Rivers Catchment Management Authority (CMA) funded project entitled 'Ensuring sustainable development in coastal lake catchments of NSW Northern Rivers (CLAM project)'.

The report summarises the quality of data in the Terranora Broadwater CLAM for each node and also provides an assessment of key data gaps identified by Charles Hewitt in putting the Terranora CLAM together. These gaps are:

- Extent of riparian vegetation "coverage". Riparian planting is a common program among resource managers, and many will want to assess the associated cost-benefit. Without information on existing "coverage" this is very hard, and also makes export rates hard to calculate.
- Pollutant capture rates of riparian planting, WSUD elements, stormwater enforcement, education etc., particularly for pathogens.
- Number of septs on a catchment basis. These had to be estimated from aerial photographs.

Three groups of scenario combinations were analysed:

- Stormwater retrofitting;
- Sewer upgrades; and,
- Urban development – Residential development in Banora and development in Area E.

These are a small number of the total scenario combinations available in the CLAM but provide a useful insight in themselves into the management of the Broadwater. Key conclusions from this analysis are summarised below.

Stormwater Retrofitting

Stormwater retrofitting is likely to have impacts on pollutant inputs. However in most cases these do not lead to any change in the concentration of these pollutants in the Broadwater. The exception to this is TSS which does experience a small decrease in concentration. A major impact of stormwater retrofitting is to decrease sedimentation although this is only expected to occur at the highest level of retrofitting (100%). Decreasing sedimentation leads to both positive and negative ecological outcomes. Seagrass and saltmarsh increase by a small amount while mangroves experience a small decrease. Stormwater retrofitting can also be expected to lead to increased costs to both Council and developers.

Sewer upgrades

Sewer upgrades are associated with significant increases in costs to Council and developers but no significant impact is expected on the water quality of the Broadwater. In particular while stormwater retrofitting was associated with similar costs to sewer upgrades it is expected to lead to modest changes in water quality and ecological outcomes whereas sewer upgrades do not induce these changes.

Urban development

The trade-offs associated with urban development were shown to be quite complex. Impacts of urban development were shown to be quite broad in nature, including terrestrial and aquatic ecological impacts as well as social, economic and physical impacts. While residential development in Banora is associated with similar impacts of TSS, TN and TP, and better pH outcomes as well as smaller impacts on terrestrial fauna, development in this area comes at a higher cost in terms of flooding and weeds than development in Area E. Thus the decision to develop Area E or Banora in isolation needs to be made in light of fairly complex trade-offs and neither option is preferable in all impacts. The results also show the cumulative nature of development, such that more extensive or intensive development is associated with greater impacts.

Importantly, consideration of the impacts of urban development relative to the improvements gained by sewer upgrades and stormwater retrofitting show that these options are unlikely to fully offset the increased pollution derived from urban development. Further they do nothing to offset other important impacts such as those on migratory birds and terrestrial fauna or on flood risks and associated costs. All results need to be treated with some caution given that they rely in many cases on data of a poor quality however this general result is of interest and certainly warrants further investigation where options such as sewer upgrades or stormwater retrofitting are being considered to help off-set future developments.

1 INTRODUCTION

This Sustainability Assessment report is based on results from the Coastal Lake Assessment and Management (CLAM) tool for Terranora Broadwater. This tool was developed as part of the Northern Rivers Catchment Management Authority (CMA) funded project entitled 'Ensuring sustainable development in coastal lake catchments of NSW Northern Rivers (CLAM project)'. Scenarios presented in this report were identified as an important primary focus during workshops held with Council staff and other stakeholders in November 2006. These scenarios represent a relatively small subset of the complete range of options available in the CLAM tool and are intended to:

- document the quality of data used in the Terranora CLAM and key data gaps which should be a priority for data collection
- provide a useful analysis of options of first concern to Council and other key stakeholders which can be incorporated in decision making and other planning activities on these issues; and,
- illustrate the way in which the CLAM tool can be used to show the trade-offs involved in managing the lake system.

This report is not a management plan and cannot take the place of activities associated with the development of such a plan. In particular this report did not include scope for comprehensive community consultation. It could however be used to inform such a planning process. If this were to occur, results in this report should be critically evaluated and open to criticism from members of the public. This needs to occur within the context of the supporting documentation provided in the input pages of the CLAM tool. These pages provide comprehensive documentation of the assumptions underlying data used to derive the results in this report. This information is provided to allow users to assess for themselves the varying quality of data sources underlying the CLAM tool and its relevance to the decisions being made.

1.1 What is CLAM?

The Coastal Lake Assessment and Management (CLAM) tool was developed to allow stakeholders to assess the social, economic, environmental and ecological trade-offs associated with development, remediation and use options for coastal lakes and estuaries. A population shift towards the coastal fringe in NSW has seen substantial pressures being placed on these coastal systems. Catchment areas are subject to a variety of activities including urban developments, forestry and agricultural activities, recreation and tourism and fishing and aquacultural activities. Remediation of impacts through better controls on developments, replanting of riparian areas and remediation of fringing wetlands, as well as controls on activities directly affecting estuaries such as boating, fishing and recreation are also frequently being considered by State and Local authorities. The CLAM has been developed to show the multitude of impacts arising from such pressures and potential remediation measures. It is most appropriate for strategic planning purposes such as the development of estuary management plans or in other planning activities where a high level of community participation is desirable and an open and transparent modelling tool, which provides full detail of assumptions made and data used in its population, can be of assistance.

The CLAM approach is based on the concept of Bayesian networks but provides additional decision support through tailored interfaces and in-model documentation of model assumptions and design process. More details on the CLAM model can be found in Merritt *et al.* (2006a, 2006b) and Ticehurst *et al.* (2005, 2006).

There are five main benefits which the CLAM is able to capture for strategic decision making and management activities:

- To document in a transparent way data and assumptions available to be used in making a decision;
- To allow such data and assumptions to be applied repeatedly over many (often 100,000's) iterations in a consistent manner to improve the consistency and rigour of decision making;
- To provide a sound prioritisation of key data and information gaps in the management of a lake system through open documentation of data used in the CLAM system and analysis of the implications of the uncertainty of this data for decision making;
- To play an education role, providing a tool for people to focus on learning more about the interactions between human actions and social, environmental and economic outcomes in the system;
- To provide a focus for negotiations and discussions about preferred management actions. The CLAM approach encourages people to verbalise and document why they agree or disagree with model results. This type of discourse can form a key component of any negotiation about preferred options and the nature of impacts on the system. Improved understanding and knowledge developed through such discussions and studies which come out of them can be used to update the knowledge in the CLAM system.

1.2 How should the CLAM tool and results in this Sustainability Assessment Report be used?

The CLAM tool and the results provided in this Sustainability Assessment report should be used carefully. In particular all results from the CLAM should be critically evaluated for their appropriateness before being used to make decisions. All assumptions used in populating the CLAM and any review of the data that has been undertaken are documented in the input pages found with the CLAM model. This information should be very carefully considered when using results to make any type of decision or recommendation. In particular, users should consider:

- Does the CLAM consider the specific scenarios you are interested in?
- Do the impacts look reasonable? If not, why not? If yes, why?
- Do you trust the data used to populate the model? Why/why not?
- Is there other better data available that could be used in the model or used to review/validate the results?

The CLAM has a strong potential to be used in negotiations between catchment stakeholders on management actions. It should also be useful in an educational and capacity building role.

2 TERRANORA CLAM

2.1 Conceptual framework

The Terranora Broadwater CLAM model is underpinned by the conceptual framework shown in Figure 1. This diagram shows the assumed dependencies between scenarios or actions and state variables. This demonstrates, for example, the way in which ecological outcomes, such as seagrass, are dependent on water quality parameters such as total suspended sediment or sedimentation, which in turn depend on actions such as implementing new developments or the stormwater management.

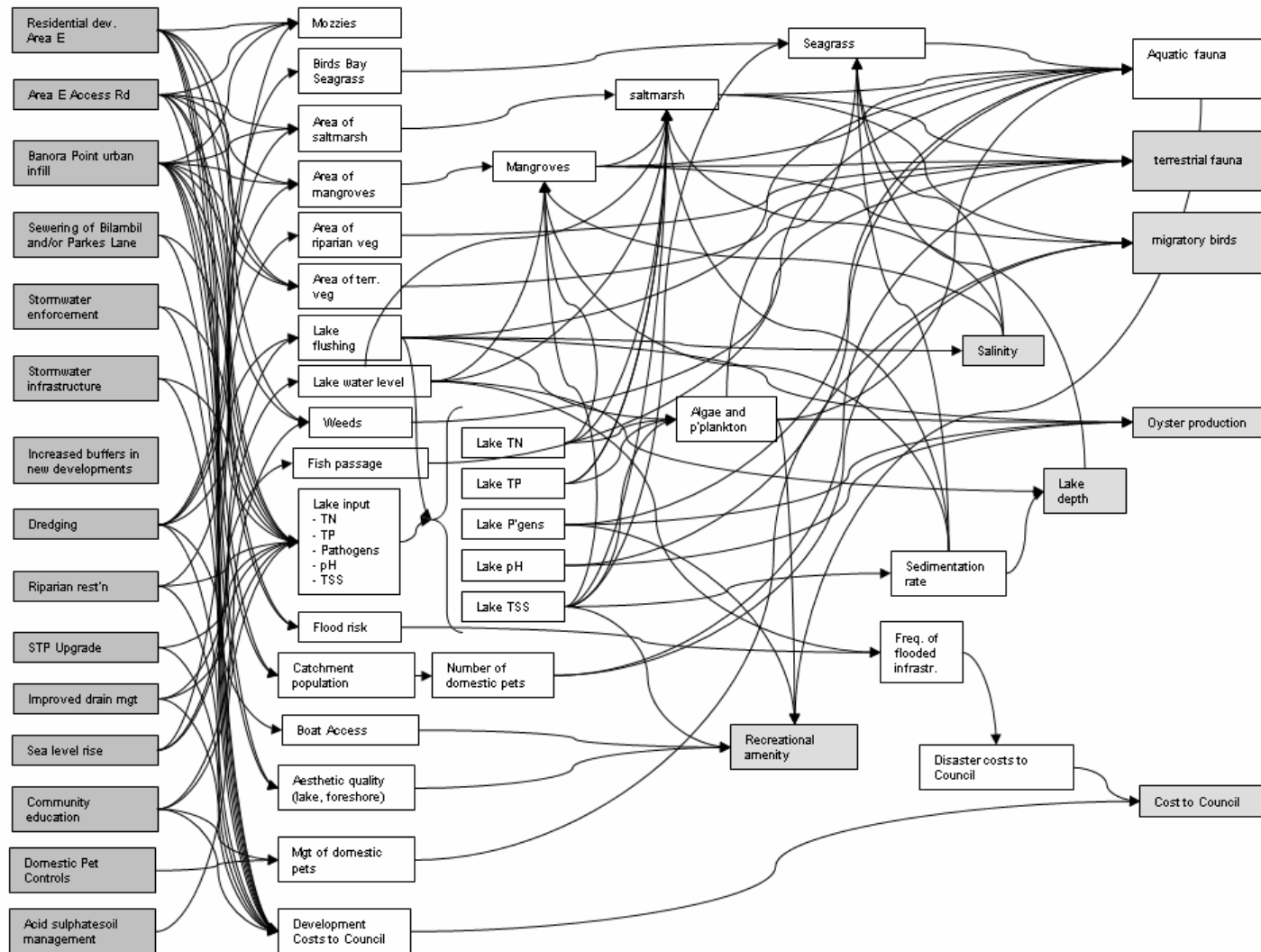


Figure 1. Terranora Broadwater conceptual framework

2.2 An assessment of data quality

The CLAM model relies upon a set of conditional probabilities to define the relationship between variables. This means that for every arrow in Figure 1 a conditional probability table must be defined which estimates the nature of the relationship. The data used to derive these conditional probability tables comes from a variety of sources including literature assumptions, calibrated and uncalibrated models, expert and local knowledge and observed data. For such a broad system a variety of data qualities is to be expected. This section provides a quality assessment of data quality for each node (ie. each box in Figure 1). A statement of priority data collection needs for Terranora lagoon is then given. This statement was provided by Charles Hewitt who was put together the data for the Terranora CLAM.

Table 1 provides a qualitative assessment of data quality for each node in the Terranora CLAM. A description of each node is provided in Appendix 1.

Table 1. Data quality in the Terranora CLAM

Node	Quality of Data	Reason	Suggested improvements
Aesthetics	Poor	Based on assumptions and iCAM combination model tool	Expert review and data input from local information on perceptions of foreshore aesthetics. Further community consultation.
Algae and Phytoplankton	Poor	Based on assumptions and iCAM combination model tool	Expert review and increased knowledge of the interactions between nutrients and algae or phytoplankton response in Terranora or similar systems.
Aquatic fauna	Poor	Based on assumptions and iCAM combination model tool	Expert review and increased knowledge of the aquatic fauna ecology in Terranora or similar systems.
Birds Bay seagrass	Very Good (a direct yes/no criterion)	If dredging occurs in the Birds Bay area then seagrass populations will be disturbed.	
Boat access	Poor	Based on assumptions and iCAM combination model tool	Expert and local review and increased knowledge of impact of options on boating access.
Cost to Council	Poor	Based on assumptions and iCAM combination model tool	Expert and local review and review of current council cost structures and relative impacts.

Development costs	Poor	Based on assumptions and iCAM combination model tool	Expert and local review and review of current development cost structures and relative impacts.
Direct Mangrove impacts	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Would also be assisted by GIS or photo interpretation to map mangrove areas (if not already available), determine suitability of artificial islands for mangroves and to provide some quantitative estimate of impacts.
Direct Saltmarsh impacts	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Would also be assisted by GIS, photo interpretation and ground-truthing to map areas of current saltmarsh (if not already available), determine suitability of artificial islands for saltmarsh and to provide some quantitative estimate of impacts.
Direct terrestrial vegetation impacts	Good	Based on GIS data and iCAM combination model tool	Expert and local review. Improved assessment of total area the 80m buffer option (Buffer Extent) would be applied to.
Disaster costs	Poor	Based on assumptions and iCAM combination model tool	Expert and local review and review of costs associated with flooding in Terranora or similar areas.
Domestic pets	Poor	Based on assumptions and iCAM combination model tool	Expert and local review and review/data on pet ownership trends in Terranora
Domestic pet management	Poor	Based on assumptions and iCAM combination model tool	Expert and local review and review/data on pet ownership and management trends in Terranora
Fish passage	Poor	Based on assumptions. No model	Expert and local review and review of fish species and movements in Terranora or similar systems.
Flood risk	Poor	Based on assumptions and iCAM combination model tool	Expert and local review and flood study or similar
Frequency of flooded infrastructure	Poor	Based on assumptions and iCAM combination model tool	Expert and local review and flood study or similar

Lake depth	Poor	Based on assumptions and iCAM combination model tool	Expert and local review, Application of flood study or similar and bathymetry of Terranora Broadwater if available
Lake flushing	Average	Based on a simple uncalibrated model. Local data were used to run this model (incl. bathymetry data)	Expert and local review. Could be improved with local hydrodynamic modelling.
Mangroves	Poor	Based on assumptions and iCAM combination model tool	Expert and local review.
Migratory birds	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. More information on habitat use by migratory birds in Terranora.
Mosquitoes	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. More information on mosquito ecology relevant to Terranora scenarios.
Oysters	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. More information on local oyster industry and input/review from oyster farmers.
Pathogen input	Average	Based on simple uncalibrated model derived from other situations. Model run with some local data	Expert review and more comprehensive local data collection, use of local data for calibration and implementation of the more comprehensive model.
Lake pathogen	Average	Based on model with some local data but primarily uncalibrated	Expert review and more comprehensive local data collection, use of local data for calibration. More detailed modelling of flushing impacts on pathogens and monitoring of levels in the lagoon could also be undertaken.

pH input	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Local data collection for calibration or baseline data.
Lake pH	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Local data collection for calibration or baseline data.
Population	Average	Based on assumptions and iCAM combination model with some quantification.	Expert and local review. Use of ABS census data or other data on local population would strengthen assumptions (assumptions not documented)
Recreational Amenity	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Local data on recreational activities and behaviour to allow better representation of impacts of different node inputs
Direct riparian vegetation impacts	Good	Based on riparian areas in scenario and iCAM combination model tool	Expert and local review.
Lake salinity	Average	Based on a simple uncalibrated model. Local data were used to run this model (incl. bathymetry data)	Expert and local review. Could be improved with local hydrodynamic modelling.
Saltmarsh	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Would also be assisted by GIS, photo interpretation and ground-truthing to map areas of current saltmarsh (if not already available), changes in saltmarsh community and better understanding of saltmarsh ecology to provide some quantitative estimate of impacts.
Seagrass	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Would also be assisted by GIS, photo interpretation and ground-truthing to map areas of current seagrass (if not already available), changes in seagrass extent and better understanding of seagrass ecology to provide some quantitative estimate of impacts.

Sedimentation rate	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. It would be much more appropriate to link Lake TSS to Sedimentation Rate via a direct relationship based on wet bulk density of sediment, area of the lake, and an assumption of the proportion captured by the lake.
Terrestrial fauna	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Data/information on local terrestrial fauna biodiversity and ecology.
TN input	Average	Based on an uncalibrated model with some local data	Expert and local review. Local data collection to provide calibration/validation data sets.
Lake TN	Average	Based on an uncalibrated model (some local data)	Expert review and more comprehensive local data collection, use of local data for calibration. More detailed modelling of flushing impacts on TN and monitoring of levels in the lagoon could also be undertaken.
TP input	Average	Based on an uncalibrated model with some local data	Expert and local review. Local data collection to provide calibration/validation data sets.
Lake TP	Average	Based on an uncalibrated model (some local data)	Expert review and more comprehensive local data collection, use of local data for calibration. More detailed modelling of flushing impacts on TP and monitoring of levels in the lagoon could also be undertaken.
TSS input	Average	Based on an uncalibrated model with some local data	Expert and local review. Local data collection to provide calibration/validation data sets. Information on riparian areas to inform model.
Lake TSS	Average	Based on an uncalibrated model (some local data)	Expert review and more comprehensive local data collection, use of local data for calibration. More detailed modelling of flushing impacts on TSS and monitoring of levels in the lagoon could also be undertaken.
Lake water level	Average	Based on simple model with limited local data	Expert and local review. Local hydrodynamic model.
Weeds	Poor	Based on assumptions and iCAM combination model tool	Expert and local review. Data/information on current status and ecology of weeds in the catchment.

Classifications used in Table 1 are:

- **Excellent:** Models based on local data, supported assumptions, expert review and calibrated/verified with measured (local) data. For direct changes in measured areas where derived from ground-truthed GIS interpretation.
- **Very good:** Models based on local data, supported assumptions, expert review and calibrated/verified with measured (local) data which may be limited in extent
- **Good:** Models supported by expert review or local data. May be calibrated/verified with measured (local) data which may be limited in extent or show some areas for improvement of model fit.
- **Average:** Uncalibrated models or based on assumptions with some supporting local data or expert review.
- **Poor:** Based on untested assumptions with little or no supporting local data or expert review.

Priority data collection areas identified by Charles Hewitt are:

- Extent of riparian vegetation "coverage". Riparian planting is a common program among resource managers, and many will want to assess the associated cost-benefit. Without information on existing "coverage" this is very hard, and also makes export rates hard to calculate.
- Pollutant capture rates of riparian planting, WSUD elements, stormwater enforcement, education etc., particularly for pathogens.
- Number of septics on a catchment basis. These had to be estimated from aerial photographs.

3 SCENARIOS

In order to develop this Sustainability Assessment analysis a relatively small subgroup of scenarios were selected from the 884,736 available in the Terranora CLAM. It was decided to focus on the following scenarios:

- Stormwater retrofitting;
- Sewer upgrade;
- Urban development: Residential development in Banora and Develop Area E.

These sets of scenarios are considered in isolation to each other. Impacts focused on depend on the likely consequence of the scenario options. The descriptions for these scenarios taken from the CLAM tool are given below. Other scenarios available in the CLAM tool are described in Appendix 2.

3.1 Stormwater retrofitting

Modelling done as part of the Environmental Impact Statement (EIS) associated with the proposed upgrade of the Tweed West and Banora Point Water Reclamation Plants (GHD, 2004) indicated the principal driver of nitrogen and phosphorus concentrations in the system is stormwater runoff. As a result of this finding the EIS recommends that various 'catchment rehabilitation' measures be implemented to reduce diffuse pollutant loads, namely:

- Bioretention basins (vegetated swales and ponds that remove nutrients and sediment)
- Gross pollutant traps
- Restoration of riparian areas.

The pollutant load reductions associated with a combination of these measures were derived from ranges provided in the EIS. The model used the following estimates:

- TN – 75% captured
- TP – 33% captured
- TSS – 55% captured

These capture rates were applied under 2 arbitrary scenario options of stormwater retrofitting across 50% and 100% of existing urban developments.

3.2 Sewer Upgrade

Tweed Shire Council (TSC) is considering the sewerage of two areas close to Terranora Broadwater. The village of Bilambil lies to the west of Terranora Broadwater, and an area known as 'the Parkes Lane area' lies to the south.

A recent study of on-site sewer systems in the Parkes Lane area produced the following results:

Numbers and type of on-site systems in the Parkes Lane area

	Primary Systems	Secondary Systems	Total
Number of Systems	63	29	92
High Risk	14	11	25
Medium Risk	49	18	67
Low Risk	0	0	0

Ref: *On-Site Sewerage Management Strategy Audit program 2004: Review for Parkes Lane, Trutes Terrace, Market Parade and Vista Close, Terranora, Tweed Shire Council (2004)*

The proportion of 'high risk' systems (27%) found in the Parkes Lane area was assumed for Bilambil in the absence of a specific study.

An estimate of a further 152 septic systems in the total catchment of Terranora Broadwater (i.e. the combined catchments of Bilambil Creek, Duroby Creek and Terranora Broadwater) was made from manual aerial photograph interpretation.

3.3 Residential development in Banora

There are two proposals for urban infill development at Banora Point, 600 houses or 920 houses. Consultation with a Tweed Shire Council representative indicated that both options constituted medium density development under the criteria used by Baginska et al (2004), i.e. 30% < impervious area < 50%. Criteria used in this report were adopted for consistency as it was the source of existing landuse data for the model. Export rates are calculated from landuse classifications, therefore there is no export rate resolution between the two scenarios.

The area available for development is estimated as 85.3 ha with the following existing landuse classifications

Area available for development	area ha
Unimproved pasture	70.7
Bushland/riparian	13
Bare	1.6
Total	85.3

(Ref: TSC GIS data and GeoLINK landuse analysis)

3.4 Develop in Area E

The 297 ha mapped as Area E comprises 128.45 ha of constrained land and 168.55 ha of developable land:

Constraints	area ha
Dams	2.32
Riparian & Landscape amenity	54.62
Wetland (including buffer)	57.53
Steep slopes	13.92
Restrictive/Unstable slopes	53.99
Area burdened by flood level	65.79
Proposed road corridor	4.90
Total constraints (many overlap)	128.45

(Ref: *Tweed Area E Comprehensive Planning Framework Draft Local Environmental Study*, Parsons Brinckerhoff 2003)

Developable area	area ha
Unimproved pasture	115.1
Bushland/riparian	53.45
Total developable area	168.55

(Ref: TSC GIS data and GeoLINK landuse analysis)

Only one development option is provided, and development is considered to be medium density under the criteria used by Baginska et al (2004), i.e. 30% < impervious area < 50%. These criteria were used as Baginska et al (2004) was the source of existing landuse data.

4 RESULTS FROM SCENARIO RUNS

4.1 Stormwater retrofitting

Two alternative stormwater options were considered in conjunction with the base case option of 'do nothing': 50% retrofit; and 100% retrofit. Overall thirty nodes experienced no impact from this scenario: Water_Lvl; Algae_&_Phytoplankton; Rec_Amenity; Disaster_Costs; Pathogen_input; Population; Direct_Terrestrial_Vegetation_Impacts; Terrestrial_Fauna; Mozzies; Aesthetics; Domestic_Pets; Migratory_Birds; Oysters; Salinity; Direct_Saltmarsh_Impacts; Domestic_Pets_Mgt; Direct_Riparian_Vegetation_Impacts; Weeds; pH_input; Boat_access; Fish_Passage; Lake_Flushing; Flood_Risk; Freq_infra_flood; Birds_Bay_Seagrass; Direct_Mangrove_Impacts; TP_lake; pH_lake; pathogens_lake; and, TN_lake. In most cases this was because there was no direct link between the action and the node. This was not always the case. For example TN and TP inputs are impacted by stormwater retrofitting but these impacts are not discernible in the Broadwater once flushing has been accounted for. Table 2 provides a summary of impacts for all other nodes. Note that these impacts are considered relative to the base case distribution. This means that a "small increase" is relative to the base case and does not necessarily infer that the variable is actually expected to increase overall. This might be the case where a variable is expected to decrease under the base case but the distribution shifts towards 'no change' for the alternative scenario option. It should also be noted that ranking something as a 'small' decrease does not necessarily mean that it is insignificant. For threatened species even a 1-3% impact may be considered significant whereas for other variables that are more robust or less value a 20-30% impact may not be considered. Ranking these impacts really requires an understanding of community values for these impacts which is not part of this assessment.

Table 2. Summary of impacts of Stormwater Retrofitting

	Retrofit 50%	Retrofit 100%
TN_input	Small decrease	Small decrease
TP_input	Very small decrease	Very small decrease
Lake_Depth	No impact	Moderate increase
Sedimentation_rate	No impact	Moderate decrease
Saltmarsh	No impact	Small increase
Dev_Costs	Moderate increase	Moderate increase
Seagrass	No impact	Small increase
cost_to_council	Moderate increase	Moderate increase
TSS_input	Small decrease	Small to moderate decrease
Mangroves	No impact	Small decrease
TSS_lake	Very small decrease	Small decrease

These results show that retrofitting has the greatest water quality impact when considering total suspended sediments. Nitrogen and phosphorus inputs are decreased by small and very small amount respectively. As was stated before these changes are not discernible in the pollutant concentrations in the broadwater once flushing is accounted for. For TSS 100% retrofitting leads to a small to moderate decrease in inputs, which in turn creates a small decrease in TSS concentrations in the broadwater. The smaller retrofitting option of 50% retrofit produces a smaller decrease in TSS but this change is still discernible in the broadwater concentration. This lower retrofitting option is not expected to have any impact on sedimentation of the broadwater and so has no ecological impacts on mangroves, seagrass or saltmarsh. The larger retrofitting option of 100% is expected to lead to a moderate decrease in sedimentation. This is expected to have significant impacts on these ecological variables, leading to an increase in both saltmarsh and seagrass and a decrease in mangroves. Finally both costs to council and developer costs are expected to experience a moderate increase.

The distribution of sedimentation is shown in more detail in Figure 2. This figure shows that under the base case the most likely outcome is no change while there is a more than 10% chance of either a small increase or decrease. Implementing the 50% retrofit option has no impact on this distribution. However once retrofitting reaches 100% there is a substantial shift in the distribution. There is now no chance of a small increase while the chances of no change are reduced to just over 10%. The most probable outcome is a small decrease and there is some chance (>10%) of a large decrease in sedimentation.

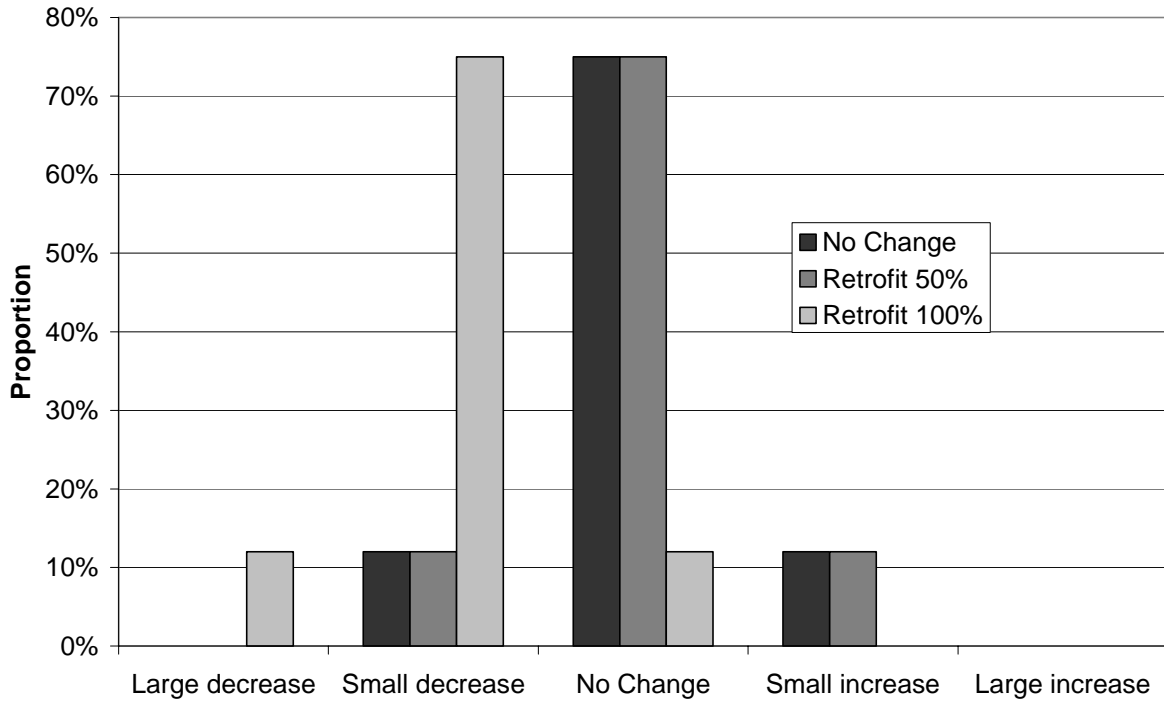


Figure 2. Impact of Stormwater Retrofitting on Sedimentation Rate

As was stated earlier this change in sedimentation leads to both positive and negative ecological outcomes as seagrasses and saltmarsh are increased while mangroves decrease. The impacts on seagrass and mangroves are shown in Figure 3 and 4 respectively.

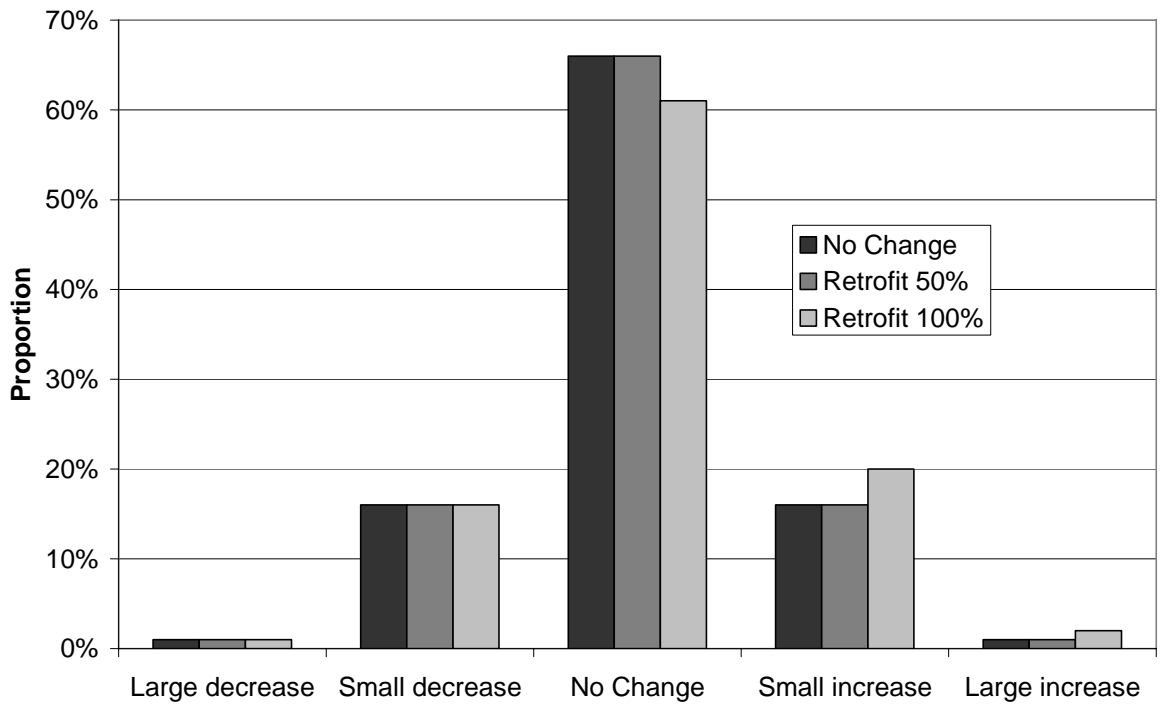


Figure 3. Impact of Stormwater Retrofitting on Seagrass

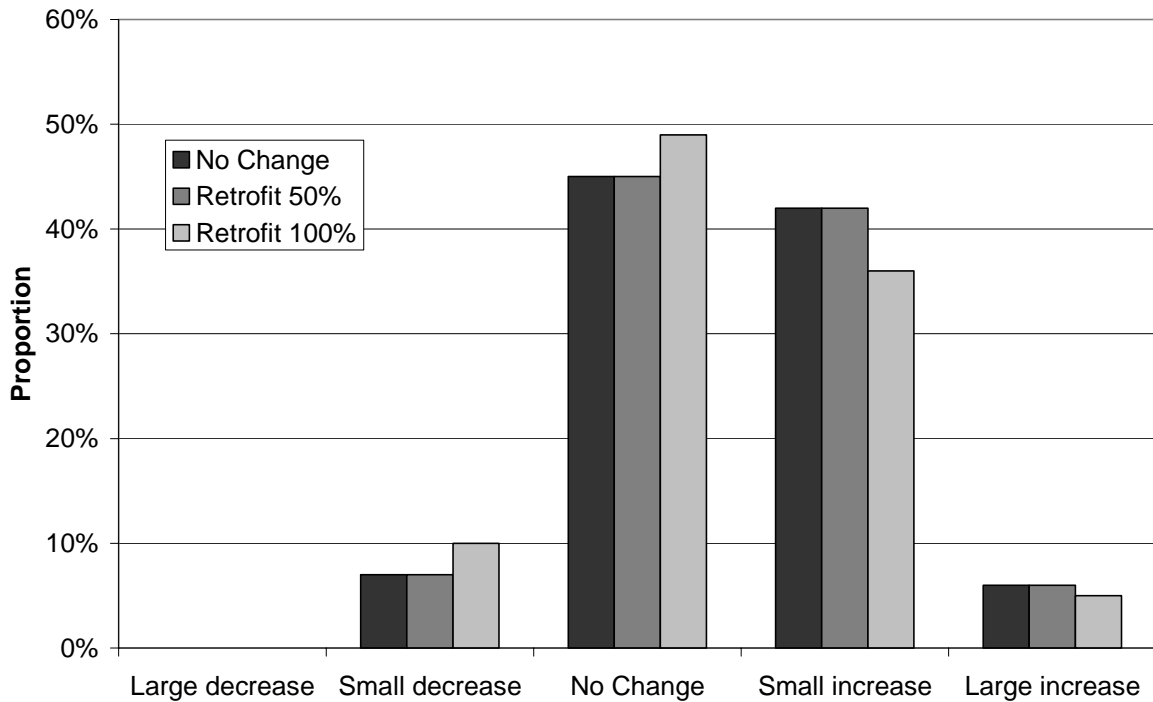


Figure 4. Impact of Stormwater Retrofitting on Mangroves

These figures show that the impacts of sedimentation are relatively subtle. As would be expected by the lack of change in sedimentation, there is no noticeable impact of the 50% retrofit option on either mangroves or seagrass. Once retrofitting is at 100% the impact is noticeable. For seagrasses the probabilities of small and large decreases are unaffected however the chance of 'no change' has been reduced while the probability of both small and large increases has been increased. These changes are all less than 10%. For mangroves the impact is spread more evenly across the entire distribution. The chance of a small and large increase is reduced, while the probabilities of 'no change' or a small decrease are increased. These changes are all less than 10%. No option induces any probability of a large decrease. Important considerations with these results are the coarseness of the output states for sedimentation rate and the quality of the data used to populate this node. It is possible that coarse representation and poor data are obscuring impacts that would occur at lower levels of retrofitting than 50%, although these could still be expected to be less than the impacts of 100% option. Also the level of retrofitting required to induce a discernible impact in sedimentation is not known, only the impacts of these two distinct options. Even with these limitations these results do show the expected bounds on impacts expected from stormwater retrofitting on sedimentation, TSS concentrations and associated ecological outcomes.

Stormwater retrofitting is also associated with significant economic costs to both Council and Developers. As was stated earlier a moderate increase in both costs is expected under either retrofit options. Figure 5 illustrates the effect of stormwater retrofitting on developer costs.

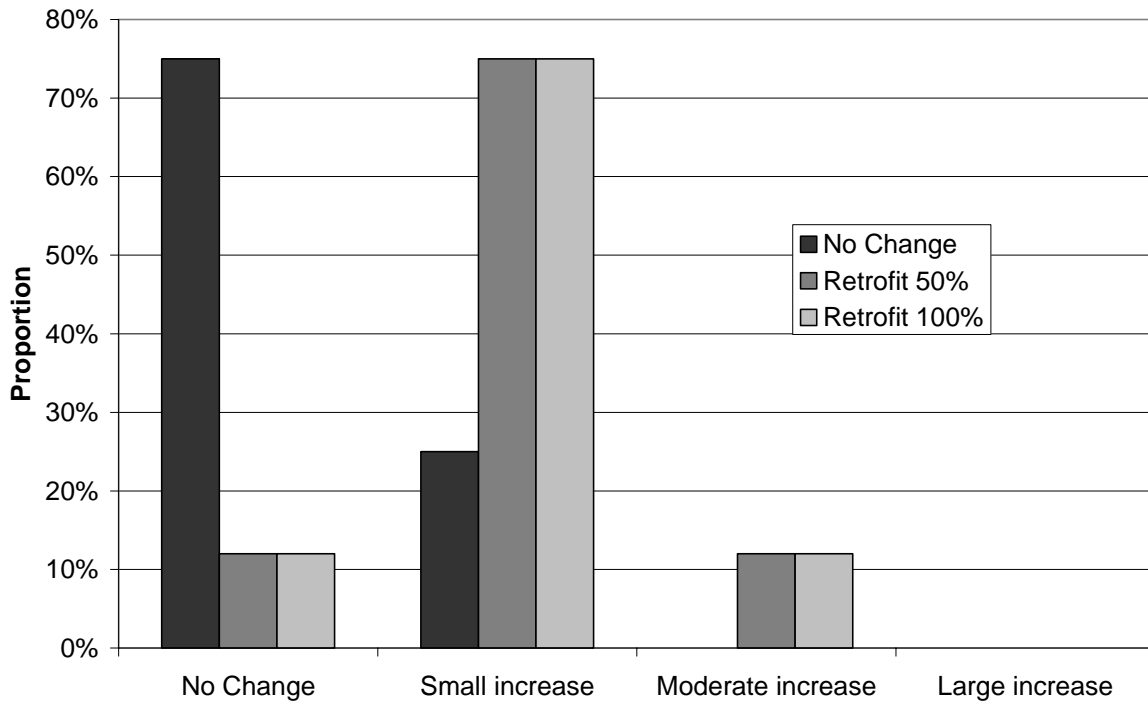


Figure 5. Impact of Stormwater Retrofitting on Developer Costs

This figure shows that under the base case the most likely option (75%) is 'no change' while there is a 25% chance of a small increase. The impacts of the two retrofitting options are the same, with the chance of 'no change' falling to approximately 12% while the most probable outcome becomes a small increase. There is also now a small chance of a moderate increase in costs. Given the poor quality of data used to populate this node these results are likely to be affected by this data quality. It is possible that better information on costs would help to distinguish between these two options. These results do indicate however that costs associated with retrofitting are likely to be one barrier to implementation of this option.

Overall these results show that while stormwater retrofitting is likely to have impacts on pollutant inputs, this does not lead to any change in the concentration of these pollutants in the Broadwater. This is with the exception of TSS which does experience a small decrease in concentration in the Broadwater. One of the main impacts of stormwater retrofitting is to decrease sedimentation although this is only expected to occur at the highest level of retrofitting. Decreasing sedimentation leads to both positive and negative ecological outcomes with seagrass and saltmarsh increasing by a small amount while mangroves can be expected to experience a small decrease. As can be expected stormwater retrofitting is also shown to increase costs to both Council and developers.

4.2 Sewer upgrade

Three options were considered for sewer upgrades in conjunction with the base case option of no change: Parkes Lane; Bilambil; and, Parkes Lane and Bilambil. These options had no effect on most nodes in the Terranora CLAM. Only three nodes were impacted: TN input; costs to council; and, developer costs. This means that while sewer upgrades might be expected to have an impact on nitrogen inputs, these are not expected to be noticeable in the Broadwater (at the level of coarseness of outputs used in the Terranora CLAM) once flushing of the Broadwater is accounted for. Impacts of sewer upgrades on TN inputs are shown in Figure 6.

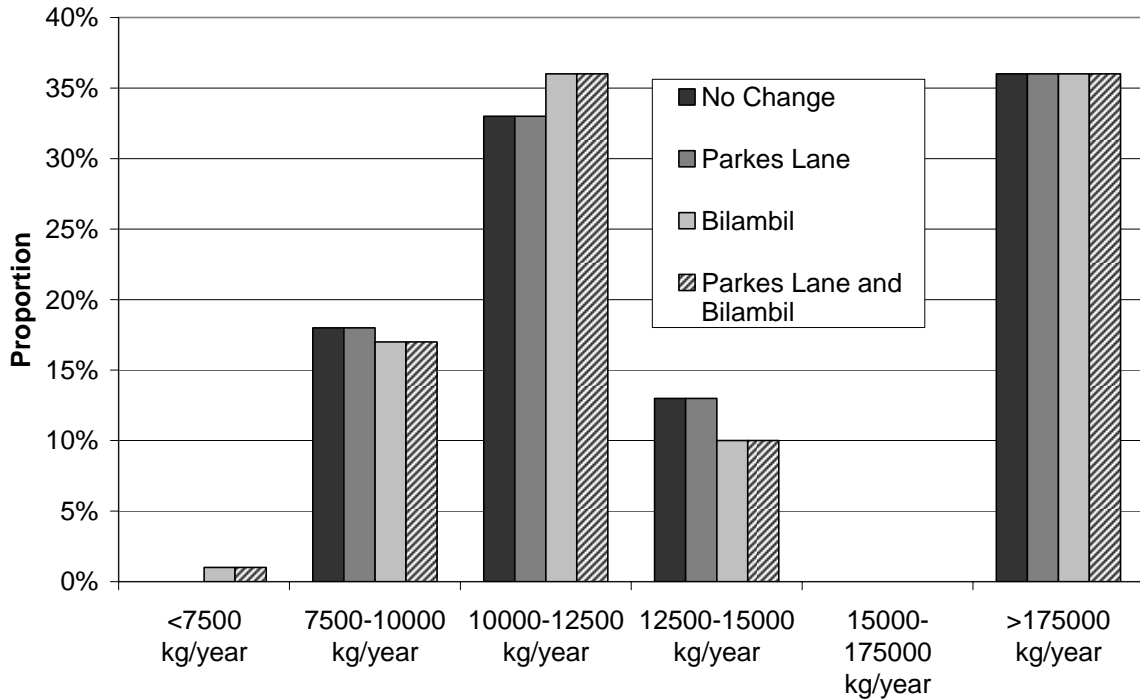


Figure 6. Impact of Sewer Upgrades on TN input

As can be seen in the figure these impacts are quite small for Bilambil and Parkes Lane land with Bilambil. No impact is observed for Parkes Lane in isolation. Upgrading the sewer in Bilambil shifts a small probability (<5%) from 12500-15000 kg/year back to 1000-12500 kg/year. Also a smaller shift occurs from 7500-10000 kg/year to <7500kg/year. The most likely outcome at greater than 35% probability is >17500 kg/year for all option, although the probability of 10-12500 kg/year is equal to this once Bilambil is implemented. These changes in TN input are quite small and do not have any noticeable impacts once the flushing of the Broadwater is considered.

The other two impacted nodes relate to increases in costs. Changes in costs for both developers and Council are shown in Figures 7 and 8 respectively.

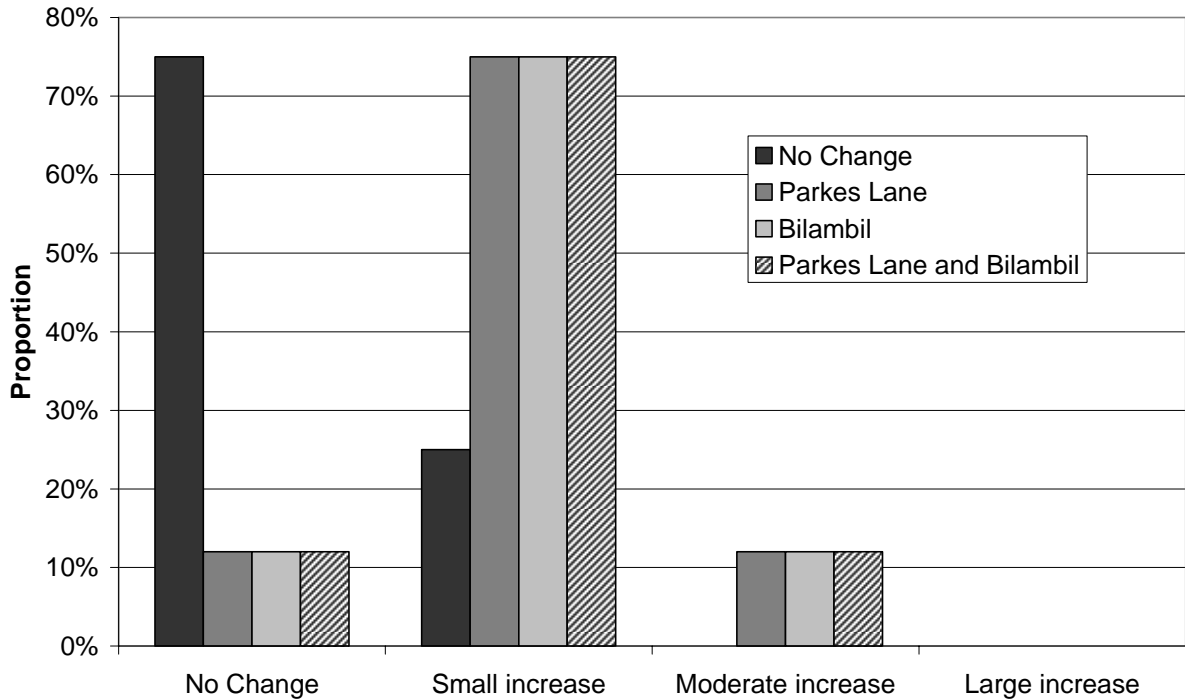


Figure 7. Impact of Sewer Upgrades on Developer costs

This figure shows that all three alternatives for sewer upgrades are associated with the same expected increase in costs to developers. This result is likely to reflect the poor quality of data used to populate this node. The most likely outcome shifts from “no change” to a small increase while there is now a change (>10%) of a moderate increase in costs.

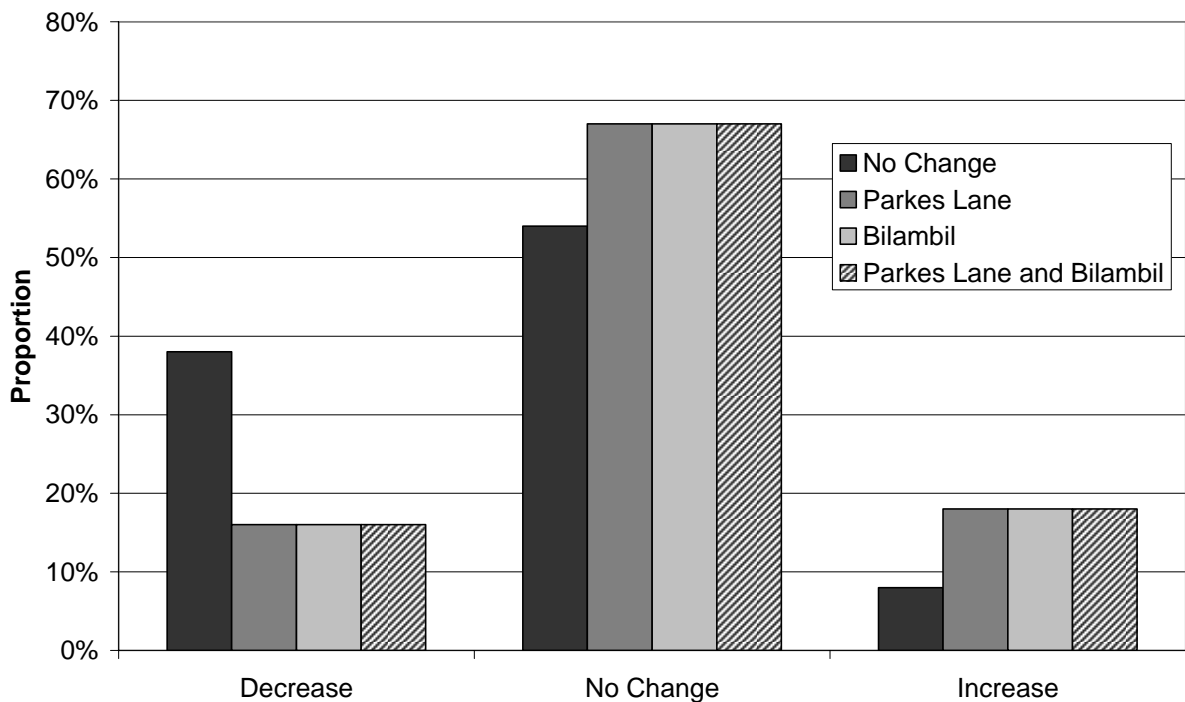


Figure 8. Impact of Sewer upgrades on Council costs

The impact of the alternatives on council costs is similar to that experienced for developer costs. In this case the chance of a decrease is reduced from nearly 40% to less than 20% while the chances of an increase are roughly doubled. The most likely outcome for the base case and all alternatives is 'no change' although this becomes more likely under the sewer retrofitting options.

Overall these results show that while sewer upgrades are associated with significant increases in costs to Council and developers, no significant impact is expected on the water quality of the Broadwater. These results should be used cautiously given the coarseness of states used in the model and the poor quality of much of the data however they provide an interesting outcome that warrants further investigation. In particular while stormwater retrofitting was associated with similar costs to sewer upgrades it is expected to lead to modest changes in water quality and ecological outcomes.

4.3 Urban Development

Two sets of urban development scenarios were considered in combination: Residential development in Banora; and, development of Area E. In all, this meant that six urban development scenarios were considered including the 'no change' option. These options had no impact on twelve nodes: Water_Lvl; Pathogen_input; Oysters; Salinity; Domestic_Pets_Mgt; Direct_Riparian_Vegetation_Impacts; Boat_access; Fish_Passage; Lake_Flushing; Birds_Bay_Seagrass; Direct_Mangrove_Impacts; and, pathogens_lake. In most cases this was because there was no direct link between urban development options and the node. One exception is pathogen inputs and subsequently lake pathogens. These results indicate that while there is a link between pathogens and urban development, impacts are not large enough to be discernible at the level of disaggregation of output states used in the Terranora CLAM. This is interesting because the states used to describe pathogens relate to ANZECC guidelines for primary and secondary contact and aquaculture. These results indicate that while urban development may impact on pathogens at levels indiscernible in the model they are not expected to change the frequency of events where primary or secondary contact or aquaculture are restricted. Table 3 provides a summary of impacts on nodes where impacts were experienced.

Table 3. Summary of impacts of urban development

	600 houses in Banora	920 houses in Banora	Develop Area E	Develop Area E, 600 houses in Banora	Develop Area E, 920 houses in Banora
Algae_&_Phytoplankton	Very small increase	Very small increase	Very small increase	Very small increase	Very small increase
TN_input	Small increase	Small increase	Small to moderate increase	Small to moderate increase	Small to moderate increase
Rec_Amenity	No impact	Very small decrease	Very small decrease	Very small decrease	Very small decrease
Disaster_Costs	Moderate increase	Moderate increase	No impact	Moderate increase	Moderate increase
TP_input	Small increase	Small increase	Small to moderate increase	Small to moderate increase	Small to moderate increase
Population	Moderate increase	Large increase	Large increase	Very large increase	Very large increase
Direct_Terrestrial_Vegetation_Impacts	Moderate decrease	Moderate decrease	Large decrease	Large decrease	Large decrease
Terrestrial_Fauna	Small decrease	Small to moderate decrease	Small to moderate decrease	Moderate decrease	Moderate decrease
Lake_Depth	Small decrease	Small decrease	Small decrease	Small decrease	Small decrease
Sedimentation_rate	Moderate increase	Moderate increase	Moderate increase	Moderate increase	Moderate increase
Saltmarsh	Small to moderate decrease	Small to moderate decrease	Small decrease	Small to moderate decrease	Small to moderate decrease
Mozzies	Moderate increase	Moderate increase	Moderate increase	Moderate increase	Moderate increase
Aesthetics	No impact	Large decrease	No impact	Large decrease	Large decrease
Dev_Costs	Small to moderate increase	Small to moderate increase	Small to moderate increase	Small to moderate increase	Small to moderate increase
Domestic_Pets	Small increase	Moderate increase	Moderate increase	Large increase	Large increase
Migratory_Birds	Small decrease	Small to moderate	Small decrease	Moderate decrease	Moderate decrease

		decrease			
Seagrass	Moderate decrease	Moderate decrease	Moderate decrease	Moderate decrease	Moderate decrease
Direct_Saltmarsh_Impacts	Moderate decrease	Moderate decrease	No impact	Moderate decrease	Moderate decrease
cost_to_council	Moderate increase	Moderate increase	Small increase	Moderate increase	Moderate increase
Weeds	Moderate increase	Large increase	Moderate increase	Large increase	Large increase
pH_input	No impact	No impact	No impact	Large decrease	Large decrease
Flood_Risk	Moderate increase	Moderate increase	No impact	Moderate increase	Moderate increase
Freq_infra_flood	Moderate increase	Moderate increase	No impact	Moderate increase	Moderate increase
TSS_input	Small increase	Small increase	Small increase	Small to moderate increase	Small to moderate increase
Mangroves	Moderate increase	Moderate increase	Moderate increase	Moderate increase	Moderate increase
TN_lake	Very small increase	Very small increase	Very small increase	Very small increase	Very small increase
TP_lake	No impact	No impact	No impact	Very small increase	Very small increase
TSS_lake	Small increase	Small increase	Small increase	Small increase	Small increase
pH_lake	No impact	No impact	No impact	Small decrease	Small decrease

These results show that urban development is expected to have a very wide range of impacts. One primary impact of urban development is to increase pollutant delivery to the estuary. This is in terms of TN, TP and TSS. Water quality impacts are worse when Area E is developed than when residential development occurs in Banora. As would be expected pollutant inputs are more greatly effected than final pollutant concentrations in the Broadwater once the effects of flushing have been accounted for. For TP flushing reduces the effect of TP increases following residential development in Banora to the extent that impacts are not observable at the level of coarseness of description of state variables in the CLAM. Impacts from Area E are still discernible. For TN and TSS impacts of both developments are discernible in the Broadwater even once flushing has been accounted for. These water quality impacts have impacts on ecological outcomes in the Broadwater. Increasing sedimentation and TSS leads to increases in mangroves but seagrasses and saltmarsh are both expected to decline. The impact on saltmarsh is also brought about by direct impacts on the area of saltmarsh through human interference with these areas not only through water quality changes. Another water quality impact to note is the influence of urban development in Area E on pH levels in the Broadwater. Development in Banora has no effect while developing Area E is expected to decrease lake pH. Urban development is also expected to have significant impacts on the terrestrial environment through increased weeds and predation and harassment of migratory birds by domestic pets. Terrestrial fauna can be expected to decline due to the loss of habitat, with this loss greater for greater areas of development. In addition residential developments in Banora are subject to flood risks and thus development in this area can be expected to increase the frequency of infrastructure flooding and associated costs. Other social costs are losses to recreational amenity and decreases in aesthetic values associated with larger developments.

Impacts of urban development on the concentration of TSS in the Broadwater are shown in more detail in Figure 9. This Figure shows that in isolation development of Area E or Banora would lead to the similar changes in TSS concentrations. The probability of 16-19 g/m³ is reduced by 5% (as it is for combined development options). There is a 3% greater chance of concentrations being in the 19-21 g/m³ band for these options, while there is a 2% increase in probability of 21-24 g/m³. No impact is experienced on the probability of the top band of TSS (>24 g/m³). Developing Area E in conjunction with Banora is shown to have cumulative impacts that are worse than either scenario in isolation. Here the probability of 19-21 g/m³ remains constant but this occurs at the expense of a 4% increase in the probability of falling in the 21-24 g/m³ band. This shift occurs with the reduction of probability of the lowest level of TSS experienced (16-19 g/m³). Thus urban development can be expected to increase TSS concentrations in the Broadwater and this increase can be expected to be greater for greater areas of development.

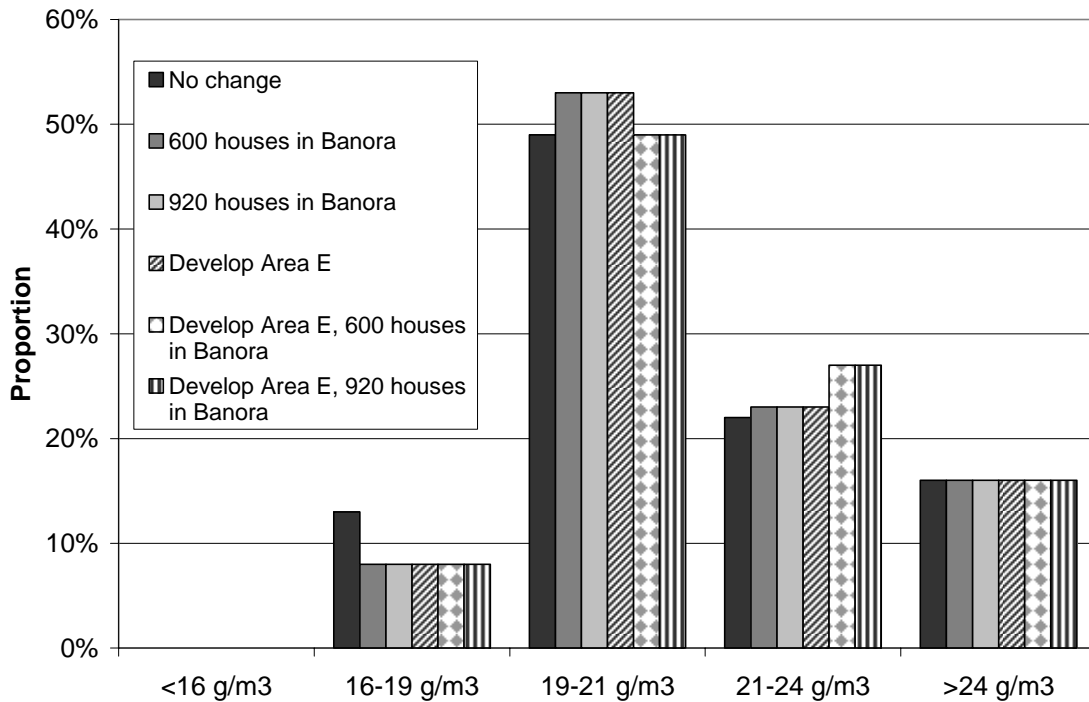


Figure 9. Impact of Urban Development options on Lake TSS

Changes in sedimentation and water quality as well as increased human intervention are expected to have impacts on ecological outcomes in the Broadwater. This is particularly the case with saltmarsh. Development in Banora is expected to directly reduce the area of saltmarsh. In addition increased sedimentation is also likely to have negative affects on saltmarsh. The consequent impacts of urban development on saltmarsh are shown in Figure 10. This figure shows that impacts on saltmarsh are dominated by expected direct impacts on saltmarsh area due to residential development in Banora rather than through water quality changes. Development of Area E in isolation leads to a 4% increase in probability of a large decrease in saltmarsh. Given that this option is not expected to have any direct impacts on saltmarsh area this result is due solely to changes in water quality. Other options show the influence of both water quality and direct area impacts on saltmarshes. In these cases there is a 12% increase in the probability of a large decrease. This result needs to be treated cautiously given the poor quality of data used to create this impact. In all cases a small decrease in the most likely outcome. Development removes the slight chance of a small increase in saltmarsh and leads to increases in the probability of large decreases as described previously.

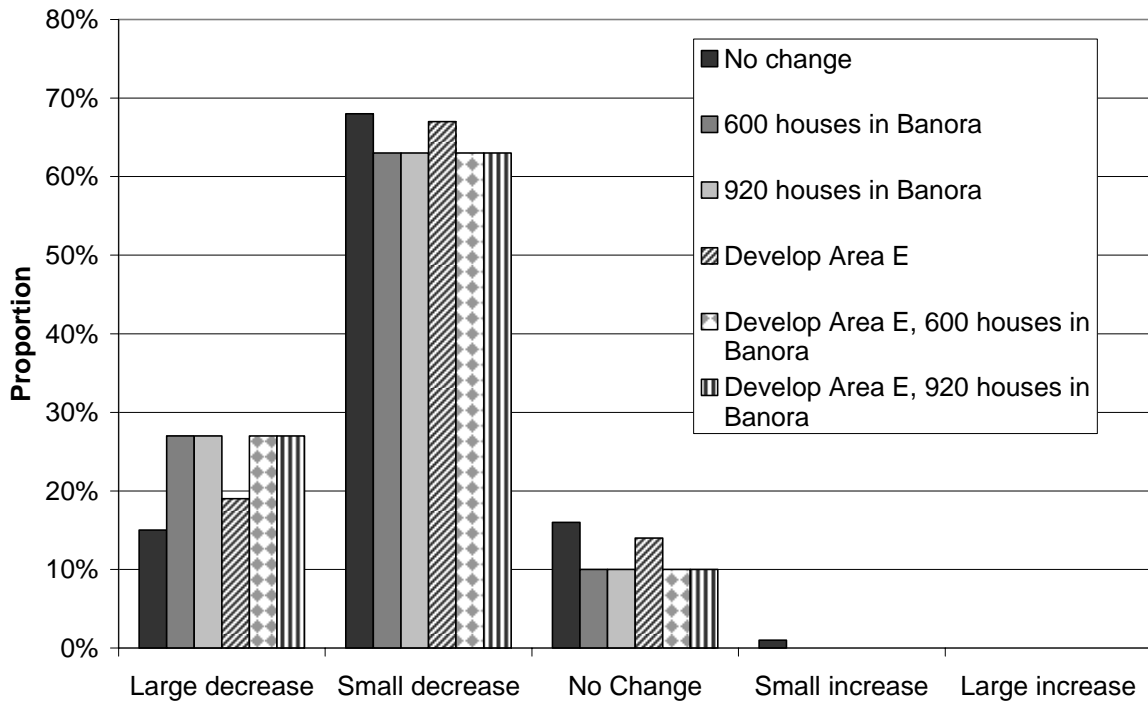


Figure 10. Impact of Urban Development options on Saltmarsh

In addition to impacts on the ecology of the Broadwater, urban development is expected to have significant impacts on terrestrial ecological outcomes. These impacts are through increases in weeds and domestic pets as well as through direct removal of vegetation for development areas. Figure 11 shows the impact of urban development on weeds in the Terranora catchment. This figure shows that under the base case the most likely outcome is expected to be a decrease in weeds. Development of 600 houses in Banora or of Area E is expected to shift this likely outcome to being 'no change, while greater development in Banora or combining developments in Banora with Area E shifts the distribution so that the most likely outcome is an increase in weeds.

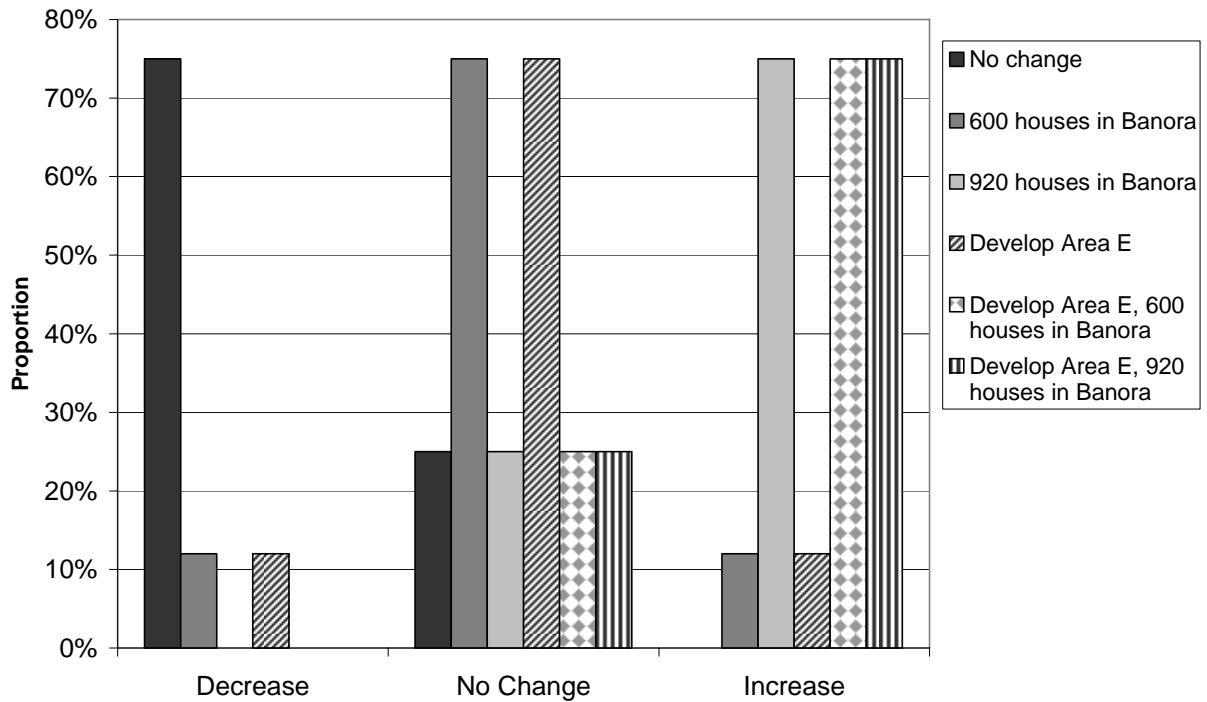


Figure 11. Impact of Urban Development on Weeds

Figure 12 shows the consequent effects of these changes in domestic pets, area of terrestrial habitat, saltmarsh and weeds on terrestrial fauna. This figure shows that the effects of urban development on terrestrial fauna are cumulative. Thus the impacts of development in both Area E and Banora are greater than for all other options, although the two options for Banora (600 and 920) can not be distinguished between these two scenarios. Development of Area E in isolation is shown to be worse than development of Banora with a greater chance of a large or small decrease. Greater amounts of development in Banora (ie. 920 houses rather than 600) also lead to worse outcomes compared to the smaller development. The most likely outcome under all options remains 'no change', but the probability of a small decrease under the combined development options is similar to this probability.

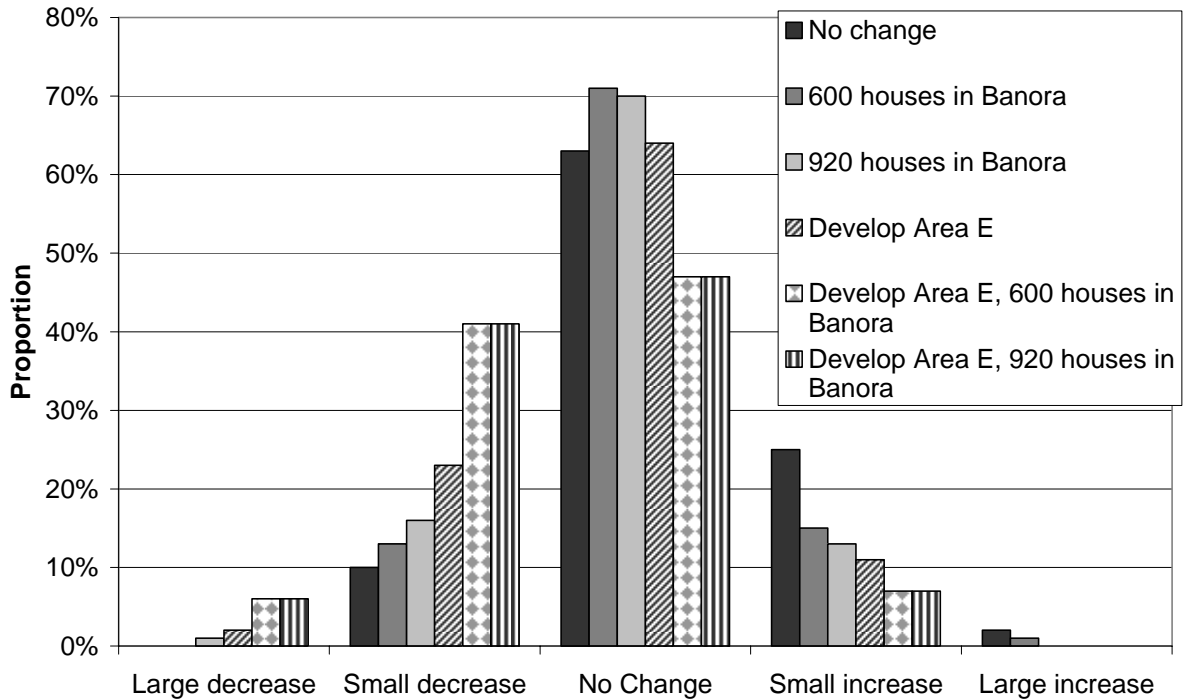


Figure 12. Impact of Urban Development on Terrestrial Fauna

Other impacts of urban development are on flooding and flood risks and the costs associated with disasters. Figure 13 shows the impact of urban development on disaster costs. This figure shows that development in Area E is not expected to have any impact on disaster costs, as would be expected given it has no additional flood risks associated with it. However, development in Banora is associated with significant flood risks and this is borne out by the consequent increase in disaster costs associated with these options. Under the base case the most likely outcome is a small decrease in disaster costs. Where Banora is developed the most likely outcome becomes 'no change' and the probability of a small increase is as likely as a small decrease.

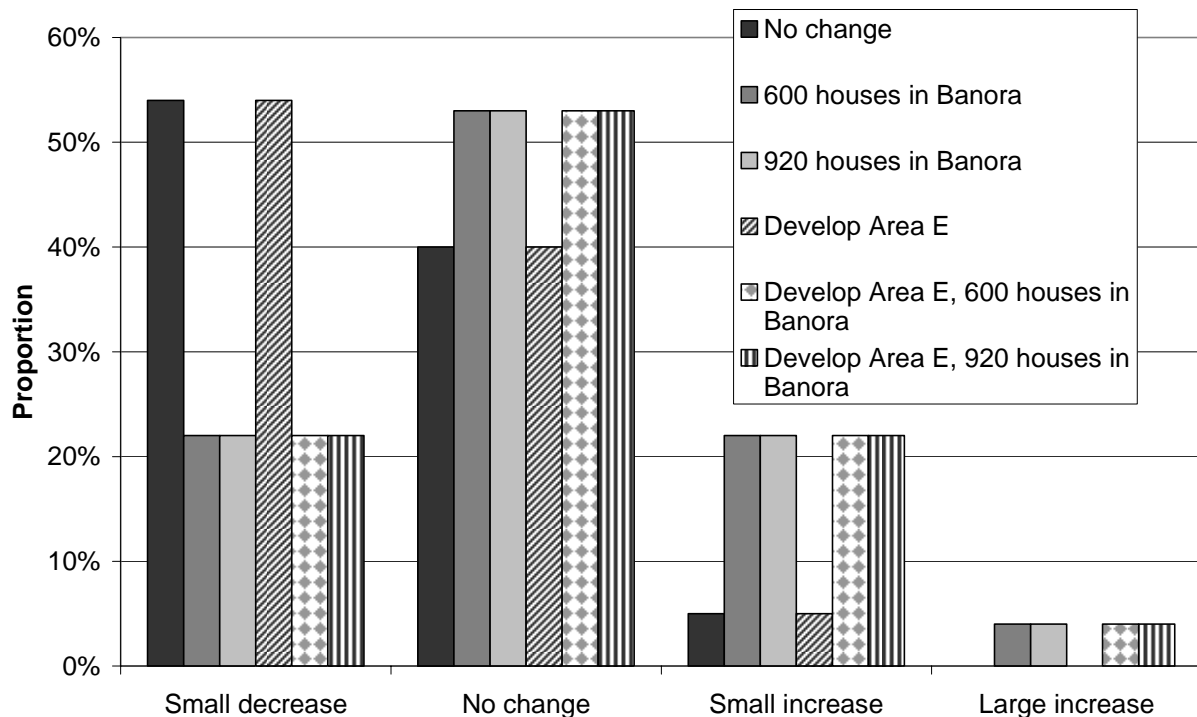


Figure 13. Impact of Urban Development on Disaster Costs

Overall these results show the complexity of trade-offs associated with urban developments as well as the broad nature of expected impacts. While residential development in Banora is associated with similar impacts of TSS, TN and TP, and better pH outcomes as well as smaller impacts on terrestrial fauna, development in this area comes at a higher cost in terms of flooding and weeds than development in Area E. Thus the decision to develop Area E or Banora in isolation needs to consider fairly complex trade-offs and neither option is preferable in all impacts. The results also show the cumulative nature of development, such that more extensive or intensive development is associated with greater impacts. Importantly consideration of these impacts relative to the improvements gained by sewer upgrades and stormwater retrofitting show that these options are unlikely to fully offset the increased pollution derived from urban development and do nothing to offset other important impacts such as those on migratory birds and terrestrial fauna or on flood risks and associated costs.

5 DISCUSSION OF THE RESULTS

This Sustainability Assessment report has provided a sample of results for stormwater retrofitting, sewer upgrades and urban development. These options are a small subset of the total number of scenarios which can be considered by the Terranora CLAM and as such do not provide conclusive evidence of the 'best' way forward from the options available. They are interesting in that they illustrate the potential for actions to improve the overall condition of the lake and catchment system.

These results demonstrate the difficulties in offsetting the consequences of urban development with positive actions such as sewer upgrades or stormwater retrofitting. Stormwater retrofitting is likely to have impacts on pollutant inputs but this does not lead to any change in the concentration of these pollutants in the Broadwater with the exception of TSS which does experience a small decrease in concentration. One of the main impacts of stormwater retrofitting is to decrease sedimentation although this is only expected to occur at the highest level of retrofitting. Decreasing sedimentation leads to both positive and negative ecological outcomes with seagrass and saltmarsh increasing by a small amount while

mangroves can be expected to experience a small decrease. Stormwater retrofitting can also be expected to lead to increased costs to both Council and developers.

In contrast sewer upgrades are associated with significant increases in costs to Council and developers but no significant impact is expected on the water quality of the Broadwater. These results should be used cautiously given the coarseness of states used in the model and the poor quality of much of the data however they provide an interesting outcome that warrants further investigation. In particular while stormwater retrofitting was associated with similar costs to sewer upgrades it is expected to lead to modest changes in water quality and ecological outcomes.

Finally the results showed the complexity of trade-offs associated with urban developments as well as the broad nature of expected impacts. While residential development in Banora is associated with similar impacts of TSS, TN and TP, and better pH outcomes as well as smaller impacts on terrestrial fauna, development in this area comes at a higher cost in terms of flooding and weeds than development in Area E. Thus the decision to develop Area E or Banora in isolation needs to consider fairly complex trade-offs and neither option is preferable in all impacts. The results also show the cumulative nature of development, such that more extensive or intensive development is associated with greater impacts. Importantly consideration of these impacts relative to the improvements gained by sewer upgrades and stormwater retrofitting show that these options are unlikely to fully offset the increased pollution derived from urban development and do nothing to offset other important impacts such as those on migratory birds and terrestrial fauna or on flood risks and associated costs.

6 ACKNOWLEDGEMENTS

This project has been funded by the Northern Rivers Catchment Management Authority. The authors would particularly like to acknowledge the efforts of Roger Stanley of the CMA who has managed to project and provided considerable time and knowledge to this work. In addition the time and efforts of the project Reference Group need to be acknowledged. This group consisted of John Schmidt, Department of Natural Resources, Brian Hughes of Coastcare (initially), David Greenhalgh of the Solitary Islands Marine Park Authority, Marcus Riches of the Department of Primary Industries and Steve Jensen of the Department for Planning. Finally this CLAM and subsequent results would not have been possible without the efforts of Tweed Shire Council, in particular Tom Alletson.

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APPENDIX 1. NODES IN THE TERRANORA CLAM

Node	Description	Output States	Units
Aesthetics	Foreshore aesthetics	Decline, No change, Improve	
Algae and Phytoplankton	Frequency and severity of algae and phytoplankton blooms	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Aquatic fauna	Aquatic Fauna Biodiversity	Large Decrease, Small Decrease, No Change, Small Increase, Large increase	
Birds Bay seagrass	Whether seagrass beds in the Birds Bay area are removed or remain as a result of dredging	Remain, Remove	
Boat access	Boat access to lake	decrease, no change, increase	
Cost to Council	Qualitative assessment of 'disaster' and 'development' costs to Council	no change, small increase, large increase	
Development costs	Qualitative representation of costs associated with developments and management actions	No Change, Small Increase, Moderate Increase, Large increase	
Direct Mangrove impacts	Area of mangroves directly affected by development activities (rather than lake processes etc.)	Small Decrease, No Change, Small Increase	
Direct Saltmarsh impacts	Area of saltmarsh directly affected by development activities (rather than lake processes etc.)	Small Decrease, No Change, Small Increase	
Direct terrestrial vegetation impacts	Area of terrestrial vegetation directly affected by development activities	> 30 ha loss, > 30 ha loss, no change, small increase, large increase	hectares
Disaster costs	Qualitative representation of costs associated with disasters	No Change, Small Increase, Large increase	
Domestic pets	Qualitative changes in number of domestic pets in the catchment	No Change, small increase, large increase	
Domestic pet management	Qualitative change in management of domestic pets in the catchment	No Change, Improve	
Fish passage	Qualitative changes in quality and extent of fish passage	Decline, No Change, Improve	
Flood risk	Qualitative representation of increased flooding risk associated with developments (note that this does not take into account rising water levels – see Frequency of Flooded Infrastructure)	Small Decrease, No Change, Small Increase, Moderate increase	

Frequency of flooded infrastructure	Qualitative representation of increased frequency of flooded infrastructure	Small Decrease, No Change, Small Increase, Moderate increase	
Lake depth	Qualitative representation of lake depth	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Lake flushing	Percentage change in the lake flushing exchange time	>10% Decrease, 10 - 5% Decrease, 5 - 0% Decrease, No Change	%
Mangroves	Qualitative representation of change in area of mangroves	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Migratory birds	Migratory Birds Biodiversity	Large Decrease, Small Decrease, No Change, Small Increase, Large increase	
Mosquitoes	Qualitative representation of change in impact of mosquitoes on residential populations	No Change, Small Increase, Moderate Increase	
Oysters	Qualitative representation of productivity of oyster industry in Terranora Broadwater	Small Decrease, Large Decrease, No Change, Small Increase, Large Increase	
Pathogen input	Quantitative representation of input of pathogens to Terranora Broadwater	<14, 14-150, 150-1000, >1000	cfu/100ml (CFU = colony forming units)
Lake pathogen	The concentration of faecal coliforms in Terranora Broadwater	<14, 14-150, 150-1000, >1000	cfu/100ml (CFU = colony forming units)
pH input	Qualitative representation of change in pH of inflows to Terranora Broadwater	Decrease, No Change, Increase	
Lake pH	Qualitative representation of change in pH of Terranora Broadwater	Decrease, No Change, Increase	
Population	Quantitative representation of change in population in the Terranora Broadwater catchment	No Change, increase up to 2000, increase up to 4000, increase up to 6000, increase over 6000	
Recreational Amenity	Qualitative representation of change in recreational amenity provided by the Terranora Broadwater	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	

Direct riparian vegetation impacts	Area of riparian vegetation directly affected by development activities (rather than lake processes etc.)	Small Decrease, No Change, Small Increase	
Lake salinity	Change in the median lake salinity	<24.5, 24.5-24.75, 24.75-25, 25-25.25, 25.25-25.5, 25.5-25.75, >25.7	Practical Salinity Units (no units)
Saltmarsh	Qualitative representation of change in extent of saltmarsh in the Terranora Broadwater catchment	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Seagrass	Qualitative representation of change in extent of seagrass in the Terranora Broadwater	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Sedimentation rate	Qualitative representation of change in sedimentation rate of the Terranora Broadwater	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Terrestrial fauna	Terrestrial Fauna Biodiversity	Large Decrease, Small Decrease, No Change, Small Increase, Large increase	
TN input	Inputs of total nitrogen to Terranora Broadwater.	<7,500, 7,500-10,000, 10,000-12,500, 12,500-15,000, 15,000-17,500, >17,500	kg/year
Lake TN	Total nitrogen in Terranora Broadwater	<260, 260-280, 280-300, 300-320, 320-340, >340	µg/L
TP input	Inputs of total phosphorus to Terranora Broadwater.	<2,000, 2,000-2,500, 2,500-3,000, 3,000-3,500, 3,500-4,000, 4,000-4,500, >4,500	kg/year
Lake TP	Total phosphorus in Terranora Broadwater	< 38, 38-42, 42-44, 44-46, 46-48, >48	µg/L
TSS input	Inputs of total phosphorus to Terranora Broadwater.	<80,000, 80,000-100,000, 100,000-120,000, 120,000-140,000, >140,000	kg/yr
Lake TSS	Total suspended solids in Terranora Broadwater		g/m ³
Lake water level	Quantitative representation in change in the lake water level (not "water depth" as termed in this model, as this is affected by sedimentation rate)	<1, 1 – 1.1, 1.1 – 1.2, 1.2 – 1.3, > 1.3	m

Weeds	Qualitative representation of change in weed coverage in the Terranora Broadwater catchment	small decrease, no change, small increase	
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APPENDIX 2. ADDITIONAL SCENARIO GROUPS AVAILABLE IN THE CLAM TOOL

1. Area E Access
2. Acid Sulfate Soil Management
3. Buffer extent
4. Domestic Pet controls
5. Drain Management
6. Dredging
7. Riparian Management
8. Sea Level Rise
9. STP Upgrades
10. Stormwater enforcement

Area E Access

There are two major access road proposals for Area E. Arbitrary names of *Route 1* (alternative) and *Route 2* (proposed) have been assigned. Both traverse vegetated areas to the north of the main development area. Route 2, the proposed route, follows an alignment further north than that of Route 1 and is therefore considered to replace 2 ha bushland/riparian areas rather than 2 ha of unimproved pasture (Route 1)

(ref: Figure 3-24 *Tweed Area E Comprehensive Planning Framework Draft Local Environmental Study*, Parsons Brinckerhoff 2003; TSC GIS data and GeoLINK landuse analysis)

Acid Sulfate Soil Management

Increased effort in enforcing mitigation measures for acid releases from Acid Sulfate Soil was modeled. Such mitigation measures would include liming, bunding and reduced excavation depth, with enforcement measures including stricter development consent conditions, more frequent development inspections and increased ranger patrols.

No quantitative data was available to model the effects of this scenario, therefore an assumption of a moderately positive effect on "pH input" to the lake was assumed.

Buffer extent

Tweed Shire Council currently requires a minimum vegetated buffer width of 40m between new developments and waterways. This scenario investigates the impact of increased capture efficiency associated with a doubling of the width of buffers.

Section 7.7.3 of the Environmental Impact Statement associated with the proposed upgrade of the Tweed West and Banora Point Water Reclamation Plants (*Banora Point and Tweed Heads West WRP Reclaimed Water Management Strategy Environmental Impact Statement*, GHD (2004)) provides some indication of the capture rates associated with riparian planting. Based on those figures, the following estimates of capture rates for increased buffers were used in the model:

- TN – 15% captured
- TP – 20% captured
- TSS – 30% captured

Domestic Pet controls

Reducing impacts on native fauna due to domestic pets was considered in terms of prohibiting domestic pets from new developments. (There is also a desire to model the positive impact on pathogen levels in the lake associated with a prohibition of pets in new developments, however the current pathogen model is unable to model this effect).

No data was available to inform the model on the extent of the effect of this scenario. Prohibition of domestic pets in new developments was considered to lead to an "improved" state of "Domestic Pets Management" (which could also be achieved via the "Community

Education" scenario), which in turn had a small effect on "Abundance and Diversity of Terrestrial Fauna".

Drain Management

Recent years have seen enormous improvements in the management of agricultural drainage networks (primarily associated with cane farming) in order to limit acid and 'black-water' drainage events. However, it is thought that these works could be expanded further, although no *specific* details on the nature and extent of such works has been considered. A qualitative (and relatively small) increase in pH drainage to the lake has been assumed as a result of the "improved management" option.

Note that the final report for the Tweed River Estuary Ecosystem Health Monitoring Program 2000 to 2001 (University of Queensland Marine Botany Group, 2003) reports that the seasonal average for pH in the Terranora Broadwater is "excellent".

Additionally, the "improved management" option is also associated with a slight improvement in "fish passage".

Dredging

The Terranora Broadwater Navigational Dredging Study (Patterson Britton, 1996) recommends dredging of varying depths in a number of locations and channels in the northern parts of the broadwater (see Figure 2.1 of the study).

The report recommends the creation of artificial islands in Trutes Bay and Charles Bay in the southern parts of the broadwater with dredging spoil. Therefore, in addition to a positive effect on boating access (the primary reason for considering dredging) and flushing time (an effect noted qualitatively in the report) dredging is also considered to have a positive effect on the extent of mangroves.

The proposed dredging regime will remove seagrass from Birds Bay in the far north of the broadwater.

Short term increases in suspended solids and nutrients (noted in the report) were not modeled as the CLAM does not accommodate time-limited effects.

Riparian Management

Tweed Shire Council works with land holders throughout the total catchment of Terranora Broadwater (i.e. the combined catchments of Bilambil Creek, Duroby Creek and Terranora Broadwater) to encourage riparian planting. Such works aim to reduce nutrient export from upslope areas, reduce streambank erosion and limit cattle access to creeks (thereby limiting pathogen export).

It was assumed that all planting would occur directly downslope of the three landuse classifications associated with agriculture, namely improved pasture, unimproved pasture and cropping. A representative of Tweed Shire Council has indicated that riparian 'coverage' of these landuses is low, however no quantitative data on the proportional 'coverage' of these landuse classifications throughout the total catchment is available. An assumption of 2.5% coverage of each landuse classification was made.

The scenario options modeled are

1. no planting
2. 5 km of planting
3. 10 km of planting
4. 20 km of planting

In order to translate these lengths of riparian planting works into additional percentage coverage of a certain landuse, an estimate of the total stream length through the catchment was made (142 km). The proportion of total stream length represented by the length associated with each planting option was then assigned to each of the three landuse classifications via a weighted average of existing landuse area.

Sea Level Rise

The sealevel is predicted to rise in the future due to climate change. The climate change scenarios were estimated from Whetton and Holper (2001) and reviewed by Dr Kevin Walsh, CSIRO atmospheric Research (pers. Comm. September 2004).

The options are to predict the increase in sea level in by the year 2030, 2050 and 2100. The predicted sealevel rise (cm) from values in the year 2004 used here were:

Rate of sea level rise	2030	2050	2100
Low	2	3.6	7.6
Medium	11	19.8	41.8
High	20	36	76

A normal distribution was assumed to describe the probabilities of the low, medium and high rates of sea level rise. Thus the assigned probabilities were 0.25, 0.5, 0.25 respectively. The probability of the various rates in sea level rise are dependant on the amount of carbon dioxide released into the atmosphere, which in turn is reliant on the national and global policies. Research into likely policies in the future is beyond the scope of this study.

STP Upgrades

To accommodate population growth in the Tweed region, Tweed Shire Council proposes to upgrade the Tweed Heads West Water Reclamation Plant (WRP) and Banora Point WRP. The Tweed Heads West WRP was constructed in the 1960's and has expanded over the years to a capacity of 10,000 equivalent persons (EP). The Banora Point WRP has been in operation since 1978 and has a capacity of 50,000 EP, with a present loading of 42,000 EP.

The proposed upgrade works will lead to an improvement in the quality of the effluent produced by both WRPs to effluent reuse standard. Additionally, the capacity of Banora Point WRP will be increased to 75,000 EP.

Both plants discharge reclaimed water into Terranora Creek downstream of the Dry Dock on the ebb tides, and will continue to do so under the proposed works.

The EIS (*Banora Point and Tweed Heads West WRP Reclaimed Water Management Strategy Environmental Impact Statement*, GHD (2004)) suggests qualitatively that the discharges from the WRPs has a limited effect on the water quality of Terranora Broadwater. By way of an assumption, the impact of the WRP discharges has been 'scaled' to 10% of that expected if the WRPs were discharging directly to the broadwater.

The scenario options currently modelled are

1. No upgrade
2. Upgrade STP's under preferred option (option 6) as outlined in the EIS

Stormwater enforcement

The potential for reduced diffuse stormwater pollution via increased enforcement of existing stormwater regulations was considered. Such increased enforcement would be primarily be increased patrols by general council rangers, and possibly the introduction of a specific environmental ranger.

In the absence of quantitative data or advice from Tweed Shire Council on the extent, nature and/or effectiveness of increased enforcement effort an assumption of 5% reduction in pollutant (TN, TP and TSS) loads was assigned to this scenario.