4.3 WATER QUALITY FOR ECOLOGY

Objective WE: Maintain water quality to protect healthy ecosystem function in the estuary and rivers

Managing water quality is an important part of managing the ecology of the catchment and estuary in a sustainable manner. Estuaries are places where fresh and saltwater mix. Floods can deliver large amounts of organic and inorganic material to the receiving waters of an estuary, and where there is little water exchange with the ocean, the estuary can become a sink for these materials. Flow regulation (water extraction, impoundment and changes to flow regimes) can further alter the variation in freshwater inputs, impacting processes and altering the balance of external versus internal loads and diffuse versus point sources of nutrients. The ecological function of the rivers and estuary is influenced by the quality of the water. Flora and fauna are at risk when water quality is degraded. The links between the rivers and the estuary mean that poor water quality in one may affect the other.

Nutrients enter or exit the estuary through surface water, groundwater, sediments, atmosphere and cycle within the flora and fauna. Nitrogen and phosphorous are considered key nutrients responsible for plant growth and the degree to which their concentrations are modified is largely determined by factors such as depth, flushing time, river flow, dissolved oxygen and a number of biological interactions at a number of scales. If there are surplus nutrients entering from the catchment, an estuary has the potential to become eutrophic (nutrient enriched) and develop plant biomass (usually algae) that can severely alter ecosystem structure and function.

The sediments in an estuary provide one of the major habitats from which many significant ecological processes occur. The interactions that occur between the biota and their environment and knowledge of the characteristics and distribution of the sediments are essential to understanding these processes. Estuarine sediments strongly interact with the over-lying surface waters, and can modify physical, chemical and biological processes. They are derived principally from riverine sources although the sea also provides sandy material brought in during storms and by strong tidal currents.

Contaminants such as heavy metals and pesticides can accumulate within sediments and have the potential to cycle through the food chain. These compounds can be toxic to aquatic organisms and can bioaccumulate in fish, shellfish and humans. These compounds enter estuaries from urban stormwater, atmospheric fallout and industrial discharges.

4.3.1 Issues & Threats

WE1. Disturbances to environmental flow

The flow in streams is naturally variable and determined by extremes of flood and drought. The volume and velocity of flow influences the amount of habitat and food available for the instream organisms as well as influencing water quality. The variability of flow as evidenced by frequent changes in water levels and changes in the "wetted area" is critical for maintaining biological productivity, triggering fish and waterbird breeding and the regeneration of wetland plants (DLWC, 1997). Disturbances and effects on aquatic ecology related to environmental flow have been discussed in Section 2.2.5. Release of water from dams has the potential to alter the downstream aquatic ecology. This can occur through discharge of cold water (thermal pollution) and also through the release of pests into downstream environments.

WE2. Increased sediment and nutrient loads from existing landuses affect water quality

Historically, sediment and nutrient control have not been a concern in the development of urban areas. This has created stores of nutrients and sediments previously removed from the catchment, and deposited in the estuary and waterways. Practices in existing urban areas continue to contribute nutrients and sediments to the estuary. The stormwater system can convey sediments, nutrients and other pollutants from activities such as fertilisation, top dressing, car washing, dog faeces and detrital material to downstream environments. Historically, urban development was not planned in a way that provided space for stormwater treatment devices. Retrofitting stormwater treatment and removal devices is expensive and high in maintenance and often unpopular with adjacent residents.

There has been agricultural activity in the catchment since the arrival of settlers to the Wyong area. Much of the original agricultural land is still in use today and as such the main threats to nutrient and sediment loads come from the operation of existing agricultural areas rather than the development of new ones. Turf farming has been identified as being the most significant form of intensive agriculture in the catchment (WSC, 1998b). Other forms of intensive agriculture such as market gardens and poultry farming also have the potential to generate high export rates of nitrogen and phosphorus. These activities have the potential to contribute nutrients and sediment to the waterways of the catchment, and ultimately influence the estuary.

WE3. Increased sediment and nutrient loads from new development affect water quality

Urban development is one of the most significant threats to the health of the Tuggerah Lakes estuary and its catchment. Disturbing the existing soils and vegetation of a catchment mobilises nutrients and sediments. Historically, there has been little control of sediments or nutrients from urban development. As soil is exposed through removal of vegetation and the shaping of construction sites, the potential for erosion substantially increases. Minor rainfall events are then capable of eroding and transporting sediment from the catchment where previously the rainfall may have either infiltrated or flowed over vegetated ground.

Nutrients are an issue in new developments because they are frequently bound to the surfaces of sediment. When sediments containing nutrients are eroded they take away sustenance from terrestrial environments and frequently transport it to aquatic environments. In recent years, focus has been increasing on erosion control at development sites. The use of fast growing grasses is an effective tool in erosion control, however applying fertilisers to stimulate growth in areas where there is no effective vegetation cover, can result in their transport from the catchment to the estuary.

Agricultural development is generally limited to the floodplains of Wallarah Creek, Wyong River and Ourimbah Creek. While there has been limited new agricultural development in these areas, there is the potential for changes in the type of agriculture which may impact on sediment and nutrient loads.

Road development can contribute both sediments and nutrients to waterways. The construction process involves the use of gravel, bitumen, fill and heavy machinery to shape and finish road surfaces. Historically, there has been little or no sediment and erosion control, however it should be noted that this practice has improved considerably in recent years. Nevertheless significant amounts of road base, gravel etc. can be found throughout the stormwater systems. The management of rural road maintenance has become an increasing issue for riverine health. Erosion from unsealed roads is high and without appropriate sediment and erosion control the sediments are conveyed to the rivers and streams. There are areas of the estuary where deltas of gravel and road-base have formed in front of stormwater outlets that drain main roads.

There are a number of areas in the catchment targeted for substantial development in coming years. In order to prevent future increases in sediment and nutrients loads, development must be subjected to effective control.

WE4. Toxic contaminants in runoff could affect aquatic ecology and human health

Contaminants can include trace or heavy metals, pesticides and organic compounds. Trace metals occur naturally in the environment as a result of the weathering of rocks and soil, however in high concentrations some of them can be toxic to aquatic organisms. High concentrations within the water or sediments can indicate contamination from both domestic and industrial sources. Pesticides and organic compounds can also accumulate in the sediments and may reach concentrations that are also toxic to aquatic organisms and/or have the potential to bioaccumulate within food chains.

The potential sources of contaminants for the estuary include: roads, vehicle exhausts, urban stormwater, fly-ash from power generation and industrial discharges. Once introduced to the sediments, disturbance has the potential to mobilise the contaminants back into the water column and increase the potential for bioaccumulation.

As part of the Estuary Process Study, contaminants in sediments were assessed (Roberts, 2001). In general, pesticides were below laboratory detection limits and trace metals were within the range that does not cause adverse environmental effects (Long et al., 1995). However, there was no assessment of the bioaccumulation of these contaminants within organisms of the estuary.

WE5. Stored sediments and nutrients can be mobilised

Sediments have a range of particle sizes. Smaller sediments often remain in suspension and are transported by flow. In areas of low or no flow most of these particles will drop out of suspension. Larger particles and rocks usually remain on the bed of the waterway and are slowly pushed along by attrition or moved some distance under very high flows. Under the right flow conditions, deposited sediment can be mobilised and transported to downstream environments. The effect can vary from increasing turbidity (and therefore decreasing ecological activity such as photosynthesis) to smothering habitats.

Nutrients are a risk in bed loads. Eroded soils can contain nutrients attached to their surfaces. In addition some sediment absorbs nutrients from the water column when they come into contact. These sediments then act as a sink for nutrients and can potentially become a source, releasing them under the right conditions.

Nutrients within the bottom sediments were assessed in the Estuary Process Study (Roberts, 2001). Generally, the concentrations of nutrients within the

sediments were greater within the open-water habitats compared to the shallow seagrass habitats. The fine muddy sediments within deeper habitats were capable of retaining greater concentrations of nutrients because sediments with high organic content have more “places” for nutrients to attach. The organic content of sediments generally increases as the sediment texture becomes finer (Roberts, 2001). In general, the concentrations of nutrients in the Tuggerah estuary were found to be less than or similar to those reported by King & Hodgson (1995) and those in other local estuaries (Mann et al., 1996).

WE6. Managing the ocean entrance

The entrance to Tuggerah Lakes is currently kept open by a dredging programme. This is done to minimise the risk of flooding, retain the tourist appeal of The Entrance channel and existing patterns of flushing within the estuary.

Having an open entrance allows floodwaters to escape to the ocean as they enter the estuary. A closed entrance would tend to hold floodwaters back in the estuary until the entrance broke open. A permanent entrance (e.g. breakwall) would reduce the risk of flooding by creating a larger connection to the ocean. However this could potentially alter the lake level, exposing greater areas of mud flats in the shallows and altering the ecology of the estuary.

The existing channel at The Entrance is a very popular tourist destination. Visitors and locals use it for boating, swimming, wading, fishing, prawning and picnicking. A permanent entrance would cause stronger tidal flows which may be unsuitable for many of these pursuits. A closed entrance would change the water quality in the channel, making it similar to the water quality in the main body of the estuary.

The current dredging regime allows limited exchange between the estuary and the ocean. Flushing of the estuary occurs on two scales. During floods there is no tidal exchange, however the flushing is much greater, taking with it large volumes of sediments and nutrients. During non-flood periods, there is a small flushing exchange of waters within 1 km of The Entrance where lake water is drawn out and replaced with marine water. Over time this tidal cycle, combined with river inflow and wind-driven mixing within the estuary, work together to flush the estuary around every 100 days. Modelling has shown that a permanent entrance would not change the level of flushing all that much.

Work done as part of the Estuary Process Study (Roberts, 2001) showed that nutrients are exported from the estuary at the rate of 58 T/yr of nitrogen and 10 T/yr of phosphorus. Closing the channel to the ocean would mean that these nutrients would remain in the estuary. Permanently opening or closing the

channel would change the amount of nutrients exported from the estuary. This has implications for the organisms (e.g. macroalgae) and nutrient cycling in the estuary. Recent research (Dye, 2004) has shown that assemblages of meiofauna (small benthic animals that live in the mud and help to recycle nutrients) in Tuggerah Lakes were represented by taxa that represent a system under some stress. Changing the levels of nutrients retained in the system could impact on the way that meiofauna currently process these nutrients.

The recent drought has caused repeated closures and thwarted attempts to establish a permanent entrance in Lake Illawarra (which shares some common problems with Tuggerah Lakes) over the past two years. As a result, there has been a significant drop in lake-level and extensive dieback on exposed shallow margins. The public outcry has been significant and some $4 million dollars is now being spent to reduce the tendency of the entrance to close (Geary, 2004).

WE7. Foreshore and streambank erosion adds sediment to waterways

Waves and high velocity flow can greatly increase the erosion of streambanks and foreshores. Anthropogenic sources of waves and high velocity flow can accelerate these natural processes. For example, wash generated by boats has the potential to cause increased erosion of the riverbank by undercutting and erosion. The NSW Maritime Authority attempts to address this issue by declaring speed limits and no wash zones within the navigable sections of the tributary creeks. The area of responsibility for the NSW Maritime Authority is large and the resources for enforcement are limited, resulting in non-compliance in many instances. Increased public vigilance could greatly assist in addressing this issue.

Erosion control measures, such as seawalls can cause associated environmental effects. When a seawall is constructed to protect property, there is generally a disturbance to the adjacent unprotected foreshore (due to eddies). This is an issue for the tributaries and the estuary. They can have additional effects on aquatic ecology such as on instream and riparian vegetation in the rivers. Within the estuary, seawalls can have an adverse effect on seagrass meadows and benthic ecology.

4.3.2 Options

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
WE1. Disturbances to environmental flow	WE1a. Remove existing barriers	• Restore ecological passage between the rivers and estuary • Allow for water quality changes through increased mixing	• Removing weirs creates threats to the water supply • Alteration to current flow patterns • Management of potential nutrient and sediment stores behind weirs	High	High	WSC, GWCWA, DIPNR, DPI (Fisheries)
	WE1b. Modify existing barriers to improve flow mixing and allow for migration of key species	• Retain Water Supply access for pumping • Allow for water quality changes through increased mixing • Some ecological migration	• Does not allow for full migration • Could have impact on effectiveness of pumping for water supply	Med	Medium	WSC, GWCWA, DIPNR, DPI (Fisheries)
	WE1c. Do nothing	• Maintain water supply access and efficiency	• Isolation of rivers and estuary in low flow continues • Does not support migration during water quality changes	Low	Low	WSC, GWCWA, DIPNR, DPI (Fisheries)
WE2. Increased sediment and nutrient loads from existing landuses affect water quality	WE2a. Education and partnerships with landholders/residents	• Encourages the community to participate as partners rather than dictate to them • Promote understanding of key issues – lessen impact of uninformed press reports • Activities and programmes can be tailored to needs of subcatchments	• Time lag before on the ground changes are seen • Sceptics are unlikely to be any more convinced than with other methods	Low	Low-Medium	WSC, Community

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
	WE2b. Increase audit/regulatory activity	• Could provide a revenue stream that can be used to repair offenders contribution to issue • Immediate response where degradation is imminent	• Does not foster community participation or ownership • Potential for sceptics to suggest that it is purely a "revenue-raising" exercise • Not possible to manage all problems across the catchment in timely manner	Med	Low	WSC
	WE2c. Retrofits to upper catchment areas • Including major and minor treatment devices • Specific to receiving waters • Use of swales in place of kerb/gutter	• Able to utilise a full treatment train suite of options • Expose community to stormwater management options	• Increased levels of maintenance over large areas • Less space available in the developed upper catchment for constructing treatments and maintenance access • More sites for potential public liability concerns	Med-High *(depends on number of treatments and locations)*	Medium-High	WSC
	WE2d. Retrofits to lower catchment areas • including major and minor treatment devices • Specific to receiving waters	• Traditionally, more land available lower down in the catchment (lake edges) • Single maintenance locations • Less locations for potential public liability concerns	• One-off treatment location – if it is offline for any reason, the water quality for the whole catchment is untreated.	High	Low-Medium	WSC
	WE2e. Develop a catchment audit process for assessing high risk catchments and prioritising interventions	• Target high risk catchments for further monitoring or interventions • Reduce potential for spending money in the wrong place	• Can require field calibration which requires data collection • Costs associated with data collection • Need to find a medium that all staff can use	Low	Medium	WSC
	WE2f. Maintain stormwater treatment devices	• Lengthen periods of effective device performance • Improve performance of downstream devices in the treatment train	• Expensive to maintain • Depending on design they can present OHS issues for maintenance crews during cleaning	Med	Medium	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
	WE2g. Do nothing	• No increase in public liability exposure	• One of the largest contributors to sediment and nutrients for the estuary remains untreated	Low	Low	WSC
WE3. Increased sediment and nutrient loads from new development affect water quality	WE3a. Developers required to install appropriate controls in new developments - including road construction and agricultural development - WSUD - IWCM	• Can be undertaken when land is most accessible • Developers have an incentive to create master plans and site planning that meets objectives with minimal cost • Use developer contributions for works so that Council is not exposed to capital cost	• Difficult to enforce without significant expenditure on monitoring • Exact performance is not known until entire development comes online • Council likely to be exposed to long term maintenance costs • Lag time between when contributions are due and development comes online	Low-Med	Medium-High	WSC, Developers
	WE3b. Offer rate incentives to residents for contributing to reductions in sediment and nutrient loads	• Responsibility and opportunity for controls are passed directly to the community • Encourages community to take interest • Use any funds raised from rate increases to fund environmental programmes • Provides a market for new technologies to be trialled	• Cannot force individuals to participate – they can simply opt not to contribute • This option can only be enacted on individual blocks – modern blocks have small amounts of pervious land	Med-High	Medium	WSC, Community
	WE3c. Education of new residents and new industry	• Encourages the community to participate as partners rather than dictate to them • Promote understanding of key issues – lessen impact of uninformed press reports • Activities and programmes can be tailored to needs of subcatchments	• Time lag before on the ground changes are seen • Sceptics are unlikely to be any more convinced than with other methods	Low	Low-Medium	WSC, Community

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
	WE3d. Developers deposit performance bonds to be refunded on evidence of compliant treatment devices	• Ensure any water quality measures work before developers are released from their obligations • In the event of poor or under designed systems, the funds in trust can be used to correct problems	• Strong disincentive for development in the area which has flow on effects for the local economy • Costs likely to be passed on to residents • Potential effects on land prices	Low	High	WSC, Developers
WE4. Toxic contaminants in runoff could affect aquatic ecology and human health	WE4a. Identify potential source locations - waste disposal facilities	• Allows likely locations to be targeted for works and education programmes • Provides opportunity to act before contaminants are released to the estuary	• In isolation will not prevent releases – needs to be in conjunction with a treatment or prevention programme once sources have been identified • Many sources are not known until the release has occurred	Med	Medium-High (conjunction)	WSC
	WE4b. Increase regulatory activity	• Provides a revenue stream to repair damage or • Offenders pay for programmes rather than ratepayers	• Difficult to identify locations or offenders before release • Does not encourage people to want to participate – more likely to marginalise people	Med	Low-Medium	WSC
	WE4c. Education of community in general and high risk industry groups	• Encourages the community to participate as partners rather than dictate to them • Has the potential to change community attitudes • Promote understanding of key issues – lessen impact of uninformed press reports • Allows for preventative action (as opposed to the reactive action that occurs post-release)	• Will not encourage all of the community to participate – some will not be interested or in fact believe in its importance	Low	Low	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	WE4d. Water Quality sampling programme for main inflow points to rivers and estuary	• Able to identify individual release events and track their development • It is an independent means of assessing contaminant events – rather than waiting for reports or conducting assessments of potential sites	• Only possible after the contamination event • Sampling variables (how often, under what conditions, where in the stream etc) can influence both the cost and the success of monitoring	Med	Medium	WSC
	WE4e. Retrofit treatment devices to high risk locations	• Allows for treatment of sites before release • Focus on correct management approach for individual sites – not a blanket approach	• Difficult to fund and often difficult to find appropriate land space • Potential for devices to present public health risk	High	Low-Medium	WSC
	WE4f. Assessment of bioaccumulation of contaminants	• Close a major knowledge gap regarding the fate of contaminants	• Resource intensive	Med	High	WSC, DEC
WE5. Stored sediments and nutrients can be mobilised	WE5a. Prepare management plans and options for benthic areas with significant sediment/nutrient stores	• Allows Council to target significant stores before they are disturbed • Could be used as part of the development assessment process to ensure changes to bottom sediments are minimised	• Nil	Med	Medium	WSC, DIPNR, DOL
	WE5b. Minimise disturbance of sediments	• Reduces the potential for unintended sediment remobilisation • Assists in maintaining the current sediment and water chemistry profile	• The ecology of the estuary and the rivers may require these flow changes – minimising them to protect sediments and sediment chemistry may have negative effects • Hard to predict scale and likelihood of impact from various activities – minimising them may be unnecessary	Low	High	WSC, DIPNR, DPI (FISH), DOL

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
	WE5c. Do nothing	• Stores unlikely to rapidly release sediments and nutrients provided no changes are made to the storage floor or the flow regime moving over the storage area	• No preparation in the event that these stores are released	Low	Low-Medium	WSC
WE6. Managing the ocean entrance	WE6a. Adopt Healthy Rivers Commission recommendation and allow the entrance to close	• Reduced maintenance costs • Return the estuary to natural processes of opening and closing to the sea	• Likely reduction in water clarity in the entrance channel • Potential for reduction in tourist numbers • Unknown effect on ecology of estuary	Low *(in terms of works)*	Low (in terms of assisting ecology through entrance management)	WSC, Maritime Authority, DEC, DIPNR
	WE6b. Create a permanent entrance	• Potential for increased ocean related tourism and recreation (dive charters, deep sea fishing, yachts) • Marine water may extend further into estuary (unlikely to be significantly further)	• An associated increase in tourism has not been quantified • Potential decrease in safety with an increase in tidal flow • Increased need for erosion protection around the entrance • Loss of sand from North Entrance beach • Impacts on ecology are not understood • Increased risk of invasive transfers (e.g. Caulerpa) • Need for a pilot station • Risk to life and property Nth Entrance • Increased liability for WSC,DIPNR, DOL	High	Low	WSC, Maritime Authority, DEC, DIPNR, DOL

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	WE6c. Maintain existing entrance management strategy	• Current expenditures remain in place • Existing flood patterns and therefore plans remain in place • More natural hydrodynamics than a permanent entrance • Existing ecology has adapted to this flow regime • Provides for amenity at The Entrance	• High maintenance costs • Increased flooding levels than for permanent entrance	High	High	WSC, Maritime Authority, DEC, DIPNR
	WE6d. Create 2nd entrance at Budgewoi	• Potential for ocean going access from the estuary and associated recreation • Possible improvements to the local economy • Economic benefits from sale of extracted sand	• Loss of beach continuity • Interruption of littoral sand drift • Pilot station needed (costs) • Increased tidal range • Habitat loss • Increased erosion potential	High	Low	WSC, Maritime Authority, DEC, DIPNR
WE7. Foreshore and streambank erosion adds sediment to waterways	WE7a. Rehabilitate streambanks and foreshores	• Opportunity for reshaping edges to encourage interface between ecology and waterway • Improve amenity	• Resource intensive	Med	High	Land managers (WSC, DIPNR, DPI (Forests), DOL, CMA)
	WE7b. Limit seawalls and hard structures such as jetties	• Increased likelihood of natural interface between foreshore and water • Increased habitat opportunity	• Without appropriate rehabilitation, erosion will occur	High	Low-Med	Land managers (WSC, DIPNR, DOL, CMA)
	WE7c. Do nothing	• Erosion protection that does exist will continue	• Erosive eddies will continue to remove sediment from streambanks and on foreshores	Low	Low	Land managers (WSC, DIPNR, DPI (Forests), DOL, CMA)
	WE7d. Limit activities that cause erosion (e.g. boat wash, cattle, off road vehicles)	• Target specific problem areas • Enhance habitat protection	• Difficult to enforce	Med	High	Land managers (WSC, DIPNR, DPI (Forests), DOL, CMA)

4.4 WATER QUALITY FOR HUMAN HEALTH

Objective WH: Provide water quality in rivers and the estuary safe for primary human contact

Environmental values are particular values of the environment that are important for a healthy ecosystem or public benefit, welfare, safety or health, and require protection from the effects of pollution, waste water discharges and deposits (ANZECC, 1998). This statement reinforces the need to protect the health of recreational users of the rivers and the estuary.

The ANZECC (1998) and NHMRC (1990) guidelines describe the limits that are appropriate for primary human contact. Currently, monitoring is done by council to assess compliance with these standards for several locations within the estuary (where recreation is popular).

It is important that management of the estuary continues to ensure that the water quality in the estuary and rivers can be sustained for primary human contact. A key component of this aim is to assess the threat from pathogens, pests, thermal pollution and biohazards in addition to the commonly assessed criteria (such as faecal coliforms and enterococci).

4.4.1 Issues & Threats

WH1. Sources of pathogens and faecal coliforms in the rivers and estuary are not well understood

Pathogens within our waterways pose a threat to human health. Council currently monitors the pathogens within the estuary and water supply system. The sources of these pathogens are not well understood.

A study was commissioned into the use of faecal sterols to discriminate between the sources of faecal coliforms within the Tuggerah estuary (see Roberts, 2001). The results indicated that human faecal matter is only a minor component of the total faecal pollution within the receiving waters during rain events. Faecal pollution at all sites within the estuary was significant in terms of primary contact, but it appeared to be derived principally from native birds, and to a lesser extent, domestic pets (Roberts, 2001).

Within the water supply catchment the Water Authority has identified the potential risk associated with pathogens and their transfer between the storage dams and the rivers. The potential threats are to recreational water users and the water supply system.

WH2. Toxic algae

Within the waterways there are natural assemblages of phytoplankton (microscopic algae). These organisms respond directly to inputs such as light,

and nutrients. Within these assemblages, there are species that have the potential to become toxic under the right environmental conditions. Council currently monitors phytoplankton assemblages within the estuary and dams so that it can determine whether these species have become an issue.

WH3. Contaminants in runoff could affect aquatic ecology and human health

Stormwater systems convey gross pollutants and contaminants from the catchment to the receiving waters. Some of these pollutants pose a threat to human health such as needles, broken glass and contaminants from chemical spills.

WH4. Runoff from urban catchments and sewer overflows contain faecal coliforms

Urban catchments accumulate a load of faecal contaminants in the periods between rainfall events. In an event, the coliforms are transferred through the stormwater network into the receiving waters. Occasionally there are failures in the sewerage system and sewage overflows into the stormwater system and eventually into the receiving waters. At beaches, where stormwater is discharged, faecal contamination can present a risk for primary contact recreation.

4.4.2 Options

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
WH1. Sources of pathogens and faecal coliforms in the rivers and estuary are not well understood	WH1a. Investigate potential sources of pathogens faecal coliforms in the estuary and catchment	• Allows affected areas to be targeted which will reduce the poor recreational water quality readings in the estuary • Improve level of recreational amenity in the estuary • Potentially improve community attitudes towards estuarine health	• If the faecals are from diffuse sources it will be difficult to have targeted management	Med	High	WSC, DEC
	WH1b. Do nothing	• None	• Estuary will continue to have a poor recreational water quality report • Will not improve overall impression of estuarine health for the community	Low	Low	WSC, DEC
WH2. Toxic algae	WH2a. Monitor for conditions and occurrences	• Ability to react to outbreaks of toxic algae • Opportunity to intervene if environmental conditions are increasing the likelihood of threatening bloom	• Does not provide a long term solution to the threat – merely manages it as it occurs	Low-Med	High	WSC, Joint Water Supply
	WH2c. Do nothing	• Cost savings	• Potential for interruption to water supply • Liability if human health affected	Low	Low	WSC, Joint Water Supply
WH3. Gross pollutants in runoff could affect aquatic ecology and human health	WH3a. Install GPT's at high risk locations	• Aid in removal of health hazards • Can be installed where a problem has already been identified (reactionary treatments)	• Doesn't control the source • Pollutants may escape in high flow	High	Medium	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	WH3b. Beach cleaning	• Removes majority of gross pollutants from shores of popular ocean and lakes beaches • Depending on methods, can be used to improve overall amenity on beaches	• Damage to foreshore and shallow habitats • Infrequent cleaning does not mitigate overall risk	Med	Medium	WSC
	WH3c. Do nothing	• Less disturbance to habitats	• Increased likelihood of injury or damage to human health • Loss of amenity	Low	Low	WSC
WH4. Runoff from urban catchments and sewer overflows contain faecal coliforms	WH4a. Continue to monitor faecal coliforms at recreational locations	• Fulfil legal reporting requirements • Provide public with information on water quality at selected beaches	• The sources of the faecals are not well understood (see WH1) – and monitoring alone will not address this issue	Low	Low-Med	WSC

4.5 FLOW PATTERNS AND FLOODING

Objective WP: Maintain flow patterns while minimising flooding threat to life and property

The catchment of the estuary has undergone and will continue to undergo significant disturbance, which makes sustainable management of flow patterns difficult. When a catchment is disturbed (either naturally or by anthropogenic means), the hydrology (flow patterns) are also likely to be affected.

Urban development of a catchment is an example of such a disturbance. Channelisation, decreased infiltration, increased flood peaks and increased velocities are all common changes to hydrology in a catchment that has moved from rural/natural to urban landuse. Maintaining pre-development flows, during development, would minimise the hydrologic disturbance, however this has proven difficult in practice. Other examples of disturbance include the construction of barriers such as weirs, stormwater systems, dams and road crossings which impact on the flow patterns of the catchment.

A significant threat to the maintenance of existing flow patterns is the need to minimise the risk of flood to life and property. The design of stormwater infrastructure is intended to move water quickly away from developed areas, and in so doing reduce the risk of flood. This is in conflict with the aim of maintaining pre-development flows in a developing catchment. Another conflict between flood-risk and maintenance of flow patterns is the management of the entrance to Tuggerah Lakes. Development in the catchment has occurred over time, and a number of properties are at risk of flooding in certain events. Maintaining an open entrance reduces this risk. Effective management of flow patterns needs to find a balance between the often competing demands of flood mitigation and natural flow.

4.5.1 Issues & Threats

WP1. Difficult to maintain natural flow patterns after developing a catchment

As a catchment is developed, the amount of impervious (hard) surface increases by around 60-70%. This impervious surface replaces pervious (soft) surfaces that were able to absorb rainfall and transfer it to groundwater stores or for use by for plant evapotranspiration. The rain falling on the impervious surface is now included in the runoff from the catchment. In addition to changes in hard/soft surfaces, stormwater infrastructure is usually installed. This infrastructure replaces natural intermittent drainage lines with hard drainage networks, capable of transferring runoff at a much faster rate, and removing the opportunity for water uptake and ponding along the drainage line. The net result is that the receiving waters receive both a larger total volume and faster

inflow of freshwater compared to undeveloped catchments. In addition, the inflows are more frequent as runoff from smaller events is captured where previously it would have been removed as initial loss (soil infiltration). The estuary and the rivers have been receiving freshwater in natural flow patterns for millennia. In a relatively short period of time these waterways have begun to receive increased total volumes and velocities of freshwater. The physico-chemical properties of the receiving waters are also changed under these new conditions.

There are a number of ways that stormwater design can be modified to mimic natural events. Much of it is centred on controlled release of water from storage areas, such as detention basins and constructed wetlands, into stormwater channels that are more natural in appearance and function. Most of the advances in large-scale stormwater management are centred around stormwater flow control and not on recharging the ground or evapotranspiration cycles. This may have implications for downstream environments. Where there are no negative impacts, practices such as Integrated Water Cycle Management and stormwater harvesting may achieve multiple benefits in protecting downstream environments and supplementing the water supply system.

WP2. Sedimentation, weirs, drains and river crossings can create migration barriers and affect natural flows

Natural flow patterns can be impacted by the erection of barriers across streams and waterways. Barriers can include roadways, bridges and stormwater drainage. This issue has been discussed in Section 4.2.1 (WF2).

WP3. Risk of flooding

Wyong Shire Council currently maintains an open entrance channel to the sea, in part, to alleviate the effects of severe flooding in low-lying areas around the estuary. The entrance channel is kept open by Council's dredge and the resultant spoil from the dredging is relocated to the beach immediately north of the entrance.

Under natural conditions, the entrance channel would intermittently close over due to sand drift, being forced to open only when flood conditions behind the barrier caused water to break through. When the area around the edges of the estuary were developed during the 1900's, flood management criteria were not as well defined as today. As a result, there are over 1000 residential floors that would be affected by a 1 in 100 year event, although the numbers are slowly reducing as older properties are redeveloped. For the remaining low lying properties it is worth remembering that approximately 2 extra properties are

flooded for each 3mm rise in flood level (Wallace pers com., 2004), subject to the above described redevelopment.

Changes to the way The Entrance channel is managed will have an effect on lake levels. Twin breakwalls at the entrance and opening a second entrance in the north-east section of Budgewoi Lake (Budgewoi Sandmass) have been discussed as a way to increase tidal exchange and flushing (Roberts, 2001). The AEAM project was used to model these scenarios and found that these options would not have the desired "flushing" effects (Walkerden and Gilmour, 1996). If a permanent entrance was created, lake levels would fall, potentially reducing the flood risk for some properties. If the entrance was closed, it could potentially increase the flood risk for some properties. In addition, changes in lake level may affect the area of foreshore that is exposed. Table 8 shows the predicted area of foreshore that may be exposed with a corresponding change in lake level.

Table 8. Impact of lake level change on exposed foreshore area (after Wallace, 1999).

Lake Level (m AHD)	Description	Area of Lake Exposed (ha)
0.80	Minor flood level	0
0.50	High lake level in dry weather	14
0.25	Average lake level 1980-1985	76
0.15	Average lake level 1993-1997	108
0.10	Average lake level with channels (dry weather)	132
0.00	Minimum lake level without channels (dry weather)	296
-0.05	Minimum lake level with channels (dry weather)	401

NB: The channels that are referred to in the following table are dredged channels to provide navigable access to the ocean. They were modelled as approximately 45m wide and with depths of up to 2m below sea level (Wallace, 1999).

Any discussion about entrance management must ensure that the risks and benefits for both ecology and flooding are thoroughly examined, and not only the aesthetic benefits. As such it is strongly recommended that the upcoming Floodplain Management Strategy consider the outcomes of this Study and the Tuggerah Lakes Estuary Management Plan to minimise conflicts in management approaches.

4.5.2 Options

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
WP1. Difficult to maintain natural flow patterns after developing a catchment	WP1a. Set prescriptive criteria for developers as part of the assessment process - Base requirements on desirable flow - Develop optimal stormwater system designs	• Sets clear transparent targets for development • Criteria implemented at the development stage before dwellings are constructed –less obstructions – more design flexibility	• Doesn't include flow changes from existing development • Difficult to assess • Technically difficult to implement unless undertaken as part of a suite of treatments implemented from the master plan through to lot development	Med	Medium	WSC, Developers
	WP1b. Foster collaborative research programmes in the catchment	• Access to current best management practices • Cheaper than using cutting edge consultants • Can be harnessed as a capacity building exercise	• Delays implementation of on ground works • No guarantee the research will result in a positive treatment outcome	Low	Low (short term) High (long term)	WSC
	WP1c. Retrofit appropriate treatment devices	• Can be tailored to the needs of individual catchments • Will produce improvement on current post development regimes	• Difficult to provide sufficient land • Performance is variable • Potential for liability (flooding, public safety etc)	High	Medium	WSC
	WP1d. Install devices during new developments - WSUD - IWCM	• Can be tailored to the needs of individual catchments • Ensures new developments make a minimal contribution to flow change when compared with traditional post development flows	• Performance is variable • Determining responsibility for funding, designing and maintaining devices • Potential for liability (flooding, public safety etc)	Med-High	Medium-High	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
	WP1e. Ban new development	• No further changes to existing flow patterns • Reduce potential for further degradation of sensitive habitats • Minimal exposure to public liability • Further protection of habitat that would be lost to make way for development	• Potential for damage to the local economy – job loss • Create pressure on other local government areas to meet housing requirements/demand	Low	High	WSC
WP2. Sedimentation, weirs, drains and river crossings can create migration barriers and affect natural flows	WP2a. Remove existing barriers	• Restore ecological passage between the rivers and estuary • Allow for water quality changes through increased mixing	• Removing weirs creates threats to the water supply • Alteration to current flow patterns • Management of potential nutrient and sediment stores behind weirs	High	High	WSC, GWCWA, DIPNR
	WP2b. Modify existing barriers to improve flow mixing and allow for migration of key species	• Retain Water Supply access for pumping • Allow for water quality changes through increased mixing • Some ecological migration	• Does not allow for full migration • Could have impact on effectiveness of pumping for water supply	Med	Medium	WSC, GWCWA, DIPNR
	WP2c. Do nothing	• Maintain water supply access and efficiency	• Isolation of rivers and estuary in low flow continues • Does not support migration during water quality changes	Low	Low	WSC, GWCWA, DIPNR

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
WP3. Risk of flooding	WP3a. Maintain existing entrance management programme	• Current expenditures remain in place • Existing flood patterns and therefore plans remain in place • More natural hydrodynamics than a permanent entrance • Existing ecology has adapted to this flow regime • Provides for amenity at The Entrance	• High maintenance costs • Non-natural hydrodynamics • Increased flooding levels than for permanent entrance • Unknown impacts on the physical, chemical and biological processes in the estuary	High	High	WSC
	WP3b. Create permanent entrance - either through training walls or 2nd entrance	• Potential for increased tourism (from ocean going boats) • Increase opportunity for some forms of recreation • Clear marine water may extend further into estuary (unlikely to be significantly further)	• An associated increase in tourism has not been quantified and needs to be offset against loss of low scale of recreation • Potential increase in safety risks with an increase in tidal flow (boating hazards, fast flowing currents) • Increased need for erosion protection around the entrance • Loss of sand from North Entrance beach • Impacts on ecology are not understood • Increased risk of invasive species transfers	High	Low	WSC, Maritime Authority, DEC, DIPNR

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
	WP3c. Clearing obstructions to flow in rivers and key channels	• Reduced likelihood of flooding behind obstruction • Depending on type and location, could improve amenity, environmental flows and ecology	• Depending on type and location of structure – licensing and operations could be difficult • Disposal of removed material	Med	Med-High (*depending on location)*	WSC, DIPNR, Maritime Authority Other agencies depending on licence requirements
	WP3d. Do nothing	• Maintenance savings	• Increased risk of entrance closing and potential for increased flood peaks • Obstructions in rivers may cause localised flooding in areas previously unaffected	Low	Medium	WSC, DIPNR, Maritime Authority
	WP3e. Dune shaping at The Entrance in lieu of present dredging	• Provides a natural process where the entrance could be broken by flooding • Careful trimming to a set level would allow for a minimal impact on flooding levels	• Potential for significant ongoing maintenance costs for moving of earth • Potential ecology change from more permanent closure • Level of accuracy required may be difficult to achieve and maintain	Med-High	Low-Medium	WSC, DIPNR, Maritime Authority, DPI (Fisheries)

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	WP3f. Inter-estuary connection with Lake Macquarie - Chain Valley Bay to Lake Munmorah with sluice gates to control tidal flow. Objective is to increase flushing between systems	• Potential for increased boating based tourism between Lake Macquarie and Tuggerah Lakes	• Tidal difference between southern Lake Macquarie and northern Lake Munmorah is not likely to be significant due to the similarity in distance from their respective entrance openings. • The absence of a significant tidal gradient will limit the flow between the two bodies of water • Inter-body transfer of pest species • Ecological changes around the openings • Government approvals for such a project.	High	Low	DIPNR, WSC, LMCC, OLMCC, DPI (Fisheries), Department of Lands

4.6 WATER SUPPLY

Objective WS: Provide adequate water for community water supply

The Gosford-Wyong Joint Water Supply Authority manages the water supply for the local area. The Authority is currently dealing with a number of factors that are or will in the future impact on the available supply and storage of water for community needs.

The population of the area has increased significantly in recent years, which has increased demand for potable water. While sufficient water is available for the existing population in the interim, the Authority is considering a number of options to increase the amount of potable water to cope with the increasing population.

Activities in the water supply catchment can reduce the water yield, as can climatic variability (e.g. El Niño). Issues such as these can impact on the ability of water authorities to provide sustainable supplies for the community. Generally, the supply of potable water will gain priority over environmental flows in these circumstances, potentially creating a conflict between the needs of the estuary and those of the community.

4.6.1 Issues & Threats

WS1. Increasing population puts an increased demand on water supply

Wyong Shire is expecting to house between 60,000 and 80,000 new residents over the next 20 years. The annual water supply demand for the whole system (Gosford-Wyong) is currently about 34,500 ML (under restrictions) but is projected to rise to 40,000 ML by 2021. The extraction characteristics (annual averages from 1991-03) from rivers for water use are:

- 11,597 ML/a (Wynn, 2005a) from Wyong River from a total flow of 89,060 ML (Wynn, 2005b). GWCWA is currently permitted to extract to its existing pump capacity (17,700ML/a). When they apply for a change to the pump capacity, the extraction limits will be affected by the Wyong River Water Sharing Plan (Wynn pers com., 2005).
- 3,748 ML/a (Wynn, 2005a) from Ourimbah Creek from a total flow of 26,900 ML (Wynn, 2005b). Extraction is subject to a limit under the Ourimbah Creek Water Sharing Plan of 5,000ML/a (Wynn pers com., 2005).

Gosford Wyong Councils Water Authority (GWCWA) has a long-term implementation plan for water supply augmentation. This programme was established in 1985 by the former Department of Public Works and Services

and continues to be developed via WaterPlan 2050 to ensure that a secure water supply can be delivered as the population of the Central Coast increases.

GWCWA is also exploring ways of making the existing system more efficient, and in doing so, reduce the typical demand from a serviced tenements. A range of demand management initiatives are being implemented, including rainwater tanks for new buildings, improved maintenance and operational practices and harvesting excess surface flows from urban areas for use on parks and gardens.

The long-term augmentation plan will continue to be revised to ensure that any improvements from either demand management or drought management measures (see WS2 below) are taken into account before designing and implementing measures for future populations.

WS2. Persistent drought

The existing water supply system has been placed under pressure by an unprecedented drought, and to an extent, changes to water sharing arrangements. It is important to note that under normal rainfall conditions, the system can supply approximately 47,000ML/a. The unrestricted demand in early 2005 would be approximately 34,500ML/a, which leaves a surplus of 12,500ML/a (Wynn, 2005). GWCWA has been exploring options for accessing additional supplies to combat the effects of the drought and any reductions associated with Water Sharing Plans (which have provided for more "environmental" flow in water catchment tributaries), without having to take additional water directly from tributary surface flows.

WS3. Subsidence can drain river flow

Subsidence can damage a river bed to the extent that water is drained. It is often associated with mining, and in some cases, subsidence has stopped the flow in rivers. Cracking of stream beds has been noted in some catchments south of Sydney where streams were drained, causing a major obstacle to aquatic ecology along the length of the stream. Increased mortality, decreased migration and breeding of aquatic organisms and the potential for invasive species are all possible effects of a subsidence event. With coal mining being considered in the Tuggerah Lakes catchment, the threats from subsidence should be clarified.

WS4. Water yield decline from forestry and bushfires

A potential risk for the water supply is the impact of forest clearing and bushfires on catchment water yields. Wyong Council has been discussing this

issue with DPI (Forests) in recent months, particularly with respect to the logging in the Jilliby compartment (upper Wyong River).

Some studies in Victoria (Peel et al., 2000) indicated that, for the study catchments, a recently logged area yielded initially significantly more water than an old growth forest, however, this yield dropped dramatically as regeneration and growth takes more water. The yield generally returns to normal over a number of years. Similar patterns have been observed for forests that have experienced fire.

These activities are not likely to significantly reduce yields in the water supply catchment whilst the existing logging practices remain (i.e. selective logging as opposed to clear felling).

WS5. Climatic Change

Australia is affected by variability in climate on annual as well as longer periods such as decades. Short-term climate variations are superimposed on long-term trends. Consequently, any background trends in the mean climate can change the intensity or frequency of extremes associated with the shorter-term variability. It is these extremes in climate that have the greatest impacts on human activities (BOM, 2004). This natural variability is of concern to those planning water supply capture and use.

The greenhouse effect is a natural warming process of the earth. When the sun's energy reaches the earth some of it is reflected into the atmosphere and the rest is absorbed. The absorbed energy warms the earth's surface which then emits heat energy back toward space as longwave radiation. This outgoing longwave radiation is partially trapped by greenhouse gases such as carbon dioxide, methane and water vapour which then radiate the energy in all directions, warming the earth's surface and atmosphere. Without these greenhouse gases the earth’s average surface temperature would be about 35°C cooler (BOM, 2004). Global warming is a significant challenge in planning for future water supply.

4.6.2 Options

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
WS1. Increasing population puts an increased demand on water supply	WS1a. Urban water re-use (DPWS,2002) - IWCM - Stormwater harvesting	• Use of irrigation for open space areas • Could supplement supply at a site level, household water for washing, toilets etc	• Infrastructure costs • Public education and duty of care • Impacts on downstream environments from reductions in surface/ground flow	High	Medium	WSC, Joint Water Supply, Community
	WS1b. Industrial water re-use (DPWS,2002)	• Use of irrigation for open space areas	• Infrastructure costs • Public education and duty of care	High	Low	WSC, Joint Water Supply, Industry
	WS1c. Agricultural water re-use (DPWS,2002)	• Reduction in river extractions for agricultural irrigation would translate to additional flows at the Lower Wyong and Ourimbah Creek weirs	• Nil	Low	Medium	WSC, Joint Water Supply, Landholders
	WS1e. Implement leakage reduction and pressure control programmes (DPWS,2002)	• Reduces number of leaks and the leakage flows • Sprinkler flows will be reduced, thus reducing outdoor water demand	• Effectiveness of measure depends on the level of unaccounted water, which requires improving the existing metering and monitoring system	Low-Med	Med-High	WSC, Joint Water Supply
	WS1f. Installation of rainwater tanks for all new urban and suburban houses (DPWS,2002)	• Reduce both average annual flow and daily peak flows • Reduce load on existing stormwater infrastructure	• Cost passed on to homeowner • Reduction in flows to downstream environments	Low	Med-High	WSC, Joint Water Supply
	WS1g. Implement non-residential customer audit scheme (DPWS,2002)	• Provide some visibility of use	• Risk upsetting customers	Low	Low	WSC, Joint Water Supply

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
WS2. Persistent drought	WS2a. Hunter Water supplies	• Enhance existing 6ML/day connection to provide 20ML/day (7300ML/a) from the Hunter Water supply	• Cost of constructing the connection and potential for charges for accessing other water supply stores	High	High	WSC, GWCWA
	WS2b. Groundwater (from aquifers including Ourimbah, Mangrove Weir, Erina, Narara and Woy Woy)	• Useful addition to the supply when demand exceeds the available supply from other resources • Potential for additional 12-18ML/day from a variety of aquifers(listed to the left)	• Amount of groundwater available is not sufficient to meet the growth of the Central Coast water supply needs. • Impacts on dependent downstream environments	High	Low	WSC, GWCWA
	WS2c. Desalination plant (currently being planned for Toukley Sewage Treatment Plant)	• Provides additional flexibility and robustness to the water supply systems during drought periods. • Provide a means to guarantee supply of water if future climate change impacts are greater than currently expected. • Potential for additional 20ML/day	• Desalination options are more costly to implement and have higher operating costs than river water systems. • Disposal of brine from a desalination plant is an environmental risk and requires active treatment and disposal • Energy requirements are high	High	Low-Med	WSC, GWCWA
WS3. Subsidence can drain river flow	WF3a. Ban mining under rivers	• River flow protected from draining • Protection of water quality and habitat	• Loss of potential employment in the shire • Loss of potential economic stimulus	Low	High	DIPNR, DPI (Fisheries)
	WF3b. Do nothing	• Allows mining to proceed – likely to stimulate local economy and provide jobs	• Potential for damage to environmental flows and sensitive habitats	Low	Low	DIPNR, DPI (Fisheries)

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	WF3c. Manage damage if/when it occurs	• Permits the benefits of mining • Accepts the possibility of risk • Create management plans for high risk areas	• Unlikely to be able to correct damage once it occurs • Too late for treating • Intensive high tech remediation required to fix	High	Low	DIPNR, Dept or Minieral Resources, DPI (Fisheries)
WS4. Water yield decline from forestry and bushfires	WS4a. Reserve forested land in water supply catchments (DPWS,2002)	• Potential for small increases in water yield	• Would take up to 100 years for the full benefit to be realised. • Potential loss of logging revenue and associated jobs • Exact change to flows unknown for this type of forest.	Low	High	WSC, Joint Water Supply, DPI (Forests)
WS5. Climatic Change	WS5a. Investigate impacts of climate change (global warming and natural variability) on water supply	• Determine level of risk from future climatic events • Enable planning to begin • Drought proof the community	• The notion of climate change is still not widely accepted • The exact effects are still being predicted	High	High	WSC, Joint Water Supply
	WS5b. Do nothing - Wait for agreement on likely changes to climate	• No unnecessary expenditure • Target problems as they occur	• Potentially "too little too late"	High	Low-Med	WSC, Joint Water Supply

4.7 GROUNDWATER

Objective WG: Minimise changes to groundwater flow/stores

Groundwater is a water resource whose interaction with the rivers and estuary is not well understood. Groundwater is thought to be impacted by a number of human disturbances in the catchment. These uncertainties make sustainable management difficult.

One of the more significant disturbances is urban development. Generally, urban development and land clearing results in lower infiltration (due to the increased impervious surfaces), which decreases the amount of water entering groundwater stores. Land clearing, changes to vegetation and poor farming practices can impact on the groundwater table. The results of such disturbances can include salinity, water table rise and saltwater intrusion into aquifers (in coastal areas).

Groundwater extractions are a threat to the aquifers and their ongoing management. Some land activities can contribute contaminants to groundwater such as pesticides, leachates and fertilisers. The management of the estuary should consider the potential for impacting groundwater flows and stores.

4.7.1 Issues & Threats

WG1. Development can reduce the amount of infiltration into soils and groundwater

In addition to changing evapotranspiration, there is an increase in impervious surfaces usually from 0-5% (for forested/rural catchments) to 60 or 70% impervious surfaces in newly developed areas (not including highly compacted garden/lawn soils). This creates a difference in ground surface area that can store rainfall. It is worth considering where this water would go if it were not sheeted off impervious surfaces. Some is used for evapotranspiration, the remainder would either runoff or recharge groundwater. Downstream environments may be dependent on this flow and this should be evaluated before making decisions on redirecting or reallocating the flow.

WG2. Unlicensed groundwater use

There are a number of operations throughout the catchment that extract groundwater. Many of these are unlicensed. Unlicensed extractions remove the ability of authorities to manage the water flow for community and ecological needs.

WG3. Poor knowledge of groundwater quality and its flow to the estuary and rivers

Groundwater is not well understood in terms of its interactions with the water cycle in the Tuggerah Lakes catchment or its links with the estuary. For wetland environments, groundwater can play a significant role. Long-term losses in groundwater recharge could drop the water table and in doing so, dry out wetlands.

In developing areas, the runoff from hard surfaces can replace the water that would infiltrate into the soil and possibly supply base flow to downstream environments. Harvesting the excess runoff may then represent a net loss to the downstream environments, as the groundwater flow is reduced. This is true for the Porters Creek Wetland. Although significant additional surface flow has entered the wetland, this additional flow may be the amount that was flowing to the wetland through groundwater. Harvesting the additional surface water may actually represent a net loss of water for the wetland when compared with pre-development levels.

WG4. Groundwater contamination

Groundwater can be contaminated by a range of pollutants. These include nutrients, pesticides and other contaminants. These contaminants can be transferred via aquifers to other locations, potentially impacting environments far from the site of contamination. Preliminary research (Kerry, 1998) found that faecal coliforms and nutrients in groundwater were high in some foreshore locations around the estuary.

4.7.2 Options

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
WG1. Development can reduce the amount of infiltration into soils and groundwater	WG1a. Minimise amounts of impervious surfaces in new development	• Will reduce the amount of runoff from new development – assists in protecting downstream environments • Encourages natural infiltration which will aid groundwater recharge • Supports base flow contributions to surrounding receiving waters	• May result in increased construction costs – depending on methods used for reducing impervious area • Potential for reduction in development activity – flow on effects for the economy • Residents will be responsible for maintaining pervious areas post development – may not be willing or able	Low	Medium	WSC, Developers, Community
	WG1b. Increase use of retention devices for new and existing development - Consider IWCM - Stormwater harvesting	• Increases infiltration and groundwater recharge • Assists in retaining natural downstream flows • Improves water use and reuse behaviour in the community – may delay need for new water supply infrastructure	• Maintenance will have to be undertaken by residents (at a lot level) – increased maintenance costs for Council at a development or sub-catchment level • Much of this technology is still in its infancy and can have variable performance • Poor design and maintenance can provide habitat for both mosquitoes and weeds	Med-High *(depending on scale of implementation)*	Medium-High	WSC, Community

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
	WG1c. Ban development	• Natural groundwater flows will be retained (in undeveloped aquifer catchment areas) • Infiltration will continue to recharge streams and the estuary	• Potential for damage to the local economy – job loss • Create pressure on other local government areas to meet housing requirements/demand	Low	High	WSC, DIPNR
	WG1d. Do nothing	• Reduces development commitments • Provides more affordable housing • Security in use of existing designs and methodologies for stormwater management	• Increased surface flows discharge to downstream environments • Long term losses to groundwater storage • Base flow for rivers and streams is likely to be reduced	Low	Low	WSC
WG2. Unlicensed groundwater use	WG2a. Improve quantity monitoring of groundwater resources	• Provides an independent means of assessing changes to groundwater levels in remote areas or where networking is difficult • Enables a stronger monitoring regime of aquifer quantities	• Potentially large areas to cover – experience around the estuary suggests that monitoring bores could be vandalised	Med	Medium	DIPNR
	WG2b. Increase networking with the community and landholders	• Improve general connections between the community/landholders and Council/government agencies – will aid in catchment management • Areas of concern can be targeted • Community and landholders are able to make positive contributions to catchment management	• Community and landholders are not always aware of what neighbours are doing • Not a solution for remote areas	Low	Low-Medium	WSC, DIPNR

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	WG2c. Do nothing	• Nil	• Degradation of habitats and water sources where extraction is beyond sustainable limits	Low	Low	WSC, DIPNR
WG3. Poor knowledge of groundwater quality and its flow to the estuary and rivers	WG3a. Conduct studies where groundwater knowledge is poor - Porters Creek Wetland	• Potential to close a large gap in understanding of the water cycle for the estuary • Strengthens management focus on groundwater issues that impact on the rivers and estuary	• Spatial and temporal scales for the study may produce long study time – lag may miss intervention opportunities	Low	High	WSC, DIPNR
	WG3b. Request information from corporations who have already completed detailed groundwater studies	• Access to existing information – don't have to "reinvent the wheel" • Understand where groundwater stores are, and the strength/composition of groundwater flows	• Freedom of information agreements may mean that any reports Council has access to are available to the public – may result in company information being passed to competitors	Low	Medium	WSC, DIPNR
	WG3c. Do nothing	• Nil	• Continue to be poorly informed about a potentially significant pathway for water, nutrients, pollutants • Current catchment management strategies may be misdirected – focussed potentially unnecessarily on surface water flows	Low	Low	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
WG4. Groundwater contamination	WG4a. Educate community and landholders	• If done effectively, will provide network of stakeholders with increased vigilance • Non-confrontational approach	• The main aquifers are in remote areas which limits the vigilance by educated community • Education will therefore probably only work with committed individuals on a site by site basis	Low	Low	WSC, DIPNR, Landholders, DEC
	WG4b. Monitor groundwater and audit for contamination	• Will protect groundwater supplies • Enables shut down of potentially affected bores • Provides assessment of ongoing groundwater conditions	• Does nothing to prevent contamination in the first instance • Resource intensive	High	Medium	WSC, DIPNR, DEC, Landholders
	WG4c. Do nothing	• Resources not expended on non-issues	• Increases likelihood of contamination • Contributes to potential loss of a valuable water resource	Low	Low	WSC, DIPNR, DEC, Landholders

4.8 RECOMMENDATIONS

4.8.1 Issues Identified by Reference Groups

The following issues were identified by business, community and technical reference groups as being most important to them out of a list of all water management issues.

1. Increased sediment and nutrient loads from existing landuses affect water quality (WE2)
2. Increasing population puts an increased demand on water supply (WS1)
3. Increased sediment and nutrient loads from new development affect water quality(WE3)
4. Foreshore and streambank erosion adds sediment to waterways (WE7)
5. Toxic contaminants in runoff could affect aquatic ecology and human health (WE4)
6. Water supply and irrigation needs get priority over river flow for environmental needs (WF1)

4.8.2 Additional Priorities

The following additional priorities were also identified as important:

- Risk of flooding (WP3)
- Runoff from urban catchments and sewer overflows contain faecal coliforms (WH4)
- Managing the ocean entrance (WE6)
- Inadequate understanding of riverine ecological processes and riverine water quality to allow for environmental flow management (WF5)

4.8.3 Suggested Programmes

Programme	Associated Options
Stormwater management in new urban areas focussing on sediment and nutrient management, water sensitive urban design and producing more natural flows for downstream environments	WE3a WE3d
Retrofit stormwater interventions in existing urban areas focussing on sediment and nutrient management, contaminants and gross pollutants	WE2c WE2d WE4e
Develop a catchment audit process for assessing high risk catchments and prioritising interventions	WE2e

Programme	Associated Options
Streambank rehabilitation and erosion protection	WE7a WE7d
Continue to maintain stormwater treatment devices ensuring performance data are collected and analysed	WE2f
Continue to monitor faecal coliforms at recreational locations	WH4a
Conduct appropriate research into riverine ecological processes and water quality to support environmental flow management	WF5b WF5c
Maintain river mouth dredging on a rolling 5yr programme for Tumbi, Ourimbah, Wyong and Wallarah/Spring Creeks	WP3c WP2a WF2a
Maintain ocean entrance dredging programme	WP3a WE6c

5 Vegetation Management

5.1 INTRODUCTION

This section defines the overarching principle and sets future objectives for managing the various vegetation communities that exist within the catchment and the estuary. Generally, the approach is that by providing appropriate habitats for the catchment and estuary, the ecology is more likely to be sustained. The objectives have been set according to the water environment surrounding the vegetation community. In order to meet these objectives, it is necessary to a) define any issues that currently prevent the objectives from being met and b) implement options to address these problems.

There are four main hydrological areas that have been used to group vegetation management activities; wetland, estuarine (aquatic and semi-aquatic), floodplain and riverine/riparian. These groupings were selected because they are all links between the ecology of the catchment and that of the receiving waters. The remainder of the section examines each objective in detail, focussing on the issues that prevent the objective from being met, and providing potential options to address such issues.

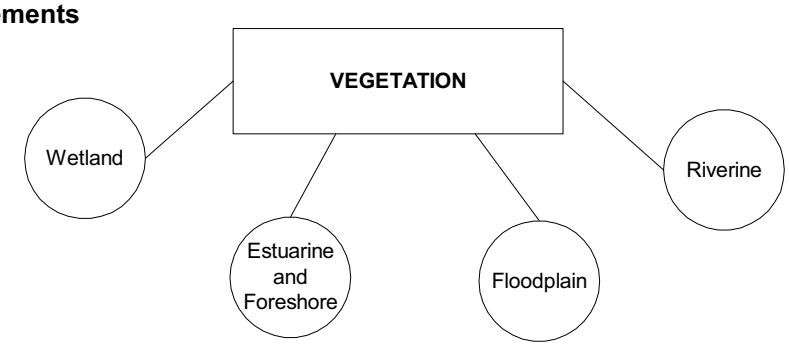
5.1.1 Principle

The Central Coast Catchment Blueprint identified a number of "first-order" objectives for ongoing catchment management. Vegetation management was one of the first order objectives and was expressed as:

The physical structure and vegetation of river, lake and wetland riparian zones are protected (and rehabilitated where required) to sustain healthy ecosystems

This principle relates to the catchment but is also applicable to sustainable management of the estuary.

5.1.2 Elements



5.2 FRESHWATER WETLAND VEGETATION

Objective VW: Protect, maintain & restore freshwater wetland vegetation

Wetlands are significant in terms of their biodiversity and the ecological processes that occur within them. The vegetation within wetlands has an important role as a habitat structure and provides some measure of filtration for pollutants such as sediments and nutrients. Wetlands are utilised by various species as transitional or nursery habitats, forming a key link between the catchment and riverine/estuarine environments. As filters, wetlands have the capacity to buffer downstream environments from upstream activities and inflows. An example of this is Porters Creek Wetland. The wetland currently acts as a buffer between the development in the Warnervale and Wadalba areas and Wyong River. In this capacity, wetlands risk being degraded as they may be impacted by upstream disturbances.

A number of wetlands in Wyong Shire are protected by various pieces of legislation and planning instruments, including SEPP 14 and the 7(g) zoning, which are designed to avoid wetland degradation or loss. Some wetlands within the catchment are relatively untouched, and as such require protection. Others have been impacted in the past and will require ongoing maintenance and restoration.

5.2.1 Issues & Threats

VW1. No active monitoring and management of important wetlands

Within the Wyong Shire there are a number of freshwater wetlands, which are important to the ecology of the system. Some of these wetlands are protected via Council zoning and SEPP 14. Whilst these wetlands have been identified there are no data on their ecological function and/or biodiversity. Porters Creek and Colongra wetlands have had some monitoring programmes in place. These programmes have been done to answer specific questions such as the impact of Warnervale Airport extension on Porters Creek and the impact of saltwater intrusion into Colongra Wetland. Whilst these wetlands were considered to be important, there were no active assessments being made, nor management activities done. The risk is that while the identification of wetlands is important, it is also important to evaluate threats from surrounding activities and intervene where appropriate.

VW2. Activities in upstream catchments can change downstream wetlands

Wetlands are particularly susceptible to changes in the hydrology of their water source. There are many ways in which hydrology can be affected. Some of these include:

- Changing evapotranspiration rates (from loss of trees or regenerating forests).
- Increased impervious surfaces.
- Detention of runoff.
- Changes to the wetting and drying cycles.
- Reduction in groundwater infiltration.

When planning for catchment use, the effects on the water cycle is often assumed and not often examined. Changing the vegetation cover of forested areas has an impact on the amount of water yield from the catchment. The same will be true for developing areas. Many of the developing areas in Wyong Shire are initially well vegetated. Clearing of this land often amounts to clear felling for the purpose of making the land more accessible for home owners and developers. The stormwater design process considers the change in evapotranspiration in modelling, however the impact of this change on downstream environments is not generally considered.

VW3. Invasive species can degrade important habitats

The effect of development on terrestrial ecosystems is widespread. Residential development in particular can lead to weeds being exported to the lower catchment through stormwater runoff or by transport through other mechanisms (animals, wind, shoes etc.). Stormwater system designs have a particular role in the transport of weeds, as many of the detention basins necessary to retard flows (for flood and habitat protection) are of a form and location that lends itself to weed proliferation. The problem occurs when larger flows move through these basins and disperse seeds and fragments of the weed throughout the stormwater systems. On occasions these weeds can move as far as the estuary, particularly in the heavily developed catchments immediately surrounding the lakes. The weeds can also be dispersed into an otherwise undamaged terrestrial ecosystem, where they can take hold. As has been the case throughout much of Australia, invasive species tend to dominate in areas where native species have been stressed or removed. Under these conditions, many introduced species have proven much better in adapting to the new conditions and have thrived (see Roberts et al., 1999).

5.2.2 Options

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
VW1. No active monitoring and management of important wetlands	VW1a. Target "at risk" wetlands & undertake monitoring and management	• Actions and strategies directed at wetlands that most need them • Preventative action – enables intervention before degradation occurs • Can be combined with Natural Assets Register to secure funding	• Likely to be resource intensive • Doesn't necessarily occur before development takes place (missed best opportunity to prevent degradation) • Difficult to estimate value of wetlands as natural assets (other than to cost their replacement value)	Medium	Medium – High	WSC
	VW1b. Do nothing	• Minimise a potentially large ongoing maintenance & resource cost	• Loss of diversity & abundance of wetland and remnant vegetation • Increased proliferation of weeds • Loss of habitat for wetland fauna • Increased likelihood of degradation of habitats downstream of stressed wetlands • Potential for exposure to prosecution under the Threatened Species Act • Failed wetland may require significant capital works to remediate (may extend to downstream remediation)	Low	Low	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	**Difficulties**			
	VW1c. Implement Porters Creek Wetland Management Plan	• Determine if best practice management options can reverse degradation • Provide source control • Protect Wyong River and the estuary from increased pollutants (from the new development) • Rehabilitation of floodplain vegetation • Increased community awareness	• Resource intensive and represents a significant long term cost & commitment • Only deals with Porters Creek wetland – is not inclusive of other wetland areas in the catchment	$100K annually *(already committed by WSC in 2001)*	Medium (localised)	WSC
VW2. Activities in upstream catchments can change downstream wetlands	VW2a. Ban development	• Minimises likelihood of future degradation to downstream wetlands • Minimises disturbance to existing ecology in the developable area • Frees future management & maintenance funds	• Existing degradation is not re-mediated • Potential for damage to the local economy – job loss • Create pressure on other local government areas to meet housing requirements/demand	High *(flow on costs from losses to wider economy)*	High	WSC, DIPNR

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VW2b. Improve controls for new development to treat upstream urban runoff & mimic natural flows	• Allows intervention before the development causes problems • Can be funded through developer contributions & potentially through bonded development • Natural flows to the wetland will generally produce natural flows for the environments below the wetland • Minimise disturbance to faunal communities that depend on natural water patterns	• Difficult to mimic natural flows post development (see Issue WP1) • Flow control devices can potentially become sources of weeds • Development impacts are not completely mitigated • Often degradation occurs many months or years after development as all lots come online – bonding may need to be over a long time frame	High	Medium-High	WSC, Developers
	VW2c. Retrofit control structures/systems to treat existing urban areas once wetland effects become evident	• Target affected areas, rather than expend resources on areas that may not be under threat (or can reasonably be sacrificed) • Designs that are scaled to treat only the affected area	• Unlikely to have sufficient land area or resources to implement retrofits • Council may have to fund the implementation & maintenance costs for these structures	High	Medium	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VW2d. Implement Porters Creek Wetland Management Plan	• Determine if best practice management options can reverse degradation • Provide source control • Protect Wyong River and the estuary from increased pollutants (from the new development) • Rehabilitation of floodplain vegetation • Increased community awareness	• Resource intensive and represents a significant long term cost & commitment • Only deals with Porters Creek wetland – is not inclusive of other wetland areas in the catchment	$100K annually *(already committed by WSC in 2001)*	Medium (localised)	WSC
VW3. Invasive species can degrade important habitats	VW3a. Rehabilitate degraded upstream habitats likely to propagate weeds	• Minimise weed propagation throughout the catchment • Increase viability of native flora & dependent fauna • Improve linkages between the catchment, wetland and downstream environments • Upstream habitats provide a buffer for the wetland (perhaps sacrificial buffers)	• Fragmented nature of upstream habitat may affect long term viability • Landuses in the area (i.e. urban, rural and industrial) may threaten rehabilitation without appropriate education and control	Medium *(could be included as part of the $100K flagged in the PCW Man. Plan)*	Medium	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VW3b. Actively manage weed sources upstream of the wetlands	• Minimises the likelihood of invasive propagation throughout linked drainage lines • Addressing problem at source means minimising area of disturbance within the catchment	• Careful management is required otherwise areas outside of the treatment zone will be impacted • Invasive recruitment is more likely in fragmented/disturbed habitats – unless these habitats are managed, some form of invasive species is likely to dominate	Low-Med	Medium-High	WSC
	VW3c. Actively manage weeds in the wetland	• Improve viability of native species in wetlands • Minimise threat to biodiversity in the wetland • Could be harnessed to provide an education tool for upstream residents and operators	• Provides an end of pipe solution – alone, this will not slow the introduction of invasives • Does not address the conditions that allow invasives to dominate	Medium	Medium	WSC
	VW3d. Re-establish native vegetation structures that limit the capacity of weed growth	• Improving vegetation structures increase the long term viability of remnant native vegetation & dependent fauna • Improve available habitat for native fauna	• In isolation this will not produce a lasting solution – will require complimentary active weed control • Changes to inflows from the catchment will make it difficult to preserve natural inputs to habitats	Low-Med	Low-Medium	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VW3e. Do nothing	• Minimise exposure to long term maintenance programme	• Invasive species will increase in abundance throughout the catchment • Native vegetation will decrease • Native fauna will be under pressure from opportunistic species through loss of habitat and food source • Potential for exposure to prosecution under the Threatened Species Act	Low	Low	WSC
	VW3f. Investigate use of incentives to encourage landholders to remove invasive species on their land	• Positive way to achieve invasive monitoring and management • Landholders likely to come along as partners	• How would the programme be administered • Cost • Monitoring performance and compliance would be difficult	Med-High	Low-Medium	WSC, Landcare

5.3 AQUATIC AND SEMI-AQUATIC ESTUARINE VEGETATION

Objective VE: Protect, maintain & restore aquatic and semi-aquatic estuarine vegetation

Both aquatic and semi-aquatic vegetation are important to estuaries. Roberts (2001) identified phytoplankton, macroalgae, seagrasses and saltmarsh as being important groups within the Tuggerah Lakes estuary.

Macroalgae is an important source of food for fish, gastropods, crustaceans and birds. It has the capacity to rapidly assimilate available nutrients in the water column and its biomass may respond to changes in nutrients from catchment runoff. Excess macroalgae has been linked to declines in the aesthetic amenity of the estuary. In particular, the decomposition of macroalgae in shallow-water is thought to contribute to odours that are sometimes present in the sediments. Stormwater and foreshore management activities are likely to continue to have a strong influence over the spatial and temporal patterns found in assemblages of macroalgae. Some form of active management may be required to ensure that blooms of macroalgae do not return to what was common during the 1980's.

Seagrasses are an integral part of the ecology of the estuary as both a habitat and a food source for a variety of species. While some species of birds and fish feed directly on the seagrasses, others use the epiphytic growth on the leaves as a source of food. Seagrasses are believed to be important as nursery habitats for fish. Seagrasses draw their nutrients from the sediments. In an estuary, where there is a potential for increasing levels of nutrients in sediments, the presence of seagrasses provide a very important buffer. The presence of seagrass wrack in the estuary has been an issue for some members of the community. Modified edges of the estuary make it difficult for wrack to be deposited on the shore. In many areas, the wrack builds up against the shoreline and decomposes in the water, affecting the ecology and then amenity. The cover of seagrasses has declined by up to 50% over the past 40 years (Roberts, 2001).

Saltmarshes provide an interface between the estuary and the foreshore (i.e. between the terrestrial and aquatic component). Fringing wetland vegetation and saltmarsh around the lakes has been reduced as a result of development by 85% (Roberts and Chapman, 2003). Saltmarsh is an important ecological community that has recently been listed as a threatened ecological community in NSW. This will greatly limit the amount of human intervention in foreshore areas where saltmarsh is found. Saltmarsh is an important habitat for a number of aquatic and terrestrial faunal species. It is also thought to play an important role in the breakdown of seagrass wrack. These important assemblages play significant roles in the ecology of the estuary. Careful management of these assemblages will continue to sustain dependent organisms and in so doing, aid in protecting the long-term health of the estuary.

5.3.1 Issues & Threats

VE1. No existing plan for identifying, rehabilitating and managing significant foreshore habitats

The foreshores of Tuggerah Lakes are those areas where the terrestrial meets the aquatic, and include estuarine beaches, saltmarshes and wetlands, council reserves, privately owned land and some National Parks. It is here that the community's interaction with the estuary begins and where their perceptions about the “health” of the lake are developed. Wyong Shire Council has the responsibility for maintenance and on-the-ground works of the foreshores of the estuary, whilst various state agencies also have legislative and managerial responsibilities.

Council developed policies and guidelines for managing foreshores and beach cleaning around the estuary, which are currently under review as new information and best management practices keep evolving. In general, these guidelines focus on the maintenance of stormwater treatment zones and gross pollutant traps to maximise the removal of sediments and nutrients before they enter the estuary, and the removal of rubbish and seagrass wrack from beaches and foreshores. Other policy and guideline procedures that also have the potential to impact on foreshore management include reserves and litter collection, amenities cleaning, mowing and dredging operations.

VE2. Changes in water quality can affect aquatic and semi-aquatic vegetation

Seagrasses provide nursery grounds and food for commercially important prawns, fish and wading birds and generally act as a structural habitat for a variety of estuarine animals and plants. Seagrasses provide a role in stabilising bottoms and shorelines and act as a natural water filter for suspended solids. Large-scale declines (up to 85%) in seagrass meadows have been recorded within NSW estuaries. Increased turbidity, siltation, nutrients and epiphytic and benthic algae have the potential to cause a reduction in the distribution and abundance of seagrasses. In extreme cases, large ‘blooms’ of macroalgae can reduce the light available for seagrasses and cause a reduction in their diversity and abundance. The combined effects of respiration and subsequent processes of decomposition can create anoxic conditions at the sediment-water interface, resulting in significant increases in nutrients being recycled back into the water column. Severe anoxia and the production of toxic sulphide can also cause massive migration or mortality of the benthic fauna which further impact on the system.

Unlike seagrasses, macroalgae are confined to obtaining nutrients for growth from the water column (Nielson and Jernakoff, 1996) and many of the ephemeral species rapidly expand their biomass in response to nutrient enrichment (Duarte, 1995). The proliferation of macroalgae in estuaries is thought to be a symptom of eutrophication. Nutrient up-take and release by macroalgae has been shown to influence water column nitrogen concentrations on a bay-wide scale (Piriou and Ménesguen, 1992; Peckol et al., 1994).

Phytoplankton are the microscopic free-floating algae which are a primary source of food for many organisms including zooplankton (small floating animals), invertebrates (e.g. oysters) and fishes (Cummins et al., 2004). Phytoplankton populations respond quickly to changes in temperature, salinity, light and nutrients. River discharges, tidal inflows and wind-induced currents can cause localised differences in these factors, leading to patchiness in the distribution of phytoplankton (Cummins et al., 2004).

If there is a surplus of nutrients, the estuary has the potential to become eutrophic causing algal blooms, which can alter ecosystem structure and function. Responses to nutrient enrichment are varied, with some systems developing blooms of phytoplankton whilst others have macroalgae. Although the effects of eutrophication have been documented, the exact conditions and mechanisms responsible for promoting persistent algal blooms are poorly understood. Phytoplankton blooms are increasing in their frequency and extent in marine and estuarine waters worldwide. Under bloom conditions, phytoplankton can decrease light penetration and reduce the amount of oxygen within the water column. Some species also have the ability to produce toxic compounds.

VE3. Recreational activity can damage sensitive habitats

Saltmarsh is limited to the edges of the estuary because it need requires occasional tidal inundation. Anthropogenic disturbance can be high in these areas because humans tend to interact with the estuary in this zone. Saltmarsh can be disturbed by boat access and use, vehicle access and pedestrian traffic for swimming and other activities. The community also cause disturbance to the foreshores through mowing, land reclamation, construction of illegal structures and the introduction of exotic lawns and weeds. Saltmarsh is discussed in detail in Section 2.

VE4. Maintenance programmes can damage sensitive habitats

Wyong Shire Council has responsibility for maintaining and regularly cleaning public foreshores around the Tuggerah Lakes estuary. This is done to improve recreational amenity and is considered important for tourist areas such as

Canton Beach. Seagrass and macroalgae wrack and dangerous objects such as broken glass and syringes are removed using a tractor and rake. A foreshore maintenance and beach cleaning procedure manual has been prepared by Council, and is regularly reviewed and updated (WSC, 1998a). Council has been collecting seagrass wrack from public foreshores for many years, however the potential environmental impacts associated with these operations has never been quantified. Potential effects include the physical disturbance to the structure of the beach and the fauna and flora that live there.

The maintenance dredging of river mouths such as Tumbi Creek have implications for aquatic and semi-aquatic estuarine vegetation. Aquatic vegetation such as seagrasses and macroalgae can be directly affected by dredging or indirectly affected by changes in environmental conditions (such as turbidity and nutrients) induced by dredging activity. Semi-aquatic vegetation such as saltmarshes can be affected by detention basins, dewatering activities and machinery on the foreshore (see Section 2.2.8.5 for further information on Tumbi Creek and dredging).

VE5. Sea level rise

A significant sea level rise is one of the major anticipated consequences of climate change. This may cause some low-lying coastal areas to become completely submerged, while others will increasingly face short-lived high-water levels. These anticipated changes could have a major impact on the lives of coastal populations (Griggs, 2001).

Sea level rise has implications for Tuggerah Lakes. Increased water levels are expected in the estuary. Potential impacts on the estuary include:

- Flooding of low-lying properties.
- Scouring of entrance channel and surrounding edges.
- Increased need for erosion protection will probably take precedence over environmental protection (i.e. seawalls built to protect property rather than allow inundation).
- Change in seagrass distribution with increased depth (decreasing light penetration).
- Ecological reactions to changed environmental conditions (e.g. fisheries may suffer as seagrass habitats change).
- Loss of freshwater wetlands close the estuary.

5.3.2 Options

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
VE1. No existing plan for identifying, rehabilitating and managing significant foreshore habitats	VE1a. Develop foreshore management plan	• Provide clear direction for Council and other landholders in managing ecology of foreshore areas • Can be combined with existing operational documents • Provides a management framework for trialling different methods of managing the foreshore without creating a new programme each time • Could be used to designate recreational and rehabilitation zones within the foreshore area • Can be used to encourage residents and the community at large to engage in rehabilitation activities.	• Potentially unpalatable for residents adjacent to foreshore areas – particularly if they are not consulted during the development of such a plan • Will require monitoring to assess it's value • As this will be a new management approach with a high degree of public visibility – there will need to be a strong commitment to its implementation to avoid changes in direction	Med – High *(Long-term maint. costs)* *(Potential impacts on value of surrounding land where rehab is undertaken)*	High	WSC, Community, Department of Lands
	VE1b. Do nothing	• Minimal disruption/angst among residents • No changes to maintenance & management routine	• Less opportunity to improve wrack & algae management • Loss of saltmarsh from foreshore • Potential loss of foreshore dependent species • No opportunity to improve community awareness	Low	Low	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
VE2. Changes in water quality can affect aquatic and semi-aquatic vegetation	VE2a. Improve sediment & erosion controls for urban & agricultural activities according to load contribution • Bonded development • Increased auditing • Improved WQ monitoring • Increased community awareness	• Minimise increases in turbidity in the estuary • Reduce opportunity for choked streams and drainage lines to flood • Minimise disturbance to downstream ecology • Preserve integrity of soil landscapes in the catchment • Defer need for dredging in tributaries (e.g. Tumbi Creek)	• Difficult to regulate sediment and erosion controls particularly in agricultural catchments • Little physical data available to determine where greatest proportion of the load comes from • Requires improved controls by Council operations to avoid the perception of "double standards"	Medium	High	WSC, Landholders, Community, Developers
	VE2b. Improve nutrient controls for urban & agricultural activities according to load contribution • Retrofits • Community awareness • Bonded development	• Reduce available nutrients in river & estuary water column • Minimise potential for algal blooms • Minimise further enrichment of riverine & estuarine sediments	• Most nutrient controls are not 100% effective at removing increased nutrient loads • Nutrient treatment usually requires large amounts of land • Performance of nutrient removal devices can be highly variable • Little physical data available to determine where greatest proportion of the load comes from	High	High	WSC, Landholders, Community, Developers

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VE2c. Maintain existing hydrodynamic profile • Continue dredging regime • WQ impacts from any new entrance mgt. to be considered	• Current ecological profile of estuary more likely to be maintained • Minimise opportunity for algal blooms • Retain current lake surface area • Current WQ profile likely to be maintained	• Against public expectation • Low abundance & diversity for some species will remain • Runs contrary to the natural progression of the estuary	Medium	High	WSC, DIPNR, Community, DEC, DPI (Fisheries)
	VE2d. Investigate methods for limiting sediment suspension & re-suspension • Remove particulates from the water column • Minimise velocities & disturbance to estuarine sediments	• Limit turbidity from wind-driven mixing • Potentially increase light penetration – increase seagrass coverage • Potential increase in abundance of species that are limited by turbid water – sponges etc. • Clearer water is a perceived improvement in water "health" by the community	• May result in unintended effects on ecology by altering important natural processes - shallow estuaries are often turbid • Any chemical application likely to be opposed by both the community and all levels of government	Low-Med *(to investigate methods, the cost is likely to be low – carrying out the methods may be expensive)*	Medium	WSC, DIPNR, DEC, DPI (Fisheries)

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VE2e. Do nothing	• Natural progression toward a filled in estuary is more likely • Minimise exposure to significant maintenance costs	• At some point a fundamental shift from estuarine ecological profile toward freshwater is likely – this will have a negative effect on amenity and is unlikely to be tolerated by the community • Increased need for dredging • Increased occurrences of algal blooms • Increased seagrass presence close to shore	Low	Low	WSC, DIPNR
VE3. Recreational activity can damage sensitive habitats	VE3a. Restrict boating where seagrasses are threatened	• Improve viability of existing seagrass communities and dependent organisms (fish, Syngnathids etc) • Reduced disturbance for other ecological communities near the affected seagrasses	• Potential for loss of tourism if the restricted areas are large in size, or affect significant tourist activity (such as boat racing, fishing etc) • Establishing such a zone would require significant research & monitoring – resource intensive	Low-Med	Low-Medium	WSC, DPI (Fisheries), Maritime Authority
	VE3b. Improve community awareness of threats to foreshore & nearshore ecology from recreation • Rehabilitation days & instructional • Letter drops • Signage	• Community will become partners in estuarine management • Soft approach to reversing some damaging practices undertaken by both Council and the community in the pursuit of active & passive recreation	• Sceptics are unlikely to change behaviour through education alone • Will not result in rehabilitation alone – works will be required	Low	Medium-High	WSC, Department of Lands

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VE3c. Designate recreation & rehabilitation areas (active & passive) for nearshore & foreshore zones • Restrict recreation in rehabilitation areas • Provide for amenity over ecology in rec. areas	• Allow managers to target areas most likely to benefit from rehabilitation & prioritise accordingly • Management can provide for recreation and amenity above ecological concerns in designated areas • Allows for improved tourist potential in some locations • Rehabilitation will be viewed more positively if it is shared with community "wants"	• The selection of locations may be contentious • Ratepayers with water frontage may wish to pursue their own amenity improvements when they may be within rehabilitation zones	Medium	High	WSC, DPI (Fisheries), DEC, DIPNR, Department of Lands, Community
	VE3d. Ensure that foreshore ecology is considered when developing recreation areas - Seawalls - Jetties	• Education could be achieved by introducing the community to the ecology of the recreation area (signage etc) • Future improvements to OS&R foreshores will be considered in rehab vs recreation terms • Development within Coastal Zone can be included	• Most development is complete adjacent to the estuary • Council is unlikely to be able to buyback properties for rehabilitation purposes • Residents are concerned about declining property prices near the estuary	Low	Low-Medium	WSC, Community

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
VE4. Maintenance programmes can damage sensitive habitats	VE4a. Designate recreation & rehabilitation areas (active & passive) for nearshore & foreshore zones • Restrict management activities (e.g. mowing) in rehabilitation areas • Provide for amenity over ecology in rec. areas (remove wrack + algae + beach nourishment)	• Allow managers to target areas most likely to benefit from rehabilitation & prioritise accordingly • Provides Council with clear direction on appropriate management actions in specified areas • Allows for improved tourist potential in some locations • Rehabilitation will be viewed more positively if it is shared with community "wants"	• The selection of locations may be contentious • Ratepayers with water frontage may wish to pursue their own amenity improvements when they may be within rehabilitation zones	Medium	High	WSC, DPI (Fisheries), DEC, DIPNR, Department of Lands, Community
	VE4b. Restrict wrack harvesting in rehabilitation zones	• Minimises disturbance in nearshore zones of estuary • Promotes natural processes in shallow habitats • Minimises impact on wrack/seagrass dependent species (e.g. Syngnathids) • Reduced costs for Council's maintenance budget • Combined with saltmarsh rehab will allow for natural decomposition of wrack	• May be unpopular if rehabilitation zones coincide with residences i.e. no wrack harvesting allowed • Unlikely to result in improvements in isolation – consider combining with saltmarsh rehab and foreshore sculpting	Low	Medium	WSC, DPI (Fisheries), DEC, Community

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VE4c. Restrict mowing in rehabilitation zones	• Minimises disturbance in foreshore zones of estuary • Allows for decomposition of seagrass wrack through rehabilitation of saltmarsh • Improves viability of saltmarsh communities & dependent species	• Community has concerns about pest invasion (snakes, rodents etc) • Will require strong communication and vision to avoid a reduction in amenity	Low	Medium	WSC, Department of Lands
	VE4d. Inform private landholders about their rights & responsibilities regarding wrack & foreshore management	• Allows community to become active in estuarine management • Building partnerships assists Council in managing & monitoring a large expanse of shore	• May be very contentious with some residents – argue that increased rates for water frontage entitles them to maintain their foreshore & nearshore areas	Low	Low-Medium	WSC, DPI (Fisheries)
	VE4e. Limit dredging by improving sediment & erosion source control • Bonded development • Increased auditing • Improved WQ monitoring • Increased community awareness	• Reduce likelihood that dredge spoil will be disposed of in the estuary • Minimise flooding from choked streams & drainage lines • Avoid unnecessary disturbance of & changes to sediment chemistry • Minimise disturbance to downstream ecology • Preserve integrity of soil landscapes in the catchment • Minimise turbidity increases in the estuary	• Difficult to audit sediment and erosion controls over a large catchment • Requires improved controls by Council operations to avoid the perception of “double standards”	Medium	High	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
VE5. Sea Level Rise	VE5a. Construct Seawalls	• Protect low-lying and waterfront properties from the effects of sea-level rise	• Effects on surrounding foreshore ecology and on estuarine processes that depend on the foreshore interaction	High	Low	WSC
	VE5b. Entrance management	• May be the most effective way of combating/managing sea level rise	• May produce unknown and unintended ecological response	High	Medium	WSC

5.4 FLOODPLAIN VEGETATION

Objective VF: Protect, maintain & restore floodplain vegetation

Floodplain vegetation provides a number of important functions in the Tuggerah Lakes catchment. These include habitat, erosion protection and providing linkages between other ecosystems in the catchment such as wetlands and rivers.

The floodplains in the catchment have been largely developed and/or heavily modified, especially in the lower catchment. Historically, the floodplains have been developed for agriculture including grazing and turf farming. Increasingly, these agricultural areas are being re-developed into urban residential areas (as with Warnervale/Wadalba). While it could be argued that the floodplains have had altered ecological function for some time, this is reduced further with the conversion to urban areas, reducing the buffering capability and increasing the impacts on surrounding environments. The remaining areas of floodplain vegetation need protection and maintenance and consideration should be given to restoring floodplain vegetation where sustainable ecological function and buffering of surrounding environments can be achieved.

5.4.1 Issues & Threats

VF1. Changes to flow volumes and patterns

The soil moisture in the riparian zone depends on the water depth in the river. The habitat of deep-rooted riparian plants is characterised by the variability of flow depth. Changes in flow variability will alter the characteristics of these habitats. Groundwater can be highly significant in sustaining floodplain vegetation. Water movement connects the floodplain subsurface to the surface; for example by root uptake, by surface discharge, by infiltration, and by downwards diffusion and percolation. Many floodplain trees have root systems which take advantage of the water found in floodplain aquifers during dry conditions. When the groundwater is saline, conditions are extremely stressful even for salt-tolerant trees.

Groundwater depths have changed dramatically since European settlement, sometimes rising due to clearance of deep-rooted native vegetation, irrigation and weirs, and sometimes falling due to exploitation and uncapped bores. Where floodplain channels are used to deliver water, groundwater layers develop in the immediate riparian zone. Water-retaining structures such as weir pools or regulators cause groundwater levels to rise immediately upstream. Although the short-term effect on trees is usually vigorous growth, the long-term effect is to restrict the root zone.

Some floodplains now receive water from stormwater drainage and so can be nearly permanently flooded whereas formerly they dried out from time to time. This extreme increase in flood frequency produces dramatic changes in the character of the aquatic habitat and in the composition of plant and animal communities (MDBC, 2001).

VF2. Loss, fragmentation or degradation of habitat

As the catchment of the estuary is developed, breaks in terrestrial habitats often occur. Parcels of land are usually divided into discrete units in terms of area and in relation to surrounding landscape or engineered features (rivers, roads etc). Only in recent years has the concept of designing around a terrestrial habitat or area of ecological significance been included in the planning process.

Where there are isolated remnants of vegetation within a region dominated by agricultural or urban landuses, ecological interactions can result other than those caused by loss of habitat alone. Through time, ecological degradation can lead to an alteration of fundamental ecosystem processes which challenges ecological sustainability. Typically, the remaining biota in a vegetation fragment, undergo alterations in population dynamics: this may include a reduction in the number of species present, altered species dominance, and invasion by exotic species. Furthermore, the isolation within fragments may have negative genetic consequences for any remaining biota and small populations are at a greater extinction risk. Active management, particularly weed control may be necessary to maintain the biotic integrity within any of the preserved fragments (Kinhill, 1998).

VF3. Invasive species can degrade important habitats

While the management options for invasive species in floodplains vary from those for freshwater wetlands, the issues are similar. Issue VW3 of Section 4.2.1 describes these issues.

5.4.2 Options

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
VF1. Changes to flow volumes and patterns *(issue largely addressed by options listed in WF1-5 from section 3.2.1)*	VF1a. Adopt Water Sharing Plans (option WF1a)	• Provide for environmental flows in the allocation of flow from a catchment	• Not based on ecological limits, therefore may be inappropriate for some floodplain habitat	Low	Medium-High	WSC, DIPNR, Landholders
	VF1b. Remove existing barriers or Modify existing barriers to improve flow mixing and allow for migration of key species (options WF2a & WF2b) • Weirs • Farm dams • Drainage networks	• Fosters a return to more natural patterns of flow (including patterns of flood and inundation) • Improves mobility for migratory species • Aids seed dispersion	• Potential impacts on water supply for community and agriculture • Increased potential for flooding of life and property	High	Low-Medium	WSC, DIPNR, Landholders
	VF1c. Do nothing	• Current land management practices remain unaffected (urban & agricultural activities)	• Seasonal flow patterns will be permanently lost resulting in a shift in vegetation abundance & diversity • Create difficult conditions for native species which may be supportive conditions for invasives • Potential for interruption to the breeding cycle for certain species	Low	Low	WSC, DIPNR, Landholders

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VF1d. Improve understanding of flow induced baseline ecological changes (options WF5b, c & d)	• Allow decisions to be made based on the ecological needs of the floodplain	• This option must be combined with an active programme to improve floodplain vegetation • Lag between understanding and undertaking may create further pressure on vegetated communities	High	Medium	WSC
	VF1e. Allow controlled flooding of floodplain areas for rehabilitation	• Natural levels of inundation will support floodplain vegetation & dependent species	• Existing development is based on probabilities of flooding frequency – altering these frequencies may have damaging consequences (loss of crops, property damage etc)	High	Medium	WSC, DIPNR, Landholders
VF2. Loss, fragmentation or degradation of habitat	VF2a. Adopt and implement a planning and conservation strategy	• Provides clear direction to developers and Council on developable land and that set aside for conservation • Protects viable communities for the long term	• Strong resistance from some landholders – land valuations perceived to be under threat • No allowances for compensation over loss of land	Low *(although potentially quite high for some land owners)*	High	WSC, Landholders
	VF2b. Do nothing	• No impediments to development of the catchment • Can provide significant amounts of housing in the short term	• Continued decline in abundance and diversity of native species • Loss of important terrestrial buffers for the downstream environment – can expect to see a decline in downstream ecology	Low	Low	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VF2c. Offer incentives to landholders to preserve significant communities	• Allows landholders to take a supporting role in management of the floodplains • Provides some financial compensation (albeit minor) for loss of developable land	• Incentives are likely to be very small (perhaps even token) • Those with the most significant communities are likely those with the most to lose – therefore most unlikely to participate.	Med-High	Medium	WSC, Landholders
	VF2d. Develop strong rehabilitation programmes in post-development areas • Education • Landcare groups • Tree planting scheme • Advice on native gardening & planting	• Encourage participation & interest from the local community about the importance of local habitats • Build strong networks of local land "managers" – valuable information exchange tool	• Sceptics are unlikely to be convinced • Much of the damage is done during development and may take many years of hard work to remediate – require a long community participation and attention span	Medium	Medium	WSC, Community
VF3. Invasive species can degrade important habitats	VF3a. Rehabilitate degraded upstream habitats likely to propagate weeds	• Minimise weed propagation throughout the catchment • Increase viability of native flora & dependent fauna • Improve linkages between the floodplain, wetland and downstream environments • Upstream habitats provide a buffer for the floodplain (perhaps sacrificial buffers)	• Fragmented nature of upstream habitat may affect long term viability • Landuses in the area (i.e. urban, rural and industrial) may threaten rehabilitation without appropriate education and control	Medium	Medium	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VF3b. Actively manage weed sources upstream of the floodplain	• Minimises the likelihood of invasives propagation throughout linked drainage lines • Addressing problem at source means minimising area of disturbance within the catchment	• Careful management is required otherwise areas outside of the treatment zone will be impacted • Invasives recruitment is more likely in fragmented/disturbed habitats – unless these habitats are managed, some form of invasive species is likely to dominate	Low-Med	Medium-High	WSC
	VF3c. Actively manage weeds in floodplain	• Improve viability of native species in floodplain • Minimise threat to biodiversity in the floodplain • Could be harnessed to provide an education tool for upstream residents and operators	• Provides an end of pipe solution – alone, this will not slow the introduction of invasives • Does not address the conditions that allow invasives to dominate	Medium	Medium	WSC
	VF3d. Re-establish native vegetation structures that limit the capacity of weed growth	• Improving vegetation structures increase the long term viability of remnant native vegetation & dependent fauna • Improve available habitat for native fauna	• In isolation this will not produce a lasting solution – will require complimentary active weed control • Changes to inflows from the catchment will make it difficult to preserve natural inputs to habitats	Low-Med	Low-Medium	WSC

Issue	Option	Outcomes		Cost	Ability to address Issue?	Responsibility
		Benefits	Difficulties			
	VF3e. Investigate use of incentives to encourage landholders to remove invasives on their land	• Positive way to achieve invasive monitoring and management • Landholders likely to come along as partners	• How would the programme be administered • Monitoring performance and compliance would be difficult	Med-High	Low-Medium	WSC, Landcare