Great Keppel Island Resort EIS

For GKI Resort Pty Ltd

Water Cycle Management Report

21 October 2011

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Revision E

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EXECUTIVE SUMMARY

This Report has been prepared by Opus International Consultants (Opus) on behalf of GKI Resort Pty Ltd to provide an overview of proposed water cycle management strategies associated with the Great Keppel Island (GKI) Resort Revitalisation Plan, including addressing water supply, wastewater and stormwater management. The contents of this Report are to be included as part of the overall Environmental Impact Statement (EIS) prepared for the GKI Resort Revitalisation Plan.

Specifically, this Report has been prepared to address parts of sections 2.5 and 3.4 of part B of the "Terms of Reference for EIS – Great Keppel Island Resort Project" issued by the Queensland Coordinator-General and dated June 2011 and relevant requirements of the "Guidelines for an Environmental Impact Statement for the Great Keppel Island Tourism and Marina Development, Queensland" issued by the Australian Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) in conjunction with the Great Barrier Reef Marine Park Authority (GBRMPA).

The GKI Resort Revitalisation Plan proposes to create a low rise, eco-tourism resort on Great Keppel Island incorporating a new 250 suite, 4 or 5 star resort hotel at Fisherman's Beach; a new 250 berth, all-weather safe access marina facility at Putney Beach including a retail village; an 18-hole championship golf course; a new runway and airport terminal; 750 eco-tourism villas; 300 eco-tourism apartments; staff accommodation and sporting fields. As part of the GKI Resort Revitalisation Plan, a new GKI Research Centre and Biodiversity Conservation Fund (BCF) will be established, the original Leeke's Homestead will be restored and a significant proportion of the Island will be protected for conservation.

Great Keppel Island is the largest island in the Keppel Island Group and is located approximately 12 km off the coast of Yeppoon on the Central Queensland coast. GKI is included within the Rockhampton Regional Council local government area. Until recently the Island has been occupied by a number of different commercial accommodation facilities ranging from camping ground style accommodation to resort level accommodation. The original GKI Resort was the main tourism resort located on the Island and comprised 190 guest rooms. These facilities were closed in early 2008. The Island is currently occupied by two backpackers' facilities, 10 residential properties and 10 commercial premises. Access to the Island is currently via ferry and cruise ship services from the Rosslyn Bay / Keppel Bay Marina on the mainland.

The proposed water cycle management strategy for the GKI Resort Revitalisation Plan as outlined in this Report has been developed in a holistic manner in accordance with the principles of water sensitive urban design and aims to:

- Minimise demand on limited water resources, particularly potable water supplies, by maximising water use efficiency and maximising the use of alternative water supplies (e.g. rainwater, treated effluent, harvested stormwater) for non-potable purposes;

- Maximise the beneficial reuse of wastewater and reduce the volume of wastewater requiring disposal;

- Ensure wastewater is adequately treated to a standard 'fit for purpose' prior to reuse or disposal to reduce the risk of potential environmental and public health impacts;

- Ensure the collection, storage and reuse or disposal wastewater during construction and operation of the GKI Resort Revitalisation Plan does not adversely impact on the natural environment or communities on and off the Island;

- Ensure stormwater is adequately treated to reduce the risk of potential impacts on the environmental values of receiving waters;

- Ensure stormwater is managed to maintain existing hydrologic behaviour by providing appropriate detention where necessary to ensure non-worsening of peak discharge velocities;

- Ensure water cycle management infrastructure, including stormwater quality improvement devices, detention basins and treated effluent storages, is designed and located to integrate into the landscape to enhance visual, social, cultural and ecological values; and,

- Continually improve the process for managing water supply, wastewater and stormwater associated with the GKI Resort Revitalisation Plan by conducting regular audits to identify opportunities to reduce, reuse or recycle waste, including wastewater, and to prevent environmental harm.

This Report acknowledges that valuable water resources on the Island were poorly managed during operation of the former GKI resort and outlines a strategy that will provide water security for the GKI Resort Revitalisation Plan while significantly reducing the potential for impacts on water resources in the future and enabling groundwater aquifers damaged in the past to be restored.

Key elements of the proposed water cycle management strategy are described as follows:

Water Supply and Storage:

Total annual average water demand for operation of the GKI Resort Revitalisation Plan has been estimated to be 1,884kL/day of which 493 kL/day is required for internal purposes and 1,391 kL/day is required for external purposes, primarily comprising irrigation of the golf course and other landscaped areas.

Peak occupancy is expected to occur in January and will result in an average daily internal water demand of 855 kL/day, which coincides with an average daily external water demand of 1,426 kL/day to equate to a total average water demand for January of 2,281 kL/day.

Peak irrigation water demand is expected to occur in November and will result in an average external water demand of 1,942 kL/day, which coincides with an internal average daily water demand of 527 kL/day to equate to a total average water demand for November of 2,469 kL/day.

The above water demand estimates are based on the use of water efficient fixtures and fittings, which will be installed throughout all resort and marina facilities. To calculate total water demands, an average domestic water demand of 228L/EP/day has been determined as appropriate for the GKI Resort Revitalisation Plan. A maximum design population of 3,973 EP has been estimated and includes approximately 3,000 EP within the Fisherman's Beach and Marina Precincts and approximately 1,000 EP within the Clam Bay Precinct.

To meet estimated water demand during operation of the GKI Resort Revitalisation Plan it is proposed to maximise the use of treated effluent, and captured rainfall and stormwater runoff to reduce demand for valuable potable water supplies, while ensuring security of water supply by via connection to Council's mainland water supply network. Specifically, the following water supply sources will be used.

Potable Water Supply

- All required potable water (i.e. drinking water) supply will be derived from Rockhampton Regional Council's municipal water supply scheme on the mainland (as operated by Fitzroy River Water for the Council) via a new water main to be installed within the Utility Services Corridor;
- During the design stage of the Project, the viability of increased rainwater reuse for apartments and villas will be investigated. This would involve UV disinfection of the potable use component. It is estimated that 100% of the demand for the apartments and villas would be available for the months of December to June inclusive and, in median rainfall years, up to 50% or more in the months of July to November inclusive.

Non-Potable Internal Water Supply

- Primary water supply for non potable uses to toilets and laundries within all facilities will be derived from captured rainwater via roof runoff collected and stored in tanks and pumped back to the relevant fixtures. Where necessary, rainwater supply to these fixtures will be supplemented by top up from the main potable supply.

Non-Potable External Water Supply

- Water supply for irrigation purposes will be provided from the following sources, in order of priority, and subject to availability:
  - Rainwater captured and stored from roof runoff to all facilities to be used for irrigation purposes adjacent to the respective facilities;
  - Treated effluent derived from the Island-based WWTP(s) will provide the primary water supply for irrigation of the golf course along with irrigation of other landscaped areas where excess supply is available;
  - Harvested stormwater runoff captured within the purpose-designed and built pond system incorporated into the golf course will be used to supplement treated effluent supplies for irrigation of the golf course;
  - Additional purpose-designed and built stormwater harvesting systems may also be installed in other areas around the resort (subject to feasibility, final design and availability of sufficient water); and
  - Any additional requirements for irrigation water supply, particularly for the golf course, would be sourced from the potable water supply via the mainland connection.

A detailed water balance has been undertaken and demonstrates that:

- Rainwater reuse will account for between 3% and 9% of total water demand;

- Treated effluent reuse will account for between 16% and 28% of total water demand; and
- Harvested stormwater will account for between 4% and 13% of total water demand.

Water derived from the mainland connection to Rockhampton Regional Council's water supply system will therefore be required to supply approximately 50% to 77% of the total water demand for this Project on average. During January, an average 645 kL/day will be required from the mainland water supply connection with a peak day mains water demand for January of 968 kL/day. During November, an average 1,436 kL/day will be required from the mainland water supply connection with a peak day mains water demand for November of 1,579 kL/day. The peak day demands assume a 1.5 peaking factor on the average domestic demand for the month and a 1.1 peaking factor on irrigation demand for the month.

Although it is unlikely that the internal water demand and external water demand will coincide, it is recommended that sizing of the mainland water supply connection be based conservatively on such an occurrence. This approach to sizing of the mainland connection will avoid the need for possible augmentation of the main and associated seabed disturbance in the future and will ensure sufficient capacity is available to support the high early water requirements associated with establishment of the golf course, which coincides with low treated effluent production in the early stages of the Project.

Emergency Water Supply

In the event of a disruption to the potable water supply connection to the mainland, it is estimated that between 3-7 days of emergency potable water supply may be sourced from mainland water stored within reservoirs on the Island. In the event of an extended disruption to the mainland water supply connection, water restrictions will be imposed, additional potable water may be barged over from the mainland or consideration may need to be given to reducing guest occupancy and staffing to ensure that adequate water is available.

Fire Fighting Water Supply

Water supply for fire fighting will be provided by the provision of dedicated fire storage within the water storage reservoirs, fire pumps (if required following assessment in the detailed design stage) and the provision of fire hydrants and hose reels within the water reticulation system adjacent to the various buildings throughout the GKI Resort Revitalisation Plan.

Construction Water Supply

During Stage 1 of construction, water supply will be sourced from the existing groundwater bores installed within the Long Beach Aquifer. The maximum long term sustainable yield from the Long Beach Aquifer has recently been assessed by Douglas Partners (2011) as 100 kL/day, which could be drawn from two bores having a maximum extraction capacity of 50kL/day each. Estimated water demand for Stage 1 construction is approximately 5 ML/ annum for construction (say an average of 20 kL/day for 250 working days and, with a peaking factor of 2, a peak day of 40 kL/day) and up to 50 kL/day for domestic purposes for construction workers. Total Stage 1 construction water demand would thus peak at around 90 kL/day. This is within the sustainable yield of the Long Beach Aquifer. Once the mainland water supply connection is operational, no further extraction of groundwater resources is proposed for construction or operation of the resort.

With the exception of treated effluent production, minimal treatment will be required for proposed water supply sources to be used on the Island. Treatment is likely to be limited to disinfection of groundwater supplies for Stage 1 construction and supplementary disinfection of mainland water supplies prior to storage on the Island due to the length of of the pipeline from the mainland.

Key water supply infrastructure to be constructed for the GKI Resort Revitalisation Plan will include:

- A 16 km water supply main within the Utility Services Corridor extending from Council's water supply network along the Scenic Highway near Emu Park to the GKI water supply network at the Marina Precinct;

- Storage tank (to receive the mainland supply) and pumps adjacent to the Marina Precinct to pump to high level water storage tanks for distribution;

- Two potable water reticulation systems are proposed - one for the Fisherman's Beach and Marina Precincts and the other for the Clam Bay Precinct. Both systems will be serviced by high-level water storage tanks fed by trunk delivery mains from mainland supply. Some higher elevation accommodation facilities may require small booster pumps to deliver reticulated water supply;

- Rainwater tanks, stormwater harvesting ponds / tanks and treated effluent storage tanks for supply of non-potable water; and,

- Non-potable water reticulation systems to distribute treated effluent, harvested stormwater and collected rainwater for irrigation and other purposes.

Wastewater, Treatment and Reuse

A new wastewater treatment plant (WWTP) will be constructed on the Island to treat all sewage generated by the GKI Resort Revitalisation Plan. Up to two WWTPs may be constructed on the Island depending on the final layout and staging of the Project. The new WWTP(s) will have a total peak design capacity of approximately 4,000 EP. This is likely to include WWTP with a peak design capacity of approximately 3,000 EP for the Fisherman's Beach and Marina Precincts, which is expected to be constructed in at least two stages of 1500 EP each or possibly three stages of 1,000 EP each. A WWTP with a peak design capacity of approximately 1,000 EP may also be constructed for the Clam Bay Precinct, which is expected to be constructed in two stages of 500EP each.

An average dry weather flow (ADWF) of 180L/EP/day has been estimated for the GKI Resort Revitalisation Plan, which is equivalent to the estimated internal water demand. However, an ADWF of 200L/EP/day has been adopted for modelling of treated effluent irrigation to ensure a conservative approach to sizing of the irrigation area and wet weather storage requirements in order to reduce the risk of potential environmental impacts.

It is proposed that treated effluent produced by the Island-based WWTP will be beneficially reused for irrigation of the golf course and other landscaped areas. As the volume of treated effluent likely to be produced by the GKI Resort Revitalisation Plan is expected to be sufficient to only partially meet the irrigation requirements of the proposed golf course, no other forms of reuse (eg. toilet flushing) are considered feasible at this time.

A comprehensive daily water and nutrient balance model has been undertaken for the proposed irrigation scheme based on over 50 years of site specific climatic data. This modelling has demonstrated that in most years, 100% of all treated effluent produced by the Island-based WWTP will be reused for irrigation of the golf course and other landscaped areas, assuming provision of at least 31 hectares of irrigation area and 37ML of wet weather storage. During extreme wet weather events expected to occur on average about once every 10 years, a small proportion of treated effluent may be discharged via an ocean outfall. The ocean outfall will be approximately 1,000 metres in length and will extend from Long Beach. The ocean outfall will be located and designed to achieve sufficient separation to sensitive uses and to provide for adequate dispersion in accordance with the requirements of the GBRMPA.

To further reduce the frequency of overtopping and to provide a buffer against potential increases in rainfall intensity due to projected climate change impacts, it is proposed that a total wet weather storage capacity of 44ML will be provided. This equates to an additional 7 ML or approximately 20% more wet weather storage than considered in the modelling, which suggests that ocean discharge is actually likely to occur much less frequently than the once every 10 years shown by the modelling.

The WWTP(s) will be designed to treat sewage generated by the Project to the following standard:

Quality Characteristic	Unit	Release Limit	Limit Type
E. coli	cfu/100mL	<1 (<10)	Median (95th percentile)
5-day Biological Oxygen Demand	mg/L	<20	Median
Turbidity	NTU	<2 (<5)	Median (Maximum)
Suspended Solids	mg/L	<5	Median
Total Dissolved Solids	mg/L	<1,000	Median
pH		6.0 – 8.5	Range
Total Nitrogen	mg/L	<20	Median
Total Phosphorous	mg/L	<7	Median
Free Chlorine Residual[1]	mg/L	0.5-1.0	Range

The proposed treatment standard is consistent with the minimum water quality requirements specified for "Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application" under the *Australian Water Quality Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (ANZECC, 2006). Proposed total nitrogen and total phosphorous concentrations have been determined as appropriate based on a comprehensive assessment of the nutrient assimilation capacity of soils and vegetation within the proposed irrigation area.

A range of treatment systems and processes are capable of achieving the above standard of treatment, with the preferred option to be selected at the design stage. Selection of the preferred treatment system will need to take into account the following factors:

- Proposed staging of the Project over 12 years, with associated progressive increases in sewage generation and treated effluent available for irrigation;
- Highly variable hydraulic loading associated with fluctuating occupancy over the year ranging from approximately 1,069 EP to 3,750 EP for the completed Project;

- Proximity of odour and noise sensitive receivers to the proposed WWTP(s) sites; and,
- The environmentally sensitive nature of the site, which requires a robust and reliable treatment system to ensure a consistent and high standard of treated effluent is produced so as to mitigate the potential for adverse impacts on public health and the environment.

At this stage, a proprietary package treatment plant incorporating membrane bio-reactor (MBR) technology (or similar) combined with UV disinfection is considered the preferred option due to its proven ability to achieve the required standard of treatment, relatively small footprint, relatively enclosed treatment components to reduce odour and the capacity to install multiple parallel plants to facilitate staging and operational flexibility.

Modelling of the proposed irrigation of treated effluent to the golf course and other landscaped areas demonstrates that proposed total nitrogen, total phosphorous and salinity levels will have no adverse impacts on soil quality or plant health within the irrigation area, and that nutrient levels in groundwater discharging to Leeke's Creek downstream of the irrigation area will not exceed relevant water quality objectives. Nutrient levels within treated effluent have also been assessed as achieving the required water quality objectives within a small mixing zone surrounding the ocean outfall based on possible emergency discharge events and are therefore unlikely to impact on ecological communities surrounding the outfall.

Modelling of proposed treated effluent irrigation indicates that the proposed application of treated effluent will account for approximately 30-40% of the total annual irrigation requirements for tees, greens and fairways which are expected to account for approximately 50% of the total golf course area. Treated effluent will be used to meet 100% of the annual irrigation requirements for remaining areas of the golf course.

Proposed wet weather storage will be provided as a series of ponds incorporated into the golf course design. Given the high standard of treatment, there is considered to be minimal risk to public health associated with these open storages provided they are appropriately managed. Wet weather storage ponds will be lined to prevent infiltration to groundwater due to the high permeability of natural soils. Stormwater runoff will be prevented from entering wet weather storage ponds to reduce the risk of overtopping. Additional stormwater harvesting ponds will be incorporated into the golf course design to collect surface runoff from recycled irrigation areas. Collected stormwater will be used to supplement irrigation water supplies, while the stormwater ponds will also assist in reducing the direct release of golf course runoff to natural waterways.

The potential for cyano-bacterial growth within proposed wet weather storage and stormwater harvesting ponds is relatively low given that regular mixing and changes in level will occur as water is extracted for irrigation. Nevertheless, regular monitoring of water quality within these ponds will also be undertaken to enable early identification and treatment of any potential eutrophication likely to contribute to algal blooms.

A preliminary treated effluent irrigation management plan has been developed for the GKI Resort Revitalisation Plan and outlines a range of routine procedures, environmental control measures, contingency plans, monitoring and reporting requirements to ensure ongoing operation of the treated effluent irrigation scheme does not have any adverse impacts on public or environmental health.

Stormwater Drainage:

In accordance with water sensitive urban design (WSUD) principles and best practice environmental stormwater management, stormwater drainage systems incorporated into the GKI Resort Revitalisation Plan will primarily utilise surface drainage techniques (such as grassed swales) rather than traditional underground piped drainage systems. This will minimise the need for significant excavation for installation of stormwater pipe trenches while also enabling stormwater drainage systems to be utilised as landscape features.

The proposed stormwater strategy also aims to treat stormwater at the source using bio-retention filters that utilise native vegetation and natural sand materials. The bio-filters remove sediment and nutrients from stormwater before allowing the stormwater to infiltrate into the natural sandy soils mimicking the natural process of groundwater recharge through rainwater infiltration that occurs on the Island.

The proposed stormwater management strategy developed for the GKI Resort Revitalisation Plan has been designed to comply with *State Planning Policy (SPP) 4/10 - Healthy Waters* (May 2011) and the draft *Urban Stormwater - Queensland Best Practice Environment Management Guidelines 2009*. To demonstrate compliance, existing and post-development hydrologic behaviour within catchments containing elements of the GKI Resort Revitalisation Plan has been analysed to determine changes to peak surface flow rates and annual runoff volumes resulting from the Project. To assess the potential impacts of stormwater runoff generated by the GKI Resort Revitalisation Plan on the surface water quality in receiving waters, modelling has been undertaken using MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software.

The Project will increase the area of impervious surfaces (roads, roofs and the like) and reduce the area of pervious surfaces within a number of drainage catchments on GKI. This change in the relativity of impervious area to pervious area will alter the proportions of rainfall volume that becomes surface runoff, groundwater or is lost through evapo-transpiration.

Despite the proposed increase in impervious area within catchments containing elements of the GKI Resort Revitalisation Plan, modelling has demonstrated that post-development peak surface flow rates in waterways on the Island can be maintained at less than existing peak rates by installing suitably sized detention basins at appropriate locations within these catchments. As such, the Project is deemed to comply with the waterway stability objective of SPP 4/10, which requires that new developments manage flows such that the post-development one-year ARI event discharge rate within the downstream waterway is no greater than the pre-development peak one-year ARI event discharge rate. By mitigating peak surface flow rates in this manner, the potential for scouring and erosion in downstream waterways is significantly reduced.

Detention structures will comprise low impact designs utilising low grassed or vegetated mounds enclosing open space that can be readily incorporated as part of the landscape design for the Project. Preliminary sizing of detention basins and bio-retention systems have been specified for each catchment to achieve the required levels of flow attenuation and pollutant reduction. Although the exact location and design of detention basins will need to be confirmed during detailed design stages, modelling undertaken to date indicates that detention requirements to mitigate post-development peak flow rates to, or below, pre-development levels are relatively small. As such, it is anticipated that the required detention basins can be readily integrated into landscaped elements of the GKI Resort Revitalisation Plan without requiring any significant increase in the Project footprint.

Annual runoff volumes, and particularly the distribution of rainfall to surface flow, groundwater and evapo-transpiration, were analysed using continuous simulation analysis in the hydrologic module of MUSIC software. As would be expected, analysis suggests that generally, surface flow volumes will increase, flow volumes to groundwater will increase slightly, and evapo-transpiration volumes will decrease. It has been determined however, that installation of rainwater tanks to capture and reuse roof water and infiltration into the natural sandy soils from proposed detention basins and bio-retention systems will assist in mitigating annual runoff volumes to an acceptable level. The harvesting of stormwater runoff for irrigation water supply proposed as part of the water cycle management strategy will further contribute to reducing surface runoff volumes.

To protect in-stream ecology of ephemeral freshwater waterways, SPP 4/10 also requires new development to manage the increase in the number of small runoff events that occur from impervious surfaces compared to natural vegetated surfaces. This objective is typically satisfied by capturing and managing the first 10mm of runoff from impervious surfaces each day. Only two of the catchments affected by the GKI Resort Revitalisation Plan discharge to ephemeral freshwater streams, these being Catchment 9, which discharges to Putney Creek and Catchment 11, which discharges to Leeke's Creek. The proposed bio-retention and detention structures in these two catchments intercept all runoff from impervious surfaces before it reaches the respective defined waterways. In both catchments, the daily infiltration capacity of the treatment structures far exceeds the volume of the first 10mm of rainfall on the respective impervious surfaces, thus significantly reducing the potential for any increase in the frequency of low flow events.

Given the nature of the site and its environmental significance, it is important that stormwater quality improvement devices are robust and well proven. Best practice vegetated bio-retention systems, including bio-retention basins, swales and infiltration areas will be installed to remove gross pollutants, sediments and nutrients from stormwater flows prior to discharge. Across a large proportion of the site, subsoils comprise of high permeability sand. The permeability of the subsoils determined through geotechnical investigations has been shown to be similar to the design permeability of the filters used in bio-retention basins or swales and significantly higher than that of typical mainland soils. Bio-retention filtrate can therefore drain directly to the sandy substrate with no specific under-drainage pipes required in the bio-retention areas.

This will significantly reduce or avoid the need for an extensive network of drainage pipes and associated trenching that would otherwise be required. As such, the extent of ground disturbance and vegetation clearing likely to be required for installation of the stormwater treatment will generally be limited to that required for installation of the stormwater treatment devices themselves. Infiltration of treated stormwater through the base of the bio-retention facilities will also contribute to recharge of groundwater resources mimicking the natural rainwater infiltration that occurs on the Island. It will also eliminate the concentration of drainage flows to a limited number of discharge points, which significantly reduces the potential for scouring and erosion.

Modelling of stormwater runoff using MUSIC software demonstrates that proposed stormwater quality improvement measures will readily achieve required annual pollutant load reduction targets and will result in no worsening of stormwater pollutant concentrations compared to modelling of the pre-developed catchment.

Although bio-retention systems are capable of removing gross pollutants such as litter, frequent removal of debris is required to maintain effectiveness. As such, to prevent litter from resort areas entering waterways where it may harm wildlife, specific gross pollutant traps will be installed as part of the stormwater treatment train in key locations where litter generation is most likely to be concentrated and where the risk of entering waterways is greatest (e.g. the Marina Precinct).

Specific stormwater management measures will be provided in high risk areas likely to contain significant quantities or types of contaminants not consistent with the assumptions of the stormwater modelling described in this section. This includes, but may not be limited to, the golf course, and areas used for the storage and handling of hazardous substances (e.g. chemicals, fuels and oils), bulk waste storage areas and maintenance workshops.

Stormwater management on the proposed golf course will consist of the following elements:

- Surface runoff from the proposed golf course will be diverted to stormwater harvesting ponds for reuse for irrigation of the golf course;
- Golf course runoff will be directed to the stormwater harvesting ponds through a series of grassed swales and/ or bio-retention basins to facilitate removal of gross pollutants (e.g. litter) sediment and nutrients prior to entering the stormwater harvesting ponds;
- Stormwater harvesting ponds will incorporate an overflow provided with appropriate scour protection and outletting to a grassed overland flow channel providing further treatment prior to ultimately discharging to Leeke's Creek;
- Stormwater will be prevented from draining into wet weather storage ponds containing recycled water; and,
- Monitoring of water quality within the stormwater harvesting ponds will be undertaken as part of the irrigation management plan proposed for the golf course to ensure water quality is 'fit for purpose'.

Stormwater management proposed for other high risk areas will be designed to prevent stormwater coming into contact with contaminants (e.g. use of perimeter diversion systems, sealing and covering of the area) and to prevent the release of contaminants accidentally spilled or leaked within the area (e.g. bunding). Any stormwater that does enter such areas would be collected and tested to ensure compliance with relevant water quality standards prior to disposal. A preliminary Hazardous Substance Storage Management Plan has also been prepared for such areas to mitigate potential impacts from the spillage or leakage of hazardous substances.

To support the above stormwater quality improvement concepts, overall civil, landscape and architectural designs will incorporate appropriate surface shaping to facilitate surface flow transport systems and bio-retention requirements.

As part of the stormwater management strategy for the site, it has also been proposed to permanently open the mouth of Putney Creek to tidal movements, which will increase fisheries productivity and flushing to prevent the formation of eutrophied conditions that may contribute to algal blooms and subsequent odour nuisance. To achieve this, a lined discharge channel will be constructed below the boardwalk and esplanade, with a sediment basin incorporated towards the upstream end of the new channel. This will reduce the potential for silting up of the marina basin thereby reducing the need for ongoing maintenance dredging.

1. INTRODUCTION

This Report has been prepared by Opus International Consultants (Opus) on behalf of GKI Resort Pty Ltd to provide an overview of proposed water cycle management strategies associated with the Great Keppel Island (GKI) Resort Revitalisation Plan, including addressing water supply, wastewater and stormwater management. The contents of this Report are to be included as part of the overall Environmental Impact Statement (EIS) prepared for the GKI Resort Revitalisation Plan.

The GKI Resort Revitalisation Plan has been developed in accordance with the principles of Water Sensitive Urban Design (WSUD). WSUD is a holistic approach to the planning and design of urban development that aims to minimise negative impacts on the natural water cycle and protect the health of aquatic ecosystems. It promotes the integration of stormwater, water supply and sewage management at the development scale.

WSUD represents a fundamental change in the way urban development is conceived, planned, designed and built. Rather than using traditional approaches to impose a single form of urban development across all locations, WSUD considers ways in which urban infrastructure and the built form can be integrated with a site's natural features. In addition, WSUD seeks to optimise the use of water as a resource.

The key principles of WSUD are to:

- Protect existing natural features and ecological processes;
- Maintain the natural hydrologic behaviour of catchments;
- Protect water quality of surface and ground waters;
- Minimise demand on the reticulated water supply system;
- Minimise sewage discharges to the natural environment; and
- Integrate water into the landscape to enhance visual, social, cultural and ecological values.

This Water Cycle Management Report outlines a strategy to address water supply, wastewater and stormwater management aspects of the GKI Resort Revitalisation Plan in a holistic manner to demonstrate consistency with the above principles.

1.1 PROJECT OVERVIEW

The GKI Resort Revitalisation Plan (refer to **Appendix A – GKI Resort Revitalisation Plan**) proposes to create a low rise, eco-tourism resort on Great Keppel Island.

The proposal involves:

- Demolition of the old resort and construction of a new 4 or 5 star resort hotel at Fisherman's Beach comprising 250 suites and day spa;
- Dredging activities for construction of the marina and re-nourishment of Putney Beach using dredge spoil;

- A new all-weather safe access marina facility at Putney Beach comprising 250 berths, a ferry terminal, emergency services facilities, yacht club, and dry dock storage;
- A retail village with a mix of cafes, restaurants and clothing shops around the marina;
- An 18-hole golf course, designed by Greg Norman Golf Course Design and including club house, integrated with essential habitats and ecological corridors, and located on previously disturbed grazing lands;
- New runway and airport facilities;
- 750 eco-tourism villas incorporating sustainable building design, rooftop solar panels and water tanks;
- 300 eco-tourism apartments incorporating sustainable building design, rooftop solar panels and water tanks;
- Installation of power, water and telecommunications connections between the Island and mainland;
- Associated service facilities and utilities (waste collection area, fire-fighting and emergency services hub, fuel, solar, wastewater treatment plant etc), including 200 bed staff accommodation facilities;
- Establishment of the GKI Research Centre and Biodiversity Conservation Fund (BCF) which will aim to deliver a better understanding of the surrounding marine and terrestrial environments and to actively undertake conservation works to enhance the natural environment;
- A new sports oval which can be used by resort guests and other GKI residents and visitors; and
- Restoration of the original Leeke's Homestead.

It is envisaged that approximately 685 full time, part time and casual staff will be required once the resort is fully operational. Most operational staff will work standard shift hours and will be sourced from the Capricorn Region. The majority of staff will travel to the Island via ferry for each shift, before returning home to the mainland after their shifts. Up to approximately 300 staff on average are expected to utilise the new 200 bed staff accommodation facility to be provided on the Island as part of the GKI Resort Revitalisation Plan.

The GKI Resort Revitalisation Plan will be constructed in stages, with Stage 1 involving construction of the Fisherman's Beach hotel and day spa, the marina facility including retail precinct, one hundred and fifty (150) apartments and internal infrastructure (power, water, sewerage, stormwater, roads). It is expected that Stage 1 will take approximately 18 months to construct at a cost of around $150 million. Completion of the GKI Resort Revitalisation Plan is expected to take 12 years, finishing around 2023.

Construction workers will be ferried to and from the Island where possible and practical. It is envisaged that rooms at the old resort as well as other accommodation options on the Island will be utilised to provide accommodation on the Island for some construction workers.

1.2 LOCALITY OVERVIEW

Great Keppel Island is located approximately 12 km off the coast of Yeppoon on the Central Queensland coast. GKI is included within the Rockhampton Regional Council local government area.

GKI is the largest island in the Keppel Island Group, which comprises a group of sixteen islands, including North Keppel Island Corroboree Island Pumpkin Island Miall Island Middle Island Barren Island Halfway Island and Humpy Island. Apart from GKI and Pumpkin Island all of the other Keppel Islands are designated National Parks.

The proposed GKI Resort Revitalisation Plan applies to the areas of GKI that are leased by GKI Resort Pty Ltd, which covers an area of approximately 900 hectares consisting of multiple land tenures. The GKI Resort Revitalisation Plan also includes Unallocated State Land to be developed for the marina and areas to accommodate utility service connections between GKI and the mainland.

There are seventeen beaches on GKI and its natural environment offers a wide range of activities including swimming, diving, snorkelling and bushwalking.

1.3 CURRENT AND PREVIOUS DEVELOPMENT

Until recently the Island has been occupied by a number of different commercial accommodation facilities ranging from camping ground style accommodation to resort level accommodation. The original GKI Resort was the main tourism resort located on the Island and comprised 190 guest rooms. These facilities were closed in early 2008.

The Island is currently occupied by two backpackers' facilities, ten residential properties and ten commercial premises. Access to the Island is currently via ferry and cruise ship services from the Rosslyn Bay / Keppel Bay Marina on the mainland.

In the 1990s when the former GKI resort was operating, the average daily population on the Island (staff, residents, overnight and day visitors) was approximately 765 persons while the maximum possible daily population was approximately 2,600 persons (Foresight Partners, 2011). The peak daily population for the Island during operation of the former resort (i.e. 2,600 persons) is therefore comparable with the anticipated average daily population projected for the revitalised resort (i.e. 2,274 persons) (Foresight Partners, 2011).

1.4 SCOPE AND OBJECTIVES

The purpose of this Report is to outline a water cycle management strategy to address water supply, wastewater and stormwater management associated with the demolition, construction and operation of the resort to ensure no adverse impacts on surrounding environments and communities. Specifically, the water cycle management strategy for the GKI Resort Revitalisation Plan aims to:

- Minimise demand on limited water resources, particularly potable water supplies, by maximising water use efficiency and maximising the use of alternative water supplies (e.g. rainwater, recycled water, harvested stormwater) for non-potable purposes;
- Maximise the beneficial reuse of wastewater and reduce the volume of wastewater requiring disposal;
- Ensure wastewater is adequately treated to a standard 'fit for purpose' prior to reuse or disposal to reduce the risk of potential environmental and public health impacts;
- Ensure the collection, storage and reuse or disposal of wastewater during construction and operation of the GKI Resort Revitalisation Plan does not adversely impact on the natural environment or communities on and off the Island;

- Ensure stormwater is adequately treated to reduce the risk of potential impacts on the environmental values of receiving waters;

- Ensure stormwater is managed to maintain existing hydrologic behaviour by providing appropriate detention where necessary to ensure non-worsening of peak discharge velocities;

- Ensure water cycle management infrastructure, including stormwater quality improvement devices, detention basins and recycled water storages, is designed and located to integrate into the landscape to enhance visual, social, cultural and ecological values; and

- Continually improve the process for managing water supply, wastewater and stormwater associated with the GKI Resort Revitalisation Plan by conducting regular audits to identify opportunities to reduce, reuse or recycle waste, including wastewater, and to prevent environmental harm.

This Report has been prepared to address parts of sections 2.5 and 3.4 of part B of the "Terms of Reference for EIS – Great Keppel Island Resort Project" issued by the Queensland Coordinator-General and dated June 2011, which requires the following issues to be considered in the Environmental Impact Statement (EIS):

2.5 Associated Infrastructure

2.5.4 Water supply and storage

Provide information on the proposed water usage by the project, including details on:

- *water supply design*
- *the ultimate supply required by full occupancy of the development*
- *the quality and quantity of all water supplied to the site during the construction and operational phases*
- *estimated water requirements and supply options for operation and maintenance of the golf course*
- *fire fighting flows required*
- *a site plan outlining actions to be taken in the event of failure of the main water supply*
- *potential for recycling of treated waste water*
- *if applicable, describe the methods to be employed to prevent/control cyano-bacterial growth in open water storages.*

Describe proposed sources of water supply given the implication of any approvals required under the Water Act 2000. Emphasis must be placed on demand and supply variability to demonstrate self-sufficiency of the project (e.g. during all stages of development and ongoing use, including reasonable predicted low rainfall).

Estimated rates of supply from each source (average and maximum rates) must be given and proposed water conservation and management measures must be described.

Determination of potable water demand must be made for the project, including the temporary demands during the construction period. Details must be provided of any existing town water supply to meet such requirements. Detail should also be provided to describe any proposed on site water storage and treatment for use by the site workforce during construction and operational phases.

A description should be provided of how any onsite water supplies are to be treated, contaminated water is to be disposed of and any decommissioning requirements and timing of temporary water supply/ treatment infrastructure is to occur.

2.5.5 Stormwater drainage

Describe the proposed stormwater drainage system, and the proposed disposal arrangements, including any off site services.

The EIS must detail the sources of stormwater and the quantity, quality and location of discharge to watercourses including the Great Barrier Reef Marine Park. Provide details on the standard of proposed stormwater treatment systems, including examples of quality improvement devices (sediment removal, gross pollutant traps), the schedule and timing of stormwater release from potential discharge points (spread of flow and scour protection), and the maintenance regime for the stormwater treatment systems.

2.5.6 Waste

The proposed management of solid and liquid wastes must be detailed with consideration given to the suitability of available waste disposal options. Particular attention must be given to the capacity of wastes to generate acidic, saline or sodic conditions.

Liquid waste

Describe the sewerage infrastructure required by the project, including:

- *options proposed for wastewater treatment and the proposed system for odour control*
- *peak design capacity evaluation of the wastewater treatment system and associated infrastructure using equivalent persons*
- *determination of the potential emergency effluent storage that would be required in an extended rain event (50 and 100-year wet weather storage ARIs accounting for climate change)*
- *the proposed disposal and/or reuse of the treated effluent and the management of such use. An irrigation plan should be provided detailing where the use of treated effluent is likely. Details of the likely impacts of treated effluent on surface water and groundwater quality should also be provided*
- *the siting and maintenance regime for the system*
- *all waste streams including demolition and construction wastes.*

Note: Issues relating to solid wastes that are also covered by this section of the ToR have been addressed separately in the "Waste Management Report" prepared by Opus International Consultants (2011a).

3.4 Water resources

3.4.1 Description of environmental values

This section of the EIS should provide a description of the existing water resources that may be affected by the project in the context of environmental values as defined in such documents as the EP Act, Environmental Protection (Water) Policy 2009 [EPP (Water)], Australia and New Zealand Guidelines for Fresh and Marine Water Quality 2000, the EPA Queensland Water Quality Guidelines 2009, and any relevant local and regional guidelines.

An indication of the quality and quantity of water resources in the vicinity of the project area should be given. This section should describe:

- *existing surface and groundwater in terms of physical, chemical and biological characteristics, and the interaction between surface and groundwater*
- *the recharge and discharge areas for groundwater on and around the island*
- *existing surface drainage patterns, flows, history of flooding including extent, levels and frequency and present water uses.*

The environmental values of the surface waterways and ground water of the affected area should be described in terms of:

- *values identified in the EPP (Water)*
- *physical integrity, fluvial processes and morphology, including riparian zone vegetation and form, if relevant*
- *any impoundments (e.g. dams, levees, weirs etc.)*
- *hydrology of waterways and groundwater*
- *sustainability, including both quality and quantity*
- *dependent ecosystems*
- *existing and other potential surface and groundwater users*
- *any Water Resource Plans relevant to the affected catchments*
- *possible discharge areas – where the groundwater seeps into coastal waters.*

If the project is likely to use or affect local sources of groundwater, this section should provide a description of groundwater resources in the area in terms of:

- *geology/stratigraphy*
- *aquifer type—such as confined, unconfined*
- *depth to and thickness of the aquifers*
- *depth to water level and seasonal changes in levels*
- *groundwater flow directions (defined from water level contours)*
- *interaction with surface water*
- *possible sources of recharge*
- *potential exposure to pollution*
- *current access to groundwater resources in the form of bores, springs, ponds, including quantitative yield of water and locations of access*
- *water quality, especially salinity and nitrates.*

The groundwater assessment should also be consistent with relevant guidelines for the assessment of acid sulphate soils including spatial and temporal monitoring to accurately characterise baseline groundwater characteristics. Specific reference should be made to relevant legislation or water resource plans for the region. The review should also provide an assessment of the potential take of water from the aquifer and how current users and the aquifer itself and any connected aquifers will be affected by the take of water.

The review should include a survey of existing groundwater supply facilities (bores, wells, or excavations) to the extent of any environmental harm. The information to be gathered for analysis is to include:

- *location*
- *pumping parameters*
- *draw down and recharge at normal pumping rates*
- *seasonal variations (if records exist) of groundwater levels*
- *historical environmental health data on groundwater held by the Rockhampton Regional Council.*

A network of observation points which would satisfactorily monitor groundwater resources both before and after commencement of operations should be developed.

The data obtained from the groundwater survey should be sufficient to enable specification of the major ionic species present in the groundwater, pH, electrical conductivity and total dissolved solids and relate to climate variation.

If in the event of the need for a desalination plant this would require detailed hydrodynamic modelling of the brine plume and its affect on the natural environment.

3.4.2 Potential impacts and mitigation measures

This section should assess potential impacts of the project on water resource environmental values identified in the previous section. It should also define and describe the objectives and practical measures for protecting or enhancing water resource environmental values, to describe how nominated quantitative standards and indicators may be achieved, and how the achievement of the objectives will be monitored, audited and managed. Discuss potential impacts from sewage treatment plant overflows and pump station overflows. Matters to be addressed should include:

- *potential impacts on the flow and the quality of surface and ground waters from all phases of the project, with reference to their suitability for the current and potential downstream uses, including aquatic ecosystem protection and discharge licences*
- *implications of irrigation and maintenance of the golf course with fertilizers and pesticides, especially on groundwater quality and ultimate effects on surrounding coastal waters and sediments*
- *an assessment of all likely impacts on groundwater depletion or recharge regimes*
- *potential impacts of surface water flow on existing infrastructure, with reference to the EPP (Water) and the Water Act 2000*
- *chemical and physical properties of any waste water including stormwater at the point of discharge into natural surface waters, including the toxicity of effluent to flora and fauna. Having regard to the requirements of the Environmental Protection (Water) Policy, the EIS must present the methods to avoid stormwater contamination and the means of containing, recycling, reusing, treating and disposing of stormwater*
- *potential impacts on other downstream receiving environments, if it is proposed to discharge water to a riverine system*
- *the results of a risk assessment for uncontrolled releases to water due to system or catastrophic failure, implications of such emissions for human health and natural ecosystems, and list strategies to prevent, minimise and contain impacts*
- *an assessment of the environmental and health impact of the discharges and the potential for any chemicals or toxins to bio-accumulate in the aquatic environment (both flora and fauna).*

Management strategies should be adequately detailed to demonstrate best practice management and that environmental values of receiving waters will be maintained to nominated water quality objectives. Monitoring programs, which will assess the effectiveness of management strategies for protecting water resources during the construction, operation and decommissioning of the project, should be described. Outline how these strategies are incorporated into appropriate sections of the EMP.

Surface water and water courses

The hydrological impacts of the proposal on surface water and water courses should be assessed, particularly with regard to stream diversions, scouring and erosion and changes to flooding levels and frequencies both upstream and downstream of the project. When flooding levels will be affected, modelling of afflux should be provided and illustrated with maps.

The need or otherwise for licensing of any diversions, water impoundments, placement of fill or destruction of native vegetation within any water course, lake or spring under the Water Act 2000 and the Fisheries Act 1994 should be discussed. Water allocation and water sources, including impacts on existing water entitlements, including water harvesting, should be established in consultation with DERM.

Wastewater treatment

Reference should be made to the properties of the land disturbed and processing liquid wastes, the technology for settling suspended clays from contaminated water, and the techniques to be employed to ensure that contaminated water is contained and successfully treated on the site.

In relation to water supply and usage, and wastewater disposal, the EIS should discuss anticipated flows of water to and from the proposal area. Where dams, weirs or ponds are proposed, the EIS should investigate the effects of predictable climatic extremes (storm events, floods and droughts allowing for climate change) on: the capacity of the water storages (dams, weirs, ponds), the ability of these storages to retain contaminants; the structural integrity of the containing walls; relevant operating regime and the quality of water contained, and flows and quality of water discharged. The design of all water storage facilities should follow the technical guidelines on site water management. Options for mitigation and the effectiveness of mitigation measures should be discussed with particular reference to sediment, acidity, salinity and other emissions of a hazardous or toxic nature to human health, flora or fauna.

Groundwater

The EIS should include an assessment of the potential environmental impact caused by the project (and its associated project components) to local groundwater resources, including the potential for groundwater induced salinity and contamination from use of pesticides and fertilisers on the golf course and other areas of the resort.

The response of the groundwater resource to the progression and final cessation of the proposal should be described.

An assessment should be undertaken of the impact of the project on the local ground water regime caused by the altered porosity and permeability of any land disturbance.

Any potential for the project to impact on groundwater dependent vegetation and stygofauna should be assessed and described. Avoidance and mitigation measures should be described.

Note: Parts of this section have been addressed separately in reports prepared by Douglas Partners, FRC Environmental and Water Technology. Where relevant to development of the water cycle management strategy, reference has been made to the pertinent information contained in these other reports.

The Report also addresses relevant requirements of the “Guidelines for an Environmental Impact Statement for the Great Keppel Island Tourism and Marina Development, Queensland” issued by the Australian Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) in conjunction with the Great Barrier Reef Marine Park Authority (GBRMPA).

2. LEGISLATIVE REQUIREMENTS

2.1 ENVIRONMENTAL PROTECTION ACT 1994

The *Environmental Protection Act 1994* (EP Act), which is administered by the Department of Environment and Resource Management (DERM), was established with the purpose "to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development)."

The EP Act utilises a number of mechanisms to achieve its objectives. These include:

- creating a general environmental duty,
- licensing environmentally relevant activities (ERAs); and
- issuing environmental protection policies.

2.1.1 General Environmental Duty

All persons involved in the GKI Resort Revitalisation Plan, including establishment and operation of proposed water supply, wastewater and stormwater management schemes, are subject to a general environmental duty of care under sections 319 and 320 of the EP Act. Section 319 of the Act, which conveys the general environmental duty, states that a person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm.

Furthermore, section 320 of the Act requires than if any person, while carrying out an activity, becomes aware that serious or material environmental harm is caused or threatened by any person's act or omission in carrying out the activity, they must as soon as reasonably practicable after becoming aware of the event, notify their employer or give written notice to the administering authority of the event, its nature and the circumstances in which it happened.

2.1.2 Environmentally Relevant Activities

Environmentally relevant activities are defined in schedule 2 of the *Environmental Protection Regulation 2008*. It is an offence to conduct an ERA without:

- A current development approval authorising the activity to be undertaken on the premises; and
- A current registration certificate authorising the person to undertake an ERA on the premises.

The following environmentally relevant activities as defined under schedule 2 of the *Environmental Protection Regulation 2008*, are likely to be associated with the water cycle management aspects of the GKI Resort Revitalisation Plan:

> ***ERA 63(2)(c)*** *– Sewage treatment – operating sewage treatment works, other than no release works, with a total peak design capacity of – 1,500 to 4,000EP.*

As part of the waste management strategy for the GKI Resort Revitalisation Plan as described in the "Waste Management Report" prepared by Opus International Consultants (2011a) it is proposed that biosolids from the wastewater treatment plant will be stabilised and treated, along with other organic wastes, for use as a soil conditioner on the golf course and landscaped areas on the Island. This activity conforms to the definition of ERA 53 defined under schedule 2 of the *Environmental Protection Regulation 2008* as follows:

> *ERA 53 Composting and soil conditioner manufacturing - composting and soil conditioner manufacturing (the relevant activity) consists of manufacturing, from organic material or organic waste, 200t or more of compost or soil conditioners in a year.*

Prior to commencement of the activity, development approval will be required for the above ERAs under chapter 4 of the *Environmental Protection Act 1994*. The resort operator will also be required to obtain a registration certificate to operate the above ERAs.

2.1.3 Environmental Protection Policies

EPPs hold the status of a regulation under the *Environmental Protection Act 1994*. EPPs set out environmental values that must be protected and provide for specific offences. As subordinate legislation to the EP Act, the EPPs bind all persons. The following EPPs have been declared and are relevant to this Project:

- *Environmental Protection (Water) Policy 2009;*
- *Environmental Protection (Noise) Policy 2008;*
- *Environmental Protection (Air) Policy 2008;*
- *Environmental Protection (Waste Management) Policy 2000;* and
- *Environmental Protection (Waste Management) Regulation 2000.*

Consideration shall be given to these policies in developing environmental management plans for water cycle management aspects of the GKI Resort Revitalisation Plan.

2.2 WATER ACT 2000

The purpose of this Act is to advance sustainable management and efficient use of water and other resources by establishing a system for the planning, allocation and use of water, to ensure the delivery of sustainable and secure water supply and demand management in designated regions and to establish a framework for the establishment and operation of water authorities.

Under the Act, a person must not take, supply or interfere with water to which the Act applies without a permit or other authorisation under the Act. A person also must not destroy vegetation, excavate or place fill within a watercourse, lake or spring without a permit or other authorisation under the Act.

For the purpose of this Act, a ‘watercourse’ is defined as:

> *(1) A watercourse is a river, creek or other stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently, regardless of the frequency of flow events—*
>
> > *(a) in a natural channel, whether artificially modified or not; or*
> >
> > *(b) in an artificial channel that has changed the course of the stream.*
>
> *(2) A watercourse includes any of the following located in it—*
>
> > *(a) in-stream islands;*
> >
> > *(b) benches;*

(c) bars.

(3) However, a watercourse does not include a drainage feature.

Watercourses meeting the above definition that occur within areas to be developed for the GKI Resort Revitalisation Plan include, but may not be limited to, Leeke's Creek and Putney Creek.

No taking of water from any surface watercourses requiring approval under the *Water Act 2000* is proposed as part of the water cycle management strategy for the GKI Resort Revitalisation Plan. However, the extraction of groundwater from production bores within the Long Beach Aquifer for use during construction will require a water licence for taking water from an aquifer under section 206 of the Act.

At this stage, no works involving destroying vegetation, excavating and placing fill are proposed to occur within Leeke's Creek. However, proposed drainage works around the mouth of Putney Creek associated with marina construction are likely to involve removal of vegetation, excavation and possible filling within a watercourse and may therefore require a Riverine Protection Permit under section 266 of the Act. Depending on the final design of these works, development approval for operational works may also be required under section 206 of the Act for interfering with the flow of water.

2.3 WATER SUPPLY (SAFETY & RELIABILITY) ACT 2008

The purpose of this Act is to provide for the safety and reliability of water supply by, amongst other things, establishing a regulatory framework for providing water and sewerage services in the State, including functions and powers of service providers; and providing a regulatory framework for providing recycled water and drinking water quality, primarily for protecting public health.

The relevant recycled water provisions of the *Water Supply (Safety and Reliability) Act 2008* commenced on 1 July 2008 and are administered by the Department of Environment and Resource Management (DERM). The primary aim of the recycled water provisions is to protect public health and for certain schemes known as critical recycled water schemes, to ensure continuity of operation of the scheme to meet the essential water supply needs of the community or industry.

The Act requires that a recycled water provider must have either of the following before supplying recycled water unless they are covered by a transitional period:

- a recycled water management plan (RWMP) approved by the regulator; or
- an exemption from preparation of a RWMP granted by the regulator (refer to recycled water management plan exemption guidelines).

Transitional periods about recycled water are specified in sections 631–634 of the Act.

Under the Act, a 'recycled water provider' is defined as an entity that:

(a) owns infrastructure for—

(i) the production and supply of recycled water other than coal seam gas water; or,

(ii) the production and supply, or the supply only, of recycled water that is coal seam gas water; or

(b) another entity, prescribed under a regulation, that owns infrastructure for the supply of recycled water other than coal seam gas water.

The Act defines 'recycled water' as:

(a) any of the following that are intended to be reused:

(i) sewage or effluent sourced from a service provider's sewerage;

(ii) wastewater, other than water mentioned in subparagraph (i); or,

(b) coal seam gas water that augments a supply of drinking water.

Although the resort operator will own infrastructure used for supplying water or sewerage services, the operator of the resort is not considered to comprise a 'service provider' as defined in the Act, on the basis that the service will be used only by the owner of the infrastructure (i.e. GKI Resort Pty Ltd) or the owner's guests or employees (e.g. resort guests).

On the basis of the above, recycled water generated by the GKI Resort Revitalisation Plan is not considered to be covered by the *Water Supply (Safety & Reliability) Act 2008*. However, this may change depending on whether infrastructure owned by GKI Resort Pty Ltd is to be used to provide water and sewerage services for other private properties on the Island.

2.4 PUBLIC HEALTH ACT 2005

Pursuant to section 57F of the *Public Health Act 2005*, a recycled water provider has a general obligation to ensure the recycled water supply is 'fit for purpose'.

Although GKI Resort Pty Ltd is not considered to comprise a 'service provider' or 'recycled water provider' under the *Water Supply (Safety & Reliability) Act 2008,* and is therefore not subject to section 57F of this Act, the resort operator has a general duty of care to its staff and guests to ensure that recycled water generated and reused on site is 'fit for purpose' and does not result in unacceptable risks to public health or the environment.

The *Public Health Regulation 2005* defines minimum water quality criteria that must be complied with for recycled water to be deemed 'fit for purpose' for a range of recycled water reuse purposes. The water quality criteria specified in the *Public Health Regulation 2005* relate specifically to the protection of public health and does not limit the requirement for recycled water quality to be suitable for its intended use in terms of preventing adverse environmental impacts.

The *Public Health Regulation 2005* does not specify minimum water quality criteria that must be complied with for reuse of recycled water for irrigation of a golf course and possibly other landscaped areas as proposed by the water cycle management strategy outlined in this Report.

2.5 COASTAL PROTECTION & MANAGEMENT ACT 1995

The purpose of this Act is to provide for the protection, conservation, rehabilitation and management of the coast, including its resources and biological diversity, which is to be achieving, amongst other things by preparing coastal management plans and declaring coastal management districts in the coastal zone as areas requiring special development controls and management practices.

Works associated with the proposed water cycle management strategy as outlined in this Report, that are likely to require approval under the *Coastal Protection and Management Act 1995*, include, but may not be limited to:

- Construction of the mainland water supply connection within tidal waters and a Coastal Management District;
- Construction of the emergency ocean outfall for recycled water discharge during extreme wet weather events within tidal waters and a Coastal Management District; and
- Construction of stormwater drainage works within and around the marina, including works associated with the mouth of Putney Creek, which will occur within tidal waters and a Coastal Management District.

These works will require development approval for operational works involving tidal works and works within a Coastal Management District.

2.6 FISHERIES ACT 1994

The main purpose of this Act is to provide for the use, conservation and enhancement of the community's fisheries resources and fish habitats in a way that seeks to apply and balance the principles of ecologically sustainable development. This is to be achieved through the management and protection of fish habitats; the management of commercial, recreational and indigenous fishing; the prevention, control and eradication of disease in fish; and the management of aquaculture. Works requiring approval under this Act include operational works in a declared fish habitat area, removal or damage of marine plants, or constructing a waterway barrier.

Works associated with the proposed water cycle management strategy as outlined in this Report, that are likely to require approval under the *Fisheries Act 1994*, include, but may not be limited to:

- Construction of the mainland water supply connection, which is likely to require development approval for operational works involving the removal of marine plants (including mangroves);
- Construction of the emergency ocean outfall for recycled water discharge during extreme wet weather events, which is likely to require development approval for operational works involving the removal of marine plants;
- Construction of stormwater drainage works within and around the marina, including works associated with the mouth of Putney Creek, which is likely to require development approval for operational works involving the removal of marine plants; and
- Depending on the final location of proposed roads and detention basins, construction of any such infrastructure within waterways identified as supporting fish movement may involve constructing waterway barrier works requiring development approval for operational works.

3. EXISTING ENVIRONMENT

3.1 TOPOGRAPHY

The topography of GKI is dominated by two (2) ridgelines aligned in a northwest to southeast direction across the Island. The southern ridgeline has a maximum elevation of approximately 175m AHD, while elevations along the northern ridgeline range between approximately 75m AHD at the north western extent up to 155m AHD in the south eastern extent. These ridgelines extend to the shoreline forming rocky headlands and cliffs. A series of sandy beaches exist between the rocky ridgelines and associated headlands.

Coastal sand dunes characterised by a flat to slightly undulating topography exist between Wreck Bay and Butterfish Bay in the north eastern area of the Island as well as in the south western area of the Island between Long Beach, Fisherman's Beach and Putney Beach.

A broad valley exists in the central area of the Island between the two (2) major ridgelines. This valley falls in a north westerly direction from an elevation of approximately 65m AHD at the rocky headland along Clam Bay down to sea level at Leeke's Beach.

3.2 GEOLOGY

Reference to the Rockhampton 1:100,000 Geological Sheet (DNRW, 2006 in Douglas Partners, 2010) indicates that the underlying geology of GKI is primarily comprised of the Carboniferous aged Shoalwater Formation of the Curtis Island Group, which overlies the early Palaeozoic Wandilla Formation that is quite widespread along the adjacent mainland coastline. The major hills and slopes on GKI are formed of Late Palaeozoic quartzose, arenite and mudstone of the Shoalwater Formation.

Geological mapping further indicates that within the three (3) main lower lying areas on the Island a thin layer of Quaternary deposits overlies the Carboniferous sequence. Within the north eastern part of the Island between Wrecks Bay and Butterfish Bay, and the south western part of the Island between Long Beach and Fisherman's Beach, this veneer of Quaternary sediments consists predominantly of coastal sand dunes and sand beach ridges, with foredune sands in the area around Putney Beach and Fisherman's Beach. The central western part of the Island within the drainage basin of Leeke's Creek is mapped as Quaternary aged fine-grained estuarine and alluvial deposits consisting of clay, silt, sandy mud and minor gravel.

In addition to these sand units identified on geological mapping, reference to the "Report on Preliminary Geotechnical Assessment for Proposed Great Keppel Island Resort, Great Keppel Island" prepared by Douglas Partners (December 2010) indicates that an extensive coastal dune sand deposit also extends across the central part of the Island from Leeke's Beach towards Clam Bay, but falling short of extending the full width of the Island due to the presence of a rocky outcrop along the Clam Bay coastline.

3.3 SOILS

Reference to the "Report on Preliminary Geotechnical Assessment for Proposed Great Keppel Island Resort, Great Keppel Island" prepared by Douglas Partners (December 2010) indicates that soils within the Fisherman's Beach Precinct and Clam Bay Precinct, which will contain the majority of water cycle management infrastructure, primarily comprise high permeability sand characterised by a saturated hydraulic conductivity (K_{sat}) of between 1.5m/day and 3.5m/day.

These soils are further described as very loose, fine to medium grained sands, initially dark brown and grey near the surface, grading to light brown, orange-brown and light grey with depth. Some silt and small amounts of organic material comprising small rootlets occur within the topsoil layer, while shell fragments were occasionally encountered at various depths within the profile.

According to Douglas Partners (2010), sandy soils within the Fisherman's Beach Precinct and Clam Bay Precinct are characterised by neutral to slightly acidic pH (pH = 5.4-7.4). Laboratory analysis determined these soils fall within Emerson Class 6 and are therefore considered to have a Medium potential for erosion.

3.4 SURFACE WATER

Great Keppel Island is the largest island in a group of sixteen (16) continental islands called the Keppel Island Group. The Keppel Island Group covers an area of 14.5 km^2 and is located at the southern end of the Great Barrier Reef, approximately 12km offshore of Yeppoon in Central Queensland and more than 200km inshore of the Outer Barrier Reef and the Swain Reef complex (FRC Environmental, 2011).

Fifteen (15) of the islands in the Keppel Island Group, excluding Great Keppel Island are designated National Park. The Great Barrier Reef Marine Park surrounds the Keppel Island Group and together they form the Great Barrier Reef World Heritage Area, the world's largest reef and island archipelago.

The Keppel Island Group is located directly offshore of the Fitzroy Basin, which is the largest river basin draining into the Great Barrier Reef. The islands lie in a shallow basin north of Keppel Bay, and are surrounded by a patchwork of fringing reefs (GBRMPA, 2007).

A range of coastal ecosystems have been identified on and surrounding Great Keppel Island through surveys undertaken by FRC Environmental (2011). Surrounding the Island is a combination of coral reefs, seagrass meadows, soft sediment communities, while on the Island exist rocky shore communities, sandy beaches providing possible turtle nesting sites, and mangrove forests fringing Leeke's Creek and Putney Creek.

Fourteen (14) distinct catchments for surface drainage have been identified on GKI. The location of the various drainage catchments identified on GKI is shown on the Catchment Plan contained in **Appendix B – Catchment Plan**. The development areas proposed under the GKI Resort Revitalisation Plan fall within the following catchments:

- Putney Creek (discharging at Putney Beach);
- Leeke's Creek (discharging at Leeke's Beach);
- Clam Bay;
- Long Beach; and
- Fisherman's Beach.

Waterways on the Island are largely ephemeral, flowing only during and shortly after storm events. In the lower reaches, gradients in the main waterways are relatively low and ponding can occur for periods after rain. There are no gauging facilities on any of the waterways and no historical flow records are available.

A tidal wetland known as Leeke's Wetland is located behind Leeke's Beach. A wetland area also exists along Putney Creek near the mouth. Due to a combination of local wave action, and the relatively low and intermittent flows along Putney Creek, the Creek mouth is regularly blocked by the formation of a sandbar. However, during large storm events, the sandbar is flushed out allowing tidal flows into the lower reaches of the Creek. Eventually, wave action reconstructs the sandbar and the lower reaches revert to a brackish wetland until the next major storm event.

Water quality surveys were undertaken at a number of sites on and surrounding GKI (as well as two mainland sites) by FRC Environmental (2011). Physico-chemical measurements were recorded for a total of thirty-one (31) sites, including:

- Three (3) sites within estuarine areas of Leeke's Creek, plus two (2) near-shore sites adjacent to the Leeke's Creek mouth;
- Eight (8) near-shore sites around Putney Point and Putney Beach; and
- Eighteen (18) off-shore sites within marine waters surrounding the Island.

More detailed water quality sampling was also undertaken by FRC Environmental (2011) for twelve (12) sites around the Island including:

- Putney Creek;
- Fisherman's Beach;
- Leeke's Creek Mouth;
- Leeke's Beach;
- Marina (3 sites);
- The Spit;
- Clam Bay;
- Long Beach;
- Wreck Beach; and
- Passage Rocks.

Water sampling was undertaken during the following seasons:

- Pre-wet – 15 to 19 November 2010;
- Wet – 17 to 21 January 2011; and
- Post-west – 30 March to 2 April 2011, and 1 to 2 May 2011.

A detailed description of existing water quality is contained in FRC Environmental (2011). However, a summary of key findings relevant to this Water Cycle Management Report is provided below:

- **pH** - slightly (typically within 0.2 pH units) below the relevant *Queensland Water Quality Guidelines* (QWQG) (DERM, 2009) trigger value range at several sites during the wet and post-wet surveys, and near Fisherman's Beach (site WQ08 and WQ19) during the pre-wet survey;

- **Dissolved oxygen** - levels near the surface were often above the relevant QWQG trigger value range whereas levels at depth were often below the relevant range. Leeke's Creek tended to have lower dissolved oxygen levels than other sites;

- **Turbidity** - several sites exceeded the relevant QWQG trigger value during the wet and post-wet surveys. Turbidity tended to be highest in Leeke's Creek but was also relatively high near Passage Rocks and Putney Point;

- **Total suspended solids** - exceeded the relevant QWQG trigger value at Leeke's Creek mouth in the post-wet survey and at Putney Creek in the pre-wet season survey. Concentrations were generally highest in the post-wet survey;

- **Total nitrogen** - exceeded the relevant QWQG trigger value at Putney Creek in the pre and post-wet surveys, and was particularly high in the pre-wet survey. In the pre-wet survey, sites at Fisherman's Beach, Leeke's Creek mouth, Marina 4 and The Spit also exceeded the relevant QWQG trigger value. In the post-wet survey, sites at Clam Bay, Marina 1 & 2, Passage Rocks and Wreck Beach also exceeded the relevant trigger value. In the wet survey, the Long Beach site exceeded the relevant trigger value;

- **Total phosphorus** - exceeded the relevant QWQG relevant trigger value at Putney Creek in the pre- and post-wet surveys, and was particularly high in the pre-wet survey. The concentration at each site in each survey exceeded the relevant QWQG trigger value, and concentrations were generally higher in the wet and post-wet survey than the pre-wet survey;

- **Chlorophyll-a** (an index of phytoplankton abundance) - offshore of The Spit was below the QWQG upper trigger value (2µg/L) throughout the recording period despite the concentration of nitrogen in nearby waters exceeding the QWQG upper trigger value prior to the survey, and the concentration of phosphorus exceeding the QWQG upper trigger value before and after the survey. The concentration of chlorophyll-a ranged from 0.3µg/L at 9pm on 22 February to 0.7µg/L at 7pm on 8 March and followed a cyclic pattern. The cyclic pattern reflects small phytoplankton blooms, which are related to environmental factors such as water temperature and nutrient availability;

- **Heavy metals** –

  - Total arsenic - below the laboratory detection limit at all sites during all surveys, except in Putney Creek during the pre-wet survey;

  - Total copper - exceeded the relevant trigger value under the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* (ANZECC Guidelines) (ANZECC & ARMCANZ, 2000) in Putney Creek and at the mainland sites in the post-wet survey;

  - Total zinc - exceeded the relevant trigger value under the ANZECC Guidelines at most sites in the post-wet survey, and was particularly high near The Spit and to a lesser extent in Putney Creek and at Kinka Beach; and

  - Other metals and metalloids (cadmium, chromium, nickel, lead and mercury), total petroleum hydrocarbons, aromatic hydrocarbons and organochlorine pesticides were below laboratory detection limits and / or relevant trigger values at all sites in all surveys.

3.5 GROUNDWATER

A series of groundwater studies have been undertaken on GKI by Douglas Partners (Douglas Partners, 2006; Douglas Partners, 2007; and Douglas Partners, 2011). These studies have identified shallow groundwater resources within the various sand dune deposits on the Island which have been described as:

- North East Aquifer – associated with the dune sand deposits between Butterfish Bay and Wreck Beach;
- Long Beach Aquifer – associated with the south eastern part of the coastal dune sand deposit extending from Long Beach to Fisherman's Beach / Putney Beach;
- Resort Aquifer – associated with the north western part of the coastal dune sand deposit extending from Long Beach to Fisherman's Beach / Putney Beach; and
- Central Dune Aquifer – associated with the north western part of alluvial sand deposit extending from Leeke's Beach almost through to Clam Bay.

The Central Dune Aquifer was only recently identified through the investigations by Douglas Partners (2011), as this area was not previously considered likely to contain shallow groundwater resources based on geological mapping of the area identifying the presence of rock associated with the Shoalwater Formation rather than any extensive sand deposits.

Assuming uniform and continuous extraction rates, the long term sustainable yields for these aquifers were estimated by Douglas Partners (2011) to be:

- North East Aquifer – 270kL/day - extracted from 2 x 100kL/day and 1 x 70kL/day production bores located in the central part of the aquifer;
- Long Beach Aquifer – 100kL/day - extracted from 2 x 50kL/day production bores; and
- Central Dune Aquifer – 90kL/day – extracted from 1 x 70kL/day and 1 x 20kL/day production bores.

No assessment of sustainable yield from the Resort Aquifer was undertaken as this aquifer was not considered suitable for extraction due to high likelihood of further saltwater intrusion.

A general description of each of the shallow aquifers identified on GKI by Douglas Partners (2011) is provided in **Table 3.1**.

TABLE 3.1: Summary of Shallow Groundwater Aquifer Properties

Attribute	North East Aquifer	Long Beach Aquifer	Resort Aquifer	Central Dune Aquifer
Geology	Well-sorted orange-brown, fine to medium grained sand over light grey-yellow, fine to medium grained sand.	Well-sorted light orange-brown, fine to medium grained sand over light grey-yellow, fine to medium grained	Well-sorted light orange-brown, fine to medium grained sand over light grey-yellow, fine to medium grained	Poorly-sorted fine to medium grained sand within some silty sand.

Attribute	North East Aquifer	Long Beach Aquifer	Resort Aquifer	Central Dune Aquifer
		sand.	sand.	
Thickness	7.5m – 21.5m 5m – 18m (saturated)	6m – 17m 5m – 11m (saturated)	6m – 12m 2m – 5m (saturated)	2.5m – 17m 3m – 10m (saturated)
Aquifer Type	Unconfined	Unconfined	Unconfined	Unconfined
Recharge	Mainly rainfall infiltration, some runoff from slopes to north and south (approx. 80-295 ML/year).	Mainly rainfall infiltration, some runoff from slopes to northeast and southwest (approx. 60-215 ML/year).	Mainly rainfall infiltration, some runoff from slopes to northeast and southwest (approx. 120-430 ML/year).	Mainly infiltration of direct rainfall, some runoff from slopes to northeast and southwest, and seepage from sands above bedrock along Clam Bay headland (approx. 70-265 ML/year).
Direction of Flow	Towards both Butterfish Bay and Wreck Beach from a central mound.	Southeast towards Long Beach.	West towards Putney Beach and Fisherman's Beach.	North west towards Leeke's Beach.
Hydraulic Conductivity	21 m/day	20 m/day to 21 m/day	20 m/day to 21 m/day	0.6 m/day to 8 m/day
Long Term Sustainable Yield[1]	270 kL/day	100 kL/day	Not assessed.	90 L/day

Notes:

1. Assuming uniform & continuous extraction rates. No assessment of sustainable yield from the Resort Aquifer was undertaken as this aquifer was not considered suitable for extraction due to high likelihood of further saltwater intrusion.

According to Douglas Partners (2011), nine (9) registered groundwater bores are listed on DERM's groundwater database on GKI. These bores are located within the former resort area pumping from the Resort Aquifer and near Long Beach pumping from the Long Beach Aquifer. Standing groundwater levels in these bores range between 1m and 9m below ground surface level.

Groundwater quality monitoring undertaken by Douglas Partners (2011) describes groundwater quality within each of the shallow aquifers as:

- **North East Aquifer:**
    - fresh water, low dissolved salt content, slightly acidic within the central area to slightly alkaline near the beaches;
    - relatively high total hardness;
    - heavy metal levels below drinking water guidelines; and
    - considered suitable for potable / drinking water purposes.

- **Long Beach Aquifer:**
    - generally fresh water, with low dissolved salt content, slightly acidic;
    - heavy metal levels below drinking water guideline;
    - evidence of saltwater intrusion as indicated by high electrical conductivity and high alkalinity was recorded in the Long Beach Pump House Bore in 2006 & 2007, but more recent monitoring shows this bore appears to be recovering with a more acidic pH and much lower electrical conductivity in 2010; and

- considered suitable for potable / drinking water purposes.

- **Resort Aquifer:**
  - generally fresh water, with low dissolved salt content and slightly acidic in the upper, central parts of the aquifer;
  - evidence of saltwater intrusion as indicated by high electrical conductivity and high alkalinity was recorded in monitoring bores near Fisherman's Beach in 2006 & 2007, but more recent monitoring for one of the bores in this area appears to show the aquifer is recovering with a more acidic pH and much lower electrical conductivity in 2010; and
  - no further chemical, physical or biological analysis undertaken as this aquifer was not considered suitable for extraction due to high likelihood of further saltwater intrusion.

- **Central Dune Aquifer:**
  - variable quality;
  - generally fresh water although slightly brackish in areas of silty sand and possibly more saline beneath the tidal wetland behind Leeke's Beach;
  - acidity slightly below drinking water guidelines;
  - chloride and hardness exceeded aesthetic levels of drinking water guidelines;
  - heavy metal levels generally within drinking water guidelines; and
  - suitability for potable / drinking water purposes dependent on extraction location.

4. WATER QUALITY OBJECTIVES

Water quality objectives represent the quality of water required to sustain all the environmental values for a waterway and are used in waterway management. Environmental values are the specific values of a waterway determined by physical, biological, social, economic and historical features and these values are protected under the *Environmental Protection (Water) Policy 2009*.

4.1 SURFACE WATER

FRC Environmental (2011) has identified the following environmental values for surface waters within and surrounding the study area:

- Ecosystem protection (slightly to moderately disturbed) – the intrinsic biological value of aquatic ecosystems that are affected adversely, to a relatively small but measurable degree, by human activity;
- Aquaculture and human consumption of aquatic foods;
- Primary recreation – health of humans undertaking activities where there is a high probability of water being swallowed (e.g. swimming);
- Secondary recreation – health of humans undertaking activities where there is a low probability of water being swallowed (e.g. boating and fishing);
- Visual recreation – amenity of waterways for recreation that does not involve direct contact with the water (e.g. picnicking next to the waterway); and
- Cultural heritage – indigenous and non-indigenous cultural heritage.

Specific water quality objectives for coastal waters of the Fitzroy Catchment are discussed in the *Draft Establishing Environmental Values, Water Quality Guideline and Water Quality Objectives for Fitzroy Basin Waters* (DERM, 2010). These objectives have been derived from the relevant local, regional and national water quality guidelines, including:

- *Water Quality Guidelines for the Great Barrier Reef Marine Park* (GBRMPA, 2009);
- *Queensland Water Quality Guidelines* (QWQG) (DERM, 2009) - for coastal / inshore waters; and
- *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* (ANZECC & ARMCANZ, 2000) – guidelines for Tropical Australia (Table 1.1, Table 1.2 and Table 1.3).

Reference has therefore been made to each of these guidelines to determine appropriate water quality objectives for waters potentially impacted by water cycle management aspects of the GKI Resort Revitalisation Plan. Specifically, the following guidelines were considered most appropriate:

- Water quality objectives for estuarine sites in Leeke's Creek and Putney Creek have been based on:
    - Trigger values for mid-estuarine waters of the Central Coast Queensland Region (slightly to moderately disturbed waters) from QWQG (DERM, 2009); and
    - 99% protection trigger values from ANZECC & ARMCANZ (2000) as these values were most similar to the GBRMPA trigger values.

- Water quality objectives for marine sites adjacent to Great Keppel Island have been based on:
  - Trigger values for open coastal waters of the Central Coast Queensland Region (slightly to moderately disturbed waters) from QWQG (DERM, 2009); and
  - 99% protection trigger values from the ANZECC & ARMCANZ (2000) as these values were most similar to the GBRMPA trigger values.

Based on these guidelines, the following water quality objectives have been developed for surface water quality:

TABLE 4.1: Proposed Water Quality Objectives for Surface Waters

Water Quality Parameter	Units	Marine Waters	Leeke's Creek & Putney Creek
Physico-chemical			
Temperature	°C	--	--
pH	pH units	8.1 – 8.4[1]	7.0 – 8.4[2]
Electrical Conductivity	µS/cm	--	--
Dissolved Oxygen	% saturation	95 - 105[1]	85 – 100[2]
Turbidity	NTU	1.0[1]	8.0[2]
Total Suspended Solids	mg/L	2.0[1]	20[2]
Total Nitrogen	µg/L	140[1]	300[2]
Total Phosphorous	µg/L	20[1]	25[2]
Chlorophyll-a	µg/L	2[1]	NA[2]
Heavy Metals			
Arsenic	µg/L	--	--
Cadmium	µg/L	0.7[3] (5.5[4])	0.7[3] (5.5[4])
Chromium (Cr III)	µg/L	7.7[3] (27.4[4])	7.7[3] (27.4[4])
Chromium (Cr VI)	µg/L	0.14[3] (4.4[4])	0.14[3] (4.4[4])
Copper	µg/L	0.3[3] (1.3[4])	0.3[3] (1.3[4])
Lead	µg/L	2.2[3] (4.4[4])	2.2[3] (4.4[4])
Mercury	µg/L	0.1[3] (0.4[4])	0.1[3] (0.4[4])
Nickel	µg/L	7[3] (70[4])	7[3] (70[4])
Zinc	µg/L	7[3] (15[4])	7[3] (15[4])
Petroleum Hydrocarbons			
C6-C9	µg/L	--	--
C10-C14	µg/L	--	--
C15-C28	µg/L	--	--
C29-C36	µg/L	--	--

Water Quality Parameter	Units	Marine Waters	Leeke's Creek & Putney Creek
Aromatic Hydrocarbons			
Benzene	µg/L	500[3] (700[4])	500[3] (700[4])
Toluene	µg/L	--	--
Ethylbenzene	µg/L	--	--
m+p-xylene	µg/L	--	--
o-xylene	µg/L	--	--
Organochlorine Pesticides	µg/L	--	--
Aldrin	µg/L	--	--
alpha-BHC	µg/L	--	--
beta-BHC	µg/L	--	--
gamma-BHC	µg/L	--	--
delta-BHC	µg/L	--	--
cis-Chlordane	µg/L	--	--
trans-Chlordane	µg/L	--	--
p,p-DDD	µg/L	--	--
p,p-DDE	µg/L	--	--
p,p-DDT	µg/L	--	--
Dieldrin	µg/L	--	--
alpha-endosulfan	µg/L	--	--
beta-endosulfan	µg/L	--	--
Endosulfan	µg/L	0.005[3] (0.01[4]) and 0.005[5]	0.005[3] (0.01[4]) and 0.005[5]
Endrin	µg/L	0.004[3] (0.008[4])	0.004[3] (0.008[4])
Endrin aldehyde	µg/L	--	--
Endrin ketone	µg/L	--	--
Heptachlor	µg/L	--	--
Heptachlor epoxide	µg/L	--	--
Hexachlorobenzene	µg/L	--	--
Methoxychlorobenzene	µg/L	--	--
Mirex	µg/L	--	--

Notes:
1. *Queensland Water Quality Guidelines* (DERM, 2009) for Open Coastal Waters (up to 20 km from the seaward edge of the enclosed coastal areas of the Fitzroy region) of the Central Coast Queensland Region (slightly to moderately disturbed waters).
2. *Queensland Water Quality Guidelines* (DERM, 2009) for Mid-Estuarine Waters of the Central Coast Queensland Region (in slightly to moderately disturbed waters).
3. *Australian and New Zealand Water Quality Guidelines* (ANZECC & ARMCANZ, 2000) for slightly to moderately disturbed waters (99% ecosystem protection).

4. *Australian and New Zealand Water Quality Guidelines* (ANZECC & ARMCANZ, 2000) for slightly to moderately disturbed waters (95% ecosystem protection).
5. Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA, 2009)

Although there are no published water quality objectives to protect environmental values such as visual recreation and cultural heritage, the following guidelines typically apply:

- Visual recreation – water should be free of: floating debris; oil and grease; substances that produce undesirable colour, odour, taste or foaming; and undesirable aquatic life such as algae or dense growth of attached plants or insects; and

- Cultural heritage – protect or restore indigenous and non-indigenous cultural heritage, consistent with relevant policies and plans.

4.2 GROUNDWATER

Current uses and environmental values of each of the shallow aquifers as described by Douglas Partners (2011) include:

- **North East Aquifer:**
  - No existing or proposed groundwater extraction bores known to be utilising this aquifer;
  - Possible groundwater dependent ecosystems, including deep-rooted vegetation and marine ecosystems at Butterfish Bay and Wreck Bay potentially dependent on fresh water discharges from this aquifer; and
  - Water quality suitable for raw drinking water (for human consumption), irrigation of crops, stock watering and groundwater dependent ecosystems.
- **Long Beach Aquifer:**
  - Although a number of groundwater extraction bores are installed within this aquifer, none of these bores are currently being utilised;
  - Possible groundwater dependent ecosystems, including deep-rooted vegetation and marine ecosystems at Long Beach potentially dependent on fresh water discharges from this aquifer; and
  - Water quality suitable for raw drinking water (for human consumption), irrigation of crops, stock watering and groundwater dependent ecosystems.
- **Resort Aquifer:**
  - A number of groundwater extraction bores are installed within this aquifer but these are not currently used by GKI Resort Pty Ltd and are not known to be used currently by any other landowners on the Island; and
  - Water quality suitable for raw drinking water (for human consumption), irrigation of crops and stock watering.
- **Central Dune Aquifer:**
  - No existing or proposed groundwater extraction bores known to be utilising this aquifer;

  - Possible groundwater dependent ecosystems, including deep-rooted vegetation and marine ecosystems within the tidal wetlands and at Leeke's Beach potentially dependent on fresh water discharges from this aquifer; and
  - Water quality suitable for raw drinking water (for human consumption), irrigation of crops, stock watering and groundwater dependent ecosystems.

On the basis of the above, the following water quality objectives have been established for groundwater resources within the study area:

- **Long Beach Aquifer:**
  - A number of existing groundwater bores access this aquifer;
  - These bores may potentially be used for supply of construction water for the GKI Resort Revitalisation Plan; and
  - As such, water quality objectives for this aquifer are based on the *Australian Drinking Water Guidelines* (ADWG) (NHMRC, 2004).
- **Resort Aquifer:**
  - A number of existing groundwater bores access this aquifer;
  - It is understood that these bores are not currently used by any local residents or businesses on the Island but they have historically been used for supply of drinking water to the former GKI resort and possibly Island residents; and
  - As such, water quality objectives for this aquifer are conservatively based on the *Australian Drinking Water Guidelines* (ADWG) (NHMRC, 2004).
- **Central Dune Aquifer:**
  - No groundwater extraction or use currently occurs or is proposed to occur from this aquifer;
  - As such, water quality objectives for the purpose of assessing the proposed water cycle management scheme have been based on those established for the point of discharge or interaction between groundwater and surface waters, which comprises Leeke's Creek. As described above, WQOs for Leeke's Creek have been based on:
    - Trigger values for mid-estuarine waters of the Central Coast Queensland Region (slightly to moderately disturbed waters) from QWQG (DERM, 2009); and
    - 99% protection trigger values from ANZECC & ARMCANZ (2000) as these values were most similar to the GBRMPA trigger values.

No groundwater extraction, storage or irrigation of recycled water, storage or handling of hazardous substances will occur within the catchment of the North East Aquifer. As such, no water quality objectives have been set for this aquifer.

4.3 ANALYSIS

To assess potential impacts of the proposed water cycle management strategy on receiving water quality and demonstrate compliance with water quality objectives, a range of modelling has been undertaken using software approved by DERM, including:

- MEDLI – Model for Effluent Disposal using Land Irrigation (Version 1.3); and
- MUSIC – Model of Urban Stormwater Improvement Conceptualisation (Version 4).

The results of this modelling are discussed in **sections 10** and **11** of this Report, respectively.

In addition to this, modelling of potential water quality impacts on the Central Dune Aquifer associated with irrigation of recycled water on the golf course has been undertaken by Douglas Partners using MODFLOW, which comprises a numerical, three-dimensional groundwater flow model developed by the United States Geological Survey (McDonald & Harbaugh, 1988 in Douglas Partners, 2011).

Water Technology (2011) also describes the outcomes of dispersion modelling of possible emergency discharge of recycled water via ocean outfall.

5. EXISTING INFRASTRUCTURE

5.1 WATER SUPPLY

5.1.1 Overview

Prior to 2004, the former GKI resort relied exclusively on groundwater for its water supply needs. A series of groundwater bores have been commissioned and decommissioned throughout the resort complex since its inception for potable water supply and landscape irrigation. At present, the resort's groundwater bores have all been decommissioned with the exception of the back-up bore water pump located near Long Beach.

Investigations conducted during the 1990s identified a range of issues with the Island's groundwater supply, including reduced water quality, mainly increased salinity, and extensive leaking of the reticulation system.

From late 2004 until the closure of the former GKI resort in 2008, potable water was supplied by a reverse osmosis (RO) desalination plant leased and operated by a third party. The RO plant had a maximum daily capacity to produce 300kL of potable water per day. Two (2) seawater pumps provided raw water for the RO plant from intake pipes located off Fisherman's Beach. The RO permeate was then chlorinated and pumped via a rising main to a tank compound for storage. Reject brine, up to 490 kL per day from the RO process, was returned to the ocean via a pipeline discharging offshore from Putney Beach. In case of a malfunction of the RO plant or excessive demand backup water supply was provided by groundwater bores located adjacent to Long Beach.

Potable water storage was provided by five (5) ground level tanks located within a compound on a hill above the Hillside Villas on the southwest side of the airstrip. The tank compound contains three (3), 27.5kL polypropylene tanks and two (2), 150kL pvc-lined panel tanks giving a total potable water storage volume of 382.5kL. From the tank compound, potable water was reticulated to the resort under gravity, with the exception of the Hillside Villas, which required a booster pump due to the higher elevations.

Private properties surrounding the former GKI resort have also historically extracted groundwater from the same aquifer as the former resort, but also used, to a lesser degree, rainwater tanks. Most of these surrounding properties now rely almost exclusively on rainwater tanks.

An indicative plan showing the location of water supply infrastructure servicing the former GKI resort is provided in **Appendix C – Existing Water Supply & Wastewater Infrastructure**.

5.1.2 Historical Water Demands

To establish historical water demands for the former GKI resort, reference has been made to data contained in the "Great Keppel Island Water & Wastewater Infrastructure Audit Report" dated 13 September 2007 and prepared by Sustainable Solutions International Pty Ltd (SSI). According to this report, the assumption was made based upon advice from resort management at the time that potable water was only used within the resort and was not used for any form of irrigation.

SSI (2007) reported the following conclusions for the period between December 2004 and May 2007:

Average water consumption by the resort was approximately 180kL/day;

Average per capita water consumption was approximately 1,059L/person/day;

Expected water consumption for the resort, based upon an assessment of the efficiency of existing fixtures and fittings and water demands compared to other similar resorts, was approximately 180 to 300 L/person/day;

No direct correlation was established between water produced and guest population due to the wide variability of each of the data sets; and

The water supply system was known to have significant leaks and water was frequently used to washdown hard surfaces around the resort.

SSI (2007) further reports that the wastewater treatment plant servicing the former GKI resort, has a capacity to treat up to 248.5kL of effluent per day, based on a maximum design population of 710 persons per day at 350L/person/day.

Peak water demand and effluent flows were recorded in January 2006 with 7,342kL of water produced by the desalination plant and 4,689kL of effluent treated at the wastewater treatment plant, which was related to approximately 9,200 person nights. During January 2006, there was a difference of 2,653kL (7,342kL – 4,689kL) between water produced by the desalination plant and effluent treated by the wastewater treatment plant. This represents a 36% deficit between the volume of desalinated water produced and the volume of effluent treated. During 2006, SSI (2007) identified a 37% average annual deficit between the volume of desalinated water produced and the volume of effluent treated, with SSI (2007) attributing the losses to unidentified leaks in the reticulation system.

Figure 5.1 provides a comparison of the total volume of desalinated water produced by the RO plant and the total volume of effluent treated at the wastewater treatment plant on the Island during 2006 along with an indication of approximate occupancy at the resort over this period as measured by the number of guests plus 100 staff. It should be noted that the volume of desalinated water produced during June 2006 was omitted from presentation of this data due to a malfunction of the water meter during that period.

Figure 5.2 provides a comparison of the volume of desalinated water produced per capita and effluent treated per capita on a monthly basis derived from data for 2006. Although a direct relationship between the population, and water and sewage demands would generally be observed, no such correlation is evident in this instance. Rather, per capita water, and to a lesser degree sewage demands, are shown to vary widely over the year. Average annual per capita rates are shown on **Figure 5.2** for comparison.

To account for the lack of data relating to water produced in June, an average between May and July was assumed to produce the 1,069L/person/day, which is close to the 1,059L/person/day indicated by SSI (2007). **Figure 5.2** also indicates that the volume of desalinated water produced per capita and effluent treated per capita was highest in May 2006, which corresponds to the lowest monthly population for the year.

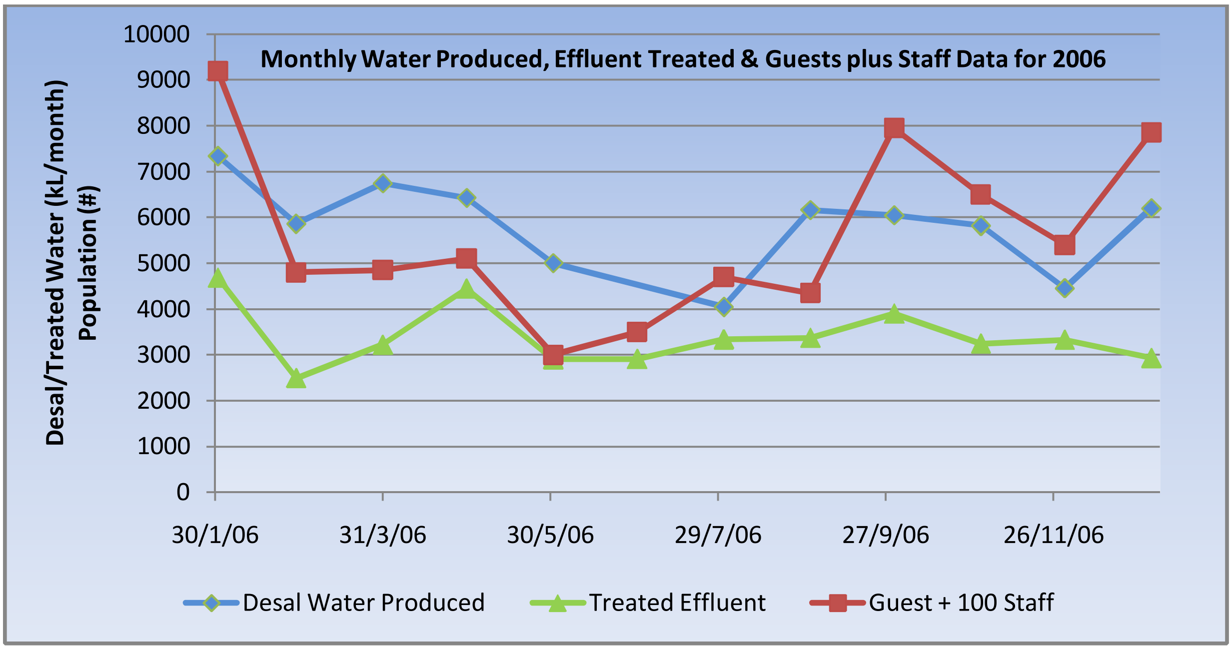


FIGURE 5.1: Monthly Water Produced, Effluent Treated & Guests plus Staff Data for 2006

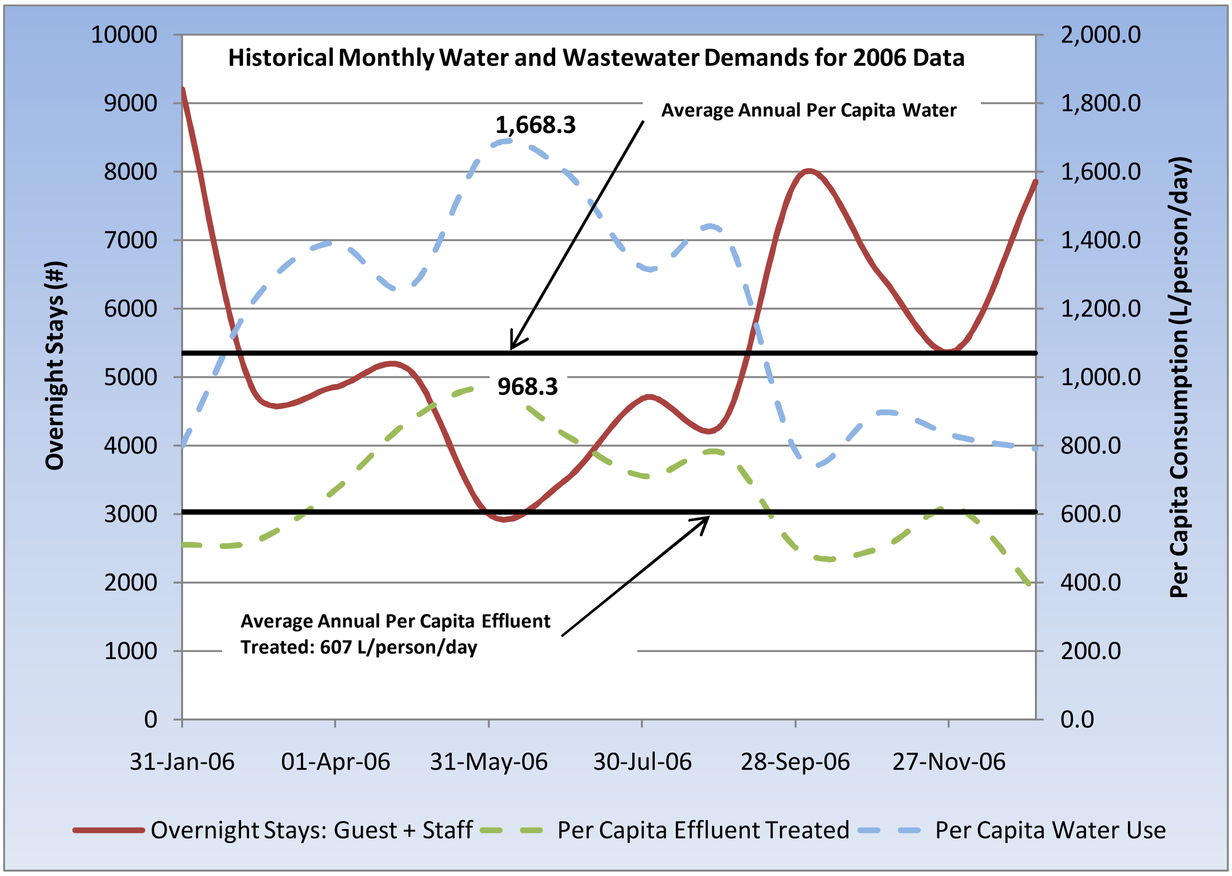


FIGURE 5.2 : Historical Per Capita Water and Wastewater Demands for 2006 based on Monthly Data

In order to better understand the relationship between water produced, effluent treated and population, the population figures were averaged out to 5,600 persons per month (67,200 person per year divided evenly over 12 months) and per capita consumption figures for 5,600 persons were calculated against the total volume of water produced and effluent treated (refer to **Figure 5.3**).

Figure 5.3 shows that a peak water consumption rate of 1,311L/person/day occurred in January, which is 1.23 times the average per capita water consumption rate estimated to be 1,069L/person/day. As such, peak monthly water demand for the resort could generally be expected to be 1.23 times average annual demand. This compares with Table 5.4 – Indicative Ranges of Overall Peaking Factors contained in Chapter 5 - Demand Flow and Projection of DERM's *Planning Guidelines for Water Supply and Sewerage*, which indicates a peak day factor of 1.5 to 1.7 for schemes with < 5,000 equivalent persons. The 1.23 peaking factor estimated is below this guideline, which may be attributable to the high base flow of unallocated water lost in the reticulation and the limited ability to vary water production from the RO process during reduced demand periods, which may have resulted in excess water being diverted to irrigation or overfilling the tank compound.

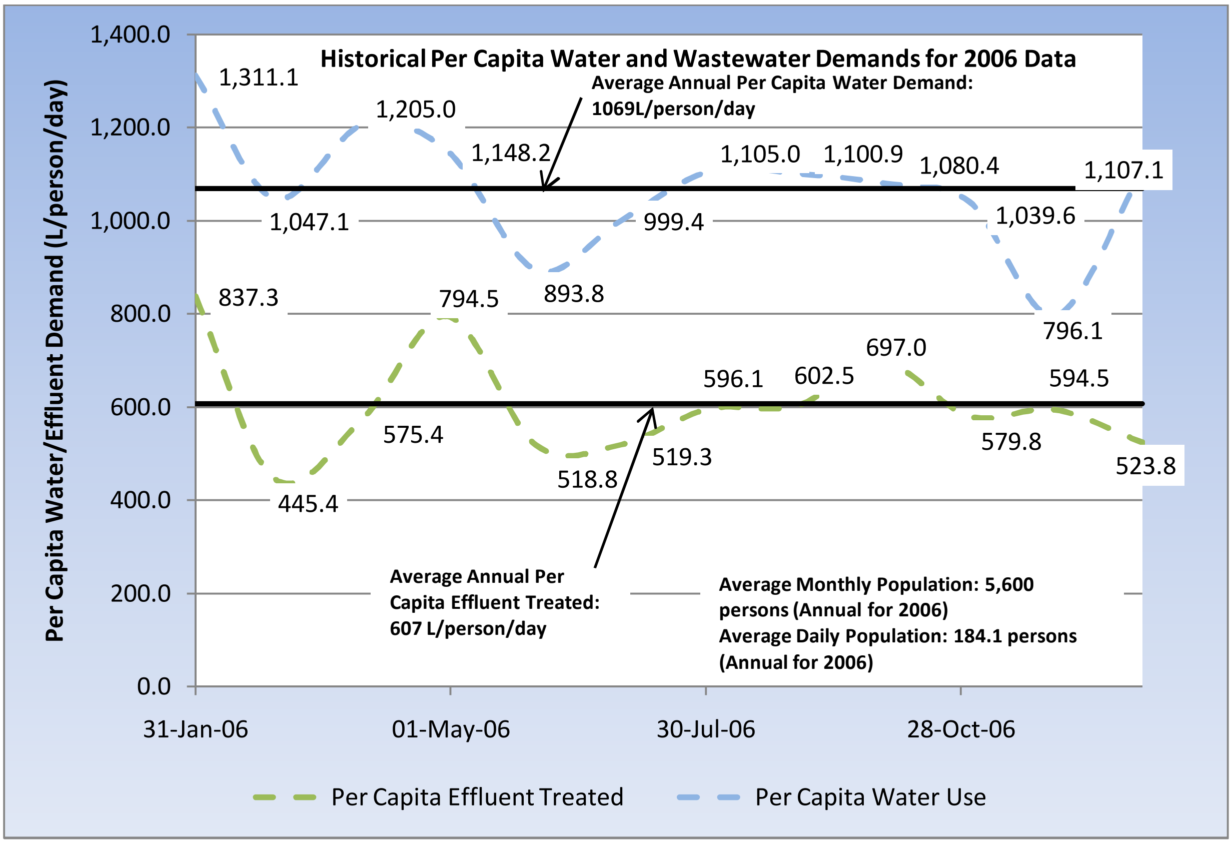


FIGURE 5.3: Historical Per Capita Water and Wastewater Demands for 2006 based on Average Annual Data

Figure 5.3 also shows that a peak wastewater generation rate of 837L/person/day occurred in January, which is 1.38 times the average per capita rate of wastewater generation of 607L/person/day. As such, peak monthly wastewater generation for the resort could generally be expected to be 1.38 times average annual production.

If the assumption is made that the difference between water produced and effluent treated is due entirely to reticulation losses, then a maximum of 57% (607 / 1,069 x 100%) of water produced entered the wastewater system based on 2006 data. This figure could be lower if groundwater infiltration is considered to be entering the sewer reticulation system.

Based upon these findings, it can be reasonably assumed that after reticulation losses, which are assumed to account for up to 43% of total water produced, guests and staff have historically consumed between 450 and 750L/person/day.

5.2 WASTEWATER TREATMENT & DISPOSAL

5.2.1 Overview

From late 2004 until closure of the former GKI resort in 2007-2008, wastewater from the resort was collected by gravity reticulation and pumped to a central wastewater treatment facility located on Lot 46 on LN2763, which is situated along the access road at the western end of the runway.

According to SSI (2007), the wastewater treatment plant had the following operational design capabilities:

- Maximum Population: = 710 persons
- Per capita Flow Rate: = 350 L/person/day
- Maximum Daily Flow Rate: = 248 kL/day (based on 710 persons x 350 L/EP/day)
- BOD Load: = 137 kg/day (based on 710 persons x 193 g/EP/day)
- Total Suspended Solids Load: = 99.4 kg/day (based on 710 persons x 140g/EP/day)
- Air Requirement: = 250kg/day

The treatment process for the existing wastewater treatment plant consisted of the following:

- Inflows of raw effluent passed through a static screen where gross solids were collected and transferred for storage in an adjacent bunded area;
- Screened liquid was then transferred to an old oxidation ditch that served as a balancing tank and was utilised for pH correction;
- Wastewater was then pumped to two (2) parallel treatment trains consisting of aeration, clarification and sludge aging:
    - The nitrification / denitrification process was conducted in the aeration phase;
    - Wastewater was then transferred to the two (2) clarifiers;
    - Alum dosing was conducted in the clarifiers to precipitate phosphorus; and
    - The settled sludge in the clarifiers was transferred to a sludge stabilisation tank.

- Clarified wastewater was then pumped to a Dyna sand filter;
- After being filtered, wastewater was then dosed with chlorine and stored in a 250kL treated effluent holding tank; and
- Backwash from the sand filter was returned to the balance tank for retreatment.

Treated effluent within the 250kL holding tank was then metered and pumped to the golf course for irrigation with a portion being pumped to a 50kL holding tank above the Hillside Villas for irrigation of landscaped areas.

5.2.2 Environmental Licence

The existing wastewater treatment plant that serviced the former GKI resort was licensed under the *Environmental Protection Act 1994* for ERA 15(b) – Sewage treatment – operating a standard sewage treatment works having a peak design capacity to treat sewage of 100 or more equivalent persons but less than 1,500 equivalent persons (refer to **Appendix D – Existing Environmental Licence (No. CR0061)**. Licence No. CR0061 was granted to Great Keppel Island Resort Pty Limited by the former Environmental Protection Agency on 13 May 1998 and subsequently amended on 15 July 1998, shortly after the *Environmental Protection Regulation 1998*, which required such licences to be obtained, came into effect.

Under the conditions of Licence No. CR0061, treated effluent discharged from the wastewater treatment plant servicing the former GKI resort was primarily required to be irrigated to land including the golf course and garden areas around the villas. A minimum land application area of 4.8 hectares was required to be provided for irrigation of treated effluent. Treated effluent used for irrigation of the golf course and gardens was required to comply with the effluent release limits in **Table 5.1** below:

TABLE 5.1: Existing Licence Release Limits for Irrigation

Quality Characteristics	Units	Release Limit	Limit Type
5-day Biochemical Oxygen Demand	mg/L	20	Maximum
Suspended Solids	mg/L	30	Maximum
pH	pH	6.5 - 8.5	Range
Faecal Coliforms	cfu/100mL	10	Maximum

During periods when weather or soil conditions preclude the application of treated effluent to land licence conditions authorised the discharge of treated effluent to the ocean via an outfall pipeline. The ocean outfall pipeline extended into the ocean from between the northern end of Putney Beach and Half Tide Rocks.

On a dry weather day, the licence conditions allowed for up to 250 cubic metres of treated effluent to be discharged while on a wet weather day, a maximum of 500 cubic metres was permitted to be discharged. Under the conditions contained in Schedule C of Environmental Licence No. CR001, treated effluent discharged from the ocean outfall was required to comply with the effluent quality release limits in **Table 5.2** below:

TABLE 5.2: Existing Licence Release Limits for Ocean Outfall

Quality Characteristics	Units	Release Limit	Limit Type
5-day Biochemical Oxygen Demand	mg/L	20	Maximum
5-day Biochemical Oxygen Demand	mg/L	5	90th Percentile
Suspended Solids	mg/L	30	Maximum
Suspended Solids	mg/L	5	90th Percentile
pH	pH	6.5 - 8.5	Range
Dissolved Oxygen	mg/L	2	Minimum
Ammonia Nitrogen	mg/L	1	Maximum
Total Phosphorus as P	mg/L	7	Maximum
Total Phosphorus as P	mg/L	4	90th Percentile
Free Residual Chlorine	mg/L	0.3 - 0.7	Range

According to the previous resort operators, the ocean outfall was not often used with the preference being to maximise use of treated effluent for irrigation of the golf course and resort landscaping.

5.2.3 Historical Wastewater Generation

As discussed in section 5.1.2 above, an assessment of historical wastewater generation for the former GKI resort has been undertaken based on data contained in the “Great Keppel Island Water & Wastewater Infrastructure Audit Report” dated 13 September 2007 and prepared by Sustainable Solutions International Pty Ltd (SSI). According to SSI (2007), the wastewater treatment plant servicing the former GKI resort, has a capacity to treat up to 248.5 kL of effluent per day, based on a maximum design population of 710 persons per day at 350 L/person/day.

Peak wastewater generation was recorded in January 2006 with 4,689 kL of effluent treated at the wastewater treatment plant during the month. An average annual per capita wastewater generation rate of 607 L/person/day was estimated for the former resort based on available data from 2006. A peak wastewater generation rate of 837L/person per day was estimated based on available data from January 2006. The peak wastewater generation rate was determined to be 1.38 times the average per capita rate of wastewater generation of 607L/person/day. As such, peak monthly wastewater generation for the resort could generally be expected to be 1.38 times average annual production.

5.3 STORMWATER DRAINAGE

Existing stormwater drainage within the existing resort area generally consists of the following:

- Stormwater runoff from the Fisherman’s Beach area generally, including the existing resort and much of the airstrip, drains from the beachfront dune through the existing resort area to a detention basin located on the western side of the existing airstrip. Refer to Photo 5.1 below. Most of the detained water infiltrates into the sandy soil with overflow only expected to occur during very high rainfall events. Such overflow then drains to to Fisherman’s Beach via the natural drain in Photo 5.2 below; and,

- A small area to the southern end of Fisherman’s Beach drains directly to the beach via a small watercourse. Some scouring is evident in parts of the watercourse above the beach. However, the beach sand is not eroded, indicating that the flow is not frequent and that the sand builds back up onto the beach area after storm flows. Refer to Photos 5.3 and 5.4 below.

Photo 5.1: Resort Detention Basin (located to the western side of the existing airstrip).

Photo 5.2: Overflow from Resort Detention Basin to Fisherman's Beach

Photo 5.3: Stormwater drainage at southern end of Fisherman's Beach.

Photo 5.4: View as in Photo 5.3 from further down the beach.

6. OPTIONS ANALYSIS

A wide range of options are available for managing water supply, wastewater and stormwater drainage associated with the GKI Resort Revitalisation Plan. Each of these options has associated advantages and disadvantages in relation to social, economic and environmental aspects. The following sections provide an assessment of each of the options considered in developing the water cycle management framework for the GKI Resort Revitalisation Plan. The proposed water supply and wastewater management schemes are outlined in more detailed in **sections 9 and 10**, while the proposed stormwater management system is outlined in more detailed in **section 11**.

6.1 WATER SUPPLY

Description/ Comment	Advantages	Disadvantages	Conclusion
Connection to Council's mainland reticulated water supply system.			
Installation of a 16km long water main within the Utility Services Corridor from an existing main located near the Scenic Highway at Emu Park to the proposed marina on GKI. Water will be treated to drinking water standard at Council's facilities on the mainland. Supplementary chlorination may be required prior to storage on the Island to provide an effective disinfection residual due to the relatively long transfer distance.	• Reliable - less prone to drought than Island sourced water due to relatively large capacity of watercourse providing extra buffering. • Flexible - supply able to respond to fluctuations in demand due to capacity of water source. • No direct discharges to the environment (i.e. compared to return brine from desalination plant). • No ongoing environmental disturbance (e.g. compared to groundwater extraction). • Consistent – water quality not prone to variation or contamination (e.g. by saline intrusion or surface activities such as effluent irrigation). • Moderate energy consumption relative to other uses (i.e. lower than desalination but higher than other options due to pumping distances).	• Relatively high capital cost associated with constructing mainland pipeline connection. • Mainland connection potentially subject to damage causing disruption to supply during cyclonic events or boat anchor strike.	This option is considered an important component of the water supply scheme in terms of achieving water security.
Extraction and use of groundwater resources on GKI.			
Installation of groundwater supply bores to extract groundwater from the various dune sand aquifers on the	• Relatively high quality water source, requiring minimal treatment.	• Total available sustainable yield is insufficient to fully meet the total water demand requirements of	This is not a preferred option to provide ongoing water supply during operation of the GKI Resort Revitalisation Plan due

Description/ Comment	Advantages	Disadvantages	Conclusion
Island. Assuming uniform and continuous extraction rates, the long term sustainable yields for these aquifers were estimated by Douglas Partners (2011) to be: • North East Aquifer – 270kL/day - extracted from 2 x 100kL/day and 1 x 70kL/day production bores located in the central part of the aquifer; • Long Beach Aquifer – 100kL/day - extracted from 2 x 50kL/day production bores; and • Central Dune Aquifer – 90kL/day – extracted from 1 x 70kL/day and 1 x 20kL/day production bores. The aquifer identified within the area of the former resort was not consider suitable for extraction due to poor water quality and potential for contamination from saline intrusion and surface activities. Groundwater resources are of high quality and generally consistent with drinking water guidelines, with treatment likely to be limited to disinfection by chlorination or UV.	• Low to moderate energy consumption, with pumping required for extraction and distribution. • Readily able to be used in conjunction with other water supply sources. • Long Beach aquifer already developed with existing bores. • Existing groundwater bores able to be used to provide construction water supply prior to construction of additional water supply infrastructure. • Relatively low capital and ongoing costs given production bores already exist within the Long Beach Aquifer and groundwater quality of high standard likely to require only minimal treatment infrastructure and costs.	the GKI Resort Revitalisation Plan. • Relatively remote location of potential borefields and supply points would require construction of significant lengths of new roads, power infrastructure and rising mains if this resource was fully developed, including clearing and disturbance within otherwise undisturbed parts of the Island. • Reliability of groundwater supply dependent on rainfall and subsequent recharge of aquifers. • Groundwater resources subject to possible contamination from surface activities such as effluent irrigation, fuel and chemical storage if not appropriately managed. • Long term viability of groundwater resources uncertain due to possible effects of climate change, including increased risk of saline intrusion due to rising sea levels and decreased average annual rainfall. • Low level of community support due to historical over-extraction from Resort Aquifer.	to the risk of saline intrusion and other water quality impacts, and the unreliability of supplies as a result of drought and climate change. However, short term, small-scale extraction from the existing production bores at Long Beach is a preferred option to provide water supply for Stage 1 of construction prior to establishing a mainland connection.
Installation of rainwater tanks for roof water collection and reuse.			
Installation of rainwater collection systems on all available rooftops for capture in rainwater storage tanks to reduce water demands from other supply sources. Installation of rainwater tank collection systems and reuse of collected rainwater for internal uses such as toilet flushing and washing machines is mandatory when connecting to mains water supply in Queensland.	• Rainwater quality is typically high, therefore no treatment is typically required for non-potable use while only minimal treatment (e.g. disinfection) is required for potable use. • Very low energy consumption as water is largely collected and reused at its source with localised pumping only.	• Available yield is insufficient to fully meet the total water demand requirements of the GKI Resort Revitalisation Plan therefore cannot be relied upon as sole water supply source. • Reliability of supply is dependent on rainfall and may therefore be limited during drought conditions.	This option is considered an important component of the water supply scheme in terms of achieving the sustainability objectives of the GKI Resort Revitalisation Plan but cannot be relied upon as the sole water supply source due to susceptibility of supplies to drought and climate change.

Description/ Comment	Advantages	Disadvantages	Conclusion
Collected rainwater may also be used for potable consumption provided adequate treatment, including disinfection by UV, chlorination or similar, is provided.	• Relatively low installation costs and minimal ongoing operational costs. • Readily able to be used in conjunction with other water supply sources. • Rainwater tanks can be installed above ground or underground, and are co-located with buildings & infrastructure thereby reducing the need to clear additional land for installation. • Likely to be consistent with sustainability objectives of the GKI Resort Revitalisation Plan.	• Long term viability uncertain due to possible effects of climate change, including reduced average rainfall.	
Construction of water storage dam / weir on watercourses on GKI.			
Construction of dams / weirs to provide water storage by impounding stream flows on existing watercourses on the Island. Required treatment would likely involve: • settlement of suspended solids; • sand filtration to remove fines; • flocculation to remove chemical contaminants; and • disinfection by chlorination/ UV irradiation.	• May provide an alternative form of water supply on the Island that would enable the GKI Resort Revitalisation Plan to be self-sufficient in relation to water supply avoiding the need for a mainland connection.	• Fresh surface water resources on GKI are limited, with most watercourses being ephemeral only and conveying relatively low volumes of water. • Water quality likely to require significant amount of treatment to meet drinking water standards. • High energy consumption to treat and subsequently distribute water supplies. • Reliability of supply is dependent on rainfall and may therefore be limited during drought conditions. • Long term viability uncertain due to possible effects of climate change, including reduced average rainfall. • Relatively high capital costs and ongoing operational costs for constructing and maintaining storages and associated treatment and distribution systems.	This option is not a preferred component of the water supply scheme due to the potential environmental impacts, high treatment requirements and susceptibility to drought and climate change.

Description/ Comment	Advantages	Disadvantages	Conclusion
		• Potential for contamination of water supply by activities such as effluent irrigation if occurring in storage catchments and not managed appropriately. • Construction of storage would require removal of riparian vegetation and modification of in-stream habitats, including potential impacts on fish migration. • Unlikely to be consistent with the sustainability objectives of the project.	
Harvesting of stormwater runoff from proposed golf course on GKI.			
Harvesting of stormwater runoff from the golf course area within ponds designed to provide water features on the course while also providing a water supply source for irrigation. No treatment would be required if used only for irrigation.	• Reduce the need to use other sources of water, including potable water from the mainland for irrigation. • Ponds can be readily incorporated into the golf course to enhance the aesthetic appearance and provide challenging playing hazards. • Water quality suitable for irrigation with no treatment required. • Minimal distribution infrastructure required as stormwater is harvested and reused in the same area. • Harvesting of golf course runoff will reduce the discharge of nutrients contained in effluent and fertilisers to natural waterways will enable beneficial reuse of these nutrients by irrigating collected runoff across the golf course.	• Water quality not suitable for potable uses without significant treatment. • Pond would require liners due to highly permeable / sandy soils. • Open storages may require algal management to prevent harmful blooms if excessive nutrients are allowed to accumulate. • Long term viability uncertain due to possible effects of climate change, including reduced average rainfall.	This option is considered to comprise an important component of the water supply scheme as it provides an alternative source of irrigation water to potable water supplies from the mainland.
Installation of a desalination plant on GKI.			
Installation and operation of a Reverse Osmosis Desalination Plant based on GKI. Desalinated water would then require disinfection by	• May be used in conjunction with other supply sources to reduce demands from those sources but could also be designed to meet	• High energy consumption associated with reverse osmosis process and additional energy required to distribute around the	Desalination is not considered to be a preferred option for water supply, largely due to high ongoing costs and energy consumption, and potential

Description/ Comment	Advantages	Disadvantages	Conclusion
chlorination or UV irradiation. Waste brine would need to be discharged most likely via a return pipeline into the ocean.	the full water supply demands of the GKI Resort Revitalisation Plan enabling the resort to be self-sufficient and independent of mainland supplies.	Island. • Highly saline brine is returned to the marine environment. • Requires high level of maintenance and technical expertise to operate. • Relatively high capital and ongoing costs. • Limited flexibility in managing water supply to respond to high level of fluctuation in demand.	environmental impacts associated with high salinity brine discharge to Marine Park.
Barging water from mainland.			
Delivering water from mainland to GKI by barge. As the source water would be produced at Council's municipal water treatment plant, no additional treatment would be required.	• Could be used as a back-up water supply following disruption to other water supplies (e.g. due to a cyclone event). • Could be used during the construction phase of GKI Resort. • Relatively low capital costs as no treatment infrastructure required, only Island-based storage and distribution infrastructure needed.	• High energy consumption required relative to volume of water delivered. • Only relatively small quantities of water would be able to be delivered at any one time therefore unlikely to be sufficient to meet full demands of development - back-up supply only. • High ongoing costs to purchase water from Council and shipping costs. • Limited reliability due to potential for barge to be delayed during adverse weather.	This is not considered to be a preferred option for water supply, largely due to the high level of energy consumption relative to quantity of water delivered, which reduces overall sustainability of the water supply. However, this option may be viable as temporary supply during construction or after an emergency event such a cyclone.

6.2 WASTEWATER MANAGEMENT

6.2.1 Sewerage Collection

Description/ Comment	Advantages	Disadvantages	Conclusion
Traditional Gravity System			
Conventional precast concrete manholes connected with uPVC, HDPE and/or ductile iron/cement lined rubber jointed pipes which gravity feed to sewage pumping stations that deliver raw wastewater to the treatment works.	• Materials readily sourced from local providers. • Long established, well understood construction methodology.	• Potentially high groundwater infiltration rates due to joints and high water table. • System becomes progressively deeper to construct as the system increases with size.	This is not a preferred option due to the potential for significant groundwater infiltration.

Description/ Comment	Advantages	Disadvantages	Conclusion
		• Odour control may be required at sewage pumping station(s) unless sealed.	
"NuSewer" Low Leak System			
Similar to traditional gravity sewer in function. Pipes are made of welded polyethylene eliminating most joints, which reduces infiltration and root intrusion. System can accommodate vertical and horizontal bends, which reduces the number of manholes. As with traditional sewers, the pipes gravity feed to sewage pumping stations that deliver raw wastewater to the treatment works.	• Significantly lower groundwater infiltration compared to traditional sewer system resulting in lower treatment costs and energy consumption. • Fewer manholes required as the pipes are flexible.	• Materials not as readily available as traditional systems. • Requires some specialist knowledge for installation. • Odour control may be required at sewage pumping station(s) unless sealed.	This is the preferred option primarily on the basis of the low infiltration potential.
Vacuum System			
A vacuum system collects sewage from buildings via gravity into a collection tank. A centralised vacuum chamber draws the sewage from the individual tanks along a shallow vacuum rising main towards the treatment works or a traditional sewage pumping station.	• Entire system is relatively shallow to construct. • Few if any manholes required. • Piping system can be installed within a narrow trench, which can bend around obstacles such as trees.	• Materials not as readily available as traditional systems. • Requires specialist knowledge for installation and operation. • System performs better on low topography due to the limit a vacuum can draw sewage uphill. • Individual grinders may be needed in collection tanks to reduce solids to a manageable size so as not to block the system. • Odour control may be required at sewage pumping station(s) unless sealed.	This is not the preferred option largely due to the relatively steep topography of parts of the Island and the need for specialty materials and technical expertise for installation and maintenance.
Pressure System			
A pressure system consists of a small collection tank at each building serviced by sewerage. Each tank is fitted with a small grinder pump that feeds a common rising main that discharges to treatment works or a sewage pumping station	• Entire system is relatively shallow to construct. • Few if any manholes required. • Piping system can be installed with a narrow trench, which can bend around obstacles such as trees.	• Requires some specialist knowledge of installation and operation. • Greater chance of individual pump malfunction due to increased quantity to service every building.	This is one of the preferred options in conjunction with the NuSewers: • This option is recommended for low density areas such as the ecotourism villas; • System reduces construction footprint and therefore vegetation clearing requirements; • Individual grinders needed in collection tanks to

Description/ Comment	Advantages	Disadvantages	Conclusion
			reduce solids to a manageable size so as not to block the system; and • Odour control may be required at sewage pumping station(s)

6.2.2 Wastewater Treatment

Description/ Comment	Advantages	Disadvantages	Conclusion
Pre-treatment and pump to mainland for treatment at Council WWTP.			
Rockhampton Regional Council has indicated their wastewater treatment and recycled water infrastructure has the capacity to accept all effluent from the GKI Resort Revitalisation Plan. In order to transfer wastewater approximately 16 kilometres back to the mainland for treatment, raw wastewater must be pre-treated to reduce the negative effects of hydrogen sulphide build-up due to septicity issues associated with long detention times.	• No treatment plant required on the Island. • No issues with regard to effluent disposal including contamination of groundwater, ocean discharge of effluent.	• Increased potable water needed to make up for shortfall by not reusing any recycled water produced from Island-based treated wastewater. • Increased risk of potential environmental impacts associated with accidental damage to pipeline resulting in relatively untreated wastewater discharge to the ocean. • Hydrogen sulphide corrosion of infrastructure due to the long period of time it will take for wastewater to travel from GKI to the mainland treatment plant. • Relatively high ongoing cost to GKI Resort to provide at least primary treatment and pumping as well as ongoing charges for sewage treatment and purchase of potable water that could not be offset by reuse of recycled water use produced at Island-based WWTP. • Relatively high capital cost associated with constructing mainland pipeline connection. • Mainland connection potentially subject to damage causing disruption to supply during cyclonic events or boat anchor strike. • Does not fully reflect the self-sustainability	This is not a preferred option due to the potential environmental impacts of accidental discharge of untreated wastewater and the lost opportunity to reuse treated wastewater to offset non-potable water supplies on the Island.

Description/ Comment	Advantages	Disadvantages	Conclusion
		objectives of the GKI Resort Revitalisation Plan.	
Individual On-Site Treatment and Disposal Systems			
Installation of individual treatment and disposal systems for each villa with separate on-site treatment and disposal systems to service core facilities such as the Fisherman's Beach Resort Precinct and Marina Precinct.	• Individual treatment would provide for easier staging of development.	• Many individual treatment units do not support the large-scale reuse of recycled water for irrigation of areas such as the golf course. • Small-scale treatment units unlikely to achieve the same high level of treatment able to be achieved by a larger scale plant. • Many individual units with relatively high level of inspection and maintenance, including pump out of septic tanks. • High risk of degradation of groundwater due to lower standard of treatment. • Requires relatively large area of land near each villa and other facilities to contain treatment and disposal infrastructure.	This is not a preferred option due to the ongoing maintenance difficulties and costs, and the potential for water quality impacts due to lower standard of treatment.
Single WWTP on GKI			
Installation of a single wastewater treatment plant servicing the entire GKI Resort. Preferred location would depend on providing buffers to sensitive receivers, and considering the proximity to wastewater sources and recycled water reuse sites.	• Only one wastewater treatment plant to license, operate, maintain and monitor. • Larger treatment systems are typically more efficient than smaller treatment systems. • Less time and fewer staff required to operate a single plant as opposed to multiple plants. • Ensures consistent standard of treatment for all wastewater generated across the Island. • A single WWTP would consume less energy than multiple WWTPs.	• A single plant would require multiple, expandable treatment trains to accommodate progressive increase in flows over the 12 year construction period (Note: Two or more parallel plants enable greater operational flexibility).	This could be and is a viable option with the preferred location of the plant to be in the Clam Bay Precinct in close proximity to the recycled water irrigation area.
Multiple WWTPs on GKI			
Installation of two wastewater treatment plants, including: • One WWTP servicing the Fisherman's Beach and	• Provides greater flexibility to support staging of the development. • Reduces the need to pump	• Double the ongoing licence fees and monitoring would be required for two WWTPs.	Preferred option. However, with reuse of recycled water largely intended for the golf course, the single WWTP option is to be

Description/ Comment	Advantages	Disadvantages	Conclusion
Marina Precincts - most likely located on the north eastern side of the airstrip within the vicinity of the facilities maintenance compound; and • One WWTP servicing the Clam Bay Precinct - most likely located to the north west of the golf course. However, the exact location would depend on providing buffers to sensitive receivers.	wastewater from Clam Bay Precinct to Fisherman's Beach Precinct or vice versa for treatment.	• Need to pump recycled water from Fisherman's Beach WWTP across to the Clam Bay Precinct for irrigation of the golf course. • Treatment likely to be less efficient than a single plant due to the smaller size of each individual plant. • Higher energy consumption than a single plant.	further considered during the design phase.
Wastewater Treatment Plant Options			
Sludge sedimentation and stabilisation / oxidation lagoons as follows: • Grit chambers / screens to remove floating solid items and grit. Screened solids and grit disposed of at a licensed landfill facility on the mainland; • Primary sedimentation tanks with collected sludge to sludge digestion tanks, sludge removed, dewatered, dried and used for landscaping, liquid from sludge process passed to the stabilisation lagoons; • Stabilisation / oxidation lagoons for treatment of liquid from sedimentation tanks; • Effluent from the stabilisation lagoons pumped to the golf course storage pond(s).	• Robust system with minimal power requirement. • Simple technology and low maintenance. • Relatively low cost solution. • With minimal power requirement, system is not significantly affected by power outages.	• System would need to be combined with a membrane or similar filtration system and disinfection in order to achieve the required recycled water quality for unrestricted use. • Likely to require significant buffer (e.g. 500 to 800m) between plant and to tourist / residential facilities. • Odour may be an issue from time to time. • Requires relatively large area of land for plant.	This option is not preferred on the basis that the treatment system is not likely to be capable of achieving the required recycled water quality.
Sludge sedimentation and oxidation ditches: • Grit chambers / screens to remove floating solid items and grit. Screened solids and grit disposed of at a licensed landfill facility on the mainland; • Primary sedimentation tanks with collected sludge to sludge digestion tanks, sludge removed, dewatered, dried	• Robust system with minimal power requirement. • Simple technology and low maintenance. • Relatively low cost solution.	• System would need to be combined with a membrane or similar filtration system and disinfection in order to achieve required recycled water quality for unrestricted use. • Likely to require significant buffer (e.g. 500 to 800m) between plant and to tourist / residential facilities. • Odour may be an issue from time to time.	This option is not preferred on the basis that the treatment system is not likely to be capable of achieving the required recycled water quality.

Description/ Comment	Advantages	Disadvantages	Conclusion
and used for landscaping, liquid from sludge process passed to the oxidation ditches; • Oxidation ditches for treatment of liquid from sedimentation tanks; • Finishing lagoons; and • Effluent from the finishing lagoons pumped to the golf course storage pond(s).		• Requires relatively large land area for plant.	
Proprietary package treatment plants (MBR or similar): • Grit chambers / screens (within package plant) to remove floating solid items and grit. Screened solids and grit disposed of at a licensed landfill facility on the mainland; • Package plant with treatment and retention times to meet the required treatment standard for unrestricted reuse for irrigation of the golf course and ocean outfall. Note that the package treatment plants could be based on membrane bioreactor technology (MBR system) with UV disinfection after the plant. • Effluent from the package plant pumped to the golf course storage pond(s), or, when required, direct to the ocean outfall.	• Package plant capable of producing recycled water quality suitable for irrigation of golf course with unrestricted access. • Package plant capable of producing recycled water quality suitable for direct discharge via the ocean outfall. • MBR technology is well proven and capable of producing high quality effluent. • MBR type and other package plants generally have a small footprint (i.e. are compact and require minimal land area). • Odour issues are generally low to non-existent – allowing these plants to be located close to residential dwellings etc.	• Relatively higher cost than stabilisation lagoon or oxidation ditch systems above. • Relatively high maintenance requirements needing specialist skills and knowledge. • Relatively higher operating and maintenance costs than stabilisation lagoon or oxidation ditch systems above. • Require substantial power for operation.	This is the preferred option due to the smaller footprint, proven ability to produce high quality effluent and less odour generation issues.

6.2.3 Wastewater Effluent Reuse & Disposal

Description/ Comment	Advantages	Disadvantages	Conclusion
100% discharge of treated wastewater via ocean outfall.			

Description/ Comment	Advantages	Disadvantages	Conclusion
Discharge all treated wastewater to the ocean via an outfall pipeline extending from Long Beach.	• Avoids requirement for construction of large wet weather storage ponds. • Requires fewer pumps than an irrigation / non-potable water supply system or mainland return rising main.	• Increased risk of potential impacts including cumulative impacts on water quality and ecological communities near the outfall due to reliance solely on the treatment plant to achieve required water quality as opposed to additional treatment achieved through assimilation of treated wastewater by plants and soils during irrigation. • To achieve water quality objectives given volume and frequency of discharge, wastewater will require a very high level of nutrient removal, which typically involves significant energy consumption and / or use of chemical treatment processes. • Does not achieve any beneficial reuse of water or nutrients contained in treated wastewater and is therefore not consistent with sustainability objectives of the GKI Resort Revitalisation Plan. • Increased requirement for potable water sources to be used for non-potable purposes. • Negative perception of ocean disposal by potential guests as well as within the broader community.	This option is not preferred primarily on the basis that it is inconsistent with the sustainability objectives of the GKI Resort Revitalisation Plan, which aims to maximise beneficial reuse wastewater and due to the increased risk of environmental harm.
95% Reuse of recycled water for irrigation of golf course and other landscaped areas with 5% discharge of treated wastewater via ocean outfall			
Reuse of 95% of recycled water produced by an Island-based WWTP for irrigation of the golf course and other landscaped areas. Discharge up to 5% of treated wastewater to the ocean via an outfall pipeline extending from Long Beach. Assuming a 31 hectare irrigation area, this option would require a wet weather storage pond of approximately 13ML plus 2.6ML climate change buffer.	• Achieves 95% beneficial reuse of treated wastewater averaged over a 50 year period, which is consistent with DERM's general policy for sewage treatment plants involving effluent reuse. • Provides a controlled point of release to the ocean in the event of wet weather storage reaching capacity as opposed to possible uncontrolled release to the environment from overtopping of wet weather storage.	• Due to the volume and frequency of discharge, subject to more detailed dispersion modelling, a greater level of nitrogen and phosphorus removal may be required compared to recycled water used for irrigation meaning multiple treatment trains could be needed. • Not considered to maximise beneficial reuse of treated wastewater in accordance with the sustainability objectives of the GKI Resort	This is not the preferred option largely on the basis that the level of reuse does not meet the sustainability objectives of the GKI Resort Revitalisation Plan.

Description/ Comment	Advantages	Disadvantages	Conclusion
	• Requires only a relatively small wet weather storage (less land area and materials for lining) compared to irrigation schemes achieving a higher level of reuse.	Revitalisation Plan.	
100% Reuse recycled water for irrigation of golf course and other landscaped areas with, with emergency discharge			
Reuse of practically 100% of recycled water produced by an Island-based WWTP for irrigation of the golf course and other landscaped areas. Discharge only in extreme weather events (i.e. 1 in 10 year event) when treated wastewater may be discharged to the ocean via an outfall pipeline extending from Long Beach. Assuming a 31 hectare irrigation area, this option would require a wet weather storage pond of approximately 37ML plus approximately 7ML climate change buffer.	• Achieves practically 100% beneficial reuse of recycled water for irrigation of golf course and other landscaped areas. • During extreme weather events the dispersion modelling of the outfall demonstrates water quality objectives can be achieved within small mixing zone based on same standard of nutrient removal proposed for reuse by irrigation (N=20mg/L, P=7mg/L) meaning multiple treatment trains are not required. • Provides a controlled point of release to the ocean in the event of extreme weather storage reaching capacity as opposed to possible uncontrolled release to the environment from overtopping of wet-weather storage.	• A small proportion of treated wastewater potentially remains unused (i.e. less than 1% averaged over 50 years). • Capital costs associated with construction of irrigation infrastructure as well as outfall pipeline which will have limited use.	This is the preferred option on the basis that it achieves the maximum reuse of recycled water while providing a feasible wet weather storage, and limiting discharge to the ocean to extreme wet weather events (i.e. 1 in 10 years on average) when water quality will likely be degraded by more significant land-based pollutant sources.
Installation of non-potable water reticulation to enable use of recycled water for non-potable purposes such as toilet flushing, laundry and garden use.			
Installation of a network of "third pipe" or "purple pipe" reticulation to enable recycled water to be used for non-potable internal purposes such as toilet flushing and laundry as well as external irrigation and washdown.	• Provides an alternative source of non-potable water supply to replace potable water demand for certain purposes, that is not dependent on rainfall as is the case for harvested stormwater runoff and roof water collection. • Consistent with sustainability objectives of the GKI Resort Revitalisation Plan.	• High ongoing compliance costs associated with ongoing monitoring and reporting required for dual reticulation schemes to protect public health. • The volume of recycled water produced would achieve only limited reduction in demand for potable water supplies, given that non-potable water supply for toilet flushing, washing machines, garden watering, car and boat washdown, can also be derived from rainwater harvesting. • The availability of recycled water will be highly variable due to the fluctuating occupancies and therefore generation of wastewater effluent	This option is not preferred due to the high establishment and ongoing maintenance / compliance costs and the relatively small proportion of recycled water that could be used for this purpose relative to the cost of the scheme. Note also, that the estimated quantity of effluent available can more readily and economically be used for Golf Course irrigation.

Description/ Comment	Advantages	Disadvantages	Conclusion
		associated with tourist facilities, and is therefore not considered to be a sufficiently reliable source of water for these types of non-potable purposes. • Not all recycled water produced by the GKI Resort Revitalisation Plan could be reused for this purpose. As such, dual reticulation would need to be combined with an alternative reuse option such as irrigation. • Significant ground disturbance and ongoing pumping costs / energy consumption would be associated with the extensive recycled water distribution and storage system required for a dual reticulation scheme. • Achieves beneficial reuse of water component of recycled water only, not beneficial reuse of nutrients as occurs through irrigation to the golf course.	

6.3 STORMWATER MANAGEMENT - OPTIONS

No options discussion is made in relation to the stormwater component of this report. This is due to:

- The porous sandy soils on the Island in the areas of resort development;
- The sandy soils being similar to the material that would normally be sourced for drainage material under bio-retention basins and the like;
- The use of low impact grassed basins and swales, incorporated into the landscaping and effectively mimicing the natural processes on the Island, to form the stormwater drainage and stormwater treatment arrangements;
- Given the above, the obvious use of the existing soil material within the bio-retention and detention basins, swales etc.

Refer also to the stormwater **section 11**.

7. PROJECTED DEMAND

While the historical water and sewage demands estimated for the former GKI resort provide some relevant background data in relation to how the former resort managed its water resources, the historical demand figures are not considered relevant to calculation of future demands. This is particularly so given that the GKI Resort Revitalisation Plan proposes to:

- Completely rebuild and expand the resort facilities with an emphasis on sustainable water use;
- Provide rehabilitated or new water and sewerage infrastructure;
- Include the installation of various water efficiency measures; and
- Involve extensive reuse of rainwater.

As such, the following sections describe the methodology used to calculate the total water supply and sewage demands for the GKI Resort Revitalisation Plan based on an estimated demand per person and an estimated number of persons for the resort at various occupancies.

7.1 PROJECTED OCCUPANCY

Table 7.1 provides a summary of the expected number of staff and visitors, and average occupancy for the resort during operation as derived from the report entitled "Forecast Economic Impacts - Proposed Revitalisation of Great Keppel Island", dated June 2011 and prepared by Foresight Partners Pty Ltd.

TABLE 7.1: Estimated Average & Maximum Occupancy for GKI Resort Revitalisation Plan

Use	Units	Average Occupancy Rate	Persons / Occupied Unit	Annual Person Days	Average Person Days	Max. Occupancy Rate	Persons / Occupied Unit	Annual Person Days
Hotel Rooms	250	65%	2.2	130,488	358	100%	2.2	200,750
Villas	750	50%	2.5	342,187	938	100%	2.5	684,375
Apartments	300	50%	2.5	136,875	375	100%	2.5	273,750
Marina Berths	250	20%	2.2	40,150	110	100%	2.2	200,750
Day Visitors	N/A	N/A	N/A	36,500	100	N/A	N/A	36,500
Staff Accommodation	200	95%	1.5	95,760*	262	100%	1.5	100,800
Staff Commuting	N/A	N/A	N/A	48,000	132	N/A	N/A	48,000
Annual Total				829,960	2,274			1,544,925
Average per Day				**2,274**			**Maximum per Day**	**4,233**
Average per Month				**69,163**				

Assumes 285 staff occupying premises for an average of 48 weeks per year (285 staff x 7 days/week x 48 weeks = 95,760 annual person days).

These occupancy rates have been adopted as the basis for calculating water supply and wastewater requirements for the GKI Resort Revitalisation Plan. The figure of 4,233 persons represents a theoretical maximum occupancy for the resort. Although the resort would have the capacity to accommodate this figure, it is unlikely to actually have such a population in reality. Therefore, this maximum capacity is considered for design purposes only. From historical data, the theoretical maximum daily population would occur in the month of January which corresponds to the annual summer school holiday period.

In order to calculate water supply demands and wastewater flows, the number of persons estimated by Foresight Partners to be utilising the resort first need to be converted to Equivalent Persons (EP). EP is typically used as the primary population criteria for the design of water supply and sewerage schemes.

An Equivalent Person (EP) is defined in DERM's *Planning Guidelines for Water Supply & Sewerage Schemes* (DERM, 2010) as:

> *The water supply demand or the quantity and/or quality of sewage discharge for a person resident in a detached house. It is also applied to:*
> - *The number of persons who would have a water demand equivalent to the establishment being considered.*
> - *The number of persons who would contribute the same quantity and/or quality of domestic sewage as the establishment being considered.*

For non-residential developments such as that proposed by the GKI Resort Revitalisation Plan, the water supply and sewage demand for each activity is calculated in relation to the number of persons resident in a detached house who would have the same water demand or would generate the same amount of sewage as the activity proposed.

For example, a person who commutes to the Island for work would not be expected to use as much water or generate as much sewage as a person or staff member living on the Island. This is basically because the commuting staff member will not prepare any meals or do any laundry, which generate significant water and sewage demand. As such, each person that is a commuting staff member would only be accounted for as a proportion of an EP, in this case 0.32 EP whereas a staff member resident on the Island would be accounted for as a whole EP or 1.0 EP. To determine the number of EP for retail and commercial activities, the gross floor area of the facility is typically used, as floor area is assumed to provide an indication of the number of persons that can use a facility.

The following section provides an overview of the maximum number of EP associated with the proposed GKI Resort Revitalisation Plan.

7.2 ESTIMATED EQUIVALENT PERSONS

Information derived from section 3.2 of the "Forecast Economic Impacts Report" prepared by Foresight Partners as presented in **Table 7.1** above, has been used as the basis for an estimation of equivalent persons and for occupancy levels for the Project.

Specifically, the number of persons per occupied unit estimated by Foresight Partners (2011) for proposed villas, apartments, hotel rooms etc have been adopted as the number EP for these components of the development on the basis that the nature of the activity is comparable to a residential activity so that a person staying in an apartment for example, could be expected to generate the same water supply and sewage demand as a person resident in a detached house.

However, for other components of the development that are not residential in nature (e.g. retail) or where a more relevant reference to the number of EP exists for an activity, then an alternative number of EP has been adopted. In general, where the number of EP has not been derived directly from Foresight Partners (2011), the number of EP has been determine with reference to schedule D of the former Livingstone Shire Council (LSC) *Planning Scheme Policy No.5 – Development contributions for water supply and sewerage, June 2006*. Note that while there has been a recent amalgamation of the local councils to form the Rockhampton Regional Council (RRC) (including the Livingstone Shire Council), the provisions of the LSC planning schemes are still current – pending issue of an overall planning scheme for the RRC.

Schedule D of the former LSC *Planning Scheme Policy No.5 – Development contributions for water supply and sewerage, June 2006* specifies maximum Equivalent Tenement (ET) densities for a range of uses. To convert an ET based on floor area to EP, the ET density is multiplied by 3 (i.e. equivalent to a tenement with an occupancy of 3 persons) as per the Livingstone Shire Council policy.

Table 7.2 below presents the EP calculations adopted for the purpose of determining the water supply and sewage demands for the GKI Resort Revitalisation Plan. The following assumptions have been made within the EP calculations:

- Hotel – all one bedroom, EPs as per occupancies projected by Foresight Partners (2011);
- Apartments – 40% one bedroom, 40% two bedroom, 20% three bedroom and EPs as per occupancies projected by Foresight Partners (2011);
- Villas– all three bedroom and EPs as per occupancies projected by Foresight Partners (2011); and
- Day Visitors - average of 100 per day as projected by Foresight Partners (2011).

TABLE 7.2: Equivalent Person Estimation for GKI Resort Revitalisation Plan

Area	ET Factor	EP / Unit or m^2	Unit	No. or Area	EP
Fisherman's Beach Precinct					
Fisherman's Beach Hotel (250 rooms)					
Rooms – all one bedroom		2.2	No.	250	**550**
Restaurant, Hotel, Licensed Premises	0.0083	0.0249	m^2	800	**20**
Retail Shops	0.0042	0.0126	m^2	200	**3**
Ecotourism Villas (383 villas)					
Assume 100% Short Term Accommodation – three bedrooms		2.5	No.	383	**958**
Ecotourism Apartments (150 apartments)					
Assume 40% Short Term Accommodation - one bedroom		2.2	No.	60	**132**
Assume 40% Short Term Accommodation - two bedroom		2.5	No.	60	**150**
Assume 20% Short Term Accommodation - three bedroom		2.5	No.	30	**75**
Fisherman's Beach Resort					

Area	ET Factor	EP / Unit or m^2	Unit	No. or Area	EP
Restaurants, Café, Fast Food	0.0083	0.0249	m^2	500	**12**
Retail Shops (including pro shop)	0.0042	0.0126	m^2	1,500	**19**
Swimming Pool, Tennis Court & Gymnasium					
Staff					
Living on site - allow one bedroom unit - long term		1.5	No.	200	**300**
Living off site		0.32	No.	200	**64**
Day Visitors					
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No.	70	**7**
Allow nominal for public facilities					**12**
Airport					
Total Area = 3,500m^2, assume 1,000m^2 retail / commercial	0.0042	0.0126	m^2	1,000	**13**
Marina Precinct:					
Marina					
Berths		1	No	250	**250**
Yacht Club - Licensed Premises, Restaurant, Café	0.0083	0.0249	m^2	1,000	**25**
Retail Shops	0.0042	0.0126	m^2	6,000	**76**
Day Visitors					
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**
Ecotourism Apartments (150 apartments)					
Assume 40% Short Term Accommodation - one bedroom		2.2	No	60	**132**
Assume 40% Short Term Accommodation - two bedroom		2.5	No	60	**150**
Assume 20% Short Term Accommodation - three bedroom		2.5	No	30	**75**
Clam Bay Precinct:					
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m^2	2,500	**32**
Ecotourism Villas (367 No.)					
Assume 100% Short Term Accommodation – three bedroom		2.5	No	367	**918**
TOTAL EP					**3,973**

Based on the above, the maximum projected population for design purposes for the GKI Resort Revitalisation Plan is estimated to be **3,973 EP**.

7.3 PROJECTED WATER DEMAND

7.3.1 Per Capita Water Demand

Table 7.3 below provides a comparison of the estimated internal water demand for an EP in a typical household assuming standard fixtures and water saving devices. The water demands in the following table have been established based on experience with the individual fixtures and demonstrates the reduction in water demand that can be achieved by installing water saving devices.

To reduce pressure on limited water resources, water saving devices will be installed in all buildings and facilities within the GKI Resort Revitalisation Plan and accordingly, the estimated internal demand assuming water saving devices are installed has been adopted for calculation of projected water demand.

TABLE 7.3: Estimated Internal Water Supply - Average Daily Demand – Standard Water Fixtures and Water Saving Devices

Water Use	Water Demand – Standard Fixtures	Water Demand – Water Saving Devices
	L/EP/d	L/EP/d
Drinking/ Cooking	15	15
Bathroom	75	50
Toilets	30(1)	30(1)
Laundry	25	25
Hot Water	60	60
Total	**205**	**180**

Notes: 1. Assumes 6L/3L dual flush toilets for both standard and water saving fixture scenarios, as per minimum WELS 3 Star standard. Note that WELS 4 Star standard with 4.5/3L flush may also be considered.

The above internal water demand figures are considered to provide an indication of the per capita water demand that would be expected for a 1 bedroom apartment with 2.2 EP/apartment and a 2 or 3 bedroom apartment or villa with 2.5 EP/apartment or villa proposed under the GKI Resort Revitalisation Plan assuming water saving devices are installed (i.e. reduced flush toilets, aerator faucets and shower-heads etc).

For the purposes of determining an external water demand for a proposed 1 bedroom apartment with 2.2 EP/apartment and a 2 or 3 bedroom apartment or villa with 2.5 EP/apartment or villa, it has been assumed that approximately 40 L/EP/day may be required for garden watering. This is based on an assumption of approximately 40-45 m^2 of garden per villa / apartment and an average irrigation rate of 30 mm/week for 26 weeks/year. An allowance of 8 L/EP/day has also been assumed for other external use such as hosing down hardscape.

Based on the above estimated water demands for proposed villas and apartments, assuming installation of water saving devices, and assuming that this level of water demand per EP is reflected across all of the GKI Resort Revitalisation Plan, the average daily water demand per EP would be:

- **180 L/EP/day** (internal demand);
- **48 L/EP/day** (external demand); and
- **228 L/EP/day** (total water demand).

The adopted average daily water demand of 228 L/EP/day with water saving fixtures compares to the following:

- **137 to 194 L/person/day** from the *Draft Urban Water Use Study of South East Queensland (NRM, 2005)* for a "resort, hotel, motel" unit with standard fixtures. The adopted figure of 228 L/EP/day thus includes a significant design contingency of 17.5 % (228 / 194 = 1.175) and / or is a reflection of the likely higher usage of water associated with the tropically located GKI Resort Revitalisation Plan.

- **540 L/person/day** from the *Livingstone Shire Planning Scheme* based on 3 persons per ET. Note that this is for urban situations with larger housing lot sizes and thus more garden watering etc.

- **180 to 300 L/person/day** estimated range derived from *Great Keppel Island Water, Wastewater Infrastructure Audit Report*, 13 September 2007 prepared by Sustainable Solutions International Pty Ltd. The median value was 250 L/person/day.

- **177 L/person/day** for internal residential consumption *Hummock Hill Island Feasibility Investigation*, 11 July 2007 prepared by Cardno. In comparison, an internal water demand of 180L/EP/day out of the total 228L/EP/day is estimated for the GKI Resort Revitalisation Plan.

- **134 to 199 L/person/day** from *Draft Urban Water Use Study of Southeast Queensland* (NMR, 2005) for Holiday Accommodation (houses, units, townhouses).

The average daily water demand for each of the facilities within the GKI Resort Revitalisation Plan will be confirmed during the detailed design stage.

7.3.2 Fire Fighting Water Demand

Fire fighting flows will be provided by the provision of dedicated fire storage within the water storage reservoirs, fire pumps (if required following assessment in the detailed design stage) and the provision of fire hydrants and hose reels within the water reticulation system adjacent to the various buildings.

A fire flow of 25 L/sec with a minimum of 4 hours fire storage capacity (a total of 360 kL) would be proposed for all resort facilities. The fire fighting flow for the larger buildings such as the resort / core facilities will depend upon the final level of fire compartmentalisation provided through structural building design. The system will be assessed during the design stage to cater for fire flows commensurate with the level of fire compartmentalisation provided.

It is anticipated that fire fighting services for the GKI Resort Revitalisation Plan will be:

- Similar to a small rural fire service with light vehicle(s), small tank and pumps for minor grass fires and hydrant hoses for use with the fixed hydrants in the reticulation system; and

- Operated by the maintenance staff supplemented by volunteers from the general resort staff, with appropriate training.

7.3.3 Total Water Demand

The total water demand estimated for accommodation, commercial and retail components of the GKI Resort Revitalisation Plan is based on the average daily water demand of 228 L/EP/day determined in **section 7.3.1** multiplied by the number of equivalent persons (EP) as outlined in **Table 7.2** and the occupancy projections as provided by Foresight Partners (2011).

However, in addition to the internal and external water demands estimated for the core resort facilities as described above, an estimate of irrigation water supply requirements for the proposed golf course has also been made. Estimated rates of irrigation required to maintain the golf course based on average rainfall and evapo-transpiration have been provided by Greg Norman Golf Course Design. Irrigation at the rates specified by the golf course designer is only proposed for parts of the golf course comprising tees, greens and fairways rather than the entire golf course.

As such, estimation of the total volume of irrigation water required is based on the rates specified by the golf course designer multiplied by the estimated area of tees, greens and fairways. Based on reference to a report published by the Environmental Institute of Golf (2006), it has been estimated that the area of tees, greens and fairways accounts for approximately 49% of the total area of maintained turf, which in this case, equates to 49% of 31 hectares or approximately 15.2 hectares.

Table 7.4 provides a summary of the estimated irrigation water demand for the proposed golf course.

TABLE 7.4: Estimated Golf Course Irrigation Requirements

Month	Irrigation Rate Required for Tees, Greens & Fairways (ML/ha/month)	Total Volume of Irrigation Water Required for Tees, Greens & Fairways (15.2ha) (ML/month)
January	1.26	19.077
February	0.78	11.799
March	1.18	17.946
April	1.27	19.326
May	1.11	16.790
June	0.94	14.217
July	0.98	14.871
August	1.11	16.862
September	1.41	21.462
October	1.63	24.826
November	1.75	26.594
December	1.38	20.965
Annual	**14.80**	**224.737**

It should be noted that above irrigation demand is based on irrigating tees, greens and fairways at the full rate proposed by the golf course designer, which may be achieved using a combination of recycled water and other water supply sources. However, as the rate of irrigation is not as critical for other areas of golf course not comprising tees, greens and fairways, these areas will be irrigated using recycled water only at the rate determined to be sustainable through MEDLI modelling as discussed in **section 10.3** so as to reduce the total demand for irrigation water supplies.

Monthly water demand figures for the golf course and core resort facilities as described above have been used to formulate **Appendix E - Water Balance Spreadsheets,** which includes the following:

- Overall Water Balance Summary; and
- Monthly Water Balance - January to December.

Table 7.5 summarises relevant average and peak water demand figures derived from **Appendix E - Water Balance Spreadsheets.** The sources of water proposed to meet this demand are discussed in **section 8.**

TABLE 7.5: Comparison of Average Daily Water Demand with Peak Daily Water Demands

Estimated Water Demand	Internal	External	Total
Average Daily Water Demand[1]	493 kL/day	1,391 kL/day	1,884 kL/day
Peak Occupancy Month - Water Demand (January)[2]	855 kL/day	1,426 kL/day	2,281 kL/day
Peak Month – Water Demand (November)[3]	527 kL/day	1,942 kL/day	2,469 kL/day
Maximum Internal & External Water Demand	855 kL/day	1,942 kL/day	2,797 kL/day

Note:
1. Average over 12 months based on total water usage over 12 months assuming average occupancy from **Appendix E - Water Balance Spreadsheets**.
2. Peak Occupancy occurs in January with typical occupancies of 98% for the Hotel, Villas & Apartments and other facilities. Internal water demand is at its highest during this month, but total water demand is not at its highest as rainfall and availability of recycled water for irrigation reduce the demand for external irrigation water supplies.
3. Peak Monthly Water Demand occurs in November. Although typical occupancies are less than in January at only about 95% occupancy for the Hotel, 65% for Villas & Apartments and other facilities, total water demand is at its highest due to the demand for irrigation water supplies at the end of the typical dry season.

It should be noted that there will always be a degree of uncertainty in relation to the actual water supply demand figures that should be used for water supply schemes both in terms of the expected occupancy and per capita water usage. This is not a unique issue for an island resort, but is exacerbated by the high variability in terms of occupancy. As such, the adopted water supply system will need to be designed with a degree of flexibility to account for these uncertainties.

7.4 PROJECTED WASTEWATER FLOWS

7.4.1 Per Capita Wastewater Flow

An Average Dry Weather Flow (ADWF) of 180 L/EP/day has been calculated for the GKI Resort Revitalisation Plan. The estimated ADWF of 180 L/EP/day is equivalent to the estimated internal water demand described in section 7.3.1.

Notwithstanding, preliminary assessment of recycled water reuse has been based on an ADWF of 200 L/EP/day. This is to ensure a conservative assessment of irrigation area and wet weather storage requirements for the recycled water irrigation scheme given the environmentally sensitive nature of the site. An ADWF of 200 L/EP/day is consistent with the ADWF used for calculating peak design capacity for ERA 63 - Sewerage treatment works under schedule 2, part 13, item 63 of the *Environmental Protection Regulation 2008*.

7.4.2 Estimated Equivalent Persons

The estimated EP for the purpose of establishing wastewater flows for the GKI Resort Revitalisation Plan is the same as for the water demand in **Table 7.2**. The maximum estimated EP for the GKI Resort Revitalisation Plan is 3,973 EP. As such, the proposed WWTP will conform to the definition of ERA 63(2)(c) which is defined in schedule 2 of the *Environmental Protection Regulation 2008* as follows:

> *ERA 63(2)(c) – Sewage treatment – operating sewage treatment works, other than no release works, with a total peak design capacity of – 1,500 to 4,000EP.*

7.4.3 Total Wastewater Flow

Based on an ADWF of 180 L/EP/day estimated for the Project in **section 7.4.1** and an estimated average number of equivalent persons per month as detailed in **Appendix E - Water Balance Spreadsheets**, the following average monthly wastewater flows have been estimated:

TABLE 7.6: Estimated Monthly Wastewater Flows (@180L/EP/day)

Month	EP x Occupancy	ADWF for Month @ 180 L/EP/day	
		ML/day	ML/month
January	3750.1	0.675	20.925
February	1724.5	0.310	8.692
March	1847.5	0.332	10.309
April	2143.8	0.386	11.577
May	1069.3	0.192	5.967
June	1193.2	0.215	6.443
July	1666.6	0.300	9.300
August	1570.6	0.283	8.761
September	3075.1	0.554	16.606
October	2262.7	0.215	12.626
November	2313.4	0.416	12.492
December	3303.3	0.595	18.432

As can be seen from **Table 7.6**, the quantity of wastewater generated by the resort will vary significantly throughout the year depending on occupancy rates.

It should be noted that while the above table represents the estimated ADWF for the Project, figures adopted for modelling of recycled water irrigation to land have been based on 200 L/EP/day to provide a conservative assessment of irrigation area and wet weather storage requirements. Details of monthly wastewater flows adopted for MEDLI modelling purposes are provided in **section 10.3**.

8. WATER BALANCE

8.1 WATER SUPPLY SOURCES

A number of water supply sources are available to meet the projected water demands of the GKI Resort Revitalisation Plan. The preferred water supply sources for operation of the resort as determined through the above options analysis, include:

Potable Water Supply:

- Potable water sourced from Rockhampton Regional Council's water treatment facilities on the mainland.

Non-Potable Water Supply:

- Treated effluent produced from treatment of sewage effluent at the Island-based WWTPs;
- Harvested stormwater runoff from the golf course;
- Harvested stormwater runoff from resort hardstand areas;
- Rainwater collected from roof areas; and
- Potable water sourced from Rockhampton Regional Council's water treatment facilities (to supplement above sources only).

Groundwater resources are also available; however this resource has been identified for water supply to the Stage 1 construction only and will not form a fundamental component of the overall water supply strategy for the GKI Resort Revitalisation Plan during operation.

The following section provides an estimate of the amount of water supply that is likely to be derived from each of the above sources to meet the total water demands of the project.

8.1.1 Rainwater Collection

In accordance with the *Queensland Development Code* (QDC)*,* once the facilities are connected to a mains water supply, such as is proposed by the mainland connection to Council water supply, rainwater collection and reuse for toilet flushing, laundry and external use is mandatory. As such, rainwater collected from roof areas will be used as the primary source of water supply for internal non-potable uses (e.g. toilet flushing, laundry) and some external non-potable uses (e.g. car and boat washdown, garden watering, hosing down of hardscape).

Based on the estimated internal and external water demand figures determined for a 1 bedroom apartment with 2.2 EP/apartment and a 2 or 3 bedroom apartment or villa with 2.5 EP/apartment or villa assuming water saving devices are installed as described in **section 7.3.1**, it is estimated that the maximum potential volume of rainwater reuse for an apartment or villa would be approximately 79 L/EP/day out of a total water demand of 228L/EP/day. This 103L/EP/day includes the estimated rate of water consumption for toilets (30L/EP/day), laundry (25L/EP/day), garden watering (40L/EP/day) and other external use (8L/EP/day).

Notwithstanding, the extent of rainwater use also depends on the availability of stored rainwater. The availability of stored rainfall depends on the amount of rainwater that can be collected, which depends primarily on the amount of rainfall, the roof area available for collection and the storage capacity of the rainwater tanks.

During the design stage of the Project, the viability of increased rainwater reuse for apartments and villas will be investigated. This would involve UV disinfection of the potable use component. It is estimated that 100% of the demand for the apartments and villas would be available for the months of December to June inclusive and, in median rainfall years, up to 50% or more in the months of July to November inclusive.

Tables 8.1 and 8.2 provide an estimate of the proportion of the total water demand for a 1 bedroom apartment and a 2 or 3 bedroom apartment or villa with water saving devices that could reasonably be met by rainwater reuse assuming a reasonable amount of rainwater tank storage is provided (not less than the minimum of 1,500 L/ toilet pan as per QDC). The rainwater reuse will be confirmed by detailed modelling in the final design stage of the project.

TABLE 8.1: Estimated Water Supply - Average Daily Demand – 1 Bedroom Apartment (2.2 EP) - Water Saving Fixtures and Rainwater (RW) Reuse

Water Use	Water Demand – Water Saving Devices + Rainwater (RW) Reuse			
	L/EP/day (External Supply)	L/hh/day (@2.2 EP) (External Supply)	L/EP/day (RW Reuse)	L/hh/day (@2.2 EP) (RW Reuse)
Drinking/ Cooking	15	33		
Bathroom	50	110		
Toilets	6(1)	13	24(1)	53
Laundry	5(1)	11	20(1)	44
Hot Water	60	132		
Subtotal (Internal)	**136**	**299**	**44**	**97**
Garden watering		43(2)		43(2)
Other (hosing down, boat washing etc)		10(2)		10(2)
Subtotal (External)		**53**		**53**
Subtotal (Internal & External)		**352**		**150(3)**
Total / EP @ 2.2 EP/hh	External Supply	**160**	Rainwater Reuse	**68**
Total Water Demand/ EP	**228 L/EP/d**			

Notes:
1. Assumes 80% from rainwater, 20% from external supply.
2. Assumes 50% from rainwater, 50% from external supply. Allows for 40m^2 garden area per apartment at average irrigation rate of 30 mm/week for 26 weeks/year.
3. At median 950 mm rainfall/ year, requires approx 58m^2 roof area (58m^2 x 950 mm/year / 365 = 150 L).

TABLE 8.2: Estimated Water Supply - Average Daily Demand – 2 or 3 Bedroom Apartment or Villa (2.5 EP) - Water Saving Fixtures and Rainwater (RW) Reuse

Water Use	Water Demand – Water Saving Devices + Rainwater (RW) Reuse			
	L/EP/day (external supply)	L/hh/day (@2.5 EP/hh (external supply)	L/EP/day (RW Reuse)	L/hh/day (@2.5 EP/hh) (RW Reuse)
Drinking/ Cooking	15	37.5		
Bathroom	50	125		
Toilets	6(1)	15	24(1)	60
Laundry	5(1)	12.5	20(1)	50
Hot Water	60	150		
Subtotal (Internal)	**136**	**340**	**44**	**110**

Water Use	Water Demand – Water Saving Devices + Rainwater (RW) Reuse			
	L/EP/day (external supply)	L/hh/day (@2.5 EP/hh (external supply)	L/EP/day (RW Reuse)	L/hh/day (@2.5 EP/hh) (RW Reuse)
Garden watering		48(2)		48(2)
Other (hosing down, boat washing etc)		12(2)		12(2)
Subtotal (External)		**60**		**60**
Subtotal (Internal & External)		**400**		**170(3)**
Total / EP @ 2.5 EP/hh	External Supply	**160**	RW Reuse Supply	**68**
Total Water Demand/ EP	**228 L/EP/d**			

Notes:

1. Assumes 80% from rainwater, 20% from external supply.
2. Assumes 50% from rainwater, 50% from external supply. Allows for approximately 45m^2 garden area per apartment at average irrigation rate of 30 mm/week for 26 weeks/year.
3. At median 950 mm rainfall/ year, requires approx 65m^2 roof area (65m^2 x 950 mm/year / 365 = 170 L).

Based on the above, it is estimated that approximately 68 L/EP/day or about 30% of total water demand for apartments and villas is likely to be met by rainwater reuse. This compares to a total potential rainwater reuse of 103 L/EP/day that could be achieved if sufficient rainfall, tank storage capacity and roof area was available to ensure enough rainwater was stored and available to meet demand throughout the year.

For the other resort facilities, such as the hotel and retail / commercial components, which have limited roof area for rainwater collection relative to the numbers of occupants, it has been assumed that only approximately 28 L/EP/day or about 12% of total water demand is likely to be met by rainwater reuse.

As the level of rainwater use depends largely on the availability of rainwater, it has also been assumed in the water balance calculations, that during lower rainfall months (i.e. July through to November), rainwater reuse for the apartments and villas may also be approximately 28 L/EP/day.

Rainwater collected from roof areas of individual buildings / facilities will be stored in on-site tanks adjacent to the collection location. Rainwater tank storage will be plumbed back into the buildings / facilities for use in toilets and washing machines as well as connection to external hose cocks for rainwater use in garden watering and other external use (e.g. Hosing down of hardscape, boat washing).

It is estimated that in an average rainfall year, approximately 35,000 kL/annum of rainwater could be collected from roof areas. This equates to an average of 2,916 kL/month or within the range between 1,388 kL/month during August up to 6,521 kL/month during January.

Notwithstanding the variability, this rainwater reuse for non-potable purposes will significantly reduce the total volume of water required from the mainland supply. Although rainwater can also be used for potable purposes (e.g. drinking water) with only minor treatment (e.g. disinfection), at this stage it has been estimated based on roof areas available for collection and provision of a reasonable volume of storage, that sufficient rainwater supply for non-potable purposes only will be available.

However, with additional storage and collection from an increased roof area, it may be possible to collect additional rainwater that may justify the installation of treatment systems to enable reuse of collected rainwater for potable uses, or alternatively, to extend the use of the collected roof water for non-potable uses. For the purpose of this water balance, a conservative approach to sourcing rainwater supplies has been adopted to ensure the capacity of the mainland connection required is not undersized.

8.1.2 Treated effluent

Treated effluent produced from treatment of sewage effluent at the Island-based WWTPs will be used as the primary source of water supply for irrigation of the golf course. Although not expected, any excess recycled wastewater (if available) would be used for irrigation of other landscaped areas.

Although the estimated wastewater flow (ADWF) for the GKI Resort Revitalisation Plan is 180 L/EP/day, to account for losses in the treatment process (e.g. water content in sludge), it has been conservatively assumed for the purpose of the water balance, that only about 95% or 171 L/EP/day of wastewater influent to the WWTP will be discharged from the WWTP as recycled water available for reuse.

As such, during peak occupancy in January, the average daily volume of recycled water available is estimated to be approximately 641 kL/day. The daily volume of recycled water available on average over a year is estimated to be approximately 370 kL/day.

It is estimated that up to 135,000 kL/annum of recycled water may be available for irrigation of the golf course. This equates to an average of about 11,250 kL/month or within the range between 5,668 kL/month during May up to 19,879 kL/month during January.

8.1.3 Harvested Stormwater (Golf Course)

Harvested stormwater runoff from the golf course will be used as a supplementary source of water supply for irrigation of the golf course and other landscaped areas. Harvested stormwater runoff from the golf course will be collected in a series of ponds incorporated into the golf course and stored for reuse.

It is estimated the amount of stormwater runoff collected could be up to approximately 43,000 kL/annum. This equates to an average of 3,853kL/month or within the range between 200 kL/month during September, which is characterised by very low rainfall and 7,010 kL/month during March, which is characterised by high rainfall on average.

Actual quantities harvested will depend on the grading of the golf course and thus the extent of catchment area draining into the golf course ponds. These figures will need to be assessed in detail during the design stage to confirm the practicality of such runoff being collected and reused in the irrigation system.

In addition to providing an alternative source of water to reduce demand from Council's potable water supply, harvesting of stormwater from the golf course will also enable runoff from the golf course to be monitored and where necessary, treated, prior to release to downstream waterways. Stormwater harvesting ponds will therefore be multi-purpose serving as water features enhancing the amenity of the golf course and surrounding villas while also providing a source of irrigation water supply and stormwater quality improvement.

8.1.4 Harvested Stormwater (Other Areas)

Harvested stormwater runoff from resort hardstand areas may be used as a source of water supply for irrigation of landscaping and washdown of hardscape areas around the resort, adjacent to areas of collection.

During an average rainfall year, it is estimated that approximately 10,500 kL/annum could potentially be harvested from this source. This equates to an average of 875 kL/month or within the range between 200 kL/month during September, which is characterised by very low rainfall and up to 1,805 kL/month during March, which is characterised by high rainfall on average.

The harvesting of stormwater from these areas will be assessed in detail during the design stage. Depending upon the practicalities and economics, it may be more beneficial to collect additional rainwater from roof water collection via larger storage tanks.

8.1.5 Mainland Water Supply

Connection to Council's mainland water supply provides a reliable, flexible and secure high-quality water source for the GKI Resort Revitalisation Plan. Although a mainland connection has the potential to supply 100% of the Project's water demands, this approach would not be consistent with the sustainability objectives of the GKI Resort Revitalisation Plan, which aim to maximise water use efficiency and use of alternative water supplies for non-potable purposes to reduce pressure on limited water resources.

As such, the mainland water supply connection will provide 100% of the total *potable* water demand for the Project but will only be used to supplement other available water supplies for *non-potable* purposes as described above. Potable water sourced from Rockhampton Regional Council's water treatment facilities on the mainland will therefore be used as the sole source of water supply for potable purposes such as drinking water, cooking and showers.

The total volume of water derived from this source will depend on demand but is expected to range between an average of approximately 1,275 kL/day and a maximum peak of 2,270 kL/day, including water required for potable and non-potable purposes. Of this volume, on average approximately 397 kL/day (average throughout the year) to 645kL/day (average per day in peak demand month of January) will be required for internal purposes while approximately 494 kL/day (average throughout the year) to 1,436 kL/day (average per day in peak demand month of November) will be required for external purposes.

Advice from Rockhampton Regional Council indicates that sufficient water is available from their facilities to meet the above demands projected for the GKI Resort Revitalisation Plan. However access and usage charges will apply.

8.2 AVERAGE DEMAND & PEAKING FACTORS

The following **Tables 8.3, 8.4 and 8.5** provide an assessment of average and peak water demands relative to the proportion of demand that is likely to be offset by alternative sources of water such as rainwater, harvested stormwater and recycled water as described above. This enables the total amount of water required from Council's mainland water supply network to be estimated.

TABLE 8.3: Average Annual Water Demand

Estimated Water Demand[1]	Internal	External
Average Water Demand	493 kL/day	1,391 kL/day
Less: Offset from collected rainwater reuse for toilets etc.	(96 kL/day)	
Less: Offset from use of collected rainwater, harvested stormwater and recycled water for irrigation of the golf course and other landscaped areas.		(513 kL/day)
Subtotal	**397 kL/day**	**878 kL/day**
Total Mains Water Requirement – Annual Average / Day (= flow over 24 hours)	**1,275 kL/day (=14.8 L/sec)**	

Note:
1. Average over 12 months based on total water usage over 12 months with average occupancy from **Appendix E - Water Balance Spreadsheets**.

TABLE 8.4: Peak Occupancy - Monthly Water Demand

Estimated Water Demand for January[1]	Internal	External
Average Water Demand for January	855 kL/day	1,426 kL/day
Less: Offset from collected rainwater reuse for toilets etc.	(210 kL/day)	
Less: Offset from use of collected rainwater, harvested stormwater and recycled water for irrigation of the golf course and other landscaped areas.		(932 kL/day)
Subtotal	**645 kL/day**	**494 kL/day**
Internal Peak Day Water Demand (1.5 x Average)	968 kL/day	
External Peak Day Water Demand (1.1 x Average)		543 kL/day
Total Mains Water Peak Day Requirement for January (= flow over 24 hours)	**1,511 kL/day (=17.5 L/sec)**	

Note:
1. Peak Occupancy occurs in January with typical occupancies of 98% for the Hotel, Villas & Apartments and other facilities. Internal water demand is at its highest during this month, but total water demand is not at its highest as rainfall and availability of recycled water for irrigation reduce the demand for external irrigation water supplies.

TABLE 8.5: Peak Monthly Water Demand

Estimated Water Demand for November[1]	Internal	External
Average Water Demand for November	527 kL/day	1,942 kL/day
Less: Offset from collected rainwater reuse for toilets etc.	(66 kL/day)	
Less: Offset from use of collected rainwater, harvested stormwater and recycled water for irrigation of the golf course and other landscaped areas.		(506 kL/day)
Subtotal	**461 kL/day**	**1,436 kL/day**
Internal Peak Day Water Demand (1.5 x Average)	691 kL/day	
External Peak Day Water Demand (1.1 x Average)		1,579 kL/day
Total Mains Water Peak Day Requirement for November (= flow over 24 hours)	**2270 kL/day (= 26.3 L/sec)**	

Note:
1. Peak Monthly Water Demand occurs in November. Although typical occupancies are less than in January at only about 95% occupancy for the Hotel, 65% for Villas & Apartments and other facilities, total water demand is at its highest due to the demand for irrigation water supplies at the end of the typical dry season.

While it is unlikely that the peak occupancy will coincide with peak landscaping use, it can be seen from the above tables that such a situation would give rise to a total water demand of 2,547 kL/day based on a peak internal water demand of 968 kL/day (from January) and a peak external water demand of 1,579 kL/day (from November).

Although water demand calculations will need to be determined at the detailed design stage, for the purpose of this assessment it is considered appropriate that the maximum potential peak (i.e. 2,547 kL/day or 29.5 L/sec over 24 hours) be adopted for sizing of critical water supply infrastructure such as the mainland supply connection. This approach to sizing of the mainland connection will also ensure sufficient capacity is available to support the high early water requirements associated with establishment of the golf course during Stages 2 and 3 (i.e. over 2014 and 2015), which coincides with relatively low recycled water production in the early stages of the Project.

TABLE 8.6: Per Capita Demand and Peaking Factor Comparison

Source Reference	Average Daily Demand	Peaking Factor: Mean Day Maximum Month		Peaking Factor: Maximum Day Maximum Month	
	L/EP/day	x AD	L/EP/day	x AD	L/EP/day
Livingstone Shire Council (LSC) Guidelines	270	1.4	378	1.89	510
Median Value from SSI Report	250				
Adopted Values for GKI Resort Revitalisation Plan	228 (internal) 220 (external)	1.2 *(1)	---	1.8*(2)	---

Note:

1. Taking the peak month occupancy in Table 8.6 and average demand in Table 8.5 gives 1511 kL/day / 1275 kL/day = 1.2.
2. Taking the peak water usage month in Table 8.7 and average demand in Table 8.5 gives 2270 kL/day / 1275 kL/day = 1.8.
3. While these figures are less than the peaking factors from the former LSC guidelines, the very large water demand for the golf course has a large influence.

Due to the fluctuating population typically expected for tourist resorts, the mean-day-maximum-month demand and maximum-day demand are expected to be higher than the peaking factors indicated in the former Livingstone Shire Council Guidelines. As indicated in the notes above, the high water demand for the golf course has a significant influence. Also, if the mainland connection is finally designed for the peak internal water demand of 968 kL/day (from January) and the peak external water demand of 1,579 kL/day (from November) resulting in a total potential peak demand of 2,547 kL/day, then the peaking factor will be 2,547 / 1,275 = 2.0.

8.3 SUMMARY

Figure 8.1 illustrates the proportion of total water demand that can be met by the above water supply sources for the following scenarios:

- Annual Average Water Demand;
- Peak Occupancy (Internal) Water Demand Month (January); and

- Peak Irrigation (External) Water Demand Month (November).

This graph illustrates that:

- Rainwater reuse contributes between 3% and 9% of total water demand;
- Treated effluent reuse contributes between 16% and 28% of total water demand; and
- Harvested stormwater contributes between 4% and 13% of total water demand.

Water derived from the mainland connection to Rockhampton Regional Council's water supply system will therefore be required to supply approximately 50% to 77% of the total water demand for this project on average.

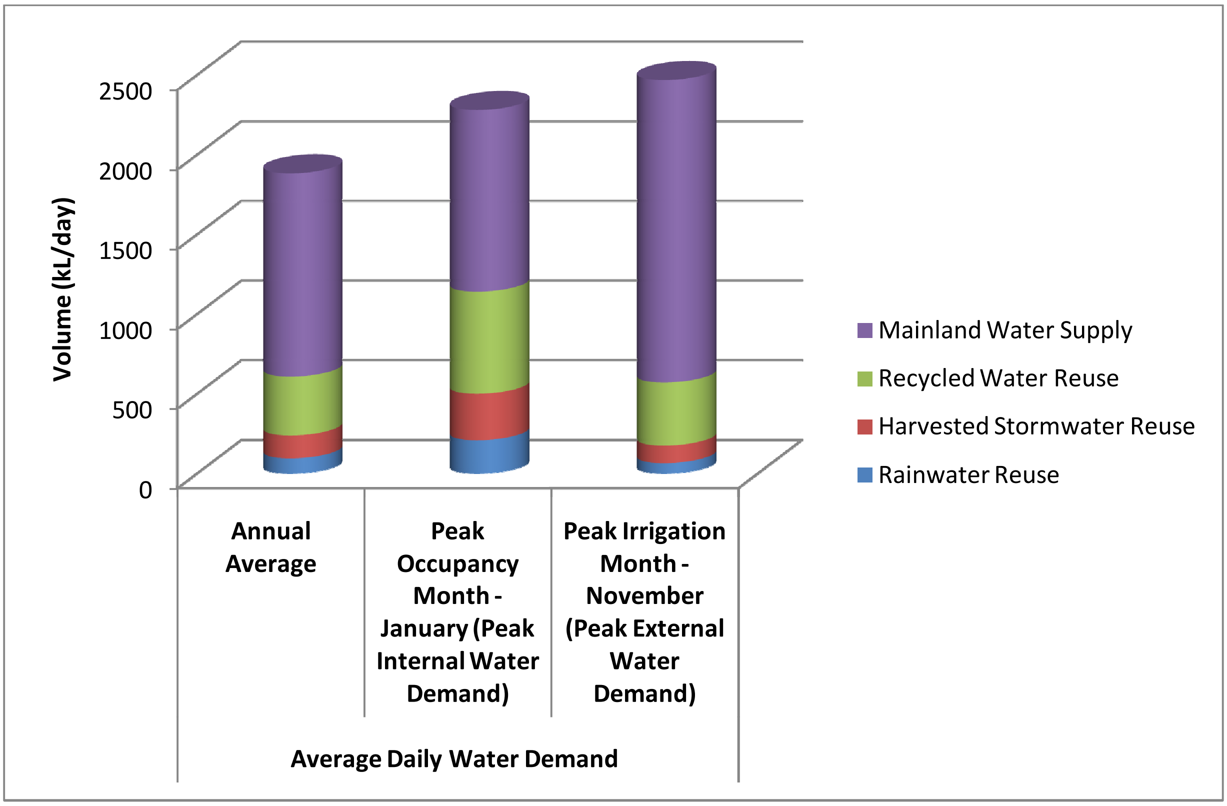


FIGURE 8.1: Summary of Water Supply Sources Relative to Water Demand

8.4 STAGING

The proposed staging of infrastructure for the GKI Resort Revitalisation Plan is summarised as follows:

TABLE 8.7: Summary of Proposed Staging

Transport Infrastructure:		
Stage 1	Marina Facility	Mid 2012 to end 2013
Stage 1	Ferry Terminal	Mid 2012 to end 2013
Stage 1	Barge Facility	Mid 2012 to end 2013
Stage 1	Runway & Airport Terminal	Mid 2012 to end 2013

Stage 1 – 8 Stage 1 - 8	Roads Public Walkways/ Bicycle Tracks	Start 2013 to mid 2022 Start 2013 to mid 2022
Services Infrastructure:		
Stage 1 Stage 1 Stage 1 - 7	Power Supply to the Island Water Supply to the Island Wastewater Treatment Facilities	Mid 2012 to end 2013 Mid 2012 to end 2013 Start 2013 to mid 2022
Social Infrastructure:		
Stage 2 – 9 Stage 2 Stage 2 – 6 Stage1	Landscaping Sport & Recreation Oval Environmental Protection Research Centre/ Police Centre	Start 2014 to end 2022 Start 2014 to mid 2014 Start 2014 to mid 2018 Early 2013 to late 2013
Tourism Infrastructure:		
Stage 1 Stage 1 Stage 1 Stage 2 Stage 3 Stage 2 - 10	Fisherman's Beach Hotel & Spa Marina Retail Precinct Apartments St 1 (150) Apartments St 2 (75) Apartments St 3 (75) Villas Stage 1 to 10 (75 each)	Mid 2012 to end 2013 Mid 2012 to end 2013 Mid 2012 to end 2013 Start 2014 to end 2014 Start 2015 to end 2015 Start 2104 to end 2023
Golf Course:		
Stage 2 – 3 Stage 3	Golf Course Golf Course Facility	Start 2014 to end 2015 Early 2015 to end 2015

The following table outlines the growth in the volume of water required from the mainland water supply and the volume of recycled water available for irrigation based on the proposed staging.

TABLE 8.8: Expected Growth in Annual Water Demand and Treated effluent Availability based on Proposed Staging

Stage / Completion By	Total EP		Projected Annual Mains Water Demand[1] (ML/year)			Available Treated effluent[2]	
	EP/ Stage	Cumulative	Internal	External	Total	Cum. EP x 54.4%	ML/ year
Stage 1 / by end 2013	1522	1522	56	30	96	828	52
Stage 2 / by mid 2014	548	2070	76	50	126	1126	70
Stage 3 / by end 2015	399	2469	90	320	410	1342	84
Stage 4 / by end 2016	188	2657	97	320	417	1446	90
Stage 5 / by end 2017	188	2845	104	320	424	1548	97
Stage 6 / by end 2018	188	3033	111	320	431	1650	103
Stage 7 / by end 2019	188	3221	118	320	438	1752	109
Stage 8 / by end 2020	188	3409	124	320	444	1854	116
Stage 9 / by end 2021	188	3597	131	320	451	1956	122
Stage 10 / by end 2022	188	3785	138	320	458	2058	128
Stage 11 / by end 2023	188	3973	145	320	465	2160	135

Note:

1. Demand is after completion of relevant stage with:
   - Internal water demand prorated based average 397kL/day (from mains supply after rainwater reuse) from **Table 8.3** x (365 / 1000) x cumulative EP / total 3,973 EP for completed Project.

- External water demand based on average 878kL/day (after stormwater reuse and recycled water reuse) from **Table 8.5** after Stage 3 with completion of golf course. Nominal allowances after Stages 1 and 2 for resort and marina landscaping etc.

2. Available effluent is based on 171 L/EP/day x (365 / 10^6) x cumulative EP x 54.4%. The 54.4 % factor is used as this is the average EP x Occupancy of 2,160 (from **Appendix E - Water Balance Summary Spreadsheet**) for the completed Project (2160 / 3973 = 54.4%).

9. WATER SUPPLY SCHEME

Based on consideration of the available options as discussed in **section 6.1**, the water supply scheme proposed for the GKI Resort Revitalisation Plan is likely to consist of:

9.1 CONSTRUCTION (STAGE 1)

Water supply for Stage 1 construction will be sourced from two (2) production bores installed within the Long Beach Aquifer. These bores will only be operational for a short period of time whilst the mains supply is brought across from the mainland. These bores will need to be equipped, possibly with solar operated pumping systems. The maximum continuous extraction rate per production bore is 50 kL/day (Douglas Partners, 2011), or a combined total of 100 kL/day for the aquifer.

Stage 1 construction water supply is estimated at:

- 5 ML/annum for construction puposes. Allowing for, conservatively 250 working days this would give an average of 20 kL/day and, with a peaking factor of 2, a peak day of 40 kL/day; and,
- Up to 50 kL/day for domestic purposes for construction workers based on approximately 350 EP at a maximum demand of 150 L/EP/day (say, 250 EP for up to 250 construction workers in facilities on the Island 40 EP for messing facilities and 60 EP for up to 200 workers ferried to the Island each day). This is based on a maximum of 450 workers in Strage 1 as outlined in the Construction Report.

The total estimated Stage 1 construction water demand is thus in the order of 70 kL/day (average) and 90 kL/day (peak). This may also be offset by rainwater collection, effluent reuse and stormwater harvesting.

With a Stage 1 construction water supply demand of less than 100 kL/day estimated as outlined above, the existing production bores within the Long Beach Aquifer are expected to provide adequate water supply to meet the full demand for Stage 1 of construction.

Construction water requirements are discussed in more detail in the Construction Report.

9.2 OPERATION & CONSTRUCTION (POST-STAGE 1)

The proposed water supply scheme for the GKI Resort Revitalisation Plan has been designed to maximise water use efficiency and minimise pressure on mainland potable water supplies through:

- Installation of water efficient fixtures within all resort facilities;
- In accordance with the *Queensland Development Code*, collected rainwater will be used as the primary water supply for toilets, laundry and landscaping needs adjacent to buildings;
- Reuse of 100% of all recycled water produced by the Island-based WWTP in most years for irrigation of the golf course and possibly other landscaped areas where excess supplies are available, with less than 1% of recycled water produced over a 50 year period likely to be discharged to the ocean; and

- Harvesting of stormwater runoff from the golf course and possibly other areas around the resort where practicable, to supplement irrigation water supplies from other sources.

At this stage, the proposed water supply scheme has not included estimated demand for other existing private development on the Island. However, consolidation of delivery of water supply services across the Island may provide a number of benefits, including providing greater reliability of supply in terms of quality and quantity of water available to existing residents and commercial operators.

Given the relatively small water demands associated with existing development, it is considered feasible for existing development to be incorporated into the water supply scheme for the GKI Resort Revitalisation Plan without any significant modification of the proposed scheme. However, the implications for design and sizing of water supply, storage and distribution should private development be included would need to be confirmed at the detailed design stage along with negotiations between the relevant parties in relation to funding of the infrastructure and ongoing supply costs.

The design of the water supply system will incorporate the following features:

- A 16km water main will be installed within the Utility Services Corridor to connect water supply infrastructure on GKI with Rockhampton Regional Council's existing water supply infrastructure located near the Scenic Highway at Emu Park on the mainland;

- Storage tank (to receive the mainland supply, incorporating disinfection system) and pumps will be installed adjacent to the Marina Precinct to pump to the high level water storage tanks described below;

- Two (2) potable water reticulation systems are proposed, including one servicing the Fisherman's Beach and Marina Precincts and the other servicing the Clam Bay Precinct.

  Both systems are proposed to be serviced by high-level water storage tanks fed by trunk delivery mains from the mainland supply via tank and pumps near the Marina Precinct. Some higher elevation accommodation facilities may require small booster pumps to deliver reticulated water supply; and,

- Potable water reticulation will be installed to service all resort accommodation, commercial and retail facilities, along with some landscaped areas such as the golf course to supplement irrigation supplies.

A schematic outline of the water supply scheme is shown in **Figure 9.1** below and a preliminary layout plan is shown in **Appendix F – Water Supply Scheme Layout.**

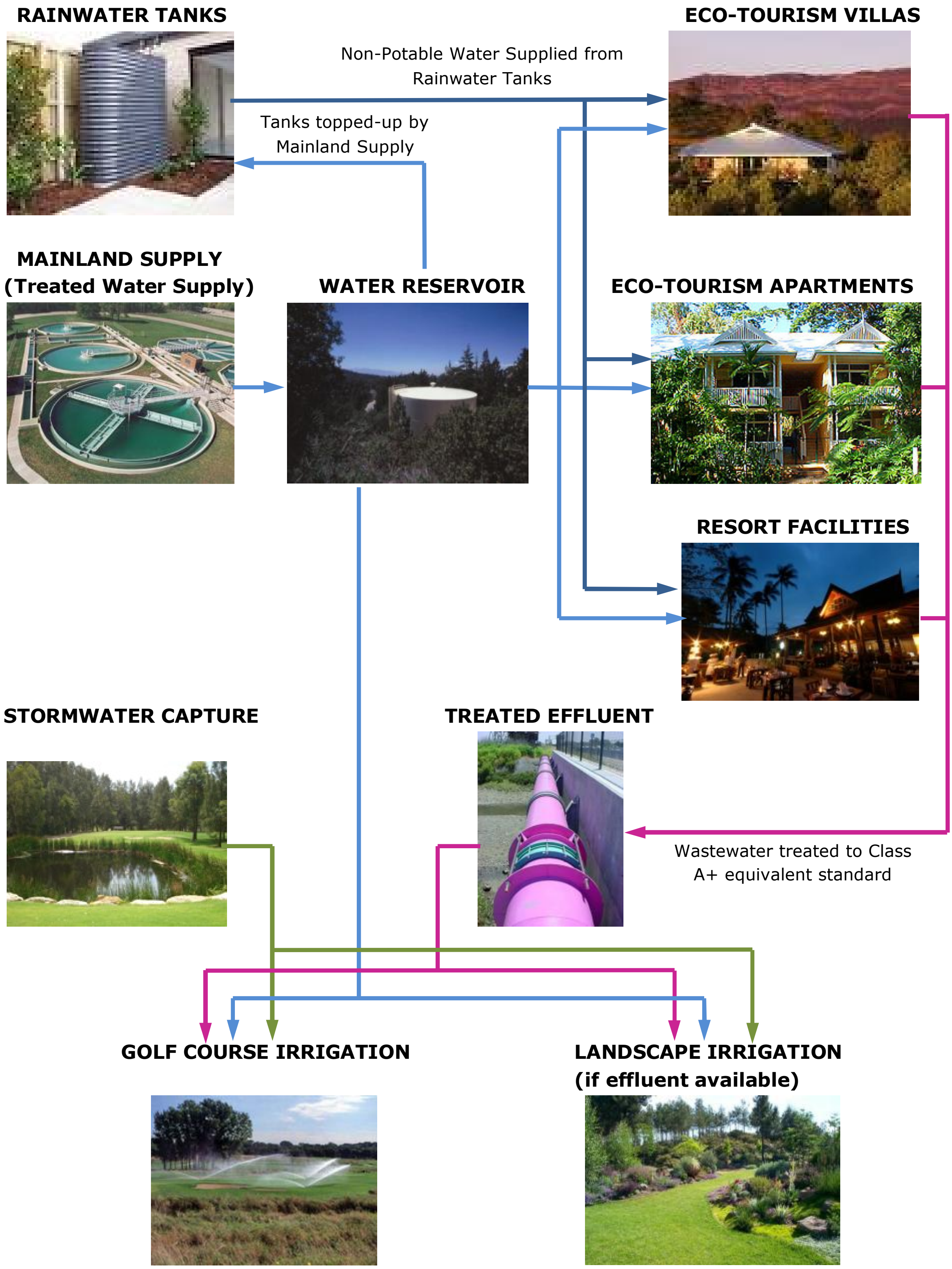


FIGURE 9.1: GKI Resort Revitalisation Plan - Water Supply Schematic

9.2.1 Water Supply Source

Sources of water supplies required for operation and remaining stages of construction after Stage 1 will comprise the following:

Potable Water Supply

- All required potable water (i.e. drinking water) supply will be derived from Rockhampton Regional Council's municipal water supply scheme on the mainland via a new water main to be incorporated within the Utility Services Corridor;

Non-Potable Internal Water Supply

- Primary water supply for non potable uses to toilets and laundries within all facilities will be derived from captured rainwater via roof runoff collected and stored in tanks and pumped back to the relevant fixtures. The capture and reuse of rainwater is in accordance with the *Queensland Development Code*. Where necessary, rainwater supply to these fixtures will be supplemented by top up from the main potable supply in accordance with the *Queensland Development Code*.

Non-Potable External Water Supply

- Water supply for irrigation purposes will be provided from the following sources, in order of priority, and subject to availability:
  - Rainwater captured and stored from roof runoff to all facilities to be used for irrigation purposes adjacent to the respective facilities;
  - Treated effluent derived from the Island-based WWTP(s) will provide the primary water supply for irrigation of the golf course along with irrigation of other landscaped areas where excess supply is available;
  - Harvested stormwater runoff captured within the purpose-designed and built pond system incorporated into the golf course will be used to supplement recycled water supplies for irrigation of the golf course;
  - Additional purpose-designed and built stormwater harvesting systems may also be installed in other areas around the resort (subject to feasibility, final design and availability of sufficient water); and
  - Any additional requirements for irrigation water supply, particularly for the golf course, would be sourced from the potable water supply via the mainland connection.

Emergency Water Supply

In the event of a disruption to the potable water supply connection to the mainland the following contingency strategy is proposed:

- Stored potable water in reservoirs on the Island will be preserved by restricting water usage from this supply to essential purposes only (i.e. domestic use only). Assuming reservoirs are full and allowing for dedicated fire storage, at least 3 days storage at peak day demand of 968kL/day and at least 7 days storage at average day demand of 397kL/day would be available for domestic uses. With water restrictions in place, the number of days of supply should be able to be significantly extended;

- Suspend use of mainland water supply for irrigation and limit irrigation to use of recycled water and harvested stormwater;
- If required, arrange for additional potable water supplies to be transported by barge across from the mainland; and,
- Undertake remedial repairs to the mainland water supply connection.

In the event of an extended disruption to the mainland water supply connection, consideration may need to be given to reducing guest occupancy and staffing to ensure that adequate water is available.

9.2.2 Treatment Standard

DERM's *Planning Guidelines for Water and Sewerage* states that where there is a reticulated drinking water supply, water of drinking water quality should be used for human consumption, food preparation, utensil washing, oral hygiene and bathing (AS/NZS 3500, AS/NZS 4020, WSAA, 2002, *Water Supply Code of Australia*).

As such, all potable water supplies to the GKI Resort Revitalisation Plan will be required to comply with the *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2004).

In addition to the above, all water used for non-potable purposes will be monitored to ensure it is 'fit for purpose' so as to minimise potential environmental and public health risks.

9.2.3 Treatment Process

Potable water supply for the GKI Resort Revitalisation Plan will be sourced from Rockhampton Regional Council's municipal water supply system and will therefore comply with the *Australian Drinking Water Guidelines* at the source. However, due to the extended time that water will be stored within the 16km water main connection between the mainland and GKI, and within storage tanks on the Island disinfection by either chlorination or UV irradiation is likely to be required prior to the water entering the Island storage tanks to ensure bacterial levels comply with the *Australian Drinking Water Guidelines* at the point of supply.

In order to minimise electricity consumption on the Island disinfection of the water supply by chlorination is preferred over the use UV irradiation, which requires high levels of ongoing energy inputs. The chlorination process would involve the supply of hypochlorite to the Island in the form of powder or solution and injection of a hypochlorite solution, by dosing pump, into the water supply adjacent to the high level water storage tanks. However, both systems would be reviewed in the final design stage.

9.2.4 Storage

Potable water storage on the Island will consist of the following:

- Storage tank (to receive the mainland supply) and pumps adjacent to the Marina Precinct to pump to high level water storage tanks;

- High level water storage tanks to serve the two (2) potable water reticulation systems: one for the Fisherman's Beach and Marina Precincts and the other for the Clam Bay Precinct. Both systems are proposed to be serviced by high-level water storage tanks fed by trunk delivery mains from the mainland supply via the tank and pumps adjacent to the Marina;

- The storage tank(s) for the Fisherman's Beach and Marina Precincts is likely to be in the order of 3 ML in size. This would allow for 0.36 ML of fire storage, as per **section 7.3.2** above, and around 3.5 days storage capacity at the January day peak domestic demand of 726 kL/day (75% of 968 kL/day) and around 8 days storage capacity at the annual average daily domestic demand of 298 kL/day (75% of 397 kL/day); and,

- The storage tank(s) for the Clam Bay Precincts is likely to be in the order of 1 ML in size. This would allow for 0.36 ML of fire storage, as per **section 7.3.2** above, and around 3.0 days storage capacity at the January day peak domestic demand of 242 kL/day (25% of 968 kL/day) and around 7 days storage capacity at the annual average daily domestic demand of 99 kL. Day (25% of 397 kL/day).

Other water storage on the Island will include the following:

- Rainwater tanks associated with the collection and storage of roof water for reuse for non-potable purposes (toilets, laundries, garden watering and washdown).

  Individual rainwater tanks will be provided for each apartment and villa (either proprietary above ground tanks or underground tanks built within the foundations under the buildings where space or amenity issues exist).

  Combined rainwater storage tanks will be provided for central core facilities including the hotel, as well as other commercial/ retail facilities such as the Marina Village, golf clubhouse and airport terminal;

- Underground or open surface storages for harvested stormwater. These could be open lined ponds, proprietary underground storage systems or purpose built underground tanks depending on space availability and amenity issues. Alternatively, if determined in final design to be more efficient and economic, larger tanks may be incorporated into the rainwater tanks to capture additional roof rainwater. This would generally be advantageous with roof rainwater being of higher quality than stormwater runoff from ground areas;

- Open lined storage ponds on the golf course for collection and reuse of stormwater runoff for irrigation purposes. These ponds will incorporate stormwater quality improvement to treat stormwater runoff from the golf course prior to discharge of captured stormwater not required for irrigation; and,

- An open lined storage pond for recycled water to provide balancing storage associated with the reuse of recycled water for irrigation of the golf course (and other areas if required). This pond system has been sized to balance the storage of inflow recycled water produced by the WWTP with the volume of water required for irrigation, such that recycled water will be stored during wet weather when soil conditions preclude irrigation.

9.2.5 Distribution

Potable water distribution will consist of the following:

- Two (2) potable water reticulation systems are proposed, including one servicing the Fisherman's Beach and Marina Precincts and the other servicing the Clam Bay Precinct;

  Both systems are proposed to be serviced by high-level water storage tanks fed by trunk delivery mains from the mainland supply via tank and pumps near the Marina Precinct. Some higher elevation accommodation facilities may require small booster pumps to deliver reticulated water supply; and

- Potable water reticulation will be installed to service all resort accommodation, commercial and retail facilities, along with some landscaped areas such as the golf course to supplement irrigation supplies.

10. WASTEWATER TREATMENT & REUSE SCHEME

10.1 CONSTRUCTION

Although it is intended that the existing wastewater treatment plant that serviced the former GKI resort will be demolished and replaced with a new facility, the existing treatment plant shall temporarily be re-commissioned to treat wastewater during the initial phases of construction prior to construction of the new treatment plant, which is scheduled to occur during Stage 1.

Prior to being re-commissioned, the existing wastewater treatment plant will be refurbished to ensure it is capable of effectively treating sewage effluent generated during construction to the required standard to comply with the conditions of Licence No. CR0061, which it is understood remains current.

The volume of sewage effluent expected to be generated during Stage 1 of construction prior to commissioning of the first stage of the new WWTP(s) is estimated to be up to approximately 50 kL/day for 350 EP at a maximum of 150 L/EP/day (say, 250 EP for up to 250 construction workers in facilities on the Island, 40 EP for messing facilities and 60 EP for up to 200 workers ferried to the Island each day). This is based on a maximum of 450 workers in Stage 1 as outlined in the Construction Report. As outlined in **section 5.2** above, this is within the capacity and licence limits specified for the existing wastewater treatment plant.

Treated effluent generated during Stage 1 of construction will be discharged via irrigation of a pre-designated area, likely to include the area of the former golf course previously used for irrigation of recycled water, in accordance with the conditions of the existing environmental licence. Alternatively, it may also be partly used to assist with irrigation of disturbed areas of the new airstrip to assist with turf/ landscaping establishment.

10.2 OPERATION & CONSTRUCTION (POST-STAGE 1)

Based on consideration of relevant options, the proposed wastewater treatment and reuse scheme for GKI Resort Revitalisation will likely consist of:

- A wastewater collection system comprised of:
  - A combination of traditional gravity sewers, but using the NuSewer or similar system to minimise groundwater infiltration (due to the high water table on the Island) and pumped systems where appropriate;
  - A specialist proprietary pump out system for the marina berths; and
  - Pumping stations for transfer of the wastewater, after collection, to the WWTP(s).
- Either two (2) WWTPs, including one (1) WWTP servicing the Fisherman's Beach and Marina Precincts and one (1) WWTP servicing the Clam Bay Precinct OR a single WWTP servicing all precincts within the GKI Resort Revitalisation Plan;
- All wastewater will be treated to a standard consistent with the minimum water quality requirements specified for "Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application" under the *Australian Water Quality*

Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) (ANZECC, 2006), with nutrient levels reduced to 20mg/L of Total Nitrogen and 7mg/L of Total Phosphorous;

- In most years, 100% of all wastewater generated by the GKI Resort Revitalisation Plan and treated at the Island-based WWTP(s) will be used for irrigation of the golf course and possibly other landscaped areas around the resort;

- Wet weather storage ponds with a capacity of at least 44ML (including a 7ML storage buffer to account for potential increase in rainfall intensity due to climate change) will be provided, most likely in the form of open ponds incorporated into the golf course; and

- During extreme wet weather events, when soil conditions are unsuitable for irrigation and wet weather storage ponds reach capacity, a small proportion of recycled water may be discharged via an ocean outfall extending from Long Beach. Current modelling based on a 37 ML storage indicates that overtopping of the wet weather storage and subsequent ocean discharge may occur on average, once every 10 years. However, provision of an additional 20% storage capacity to account for climate change is likely to reduce this frequency further, particularly during the early years of the scheme.

A schematic outline of the wastewater collection, treatment and reuse scheme is shown in **Figure 10.1** below and a preliminary layout plan is shown in **Appendix G – Wastewater Scheme Layout.**

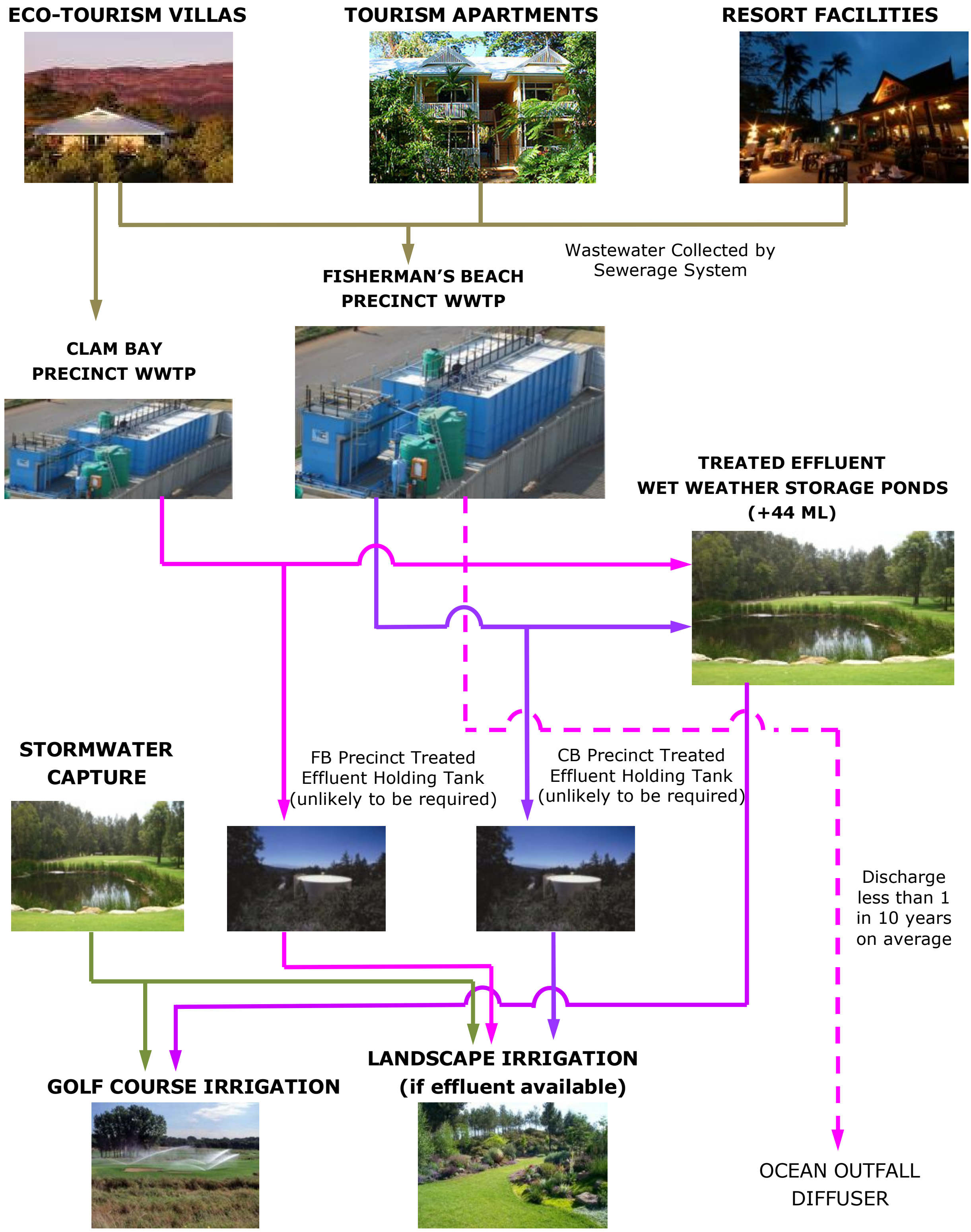


FIGURE 10.1: Great Keppel Island Resort Revitalisation Plan - Wastewater Collection and Treated effluent Reuse Schematic

10.2.1 Wastewater Collection

Wastewater collection to deliver sewage from the generation source to the WWTP(s) is proposed as follows:

- Throughout the resort generally (unless listed below), a gravity system using "NuSewers" will be used due primarily to their lower infiltration rates compared to traditional sewers and the lower cost compared to a vacuum or pumped system. The NuSewers Design and Construction Specification, Queensland Urban Utilities, Sewerage Standards describes "NuSewers' as:

  NuSewers comprise fully welded PE pipes, fittings and maintenance shafts. The elimination of rubber ring joints will minimize groundwater infiltration and tree root intrusion reducing maintenance and sewage treatment costs.

  NuSewers are designed on the basis that inspection will be undertaken with CCTV equipment and blockages cleared using jet rodders. This approach allows the sewer alignment to include both horizontal and vertical curves minimising the number of maintenance access structures compared to a traditional sewer system. With NuSewers the majority of access structures will be PE maintenance shafts. However, manholes will be required for complex sewer junctions and at strategic locations for the removal of miscellaneous items that occasionally enter the sewer system.

- For Marina Apartments and any Apartments / Villas located on steep ground, either a "NuSewer" gravity system or individual unit grinder pump stations with small diameter common rising main following ground contours will be used. These individual units require less ground disturbance compared to traditional gravity sewers. These individual units will only be used as demand requires.

- For the Marina Berths, a specialised wastewater pump-out facility will be necessary within the Marina Precinct for the acceptance of wastewater pumped from berthed watercraft. New marina waste management facilities shall be provided in accordance with the Best Practice Guidelines for the Provision of Waste Reception Facilities at Ports, Marinas and Boat harbours in Australia and New Zealand (reference) and relevant legislation.

In the event of power failure or equipment breakdown, the following contingency measures would apply within the collection system:

- The gravity sewer system would be unaffected up until the collection well of pumping stations;

- Any individual unit grinder pump stations (where installed to villas) would have a storage capacity within the pump collection well for at least 4 hours at ADWF. This would typically involve around 100 litres of storage within the collection well for each villa;

- Main pumping stations would be provided with:

  - 100% standby pumping capacity within the station to cover pump mechanical breakdown;

- An alarm system to advise maintenance staff of power or mechanical failure;
- Capacity within the emergency back-up generator for the resort and / or provision (i.e. power bypass switch) within the pumping station to connect up an individual emergency generator brought to the pumping station to cover power failures; and
- Minimum of 2 hours storage capacity at ADWF within the pump station wet wells and contributing reticulation mains (and overflow storage if required with any overflow being returned to the wet well).

Odour control within the collection system would be achieved by sealing of all manholes and pumping stations, thus containing any odours within the system.

10.2.2 Treatment Standard

The proposed treatment standard has been determined in relation to the proposed uses of recycled water, which include:

- Irrigation of the golf course;
- Irrigation of other sporting fields and landscaped areas (where the availability of recycled water exceeds the sustainable irrigation requirements of the golf course); and
- Emergency discharge of recycled water during extreme wet weather events via ocean outfall.

The Queensland *Water Quality Guidelines for Treated effluent Schemes* (DERM, 2008) does not specify any minimum water quality criteria for proposed recycled water uses such as irrigation of golf course, sporting fields and other landscaped areas. Rather, these Guidelines refer to various national and industry guidelines that could be used as a benchmark, including the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (ANZECC, 2006) as well as various guidelines for use of recycled water for growing crops, dairy farming, beef cattle feedlots and piggeries, which are not relevant to the proposed scheme.

Accordingly, consideration has been given to the recommended treatment processes, on-site controls and water quality objectives for recycled water used for purposes similar to the range of uses described above, as outlined in the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (ANZECC, 2006). An extract from Table 3.8 of these Guidelines is provided in **Table 10.1**.

TABLE 10.1: Recommended Treatment & Water Quality Criteria for Municipal Uses[2]

Log Reduction Targets	Indicative Treatment Process	Log Reductions Achievable by Treatment	On-Site Preventative Measures	Water Quality Objectives
Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application				
Viruses = 5.0 Protozoa = 3.5 Bacteria = 4.0	Advanced treatment required such as: ▪ Secondary,	Viruses = 5.0 Protozoa = 3.5 Bacteria = 4.0	No specific measures.	To be determined on case-by-case basis.

[2] ANZECC (2006) *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) – Table 3.8*

Log Reduction Targets	Indicative Treatment Process	Log Reductions Achievable by Treatment	On-Site Preventative Measures	Water Quality Objectives
	coagulation, filtration and disinfection ▪ Secondary, membrane filtration, UV light			Could include turbidity criteria for filtration, disinfectant Ct or dose (UV) E. coli <1 per 100mL
Municipal Use – with restricted access and application				
Viruses = 5.0 Protozoa = 3.5 Bacteria = 4.0	Secondary treatment with disinfection	Viruses = 2.0-3.0 Protozoa = 1.0 Bacteria = >6.0	Restrict public access during irrigation ***and one of*** the following: ▪ No access after irrigation, until dry (1-4 hours) ▪ Minimum 25-30m buffer to nearest point of public access ▪ Spray drift control (e.g. low-throw sprinklers, vegetation screening, anemometer switching Log reductions achieved by on-site preventative measures: ▪ Restrict public access during irrigation = 2.0 ▪ No access after irrigation, until dry (1-4 hours) = 1.0 ▪ Minimum 25-30m buffer to nearest point of public access = 1.0 ▪ Spray drift control = 1.0	BOD <20mg/L SS <30mg/L Disinfectant residual (e.g. minimum chlorine residual) or UV dose *E. coli* <100 per 100mL
Municipal Use – with enhanced restrictions on access and application				
Viruses = 5.0 Protozoa = 3.5 Bacteria = 4.0	▪ Secondary treatment with >25 days lagoon detention or primary treatment with >50 days lagoon detention ▪ Secondary treatment	Viruses = 1.0-3.0 Protozoa = 1.0-3.0 Bacteria = 3.0-4.0 Viruses = 0.5-2.0 Protozoa = 0.5-1.0 Bacteria = 1.0-3.0	Restrict public access during irrigation ***and combinations*** of the following: ▪ No access after irrigation, until dry (1-4 hours) ▪ Minimum 25-30m buffer to nearest point of public access ▪ Spray drift control (e.g. low-throw sprinklers, vegetation screening, anemometer	BOD <20mg/L SS <30mg/L *E. coli* <1000 per 100mL

Log Reduction Targets	Indicative Treatment Process	Log Reductions Achievable by Treatment	On-Site Preventative Measures	Water Quality Objectives
			switching Log reductions achieved by on-site preventative measures: ▪ Restrict public access during irrigation = 2.0 ▪ No access after irrigation, until dry (1-4 hours) = 1.0 ▪ Minimum 25-30m buffer to nearest point of public access = 1.0 ▪ Spray drift control = 1.0	

In order to provide flexibility in irrigation scheduling and reduce potential risks to site users, it is proposed to adopt a standard of treatment generally consistent with that required for "Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application".

The above guidelines refer primarily to minimum recycled water quality criteria to protect public health. However, given the environmentally sensitive nature of GKI, it is also essential to ensure that recycled water used on the Island or discharged to the environment is treated to a suitable standard to adequately reduce potential environmental impacts. In particular, it is important to ensure that the level of nutrients such as nitrogen and phosphorous contained in recycled water, are compatible with the nutrient assimilation capacity of soils and plants within the irrigation areas. This will ensure maximum beneficial use of these essential nutrients whilst not resulting in excessive runoff or leaching of nutrients into surface or groundwater where such nutrients may result in eutrophication, possible algal blooms and subsequent de-oxygenation of waters that may impact on aquatic fauna.

To determine appropriate nutrient limits for recycled water reused for irrigation on the Island modelling has been undertaken using the computer-based MEDLI (Model for Effluent Disposal using Land Irrigation) Version 1.30 program developed by the Department of Natural Resources & Mines. MEDLI is a DERM approved complex, daily time-step, hydrological and nutrient balance simulation model for effluent irrigation systems. The program incorporates historical climatic data for the locality, along with input parameters specific to each effluent irrigation system (i.e. effluent quality and quantity, land area, storage size, soil nutrient adsorption and vegetation nutrient uptake capacities) to assess the hydrological and nutrient balance of the system. The results of MEDLI modelling are discussed in more detail in **section 10.6**. However, it is noted that the outcomes of the modelling indicate that irrigation of recycled water containing on average, 20 mg/L of nitrogen and 7 mg/L of phosphorous, will not result in any increase in nutrients in runoff or leaching from the irrigation area compared to modelling of existing conditions (i.e. no irrigation) within the proposed irrigation area.

As recycled water may be discharged via an ocean outfall during extreme wet weather events when irrigation of the golf course and other landscaped areas is not required, consideration has also been given to the minimum water quality criteria for such discharges prescribed under section 135(4) of the

Great Barrier Reef Marine Park Regulations 1983. These Regulations specify the following minimum effluent quality criteria for discharge of recycled water to the Great Barrier Reef Marine Park where no more than 5% of the total annual volume of effluent generated is discharged into the Marine Park:

- BOD5 = 20 mg/L (maximum);
- Suspended Solids = 30 mg/L (maximum);
- pH Range = 6.0-8.5;
- Dissolved Oxygen = 2 mg/L (minimum);
- E.coli = <200 CFU/100mL (mean);
- E.coli = <1000 CFU/100mL (80th percentile);
- Total Oil and Grease = <10 mg/L (maximum);
- No visible slick or sign of oil or grease; and
- Effluent does not contain by-products of chlorine disinfection that may pollute water in a manner harmful to animals or plants in the Marine Park.

In addition, GBRMPA's Policy for *Sewage Discharges from Marine Outfalls to the Great Barrier Reef Marine Park* (GBRMPA, 2005) indicates that the maximum load of Total Nitrogen and Total Phosphorous that can be discharged via a marine outfall into the Marine Park will be calculated based on tertiary equivalent nutrient concentrations of 5 mg/L for total nitrogen and 1 mg/L for total phosphorous. Based on the outcomes of MEDLI modelling, it is anticipated that emergency discharge via the ocean outfall will be required only about once every ten years on average. Averaged over the 53 year modelling period, the amount of recycled water discharged via the ocean outfall would equate to approximately 0.76 ML/year. Adopting a total nitrogen concentration of 20 mg/L and a total phosphorous concentration of 7 mg/L, this would result in the discharge of approximately 15.2 kg/year of nitrogen and 5.32 kg/year of phosphorous.

In order to determine the maximum load of total nitrogen and total phosphorous that could be discharged via the ocean outfall in accordance with GBRMPA's Policy for *Sewage Discharges from Marine Outfalls to the Great Barrier Reef Marine Park* (GBRMPA, 2005), tertiary equivalent nutrient concentrations of 5mg/L for total nitrogen and 1mg/L for total phosphorous have been multiplied by the total amount of recycled water produced by the GKI Resort Revitalisation Plan which equates to approximately 157.7 ML/year. On this basis, discharge of all recycled water generated by the project treated to a tertiary standard would result in the release of approximately 788.5 kg/year of nitrogen and 157.7 kg/year of phosphorous.

As such, the total amount of nitrogen and phosphorous discharged assuming discharge only during extreme wet weather events (i.e. 1 in 10 years on average) at a concentration of 20 mg/L of total nitrogen and 7 mg/L of total phosphorous is less than 4% of the amount that would be released if all effluent generated by the GKI Resort Revitalisation Plan was treated to a tertiary standard of 5 mg/L of total nitrogen and 1 mg/L of total phosphorous and discharged via ocean outfall.

On the basis of the above, it is proposed that all effluent generated by the GKI Resort Revitalisation Plan will be treated to comply with the minimum water quality criteria specified in **Table 10.2**.

TABLE 10.2: Proposed Minimum Treated effluent Quality Criteria

Quality Characteristic	Unit	Release Limit	Limit Type	Monitoring Frequency
E. coli	cfu/100mL	<1 (<10)	Median (95^{th} percentile)	Weekly
5-day Biological Oxygen Demand	mg/L	<20	Median	Weekly
Turbidity	NTU	<2 (<5)	Median (Maximum)	Continuous
Suspended Solids	mg/L	<5	Median	Weekly
Total Dissolved Solids	mg/L	<1,000	Median	Weekly
pH		6.0 – 8.5	Range	Weekly
Total Nitrogen	mg/L	<20	Median	Monthly
Total Phosphorous	mg/L	<7	Median	Monthly
Free Chlorine Residual[1]	mg/L	0.5-1.0	Range	Continuous

Note:

1. Only applies where chlorination is used for disinfection. Disinfection is not preferred where discharge to the ocean is likely to occur.

The above standard of treatment is consistent with the specified water quality objectives for "Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application" as defined under the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) (ANZECC, 2006) and is considered to be suitable for the following recycled water reuse options:

- Irrigation of the golf course;
- Irrigation of other sporting fields and landscaped areas (where the availability of recycled water exceeds the sustainable irrigation requirements of the golf course); and,
- Emergency discharge of recycled water during extreme wet weather events via ocean outfall.

It is anticipated that monitoring of recycled water quality will occur at the outlet of the WWTP(s) at the approximate frequencies listed in the **Table 10.2** above to ensure recycled water quality achieves the above levels at discharge from the WWTP(s).

10.2.3 Treatment Process

Based on consideration of the available options as discussed in **section 6.2,** the preferred option for treatment of wastewater generated by the GKI Resort Revitalisation Plan is an Island-based WWTP(s). Treatment of wastewater on GKI may be undertaken using a single WWTP or multiple WWTPs.

If two (2) wastewater treatment plants (WWTPs) are to be provided on the Island these would most likely be located as follows, subject to final design, plant selection and buffer zone requirements:

- A WWTP servicing the Marina Precinct and Fisherman's Beach Precinct (including marina facilities, hotel, apartments, villas, commercial / retail, airport terminal and staff accommodation) – most likely located on the north eastern side of the airstrip within the vicinity of the facilities maintenance compound; and

- A WWTP servicing the Clam Bay Precinct – most likely located to the north west of the golf course.

If a single WWTP is to be provided on the Island this would most likely be located to the north west of the golf course, noting that this would be located in close proximity to the primary area of proposed recycled water irrigation. However, a site to the north west of the airport and near the maintenance facility would also be considered. This latter site would involve pumping of wastewater from the Clam Bay Precinct and then pumping of all effluent from the WWTP to the Golf Course storage pond.

Another aspect to reviewed in the final design of the wastewater treatment facilities is the early completion of the Golf Course and associated facilities with villas in the Clam Bay Precinct not commencing until around 2017 – according to the staging plans within the Construction Report. An option is to provide a temporary self contained package WWTP for the Golf Course facilities with effluent pumped to the storage pond. This temporary plant would then be removed from the Island once the villas came on line with the permanent connection to the main WWTP constructed.

Selection of the preferred type of treatment system will need to take into account a range of factors including, but not limited to:

- The staging of the Project over 12 years (as summarised in **section 8.4**) and with the EP growth as indicated in **Table 8.8** in that section;

- The variability of the hydraulic loading on the treatment system with the fluctuating occupancy over the year ranging (for the completed Project) from approximately 1,069EP to 3,750EP. The monthly variability of the hydraulic loading for the completed Project can be seen in **Table 8.8** above;

- Potential for odour nuisance and requirements for buffer zones to prevent adverse impacts on the amenity of residential and tourist accommodation on the Island; and

- Ability to consistently achieve the high standard of treatment, including disinfection and nutrient removal, required to be 'fit for purpose' for proposed recycled water reuse, to prevent potential public health impacts and to prevent contamination of groundwater aquifers, soils and water quality within the Great Barrier Reef Marine Park.

A number of wastewater treatment processes and systems would be capable of achieving the required standard of treatment. Although the exact treatment process and system used will be determined at detailed design stage, one of the preferred options at this stage comprises a proprietary package treatment plant utilising membrane bio-reactor (MBR) or similar technology system. This type of system would incorporate:

  - Grit chambers/ screens to remove floating solid items and grit. Screened solids and grit would be collected and disposed of at a licensed landfill facility on the mainland;

  - Sedimentation/ sludge tanks contained within the package plant – settled sludge directed to sludge digestion tanks (within the package plant), sludge removed, dewatered, dried and used for landscaping;

- Liquid from sedimentation/ sludge processes is then passed through the bio-reactor membrane to remove suspended solids and solids returned to the sedimentation/ sludge tanks for re-processing;

- Effluent passed through the bio-reactor membrane is then disinfected with UV to achieve an *E. coli* level of <1 cfu/100mL before being pumped to the wet weather storage pond(s) on the golf course; and

- Treated effluent from the wet weather storage ponds is then irrigated across the golf course.

Advantages and disadvantages of the above package plant system, compared to the other options assessed, are discussed in **section 6.2.**

In the event of power failure or equipment breakdown, the following contingency measures would apply within the treatment system:

- As outlined in the Power and Commnications Report (AECOM 2011), there will be dedicated standby generator provision made for the WWTP(s). Primary power for the resort is also based on solar supply with the mainland power connection main as the next primary supply. Given the relatively high security of power supply for the WWTP(s), the risk of wastewater overflows is accordingly considered to be relatively low.

- Due to staging requirements and operational flexibility, treatment systems would involve duplication (or triplication) of treatment plant processes, thus allowing for one system to be out of service for short periods in the event of maintenance requirements (programmed maintenance being undertaken at low flow / low occupancy times) or emergency breakdown situations; and

- In the event of power failures, the package plants would be able to be designed to contain up to approximately 10 hours x ADWF within various components of the treatment plant and/ or within a separate bypass storage pond. After power is restored, the bypassed flow is then returned from the storage pond back through the package plant for treatment. The storage requirement (within the plant and/ or separate storage pond) would be 312 kL (10/ 24 hrs x 200 L/EP/day x 3750 @98% occupancy). 10 hours storage should be more than sufficient time for maintenance staff to respond to system monitoring with warnings of overflows an any issues with the strating up of standby generators.

- In accordance with the DERM Guideline *Framework for Managing Sewerage Infrastructure to Reduce Overflows & Environmental Impacts* and noting the sensitive area of the Island within the GBMNP, there would be, as part of the contingency planning for the operation of the wastewater treatment:

    - A 24/ 7 Emergency Response Plan incorporating remediation and clean up procedures investigation and improvement plans. Remediation and clean up in this case would be expected to mainly involve ensuring the return of any overflow from the storage pond and clean up of the storage pond area on completion;
    - “Due Diligence” Practices in the design and operation including risk management principles to minimise the potential for overflows and environmental harm (including the features as outlined above, risk of overflows minimised with back up power generation),

community exposure to overflows minimised with any overflow contained within the WWTP and associated overflow storage pond within the fenced WWTP compound;
  - Organisational management with clearly defined accountabilities within the maintenance hierarchy for the appropriate operational and maintenance aspects of the wastewater system, pumping stations, WWTP, back-up generators etc; and,
  - Reporting procedures as outlined.

Odour issues are unlikely with a packaged plant such as MBR as the process components are effectively sealed within the plant. Odour issues may arise in the event of power failure when influent is diverted to temporary storage in open ponds adjacent to the plant. However, such events are expected to be rare with a number of treatment trains and back-up power being provided. Nevertheless, appropriate buffer distances should be provided between the WWTP and sensitive receivers to reduce the potential for odour nuisance.

10.2.4 Treated effluent Reuse

Following consideration of the range of options available for reuse of recycled wastewater produced by the Island-based WWTP, the preferred reuse scheme consists of:

- Reuse of recycled water for irrigation primarily of the golf course, with any excess recycled water produced used for irrigation of other landscaped areas, preferably around the golf course villas to minimise the need for pumping recycled water across to the Fisherman's Beach Precinct; and

- During extreme wet weather events (i.e. 1 in 10 years on average), excess recycled wastewater may be discharged via an ocean outfall extending from Long Beach.

As construction of the golf course will occur in Stage 2-3, commencing in 2014 or about 2 years after other components of the GKI Resort Revitalisation Plan, an alternative recycled water irrigation area will need to be provided in the early stages. It is anticipated that irrigation of recycled water to assist in establishing turf adjacent to the airstrip will occur during the early stages of the Project prior to construction of the golf course. Treated effluent may also be used in the early stages for irrigation within the 'turf nursery' that is likely to be established to grow the turf required to construct the golf course.

Although consideration was given to reuse of recycled water for other non-potable purposes within the resort (e.g. toilet flushing, washing machines, garden watering, washdown) through a dual reticulation system, this option was not considered preferable on the basis that:

- The volume of recycled water produced would achieve only limited reduction in demand for potable water supplies, given that non-potable water supply for toilet flushing, washing machines, garden watering, hardscape and boat washdown, will be derived from rainwater harvesting;

- The availability of recycled water will be highly variable due to the fluctuating occupancies and therefore generation of wastewater effluent associated with tourist facilities, and is therefore not considered to be a sufficiently reliable source of water for these types of non-potable purposes;

- In excess of 99% of recycled wastewater produced can be sustainably and beneficially reused for irrigation of the golf course thereby minimising the need to secure other water supply sources for this purpose; and

- Significant ground disturbance and ongoing pumping costs / energy consumption would be associated with the extensive recycled water distribution and storage system required for a dual reticulation scheme.

Reuse of recycled water for irrigating landscaping, open spaces and sports fields has gained widespread use across Australia and other countries as a way to conserve valuable water resources. Given the limited availability of water resources on GKI and the relatively high irrigation water demands of the proposed golf course, the use of recycled wastewater to meet the irrigation demands for landscaping, and particularly the proposed golf course, is considered to comprise the most beneficial reuse for recycled wastewater produced from wastewater generated by the GKI Resort Revitalisation Plan. This view is supported by *Technical Report 34* prepared for the CRC Reef Research Centre (Gallagher & Volker, 2004) with the statement referring to GBRMPA's sewage system requirements introduced in 1991, *"One of the principal strategies of the sewer management policy was encouragement to reuse effluent on the islands for irrigation of gardens, golf courses and other grasslands".*

Reuse of recycled wastewater for irrigation of the golf course and possibly other landscaped areas (where excess recycled water is available), not only reduces pressure on other water supply sources, but also enables the beneficial reuse of nutrients contained in the recycled wastewater to support plant growth within the irrigation area. Application of nutrients contained in recycled water to vegetation enables natural biological processes to be used to further reduce nitrogen and phosphorus components before potentially entering groundwater or surface water systems, rather than using chemical reaction processes within a treatment plant. Such chemical treatment processes typically require large inputs in terms of energy to achieve the levels of nutrient reduction that can be achieved by healthy vegetation. Application of nutrients contained in recycled water to vegetation also reduces the need to apply additional fertilisers, which are usually derived from synthetic or inorganic sources.

While nutrients applied to the golf course and other landscaped areas are beneficial to plant growth within these areas, it is necessary to ensure that the amount of nutrients applied does not exceed the hydraulic and nutrient assimilation capacity of soils and plants within the irrigation area, otherwise nutrients may be leached into groundwater and ultimately surface water bodies. To determine the amount of nutrients contained in recycled water and the rate of application that can be sustainably applied to the irrigation area, a detailed water and nutrient balance has been undertaken as described in the following section.

All recycled water irrigation will be undertaken in accordance with an approved irrigation management plan (refer to **Appendix H - Preliminary Irrigation Management Plan**).

10.3 MEDLI MODELLING

10.3.1 MEDLI Input Values

To determine a sustainable strategy for application of recycled water for irrigation on the Island the computer-based MEDLI (Model for Effluent Disposal using Land Irrigation) Version 1.30 program developed by the former Department of Natural Resources & Mines was used. MEDLI is a DERM approved complex, daily time step, hydrological and nutrient balance simulation model for effluent irrigation systems. The program incorporates historical climatic data for the locality, along with input parameters specific to each effluent irrigation system (i.e. effluent quality and quantity, land area, storage size, soil nutrient adsorption and vegetation nutrient uptake capacities) to assess the hydrological and nutrient balance of the system.

The objective of MEDLI modelling undertaken for this Project was to determine an appropriate standard of treatment, irrigation schedule, irrigation area and wet weather storage volume requirements to maximise the beneficial reuse of sewage effluent generated by the GKI Resort Revitalisation Plan without resulting in any adverse environmental or human health impacts.

The MEDLI model simulates operation of the proposed irrigation system over a fifty-three (53) year period based on climatic data for the period between 1 January 1957 and 31 December 2009. Relevant inputs and outputs to the model are described in the following sections:

Climate

Fifty-three (53) years of historical climatic data has been compiled for GKI by DERM, including rainfall, pan evaporation, temperature and radiation data. A summary of average annual rainfall and pan evaporation data compiled for GKI over a fifty-three (53) year period is provided in **Table 10.3** below.

TABLE 10.3: Average Annual Rainfall & Pan Evaporation Percentile Totals

Characteristics	Average	10th Percentile	50th Percentile	90th Percentile
Rainfall (mm/year)	1,045	688	1,062	1,478
Pan Evaporation (mm/year)	1,848	1,715	1,837	1,997

Based on the above, it is estimated that an average rainfall deficit of 803mm/year may be expected to occur on GKI in a year characterised by average rainfall and evaporation. The minimum rainfall deficit that would be expected in a year of above average rainfall and below average evaporation would be 237 mm/year. The maximum rainfall deficit that would be expected in a year of below average rainfall and above average evaporation would be 1,309 mm/year.

Irrigation scheduling adopted for MEDLI modelling has been developed with consideration of this rainfall deficit. The proposed irrigation scheme results in a total average annual rainfall of less than the average rainfall deficit of 803 mm/year, which suggests that recycled water irrigation, will only partially compensate for the natural rainfall deficit and supplementary irrigation sources other than recycled water may be required to maintain the golf course to the standard required for championship competition.

Hydraulic Loading

The following ADWF rates have been adopted for MEDLI modelling:

TABLE 10.4: Estimated Monthly Wastewater Flows (@200L/EP/day) Adopted for MEDLI Modelling

Month	EP x Occupancy	ADWF for Month @ 200 L/EP/day	
		ML/day	ML/month
January	3,750.1	0.75	23.25
February	1,724.5	0.34	9.66
March	1,847.5	0.37	11.45
April	2,143.8	0.43	12.86
May	1,069.3	0.21	6.63
June	1,193.2	0.24	7.16

Month	EP x Occupancy	ADWF for Month @ 200 L/EP/day	
July	1,666.6	0.33	10.33
August	1,570.6	0.31	9.74
September	3,075.1	0.62	18.45
October	2,262.7	0.45	14.03
November	2,313.4	0.46	13.88
December	3,303.3	0.66	20.48

Effluent Concentrations

The following effluent concentrations were input into the MEDLI model and are based on the proposed standard of treatment described in **section 10.2** above:

- Total Nitrogen = 20 mg/L
- Total Phosphorous = 7 mg/L
- Total Dissolved Solids = 1,000 mg/L
- Electrical Conductivity = 1.563 dS/m

Soils Data

Adjusted default soil properties for 'Sand' have been adopted in the MEDLI modelling. The default properties of 'Sand' contained within MEDLI were generally considered appropriate to use based on reference to soil profiles and properties identified through geotechnical investigations undertaken on the Island by Douglas Partners (Douglas Partners, 2010). Geotechnical investigations identified that soils within intended irrigation areas primarily comprise high permeability sands. Field testing of soil saturated hydraulic conductivity (K_{sat}), indicated that sands on GKI were characterised by significantly higher saturated hydraulic conductivity compared to default 'Sand' properties contained within MEDLI. Accordingly, a modified soil type was created based on the default 'Sand' by doubling the saturated hydraulic conductivity throughout the soil profile.

Soil nutrient properties were also adjusted from the default 'Sand' soil type. Soil organic nitrogen was increased from 350 mg/kg to 450 mg/kg to reflect the maximum soil organic nitrogen result recorded in samples of GKI sand collected during geotechnical investigations. Relatively low soil nitrate concentrations were recorded in sand samples collected on GKI, however the higher default figure of 7 mg/kg was adopted as the initial soil nitrate nitrogen. By adopting higher initial nitrogen concentrations for soils than actually occur on average across the irrigation area, a conservative approach has been taken. That is, advice from DERM suggests that increasing the initial soil organic nitrogen content can be used to simulate the application of slow release fertilisers within the irrigation area, which is otherwise not possible within MEDLI.

A summary of the soil water and nutrient characteristics for the modified soil type "Great Keppel Sand" adopted in MEDLI modelling is provided in **Table 10.5** and **Table 10.6** below.

TABLE 10.5: Soil Water Characteristics Adopted in MEDLI Modelling

Properties	Unit	Soil Horizon			
		Layer 1	Layer 2	Layer 3	Layer 4
Layer Thickness	(mm)	100	500	600	300
Air Dry Moisture Content	(mm/layer)	4			
Lower Storage Limit	(mm/layer)	4	6.4	7.5	6.0
Drained Upper Limit	(mm/layer)	10.9	13.6	13.8	9.1
Plant Available Water Capacity	(mm)	6.9	36.0	37.8	9.3
Saturated Water Content	(mm/layer)	50.1	42.3	43.6	43.1
Bulk Density	(g/cm^3)	1.31	1.52	1.48	1.50
Porosity	(mm/layer)	50.6	42.6	44.2	43.4
Saturated Hydraulic Conductivity	(mm/hour)	100	100	40	20

TABLE 10.6: Soil Nutrient Characteristics Adopted in MEDLI Modelling

Properties	Units	Quantity
Soil Nitrate	mg/kg	7
Soil Organic Nitrogen	mg/kg	450
Initial Soil Solution Phosphorus	mg/L	0.01

Plant

Default parameters for “Continuous – Coastal Couch Pasture” were adopted from the MEDLI model as the majority of irrigation will occur on the proposed golf course. Advice from the golf course designer has confirmed that the turf on the course will consist of a range of Couch species.

The default harvest trigger within the MEDLI model was adopted, which results in harvesting being triggered at a yield of 2800kg/ha of biomass. This is assumed to be a much higher harvest trigger than what will actually occur on the golf course, which is likely to be harvested (mowed) frequently in order to maintain manicured tees, greens and fairways. Harvesting removes excess biomass and the nutrients it contains from the irrigation area. Furthermore, following harvest, vegetative growth in the plant is stimulated which in turn stimulates the uptake of nutrients. By adopting a less frequent harvest trigger than is likely to occur, a conservative approach to removal of nutrients from the irrigation area has been modelled.

Irrigation Scheduling

Irrigation scenarios based on a fixed daily irrigation rate and a plant available water capacity (PAWC) trigger were tested to determine an appropriate regime for this reuse scheme. The following regimes were considered generally appropriate for the scheme:

- Irrigation triggered at 80% PAWC and irrigating up to 5.0mm beyond drained upper limit (DUL); and
- Irrigating 2mm, once per day.

These irrigation regimes were determined to be appropriate on the basis that the resulting levels of nutrient leaching were generally consistent with modelled outputs of the site under no irrigation reflecting a non-worsening approach.

Although MEDLI modelling indicates that irrigation of 2mm daily will not result in any increased leaching of nitrogen compared to a no irrigation scenario, irrigation of a fixed amount each day, including rain days, is not practical from an operational perspective wherein irrigation is more likely to be based on weather, plant and ground conditions. As such, an irrigation scheme based on triggering irrigation at approximately 80% PAWC and irrigating up to approximately 5mm beyond DUL was considered to comprise the most practical and sustainable irrigation regime for GKI based on available information.

Irrigation Area

Advice from Greg Norman Golf Course Design has indicated that the proposed championship golf course is likely to comprise a total area of maintained turf (including tees, greens, fairways and rough) of approximately 31 hectares. Accordingly, an irrigation area of 31 hectares was input into the MEDLI modelling.

Fixed spray irrigation was selected as the irrigation method in MEDLI. Spray irrigators are likely to be the method used over the majority of the golf course due to the large areas requiring irrigation, although sub-surface / surface drippers or similar may be used within close proximity to sensitive receivers to reduce the potential for spray drift.

Wet Weather Storage Pond

The required volume of wet weather storage has been determined for a range of scenarios assuming a 31 hectare irrigation, including determining storage requirements for different irrigation regimes and reuse percentages. The various wet weather storage pond sizes determined through MEDLI modelling are discussed in the following section. However, for the preferred irrigation regime, which comprises a 31 hectare irrigation area and irrigating at 80% PAWC up to 5mm beyond DUL, the required wet weather storage to achieve no more than 1 overtopping event every 10 years on average is 37 ML.

In order to cater for potential increases in rainfall intensity that may occur as a result of climate change, a total wet weather storage capacity of 44 ML has been recommended. This provides for an approximate 20% increase in wet weather storage capacity. This is considered more than adequate to account for a reasonable level of climate change induced increases in rainfall intensity, which is predicted to be in the order of 48% increase in rainfall intensity for a 2-hour event, 16% increase for a 24-hour event and 14% increase for a 72 hour event (Opus International Consultants, 2011b).

Wet weather storage is likely to be provided as a series of ponds incorporated as water features within the proposed golf course. Wet weather storage should be provided separate to the stormwater harvesting ponds so as to reduce the risk of overtopping and enable monitoring of recycled water levels available for irrigation.

Given that wet weather storage will most likely be incorporated into the golf course lake system, the pond has been modelled as being 100% exposed to evaporation and rainfall, with an average depth of 3 metres and a seepage rate of 0.1 mm/day. Given the sandy nature of soils on site, an artificial clay or synthetic liner will need to be incorporated into the pond design to achieve this seepage rate. Although multiple ponds may be constructed to provide wet weather storage, a single pond system has been modelled, as the MEDLI model assumes that effluent is only drawn from a single pond for reuse.

Groundwater

Part of the golf course overlies the Central Dune Sand Aquifer identified in the Douglas Partners "Report on Assessment of Groundwater Resources" dated May 2011. Other areas that may be used for irrigation of recycled water, although unlikely, overlie the Resort Aquifer identified by Douglas Partners. Both of these aquifers are unconfined dune sand aquifers.

The thickness of the Resort Aquifer as identified by Douglas Partners is between 6m and 12m, and groundwater flows discharge to the ocean via Fisherman's Beach and Putney Beach. The thickness of the Central Dune Sand aquifer as identified by Douglas Partners is between 2.5m and 17m, and groundwater flows discharge to the ocean via Leeke's Creek and Leeke's Beach.

Due to the limitations associated with the MEDLI groundwater model, the default groundwater parameters were used for the purpose of site assessment and modelling. These parameters assume an aquifer thickness of 10m which is within the range of aquifers located within the potential irrigation areas. The model also assumes a distance of 1000m between the irrigation area and location where nitrate concentration is calculated (i.e. location of discharge or extraction). Although the distance between the potential irrigation areas and discharge locations described above is less than 1000m, the model does not allow a lesser value to be entered.

To counter this deficiency in the model, irrigation scenarios modelled have been developed to ensure no significant increase in the nutrient loads leached below the soil profile compared to a baseline or no irrigation scenario. Furthermore, relevant outputs from the MEDLI modelling relating to deep drainage and nutrient levels below the root zone, have been incorporated into groundwater pollutant models developed by Douglas Partners (2011) specific to the Central Dune Aquifer to assess potential impacts on groundwater quality and receiving waters.

10.3.2 MEDLI Outputs

A copy of relevant MEDLI summary outputs discussed in this section are provided in **Appendix I – MEDLI Summary Output Data**, including:

- MEDLI Summary Output (Baseline Scenario - No Irrigation);
- MEDLI Summary Output (Scenario 1 - Fixed Irrigation – 2 mm/day); and
- MEDLI Summary Output (Scenario 2 - 80% PAWC Irrigation).

A summary of key inputs and outputs from the MEDLI for these scenarios compared to a baseline or 'no irrigation' scenario are provided in **Table 10.7**.

TABLE 10.7: Summary of MEDLI Inputs & Outputs

MEDLI Summary Inputs & Outputs	
Hydraulic Loading:	Variable. As per **Table 10.4** of **Section 10.3.1**.
Effluent Quality Characteristics: **Total Nitrogen** **Total Phosphorous** **Total Dissolved Salts**	 20 mg/L 7 mg/L 1,000 mg/L

MEDLI Summary Inputs & Outputs						
Volatile Solids **Total Solids**	0 mg/L 0 mg/L					
Irrigation Schedule:	No Irrigation	Scenario 1a (Fixed 2mm/day)	Scenario 1b (Fixed 2mm/day)	Scenario 2a (80% PAWC)	Scenario 2b (80% PAWC)	Scenario 2d (80% PAWC)
Average Annual Rainfall (mm/year):	1045	1045	1045	1045	1045	1045
Average Annual Pan Evaporation(mm/year):	1848	1848	1848	1848	1848	1848
Irrigation Area (ha)	31	31	31	31	31	31
Average Annual Irrigation (mm/year):	0	485	508	483	493	500
Wet Weather Storage (ML)	N/A	0.6	9	13	75	37
% Reuse:	0	95%	100%	95%	100%	99%
Average annual volume of overtopping (ML/year):	N/A	7.15	0.00	7.41	0.00	0.76
Runoff (mm/year):	19.8	6.1	6.1	6.0	6.1	6.0
Deep Drainage (mm/year)	426.2	446.2	463.3	432.6	448.9	446.1
Nitrogen added in irrigation (kg/ha/yr):	0.0	81.6	83.6	75.7	60.9	69.6
Nitrogen removed by crop (kg/ha/yr):	31.7	116.7	118.7	111.7	96.8	105.4
Leached nitrate (kg/ha/year):	6.9	2.8	2.8	2.1	2.3	2.4
Concentration of nitrate in deep drainage (mg/L):	1.6	0.6	0.6	0.5	0.5	0.5
Phosphorous added in irrigation (kg/ha/yr):	0.0	34.0	35.6	33.9	35.4	35.3
Phosphorous removed by crop (kg/ha/yr):	0.1	26.1	26.7	24.9	23.3	24.4
Leached phosphate (kg/ha/year)	0.0	0.1	0.1	0.1	0.1	0.1
Average concentration of phosphate below root zone (mg/L):	0.0	0.0	0.0	0.0	0.0	0.0
Reduction in crop yield due to salinity (%):	0.0	0.0	0.0	0.0	0.0	0.0

Note: Results for the proposed scheme are highlighted grey.

A discussion of relevant results is provided in the following sections.

Reuse & Overtopping

In general, DERM's policy for approving sewage treatment plants incorporating effluent reuse is for a minimum of 95% reuse to be achieved before consideration is given to discharging recycled water to the environment for disposal. In order to achieve 95% reuse based on a 31 hectare irrigation area and irrigating at 80% PAWC up to 5mm beyond DUL, a wet weather storage of 13 ML would be required.

The modelling indicates that with 95% reuse and irrigating at 80% PAWC up to 5mm beyond DUL, the average volume of overtopping from wet weather storage ponds would be approximately 7.41 ML/year on average. This would result in overtopping occurring on approximately 167 days on average within every 10 year period.

Despite the high standard of treatment proposed, this was not considered to be an acceptable level of overtopping on the basis of the potential impacts on marine environments surrounding the ocean outfall and also on the basis that it would result in the waste of a significant volume of recycled water that could otherwise potentially be beneficially used for irrigation of the golf course to offset the need for sourcing other water supplies.

As such, consideration was given to a range of options to reduce the volume of overtopping and increase the percentage reuse, including:

- Increasing the irrigation area;
- Increasing the irrigation rate; and
- Increasing the volume of wet weather storage.

Increased Irrigation Area

The capacity to reduce overtopping of wet weather storage by increasing the irrigation area is constrained by the volume of recycled water available and the assimilation capacity of soils. Modelling of the preferred irrigation scheme based on triggering irrigation at 80% PAWC and irrigating up to 5mm beyond DUL indicates that increasing the irrigation area has minimal impact on reducing overtopping.

Under this irrigation regime, irrigation will only be triggered when the soil in the irrigation area is dried to the point where the PAWC has decreased to 80%. As such, during rainy periods and for some time following the rainy periods, the soil will be too moist to trigger irrigation. As a result, when using a PAWC trigger, increasing the irrigation area will still only increase the amount of effluent that can be irrigated during dry periods meaning wet weather storage will still need to be sized to store all effluent generated on wet days. At approximately 31 hectares a balance has been achieved where all of the incoming effluent can be irrigated during a dry day. Increasing the irrigation area beyond this will not allow more effluent to be irrigated during a dry day, as no more incoming effluent is available to irrigate on those dry days.

Increased Irrigation Rate

Although increasing the rate of application may reduce the volume of overtopping, it also increases the risk of exceeding the capacity of soils to effectively assimilate nutrients, resulting in declining soil quality, impacting on plant growth and leaching of nutrients to groundwater.

Altering the PAWC trigger limit to trigger irrigation at higher PAWC level will allow irrigation to occur when the soil is not quite as dry, thus increased irrigation can occur during wetter periods. However, adopting a higher PAWC trigger will result in soils staying wetter for longer and there will be an increased risk of nutrients leaching below the root zone of plants into underlying groundwater. Increasing the PAWC to trigger irrigation at higher than 80% tended to result in higher levels of nutrient leaching compared to the no irrigation scenario with minimal effect in reducing overtopping, and was therefore considered to be unacceptable in this instance. Furthermore, triggering irrigation when soil moisture content is still relatively high means that soils would be permanently saturated or near saturated, which has other implications for soil quality in terms of oxygen availability and microbial activity.

Similarly, adopting a fixed irrigation rate higher than 2 mm/day was also shown to result in higher levels of nutrient leaching compared to the no irrigation scenario and was therefore not considered further in the modelling assessments.

Increased Storage

Compared to the frequency and amount of overtopping predicted to occur under a reuse scheme achieving 95% reuse, a more acceptable overtopping frequency was considered to be in the order of approximately once every 10 years. To achieve this, a minimum wet weather storage capacity of 37 ML was estimated to be required using MEDLI modelling and assuming irrigation occurs at 80% PAWC up to 5mm beyond DUL. Provision of a 37 ML storage reduces the average annual volume of overtopping from about 7.41 ML/year to 0.76 ML/year and the average number of days overtopping occurs in a 10-year period is reduced from approximately 167 days to 17 days, with the duration of each overtopping event being an average of about 10 days (refer to **Figure 10.2**). The percentage of recycled water reused increases from 95% up to in excess of 99% when the wet weather storage capacity is increased from 13 ML up to 37 ML.

To achieve 100% reuse and avoid overtopping based on a 31 hectare irrigation area and irrigating at 80% PAWC up to 5 mm beyond DUL, a minimum 75 ML of wet weather storage capacity would be required. Compared to a 13 ML wet weather storage required to achieve 95% reuse, a 75 ML storage would require an additional land area of approximately 2 hectares to construct assuming an average depth of 3 metres with batters. Construction of a storage facility sized to achieve 100% reuse, would require a significant increase in the area of land and volume of materials required for this component of the project. Furthermore, the additional 62 ML of storage would be empty 95% of the time and would be required only during the most extreme rainfall events when water quality in receiving waters is already likely to be highly degraded from land-based sources of runoff.

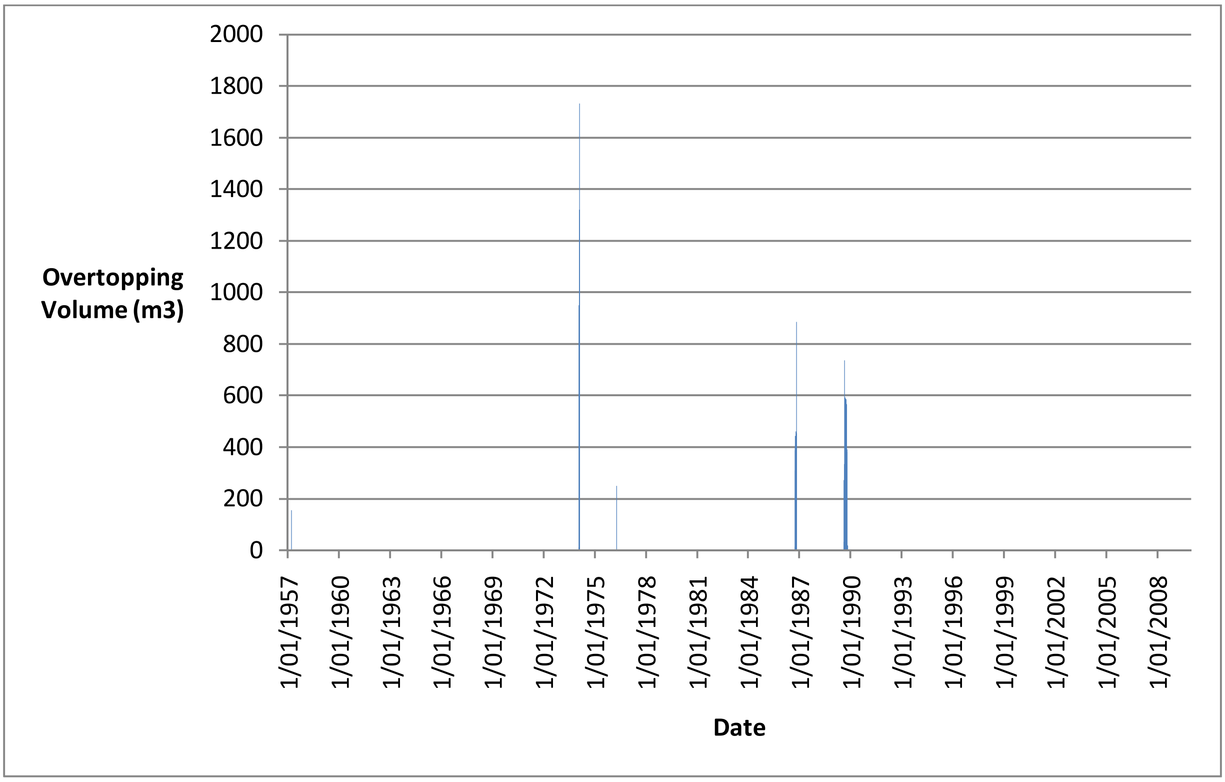


Figure 10.2: Overtopping Events Predicted Assuming Provision of 37ML Wet Weather Storage

In comparison, the additional wet weather storage capacity required to increase reuse from 95% up to just over 99% and reduce the overtopping frequency to about once every 10 years, is only 24 ML which would require only an additional 0.8 ha of land to construct.

Runoff

The results of MEDLI modelling for the proposed irrigation scheme demonstrate that no runoff of irrigated effluent will occur. Furthermore, the average rate of runoff from the irrigation area predicted for the proposed irrigation scheme (6.0 mm/year) is approximately 60% lower than the runoff rate predicted for the area when no irrigation occurs (19.8 mm/year). This lower rate of runoff is likely to be due to enhanced evapo-transpiration rates within the irrigation area associated with improved plant cover and health.

Deep Drainage

The results of MEDLI modelling for the proposed irrigation scheme indicate that the average rate of deep drainage from the irrigation area predicted for the proposed irrigation scheme (446.1 mm/year) is only slightly higher (i.e. less than 5%) than the deep drainage rate predicted for the area when no irrigation occurs (426.2 mm/year).

Nutrients

Leaching of nutrients through the soil profile and below the root zone of plants occurs when the soil is oversaturated and the capacity of soils and plant matter to adsorb and uptake nutrients is exceeded. Sustainable irrigation of recycled water encourages healthy plant growth, often resulting in greater plant cover and health than systems relying solely on rainfall due to the presence of nutrients required for plant growth contained in recycled water. This is particularly the case where there is a significant annual rainfall deficit as occurs in this locality (i.e. average deficit of 803 mm/year). Healthy plant growth in turn supports enhanced uptake of nutrients and evapo-transpiration. Irrigation scheduling based on a PAWC trigger as adopted for the proposed irrigation scheme, is generally the most effective means to achieve healthy plant growth as this approach applies recycled water when water is needed by the plant.

The results of MEDLI modelling for the proposed irrigation scheme indicate that the rate of nitrogen uptake by plant growth (105.4kg/ha/year) exceeds the amount of nitrogen applied by irrigation (69.6kg/ha/year). Furthermore, the amount of nitrogen leached below the root zone under the proposed irrigation scheme (2.4kg/ha/year) and the concentration of nitrogen in deep drainage (0.5mg/L) is substantially lower than for the baseline or no irrigation scenario (6.9kg/ha/year and 1.6mg/L respectively). **Figure 10.3** below provides a comparison of the amount of nitrogen leached below the soil profile during the proposed irrigation scheme and with no irrigation.

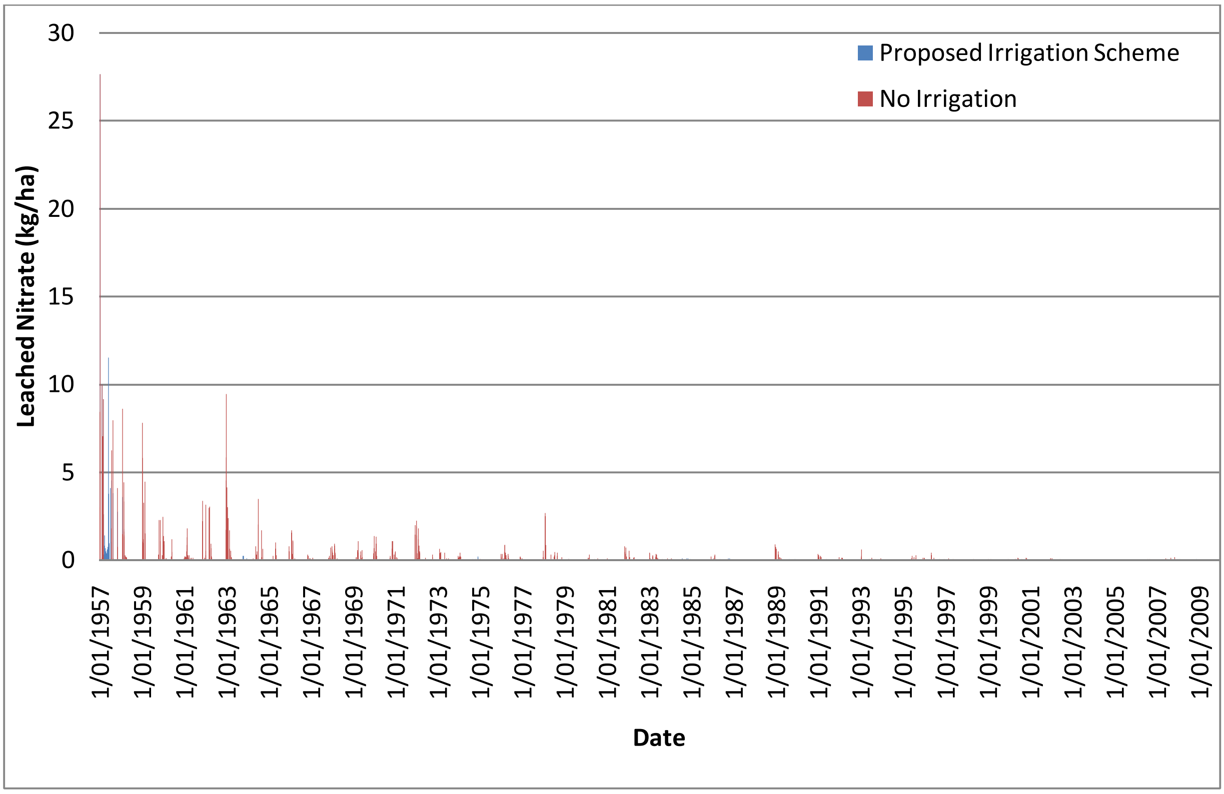


FIGURE 10.3: Comparison of Nitrogen Leached Below the Soil Profile under No Irrigation and Proposed Irrigation Scheme

The results of MEDLI modelling for the proposed irrigation scheme indicate that the rate of phosphorous uptake by plant growth (24.4kg/ha/year) is less than the amount of phosphorous applied by irrigation (35.3kg/ha/year). However, the remaining phosphorous is largely adsorbed within the soil profile. **Figure 10.4** below illustrates phosphorous adsorption within the soil profile over the life of the scheme and demonstrates that the phosphorous adsorption capacity of the soils will not be exceeded even after 50+ years of irrigation. The combination of plant uptake and soil adsorption ensure that the amount of phosphorous leached below the soil profile is comparable with the amount predicted with no irrigation.

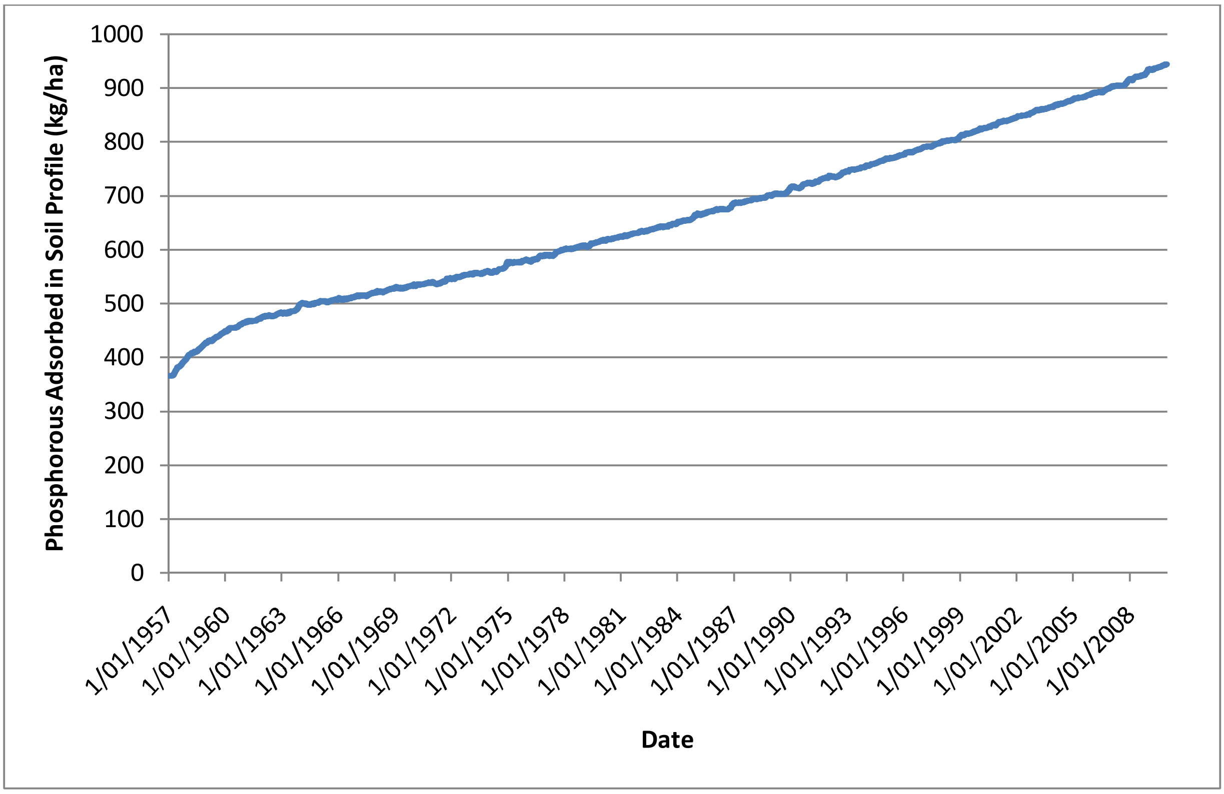


FIGURE 10.4: Phosphorous Adsorption in Soil Profile over 53 years of Treated effluent Irrigation

Groundwater

As noted above, MEDLI is generally not considered to be an effective tool for modelling potential impacts of effluent irrigation on groundwater quality where the groundwater discharge/ extraction point is located within 1000m of the irrigation area. In this instance, a small part of the irrigation area overlies the Central Dune Aquifer identified by Douglas Partners (2011).

Although the proposed irrigation scheme has been designed to result in no worsening of nutrient leaching below the soil profile compared to a no irrigation scenario, further modelling of potential groundwater impacts has been undertaken by Douglas Partners using the MODFLOW groundwater model developed to simulate the Central Dune Aquifer. Further details on the modelling process are provided in Douglas Partners (2011).

To model potential groundwater impacts, Douglas Partners incorporated the following outputs from the MEDLI modelling for the proposed irrigation scheme:

TABLE 10.8: Summary of MEDLI Outputs vs MODFLOW Inputs

Attribute	MEDLI Output Data	Data Used in MODFLOW
Irrigation Area (within catchment of Central Dune Aquifer)	31 hectares	31 hectares
Average Groundwater Recharge	378.6 m^3/year	378.6 m^3/year
Average Nitrate Concentration of Groundwater Recharge	0.5 mg/L	0.55 mg/L[1]
Average Phosphate Concentration Below Root Zone	0.0 mg/L	0.03 mg/L[1]

Note:
1. Buffer added to MEDLI output data for conservative assessment of impacts.

Groundwater pollutant modelling undertaken by Douglas Partners based on the above inputs from the proposed irrigation scheme, indicates that the concentrations of total nitrogen and total phosphorous within groundwater complies with the relevant water quality objectives of 0.3 mg/L of total nitrogen and 0.025 mg/L of total phosphorous at the point of discharge into Leeke's Creek and associated tidal wetlands.

As such, the proposed irrigation of recycled water containing an average concentration of 20 mg/L of nitrogen and 7 mg/L of phosphorous is not expected to result in any adverse impacts on water quality or environmental values associated with Leeke's Creek and associated tidal wetlands.

In addition, groundwater pollutant modelling undertaken by Douglas Partners estimated that based on an average recharge rate 378.6m^3/year, the concentrations of nitrogen and phosphorous leached below the soil profile must not exceed 0.65mg/L and 0.05mg/L respectively in order to comply with water quality objectives for Leeke's Creek.

Golf Course Maintenance

Assuming average effluent concentrations of 20 mg/L of total nitrogen and 7 mg/L of total phosphorous, the proposed recycled water scheme as described above, will apply the following amounts of nutrients to the irrigation area:

- Nitrogen = 69.9 kg/ha/year
- Phosphorous = 35.3 kg/ha/year

Limited capability is available within MEDLI to simulate the application of fertilisers to an irrigation area. A number of conservative assumptions have however been incorporated into modelling of the proposed irrigation scheme to account for possible fertiliser application to some extent. This includes:

- Adopting higher than average initial soil nitrogen levels, which acts to simulate the application of a slow release fertiliser; and
- Adopting a harvest trigger that results in less frequent removal of grass clippings and other plant growth from the irrigation area than will actually occurred on a frequently mown golf course.

To further consider the possible implications of fertiliser application within the proposed golf course irrigation area, initial effluent concentrations were increased substantially from 20 mg/L nitrogen up to 115 mg/L and from 7 mg/L phosphorous up to 25 mg/L. Modelling of effluent irrigation triggered at 80% PAWC up to 5 mm beyond DUL over a 31 hectare irrigation area resulted in the following:

- Nitrogen applied in irrigation: = 115.4 kg/ha/year
- Phosphorous applied in irrigation: = 47.2 kg/ha/year
- Average Nitrate Concentration of Groundwater Recharge: = 0.6 mg/L
- Average Phosphate Concentration Below Root Zone: = 0.0 mg/L

- Average Groundwater Recharge: = 377.5 m^3/year

As the concentrations of nitrogen and phosphorous leached below the soil profile are predicted to be less than the limits identified by Douglas Partners to achieve the required water quality objectives at Leeke's Creek, it is considered that up to approximately 115.4kg/ha/year of nitrogen and 47.2 kg/ha/year of phosphorous could be applied to the irrigation area either within effluent or applied fertilisers without impacting on water quality or environmental values within Leeke's Creek.

It is recommended that these rates be used as a guide for managing fertiliser application on the proposed golf course, with records of all fertiliser application and recycled water irrigation to be maintained. Combined with regular monitoring of soils and groundwater that will be required under the conditions of development approval that will need to be obtained for the proposed wastewater treatment plant, this approach to fertiliser management is considered to substantially reduce the potential for maintenance of the proposed golf course to impact on water quality within Leeke's Creek and other downstream receiving waters.

In addition to nutrients, the health of the plant cover also depends on the quantity of water available. The golf course designer has estimated the monthly volume of irrigation likely to be required to maintain the golf course based on average amounts of rainfall and evapo-transpiration rates. The average annual rate of recycled water applied for the proposed irrigation scheme has been compared to the required irrigation rate estimated for the golf course by the designer.

Irrigation at the rates specified by the golf course designer is only proposed for parts of the golf course comprising tees, greens and fairways rather than the entire golf course. As such, estimation of the total volume of irrigation water required is based on the rates specified by the golf course designer multiplied by the estimated area of tees, greens and fairways. Based on reference to a report published by the Environmental Institute of Golf (2006), it has been estimated that the area of tees, greens and fairways accounts for approximately 49% of the total area of maintained turf, which in this case, equates to 49% of 31 hectares or approximately 15.2 hectares.

In undertaking the water balance for this project, the irrigation water demand for the golf course assumes tees, greens and fairways are irrigated at the full rate proposed by the golf course designer using a combination of recycled water and other water supply sources. Irrigation of areas of golf course not comprising tees, greens and fairways will be irrigated using recycled water only at the rate determined to be sustainable through MEDLI modelling.

Table 10.8 provides a summary of the estimated water demands and irrigation water supplies for the proposed golf course.

TABLE 10.8: Estimated Golf Course Irrigation Requirements Compared to Treated effluent Irrigation

Month	Irrigation Rate Required for Tees, Greens & Fairways (ML/ha/month)	Total Volume of Irrigation Water Required for Tees, Greens & Fairways (15.2ha) (ML/month)	Treated effluent Irrigated to Tees, Greens & Fairways (ML/month)	Irrigation Water Deficit for Tees, Greens & Fairways (ML/month)	Treated effluent Irrigation of Remaining Golf Course (ML/month)
January	1.26	19.077	8.810	10.27	9.170
February	0.78	11.799	5.165	6.63	5.375

Month	Irrigation Rate Required for Tees, Greens & Fairways (ML/ha/month)	Total Volume of Irrigation Water Required for Tees, Greens & Fairways (15.2ha) (ML/month)	Treated effluent Irrigated to Tees, Greens & Fairways (ML/month)	Irrigation Water Deficit for Tees, Greens & Fairways (ML/month)	Treated effluent Irrigation of Remaining Golf Course (ML/month)
March	1.18	17.946	6.684	11.26	6.956
April	1.27	19.326	6.228	13.10	6.482
May	1.11	16.790	4.101	12.69	4.269
June	0.94	14.217	4.253	9.96	4.427
July	0.98	14.871	5.013	9.86	5.217
August	1.11	16.862	4.405	12.46	4.585
September	1.41	21.462	7.747	13.72	8.063
October	1.63	24.826	6.836	17.99	7.115
November	1.75	26.594	6.987	19.61	7.273
December	1.38	20.965	9.722	11.24	10.118
Annual	**14.80**	**224.737**	**75.950**	**148.79**	**79.050**

These results indicate that in addition to recycled water irrigation, between about 6.63 ML/month and 19.61 ML/month of additional irrigation water is likely to be applied to the tees, greens and fairways. As noted in **section 8.2** above, this additional water supply will be derived primarily from stormwater runoff harvested in ponds incorporated into the golf course and supplemented by water from the mains supply from the mainland.

10.3.3 MEDLI Summary

Based on the above results, the preferred recycled water irrigation scheme based on proposed effluent quality characteristics and hydraulic loading consists of:

- Irrigation Area = 31 hectares
- Wet Weather Storage = 37 ML (plus 7 ML climate change buffer)
- Trigger irrigation at 80% PAWC and irrigate up to 5 mm beyond DUL.

This scheme achieves over 99% reuse of recycled water generated by the GKI Resort Revitalisation Plan, with discharge from wet weather storages expected to occur only during extreme wet weather periods or approximately once every 10 years.

To achieve 100% reuse, a minimum 75 ML (plus 15ML climate change buffer) wet weather storage would need to be provided. Construction of this additional storage volume would require significant amounts of additional land area (> 2 hectares) and earthworks, including associated vegetation clearing as well as the importation of significant quantities of material to reduce seepage in the natural sand soils.

The proposed golf course is currently expected to comprise approximately 31 hectares of maintained turf that would be suitable for irrigation using recycled water. Depending on final design of the golf course, additional areas may be required for irrigation. In this case, landscaped gardens and turf surrounding ecotourism villas located within the same Clam Bay Precinct as the golf course would be the first preference for alternative irrigation area to minimise costs and energy consumption associated with pumping recycled water around the Island. However, landscaped gardens and turf within the Fisherman's Beach Precinct would also be acceptable for reuse of recycled water for irrigation if required being based on the same underlying soil type.

In order to ensure the ongoing sustainability of the proposed recycled water irrigation scheme and to mitigate potential environmental and public health risks associated with the scheme, a Preliminary Irrigation Management Plan has been developed and is included in **Appendix H - Preliminary Irrigation Management Plan**.

10.4 EMERGENCY WET WEATHER DISCHARGE

MEDLI modelling for the proposed recycled water irrigation scheme indicates that in excess of 99% of all recycled water generated by the GKI Resort Revitalisation Plan will be reused on the Island for irrigation of the golf course and possibly other landscaped garden and turf areas. During prolonged or extreme wet weather events, expected to occur approximately once every 10 years on average, wet weather storage ponds may reach capacity and a proportion of the recycled water may subsequently be discharged via an ocean outfall.

The likelihood of ocean discharge occurring is expected to be somewhat less than the 1 in 10 years predicted by MEDLI given that the MEDLI modelling was based on provision of a 37ML wet weather storage. However, to account for potential increases in rainfall intensity that are predicted to occur as a result of climate change, it is proposed to provide 44ML wet weather storage or almost 20% more storage than considered in the MEDLI modelling. This is considered to be an extremely conservative approach to sizing of the wet weather storage given that although increased rainfall intensity is predicted to occur as a result of climate change, a decrease in average annual rainfall is also expected to occur meaning that:

- Irrigation is likely to be triggered more often based on a soil water deficit, resulting in more recycled water being used for irrigation and less recycled water going into wet weather storage; and
- Less direct rainfall will be captured by the open wet weather storage ponds providing more capacity for storage of recycled water.

It is noted that the proposed wet weather discharge is significantly lower than the volume of discharge permitted under the environmental licence conditions for the existing wastewater treatment plant servicing the former GKI resort, which allowed for up to 250 m^3 per day of effluent to be discharged on dry weather days and up to 500 m^3 per day to be discharged on wet weather days.

To determine the location of the proposed ocean outfall, consideration has been given to GBRMPA's *Sewage Discharge Policy - Sewage Discharges from Marine Outfalls to the Great Barrier Reef Marine Park, March 2005*. This policy states that:

> *Marine outfalls should not be constructed:*
>
> i. *Within 50 metres of a permitted mooring or anchorage; or*
> ii. *Within 1000 metres of aquaculture operations, or an area regularly used for*
> iii. *swimming or other water-based activities, unless it can be demonstrated that there will be no adverse impacts on the operation or activities; or Within 1000 metres of sensitive*

environments, unless it can be demonstrated that there will be no adverse impacts on the protection of aquatic ecosystems.

For a marine outfall to be approved the GBRMPA will require that:

i. *The outfall structure be of a design which optimises diffusion and dispersal; and*
ii. *The design of the system includes consideration of water depth (deep water is preferred i.e. greater than 10 metres), current velocity, tidal range and proximity to reefs or other sensitive environments.*

A bathymetric survey has been conducted offshore to the south of Long Beach. This location was selected to provide adequate distance away from the shore, sufficient depth and exposure to offshore ocean currents to facilitate dispersion of recycled water. This location avoids identified coral reefs and has minimal impacts to existing seagrass beds (FRC Environmental, 2011).

The proposed ocean outfall will comprise a pipeline of approximately 1,000 metres in length extending from Long Beach. The outfall will be located within an area of water at least 10 metres deep to ensure sufficient depth of water is available above the diffuser across the full tidal range. The outfall will incorporate a T-shaped diffuser comprising two (2) ports approximately 75mm diameter. Modelling of predicted dispersion of discharges from the ocean outfall has been undertaken by Water Technology and is contained in their report “Great Keppel Island Resort Revitalisation Plan Coastal Environment Technical Report August 2011”.

Based on the estimated volume and duration of discharge events predicted by MEDLI modelling and assuming effluent nutrient concentrations of 20 mg/L for total nitrogen and 7 mg/L of total phosphorous, dispersion modelling by Water Technology has predicted that concentrations of total nitrogen and total phosphorous will reduce to below relevant trigger values within a small mixing zone in the immediate vicinity of the outfall. On this basis, the proposed emergency wet weather discharge of recycled water via an ocean outfall is not anticipated to have any significant impact on ecological communities near the outfall.

11. STORMWATER MANAGEMENT

The following section describes the proposed strategy for managing stormwater quality and quantity associated with the GKI Resort Revitalisation Plan to prevent any adverse impacts on receiving waters. In accordance with water sensitive urban design (WSUD) principles and best practice environmental stormwater management, stormwater drainage systems incorporated into the GKI Resort Revitalisation Plan will primarily utilise surface drainage techniques (such as grassed swales) rather than traditional underground piped drainage systems. This will minimise the need for significant excavation for installation of stormwater pipe trenches while also enabling stormwater drainage systems to be utilised as landscape features.

The proposed stormwater strategy also aims to treat stormwater at the source using bio-retention filters that utilise native vegetation and natural sand materials. The bio-filters remove sediment and nutrients from stormwater before allowing the stormwater to infiltrate into the natural sandy soils mimicking the natural process of groundwater recharge through rainwater infiltration that occurs on the Island.

11.1 CATCHMENT OVERVIEW

As noted in **Table 11.1**, fourteen distinct drainage catchments have been identified on GKI. The extents of these catchments are shown on the Catchment Plan contained in **Appendix B – Catchment Plan**. A summary of the catchment characteristics is provided below:

TABLE 11.1: Stormwater Catchment Characteristics

ID	Location	Catchment Area (Ha)	Discharge Location	Proposed Development within Catchment
1	Eastern side of headland between Secret Beach and Wreck Bay	13.716	Discharges in a dispersed manner via localised flow paths to the rocky shore. No main waterway.	Nil
2	Wreck Bay – Wreck Beach	178.304	Discharges in a dispersed manner via localised flow paths to Wrecks Beach. No main waterway.	Nil
3	Wreck Bay – Little Wreck Beach	86.740	Discharges in a dispersed manner via localised flow paths to Little Wreck Beach. No main waterway.	Nil
4	Red Beach	86.834	Discharges in a dispersed manner via localised flow paths to various small beaches / coves and Red Beach. No main waterway.	Nil
5	Clam Bay	66.781	Discharges in a dispersed manner via localised flow paths to the small beaches of Clam Bay. No main waterway.	Part of golf course and small number of ecotourism villas.
6	Southern side of headland between Wyndham Cove and Long Beach	7.473	Discharges in a dispersed manner via localised flow paths to the rocky shoreline of north eastern Long Beach. No main waterway.	Nil
7	Long Beach	39.100	Discharges in a dispersed manner along the eastern section of Long	Small number of ecotourism villas and small

ID	Location	Catchment Area (Ha)	Discharge Location	Proposed Development within Catchment
			Beach. There are few recognisable flow paths.	part of airstrip.
8	Fisherman's Beach	57.900	Discharges in a dispersed manner along the southern half of Fishermen's Beach. There are few recognisable flow paths.	Resort hotel, ecotourism villas and apartments, sporting fields,
9	Putney Creek	110.700	Contains Putney Creek, which discharges at Putney Beach.	Eco-apartments and villas, resort commercial / retail, staff accommodation, airport terminal and part of airstrip, and the facilities maintenance compound.
10	Leeke's Beach	0.284	Contains Leeke's Creek, which discharges to Leeke's Beach through the existing wetland.	Nil – but downstream of Catchment 11.
11	Central area between Clam Bay and Leeke's Beach	324.447	Discharges via Leeke's Creek in Catchment 10 to Leeke's Beach through the existing wetland.	Majority of golf course including clubhouse commercial / retail and ecotourism villas.
12	Ridgeline inland of Svendsen's Beach	13.716	Discharges in a dispersed manner via localised flow paths towards Svendsen's Beach via Catchment 10. No main waterway.	Nil
13	Western side of headland at Secret Beach	12.391	Discharges in a dispersed manner via localised flow paths to Secret Beach. No main waterway.	Nil
14	Marina Precinct	17.628	The Marina Precinct is to be constructed along the existing beachfront at the northern end of Putney Beach.	Marina retail / commercial and apartments.

Stormwater modelling and analysis as described in this section, generally excludes land not leased or intended to be leased by GKI Resort Pty Ltd. As such, model catchments have been identified based on topographic boundaries, modified as necessary to exclude land not expected to be leased by GKI Resort Pty Ltd.

As noted in **Table 11.1**, the development areas proposed under the GKI Resort Revitalisation Plan primarily fall within the following catchments:

- 5 - Clam Bay;
- 7 - Long Beach;
- 8 - Fisherman's Beach;
- 9 - Putney Creek;
- 10 - Leeke's Creek;
- 11 – Central Clam Bay / Leeke's Beach (discharging via Leeke's Beach); and

- 14 – Marina Precinct.

No development work is proposed in the remaining catchments and no changes to runoff behaviour will occur in those areas as a result of the GKI Resort Revitalisation Plan. Accordingly, only Catchments 5, 7, 8, 9, 10, 11 and 14 have been modelled.

11.2 METHODOLOGY

11.2.1 Stormwater Quantity

Existing and post-development hydrologic behaviour within catchments containing elements of the GKI Resort Revitalisation Plan has been analysed using two main methods:

- Peak surface flow rates have been calculated using probabilistic methods outlined in *Australian Rainfall and Runoff* (Institution of Engineers Australia, 2001); and

- Annual runoff volumes, and particularly the distribution of rainfall to surface flow and groundwater flow, has been analysed using continuous simulation analysis in the hydrologic module of MUSIC software.

Full details of these analyses are provided in **Appendix J - Stormwater Quantity Analysis** and are summarised in the sections below.

11.2.2 Stormwater Quality

To assess the potential impacts of stormwater runoff generated by the GKI Resort Revitalisation Plan on the surface water quality in receiving waters, modelling has been undertaken using MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software. MUSIC is a software tool that simulates the behaviour of stormwater in catchments and is the preferred tool for demonstrating the performance of stormwater quality treatment systems within urban areas.

MUSIC modelling is used to quantify stormwater pollutant concentrations and average annual loads, and to assess the effectiveness of various stormwater quality improvement devices in reducing pollutant loads and concentrations. Subsequent pollutant load reductions and discharge concentrations can then be compared against relevant water quality objectives and guidelines to determine compliance.

Detailed analysis results are provided in **Appendix K - Stormwater Quality Analysis**.

11.3 OBJECTIVES & TARGETS

11.3.1 Stormwater Quantity

The primary objectives for managing stormwater quantity have been derived from *State Planning Policy (SPP) 4/10 - Healthy Waters* (May 2011) and include:

- The waterway stability objective of SPP 4/10 requires that new developments manage flows such that the post-development one-year ARI event discharge rate within the downstream waterway is no greater than the pre-development peak one-year ARI event discharge rate; and

- To protect in-stream ecology of ephemeral freshwater waterways, SPP 4/10 requires new development to manage the increase in the number of small runoff events that occur from impervious surfaces compared to natural vegetated surfaces. This objective is typically satisfied by capturing and managing the first 10mm of runoff from impervious surfaces each day.

11.3.2 Stormwater Quality

The primary objectives for managing stormwater quality have been derived from *State Planning Policy (SPP) 4/10 - Healthy Waters* (May 2011) and the draft *Urban Stormwater - Queensland Best Practice Environment Management Guidelines 2009*, which are the primary documents used in Queensland for the planning, design and assessment of stormwater management systems.

SPP 4/10 (and supporting documents) nominates specific minimum stormwater pollutant load reductions required to be met by development throughout Queensland. The nominated minimums have been based on research and modelling work undertaken by a number of Australian organisations. The research has included operational testing of constructed stormwater quality management devices.

Adopting predictive modelling techniques to quantify estimates of stormwater pollutant concentrations and loads from urban land surfaces, and the pollutant removal efficacy of current best practice stormwater treatment infrastructure, is now an accepted method for establishing best practice stormwater management complying with SPP 4/10.

In recent years, significant research effort has been applied to develop modelling methods that can estimate the level of stormwater quality improvement necessary for a site to ensure that the defined WQOs and EVs for receiving waters can be achieved and protected. Currently, surface water quality modelling tools such as MUSIC, are only able to model and predict Total Suspended Solids (TSS), Total Phosphorous (TP), Total Nitrogen (TN) and Gross Pollutants (GP).

Stormwater quality improvement objectives for the GKI Resort Revitalisation Plan have been derived from Table 2.1b of the draft *Queensland Best Practice Environmental Management Guidelines*. For the relevant region (Central Coast South), minimum target reductions in mean annual loads for the modelled pollutants are as follows:

- Suspended Solids (TSS) = 85%
- Total Phosphorus (TP) = 70%
- Total Nitrogen (TN) = 45%
- Gross Pollutants (GP) = 90%

The target load reductions detailed in the draft *Queensland Best Practice Environmental Management Guidelines* were derived using a "diminishing returns" analysis balancing incremental community costs against improved environmental benefits. Whilst the target load reductions are not necessarily the maximum that can possibly be achieved, they have been derived following rigorous analysis.

In addition to demonstrating compliance with pollutant load reduction targets as specified above, the analysis outlined in detail below demonstrates that the stormwater quality improvement methods proposed to achieve the nominated load reductions will also reduce modelled pollutant concentrations in runoff below those which presently exist. As such, the modelling predicts that the Project will result in no worsening of existing stormwater discharge quality predicted by the modelling.

11.4 STORMWATER QUANTITY

11.4.1 Surface Flow Rates

Peak surface flow rates were calculated using the Rational Method, generally as outlined in Book IV of *Australian Rainfall and Runoff* (Institution of Engineers Australia, 2001). Surface flow rates are directly related to the proportion of impervious surface in any catchment so an increased impervious area associated with new buildings and other hardstand surfaces such as roads, increases peak surface flow rates compared to natural pervious surfaces.

Increased peak flow rates are of concern due to the increased potential for scouring and erosion that may occur where such flows are concentrated. Where surface flows are not concentrated and are discharged in a dispersed manner, the potential for scouring is generally not significantly increased. As surface flows from the Marina Precinct will discharge to the ocean without being concentrated in a channelised drainage line where scouring could occur, analysis of pre-development and post-development peak flow rates from Catchment 14 – Marina Precinct is not considered necessary.

The waterway stability objective of SPP 4/10 requires that new developments manage flows such that the post-development one-year ARI event discharge within the downstream waterway is no greater than the pre-development peak one-year ARI event discharge. Generally, detention of surface runoff from developed areas is necessary to achieve this objective. Mitigating post-development flow rates to, or below, pre-development levels also mitigates post-development waterway flow velocities to, or below, pre-development levels. Maintaining existing flow velocities means there will be no adverse impact on scouring or erosion rates, potential flooding or in-stream habitat within downstream waterways.

Tables 11.2 to 11.6 provide a comparison of pre-development and post-development peak flow rates in catchments containing elements of the GKI Resort Revitalisation Plan (except Catchment 14 – Marina Precinct). The analysis indicates that the Project could potentially increase peak flow rates by amounts ranging from 0.5% (Catchment 5 – Clam Bay) to 90.2% (Catchment 9 – Putney Creek).

To achieve non-worsening of peak flow rates and demonstrate compliance with the waterway stability objective of SPP 4/10, routing analyses have been undertaken to determine preliminary sizes of detention structures required. Details of the preliminary sizing of detention required for each catchment to achieve non-worsening of peak flow rates in downstream waterways is provided in **Tables 11.2 to 11.6.**

TABLE 11.2: Catchment 5 (Peak Flow Rates from Catchment to Clam Bay)

Average Recurrence Interval (years)	Pre-development Peak Discharge (m^3/s)	Post-development Peak Discharge - Unmitigated (m^3/s)	Post-development Peak Discharge - Mitigated (m^3/s)	% Reduction in Peak Flow	"No worsening" achieved?
1	3.22	3.23	3.19	0.9	Yes
2	4.42	4.44	4.37	1.1	Yes
5	6.34	6.37	6.29	0.8	Yes
10	7.58	7.61	7.51	0.9	Yes
20	9.24	9.28	8.98	2.8	Yes
50	12.02	12.08	11.36	5.5	Yes
100	14.11	14.18	13.14	6.9	Yes

TABLE 11.3: Catchment 7 (Peak Flow Rates to Long Beach from GKI Property & Catchments Downstream)

Average Recurrence Interval (years)	Pre-development Peak Discharge (m^3/s)	Post-development Peak Discharge - Unmitigated (m^3/s)	Post-development Peak Discharge - Mitigated (m^3/s)	% Reduction in Peak Flow	"No worsening" achieved?
1	3.08	3.89	2.62	14.9	Yes
2	4.23	5.34	3.89	8.0	Yes
5	6.05	7.65	5.91	2.3	Yes
10	7.24	9.14	7.21	0.4	Yes
20	8.82	11.14	8.64	2.0	Yes
50	11.48	14.50	10.65	7.2	Yes
100	13.47	17.02	12.20	9.4	Yes

TABLE 11.4: Catchment 8 (Peak Flow Rates to Fisherman's Beach from GKI Property).

Average Recurrence Interval (years)	Pre-development Peak Discharge (m^3/s)	Post-development Peak Discharge - Unmitigated (m^3/s)
1	3.37	4.44
2	4.63	6.09
5	6.63	8.72
10	7.91	10.41
20	9.64	12.68
50	12.53	16.48
100	14.69	19.33

Note: These flows are distributed over a wide beach frontage and are not concentrated at specific points.

Similar to Catchment 14, Catchment 8 discharges via dispersed flows across Fisherman's Beach to the ocean, with no downstream waterway that might be impacted by discharge rate increases. As such, no detention is proposed within this catchment. This will be confirmed during the final design stage and, if necessary, detention basins designed and implemented.

TABLE 11.5: Catchment 9 (Peak Flow Rates at the Mouth of Putney Creek)

Average Recurrence Interval (years)	Pre-development Peak Discharge (m^3/s)	Post-development Peak Discharge - Unmitigated (m^3/s)	Post-development Peak Discharge - Mitigated (m^3/s)	% Reduction in Peak Flow	"No worsening" achieved?
1	3.46	6.58	2.60	25.3	Yes
2	4.75	9.03	3.97	16.4	Yes
5	6.77	12.88	6.28	7.2	Yes
10	8.07	15.35	7.76	3.8	Yes
20	9.82	18.68	9.18	6.5	Yes
50	12.75	24.24	11.79	7.5	Yes
100	14.93	28.40	13.54	9.3	Yes

TABLE 11.6: Catchment 11 (Peak Flow Rates at the Mouth of Leeke's Creek)

Average Recurrence Interval (years)	Pre-development Peak Discharge (m^3/s)	Post-development Peak Discharge - Unmitigated (m^3/s)	Post-development Peak Discharge - Mitigated (m^3/s)	% Reduction in Peak Flow	"No worsening" achieved?
1	7.03	7.61	6.59	6.3	Yes
2	9.68	10.49	9.31	3.8	Yes
5	13.99	15.16	13.79	1.4	Yes
10	16.81	18.20	16.46	2.1	Yes
20	20.57	22.27	19.45	5.4	Yes
50	26.88	29.11	24.33	9.5	Yes
100	31.64	34.27	28.23	10.8	Yes

Table 11.7 below summarises the estimated size (volume and surface area) of required detention basins for each catchment. The surface area of each basin has been based on a maximum basin depth of 1.2m for a Q20 event. The nominated detention basin sizes mitigate all runoff events up to the 100 year recurrence interval. This significantly exceeds the requirements of SPP 4/10, which only requires flow mitigation up to the 1 year recurrence level.

TABLE 11.7: Required Detention Basins Sizes for Each Catchment

Catchment	Basin Volume (ML)	Basin Surface Area (Ha)
9	13.5	1.1
11	8.1	0.7
5	1.8	0.2
7	5.5	0.5

Although the exact location and design of detention basins will need to be confirmed during detailed design stages, modelling undertaken to date indicates that detention requirements to mitigate post-development peak flow rates to, or below, pre-development levels are relatively small. As such, it is anticipated that the required detention basins can be readily integrated into landscaped elements of the GKI Resort Revitalisation Plan without requiring any significant increase in the Project footprint.

A number of areas within the GKI Resort Revitalisation Plan have been identified as suitable sites for detention structures. The approximate locations of suitable detention structures (Drawing No. R03) and typical details (Drawing No. R02) are contained in **Appendix L - Stormwater Drawings**.

It is envisaged that detention structures will comprise low impact designs utilising relatively low grassed or vegetated mounds enclosing open space, which will be integrated with landscaped areas to provide multi-purpose stormwater management and landscape amenity.

Detention structures will be located such that runoff from storm events exceeding the detention basin design event can bypass safely around the outside of the structure to reduce the risk of embankment collapse that could occur if ponds are allowed to overflow in an uncontrolled manner. Civil designs (building pads, roads, surface flow paths and piped networks) will direct stormwater runoff from catchments to the relevant detention basins, primarily though the use of overland flow paths consisting of grassed swales or similar to contribute further to stormwater quality improvement and environmental health as discussed in **section 11.5**.

11.4.2 Runoff Volumes

Construction of buildings and infrastructure associated with the GKI Resort Revitalisation Plan will increase the total area of impervious surfaces on the Island and will decrease the area of pervious surfaces. This change in the relativity of impervious area to pervious area will alter the proportion of rainfall that becomes surface runoff, groundwater or is lost through evapo-transpiration.

Annual runoff volumes, and particularly the distribution of rainfall to surface flow, groundwater and evapo-transpiration, have been analysed using continuous simulation analysis in the hydrologic module of MUSIC software.

Table 11.8 below outlines the anticipated changes in average annual runoff volumes in the various catchments as a result of the proposed GKI Resort Revitalisation Plan .

TABLE 11.8: Average Annual Volumes Estimated for Pre-Development & Post-Development

Catchment	Average annual volume to surface runoff (ML per year)		Average annual volume to groundwater (ML per year)		Average annual volume to evapo-transpiration (ML per year)		Average annual volume harvested from the roof water (ML per year)
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Post-
9	21.3	85.7	133.4	184.7	687.7	570.6	2.0
11	19.1	33.1	398.7	410.9	2051.4	2024.3	9.4
5	2.2	2.4	82.4	82.3	423.7	423.6	0.2
7	3.3	13.4	80.7	87.5	415.3	398.2	2.1
8	37.6	40.7	55.0	85.6	337.8	313.8	5.2

The modelling suggests that the main change will comprise increases in surface runoff and groundwater recharge volumes in some catchments. The modelling suggests that installation of rainwater tanks to capture and reuse roof water from the ecotourism villas alone will remove approximately 19ML per annum from the volume that would otherwise become surface runoff. This is based on installation of 1,500 L of rainwater storage for each ecotourism villa. Given that it is proposed to provide rainwater capture and reuse on all core resort and marina facilities as described in **section 9.2**, the modelling provides an extremely conservative assessment of potential increases in stormwater runoff volumes.

Furthermore, the modelling does not account for infiltration losses in the surface drainage and detention basin network, which could be expected to be relatively high given the permeability of the sandy soils on the Island. The harvesting of stormwater runoff for irrigation water supply proposed as part of the water cycle management strategy will also contributing to reducing surface runoff volumes. On this basis, it can reasonably be expected that actual surface runoff volumes discharging to the main waterways post-development will be somewhat less than the modelling predicts.

11.4.3 Frequent Flow Management

To protect in-stream ecology of ephemeral freshwater waterways, SPP 4/10 requires development to manage the increase in the number of small runoff events that occur from impervious surfaces compared to natural vegetated surfaces. This objective is typically satisfied by capturing and managing the first 10mm of runoff from impervious surfaces each day.

Geotechnical investigations undertaken on Great Keppel Island confirm that soils within the main precincts are sandy and characterised by high permeability, typically between 1.5m/day and 3.5m/day.

Only two of the catchments affected by the GKI Resort Revitalisation Plan discharge to ephemeral freshwater streams, these being Catchment 9, which discharges to Putney Creek and Catchment 11, which discharges to Leeke's Creek.

The proposed bio-retention and detention structures in these two catchments intercept all runoff from impervious surfaces before it reaches the respective defined waterways. In both catchments, the daily infiltration capacity of the treatment structures far exceeds the volume of the first 10mm of rainfall on the respective impervious surfaces.

Table 11.9 below compares the required capture and disposal volume with the infiltration capacity of proposed treatment structures in each catchment. This comparison of capture and disposal volumes with infiltration capacity is conservative as it does not account for the additional infiltration that will occur from the surface drainage network. The comparison demonstrates that the proposed treatment structures provide more than sufficient capacity to manage frequent flows in accordance with SPP 4/10.

TABLE 11.9: Frequent Flow Management - Comparison of Capture and Disposal Volume with Infiltration Capacity

Catchment	Total Impervious Area (ha)	Required Daily Capture & Dispose Volume (ML)	Area of Bio-Retention & Detention Structures (ha)	Daily Disposal Capacity (ML)	Ratio of Disposal Capacity to Requirement
9 – Putney Creek	23.8	2.3	1.7	39.9	17.3
11 – Leeke's Creek	6.2	0.7	1.4	32.4	46.3

11.4.4 Putney Creek Mouth

Based on observations made during a site visit and discussions with local resident, Mr Gerry Christie, it is understood that the mouth of Putney Creek is regularly blocked by a sand bar (refer **Photo 1**). The sand bar is washed out occasionally by large storm runoff events and is then slowly rebuilt by normal wave processes on the beach. The sand bar effectively provides a sediment trap at the mouth of Putney Creek for smaller flow events (i.e. those that do not wash out the bar).

When the bar is washed out, tidal flows are able to move in and out of the mouth until beach wave processes rebuild the bar and the wetland gradually reforms until the next large storm event. As a result, ecosystems present at the creek mouth are influenced by both periodic tidal and freshwater flows. Depending on the duration of the tidal / freshwater phases, observations made during a site visit indicate that dieback of more salt-tolerant vegetation may occur during prolonged periods of sand bar formation (refer **Photos 2 and 3**).

Photo 11.1: Sand bar blockage of Putney Creek mouth observed during site visit (20 October 2010).

Photo 11.2: Vegetation near mouth of Putney Creek, showing apparent die-back of she-oaks (20 October 2010).

Photo 11.3: Vegetation further inland of Putney Creek mouth compared to Photo 2, showing more extensive evidence of apparent die-back of she-oaks (20 October 2010).

The natural hydrology of Putney Creek is believed to have been modified as a result of a number of previous land use activities, including but not limited to, construction of the existing runway, which it is understood, was built over semi-permanent waterholes and lagoons and blocked the natural drainage (CEPLA, 2011). Construction of the existing runway is likely to have modified flows within Putney Creek. However, it is uncertain whether past modification of flows has contributed to the current sand bar building process or whether this is a long standing natural process.

Construction of the marina will prevent the sand bar building wave processes from occurring, which would likely result in the Putney Creek mouth opening up to tidal influence. However, this opening up of the creek mouth would also result in sediment deposition within the proposed marina basin. The Putney Creek mouth could therefore be treated in one of three general ways:

- Remove the bar and open the creek mouth so that the lower reaches of the creek will become tidal; OR
- Re-construct the creek mouth with an artificial bar (a weir set at the existing bar level) so that the creek at the mouth is always a freshwater wetland; OR
- Re-construct the mouth with a moveable artificial bar (a collapsible or moveable weir set normally at the existing bar level but designed to be lowered occasionally to allow occasional washing out).

In relation to the above options, discussions with FRC Environmental, Chenoweth Environmental Planning and Landscape Architecture (CEPLA) and International Marina Consultants, identified that creation of an 'open' tidal creek system was considered to be the most appropriate solution from both an ecological, amenity and maintenance perspective.

By opening the creek mouth to regular tidal movement, fisheries productivity within the lower reaches of Putney Creek is expected to be increased significantly (FRC Environmental, 2011). Creation of a temporary or permanent barrier in an effort to replace the existing sand bar formation / removal process, would likely result in either permanent or temporary formation of a freshwater wetland system, which is likely to be less productive from a fisheries perspective. Given the levels of nutrients recorded within Putney Creek during water quality monitoring by FRC Environmental (2011), a closed system would likely be characterised by eutrophied conditions that could result in algal blooms with potential for consequent impacts on aquatic fauna and odour generation. For these reasons, opening of the Putney Creek mouth to reinstate what is likely to resemble the more natural hydrology prior to construction of the existing runway, would result in increased flushing and fisheries productivity.

Accordingly, at the discharge point of Putney Creek into the marina, a permanent, lined, discharge channel will be established below the boardwalk and esplanade. The boardwalk and esplanade will bridge over the channel. A lined transition zone will be established within the channel upstream of the bridged area. Lining of the channel is required to prevent scouring, which would result in increased deposition of sediment within the marina basin. A range of options are available for lining the channel to prevent scouring with the preferred material to be selected on the basis of not only being able to reduce scour, but also to provide fisheries habitat and contribute to the aesthetics of the Marina Precinct. This may involve the use of placed rock, which will provide a relatively natural substrate for establishment of various encrusting marine species, as well as creating crevices and gaps to provide habitat and refuge for a wide range of marine flora and fauna.

Based on advice from International Marina Consultants, a sediment basin has been incorporated into the proposed works at the Putney Creek mouth. The sediment basin will be constructed in the lined transition section of the channel. The sediment basin will reduce siltation within the marina thereby avoiding the need for ongoing maintenance dredging within the marina basin, which would result in ongoing disturbance of the marine environment. The design will include full provision for easy maintenance access by appropriate de-silting equipment.

11.5 STORMWATER QUALITY

11.5.1 Model Inputs & Assumptions

Rainfall and evaporation data from the Bureau of Meteorology's nearest recording (Site No. 39083 Rockhampton) has been used in MUSIC modelling, with the adopted rainfall data sequence being in accordance with that required by the *Urban Stormwater – Queensland Best Practice Environmental Management Guidelines 2009* (i.e. 1980 – 1989 at 6 minute time steps).

Soil characteristics adopted in the MUSIC have been calibrated in accordance with *MUSIC calibration based on soil conditions* using information from the geotechnical investigations (Douglas Partners, 2010) and are summarised as follows:

TABLE 11.10: Soil Characteristics in MUSIC Model

Soil Characteristic	Calibrated Input
Soil Storage Capacity	175 mm
Field Capacity	75 mm
Infiltration Capacity Coefficient - a	200
Infiltration Capacity Exponent - b	0.5
Initial Depth	50 mm
Daily Recharge Rate	75%
Daily Baseflow Rate	50%
Daily Deep Seepage Rate	0%

For the purpose of MUSIC modelling, it was assumed that rainwater from roof surfaces associated with the 750 proposed ecotourism villas only was capture d and reused. This provides a conservative assessment to modelling of potential stormwater quality impacts given that it is likely that rainwater capture and reuse will occur from the majority of roof surfaces within the GKI Resort Revitalisation Plan. The assumption of less roofwater capture and reuse conservatively overestimates the volume of runoff and thus pollutant loads in the modelling.

Pollutant generation rates adopted for various land uses within the catchments containing elements of the GKI Resort Revitalisation Plan have been derived from the *Southeast Queensland MUSIC Modelling Guidelines – Version 1*. Pollutant generation parameters for developed precincts within the GKI Resort Revitalisation Plan have been modelled using the "Rural Residential" pollutant export parameters derived from Table 3.9 of the *Southeast Queensland MUSIC Modelling Guidelines – Version 1.* The pre-development scenario and undeveloped areas within the GKI Resort Revitalisation Plan have been modelled using the "Forest" pollutant export parameters derived from Table 3.9 of the *Southeast Queensland MUSIC Modelling Guidelines – Version 1.*

Full details of the extensive MUSIC analyses (including model structure and parameters) and results are included in **Appendix K - Stormwater Quality Analyses**.

11.5.2 Management Concepts

General

Given the nature of the site and its environmental significance, it is important that stormwater quality improvement devices are robust and well proven. With that in mind, the choice of treatment devices has been limited to bio-retention basins, bio-retention swales and infiltration areas. These are all low impact structures and are key components of best practice water sensitive urban design. They are not visually intrusive and can generally be integrated with landscaping features. Maintenance requirements for such systems are not onerous and performance can be readily monitored by visual means.

Wetland treatment systems are not considered to be desirable for treatment of stormwater runoff from the GKI Resort Revitalisation Plan, on the basis that:

- Wetland treatment systems typically require at least 10 times the surface area of a bio-retention basin to achieve the same reduction in pollutant loads and would therefore be likely to increase the development footprint;
- Wetland treatment systems are also more prone to problems that can reduce their effectiveness and attractiveness, including attraction of pests (i.e. Ibis); and
- Wetland treatment systems are often much more difficult to repair if required, due to accessibility issues for machinery within wet areas.

Across a large proportion of the site, subsoils comprise of high permeability sand. The permeability of the subsoils determined through geotechnical investigations has been shown to be similar to the design permeability of the filters used in bio-retention basins or swales and significantly higher than that of typical mainland soils. Bio-retention filtrate can therefore drain directly to the sandy substrate with no specific under-drainage pipes required in the bio-retention areas.

This will significantly reduce or avoid the need for an extensive network of drainage pipes and associated trenching that would otherwise be required. As such, the extent of ground disturbance and vegetation clearing likely to be required for installation of the stormwater treatment will generally be limited to that required for installation of the stormwater treatment devices themselves. Infiltration of treated stormwater through the base of the bio-retention facilities will also contribute to recharge of groundwater resources mimicking the natural rainwater infiltration that occurs on the Island. It will also eliminate the concentration of drainage flows to a limited number of discharge points, which significantly reduces the potential for scouring and erosion.

An exception to this is the Marina Precinct where stormwater pollutant concentrations at the point of entry to the receiving water can be reduced by limiting the flow into the subsoils. Bio-retention basins in the Marina Precinct will have impermeable liners. As such, treated stormwater filtrate from these bio-retention basins will be collected in under-drainage pipes and discharged into the marina rather than being discharged into the subsoil.

Although bio-retention systems are capable of removing gross pollutants such as litter, frequent removal of debris is required to maintain effectiveness. In order to prevent litter from resort areas entering waterways where it may harm wildlife, specific gross pollutant traps will be installed as part of the stormwater treatment train in key locations where litter generation is most likely to be concentrated and where the risk of entering waterways is greatest (e.g. the Marina Precinct).

Specific Concepts

Hardstand Areas

For hardstand areas (roads, paved and sealed areas, airstrip and apron, parking areas) surface runoff will drain off the sealed area in a dispersed flow via flush kerbs or the like, and into adjoining bio-retention "cells". Where bio-retention cells are not able to be sited immediately adjacent to the sealed area, flows shall be directed to the relevant bio-retention cell via vegetated swales (as opposed to piped systems) wherever possible. Where piping is unavoidable, gully inlets should be sited in collector swales adjoining the sealed area, rather than in the sealed area itself.

Ecotourism Villas

For the ecotourism villas, roof runoff will be collected in gutters and piped to rainwater storage tanks for reuse. For the purpose of modelling, it has been assumed that 1,500L of storage tank is provided for each 200 m^2 of contributing roof area.

Where provided, rainwater tanks will be plumbed to toilet fittings for flushing, washing machines and externally for landscape watering. In the event that tanks are empty due to a lack of rainwater, automatic switching valves or float arrangements in the storage tanks will allow potable mains water to be used until rainwater is available.

All rainwater tank overflows will be directed to bio-retention cells. Where rainwater tanks are not provided, roof runoff is taken directly to the bio-retention cells for treatment prior to absorption into the natural underlying sandy soils.

Although modelling has conservatively assumed that only the ecotourism villas will contain rainwater tank capture and reuse, it is likely that all other accommodation and commercial buildings within the GKI Resort Revitalisation Plan will also incorporate storage tanks for collection and reuse of rainwater as per the *Queensland Development Code* (QDC). In this case, a similar arrangement to the ecotourism villas will be established.

Marina

For the marina and associated retail wharf area, all roof surfaces and other sealed areas will be collected and treated in the manner described above for the ecotourism villas and hardstand areas. That is, unlike traditional approaches to stormwater management, runoff from these areas will be treated prior to discharge to the ocean.

Golf Course

Stormwater management on the proposed golf course will consist of the following elements:

- All surface runoff from the proposed golf course will be diverted to stormwater harvesting ponds for reuse for irrigation of the golf course;
- Golf course runoff will be directed to the stormwater harvesting ponds through a series of grassed swales and / or bio-retention basins to facilitate removal of gross pollutants (e.g. litter) sediment and nutrients prior to entering the stormwater harvesting ponds;

- Stormwater harvesting ponds will incorporate an overflow provided with appropriate scour protection and outletting to a grassed overland flow channel providing further treatment prior to ultimately discharging to Leeke's Creek;

- Stormwater will be prevented from draining into wet weather storage ponds containing recycled water for irrigation of the golf course; and

- Monitoring of water quality within the stormwater harvesting ponds will be undertaken as part of the irrigation management plan proposed for the golf course to ensure water quality is 'fit for purpose' (refer **Appendix H - Preliminary Irrigation Management Plan**).

High Risk Areas

Specific stormwater management measures will be provided in high risk areas likely to contain significant quantities or types of contaminants not consistent with the assumptions of the stormwater modelling described in this section. This includes, but may not be limited to, areas used for the storage and handling of hazardous substances (e.g. chemicals, fuels and oils), bulk waste storage areas and maintenance workshops.

In general, such areas will be designed to prevent stormwater coming into contact with contaminants (e.g. use of perimeter diversion systems, sealing and covering of the area) and to prevent the release of contaminants accidentally spilled or leaked within the area (e.g. bunding). Any stormwater that does enter such areas would be collected and tested to ensure compliance with relevant water quality standards prior to disposal.

Further details are provided in **Appendix M - Preliminary Hazardous Substance Management Plan** and the "Waste Management Report" prepared by Opus International Consultants (2011a).

To support the above stormwater quality improvement concepts, overall civil, landscape and architectural designs will incorporate appropriate surface shaping to facilitate surface flow transport systems and bio-retention requirements.

11.5.3 Analysis Results

Detailed analysis results are provided in **Appendix K - Stormwater Quality Analysis**.

The modelling and analysis results demonstrate that the proposed mitigation measures achieve two key results:

- Reductions in mean annual loads for modelled pollutants that exceed (i.e. are better than) than the target values specified in SPP 4/10 - Healthy Waters (refer to **Table 11.11**); and

- Modelled post-development pollutant concentrations at the point of discharge to receiving waters during flow events that are equal to or lower than the modelled concentrations at the same discharge points under the existing conditions (i.e. non-worsening) (refer to **Table 11.12**).

A summary of mean annual load reduction results for each catchment is provided in **Table 11.11** below.

Table 11.11: Summary of Mean Annual Pollutant Load Reduction Results

Area	Indicator	Percent reduction target	No treatment - mean annual load (kg year^{-1})	Treated - mean annual load (kg year^{-1})	Percent reduction modelled	Complies?
5	TSS	≥85%	152.0	21.2	86.1%	Yes
	TP	≥70%	0.181	0.0422	76.7%	Yes
	TN	≥45%	1.51	0.401	73.3%	Yes
	GP	≥90%	9.91	0.0	100.0%	Yes
7	TSS	≥85%	7870.0	1040.0	86.8%	Yes
	TP	≥70%	8.00	2.00	75.0%	Yes
	TN	≥45%	63.5	23.7	62.7%	Yes
	GP	≥90%	566.0	0.0	100.0%	Yes
8	TSS	≥85%	24400	3530	85.6%	Yes
	TP	≥70%	22.6	5.84	74.1%	Yes
	TN	≥45%	180.0	72.8	59.6%	Yes
	GP	≥90%	1660.0	0.0	100.0%	Yes
9	TSS	≥85%	50100.0	7460.0	85.1%	Yes
	TP	≥70%	56.4	14.5	74.3%	Yes
	TN	≥45%	419.0	170.0	59.5%	Yes
	GP	≥90%	3790.0	0.0	100.0%	Yes
11	TSS	≥85%	16100.0	1930.0	88.0%	Yes
	TP	≥70%	16.4	3.11	81.0%	Yes
	TN	≥45%	132.0	37.4	71.7%	Yes
	GP	≥90%	1080.0	0.0	100.0%	Yes
14	TSS	≥85%	19400.0	1700.0	91.2%	Yes
	TP	≥70%	18.7	5.41	71.1%	Yes
	TN	≥45%	146.0	80.2	45.1%	Yes
	GP	≥90%	1400.0	0.0	100.0%	Yes

Table 11.12 provides a comparison of pre-development and post-development (mitigated) stormwater runoff calculations and demonstrates no worsening of stormwater quality compared to the pre-development scenario.

Table 11.12: Comparison of Pre-Development and Post-Development Runoff Concentrations

Catchment	Indicator	Existing (undeveloped) (mg/L)	Developed (mitigated) (mg/L)	Post-development concentrations are equal to or lower than existing?
5	TSS (annual mean)	31.20	6.12	Yes
	TP (annual median)	0.018	0.017	Yes
	TN (annual median)	0.273	0.262	Yes
	GP (annual median)	0.0005	0.0000	Yes
7	TSS (annual mean)	48.90	5.74	Yes
	TP (annual median)	0.020	0.018	Yes
	TN (annual median)	0.295	0.279	Yes
	GP (annual median)	0.0034	0.0000	Yes
8	TSS (annual mean)	65.80	54.20	Yes
	TP (annual median)	0.028	0.021	Yes
	TN (annual median)	0.354	0.310	Yes
	GP (annual median)	0.0866	0.0000	Yes
9	TSS (annual mean)	57.80	52.80	Yes
	TP (annual median)	0.021	0.021	Yes
	TN (annual median)	0.308	0.307	Yes
	GP (annual median)	0.0407	0.0000	Yes

Catchment	Indicator	Existing (undeveloped) (mg/L)	Developed (mitigated) (mg/L)	Post-development concentrations are equal to or lower than existing?
11	TSS (annual mean)	48.70	5.35	Yes
	TP (annual median)	0.019	0.017	Yes
	TN (annual median)	0.289	0.263	Yes
	GP (annual median)	0.0196	0.0000	Yes
14	TSS (annual mean)	12.50	12.50	Yes
	TP (annual median)	0.091	0.091	Yes
	TN (annual median)	1.020	1.010	Yes
	GP (annual median)	0.0000	0.0000	Yes

11.5.4 Stormwater Quality Improvement Devices

Typical details of the proposed stormwater quality improvement structures are illustrated on drawing number R02 contained in **Appendix L – Stormwater Drawings.**

To enhance the overall environmental benefits, it is strongly recommended that a distributed or decentralised network of smaller bio retention "cells" should be provided, rather than larger, centralised catchment scale structures. Accordingly, sizing details have been provided in a "per unit" format.

Table 11.13 below details minimum sizing (area and depth) for stormwater quality management in the various catchments.

As the detailed architectural, landscaping and civil engineering designs are developed, bio-retention structures for each specific contributing catchment area should be located in a distributed fashion throughout the developed areas to suit surface flow patterns and to enhance local landscaping.

TABLE 11.13 – Stormwater Quality Improvement Devices - Minimum Sizing Requirements

Area	Bio-retention Basin Details per 1000m^2 of Catchment Area		
	Filter Area (m^2)	Surface Area (m^2)	Extended Detention Depth (m)
5	2.5	20	0.1
7	2.5	20	0.1
8	10	20	0.1
9	5	22	0.1
11	2.0	19	0.1
14	22	40	0.1

Relevant components of the stormwater quality improvement devices will be detailed generally in accordance with details and specifications contained in the *Water Sensitive Urban Design Guidelines for South East Queensland* (Healthy Waterways - Version 1 June 2006).

11.5.5 Post-Construction Monitoring

Operational testing of full-scale constructed stormwater quality management devices has shown that correctly designed and constructed devices actually perform better than is anticipated by modelling. Accordingly, provided that stormwater quality management devices are:

- modelled using appropriate software (MUSIC);
- detailed in accordance with the Water Sensitive Urban Design Technical Design Guidelines; and
- constructed as detailed;

then no specific operational testing is necessary.

As indicated earlier, the proposed stormwater quality improvement treatment train has been specifically chosen to be robust and with proven performance. That is:

- Performance monitoring is largely visual;
- Regular maintenance is generally limited to plant health checks and removal of sediments and litter; and
- Regular maintenance can largely be carried out by general landscaping maintenance personnel.

A preliminary stormwater quality maintenance plan is included in **Appendix H - Preliminary Stormwater Quality Maintenance Plan**.

12. POTENTIAL IMPACTS AND MITIGATION MEASURES

12.1 OVERVIEW

A risk assessment of potential environmental impacts associated with proposed water cycle management aspects of the GKI Resort Revitalisation Plan has been undertaken and is described in the following section, along with proposed mitigation measures to address each identified risk. A standard risk assessment matrix as presented in **Table 12.1** has been used for the purpose of assessing risks associated with water supply, wastewater and stormwater drainage strategies proposed for the GKI Resort Revitalisation Plan.

TABLE 12.1: Risk Assessment Matrix

Probability	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Rare	Low	Low	Low	Low	Medium
Unlikely	Low	Low	Medium	Medium	Medium
Moderate	Low	Medium	Medium	High	High
Likely	Low	Medium	High	High	Extreme
Almost Certain	Medium	Medium	High	Extreme	Extreme

The following risk assessment has been based on the proposed water supply, wastewater and stormwater management strategies outlined in **sections 9, 10** and **11** of this Report.

A summary of potential impacts and proposed mitigation measures associated with water cycle management as part of the GKI Resort Revitalisation Plan is provided in **Table 12.2** below.

TABLE 12.2: Summary of Potential Water Supply, Wastewater & Stormwater Impacts and Proposed Mitigation Measures

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Construction of Water Cycle Infrastructure			
Removal of vegetation for construction of water cycle infrastructure resulting in loss of habitat and increased risk of erosion and sedimentation of waterways.	High	Low	Where possible, water cycle infrastructure requiring trenching will be co-located with other infrastructure (e.g. roads) to reduce the extent of vegetation clearing required. Proposed stormwater drainage systems

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			have been designed to maximise the use of surface flow paths (e.g. swales) for conveying stormwater from source to destination to reduce the need for installation of extensive underground piped drainage systems. Sandy subsoils will enable filtered stormwater from bio-retention treatment systems to infiltrate into natural soils to recharge groundwater and mimic the natural hydrologic system on the Island, which will also reduce the need for installation of extensive underground piped drainage systems. Rehabilitation of all areas cleared for construction of water cycle infrastructure will be provided in accordance with the requirements of relevant statutory authorities. Where necessary, environmental offsets will be provided for cleared vegetation in accordance with the relevant guidelines and policies for providing such offsets.
Excavation and filling for construction of water cycle infrastructure resulting in increased risk of erosion and sedimentation of waterways.	Low	Low	As noted above, the need for excavation and filling will be reduced by co-locating water cycle infrastructure with roads and other infrastructure, and utilising stormwater drainage systems that do not require extensive underground piped drainage networks. Best practice erosion and sediment control measures will be implemented for all works associated with construction of water cycle infrastructure. Rehabilitation of all disturbed areas will be provided in accordance with the requirements of relevant statutory authorities and will occur progressively throughout construction to minimise the duration of soil exposure to erosive forces. A preliminary erosion and sediment control plan has been prepared to outline a range of controls that should be implemented during construction of the GKI Resort Revitalisation Plan to reduce erosion and

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			sedimentation issues (refer to **Appendix O - Preliminary Erosion and Sediment Control Plan**). Stormwater diversion systems will be designed to prevent inundation of work sites and erosion and sediment control measures will be designed to remain effective during more intense rainfall events projected to occur as a result of climate change. A 20% buffer will be applied to maximum design flows to allow for a possible 16% increase in the intensity of a 24-hour rain event projected for 2070 (Opus International Consultants, 2011b).
Disturbance of acid sulphate soils for construction of water cycle infrastructure (e.g. mainland water supply connection, emergency ocean outfall) resulting in release of acid discharge and heavy metals impacting on water quality and ecological communities.	Medium	Low	Construction of water cycle infrastructure within areas containing potential acid sulphate soils shall be avoided as far as practicable through careful selection of infrastructure alignments in consultation with the relevant authorities and geotechnical advice. From initial geotechnical report, sandy soils are prevalent throughout the Island with low probability of acid sulphate soils. A potential source of acid sulphate soils would be in excavations in and near the tidal zone associated with the water pipeline and power/ communications cable. This will be minor in extent compared to the project size and can be managed as below. All construction works in areas containing potential acid sulphate soils will be undertaken in accordance with a site specific acid sulphate soil management prepared in accordance with *SPP 2 / 02 – Planning and Managing Development Involving Acid Sulphate Soils* and the *Queensland Acid Sulphate Soil Technical Manual*.
Construction of water cycle infrastructure within watercourses interfering with the flow of water and providing barriers to fish movement (e.g. pipeline and access road crossings, detention basins) resulting in decreased biodiversity.	Medium	Low	The location of proposed roads and water cycle infrastructure will be selected to minimise the need for waterway crossings or where possible, will utilise existing crossings to avoid further interference. All works within waterways supporting the movement of fish and other aquatic fauna

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			should be designed in accordance with Fisheries Queensland's Self Assessable Codes for Temporary and Minor Waterway Barrier Works and other relevant design guidelines for maintaining fish passage through such structures.
Construction of water cycle infrastructure in tidal waters (e.g. mainland water supply connection, emergency ocean outfall) resulting in disturbance of marine plants and benthic habitat and increased turbidity.	High	Medium	Exact positioning of water cycle infrastructure within tidal waters will be determined in consultation with relevant authorities based on ecological assessments to determine the least impact alignment feasible. Preference will be given to the use of construction techniques and equipment that result in the minimum level of disturbance and footprint feasible. Best practice erosion and sediment control measures will be implemented for all works within tidal waters. Rehabilitation of all disturbed areas will be provided in accordance with the requirements of relevant statutory authorities. Where necessary, environmental offsets will be provided for all marine plant removal in accordance with the relevant guidelines and policies for providing such offsets.
Operation of Water Supply Infrastructure			
Water consumption within resort facilities exceeds projected water demands resulting in increased supply costs, need for infrastructure upgrades and increased pressure on valuable water resources.	Medium	Low	Regular water efficiency audits will be undertaken by the resort, approximately every 5 years, to ensure fixtures and fittings continue to achieve desired levels of water use efficiency and to identify any losses in the water supply system due to leakage or unauthorised connections. To enable monitoring of water usage and to inform water efficiency audits, flow meters will be installed on all water supply sources, including the mainland water supply connection, distribution systems for reuse of recycled water and harvested stormwater and groundwater production bores for Stage 1 construction. Records shall be kept of all water usage for at least

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			5 years. Critical water supply infrastructure such as the mainland water supply connection will be sized using appropriate peaking factors considering potential internal demands associated with peak occupancy and peak irrigation demands associated with low rainfall periods. Regular awareness training shall be provided to all staff in relation to the importance of water use efficiency. Information shall be provided to guests through resort signage and other applications (e.g. Smartphone apps). Information relating to water usage by the GKI Resort Revitalisation Plan, including water supply sources used, will regularly be made available to the public through the resort's website or other means to demonstrate the resort's sustainability performance.
Damage to mainland water supply connection resulting in disruption to water supply services on the Island.	High	Medium	The main will be buried up to 1.2 m below the sea bed and signposted to ensure that the risk of physical damage (eg dragging of anchors etc) is minimised. In the event of damage to the mainland water supply connection, preservation of stored water will be a priority and water restrictions applied. Where necessary, potable water supplies may be transported to the Island by barge. In the event of extended disruption to the mainland water supply connection, consideration will be given to reducing guest occupancy and staffing to preserve the available water supply.
Excessive extraction of groundwater resulting in lowering of water tables impacting on groundwater dependent ecosystems.	Medium	Low	Groundwater will not be used as a primary source of water supply during operation of the GKI Resort Revitalisation Plan. Groundwater extraction from existing production bores within the Long Beach Aquifer will be used for Stage 1

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			construction water supply only. Extraction from the Long Beach production bores will not exceed 100kL/day in accordance with the assessed sustainable yield, which is more than adequate to meet projected constructed water demands of up to 90 kL/day. Flow meters will be installed on these bores to monitor extraction and records will be kept to ensure the sustainable yield is not exceeded. No production bores will be installed in the Central Dune Aquifer or North West Aquifer. No extraction from existing bores within the Resort Aquifer will occur during any stage of the Project. Monitoring of groundwater levels and water quality will be undertaken for the GKI Resort Revitalisation Plan for any periods during which groundwater extraction and / or recycled water irrigation occur on the Island.
Excessive extraction of groundwater resulting in lowering of water tables and saline intrusion, which could impact on availability of suitable water supply to other users.	Medium	Low	As above.
Operation of Wastewater Infrastructure			
Irrigation of recycled water resulting in runoff of nutrients causing contamination of surface water resources.	Medium	Low	Proposed recycled water irrigation areas are located within sandy soils characterised by high permeability and therefore low likelihood of runoff. A detailed water and nutrient balance has been undertaken and based on the proposed irrigation regime, no direct runoff of recycled water will occur. Further, runoff rates predicted by MEDLI modelling for the proposed irrigation scheme will be less than predicted rates of runoff under no irrigation due to the enhanced rates of evapo-transpiration achieved by increased plant coverage supported by irrigation. Implementation of the proposed irrigation scheme in accordance with **Appendix H - Preliminary Irrigation Management Plan**

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			combined with the naturally low risk of runoff will therefore significantly reduce the risk of runoff from the irrigation area.
Irrigation of recycled water resulting in excessive leaching of nutrients causing contamination of groundwater resources.	High	Low	All recycled water will be treated to achieve a total nitrogen concentration of <20mg/L and a total phosphorous concentration of less than 7mg/L. A detailed water and nutrient balance has been undertaken and demonstrates that recycled water treated to the proposed standard will not result in leaching of nutrients in excess of the rates expected to occur naturally and will result in nitrogen and phosphorous concentrations in groundwater that comply with water quality objectives for discharge to Leeke's Creek and Wetland. Further modelling to roughly simulate application of fertilisers within the irrigation area has established an indicative sustainable load for nitrogen application of 115.4 kg/ha/year and phosphorous application of 47.4 kg/ha/year. In conjunction with regular monitoring of soils and groundwater quality proposed in **Appendix H - Preliminary Irrigation Management Plan**, these indicative loads will be used as the basis for developing a golf course maintenance plan to reduce the risk of nutrients entering groundwater and surface water resources on and around the Island.
Irrigation of recycled water resulting in raised water tables, saturation of soils and / or ponding within the irrigation area.	Medium	Low	Proposed recycled water irrigation areas are located within sandy soils characterised by high permeability and therefore high rates of deep drainage and groundwater recharge. A detailed water and nutrient balance has been undertaken and based on the proposed irrigation regime, deep drainage rates would increase by less than 5% above deep drainage rates predicted by MEDLI modelling for the irrigation area under no irrigation scheme.

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			Implementation of the proposed irrigation scheme in accordance with **Appendix H - Preliminary Irrigation Management Plan** combined with the naturally low risk of ponding due to sandy soils will therefore significantly reduce the risk of these issues arising in the irrigation area. However, monitoring is also proposed under **Appendix H - Preliminary Irrigation Management Plan** to detect any changes in groundwater levels that may occur.
Irrigation of recycled water resulting in decreased plant health and soil quality within the irrigation area due to excessive salinity.	Medium	Low	All recycled water will be treated to achieve a maximum total dissolved solids level of 1,000mg/L. A detailed water and nutrient balance has been undertaken and demonstrates that recycled water treated to the proposed standard will not result in any impacts on plant health or soil quality. Implementation of the proposed irrigation scheme in accordance with **Appendix H - Preliminary Irrigation Management Plan** combined with the naturally sandy soils will therefore significantly reduce the risk of salinity issues arising in the irrigation area. However, monitoring is also proposed under **Appendix H - Preliminary Irrigation Management Plan** to detect any changes in groundwater levels that may occur.
Exposure of the public to recycled water as a result of spray drift during recycled water irrigation causing nuisance or illness.	High (Likely / Major)	Low (Unlikely / Minor)	All recycled water used for irrigation will be treated to a standard suitable for irrigation of public open space with unrestricted access in accordance with the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (ANZECC, 2006), which is characterised by an *E. coli* level less than 1 cfu/100mL. However, in addition to this, to further reduce the risk of public exposure to recycled water, it is intended that irrigation of the golf course will primarily occur overnight when no players will be on the

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			course. The potential for spray drift into villas will be further reduced through the use of low-throw sprinklers producing large droplet size, use of sub-surface or surface dripper systems instead of spray irrigation within 25-30 metres of villas or other sensitive receivers and avoiding irrigation during windy conditions when prevailing winds are likely to spread spray drift beyond the boundaries of the irrigation area. Signage will be provided within recycled water irrigation areas notifying the public that recycled water is used and contact should be avoided.
Exposure of the public to recycled water as a result of storage of recycled water in open ponds on the golf course causing illness.	High	Low	All recycled water discharged to wet weather storage ponds will be treated to a standard suitable for irrigation of public open space with unrestricted access in accordance with the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (ANZECC, 2006), which is characterised by an *E. coli* level less than 1 cfu/100mL. Signage will be provided around all wet weather storage ponds notifying the public that the storage contains recycled water and contact should be avoided. Access to the ponds for retrieval of balls etc will be further discouraged by planting of vegetation (e.g. sedges, reeds) around the perimeter of the ponds.
Deterioration of water quality within recycled water storage ponds causing algal blooms and odour nuisance.	Medium	Low	All recycled water discharged to wet weather storage ponds will be treated to a standard suitable for irrigation of public open space with unrestricted access in accordance with the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (ANZECC, 2006). The proposed standard of treatment is characterised by relatively low levels of nutrients to reduce the potential for cyano-bacterial and other algal blooms, and low

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			levels of organic matter that reduce the risk of odour generation. Regular maintenance of recycled water storage ponds will be carried out to control pests in accordance with relevant statutory requirements, including managing excessive wildlife populations, that may reduce water quality within the storage. The potential for algal blooms will be significantly reduced by maintaining regular turnover of water within the storage through inflows and outflows. Where necessary, additional mechanical aeration may be required.
Emergency discharge of recycled water via ocean outfall reducing water quality and impacting on ecological communities.	Medium	Low	All recycled water shall be treated to achieve a total nitrogen concentration of <20mg/L, a total phosphorous concentration of less than 7mg/L and an *E. coli* level less than 1 cfu/100mL. MEDLI modelling indicates that less than 1% of all recycled water produced will be discharged via ocean outfall over the life of the Project. MEDLI modelling based on provision of a 37ML wet weather storage pond also indicates that discharge will occur on average, once every ten years during extreme or prolonged wet weather events similar to those rain events that occurred in 1957, 1974, 1989 and 2011. To account for possible increases in rainfall intensity as a result of climate change, open recycled water storages shall incorporate an additional 7 ML storage buffer which equates to about a 20% increase in the storage requirements identified by MEDLI modelling to achieve 99% reuse of recycled water. This additional storage capacity will provide a buffer for storing additional rainfall from more intense rain events, prior to overtopping of ponds discharging via the ocean outfall. It is therefore likely that the actual frequency of discharge will be significantly less than once every 10 years. The location of the proposed ocean outfall pipeline for emergency discharge of

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			recycled water has been selected in accordance with GBRMPA requirements relating to separation to particular use areas and depth of water requirements and to maximise dispersion of possible pollutants. Modelling of pollutant dispersion by Water Technology (2011) indicates that water quality objectives will be achieved with only a relatively small mixing zone surrounding the outfall.
Damage to ocean outfall pipeline preventing emergency discharge of recycled water when required resulting in uncontrolled overtopping of storage facilities.	Medium	Low	Regular inspections of the ocean outfall pipeline will be conducted and any necessary repairs undertaken promptly to ensure it is available for use when required. In the extremely unlikely event that the ocean outfall pipeline is not available at a time when wet weather storage facilities reach capacity due to prolonged wet weather, to prevent uncontrolled overtopping of the storage facility, the level of recycled water contained within the storage will be reduced, in consultation with the relevant authorities, by irrigation to the designated irrigation area regardless of soil moisture levels.
Generation of odour caused by operation of the sewage treatment plant and associated collection & storage systems causing nuisance at a sensitive place.	High	Low	To reduce the potential for odours at the sewage treatment plant, a packaged plant such as MBR is proposed as the process components are effectively sealed within the plant. Odour issues may arise in the event of power failure when influent is diverted to temporary storage in open ponds adjacent to the plant; however such events are expected to be rare. Nevertheless, appropriate buffer distances will be provided between the WWTP and sensitive receivers to reduce the potential for odour nuisance. Odour control within the collection system would be achieved by sealing of all manholes and pumping stations, thus containing any odours within the system.

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Mechanical malfunction or electricity failure affecting the sewerage collection system resulting in release of untreated sewage to the environment.	High	Low	The gravity sewer system would be unaffected by a power outage up until the collection well of pumping stations. Any individual unit grinder pump stations will be designed with storage capacity within the pump collection well for 4 hours at ADWF to allow for repairs or back-up generators to be connected. Main pumping stations would be provided with 100% stand-by pumping capacity within the station to cover pump mechanical breakdown and an alarm system on separate power supply (e.g. solar panels) to advise maintenance staff of power or mechanical failure. Main pumping stations would also be provided with capacity within the emergency back-up generator for the resort and / or provision (i.e. power bypass switch) within the pumping station to connect up an individual emergency generator brought to the pumping station to cover power failures. A minimum of 2 hours storage capacity at ADWF would be provided within the pump station wet wells and contributing reticulation (and overflow storage if required).
Mechanical malfunction of the sewerage treatment plant resulting in release of untreated sewage to the environment.	High	Low	Due to staging requirements and operational flexibility, the treatment system would involve duplication (or triplication) of treatment plant processes. This will allow for one system to be out of service for short periods in the event of maintenance requirements (programmed maintenance being undertaken at low flow / low occupancy times) or emergency breakdown situations due to mechanical malfunction.
Loss of electricity supply resulting in shutdown of sewerage collection and treatment systems resulting in release of untreated sewage to the environment.	High	Low	The potential for electricity supply to the sewerage collection and treatment systems to be interrupted will be significantly reduced by the proposal to install solar panels on the Island to provide 100% of the Project's electricity supply needs. Given

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			the proposed installation of a mainland electricity supply connection as a back-up, sewerage collection and treatment systems will have access to dual electricity supply systems. Emergency back-up generators will be provided to the treatment plant(s). Electricity distribution around the Island is proposed to be provided underground thus significantly reducing the risk of damage during a cyclonic event. In the event of a power outage, the treatment plant would be designed to redirect incoming wastewater to a 0.4ML lined storage pond alongside the plant, which has been sized to contain up to peak occupancy of 3,750EP at ADWF for approximately 10 hours. This storage capacity has been determined to provide sufficient storage for the estimated time required to restore power or reduce occupancy of the resort to reduce incoming sewage. After power is restored, the bypassed flow would then be returned from the storage pond back through the plant for treatment. Back-up generators will be installed to maintain operation of critical components of the treatment plant such as pumping systems.
Operation of Stormwater Infrastructure			
Increased peak discharge velocities causing scouring and erosion in downstream drainage lines and impacting on waterway stability.	High	Low	The proposed stormwater management strategy for the site includes provision for detention within each catchment containing elements of the GKI Resort Revitalisation Plan (except Catchment 14 – Marina Precinct as discussed in section 11). Proposed detention has been sized to ensure peak discharge flow rates do not exceed peak discharge flow rates for an undeveloped catchment.
Increased frequency of small runoff events altering flow regimes and in-stream habitat within receiving waters, impacting on biodiversity.	Medium	Low	Putney Creek and Leeke's Creek catchments are the only catchments containing elements of the GKI Resort Revitalisation Plan that contain ephemeral freshwater streams.

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
			Due to the high permeability sandy soils in these catchments, infiltration from detention and bio-retention facilities will be high. The infiltration capacity of proposed detention and bio-retention facilities has been assessed as being sufficient to account for the first 10mm or first flush of rainfall from impervious surfaces. As such, the potential for an increase in frequency of small scale runoff events will be reduced in accordance with SPP 4/10 and therefore no significant alteration of in-stream habitats is expected to occur.
Rainfall events exceed the design capacity of stormwater drainage systems resulting in flooding of buildings and other facilities, and possible flooding of neighbouring properties.	High	Medium	Stormwater drainage systems installed on the Island will be designed to manage flows up to a 1 in 100 year AEP storm event. To account of possible increases in rainfall intensity, stormwater infrastructure will be designed with an increased capacity sized to account for projected increases in rainfall intensity, including 48% increase for 2-hour event, 16% increase for 24-hour and 14% increase for 72-hour event.
Rainfall events exceed the design capacity of stormwater treatment systems resulting in release of untreated stormwater runoff	Medium	Low	As above, but note that in such extreme rainfall events, dilution will be significant factor in lowering risk associated with untreated stormwater releases.
Discharge of contaminated stormwater runoff from high risk areas to receiving waters impacting on water quality and environmental values.	Medium	Low	High risk areas containing hazardous substances or other potentially toxic materials or activities will be designed to prevent stormwater flowing into potentially contaminated areas (e.g. diversion drains, roofing) and containing any stormwater collected in potentially contaminated areas (e.g. bunding). Collected stormwater from such areas would be tested prior to disposal at an approved location. Further management strategies for potentially contaminated areas are contained in **Appendix M - Preliminary Hazardous Substances Management Plan** and the Waste Management Report (Opus International Consultants, 2011a).
Removal of sand bar at mouth of	Medium	Low	All proposed works within the mouth of

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Putney Creek resulting in increased tidal exchange within the lower reaches of the channel, possibly altering riparian vegetation and in-stream flora and fauna.			Putney Creek will be undertaken in accordance with statutory requirements and based on comprehensive ecological assessments. Preliminary ecological advice indicates that opening up of the Putney Creek mouth to tidal movement will increase fisheries productivity and increase flushing that will reduce potential for creation of eutrophied conditions and odour nuisance.

13. CONCLUSION

This Report outlines a holistic strategy for managing water supply, wastewater and stormwater aspects of the GKI Resort Revitalisation Plan consistent with the principles of water sensitive urban design. The proposed water cycle management strategy has been designed to:

- Protect existing natural features and ecological processes;
- Maintain the natural hydrologic behaviour of catchments;
- Protect water quality of surface and ground waters;
- Minimise demand on the reticulated water supply system;
- Minimise sewage discharges to the natural environment; and
- Integrate water into the landscape to enhance visual, social, cultural and ecological values.

Water Supply

Based on an evaluation of available water resources, the most suitable and sustainable means of providing water supply to the GKI Resort Revitalisation Plan will include a combination of the following:

- A mainland water supply connection via a new pipeline installed within the Utility Services Corridor;
- Installation of rainwater storage tanks for all resort buildings to capture and reuse roof water for non-potable purposes (e.g. toilet flushing, washing machines and garden watering);
- Installation of stormwater harvesting and storage facilities throughout resort area, and reuse of harvested stormwater for landscape irrigation and hardscape hose down (subject to further assessment in the design stage);
- Reuse of recycled water produced from effluent generated by the resort for irrigation of the golf course and possibly other landscaped areas; and
- Incorporation of stormwater harvesting ponds within the golf course to capture runoff and reuse for irrigation of the golf course.

Substantial groundwater resources are available on the Island and have the potential to supply up to 36 percent of the total mains water demand for the GKI Resort Revitalisation Plan with a total combined maximum yield for all aquifers of 460kL/day, including a maximum yield of 270kL/day from the North East Aquifer alone. However, use of groundwater as a primary water supply source during operation was not considered appropriate due to the potential for saline intrusion as shown by the historically poor management of this resource on GKI. Rather, apart from short-term, small-scale use for Stage 1 construction water supply, groundwater aquifers will be allowed to recover from past overuse so as to provide a better quality and more sustainable resource for other Island users.

Although desalination could potentially meet the full water demands of the Project and was used by the previous resort, operation of a desalination plant on the Island would significantly increase energy consumption and would involve discharge of highly saline brine into the Marine Park. As such, this water supply option was not considered to be consistent with the sustainability objectives of the GKI Resort Revitalisation Plan.

Rainwater tanks are considered to be an integral component of the proposed water supply strategy for the GKI Resort Revitalisation Plan. Although not capable of supplying the total water demands of the Project, rainwater tanks comprise a relatively low energy, low cost, easy to maintain and sustainable method of supplying water to significantly reduce overall mains water supply requirements.

Opportunities have also been identified within the GKI Resort Revitalisation Plan to capture and reuse stormwater runoff for irrigation of the golf course and landscaped areas. In addition to providing an additional source of irrigation water supply, harvesting of stormwater runoff from the golf course will assist in intercepting any residual fertilisers that may remain on the golf course enabling these nutrients to be reused via irrigation and preventing their release to natural waterways downstream.

Wastewater

The proposed strategy to manage wastewater generated by the GKI Resort Revitalisation Plan, will involve:

- A wastewater collection system utilising “NuSewers” and other similar technologies that are designed to minimise groundwater infiltration (due to the high water table on the Island), thus reducing treatment costs, along with sewage pumping stations (where required);

- An Island-based wastewater treatment plant (or treatment plants) designed to treat wastewater to a standard suitable for “Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application” under the *Australian Water Quality Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (ANZECC, 2006) with nutrient removal to achieve a total nitrogen concentration of 20mg/L and a total phosphorous concentration of 7mg/L;

- Beneficial reuse of almost 100% of recycled water produced by Island-based WWTPs for irrigation of the golf course (approximately 31 hectares) and possibly other landscaped areas around the resort;

- Emergency discharge of recycled water via an ocean outfall extending from Long Beach, during periods of extreme wet weather, which is expected to occur once every 10 years on average, resulting in less than 1% of total recycled water produced being discharged over a 50 year period; and

- A wet weather storage facility with a capacity of 44ML incorporating a 7ML buffer to account for projected increases in rainfall intensity as a result of climate change, which will be incorporated into the golf course design.

Although the exact treatment system to be used for the Island-based WWTP(s) will be determined at a later design stage, a package treatment plant utilising MBR technology or similar is preferred as such systems are capable of achieving the required standard of treatment, have a relatively small footprint, can be almost fully sealed to reduce odour generation and allow for the installation of multiple parallel treatment plants to support staging of the Project and provide operational flexibility.

A comprehensive water and nutrient balance has been modelled and demonstrates that the proposed recycled water irrigation scheme will not increase nutrient leaching or runoff rates compared to modelling of a no irrigation scenario. Modelling of nutrient concentrations in groundwater at the point of discharge to Leeke's Creek has demonstrated compliance with relevant water quality objectives. Modelling of possible emergency discharge of recycled water via ocean outfall has also demonstrated that nutrient levels will achieve compliance with relevant water quality objectives within a very small mixing zone and are therefore unlikely to impact on ecological communities.

The high standard of treatment proposed for recycled water will not only mitigate potential impacts on the environment, but will also significantly reduce potential human health impacts should persons come into contact with recycled water. To further reduce this risk, additional controls have been proposed including the use of large droplet fixtures on spray irrigators, use of sub-surface or surface dripper systems in the vicinity of sensitive receivers, scheduling irrigation to occur at night and installing signage for all irrigation areas and recycled water storages.

By maximising beneficial reuse of wastewater generated by the GKI Resort Revitalisation Plan and ensuring such reuse is undertaken in a manner to prevent adverse impacts on the environment or human health, the GKI Resort Revitalisation Plan will establish a benchmark in sustainable tourism development within the Great Barrier Reef Marine Park.

Stormwater

The proposed stormwater management strategy for the GKI Resort Revitalisation Plan has been designed to:

- Comply with the requirements of the *State Planning Policy 4/10 Healthy Waters* and the draft *Urban Stormwater - Queensland Best Practice Environment Management Guidelines 2009*,
- Minimise the use of underground piped drainage systems by utilising surface drainage techniques that reduce the need for extensive excavation while enabling drainage systems to be integrated into landscape design and reducing the concentration of drainage flows to a limited number of discharge points;
- Support the collection and reuse of rainwater from impervious roof surfaces to mitigate peak flow rates while also providing an alternative water supply for resort facilities; and,
- Support the harvesting of stormwater runoff from the golf course and possibly other areas around the resort, to reduce the potential discharge of pollutants while also providing an alternative water supply for irrigation.

A series of detention basins and bio-retention systems will be installed throughout catchments containing the GKI Resort Revitalisation Plan to:

- Attenuate peak discharge flow rates to lower than existing levels for all standard average recurrence interval storm events from 1 year to 100 years;
- Facilitate infiltration of increased surface runoff volumes into highly permeable, sandy subsoils mimicking the natural groundwater recharge process that occurs on the Island; and

- Intercept and temporarily store surface flows from small runoff events so as to avoid any increase in the number of small runoff events discharging to ephemeral waterways that could potentially alter in-stream ecology.

Detention structures will comprise low impact designs utilising low grassed or vegetated mounds enclosing open space that can be readily incorporated as part of the landscape design for the Project.

Best practice vegetated bio-retention systems, including bio-retention basins, swales and infiltration areas will be installed to remove gross pollutants, sediments and nutrients from stormwater flows prior to discharge. Modelling demonstrates that proposed stormwater quality improvement measures will readily achieve required annual pollutant load reduction targets and will result in no worsening of stormwater pollutant concentrations compared to modelling of the pre-developed catchment.

It has also been proposed to permanently open the mouth of Putney Creek to tidal movements, which will increase fisheries productivity and flushing to prevent the formation of eutrophied conditions that may contribute to algal blooms and subsequent odour nuisance. To achieve this, a lined discharge channel will be constructed below the boardwalk and esplanade, with a sediment basin incorporated towards the upstream end of the new channel. This will reduce the potential for silting up of the marina basin thereby reducing the need for ongoing maintenance dredging.

14. BIBLIOGRAPHY

ANZECC and ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Primary Industries.

Cooperative Research Centre for Water Quality and Treatment (2008). *Guidance Manual for the Design and Installation of Urban Roofwater Harvesting Systems in Australia (Edition 1)*, Research Report 39

Foresight Partners Pty Ltd (2011). *Forecast Economic Impacts report for Proposed Revitalisation of Great Keppel Island*

Livingstone Shire Council (2005). *Planning Scheme Policy No. 5, Development Contributions for Water Supply and Sewerage*

SA Water (2006). *Rainwater Plumbing Guide*

State of Queensland EPA (2005). *Queensland Water Recycling Guidelines*

Sustainable Solutions International Pty. Ltd (2007). *Great Keppel Island Water, Wastewater Infrastructure Audit Report*

Australian and New Zealand Environment and Conservation Council (1997). *Best Practice Guidelines for the Provision of Waste Reception Facilities at Ports, Marinas and Boat Harbours in Australia and New Zealand*

Environmental Institute for Golf (2009). *Nutrient Use and Management on U.S. Golf Courses, Golf Course Environmental Profile*, Golf Course Superintendents Association of America. Lawrence, Kansas USA.

Foresight Partners Pty Ltd (2011). *Forecast Economic Impacts report for Proposed Revitalisation of Great Keppel Island*

Gallagher M, Volker R 2004. *Numerical studies of nitrogen flows under effluent irrigated lawns on islands in the Great Barrier Reef.* CRC Reef Research Centre Technical Report 34. CRC Reef Research Centre, Townsville.

GBRMPA (2005). *Sewage Discharges from Marine Outfalls to the Great Barrier Reef Marine Park, Sewage Discharge Policy*

Queensland Urban Utilities (2010), *Sewerage Standards, NuSewers Design and Construction Specification*

Sustainable Solutions International Pty. Ltd (2007). *Great Keppel Island Water, Wastewater Infrastructure Audit Report*

Australian and New Zealand Environment and Conservation Council (1997). *Best Practice Guidelines for the Provision of Waste Reception Facilities at Ports, Marinas and Boat harbours in Australia and New Zealand*

Terms of Reference for an Environmental Impact Statement (EIS) - Great Keppel Island Resort Project - the Coordinator-General - June 2011

Guidelines for an Environmental Impact Statement for the Great Keppel Island Tourism and Marina Development, Queensland - Department of Sustainability, Environment, Water, Population and Communities and the Great Barrier Reef Marine Park Authority - February 2011

Great Keppel Island Revitalisation Plan - Initial Advice Statement - Humphreys Reynolds Perkins - August 2010

South-East Queensland Regional Plan 2009-2031 - Implementation Guideline No.7 - Water Sensitive Urban Design: Design Objectives for Urban Stormwater Management - November 2009

State Planning Policy 4/10 - Healthy Waters - Department of Environment and Resource Management 2010

State Planning Policy 4/10 Guideline - Healthy Waters - Department of Environment and Resource Management 2010

Queensland Water Quality Guidelines 2009 - Department of Environment and Resource Management - Version 3 September 2009

DERM Guideline *Framework for Managing Sewerage Infrastructure to Reduce Overflows & Environmental Impacts*

Draft National Guideline for Water Recycling (NRMMC & EPHC 2005)

Water Quality Guidelines for the Great Barrier Reef Marine Park - Great Barrier Reef Marine Park Authority 2009

Queensland Urban Drainage Manual (QUDM) - Second Edition - 2007

Australian Rainfall and Runoff - Engineers Australia 2001

MUSIC Modelling Guidelines for South East Queensland - Water by Design - version 1 - 2010.

MUSIC Calibration Based On Soil Conditions – Andrew Macleod – July 2008

Water Sensitive Urban Design Technical Design Guidelines for the South-East Queensland - Healthy Waterways - version 1, June 2006

Report on Preliminary Geotechnical Assessment - Douglas Partners - December 2010

APPENDIX A

GKI Resort Revitalisation Plan

GREAT KEPPEL ISLAND RESORT ~ REVITALISATION PLAN

REVITALISATION PLAN 2011

PROJECT #: 093024
08 JULY 2011

GREG NORMAN GOLF COURSE DESIGN

WATG

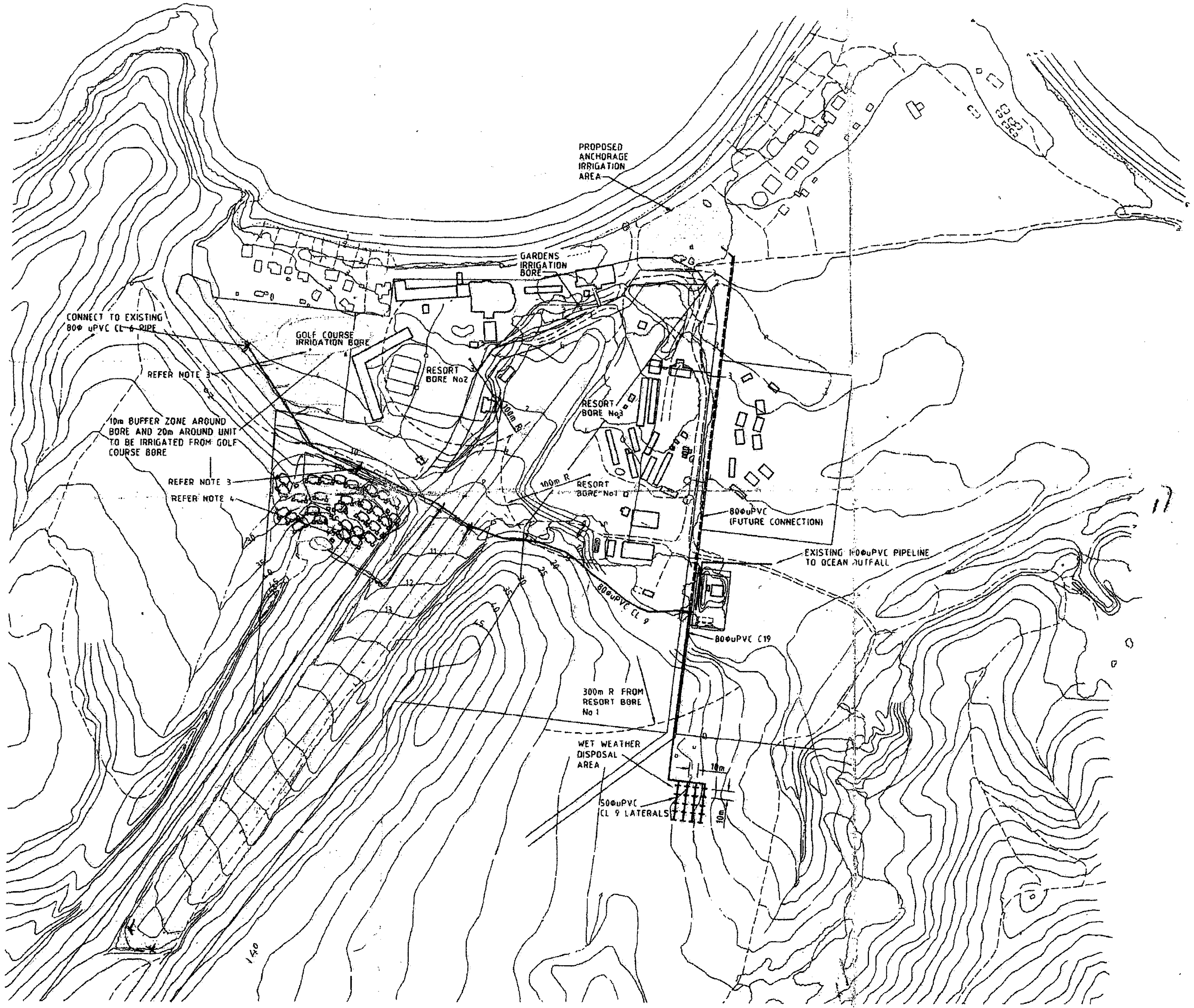
APPENDIX B

Catchment Boundaries - Proposed


LEGEND
CATCHMENT BOUNDARY
AREA NUMBER
DEVELOPED WHARF AREA
MARINA PRECINCT
SECRET BEACH
BUTTERFISH BAY
LITTLE PENINSULA
SANDHILL BEACH
SVENDSEN'S BEACH
WRECK BEACH
WRECK BAY
PUTNEY POINT
CHOCOLATE ROCKS
LEEKE'S BEACH
LITTLE WRECK BEACH
PUTNEY BEACH
CLAM BAY PRECINCT
FISHERMAN'S BEACH
FISHERMAN'S BEACH PRECINCT
SHELVING BEACH
CLAM BAY
WYNDHAM COVE
LONG BEACH
MONKEY BEACH
MONKEY POINT
LITTLE MONKEY POINT
PRELIMINARY
OPUS
Toowoomba Office
GREAT KEPPEL ISLAND
CATCHMENT BOUNDARIES - PROPOSED
N-B0160
1:10000 at A1
N-B0160.00
R01
R0

APPENDIX C

Existing Water Supply & Wastewater Infrastructure



NOTES

1. ALL CONNECTIONS/DISCONNECTIONS TO EXISTING IRRIGATION SYSTEM TO BE MADE BY PRINCIPAL AFTER ALL CONDITIONS SET OUT IN EFFLUENT MANAGEMENT PLAN HAVE BEEN MET. FOR DETAILS REFER TO DRAWING 95039 ????
2. WET WEATHER DISPOSAL AREA
   4 ROWS OF 5 RAINBIRD 2045 MAXI-PAW FULL CIRCLE IMPACT STARS WITH 10 LA NOZZLE AT 10m CENTRES
   APPLICATION RATE = 22mm/HR
   IRRIGATION AREA = 45m x 50m
3. EXISTING CONNECTION TO IRRIGATION SYSTEM TO BE DISCONNECTED. REFER DRAWING 95039 ??? FOR DETAILS
4. DISCONNECT FROM EXISTING IRRIGATION SYSTEM AND CONNECT TO VILLA SYSTEM. ALSO CONNECT 4.5kL HIGH LEVEL TANK TO VILLA IRRIGATION SYSTEM
   HIGH LEVEL TANK TO BE INSTALLED BY PRINCIPAL CONTRACTOR TO CONSTRUCT BASE SLAB AND RETAINING WALLS. REFER DRAWING 95039 ???

LEGEND

PROPOSED RE-USED EFFLUENT LINE

FUTURE RE-USED EFFLUENT LINE

McWilliam
CONSULTING ENGINEERS
41 Fortescue Street, Brisbane
Queensland 4000, Australia
PO Box 304 Spring Hill Qld 4004
Telephone (07) 831 3533
Facsimile (07) 832 3835
McWilliam & Partners Pty Ltd ACN 009 862 783
Trading as McWilliam Consulting Engineers

DRAWN MBS | DESIGNED ANH | CHECKED

TEAM MANAGER | DESIGN VERIFICATION

DIRECTOR | DATE AUG 95

0 50 100 150m

(1:2500 UNREDUCED)

AREAS

AIRSTRIP	29 430sqm
VILLAS	11 080sqm
GOLF COURSE	18 040sqm

SCALE 1:25 IRRIGAT DWG

EVENT | DETAILS | DATE | INIT

AUSTRALIAN RESORTS

CLIENT

ARCHITECT

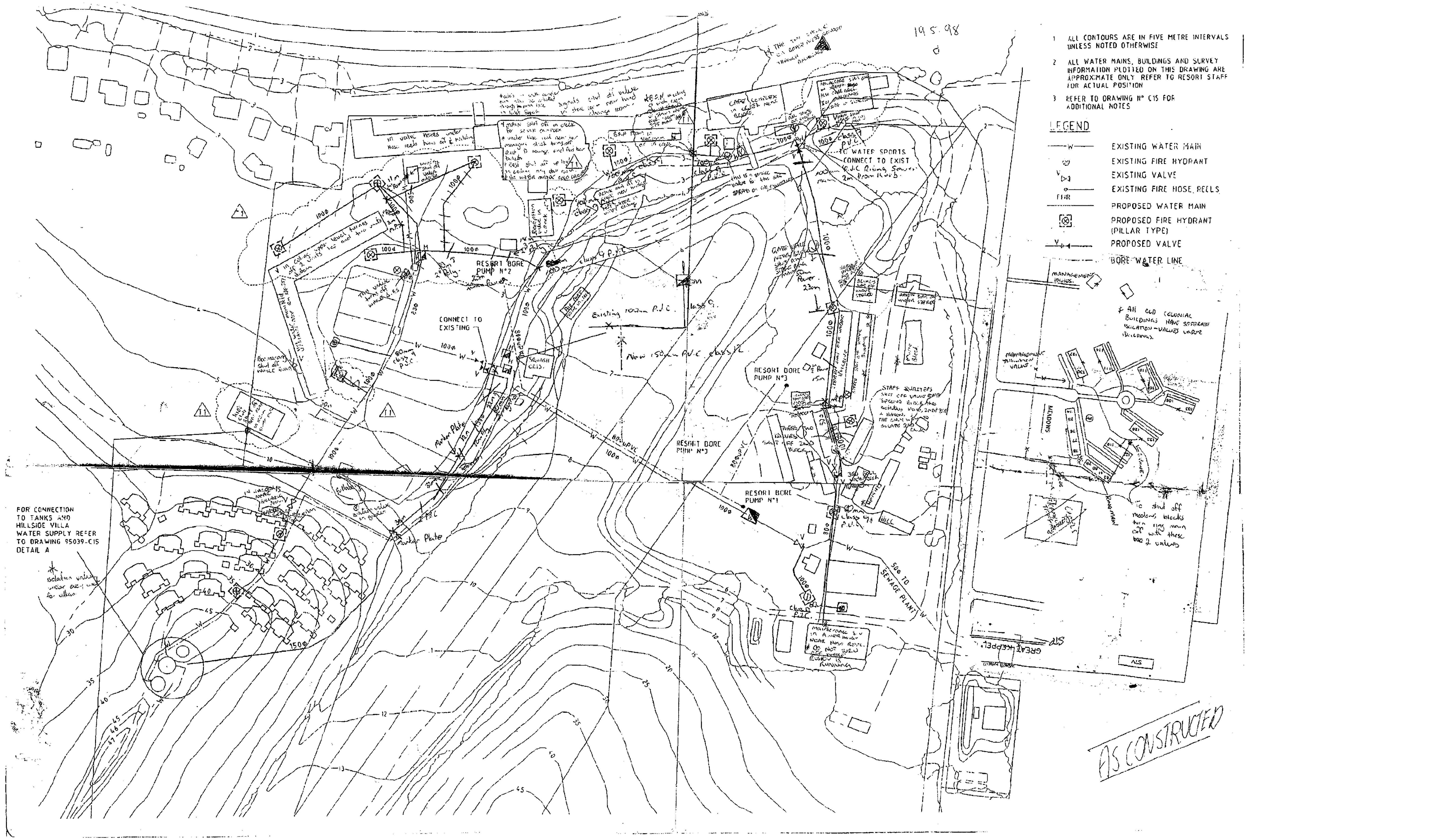
GREAT KEPPEL ISLAND
PROPOSED EFFLUENT
RE-USE SCHEME

PROJECT/DRAWING TITLE

McWilliam
CONSULTING ENGINEERS

95039 ----

PRELIMINARY



1 ALL CONTOURS ARE IN FIVE METRE INTERVALS UNLESS NOTED OTHERWISE
2 ALL WATER MAINS, BUILDINGS AND SURVEY INFORMATION PLOTTED ON THIS DRAWING ARE APPROXIMATE ONLY. REFER TO RESORT STAFF FOR ACTUAL POSITION
3 REFER TO DRAWING Nº C15 FOR ADDITIONAL NOTES
LEGEND
EXISTING WATER MAIN
EXISTING FIRE HYDRANT
EXISTING VALVE
EXISTING FIRE HOSE REELS
PROPOSED WATER MAIN
PROPOSED FIRE HYDRANT (PILLAR TYPE)
PROPOSED VALVE
BORE WATER LINE
19.5.98
RESORT BORE PUMP Nº2
RESORT BORE PUMP Nº3
RESORT BORE PUMP Nº1
CONNECT TO EXISTING
TO WATER SPORTS CONNECT TO EXIST
MEADOWS
GREAT KEPPEL
500 TO SEWAGE PLANT
FOR CONNECTION TO TANKS AND HILLSIDE VILLA WATER SUPPLY REFER TO DRAWING 95039-C15 DETAIL A
AS CONSTRUCTED

APPENDIX D

Existing Environmental Licence (No. CR0061)

FILE COPY
ENVIRONMENT

Environmental Protection Act 1994

Notice of Decision to Grant Application for Licence Amendment

Section 49

Enquiries to: Lynne Melvin
Telephone: (07) 4936 0511
Your reference:
Our reference: L-LV/09

Mr Ronald Hancock
Great! Keppel Island Resort Pty Limited
PO Box 886
BUNDABERG QLD 4670

Dear Mr Chandler

Re: Application to Amend Licence No. CR0061
by Great! Keppel Island Resort Pty Limited
in respect of the carrying out of :
15(b) - Sewage treatment
at premises/place on land described as Lot 46, Plan LN2763
County of Livingstone, Parish of Keppel
located at Great Keppel Island

Your application to amend your licence No. CR0061 has been granted.

A copy of the amended licence including the schedule of conditions is attached. The amended licence takes effect from 15 July 1998, although the original effective date of 13 May 1998 still applies in relation to lodging the annual return and annual licence fees.

Information relating to a review of the decision or appeals under this Act is printed at the back of this notice.

Nigel Holmes
Regional Manager (Environment)
Delegate of Administering Authority
Environmental Protection Act
01/07/98

Licence No. CR0061

Section 45(1)

Under the provisions of the *Environmental Protection Act 1994* this environmental authority is issued:

To: GREAT! KEPPEL ISLAND RESORT PTY LIMITED
T/A GREAT KEPPEL ISLAND RESORT

Address: PMB 8001
NORTH ROCKHAMPTON QLD 4701

in respect of carrying out the environmentally relevant activity/ies at the following place(s):

15(b) Sewage treatment - operating a standard sewage treatment works having a peak design capacity to treat sewage of 100 or more equivalent persons but less than 1 500 equivalent persons

at premises described as:

Lot 46, Plan LN2763
County of Livingstone, Parish of Keppel

Located at:

Great Keppel Island

This environmental authority is issued subject to the conditions set out in the schedules attached to this environmental authority.

The amendment to this licence takes effect from **15 July 1998.** The original licence took effect from **13 May 1998**.

Nigel Holmes

Nigel Holmes
Regional Manager (Environment) Central Coast
Delegate of Administering Authority
Environmental Protection Act 1994
01\07\98

Section 45(1)

This environmental authority consists of the following schedules:-

SCHEDULE A - GENERAL CONDITIONS

SCHEDULE B - AIR

SCHEDULE C - WATER

SCHEDULE D - STORMWATER MANAGEMENT

SCHEDULE E - LAND APPLICATION

SCHEDULE F - NOISE

SCHEDULE G - WASTE MANAGEMENT

SCHEDULE H - MONITORING AND REPORTING

SCHEDULE I - DEFINITIONS

Section 45(1)

SCHEDULE A - GENERAL CONDITIONS

Access to Copy of Environmental Authority

(A1) A copy of this environmental authority must be kept in a location readily accessible to personnel carrying out the activity.

(A2) Any record or document required to be kept by a condition of this environmental authority must be kept at the licensed place for a period of at least five years and be available for examination by an authorised person. For daily and weekly records, the record retention requirements of this condition will be satisfied if any daily and weekly records are kept for a period of at least three (3) years and these records are then kept in the form of annual summaries after that period.

Alterations

(A3) No change, replacement or operation of any plant or equipment is permitted if the change, replacement or operation of the plant or equipment increases, or is likely to substantially increase, the risk of environmental harm above that expressly provided by this environmental authority.

An example of a substantial increase in the risk of environmental harm is an increase of 10% or more in the quantity of the contaminant to be released into the environment.

Monitoring and Measurements

(A4) All determinations of the quality of contaminants released to the environment and all measurement and reporting of noise levels that are required by this environmental authority must be undertaken by a person or body possessing appropriate experience and qualifications to perform the required determinations and the required measurements.

(A5) All instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority must be calibrated, and appropriately operated and maintained.

Competency

(A6) The holder of this environmental authority shall ensure that the operation and maintenance of the licensed place is carried out by or under the supervision of a person competent to operate and maintain the sewage treatment plant.

END OF CONDITIONS FOR SCHEDULE A

SCHEDULE B - AIR

No conditions.

END OF CONDITIONS FOR SCHEDULE B

SCHEDULE C - WATER

Release of Contaminants to Waters

(C1) Contaminants must not be directly or indirectly released from the licensed place to any waters or the bed and banks of any waters except as permitted under this schedule or the Stormwater Management Schedule.

(C2) Contaminants may only be released from the licensed place to any waters when weather or soil conditions preclude the application of contaminants to land designated in Schedule E.

(C3) The only contaminants permitted to be released from the licensed place at the release point described as between the northern end of Putney Beach and Half Tide Rocks is a sewage treatment effluent.

Release Point Details

(C4) The release point must be submerged at all times.

(C5) All contaminants from release point must be released through a suitable diffuser to achieve a minimum initial dilution of 50 to 1.

Quantity of Contaminants Released

(C6) The total quantity of contaminants released from release point during any dry weather day must not exceed 250 cubic metres, and during a wet weather day must not exceed 500 cubic meters.

Quality Characteristics of Release to Waters

(C7) The release of contaminants to waters must comply, at the sampling and in situ monitoring point/s specified in Schedule H, with each of the limits specified in schedule C Table 1 for each quality characteristic.

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Pump Stations

(C8) The only pump stations permitted to release contaminants to any waters are those listed below at the corresponding overflow locations:

Pump Station No. 1	near Reception
Pump Station No. 2	grassed area adjacent to peanut pool
Pump Station No. 3	near Supervisors quarters

(C9) Pump stations whose failure would or would be likely to result in a direct or indirect release of contaminants to waters must be fitted with stand-by pumps and pump-failure alarms.

SCHEDULE C TABLE 1 - RELEASE QUALITY CHARACTERISTIC LIMITS

QUALITY CHARACTERISTICS	RELEASE LIMIT	LIMIT TYPE
5-day Biochemical Oxygen Demand. (mg/l)	20	Maximum
5-day Biochemical Oxygen Demand. (mg/l)	5	90 percentile
Suspended Solids. (mg/l)	30	Maximum
Suspended Solids. (mg/l)	5	90 percentile
pH. (pH Units)	6.5 - 8.5	Range
Dissolved Oxygen. (mg/l)	2	Minimum
Ammonia Nitrogen. (mg/l)	1	Maximum
Total Phosphorus as P. (mg/l)	7	Maximum
Total Phosphorus as P. (mg/l)	4	90 percentile
Free Residual Chlorine. (mg/l)	0.3 - 0.7	Range

END OF CONDITIONS FOR SCHEDULE C

SCHEDULE D - STORMWATER MANAGEMENT

(D1) Except as provided by the conditions of the Stormwater Management Schedule and the Water Schedule of this environmental authority, the environmentally relevant activities must be carried out by such practicable means necessary to prevent or minimise the contact of incident rainfall and stormwater runoff with wastes or other contaminants, and prevent or minimise the release or likelihood of release of any such contaminated runoff from the licensed place.

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Stormwater Management Plan

(D2) By 1July 1998 the holder of this environmental authority must develop and implement an effective and appropriate Stormwater Management Plan which details how the holder of this environmental authority will manage the actual and potential environmental impacts resulting from the contamination of stormwater at the licensed places.

(D3) The Stormwater Management Plan must address at least the following matters:

(I) prevention of incident stormwater and stormwater runoff from contacting wastes or contaminants;
(ii) diversion of upstream runoff away from areas containing wastes or contaminants;
(iii) minimisation of the size of contaminated areas;
(iv) cleaning of contaminated areas without water;
(vi) paving and roofing of contaminated areas.

(D4) A copy of the Stormwater Management Plan and any subsequent amendment must be kept at the licensed place and be available for examination by anauthorised person on request.

END OF CONDITIONS FOR SCHEDULE D

SCHEDULE E- LAND APPLICATION

Release of Contaminants to Land

(E1) The defined contaminant release area is described as golf course, gardens in front of resort villas and gardens as marked on McWilliams Consulting Engineers Job No. 95039 Plan C2, Great Keppel Island Infrastructure Upgrade, Proposed Effluent Re-use Scheme.

(E2) A minimum of 4.8 hectares of land must be provided for the contaminant release area.

(E3) The contaminant disposal area must be maintained in a proper and efficient condition so as to provide adequate assimilation, percolation, evaporation and transpiration of the released contaminants.

(E4) Spray from any release of contaminants to land must not drift beyond the boundaries of the licensed place.

(E5) Notices warning the public not to used or drink the release of contaminants to land must be prominently displayed and must be maintained in a visible and legible condition.

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(E6) Pipelines and fittings for the release of contaminants to land must be clearly identified. Standard water taps, hoses and cocks must not be fitted to contaminant release pipelines, and the contaminant release system must not be connected to other service pipelines. Lockable valves or removable handles must be fitted to the contaminant disposal areas.

Quality of Contaminants Released to Land

(E7) The contaminant release must comply, at the sampling and in-situ measurement point/s with each of the release limits specified in schedule E Table 1 for each quality characteristic.

Wet Weather Conditions

(E8) When weather conditions or soil conditions preclude the release of contaminants, the contaminants must not be released.

SCHEDULE E TABLE 1 - RELEASE QUALITY CHARACTERISTIC LIMITS

QUALITY CHARACTERISTICS	RELEASE LIMIT	LIMIT TYPE
5-day Biochemical Oxygen Demand. (mg/l)	20	maximum
Suspended Solids. (mg/l)	30	maximum
pH.	6.5 - 8.0	range
Faecal Coliforms.(Organisms/100 ml)	10	maximum

END OF CONDITIONS FOR SCHEDULE E

SCHEDULE F - NOISE

No conditions.

END OF CONDITIONS FOR SCHEDULE F

SCHEDULE G - WASTE MANAGEMENT

General

(G1) The holder of this environmental authority must not:
- (i) allow waste to burn or be burned at or on the licensed place; nor
- (ii) remove waste from the licensed place and burn such waste elsewhere.

END OF CONDITIONS FOR SCHEDULE G

SCHEDULE H - MONITORING AND REPORTING

Complaint Recording

(H1) All complaints received by the holder of this environmental authority relating to releases of contaminants from operations at the licensed place must be recorded and kept with the following details:

(a) time, date and nature of complaint;
(b) type of communication (telephone, letter, personal etc.);
(c) name, contact address and contact telephone number of complainant (Note: if the complainant does not wish to be identified then "Not identified" is to be recorded);
(d) response and investigation undertaken as a result of the complaint;
(e) name of person responsible for investigating complaint; and
(f) action taken as a result of the complaint investigation and signature of responsible person.

Monitoring of Contaminant Releases

(H2) The holder of this environmental authority is responsible for the making of determinations and keeping of records of the quality of the contaminants released for the quality characteristics, and at the frequency specified in Schedule H Table 2.

Sampling and Monitoring Point Details

(H3) Determinations of the quality of released contaminants to check conformity with the release quality characteristics specified in the Water Schedule and Land Application Schedule of this environmental authority must be undertaken at the sampling and in situ monitoring point described as:

Sampling & Monitoring Point (S&MP) - the outlet pipe from the sewage treatment plant's effluent tank.

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Monitoring of Volume of Release

(H4) The daily quantity of contaminants released must be determined by taking measurements from the meter at the outlet from the effluent tank.

(H5) Records must be kept of the results of all determinations of the daily quantity of contaminants released to land.

Report Submission

(H6) The holder of this environmental authority must ensure that the results of all monitoring performed in accordance with this environmental authority for the period covered by the return are submitted with the Annual Return.

Schedule H - Table 2

QUALITY CHARACTERISTIC DETERMINATION	RELEASE POINTS	FREQUENCY
5-day Biochemical Oxygen Demand.	S&MP	Weekly
Suspended Solids.	S&MP	Weekly
pH.	S&MP	Weekly
Dissolved Oxygen	S&MP	Weekly
Total Nitrogen	S&MP	Weekly
Total Phosphorus as P	S&MP	Weekly
Free Residual Chlorine	S&MP	Weekly
Faecal Coliforms. (Organisms/100 ml)	S&MP	Weekly

Incident Recording

(H7) A record must be maintained of at least the following events:

(a) the time, date and duration of equipment malfunctions where the failure of the equipment resulted in the release of contaminants reasonably likely to cause environmental harm;
(b) any uncontrolled release of contaminants reasonably likely to cause environmental harm and
(c) any emergency involving the release of contaminants reasonably likely to cause material or serious environmental harm requiring the use of fire fighting equipment.

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Notification of Emergencies and Incidents

(H8) Where the holder of this environmental authority has not given notification to the administering authority under section 37 of the Environmental Protection Act, as soon as practicable after becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with the conditions of this environmental authority, the holder of this environmental authority must notify the administering authority of the release by telephone or facsimile.

(H9) Where the holder of this environmental authority has not given notification to the administering authority under section 37 of the Environmental Protection Act, the notification of emergencies or incidents as required by condition number (H8) must include but not be limited to the following:

(a) The holder of the environmental authority;
(b) the location of the emergency or incident;
(c) the number of the environmental authority;
(d) the name and telephone number of the designated contact person;
(e) the time of the release;
(f) the time the holder of the environmental authority became aware of the release;
(g) the suspected cause of the release;
(h) the environmental harm and or environmental nuisance caused, threatened, or to be caused by the release; and
(i) actions taken to prevent further any release and mitigate any environmental harm and or environmental nuisance caused by the release.

(H10) Where the holder of this environmental authority has not given notification to the administering authority under section 37 of the Environmental Protection Act, not more than 14 days following the initial notification of an emergency or incident, the holder of the environmental authority must provide written advice of the information supplied in accordance with condition number (H9) in addition to:

(a) proposed actions to prevent a recurrence of the emergency or incident;
(b) outcomes of actions taken at the time to prevent or minimise environmental harm and or environmental nuisance.

Exception Reporting

(H11) The holder of this environmental authority must notify the administering authority in writing within 28 days of completion of analysis of any result of a monitoring program required by a condition of this environmental authority which indicates an exceedance of any limit specified in this environmental authority.

(H12) The written notification required by condition number (H11) above must include:

(a) The full analysis results, and
(b) Details of investigation or corrective actions taken, and
(c) Any subsequent analysis.

END OF CONDITIONS FOR SCHEDULE H

SCHEDULE I - DEFINITIONS

For the purposes of this environmental authority the following definitions apply:

(I1) "mg/l" means milligrams per litre.

(I2) "90th percentile" means that the measured values of the quality characteristic must not be greater than the release limit for any more than one out of five consecutive samples where the time interval between the taking of each consecutive sample is not less than three days.

(I3) "median" means the middle value, where half the data are smaller, and half the data are larger. If the number of samples is even, the median is the arithmetic average of the two middle values.

(I4) "maximum" means that the measured value of the quality characteristic or contaminant must not be greater than the release limit stated.

(I5) "minimum" means that the measured value of the quality characteristic or contaminant must not be less than the release limit stated.

(I6) "range" means that the measured value of the quality characteristic or contaminant must not be greater than the higher release limit stated nor lower than the lower release limit stated.

END OF CONDITIONS FOR SCHEDULE I

APPENDIX E

Water Balance Spreadsheet

Great Keppel Island - Resort Revitalisation Plan

Appendix B.1 A – Water Balance - Summary (With Irrigation to Full 31 Ha of Golf Course)
Figures derived from spreadsheets for January to December inclusive (Appendices B.2 to B.13 refer).

		Average Domestic Water Demand (kL/mth)								Golf Course Irrigation Requirement (ML/mth)				Submarine Pipe Line Flow Rate	
Month	Days in Month	EP x Occupancy (Total EP = 3,973)	Total Domestic Water (kL)	Mains Supply (kL)	Rainwater Reuse (kL)	Sewage Treatment Plant Outflow Flow @ 95% x 180 L/EP/day	Total Irrigation Requirement (kL/mth)	Effluent Volume Available (kL/mth)	SW Harvest Excluding Golf Course (kL/mth)	Golf Course Irrigation Requirement **(ML/mth)**	Golf Course Stormwater Harvest **(ML/mth)**	Golf Course Effluent Reuse *(2) **ML/mth**	Net irrigation from mains supply **(ML/mth)**	Peak Day Mains Water Required *(1) (kL/day)	Flow Rate in Submarine Pipe Line (L/sec over 24 hrs)
January	31	3750.1	26505.45	19984.44	6521.02	19879.09	44196.82	19879.09	1408.71	38.932	5.01	18.60	15.32	1510.67	17.48
February	28	1724.5	11009.39	8345.16	2664.22	8257.04	28065.82	8257.04	607.71	24.080	4.66	8.26	11.16	885.61	10.25
March	31	1847.5	13058.16	9826.27	3231.89	9793.62	40611.19	9793.62	1720.71	36.625	7.01	9.79	19.82	1178.68	13.64
April	30	2143.8	14663.67	11032.42	3631.24	10997.75	43427.60	10997.75	1805.00	39.441	5.28	11.00	23.16	1414.49	16.37
May	31	1069.3	7557.79	5703.26	1854.53	5668.34	38252.04	5668.34	1621.71	34.266	5.15	5.67	23.45	1107.92	12.82
June	30	1193.2	8161.39	6177.71	1983.68	6121.04	33000.61	6121.04	525.00	29.015	3.84	6.12	19.05	1073.92	12.43
July	31	1666.6	11779.84	10306.48	1473.36	8834.88	34334.96	8834.88	595.00	30.349	3.60	8.83	17.91	1228.07	14.21
August	31	1570.6	11101.22	9712.25	1388.97	8325.91	38398.73	8325.91	345.00	34.413	2.04	8.33	24.05	1428.79	16.54
September	30	3075.1	21033.47	18410.26	2623.20	15775.10	47786.77	15775.10	200.00	43.801	0.20	15.78	27.83	2057.61	23.81
October	31	2262.7	15992.59	13995.91	1996.68	11994.44	54651.77	11994.44	420.00	50.666	0.40	11.99	38.27	2136.65	24.73
November	30	2313.4	15823.47	13844.52	1978.95	11867.61	58258.27	11867.61	555.00	54.273	1.88	11.87	40.53	2270.93	**26.28**
December	31	3303.3	23348.06	17624.21	5723.84	17511.04	46772.09	17511.04	643.71	42.786	4.12	17.51	21.15	1603.46	18.56
ANNUAL TOTAL			180034.49	144962.89	35071.60	135025.87	507756.72	135025.87	10447.57	458.647	43.20	133.75	281.70		

Average 2160.0

*(2) Max amount = 31 ha x 60 mm/mth = 18.6 ML/mth.

*(1) Average Domestic x 1.5 + Irrigation x 1.1

Great Keppel Island - Resort Revitalisation Plan

Appendix B.1 B – Water Balance - Summary (With Mains Water Irrigation to 49% x 31 Ha (= 15.2 Ha) of Tees, Fairways & Greens to Golf Course)
Derived from Appendix B.1 A above with mains irrigation to rough areas of Golf Course deleted,

		Average Domestic Water Demand (kL/mth)								Golf Course Irrigation Requirement (ML/mth)				Submarine Pipe Line Flow	
Month	Days in Month	EP x Occupancy (Total EP = 3,973)	Total Domestic Water (kL)	Mains Supply (kL)	Rainwater Reuse (kL)	Sewage Treatment Plant Outflow Flow @ 95% x 180 L/EP/day	Total Irrigation Requirement(Excl Golf Course Rough Area) (kL/mth)	Effluent Volume Available (kL/mth)	SW Harvest Excluding Golf Course (kL/mth)	Golf Course Irrigation Requirement (Excl Rough Area) **(ML/mth)**	Golf Course Stormwater Harvest **(ML/mth)**	Golf Course Effluent Reuse *(2) **(Incl Rough Area) ML/mth**	Net irrigation from mains supply (Excl Rough Area) **(ML/mth)**	Peak Day Mains Water Required *(1) (kL/day)	Flow Rate in Submarine Pipe Line (L/sec over 24 hrs)
January	31	3750.1	26505.45	19984.44	6521.02	19879.09	24341.50	19879.09	1408.71	19.077	5.01	19.88	4.33	1120.49	12.97
February	28	1724.5	11009.39	8345.16	2664.22	8257.04	15785.02	8257.04	607.71	11.799	4.66	8.26	3.09	568.59	6.58
March	31	1847.5	13058.16	9826.27	3231.89	9793.62	21932.44	9793.62	1720.71	17.946	7.01	9.79	6.13	693.12	8.02

April	30	2143.8		14663.67	11032.42	3631.24		10997.75			23312.69	10997.75	1805.00		19.326	5.28	11.00	8.66		882.60	10.22
May	31	1069.3		7557.79	5703.26	1854.53		5668.34			20776.38	5668.34	1621.71		16.790	5.15	5.67	8.86		590.39	6.83
June	30	1193.2		8161.39	6177.71	1983.68		6121.04			18202.96	6121.04	525.00		14.217	3.84	6.12	7.38		645.80	7.47
July	31	1666.6		11779.84	10306.48	1473.36		8834.88			18856.97	8834.88	595.00		14.871	3.60	8.83	6.94		838.74	9.71
August	31	1570.6		11101.22	9712.25	1388.97		8325.91			20848.10	8325.91	345.00		16.862	2.04	8.33	10.74		956.69	11.07
September	30	3075.1		21033.47	18410.26	2623.20		15775.10			25448.26	15775.10	200.00		21.462	0.20	15.78	13.53		1533.52	17.75
October	31	2262.7		15992.59	13995.91	1996.68		11994.44			28812.11	11994.44	420.00		24.826	0.40	11.99	18.55		1436.82	16.63
November	30	2313.4		15823.47	13844.52	1978.95		11867.61			30579.04	11867.61	555.00		26.594	1.88	11.87	18.90		1477.95	17.11
December	31	3303.3		23348.06	17624.21	5723.84		17511.04			24951.23	17511.04	643.71		20.965	4.12	17.51	8.26		1146.06	13.26
ANNUAL TOTAL				180034.49	144962.89	35071.60		135025.87			273846.75	135025.87	10447.57		224.737	43.20	135.03	115.38			

Average 2160.0 EP

*(2) Allows for effluent to 31 Ha of golf course tees, fairways & greens.

*(1) Average Domestic x 1.5 + Irrigation x 1.1

Great Keppel Island - Resort Revitalisation Plan

Appendix B.2 – Water Balance - Peak Occupancy/ Wet Month - January

Area	ET Factor	EP/ Unit or m²	Unit	No. or Area	EP	Shop etc Area (m²)	Eco villa	Eco Apartment				January		31	Days		85.9	mm Median Rain
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
											Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				98%	539.0	3809.7	3341.8	467.9					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			98%	19.5	138.0	121.0	16.9					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			98%	2.5	17.5	15.3	2.1					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		98%	938.4	6632.3	4770.6	1861.7					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	98%	129.4	914.3	657.7	256.7					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	98%	147.0	1039.0	747.3	291.6					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	98%	73.5	519.5	373.7	145.8					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			98%	12.2	86.2	75.6	10.6					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			98%	18.5	130.9	114.8	16.1					
Swimming pool, tennis court & Gymnasium									98%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	2014.4	1448.9	565.4					
Living off site		0.32	No	200	**64**				95%	60.8	429.7	309.1	120.6					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				98%	6.9	48.5	42.5	6.0					
Allow nominal for facilities					**12**				98%	11.8	83.1	72.9	10.2					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	2577.0			
be a small amount available after use on Golf Course but use adjacent to Airport.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 36,900 kL for Jan)			kL	36,900													1408.7	
Mains Water Makeup (Balance of requirement)																		0.0
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	89.1	64.1	25.0					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). Small amount available after use on Golf Course.			Ha	2										1279.1		1279.1		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				60%	150.0	1060.2	930.0	130.2					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			60%	14.9	105.6	92.6	13.0					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			60%	45.4	320.6	281.2	39.4					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				98%	2.9	20.8	18.2	2.6					
Allow nominal for facilities									98%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	98%	129.4	914.3	657.7	256.7					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	98%	147.0	1039.0	747.3	291.6					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	98%	73.5	519.5	373.7	145.8					

Catchments 5 & 11 - Golf Course Precinct:

Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			98%	30.9	218.2	156.9	61.2						
Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														38932.0	0.0	(rainfall included in requirement)			
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												18600.0			
On Site Stormwater Reuse (say 10% x available 51,100 kL for Jan)			kL	50100													5010.0		
Mains Water Makeup (Balance of requirement)																		15322.0	
Ecotourism Villas																			
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		98%	899.2	6355.2	4571.3	1783.9						
TOTAL					**3973**	12500	750	300		**3750.1**	**26505.5**	**19984.4**	**6521.0**	**44196.8**	**2577.0**	**19879.1**	**6418.7**	**15322.0**	Check
TOTAL in kL/day											**855.0**	**644.7**	**210.4**	**1425.7**	**83.1**	**641.3**	**207.1**	**494.3**	0.0

Check available Effluent Reuse @ EP x Occupancy x 180x 95% (kL) (Note 5)								19879.1	Note 2		
Total Water Required (kL)	**70702.3**		26505.5			44196.8					
Total Mains Water Required (kL)	**35306.5**			19984.4							15322.0
Total Mains Water Required (kL/day)	**1138.9**										
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**									
Peak Mains Water Required (kL/day)	**1510.7**										

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse nearly all required for 31 Ha at Golf Course, 100 % used up until Stage 8.
Note 3: Villas and Apartments, staff units - 228 l/p/day with 64 l/p/day from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d

Mains Water Supply - Flow Rate over 24 Hours **17.5 L/sec**

Area	ET Factor	EP/ Unit or m^2	Unit	No. or Area	EP	RW Tank Storage @ 3 kL/ unit	Rainwater Inflow Total Available		Occupancy	EP x Occupancy	Average Domestic Water Demand @ 228 L/EP/day (kL) Total Required	January Mains	RW Reuse	31 Days		85.9 mm Median Rain		
Potential for Rainwater Reuse to Apartments and Villas:																		
Total Numbers of Eco-Tourism Apartments:																		
Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	1632.8		98%	258.7	1828.6	195.8	1632.8					
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	1855.4		98%	294.0	2078.0	222.6	1855.4					
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	927.7		98%	147.0	1039.0	111.3	927.7					
Total Numbers of Eco-Tourism Villas:																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	11596.5		98%	1837.5	12987.5	1391.0	11596.5					
Total for Month (kL)							16012.4				17933.1	1920.6	16012.4					
								Percentage Mains/ Reuse				11%	89%					

Assumptions:

1. 80 m^2 of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

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Appendix B.3 – Water Balance - February

Area	ET Factor	EP/ Unit of m^2	Unit	No. or Area	EP	Shop etc Area (m^2)	Eco villa	Eco Apartment				February		28	Days	112.6	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				56%	305.5	1950.5	1710.9	239.5					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			56%	11.1	70.6	62.0	8.7					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			56%	1.4	8.9	7.8	1.1					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		36%	344.7	2200.6	1582.9	617.7					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	36%	47.5	303.4	218.2	85.2					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	36%	54.0	344.7	248.0	96.8					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	36%	27.0	172.4	124.0	48.4					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			56%	6.9	44.2	38.7	5.4					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			56%	10.5	67.0	58.8	8.2					
Swimming pool, tennis court & Gymnasium									56%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	1819.4	1308.7	510.7					
Living off site		0.32	No	200	**64**				95%	60.8	388.1	279.2	109.0					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				56%	3.9	24.8	21.8	3.0					
Allow nominal for facilities					**12**				56%	6.7	42.6	37.3	5.2					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	3378.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 35,800 kL for Feb)			kL	35,800													607.7	
Mains Water Makeup (Balance of requirement)																		0.0
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	80.4	57.9	22.6					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				22%	54.0	344.7	302.4	42.3					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			22%	5.4	34.3	30.1	4.2					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			22%	16.3	104.2	91.4	12.8					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				36%	1.1	6.9	6.0	0.8					
Allow nominal for facilities									36%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	36%	47.5	303.4	218.2	85.2					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	36%	54.0	344.7	248.0	96.8					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	36%	27.0	172.4	124.0	48.4					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			36%	11.3	72.4	52.1	20.3					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														24080.1	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												8257.0		
On Site Stormwater Reuse (say 10% x available 46,600 kL for Feb)			kL	46600													4660.0	
Mains Water Makeup (Balance of requirement)																		11163.1
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		36%	330.3	2108.6	1516.7	591.9					
TOTAL					**3973**	12500	750	300		**1724.5**	**11009.4**	**8345.2**	**2664.2**	**28065.8**	**3378.0**	**8257.0**	**5267.7**	**11163.1**
TOTAL in kL/day											**393.2**	**298.0**	**95.2**	**1002.4**	**120.6**	**294.9**	**188.1**	**398.7**

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL) (Note 5) 8257.0

Total Water Required (kL)	**39075.2**		11009.4			28065.8					
Total Mains Water Required (kL)	**19508.2**			8345.2							11163.1
Total Mains Water Required (kL/day)	**696.7**										
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**									
Peak Mains Water Required (kL/day)	**885.6**										

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with 64 l/p/day from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d

Mains Water Supply - Flow Rate over 24 Hours 10.3 L/sec

Area	**ET Factor**	**EP/ Unit or m²**	**Unit**	**No. or Area**	**EP**	**RW Tank Storage**	**Rainwater Inflow**					**February**		**28**	**Days**	**112.6**	**mm Median Rain**	
						@ 3 kL/ unit	**Total Available**		**Occupancy**	**EP x Occupancy**	**Average Domestic Water Demand @ 228 L/EP/day (kL)**							
											Total Required	**Mains**	**RW Reuse**					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	2140.3		36%	95.0	606.7	0.0	606.7
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	2432.2		36%	108.0	689.5	0.0	689.5
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	1216.1		36%	54.0	344.7	0.0	344.7

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	15201.0		36%	675.0	4309.2	0.0	4309.2

Total for Month (kL)							20989.5				5950.1	0.0	5950.1
								Percentage Mains/ Reuse				0%	100%

Assumptions:

1. 80 m^2 of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

Great Keppel Island - Resort Revitalisation Plan

Appendix B.4 – Water Balance - March

Area	ET Factor	EP/ Unit of m²	Unit	No. or Area	EP	Shop etc Area (m²)	Eco villa	Eco Apartment				March		31	Days	75.5	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				56%	308.8	2182.4	1914.4	268.0					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			56%	11.2	79.0	69.3	9.7					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			56%	1.4	10.0	8.8	1.2					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		42%	402.2	2842.4	2044.5	797.9					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	42%	55.4	391.8	281.9	110.0					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	42%	63.0	445.3	320.3	125.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	42%	31.5	222.6	160.1	62.5					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			42%	5.2	37.0	32.4	4.5					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			42%	7.9	56.1	49.2	6.9					
Swimming pool, tennis court & Gymnasium									42%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	2014.4	1448.9	565.4					
Living off site		0.32	No	200	**64**				95%	60.8	429.7	309.1	120.6					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				56%	3.9	27.7	24.3	3.4					
Allow nominal for facilities					**12**				56%	6.7	47.5	41.7	5.8					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	2265.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 63.000 kL for Mar)			kL	63,000													1720.7	
Mains Water Makeup (Balance of requirement)																		0.0
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	89.1	64.1	25.0					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				12%	30.0	212.0	186.0	26.0					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			12%	3.0	21.1	18.5	2.6					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			12%	9.1	64.1	56.2	7.9					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				42%	1.3	8.9	7.8	1.1					
Allow nominal for facilities									42%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	42%	55.4	391.8	281.9	110.0					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	42%	63.0	445.3	320.3	125.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	42%	31.5	222.6	160.1	62.5					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			42%	13.2	93.5	67.3	26.2					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														36625.5	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												9793.6		
On Site Stormwater Reuse (say 10% x available 500 kL for Mar)			kL	100200													7014.0	
Mains Water Makeup (Balance of requirement)																		19817.9
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		42%	385.4	2723.7	1959.1	764.5					
TOTAL					3973	12500	750	300		1847.5	**13058.2**	**9826.3**	**3231.9**	**40611.2**	**2265.0**	**9793.6**	**8734.7**	**19817.9**
TOTAL in kL/day											**421.2**	**317.0**	**104.3**	**1310.0**	**73.1**	**315.9**	**281.8**	**639.3**

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL)	(Note 5)							9793.6		
Total Water Required (kL)	**53669.4**		13058.2			40611.2				
Total Mains Water Required (kL)	**29644.1**			9826.3						19817.9
Total Mains Water Required (kL/day)	**956.3**									
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**								
Peak Mains Water Required (kL/day)	**1178.7**									

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with 64 l/p/day from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d

Mains Water Supply - Flow Rate over 24 Hours **13.6 L/sec**

Area	**ET Factor**	**EP/ Unit or m²**	**Unit**	**No. or Area**	**EP**	**RW Tank Storage**	**Rainwater Inflow**					**March**			**31**	**Days**	**75.4**	**mm Median Rain**
						@ 3 kL/ unit	**Total Available**		**Occupancy**	**EP x Occupancy**	**Average Domestic Water Demand @ 228 L/EP/day (kL)**							
											Total Required	**Mains**	**RW Reuse**					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	1433.2		42%	110.9	783.7	0.0	783.7
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	1628.6		42%	126.0	890.6	0.0	890.6
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	814.3		42%	63.0	445.3	0.0	445.3

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	10179.0		42%	787.5	5566.1	0.0	5566.1

Total for Month (kL)							14055.2				7685.6	0.0	7685.6
								Percentage Mains/ Reuse				0%	100%

Assumptions:

1. 80 m² of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

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Appendix B.5– Water Balance - April

Area	ET Factor	EP/ Unit of m^2	Unit	No. or Area	EP	Shop etc Area (m^2)	Eco villa	Eco Apartment				April		30	Days	60.4	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				66%	362.1	2476.5	2172.4	304.1					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			66%	13.1	89.7	78.7	11.0					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			66%	1.7	11.3	10.0	1.4					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		51%	488.3	3340.1	2402.6	937.6					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	51%	67.3	460.5	331.2	129.3					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	51%	76.5	523.3	376.4	146.9					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	51%	38.3	261.6	188.2	73.4					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			51%	6.3	43.4	38.1	5.3					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			51%	9.6	65.9	57.8	8.1					
Swimming pool, tennis court & Gymnasium									51%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	1949.4	1402.2	547.2					
Living off site		0.32	No	200	**64**				95%	60.8	415.9	299.1	116.7					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				66%	4.6	31.6	27.7	3.9					
Allow nominal for facilities					**12**				66%	7.9	54.2	47.5	6.7					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	1812.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 36,100 kL for Apr)			kL	36,100													1805.0	
Mains Water Makeup (Balance of requirement)																		368.7
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	86.2	62.0	24.2					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				12%	30.0	205.2	180.0	25.2					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			12%	3.0	20.4	17.9	2.5					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			12%	9.1	62.1	54.4	7.6					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				51%	1.5	10.5	9.2	1.3					
Allow nominal for facilities									51%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	51%	67.3	460.5	331.2	129.3					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	51%	76.5	523.3	376.4	146.9					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	51%	38.3	261.6	188.2	73.4					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			51%	16.1	109.9	79.0	30.8					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														39441.9	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												10997.7		
On Site Stormwater Reuse (say 10% x available 52,800 kL for Apr)			kL	52800													5280.0	
Mains Water Makeup (Balance of requirement)																		23164.1
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		51%	467.9	3200.6	2302.2	898.4					
TOTAL					**3973**	12500	750	300		**2143.8**	**14663.7**	**11032.4**	**3631.2**	**43427.6**	**1812.0**	**10997.7**	**7085.0**	**23532.9**
TOTAL in kL/day											**488.8**	**367.7**	**121.0**	**1447.6**	**60.4**	**366.6**	**236.2**	**784.4**

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with 64 l/p/day from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL)	(Note 5)							10997.7		
Total Water Required (kL)	**58091.3**		14663.7			43427.6				
Total Mains Water Required (kL)	**34565.3**			11032.4						23532.9
Total Mains Water Required (kL/day)	**1152.2**									
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**								
Peak Mains Water Required (kL/day)	**1414.5**									

Mains Water Supply - Flow Rate over 24 Hours **16.4 L/sec**

Area	**ET Factor**	**EP/ Unit or m²**	**Unit**	**No. or Area**	**EP**	**RW Tank Storage**	**Rainwater Inflow**					**April**		**30**	**Days**	**60.4**	**mm Median Rain**	
						@ 3 kL/ unit	**Total Available**		**Occupancy**	**EP x Occupancy**	**Average Domestic Water Demand @ 228 L/EP/day (kL)**							
											Total Required	**Mains**	**RW Reuse**					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	1148.1		51%	134.6	920.9	0.0	920.9
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	1304.6		51%	153.0	1046.5	0.0	1046.5
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	652.3		51%	76.5	523.3	0.0	523.3

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	8154.0		51%	956.3	6540.8	0.0	6540.8

Total for Month (kL)							11259.0				9031.5	0.0	9031.5
Assumptions:								Percentage Mains/ Reuse				0%	100%

1. 80 m² of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

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Appendix B.6 – Water Balance - May

Area	ET Factor	EP/ Unit of m^2	Unit	No. or Area	EP	Shop etc Area (m^2)	Eco villa	Eco Apartment				May		31	Days	78.8	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				34%	188.5	1332.2	1168.6	163.6					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			34%	6.8	48.3	42.3	5.9					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			34%	0.9	6.1	5.4	0.7					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		18%	172.4	1218.2	876.2	341.9					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	18%	23.8	167.9	120.8	47.1					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	18%	27.0	190.8	137.3	53.6					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	18%	13.5	95.4	68.6	26.8					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			34%	4.3	30.2	26.5	3.7					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			34%	6.5	45.8	40.2	5.6					
Swimming pool, tennis court & Gymnasium									34%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	2014.4	1448.9	565.4					
Living off site		0.32	No	200	**64**				95%	60.8	429.7	309.1	120.6					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				34%	2.4	17.0	14.9	2.1					
Allow nominal for facilities					**12**				34%	4.1	29.1	25.5	3.6					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	2364.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 73,200 kL for May)			kL	73,200													1621.7	
Mains Water Makeup (Balance of requirement)																		0.0
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	89.1	64.1	25.0					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				7%	18.0	127.2	111.6	15.6					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			7%	1.8	12.7	11.1	1.6					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			7%	5.4	38.5	33.7	4.7					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				18%	0.5	3.8	3.3	0.5					
Allow nominal for facilities									18%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	18%	23.8	167.9	120.8	47.1					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	18%	27.0	190.8	137.3	53.6					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	18%	13.5	95.4	68.6	26.8					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			18%	5.7	40.1	28.8	11.2					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														34266.3	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												5668.3		
On Site Stormwater Reuse (say 5% x available 128,800 kL for May)			kL	128800													5152.0	
Mains Water Makeup (Balance of requirement)																		23446.0
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		18%	165.2	1167.3	839.6	327.7					
TOTAL					**3973**	12500	750	300		**1069.3**	**7557.8**	**5703.3**	**1854.5**	**38252.0**	**2364.0**	**5668.3**	**6773.7**	**23446.0**
TOTAL in kL/day											**243.8**	**184.0**	**59.8**	**1233.9**	**76.3**	**182.8**	**218.5**	**756.3**

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with 64 l/p/day from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL)	(Note 5)							5668.3		
Total Water Required (kL)	**45809.8**		7557.8			38252.0				
Total Mains Water Required (kL)	**29149.2**			5703.3						23446.0
Total Mains Water Required (kL/day)	**940.3**									
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**								
Peak Mains Water Required (kL/day)	**1107.9**									

Mains Water Supply - Flow Rate over 24 Hours **12.8 L/sec**

Area	ET Factor	EP/ Unit or m^2	Unit	No. or Area	EP	RW Tank Storage	Rainwater Inflow				May			31	Days	78.8	mm Median Rain	
						@ 3 kL/ unit	Total Available		Occupancy	EP x Occupancy	Average Domestic Water Demand @ 228 L/EP/day (kL)							
											Total Required	Mains	RW Reuse					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	1497.8		18%	47.5	335.9	0.0	335.9
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	1702.1		18%	54.0	381.7	0.0	381.7
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	851.0		18%	27.0	190.8	0.0	190.8

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	10638.0		18%	337.5	2385.5	0.0	2385.5

Total for Month (kL)							14689.0				3293.8	0.0	3293.8
Assumptions:								Percentage Mains/ Reuse				0%	100%

1. 80 m^2 of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

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Appendix B.7– Water Balance - June

Area	ET Factor	EP/ Unit of m^2	Unit	No. or Area	EP	Shop etc Area (m^2)	Eco villa	Eco Apartment				June		30	Days	55	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				40%	221.0	1511.6	1325.9	185.6					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			40%	8.0	54.7	48.0	6.7					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			40%	1.0	6.9	6.1	0.9					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		21%	201.1	1375.4	989.3	386.1					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	21%	27.7	189.6	136.4	53.2					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	21%	31.5	215.5	155.0	60.5					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	21%	15.8	107.7	77.5	30.2					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			40%	5.0	34.2	30.0	4.2					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			40%	7.6	51.9	45.6	6.4					
Swimming pool, tennis court & Gymnasium									40%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	1949.4	1402.2	547.2					
Living off site		0.32	No	200	**64**				95%	60.8	415.9	299.1	116.7					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				40%	2.8	19.2	16.8	2.4					
Allow nominal for facilities					**12**				40%	4.8	32.8	28.8	4.0					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	1650.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 10,500 kL for Jun)			kL	10,500													525.0	
Mains Water Makeup (Balance of requirement)																		1810.7
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	86.2	62.0	24.2					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				10%	24.0	164.2	144.0	20.2					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			10%	2.4	16.4	14.3	2.0					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			10%	7.3	49.6	43.5	6.1					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				21%	0.6	4.3	3.8	0.5					
Allow nominal for facilities									21%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	21%	27.7	189.6	136.4	53.2					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	21%	31.5	215.5	155.0	60.5					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	21%	15.8	107.7	77.5	30.2					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			21%	6.6	45.2	32.5	12.7					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														29014.9	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												6121.0		
On Site Stormwater Reuse (say 20% x available 12,800 kL for Jun)			kL	12800													3840.0	
Mains Water Makeup (Balance of requirement)																		19053.9
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		21%	192.7	1317.9	948.0	369.9					
TOTAL					**3973**	12500	750	300		**1193.2**	**8161.4**	**6177.7**	**1983.7**	**33000.6**	**1650.0**	**6121.0**	**4365.0**	**20864.6**
TOTAL in kL/day											**272.0**	**205.9**	**66.1**	**1100.0**	**55.0**	**204.0**	**145.5**	**695.5**

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL)	(Note 5)							6121.0		
Total Water Required (kL)	**41162.0**		8161.4			33000.6				
Total Mains Water Required (kL)	**27042.3**			6177.7						20864.6
Total Mains Water Required (kL/day)	**901.4**									
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**								
Peak Mains Water Required (kL/day)	**1073.9**									

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with 64 l/p/day from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d

Mains Water Supply - Flow Rate over 24 Hours **12.4 L/sec**

Area	**ET Factor**	**EP/ Unit or m²**	**Unit**	**No. or Area**	**EP**	**RW Tank Storage**	**Rainwater Inflow**					**June**		**30**	**Days**	**55**	**mm Median Rain**	
						@ 3 kL/ unit	**Total Available**		**Occupancy**	**EP x Occupancy**	**Average Domestic Water Demand @ 228 L/EP/day (kL)**							
											Total Required	**Mains**	**RW Reuse**					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	1045.4		21%	55.4	379.2	0.0	379.2
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	1188.0		21%	63.0	430.9	0.0	430.9
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	594.0		21%	31.5	215.5	0.0	215.5

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	7425.0		21%	393.8	2693.3	0.0	2693.3

Total for Month (kL)							10252.4				3718.8	0.0	3718.8
								Percentage Mains/ Reuse				0%	100%

Assumptions:

1. 80 m² of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

Appendix B.8 – Water Balance - July

Area	ET Factor	EP/ Unit of m^2	Unit	No. or Area	EP	Shop etc Area (m^2)	Eco villa	Eco Apartment				July		31 Days		25 mm Median Rain		
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				54%	299.0	2113.2	1853.7	259.5					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			54%	10.8	76.5	67.1	9.4					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			54%	1.4	9.7	8.5	1.2					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		36%	344.7	2436.3	2137.1	299.2					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	36%	47.5	335.9	294.6	41.2					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	36%	54.0	381.7	334.8	46.9					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	36%	27.0	190.8	167.4	23.4					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			54%	6.8	47.8	42.0	5.9					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			54%	10.3	72.6	63.7	8.9					
Swimming pool, tennis court & Gymnasium									54%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	2014.4	1767.0	247.4					
Living off site		0.32	No	200	**64**				95%	60.8	429.7	377.0	52.8					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				54%	3.8	26.9	23.6	3.3					
Allow nominal for facilities					**12**				54%	6.5	46.1	40.4	5.7					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	750.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 11,900 kL for Jul)			kL	11,900													595.0	
Mains Water Makeup (Balance of requirement)																		2640.7
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	89.1	64.1	25.0					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				7%	18.0	127.2	111.6	15.6					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			7%	1.8	12.7	11.1	1.6					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			7%	5.4	38.5	33.7	4.7					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				36%	1.1	7.6	6.7	0.9					
Allow nominal for facilities									36%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	36%	47.5	335.9	294.6	41.2					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	36%	54.0	381.7	334.8	46.9					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	36%	27.0	190.8	167.4	23.4					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			36%	11.3	80.2	57.7	22.5					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														30349.3	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												8834.9		
On Site Stormwater Reuse (say 20% x available 18000 kL for Jul)			kL	18000													3600.0	
Mains Water Makeup (Balance of requirement)																		17914.4
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		36%	330.3	2334.6	2047.9	286.7					
TOTAL					**3973**	12500	750	300		**1666.6**	**11779.8**	**10306.5**	**1473.4**	**34335.0**	**750.0**	**8834.9**	**4195.0**	**20555.1**
TOTAL in kL/day											**380.0**	**332.5**	**47.5**	**1107.6**	**24.2**	**285.0**	**135.3**	**663.1**

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with28 l/p/day (**)from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d
** Ref Note 3: Reduced from 64 l/p/day to 28 l/p/day due to low rainfall month.

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL)	(Note 5)							8834.9		
Total Water Required (kL)	**46114.8**		11779.8			34335.0				
Total Mains Water Required (kL)	**30861.6**			10306.5						20555.1
Total Mains Water Required (kL/day)	**995.5**									
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**								
Peak Mains Water Required (kL/day)	**1228.1**									

Mains Water Supply - Flow Rate over 24 Hours **14.2 L/sec**

Area	ET Factor	EP/ Unit or m^2	Unit	No. or Area	EP	RW Tank Storage	Rainwater Inflow					July		31 Days		25 mm Median Rain		
						@ 3 kL/ unit	Total Available		Occupancy	EP x Occupancy	Average Domestic Water Demand @ 228 L/EP/day (kL)							
											Total Required	Mains	RW Reuse					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	369.6		36%	95.0	671.7	302.1	369.6
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	420.0		36%	108.0	763.3	343.3	420.0
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	210.0		36%	54.0	381.7	171.7	210.0

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	2625.0		36%	675.0	4770.9	2145.9	2625.0

Total for Month (kL)							3624.6				6587.7	2963.1	3624.6
Assumptions:								Percentage Mains/ Reuse				45%	55%

1. 80 m^2 of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

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Appendix B.9 – Water Balance - August

Area	ET Factor	EP/ Unit of m²	Unit	No. or Area	EP	Shop etc Area (m²)	Eco villa	Eco Apartment				August		31	Days	22.2	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				50%	276.3	1952.6	1712.8	239.8					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			50%	10.0	70.7	62.0	8.7					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			50%	1.3	8.9	7.8	1.1					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		33%	316.0	2233.3	1959.0	274.3					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	33%	43.6	307.9	270.1	37.8					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	33%	49.5	349.9	306.9	43.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	33%	24.8	174.9	153.5	21.5					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			50%	6.3	44.2	38.8	5.4					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			50%	9.5	67.1	58.9	8.2					
Swimming pool, tennis court & Gymnasium									50%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	2014.4	1767.0	247.4					
Living off site		0.32	No	200	**64**				95%	60.8	429.7	377.0	52.8					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				50%	3.5	24.9	21.8	3.1					
Allow nominal for facilities					**12**				50%	6.0	42.6	37.4	5.2					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	666.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 6900 kL for Aug)			kL	6,900													345.0	
Mains Water Makeup (Balance of requirement)																		2974.7
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	89.1	64.1	25.0					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				10%	24.0	169.6	148.8	20.8					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			10%	2.4	16.9	14.8	2.1					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			10%	7.3	51.3	45.0	6.3					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				33%	1.0	7.0	6.1	0.9					
Allow nominal for facilities									33%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	33%	43.6	307.9	270.1	37.8					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	33%	49.5	349.9	306.9	43.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	33%	24.8	174.9	153.5	21.5					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			33%	10.4	73.5	52.8	20.6					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														34413.0	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												8325.9		
On Site Stormwater Reuse (say 30% x available 6,800 kL for Aug)			kL	6800													2040.0	
Mains Water Makeup (Balance of requirement)																		24047.1
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		33%	302.8	2140.0	1877.2	262.8					
TOTAL					**3973**	12500	750	300		**1570.6**	**11101.2**	**9712.2**	**1389.0**	**38398.7**	**666.0**	**8325.9**	**2385.0**	**27021.8**
TOTAL in kL/day											**358.1**	**313.3**	**44.8**	**1238.7**	**21.5**	**268.6**	**76.9**	**871.7**

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL) (Note 5) 8325.9

Total Water Required (kL)	**49500.0**		11101.2			38398.7		
Total Mains Water Required (kL)	**36734.1**			9712.2				27021.8
Total Mains Water Required (kL/day)	**1185.0**							
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**						
Peak Mains Water Required (kL/day)	**1428.8**							

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with28 l/p/day (**)from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d
** Ref Note 3: Reduced from 64 l/p/day to 28 l/p/day due to low rainfall month.

Mains Water Supply - Flow Rate over 24 Hours **16.5 L/sec**

Area	**ET Factor**	**EP/ Unit or m^2**	**Unit**	**No. or Area**	**EP**	**RW Tank Storage**	**Rainwater Inflow**					**August**		**31**	**Days**	**22.2**	**mm Median Rain**	
						@ 3 kL/ unit	**Total Available**		**Occupancy**	**EP x Occupancy**	**Average Domestic Water Demand @ 228 L/EP/day (kL)**							
											Total Required	**Mains**	**RW Reuse**					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	328.2		33%	87.1	615.8	287.6	328.2
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	373.0		33%	99.0	699.7	326.8	373.0
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	186.5		33%	49.5	349.9	163.4	186.5

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	2331.0		33%	618.8	4373.3	2042.3	2331.0

Total for Month (kL)							3218.6				6038.7	2820.0	3218.6
								Percentage Mains/ Reuse				47%	53%

Assumptions:
1. 80 m^2 of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

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Appendix B.10 – Water Balance - Average Occupancy/ Dry Month - September

Area	ET Factor	EP/ Unit or m²	Unit	No. or Area	EP	Shop etc Area (m²)	Eco villa	Eco Apartment	Average Month, say			September		30	Days	20	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				93%	510.2	3490.0	3061.4	428.6					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			93%	18.5	126.4	110.9	15.5					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			93%	2.3	16.0	14.0	2.0					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		78%	746.9	5108.5	4481.1	627.4					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	78%	103.0	704.2	617.8	86.5					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	78%	117.0	800.3	702.0	98.3					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	78%	58.5	400.1	351.0	49.1					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			93%	11.5	79.0	69.3	9.7					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			93%	17.5	119.9	105.2	14.7					
Swimming pool, tennis court & Gymnasium									93%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	1949.4	1710.0	239.4					
Living off site		0.32	No	200	**64**				95%	60.8	415.9	364.8	51.1					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				93%	6.5	44.5	39.1	5.5					
Allow nominal for facilities					**12**				93%	11.2	76.3	67.0	9.4					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	600.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 4000 kL for Sept)			kL	4,000													200.0	
Mains Water Makeup (Balance of requirement)																		3185.7
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	86.2	62.0	24.2					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				26%	66.0	451.4	396.0	55.4					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			26%	6.6	45.0	39.4	5.5					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			26%	20.0	136.5	119.8	16.8					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				78%	2.3	16.0	14.0	2.0					
Allow nominal for facilities									78%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	78%	103.0	704.2	617.8	86.5					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	78%	117.0	800.3	702.0	98.3					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	78%	58.5	400.1	351.0	49.1					
Catchments 5 & 11 - Golf Course Precinct:																		

Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			78%	24.6	168.1	120.9	47.2					
Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														43801.1	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												15775.1		
On Site Stormwater Reuse (say max 40% x available 500 kL for Sept)			kL	500													200.0	
Mains Water Makeup (Balance of requirement)																		27826.0
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		78%	715.7	4895.0	4293.9	601.1					
TOTAL					**3973**	12500	750	300		**3075.1**	**21033.5**	**18410.3**	**2623.2**	**47786.8**	**600.0**	**15775.1**	**400.0**	**31011.7**
TOTAL in kL/day											**701.1**	**613.7**	**87.4**	**1592.9**	**20.0**	**525.8**	**13.3**	**1033.7**

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL) (Note 5) 15775.1

Total Water Required (kL)	**68820.2**		21033.5		47786.8	
Total Mains Water Required (kL)	**49421.9**			18410.3		31011.7
Total Mains Water Required (kL/day)	**1647.4**					
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**				
Peak Mains Water Required (kL/day)	**2057.6**					

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with28 l/p/day (**)from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d
** Ref Note 3: Reduced from 64 l/p/day to 28 l/p/day due to low rainfall month.

Mains Water Supply - Flow Rate over 24 Hours **23.8 L/sec**

Area	**ET Factor**	**EP/ Unit or m²**	**Unit**	**No. or Area**	**EP**	**RW Tank Storage**	**Rainwater Inflow**				**September**			**30 Days**		**20 mm Median Rain**		
						@ 3 kL/ unit	**Total Available**		**Occupancy**	**EP x Occupancy**	**Average Domestic Water Demand @ 228 L/EP/day (kL)**							
											Total Required	**Mains**	**RW Reuse**					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	295.7		78%	205.9	1408.5	1112.8	295.7
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	336.0		78%	234.0	1600.6	1264.6	336.0
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	168.0		78%	117.0	800.3	632.3	168.0

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	2100.0		78%	1462.5	10003.5	7903.5	2100.0

Total for Month (kL)							2899.7				13812.8	10913.2	2899.7
Assumptions:								Percentage Mains/ Reuse				79%	21%

1. 80 m^2 of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

Appendix B.11– Water Balance - October

Area	ET Factor	EP/ Unit of m^2	Unit	No. or Area	EP	Shop etc Area (m^2)	Eco villa	Eco Apartment				October		31	Days	23.6	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				76%	416.0	2940.4	2579.3	361.1					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			76%	15.1	106.5	93.4	13.1					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			76%	1.9	13.5	11.8	1.7					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		53%	507.1	3584.1	3144.0	440.2					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	53%	69.9	494.1	433.4	60.7					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	53%	79.4	561.5	492.5	69.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	53%	39.7	280.7	246.3	34.5					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			53%	6.6	46.6	40.9	5.7					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			53%	10.0	70.7	62.1	8.7					
Swimming pool, tennis court & Gymnasium									53%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	2014.4	1767.0	247.4					
Living off site		0.32	No	200	**64**				95%	60.8	429.7	377.0	52.8					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				76%	5.3	37.6	33.0	4.6					
Allow nominal for facilities					**12**				76%	9.1	64.5	56.5	7.9					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	708.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 8,400 kL for Sept)			kL	8,400													420.0	
Mains Water Makeup (Balance of requirement)																		2857.7
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	89.1	64.1	25.0					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				14%	36.0	254.4	223.2	31.2					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			14%	3.6	25.3	22.2	3.1					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			14%	10.9	76.9	67.5	9.4					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				65%	2.0	13.8	12.1	1.7					
Allow nominal for facilities									53%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	53%	69.9	494.1	433.4	60.7					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	53%	79.4	561.5	492.5	69.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	53%	39.7	280.7	246.3	34.5					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			53%	16.7	117.9	84.8	33.1					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														50666.1	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												11994.4		
On Site Stormwater Reuse (say 40% x available 1,000 kL for Oct)			kL	1000													400.0	
Mains Water Makeup (Balance of requirement)																		38271.6
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		53%	485.9	3434.4	3012.6	421.8					
TOTAL					**3973**	12500	750	300		**2262.7**	**15992.6**	**13995.9**	**1996.7**	**54651.8**	**708.0**	**11994.4**	**820.0**	**41129.3**
TOTAL in kL/day											**515.9**	**451.5**	**64.4**	**1763.0**	**22.8**	**386.9**	**26.5**	**1326.8**

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL)	(Note 5)							11994.4		
Total Water Required (kL)	**70644.4**		15992.6			54651.8				
Total Mains Water Required (kL)	**55125.2**			13995.9						41129.3
Total Mains Water Required (kL/day)	**1778.2**									
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**								
Peak Mains Water Required (kL/day)	**2136.6**									

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)

Note 2: Effluent Reuse fully required for Golf Course.

Note 3: Villas and Apartments, staff units - 228 l/p/day with28 l/p/day (**)from RW Reuse.

Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.

Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d

** Ref Note 3: Reduced from 64 l/p/day to 28 l/p/day due to low rainfall month.

Mains Water Supply - Flow Rate over 24 Hours **24.7 L/sec**

Area	ET Factor	EP/ Unit or m²	Unit	No. or Area	EP	RW Tank Storage	Rainwater Inflow				October			31	Days	23.6	mm Median Rain	
						@ 3 kL/ unit	Total Available		Occupancy	EP x Occupancy	Average Domestic Water Demand @ 228 L/EP/day (kL)							
											Total Required	Mains	RW Reuse					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Area	ET Factor	EP/ Unit or m²	Unit	No. or Area	EP	RW Tank Storage	Rainwater Inflow		Occupancy	EP x Occupancy	Total Required	Mains	RW Reuse
Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	348.9		53%	139.8	988.2	639.3	348.9
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	396.5		53%	158.9	1123.0	726.5	396.5
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	198.2		53%	79.4	561.5	363.2	198.2

Total Numbers of Eco-Tourism Villas:

Area	ET Factor	EP/ Unit or m²	Unit	No. or Area	EP	RW Tank Storage	Rainwater Inflow		Occupancy	EP x Occupancy	Total Required	Mains	RW Reuse
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	2478.0		53%	993.0	7018.5	4540.5	2478.0
Total for Month (kL)							3421.6				9691.2	6269.6	3421.6
								Percentage Mains/ Reuse				65%	35%

Assumptions:

1. 80 m² of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

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Appendix B.12 – Water Balance - November

Area	ET Factor	EP/ Unit of m²	Unit	No. or Area	EP	Shop etc Area (m²)	Eco villa	Eco Apartment			November			30	Days	30	mm Median Rain	
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				65%	357.5	2445.3	2145.0	300.3					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			65%	12.9	88.6	77.7	10.9					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			65%	1.6	11.2	9.8	1.4					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		50%	478.8	3274.7	2872.5	402.2					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	50%	66.0	451.4	396.0	55.4					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	50%	75.0	513.0	450.0	63.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	50%	37.5	256.5	225.0	31.5					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			65%	8.1	55.4	48.6	6.8					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			65%	12.3	84.0	73.7	10.3					
Swimming pool, tennis court & Gymnasium									65%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	1949.4	1710.0	239.4					
Living off site		0.32	No	200	**64**				95%	60.8	415.9	364.8	51.1					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				65%	4.6	31.1	27.3	3.8					
Allow nominal for facilities					**12**				65%	7.8	53.4	46.8	6.6					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	900.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 11,100 kL for Nov)			kL	11,100													555.0	
Mains Water Makeup (Balance of requirement)																		2530.7
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	86.2	62.0	24.2					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				12%	30.0	205.2	180.0	25.2					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			12%	3.0	20.4	17.9	2.5					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			12%	9.1	62.1	54.4	7.6					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				65%	2.0	13.3	11.7	1.6					
Allow nominal for facilities									65%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	65%	85.8	586.9	514.8	72.1					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	65%	97.5	666.9	585.0	81.9					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	65%	48.8	333.5	292.5	41.0					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			65%	20.5	140.0	100.7	39.3					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														54272.6	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												11867.6		
On Site Stormwater Reuse (say 30% x available 4,700 kL for Nov)			kL	4700													1880.0	
Mains Water Makeup (Balance of requirement)																		40525.0
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		65%	596.4	4079.2	3578.3	501.0					
TOTAL					3973	12500	750	300		**2313.4**	**15823.5**	**13844.5**	**1979.0**	**58258.3**	**900.0**	**11867.6**	**2435.0**	**43055.7**
TOTAL in kL/day											**527.4**	**461.5**	**66.0**	**1941.9**	**30.0**	**395.6**	**81.2**	**1435.2**

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL)	(Note 5)							11867.6		
Total Water Required (kL)	**74081.7**		15823.5			58258.3				
Total Mains Water Required (kL)	**56900.2**			13844.5						43055.7
Total Mains Water Required (kL/day)	**1896.7**									
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**								
Peak Mains Water Required (kL/day)	**2270.9**									

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with28 l/p/day (**)from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d
** Ref Note 3: Reduced from 64 l/p/day to 28 l/p/day due to low rainfall month.

Mains Water Supply - Flow Rate over 24 Hours **26.3 L/sec**

Area	**ET Factor**	**EP/ Unit or m²**	**Unit**	**No. or Area**	**EP**	**RW Tank Storage**	**Rainwater Inflow**					**November**		**30**	**Days**	**30**	**mm Median Rain**	
						@ 3 kL/ unit	**Total Available**		**Occupancy**	**EP x Occupancy**	**Average Domestic Water Demand @ 228 L/EP/day (kL)**							
											Total Required	**Mains**	**RW Reuse**					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	443.5		50%	132.0	902.9	459.4	443.5
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	504.0		50%	150.0	1026.0	522.0	504.0
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	252.0		50%	75.0	513.0	261.0	252.0

Total Numbers of Eco-Tourism Villas:

Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	3150.0		65%	1218.8	8336.3	5186.3	3150.0

Total for Month (kL)							4349.5				10778.1	6428.6	4349.5
								Percentage Mains/ Reuse				60%	40%

Assumptions:

1. 80 m^2 of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

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Appendix B.13 – Water Balance - December

Area	ET Factor	EP/ Unit of m^2	Unit	No. or Area	EP	Shop etc Area (m^2)	Eco villa	Eco Apartment	Average Month, say			December		31	Days		111.4	mm Median Rain
									Occupancy	EP x Occupancy	Average Domestic Water Demand (kL)			Landscape Watering (kL)				
									(Ex Foresight)		Total Required	Mains	RW Reuse	Total Required	Median Rainfall	Effluent Reuse	SW Harvested	Balance from Mains
Catchments 7, 8 & 9: Fisherman's Beach Precinct																		
Fishermans Beach Hotel																		
Rooms - One bedroom – all rooms		2.2	No	250	**550**				92%	506.0	3576.4	3137.2	439.2					
Restaurant, hotel Licensed premises etc - Gross floor area	0.0083	0.0249	m2	800	**20**	800			92%	18.3	129.5	113.6	15.9					
Retail Shops	0.0042	0.0126	m2	200	**3**	200			92%	2.3	16.4	14.4	2.0					
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms		2.5	No	383	**958**		383		84%	804.3	5684.8	4089.1	1595.7					
Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	84%	110.9	783.7	563.7	220.0					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	84%	126.0	890.6	640.6	250.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	84%	63.0	445.3	320.3	125.0					
Fishermans Beach Resort																		
Restaurants, café, Fast Food etc Gross floor area	0.0083	0.0249	m2	500	**12**	500			92%	11.5	81.0	71.0	9.9					
Retail Shops including pro shop	0.0042	0.0126	m2	1,500	**19**	1,500			92%	17.4	122.9	107.8	15.1					
Swimming pool, tennis court & Gymnasium									92%	0.0	0.0	0.0	0.0					
Staff																		
Living on site - allow one bedroom unit - Long term		1.5	No	200	**300**				95%	285.0	2014.4	1448.9	565.4					
Living off site		0.32	No	200	**64**				95%	60.8	429.7	309.1	120.6					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	70	**7**				92%	6.4	45.5	39.9	5.6					
Allow nominal for facilities					**12**				92%	11.0	78.0	68.4	9.6					
Landscape Watering (assumed 3 Ha @ 30 mm/ week)			Ha	3										3985.7	3342.0			
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0												0.0		
On Site Stormwater Reuse (say 5% x available 36,000 kL for Dec)			kL	36,000													643.7	
Mains Water Makeup (Balance of requirement)																		0.0
Airport																		
Total Area 3,500m2 allow 1,000m2 retail, etc.	0.0042	0.0126	m2	1,000	**13**				100%	12.6	89.1	64.1	25.0					
Effluent Reuse (equiv to 2 mm/ day = ~60 mm/ mth). All used on Golf Course.			Ha	0										0.0		0.0		
Catchment 14 - Marina Precinct:																		
Marina																		
Berths		1	No	250	**250**				48%	120.0	848.2	744.0	104.2					
Yacht Club - Licensed premises, restaurants, café etc Gross floor area	0.0083	0.0249	m2	1,000	**25**	1,000			48%	12.0	84.5	74.1	10.4					
Retail Shops	0.0042	0.0126	m2	6,000	**76**	6,000			48%	36.3	256.5	225.0	31.5					
Day Visitors																		
Assume 0.1 EP/ Visitor (noting also public area allowances)		0.1	No	30	**3**				84%	2.5	17.8	15.6	2.2					
Allow nominal for facilities									84%	0.0	0.0	0.0	0.0					
Marina Ecotourism Apartments (150 No.)																		
Assume 40% short term accommodation - One bedroom		2.2	No	60	**132**			60	84%	110.9	783.7	563.7	220.0					
Assume 40% short term accommodation - Two bedroom		2.5	No	60	**150**			60	84%	126.0	890.6	640.6	250.0					
Assume 20% short term accommodation - Three bedroom		2.5	No	30	**75**			30	84%	63.0	445.3	320.3	125.0					
Catchments 5 & 11 - Golf Course Precinct:																		
Golf Clubhouse including Golf Day Visitors	0.0042	0.0126	m2	2,500	**32**	2,500			84%	26.5	187.0	134.5	52.5					

Golf Course - Tees, Greens, Fairways (ex Golf Course Designer)														42786.4	0.0	(rainfall included in requirement)		
Effluent Reuse (@ maximum rate equiv to 2 mm/ day = ~60 mm/ mth)			Ha	31												17511.0		
On Site Stormwater Reuse (say 10% x available 41,200 kL for Dec)			kL	41200													4120.0	
Mains Water Makeup (Balance of requirement)																		21155.3
Ecotourism Villas																		
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	367	**918**		367		84%	770.7	5447.3	3918.2	1529.1					
TOTAL					**3973**	12500	750	300		**3303.3**	**23348.1**	**17624.2**	**5723.8**	**46772.1**	**3342.0**	**17511.0**	**4763.7**	**21155.3**
TOTAL in kL/day											**753.2**	**568.5**	**184.6**	**1508.8**	**107.8**	**564.9**	**153.7**	**682.4**

Note 1: Public areas EP = ET Factor x 3 (Ex Livingston Council Design Guideline)
Note 2: Effluent Reuse fully required for Golf Course.
Note 3: Villas and Apartments, staff units - 228 l/p/day with 64 l/p/day from RW Reuse.
Note 4: Hotel and Core facilities - 228 l/p/day with 28 l/p/day from RW Reuse.
Note 5: Sewer flow/ EP = 136 L/p/d (ext supply) + 44 L/p/d (RW Reuse) = 180 L/p/d

Check available Effluent Reuse @ EP x Occupancy x 180 x 95% (kL) (Note 5)								17511.0		
Total Water Required (kL)	**70120.1**		23348.1			46772.1				
Total Mains Water Required (kL)	**38779.6**			17624.2						21155.3
Total Mains Water Required (kL/day)	**1251.0**									
Peaking Factor (Peak Demand/ Ave Demand) = 1.5 (Dom), 1.1 (Land)	**1.5**	**1.1**								
Peak Mains Water Required (kL/day)	**1603.5**									

Mains Water Supply - Flow Rate over 24 Hours **18.6 L/sec**

Area	ET Factor	EP/ Unit or m^2	Unit	No. or Area	EP	RW Tank Storage	Rainwater Inflow				December		31	Days	111.4	mm Median Rain		
						@ 3 kL/ unit	Total Available		Occupancy	EP x Occupancy	Average Domestic Water Demand @ 228 L/EP/day (kL)							
											Total Required	Mains	RW Reuse					

Potential for Rainwater Reuse to Apartments and Villas:

Total Numbers of Eco-Tourism Apartments:

Assume 40% short term accommodation - One bedroom		2.2	No	120	**264**	792	2117.5		84%	221.8	1567.4	0.0	1567.4
Assume 40% short term accommodation - Two bedroom		2.5	No	120	**300**	900	2406.2		84%	252.0	1781.1	0.0	1781.1
Assume 20% short term accommodation - Three bedroom		2.5	No	60	**150**	450	1203.1		84%	126.0	890.6	0.0	890.6

Total Numbers of Eco-Tourism Villas:

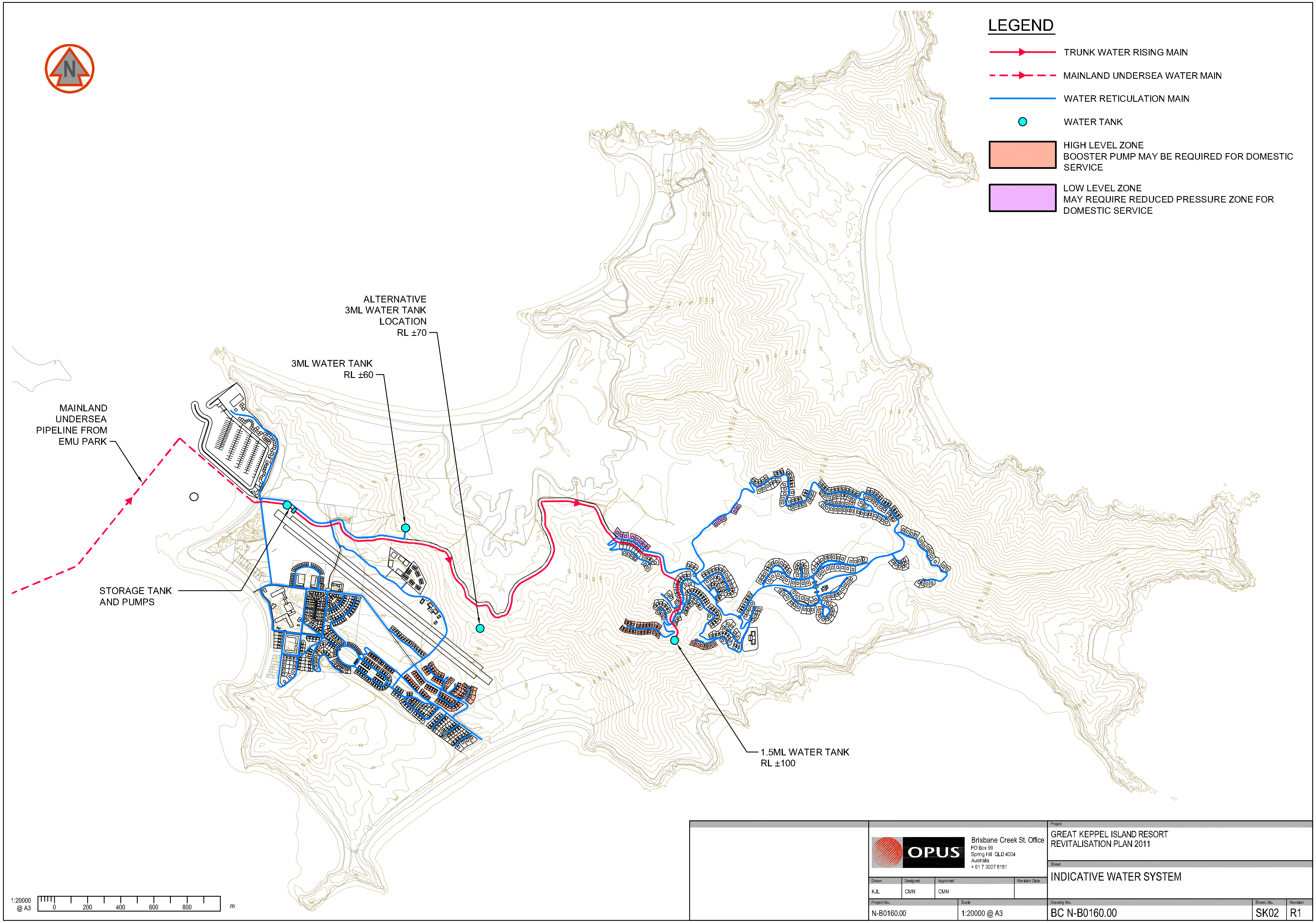
Assume 100% short term accommodation – Three bedrooms	2.5	2.5	No	750	**1875**	5625	15039.0		84%	1575.0	11132.1	0.0	11132.1

Total for Month (kL)							20765.9				15371.2	0.0	15371.2
								Percentage Mains/ Reuse				0%	100%

Assumptions:
1. 80 m^2 of roof to apartments and villas connected to rainwater reuse storage tanks.
2. Rainfall for calculation taken as median rain for month based on BOM Rainfall data.
3. Storage capacity assumed as 3000 L/ apartment or villa.
4. Rainfall capture assumed as follows:
   - 90 % with rainfall up to 50 mm/ mth;
   - 70 % with rainfall above 50 mm/ mth.

APPENDIX F

Water Supply Scheme Layout



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Project: GREAT KEPPEL ISLAND RESORT REVITALISATION PLAN 2011

Sheet: INDICATIVE WATER SYSTEM

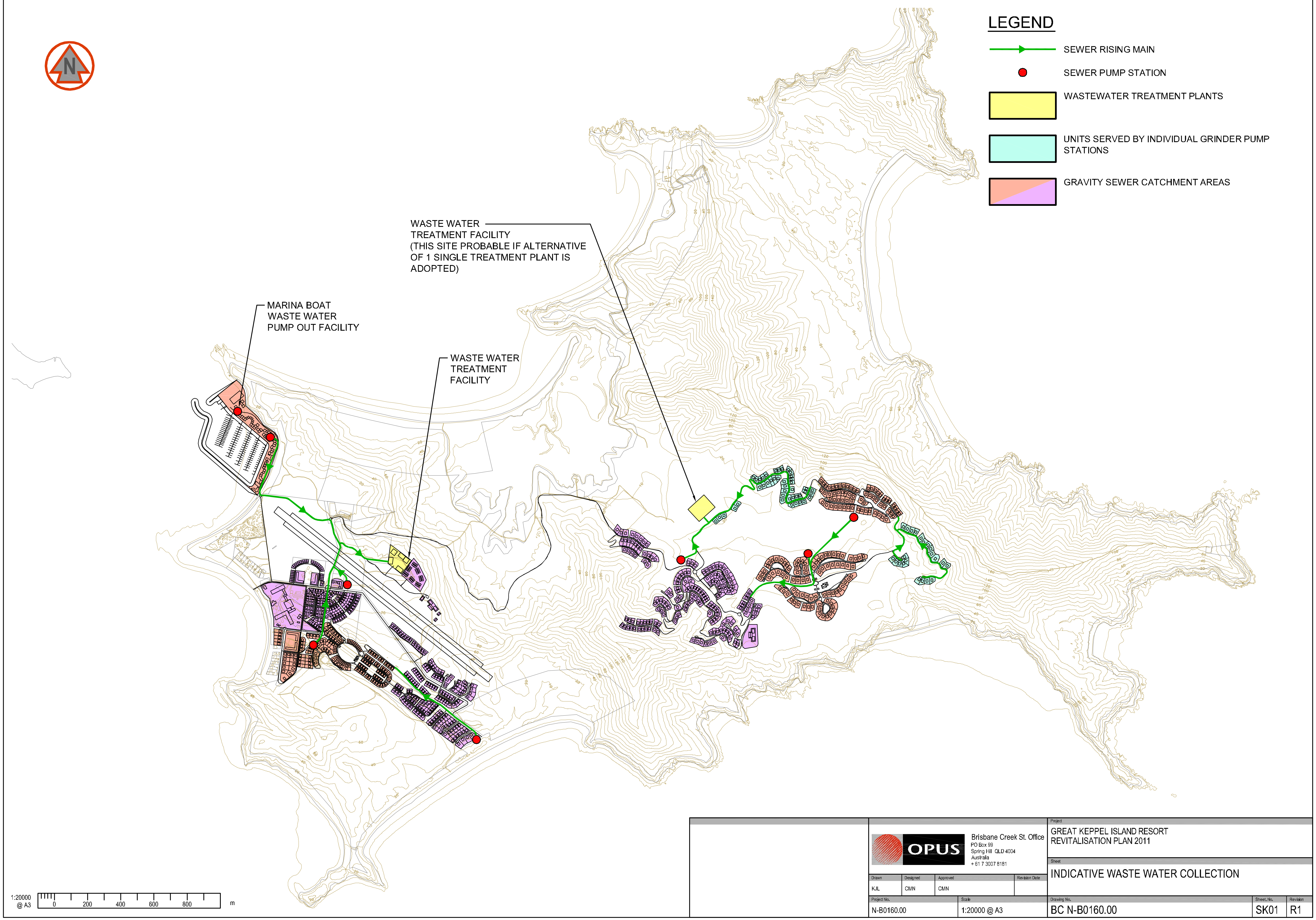
Drawn	Designed	Approved	Revision Date
KJL	CMN	CMN	

Project No.	Scale	Drawing No.	Sheet No.	Revision
N-B0160.00	1:20000 @ A3	BC N-B0160.00	SK02	R1

Original Sheet Size A3 [420x297] Plot Date

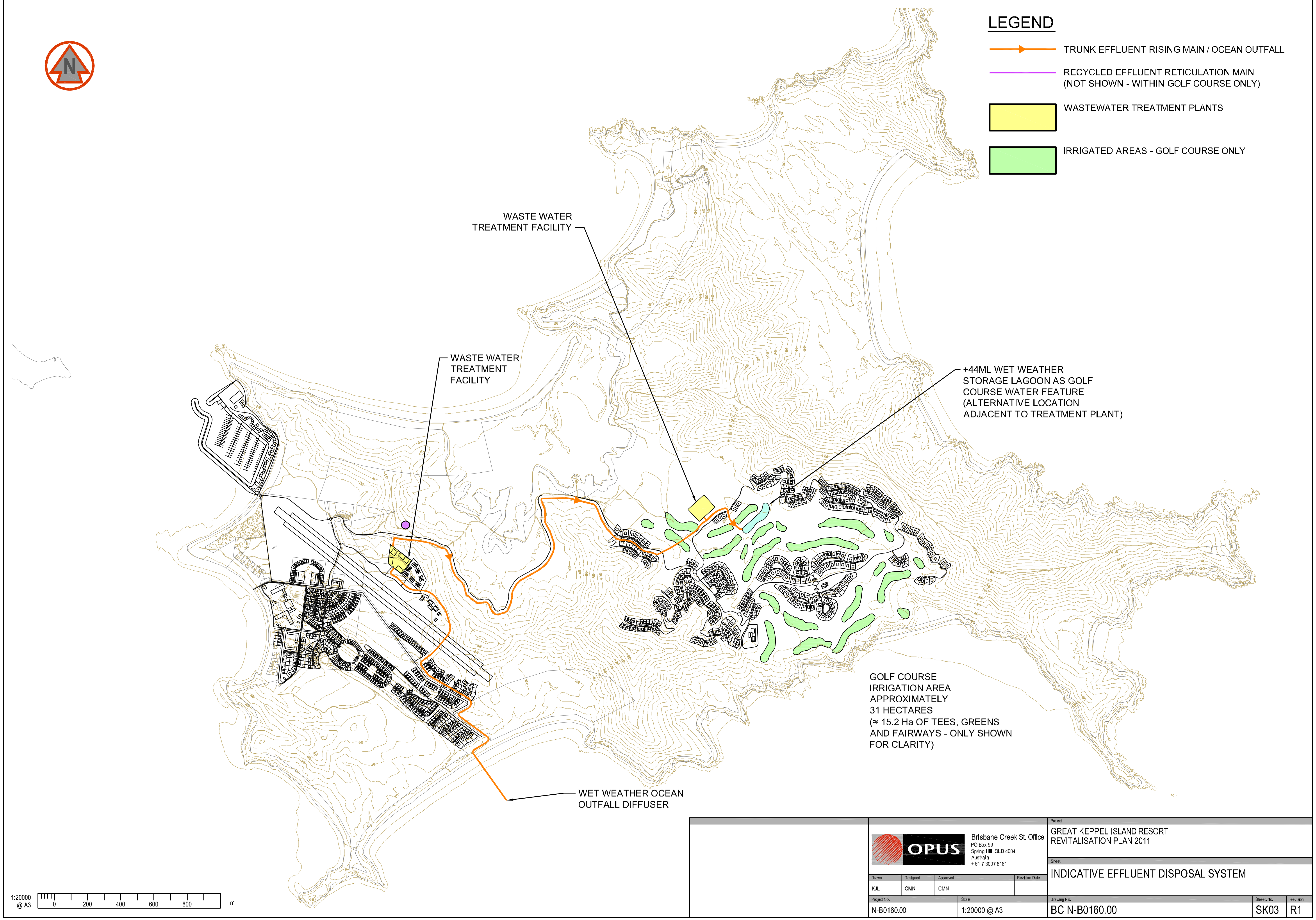
APPENDIX G

Wastewater Scheme Layout



OPUS Brisbane Creek St. Office PO Box 99 Spring Hill QLD 4004 Australia +61 7 3007 8181	Project	GREAT KEPPEL ISLAND RESORT REVITALISATION PLAN 2011
	Sheet	INDICATIVE WASTE WATER COLLECTION
Drawn: KJL	Designed: CMN	Approved: CMN
Project No.: N-B0160.00	Scale: 1:20000 @ A3	Drawing No.: BC N-B0160.00
Sheet No.: SK01	Revision: R1	

Original Sheet Size A3 [420x297] Plot Date



OPUS Brisbane Creek St. Office PO Box 99 Spring Hill QLD 4004 Australia +61 7 3007 8181				Project: GREAT KEPPEL ISLAND RESORT REVITALISATION PLAN 2011
Drawn: KJL	Designed: CMN	Approved: CMN	Revision Date:	Sheet: INDICATIVE EFFLUENT DISPOSAL SYSTEM
Project No.: N-B0160.00	Scale: 1:20000 @ A3			Drawing No.: BC N-B0160.00 / Sheet No.: SK03 / Revision: R1

Original Sheet Size A3 [420x297]   Plot Date

APPENDIX H

Preliminary Irrigation Management Plan

Great Keppel Island Resort Revitalisation Plan

Preliminary Irrigation Management Plan

For GKI Resort Pty Ltd

Revision A

15 September 2011

Opus International Consultants (PCA) Pty Ltd

ABN 89 096 110 262

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Preliminary Irrigation Management Plan

Great Keppel Island Resort Revitalisation Plan

Revision A

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DOCUMENT HISTORY

REVISION / ISSUE RECORD

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GKI Resort Pty Ltd	1				

Prepared By:

MARK FARREY
Environmental Consultant

Approved for Issue:

for **Tracey Birt**
Work Group Manager ~
Environmental & Planning

1. INTRODUCTION

This preliminary Irrigation Management Plan (IMP) has been prepared by Opus International Consultants ('Opus') on behalf of GKI Resort Pty Ltd to outline management strategies for the reuse of recycled water for irrigation as part of the Great Keppel Island (GKI) Resort Revitalisation Plan. The contents of this Plan are to be included as part of the overall Environmental Impact Statement (EIS) prepared for the GKI Resort Revitalisation Plan and will need to be updated to reflect the final design of the scheme and any relevant conditions of approval prior to implementation of the IMP.

1.1 PROJECT OVERVIEW

The GKI Resort Revitalisation Plan will involve operation of a wastewater treatment plant (WWTP) or multiple WWTP(s) to treat sewage generated by the resort and marina facilities. Recycled water produced by the Island-based WWTP(s) will be used for irrigation of the proposed golf course and possibly other landscaped areas around the resort where sufficient recycled water supply is available.

The proposed WWTP(s) will have a peak design capacity to treat an Average Dry Weather Flow (ADWF) of approximately 3,973 equivalent persons (EP) or approximately 794.6kL/day based on 200L/EP/day.

Operation of the proposed WWTP(s) will conform to the definition of environmentally relevant activity (ERA) 63(2)(c), which is defined in schedule 2 of the *Environmental Protection Regulation 2008* as follows:

> ***ERA 63(2)(c)*** *– Sewage treatment – operating sewage treatment works, other than no release works, with a total peak design capacity of – 1,500 to 4,000EP.*

Prior to commencement of the activity, development approval will be required for the above ERA under chapter 4 of the *Environmental Protection Act 1994*. The Resort Manager will also be required to obtain a registration certificate to operate the above ERA.

1.2 PURPOSE

The purpose of this IMP is to outline the requirements for operation of the proposed recycled water irrigation scheme associated with the GKI Resort Revitalisation Plan to:

- Comply with relevant legislation and standards;
- Provide strategies to mitigate potential environmental and public health risks likely to be associated with reuse of recycled water for irrigation; and
- Establish a framework for addressing potential environmental and public health risks arising in the future.

In this regard, the IMP will detail:

- Routine operating procedures to prevent or minimise environmental harm;
- Monitoring of the release of contaminants into the environment, including monitoring of environmental impact;
- Procedures for dealing with environmental incidents and complaints;

- Environmental reporting and maintenance of records; and
- Staff training and awareness of environmental issues.

The IMP has been prepared to support the Environmental Impact Statement (EIS) prepared for the GKI Resort Revitalisation Plan and is based on an assessment of environmental aspects and associated impacts identified during the preliminary planning phase of the recycled water irrigation scheme. Environmental aspects (activities and works that are likely to have an environmental impact) need to be continuously identified over the life of the scheme.

The IMP will need to be updated based on an assessment of environmental aspects and impacts during the detailed design phase of the recycled water irrigation scheme and to incorporate conditions of development approval under the *Environmental Protection Act 1994* and other relevant legislation.

The IMP will continue to evolve over the life of the scheme, taking into consideration the results of ongoing monitoring and / or the introduction of new technologies that reduce the risk of environmental harm.

2. ROLES & RESPONSIBILITIES

2.1 ORGANISATIONAL STRUCTURE

The following chart identifies the main entities likely to be involved in operation of the recycled water irrigation scheme and the relationships between these entities.

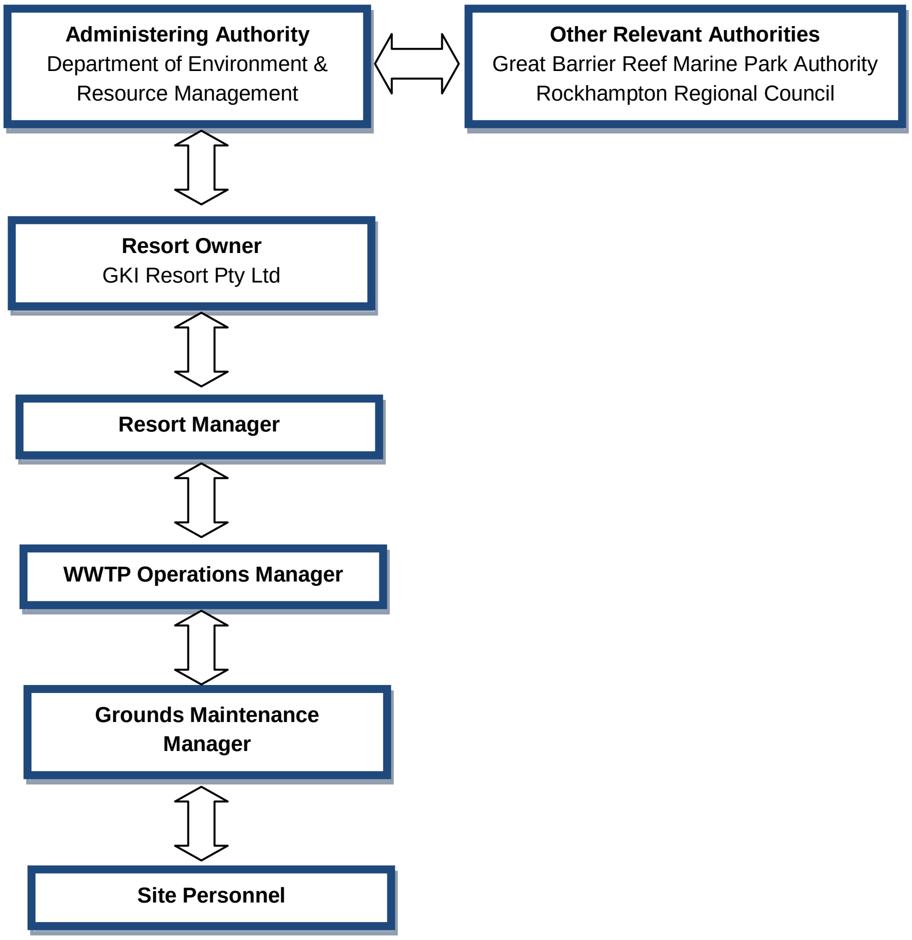

Figure 1: Recycled Water Irrigation Scheme Organisational Structure

2.2 ROLES & RESPONSIBILITIES

2.2.1 Resort Owner

The Resort Owner shall be responsible for:

- Forwarding in a timely manner, all information and reports required by this IMP and the conditions of development approval to the Administering Authority; and
- Ensuring appropriate resources are planned and made available to enable effective implementation of this IMP and conditions of development approval.

2.2.2 Resort Manager

The Resort Manager shall be responsible for:

- Coordination of all operation and maintenance activities to ensure compliance with this IMP and conditions of development approval;
- Providing regular reports to the Resort Owner detailing condition, maintenance requirements and budgetary needs for ongoing operation of the WWTP(s) and recycled water irrigation scheme;
- Forwarding all information received from the WWTP Operations Manager relating to this IMP (e.g. log sheets, incident registers, complaint registers) to the Resort Owner;
- Ensuring that all personnel involved in operation of the WWTP and recycled water irrigation scheme are aware of their responsibilities under this IMP;
- Ensuring that all personnel responsible for operation and monitoring of the WWTP and recycled water irrigation scheme are adequately trained;
- Maintaining records to ensure compliance with this IMP and conditions of development approval;
- Updating the IMP to reflect any changes in legislation or standards; and
- Collation and preparation of all information and reports (e.g. annual returns, incidents, complaints and other notifiable events) required by this IMP and conditions of development approval for submission, through the Resort Owner, to the Administering Authority.

2.2.3 WWTP Operations Manager

The WWTP Operation Manager shall be responsible for:

- Day to day operation of the WWTP;
- Maintaining all plant and equipment associated with the WWTP in a condition that ensures compliance with this IMP and conditions of development approval;
- Providing regular reports to the Resort Manager detailing the condition of all plant and equipment associated with the WWTP and recycled water irrigation scheme, and identifying any remedial works required to ensure compliance with this IMP and conditions of development approval;
- Providing regular reports to the Resort Manager detailing all maintenance activities conducted;
- Coordination of testing activities required by this IMP and conditions of development approval;
- Notifying the Grounds Maintenance Manager of any non-compliance with recycled water quality that may increase public health or environmental risks associated recycled water reuse;
- Forwarding the results of all monitoring of recycled water quality, soils, groundwater and surface waters required by this IMP and conditions of development approval to the Resort Manager;

- Ensuring that all personnel responsible for monitoring operation of the WWTP and recycled water irrigation scheme comply with the requirements of this IMP and conditions of development approval; and

- Reporting any incidents or complaints to the Resort Manager.

2.2.4 Grounds Maintenance Manager

- Day to day operation of the recycled water irrigation scheme;

- Maintaining all plant and equipment associated with the recycled water irrigation scheme in a condition that ensures compliance with this IMP and conditions of development approval;

- Providing regular reports to the WWTP Operations Manager detailing the condition of all plant and equipment associated with the recycled water irrigation scheme, and identifying any remedial works required to ensure compliance with this IMP and conditions of development approval;

- Providing regular reports to the WWTP Operations Manager detailing all maintenance activities conducted;

- Conducting testing activities associated with the recycled water irrigation scheme (ie. soil testing, surface and groundwater testing, etc) required by this IMP and conditions of development approval;

- Notifying the WWTP Operations Manager of any issues relating to possible non-compliance of recycled water quality or quantity;

- Forwarding the results of all recycled water irrigation monitoring (ie. soil testing, surface and groundwater testing, etc) required by this IMP and conditions of development approval to the WWTP Operations Manager;

- Ensuring that all personnel responsible for monitoring operation of the recycled water irrigation scheme comply with the requirements of this IMP and conditions of development approval; and

- Reporting any incidents or complaints to the WWTP Operations Manager.

2.2.5 Site Personnel

All Site Personnel shall be responsible for:

- Reporting any incidents or complaints to the WWTP Operations Manager; and

- Complying with the general environmental duty.

3. ROUTINE OPERATING PROCEDURES

3.1 REUSE SCHEME OVERVIEW

3.1.1 Wastewater Treatment Plant

The proposed WWTP will have a peak design capacity to treat an Average Dry Weather Flow (ADWF) of approximately 3,973 equivalent persons (EP) or approximately 794.6kL/day based on 200L/EP/day.

At this stage, it has not been confirmed whether a single WWTP or two WWTPs will be provided on the Island to service the GKI Resort Revitalisation Plan. This will be confirmed at detailed design stage based on the final layout and staging of the GKI Resort Revitalisation Plan, the type of treatment system to be used, land availability and buffer zone requirements.

If two WWTPs are to be provided on the Island, these would most likely be located as follows:

- A WWTP with a total design capacity of approximately 3,000EP servicing the Marina Precinct and Fisherman's Beach Precinct – most likely located on the north eastern side of the airstrip within the vicinity of the facilities maintenance compound; and

- A WWTP with a total design capacity of approximately 1,000EP servicing the Clam Bay Precinct – most likely located to the north west of the golf course.

If a single WWTP is to be provided on the Island this would most likely be located in one of the above locations.

A number of wastewater treatment processes and systems would be capable of achieving the required standard of treatment. Although the exact treatment process and system used will be determined at detailed design stage, one of the preferred options at this stage comprises a membrane bio-reactor (MBR) or similar system with UV disinfection. The advantages of this type of treatment system are:

- Relatively compact treatment system requiring a much smaller footprint than other systems;

- Proven ability to consistently produce the high quality of recycled water required;

- Largely enclosed / sealed treatment components to reduce potential odour nuisance; and

- Capacity to operate multiple treatment plants in parallel to assist with staging and to provide the operational flexibility needed given the likely fluctuation of hydraulic loading.

3.1.2 Hydraulic Loading

An Average Dry Weather Flow (ADWF) of 180 L/EP/day has been calculated for the GKI Resort Revitalisation Plan. However, preliminary assessment of recycled water reuse has been based on an ADWF of 200 L/EP/day. This is to ensure a conservative assessment of irrigation area and wet weather storage requirements for the recycled water irrigation scheme given the environmentally sensitive nature of the site.

Wastewater generation and therefore the availability of recycled water for irrigation will vary considerably over the year due to fluctuations in occupancy rates at the resort and marina facilities. Although the theoretical maximum design population for the GKI Resort Revitalisation Plan is estimated to be approximately 3,973 EP, it is estimated that the actual design population will range between approximately 1,069 EP/day in May up to 3,750 EP/day in January.

The recycled water irrigation scheme has been designed on the basis of the monthly wastewater generation rates summarised in **Table 1**, which have been calculated for the GKI Resort Revitalisation Plan based on expected occupancy rates and an ADWF of 200L/EP/day.

TABLE 1: Estimated Monthly Wastewater Flows (@200L/EP/day) Adopted for MEDLI Modelling

Month	Average Occupancy (EP/day)	ADWF for Month @ 200 L/EP/day	
		ML/day	ML/month
January	3,750	0.75	23.25
February	1,725	0.34	9.66
March	1,848	0.37	11.45
April	2,144	0.43	12.86
May	1,069	0.21	6.63
June	1,193	0.24	7.16
July	1,667	0.33	10.33
August	1,571	0.31	9.74
September	3,075	0.62	18.45
October	2,263	0.45	14.03
November	2,313	0.46	13.88
December	3,303	0.66	20.48

3.1.3 Recycled Water Quality

The WWTP will be designed to treat all wastewater generated by the GKI Resort Revitalisation Plan to the standard specified in **Table 2**.

TABLE 2: Proposed Minimum Recycled Water Quality Criteria

Quality Characteristic	Unit	Release Limit	Limit Type	Monitoring Frequency
E. coli	cfu/100mL	<1 (<10)	Median (95th percentile)	Weekly
5-day Biological Oxygen Demand	mg/L	<20	Median	Weekly
Turbidity	NTU	<2 (<5)	Median (Maximum)	Continuous
Suspended Solids	mg/L	<5	Median	Weekly
Total Dissolved Solids	mg/L	<1,000	Median	Weekly
pH		6.0 – 8.5	Range	Weekly
Total Nitrogen	mg/L	<20	Median	Monthly
Total Phosphorous	mg/L	<7	Median	Monthly
Free Chlorine Residual[1]	mg/L	0.5-1.0	Range	Continuous

Note:

1. Only applies where chlorination is used for disinfection. Disinfection is not preferred where discharge to the ocean is likely to occur.

The above standard of treatment is consistent with the minimum water quality requirements for “Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application” as defined under the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (ANZECC, 2006). Total nitrogen and total phosphorous concentrations have been determined as appropriate based on modelling of the nutrient assimilation capacity of soils and vegetation within the proposed irrigation area.

Monitoring of recycled water quality will occur at the outlet of the WWTP(s) at the approximate frequencies listed in the **Table 2** above to ensure recycled water quality achieves the above levels at discharge from the WWTP(s).

The proposed recycled water quality is considered to be suitable for the following recycled water reuse options:

- Irrigation of the golf course;
- Irrigation of other sporting fields and landscaped areas (where the availability of recycled water exceeds the sustainable irrigation requirements of the golf course); and
- Emergency discharge of recycled water during extreme wet weather events via ocean outfall.

Although the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (ANZECC, 2006) indicates that recycled water complying with the above minimum criteria is suitable for "Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application" without the need for any additional on-site preventive measures to reduce the risk associated with potentially harmful pathogens, a number of additional on-site control measures have been conservatively specified in **Section 3.2** to further mitigate potential risks.

3.1.4 Irrigation Area

Location & Size

The primary recycled water irrigation area will comprise the 18-hole championship golf course to be designed by Greg Norman Golf Course Design and located within the Clam Bay Precinct. Greg Norman Golf Course Design has indicated that the proposed championship golf course is likely to comprise a total area of maintained turf (including tees, greens, fairways and rough) of approximately 31 hectares.

MEDLI modelling of the proposed recycled water irrigation scheme has demonstrated that provision of a minimum irrigation area of 31 hectares will enable the operation of a sustainable and beneficial recycled water irrigation scheme.

Depending on final design of the golf course, additional areas may be required for irrigation. In this case, landscaped gardens and turf surrounding ecotourism villas located within the same Clam Bay Precinct as the golf course would be the first preference for alternative irrigation areas to minimise costs and energy consumption associated with pumping recycled water around the Island. However, landscaped gardens and turf within the Fisherman's Beach Precinct would also be acceptable for reuse of recycled water for irrigation if required being based on the same underlying soil type.

As construction of the golf course will occur in Stage 2-3, commencing in 2014 or about 2 years after other components of the GKI Resort Revitalisation Plan, an alternative recycled water irrigation area will need to be provided in the early stages. It is anticipated that irrigation of recycled water to assist in establishing turf adjacent to the airstrip will occur during the early stages of the Project prior to construction of the golf course. Recycled water may also be used in the early stages for irrigation within the 'turf nursery' that is likely to be established to grow the turf required to construct the golf course.

Reuse of recycled wastewater for irrigation of the golf course and possibly other landscaped areas (where excess recycled water is available), not only reduces pressure on other water supply sources, but also enables the beneficial reuse of nutrients contained in the recycled wastewater to support plant growth within the irrigation area. Application of nutrients contained in recycled water to vegetation enables natural biological processes to be used to further reduce nitrogen and phosphorus components before potentially entering groundwater or surface water systems, rather than using chemical reaction processes within a treatment plant. Such chemical treatment processes typically require large inputs in terms of energy to achieve the levels of nutrient reduction that can be achieved by healthy vegetation. Application of nutrients contained in recycled water to vegetation also reduces the need to apply additional fertilisers, which are usually derived from synthetic or inorganic sources.

Soil Properties

The proposed recycled water irrigation scheme is based on soil properties within the proposed irrigation area being generally comprised of high permeability sand, as identified within the Clam Bay Precinct and Fisherman's Beach Precinct through geotechnical investigations undertaken on GKI by Douglas Partners (Douglas Partners, 2010). A summary of soil water and nutrient characteristics adopted for MEDLI modelling of the proposed recycled water irrigation scheme is provided in **Table 3** and **Table 4** below.

TABLE 3: Soil Water Characteristics Adopted in MEDLI Modelling

Properties	Unit	Soil Horizon			
		Layer 1	Layer 2	Layer 3	Layer 4
Layer Thickness	(mm)	100	500	600	300
Air Dry Moisture Content	(mm/layer)	4			
Lower Storage Limit	(mm/layer)	4	6.4	7.5	6.0
Drained Upper Limit	(mm/layer)	10.9	13.6	13.8	9.1
Plant Available Water Capacity	(mm)	6.9	36.0	37.8	9.3
Saturated Water Content	(mm/layer)	50.1	42.3	43.6	43.1
Bulk Density	(g/cm^3)	1.31	1.52	1.48	1.50
Porosity	(mm/layer)	50.6	42.6	44.2	43.4
Saturated Hydraulic Conductivity	(mm/hour)	100	100	40	20

TABLE 4: Soil Nutrient Characteristics Adopted in MEDLI Modelling

Properties	Units	Quantity
Soil Nitrate	mg/kg	7
Soil Organic Nitrogen	mg/kg	450
Initial Soil Solution Phosphorus	mg/L	0.01

In the event that substantially different soil types or properties are encountered within proposed irrigation areas during later design stages, re-modelling will need to be undertaken to ensure the proposed irrigation regime is appropriate for the soil water and nutrient assimilation capacity of soils within the irrigation area.

Plant Properties

The proposed recycled water irrigation scheme is based on plant properties within the proposed irrigation area being generally comprised of a continuous pasture of coastal couch. Greg Norman Golf Course Design has indicated that where possible, existing grass species (preferably couch) already growing on the Island will primarily be used for establishment of the proposed golf course.

In the event that substantially different plant types occur within proposed irrigation areas, re-modelling will need to be undertaken to ensure the proposed irrigation regime is appropriate for the water and nutrient assimilation capacity of plants within the irrigation area.

3.1.5 Wet Weather Storage

The proposed recycled water irrigation scheme is based on the provision of a minimum 37ML wet weather storage plus an additional 7ML or about 20% capacity to provide a buffer for potential increases in rainfall intensity associated with projected climate change.

This is considered to be an extremely conservative approach to sizing of the wet weather storage given that although increased rainfall intensity is predicted to occur as a result of climate change, a decrease in average annual rainfall is also expected to occur meaning that:

- Irrigation is likely to be triggered more often based on a soil water deficit, resulting in more recycled water being used for irrigation and less recycled water going into wet weather storage; and
- Less direct rainfall will be captured by the open wet weather storage ponds providing more capacity for storage of recycled water.

Wet weather storage is likely to be provided as a series of ponds incorporated as water features within the proposed golf course. Wet weather storage should be provided separate to the stormwater harvesting ponds so as to reduce the risk of overtopping and enable monitoring of recycled water levels available for irrigation.

Given the sandy nature of soils on site, an artificial clay or synthetic liner will need to be incorporated into the pond design to achieve a seepage rate in the order of 0.1mm/day to prevent contamination of groundwater.

3.1.6 Ocean Outfall

The proposed recycled water irrigation scheme is expected to beneficially use 100% of all recycled water generated by the GKI Resort Revitalisation Plan in most years. However, during prolonged or extreme wet weather events, expected to occur approximately once every 10 years on average, wet weather storage ponds may reach capacity and a proportion of the recycled water may subsequently be discharged via an ocean outfall.

The likelihood of ocean discharge occurring is expected to be somewhat less than the 1 in 10 years predicted by MEDLI modelling given that the modelling was based on provision of a 37ML wet weather storage rather than provision of a 44ML wet weather storage as proposed to account of predicted climate change.

The exact location of the ocean outfall will be determined at detailed design stage taking into account the requirements of GBRMPA's *Sewage Discharge Policy - Sewage Discharges from Marine Outfalls to the Great Barrier Reef Marine Park, March 2005*, which states that:

> *Marine outfalls should not be constructed:*
>
> *i. Within 50 metres of a permitted mooring or anchorage; or*
> *ii. Within 1000 metres of aquaculture operations, or an area regularly used for*
> *iii. swimming or other water-based activities, unless it can be demonstrated that there will be no adverse impacts on the operation or activities; or Within 1000 metres of sensitive environments, unless it can be demonstrated that there will be no adverse impacts on the protection of aquatic ecosystems.*
>
> *For a marine outfall to be approved the GBRMPA will require that:*

i. *The outfall structure be of a design which optimises diffusion and dispersal; and*
ii. *The design of the system includes consideration of water depth (deep water is preferred i.e. greater than 10 metres), current velocity, tidal range and proximity to reefs or other sensitive environments.*

At this stage, the proposed ocean outfall will comprise a pipeline of approximately 1,000 metres in length extending from Long Beach. This location was selected to provide adequate distance away from the shore, sufficient depth and exposure to offshore ocean currents to facilitate dispersion of recycled water, and to avoid identified coral reefs and seagrass beds as far as practicable.

The outfall will be located within an area of water at least 10 metres deep to ensure sufficient depth of water is available above the diffuser across the full tidal range. The outfall will incorporate a T-shaped diffuser comprising two (2) ports approximately 75mm diameter.

Modelling of predicted dispersion of discharges from the ocean outfall has been undertaken by Water Technology and is contained in their report "Great Keppel Island Resort Revitalisation Plan Coastal Environment Technical Report August 2011". Based on the estimated volume and duration of discharge events predicted by MEDLI modelling and assuming recycled water nutrient concentrations of 20 mg/L for total nitrogen and 7 mg/L of total phosphorous, dispersion modelling by Water Technology has predicted that concentrations of total nitrogen and total phosphorous will reduce to below relevant water quality objectives within a small mixing zone in the immediate vicinity of the outfall. On this basis, the proposed emergency wet weather discharge of recycled water via an ocean outfall is not anticipated to have any significant impact on ecological communities near the outfall.

3.2 OPERATIONAL CONTROLS

3.2.1 Irrigation Scheduling

While nutrients applied to the golf course and other landscaped areas are beneficial to plant growth within these areas, it is necessary to ensure that the amount of nutrients applied does not exceed the hydraulic and nutrient assimilation capacity of soils and plants within the irrigation area, otherwise nutrients may be leached into groundwater and ultimately surface water bodies. A detailed water and nutrient balance has been undertaken to determine the amount of nutrients contained in recycled water and the rate of application that can be sustainably applied to the irrigation area.

Based on MEDLI modelling, it is recommended that irrigation occurs in response to low soil moisture conditions. This will maximise the beneficial reuse of recycled water while also reducing the potential for runoff and leaching of nutrients that could potentially contaminate waterways.

The irrigation schedule adopted in MEDLI modelling is based on irrigation being triggered at 80% PAWC and irrigating up to 5.0mm beyond drained upper limit (DUL). This irrigation regime was determined to be appropriate on the basis that the resulting levels of nutrient leaching were generally consistent with modelled outputs of the site under no irrigation reflecting a non-worsening approach. Irrigating only when soil moisture is low, combined with the naturally permeable sandy soils, also reduces the potential for causing runoff or ponding of recycled water within irrigation areas.

Soil moisture probes should be installed throughout the recycled water irrigation areas to monitor soil moisture conditions so that irrigation occurs generally in accordance with the above schedule.

3.2.2 Distribution System

The recycled water irrigation system will be designed, implemented and maintained to ensure that recycled water is distributed evenly across the entire irrigation area so as to avoid exceeding the water and nutrient assimilation capacity of soils and plants within certain parts of the irrigation area or not fully utilising available recycled water at the rate required to prevent overflow of the wet weather storage ponds.

Due to the large size of the irrigation area, an above ground distribution system such as fixed pivot sprinklers is proposed to distribute recycled water for irrigation over the majority of the golf course. An above ground distribution system is preferred due to the ease of maintenance and it enables easy identification of any faults that could result in failure of the irrigation system to distribute recycled water evenly across the irrigation area. The use of sprinklers able to distribute recycled water over large areas also reduces the number of system parts and components, thereby reducing maintenance requirements and costs.

Low-throw sprinklers will be used along with irrigation fittings that produce large size droplets to reduce the potential for spray drift into sensitive receivers (eg. villas). However, where irrigation is proposed within 25 to 30 metres of sensitive receivers, pressure compensated sub-surface or surface drippers are proposed to further reduce the potential for spray drift.

To the maximum extent possible, the irrigation system will be designed to incorporate gravity feed, thereby reducing reliance on pumps, which are more likely to breakdown and require additional maintenance.

3.2.3 Plant Harvesting

The recycled water irrigation area will primarily comprise golf course. As such, regular mowing, trimming and green keeping activities will occur to maintain a quality playing surface by encouraging a healthy coverage of grass. Maintaining healthy grass coverage is important in order to maximise the nutrient uptake in the irrigation area. It is therefore important to ensure that all areas used for recycled water irrigation area are regularly maintain to encourage healthy plant growth.

It is also recommended that as part of maintenance activities, all grass clippings should be removed from recycled water irrigation areas to reduce the potential for accumulation of excess nutrients. Removal of excess biomass in grass clippings also removes from the irrigation area the nutrients contained within these grass clippings. In addition, vegetative growth in plants is stimulated following harvesting, which in turn stimulates the uptake of nutrients.

3.2.4 Exclusion Zones

Although the MEDLI modelling indicates that no surface ponding or runoff of recycled water should occur as a result of the proposed recycled irrigation scheme, it is recommended that recycled water irrigation be avoided in the following areas:

- No recycled water irrigation shall occur on slopes >6%;
- No recycled water irrigation shall occur within 30 metres of the high bank of a natural waterway;
- No recycled water irrigation shall occur within 30 metres of an existing groundwater bore;
- No recycled water irrigation shall occur on land inundated by a Q100 flood / storm surge event; and
- No recycled water irrigation shall occur within any area containing remnant native vegetation.

Implementation of the above exclusion zones will reduce the potential for contamination of surface water and groundwater resources by enabling additional filtration of nutrients and other pollutants to occur as runoff / drainage passes through sandy soils and plant cover within the buffer zones. Excluding recycled water irrigation from areas of remnant native vegetation will avoid impacts on native vegetation communities that may not be adapted to higher soil moisture and nutrient levels associated with areas irrigated with recycled water.

3.2.5 Timing Restrictions

Although the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (ANZECC, 2006) indicates that recycled water complying with the above minimum criteria is suitable for "Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application" without the need for any additional on-site preventive measures to reduce the risk associated with potentially harmful pathogens, a conservative approach to irrigation is recommended such that recycled water irrigation will generally be restricted to times when public access is least likely.

This will generally occur during night time hours between about 9pm to 6am. Irrigation should commence as early as possible within this period to allow sufficient time for infiltration or drying to occur to further reduce potential exposure to the recycled water.

3.2.6 Signage

Notices must be prominently displayed on all recycled water irrigation areas, warning the public that the area is irrigated with recycled water and not to use or drink the recycled water. Similar signage should also be placed around the perimeter of recycled water storage ponds to discourage access to these ponds for retrieval of golf balls etc.

These notices must be maintained in a visible and legible condition and be in compliance with AS1319-*Safety signs for the occupational environment*.

3.2.7 Wet Weather Storage / Stormwater Harvesting Ponds

Only recycled water complying with the minimum water quality criteria specified in **Table 2** should be discharged into the wet weather storage ponds to reduce the potential for odour generation and excessive nutrient levels causing algal blooms.

Regular turnover of water stored within wet weather storage and stormwater harvesting ponds through inflows and extraction for irrigation will significantly reduce the potential for cyano-bacterial and other algal blooms. However, additional mechanical aeration may be considered during detailed design stage to provide further mixing within these storages. The use of fertilisers within the immediate vicinity of stormwater harvesting ponds should be minimised to prevent runoff containing high levels of nutrients entering storage ponds.

Regular visual and water quality monitoring of open storage ponds shall be undertaken to enable early identification of conditions that may support an algal bloom so that preventative action, such as de-stratification of the water column, can be taken. Planting of floating native aquatic plants within open storage ponds will also assist with uptake of nutrients reducing potential for algal blooms. Planting of vegetation, such as native sedges or reeds, around the perimeter of wet weather storage ponds is recommended to discourage public access to these facilities while also further assisting with the removal of nutrients that may cause algal blooms.

Management of pests shall be undertaken as necessary in accordance with the requirements of relevant authorities to control any excessive wildlife that could potentially reduce water quality within open storages.

3.2.8 Stormwater Management

Stormwater diversion systems will be installed to divert surface runoff around recycled water irrigation areas. This will prevent upstream surface runoff from coming into contact with potential contaminants (eg. nutrients) within irrigated areas, and will also ensure that soils within the irrigation area are not absorbing additional water not accounted for in the modelling. Diversion systems will also be used to prevent stormwater from draining into wet weather storage ponds containing recycled water for irrigation of the golf course so as to reduce the likelihood of recycled water storages overtopping.

Stormwater runoff from golf course areas used for recycled water irrigation has the potential to collect residual nutrients and other contaminants from the surface of the irrigation area. As such, all surface runoff from the proposed golf course will be diverted to stormwater harvesting ponds for reuse for irrigation of the golf course. Golf course runoff will be directed to the stormwater harvesting ponds through a series of grassed swales and / or bio-retention basins to facilitate removal of gross pollutants (e.g. litter) sediment and nutrients prior to entering the stormwater harvesting ponds. Stormwater harvesting ponds will incorporate an overflow provided with appropriate scour protection and outletting to a grassed overland flow channel providing further treatment prior to ultimately discharging to Leeke’s Creek.

4. MONITORING PROGRAM

4.1 GENERAL

A monitoring program shall be developed for the recycled water irrigation scheme to ensure that the nominated operational procedures and environmental controls are effective in minimising the risks to public health and the surrounding environment typically associated with the reuse of recycled water for irrigation of public open spaces.

The monitoring program shall include:

- Monitoring of the quality and quantity of recycled water discharged from the WWTP;
- Monitoring of soils within recycled water irrigation areas;
- Monitoring of groundwater within, up-gradient and down-gradient of the recycled water irrigation area;
- Monitoring of surface waters within, upstream and downstream of recycled water irrigation areas; and
- Monitoring of water quality within wet weather storage ponds containing recycled water and stormwater harvesting ponds collecting runoff from areas used for recycled water irrigation.

Proposed monitoring frequencies and contaminants to be monitored are specified in the following sections.

4.2 MONITORING

4.2.1 Recycled Water Quantity

A flow meter shall be installed at the discharge point of the WWTP(s).

The volume of recycled water discharged to wet weather storage ponds should be recorded daily.

4.2.2 Recycled Water Quality

Sampling of recycled water discharged from the WWTP shall be undertaken from the overflow of the final effluent holding tanks and shall be conducted in accordance with the DERM's *Water Quality Sampling Manual*.

The quality of recycled water discharged to wet weather storage ponds should be monitored at frequencies specified in **Table 5.**

TABLE 5: Proposed Recycled Water Quality Monitoring Frequency

Quality Characteristic	Monitoring Frequency
E. coli	Weekly
5-day Biological Oxygen Demand	Weekly
Turbidity	Continuous
Suspended Solids	Weekly
Total Dissolved Solids	Weekly
pH	Weekly
Total Nitrogen	Monthly
Total Phosphorous	Monthly
Free Chlorine Residual[1]	Continuous

Note:
1. Only applies where chlorination is used for disinfection. Disinfection is not preferred where discharge to the ocean is likely to occur.

4.2.3 Soil

Soil monitoring sites will be determined prior to commencing recycled water irrigation. The location of soil monitoring sites will include:

- A site within the recycled water irrigation area; and
- A "reference" site located within an area not irrigated using recycled water and consisting of the same soil type as occurs in the irrigation area.

Baseline monitoring of soils will occur before recycled water irrigation commences and once for each sampling event during the lifetime of the irrigation scheme. A monitoring event will most likely be required once every 6 months after commencement. Depending on the outcomes of initial monitoring, after 2 years the Administering Authority may reduce the monitoring frequency to an annual occurrence.

The soil quality characteristics that may be monitored include:

- pH
- Electrical conductivity
- Available phosphorus
- Available potassium
- Total nitrogen
- Total cations
- Cation exchange capacity
- Exchangeable sodium percentage
- Chloride
- Trace elements
- Heavy metals
- Organic carbon

All sample analyses will be undertaken by a laboratory holding appropriate certification from the National Association Testing Authority (NATA) for the relevant analyses.

Compliance shall be determined with reference to the conditions of development approval and comparison of soil quality within areas irrigated and not irrigated with recycled water to detect any deterioration in soil quality that may be attributable to recycled water irrigation.

4.2.4 Groundwater

Groundwater monitoring bores shall be installed at the following general locations:

- A site within the recycled water irrigation area;
- A "reference" site located within an area not irrigated using recycled water and hydraulically up-gradient of the recycled water irrigation area; and
- A "receptor" site located within an area not irrigated using recycled water and hydraulically down-gradient of the recycled water irrigation area.

Groundwater monitoring bores shall be constructed in accordance with the Agriculture and Resource Management Council of Australia and New Zealand manual *Minimum Construction Requirements for Water Bores in Australia, Edition 2, Revised September 2003*.

Baseline monitoring of groundwater will occur before recycled irrigation commences and once for each sampling event during the lifetime of the irrigation scheme. A monitoring event will most likely be required once every 6 months after commencement. Depending on the outcomes of initial monitoring, after 2 years the Administering Authority may reduce the monitoring frequency to an annual occurrence.

The groundwater quality characteristics that may be monitored include:

- pH
- Electrical conductivity
- Total nitrogen
- Ammonia
- Nitrite
- Nitrate
- Total phosphorus
- *E.coli*
- Biochemical Oxygen Demand

For each monitoring event, the standing water level and groundwater bore depth shall also be recorded.

All sampling and analysis of groundwater samples will be undertaken in accordance with the latest edition of DERM's *Water Quality and Sampling Manual* and *AS 5667:1998 – Water Quality – Sampling – Guidance on sampling of groundwaters*.

All sample analyses will be undertaken by a laboratory holding appropriate certification from the National Association Testing Authority (NATA) for the relevant analyses.

Compliance shall be determined with reference to the conditions of development approval and relevant water quality objectives established for the receiving waters.

4.2.5 Surface Water

Surface water quality monitoring sites shall be established at the following general locations:

- A site within Leeke's Creek located downstream of the recycled water irrigation area; and
- A site within Leeke's Creek located upstream of the recycled water irrigation area.

Baseline monitoring of surface water will occur before recycled irrigation commences and once for each sampling event during the lifetime of the irrigation scheme. A monitoring event will most likely be required once every 3 months after commencement. Depending on the outcomes of initial monitoring, after 2 years the Administering Authority may reduce the monitoring frequency to once every 6 months.

Surface water quality characteristics that may be monitored include:

- pH
- Electrical conductivity
- Total nitrogen
- Ammonia
- Nitrite
- Nitrate
- Total phosphorus
- *E.coli*
- Biochemical Oxygen Demand
- Chlorophyll a

All sampling and analysis of surface water samples will be undertaken in accordance with the latest edition of DERM's *Water Quality and Sampling Manual*.

All sample analyses will be undertaken by a laboratory holding appropriate certification from the National Association Testing Authority (NATA) for the relevant analyses.

Compliance shall be determined with reference to the conditions of development approval and relevant water quality objectives established for the receiving waters.

4.3 INSPECTIONS

In addition to monitoring requirements outlined the above, weekly inspections of all irrigation areas shall be conducted by the Grounds Maintenance Manager (or delegate) for evidence of:

- Excessive irrigation rates resulting in ponding across the irrigation area or runoff beyond the boundaries of the irrigation area;

- Inadequate treatment of recycled water resulting in decreased plant health or decreased soil condition;

- Damage to the recycled water irrigation distribution system;

- Recycled water levels within wet weather storage ponds approaching capacity; and

- Damage to any stormwater diversion drains that may result in stormwater entering wet weather storage ponds.

4.4 REPORTING

Records shall be kept by the Resort Manager and retained for at least 5 years for:

- All sampling and analysis results from recycled water discharges and flow records;
- All sampling and analysis results from monitoring of soils within the irrigation area;
- All sampling and analysis results from monitoring of groundwater within, up-gradient and down-gradient of the recycled water irrigation area;
- All sampling and analysis results from monitoring of surface waters within, upstream and downstream of recycled water irrigation areas;
- All environmental incident and complaints reporting; and
- All maintenance carried on components of the recycled water irrigation scheme, including the WWTP.

5. ENVIRONMENTAL INCIDENTS

5.1 GENERAL

All environmental incidents must be fully reported as quickly as possible to ensure that effective action is taken to prevent environmental harm, and to identify probable causes so that corrective action can be taken to prevent a recurrence or more serious event. This procedure details the requirements associated with immediate action, investigation, reporting, corrective action, follow-up actions and training for environmental incidents.

5.2 REQUIREMENTS

Should an environmental incident occur, immediate action shall be taken to contain the effects of the incident and reduce the overall level of environmental impact associated with the incident.

In the event of a major incident, the Resort Manager shall notify relevant statutory authorities (eg. DERM, GBRMPA) within 24 hours of the incident occurring.

Information to be provided with the incident report must include the following:

- The name of the holder of the Registration Certificate;
- The location of the emergency or incident;
- The number of the Registration Certificate;
- The name and telephone of the designated contact person for the Registration Certificate;
- The time of the release;
- The time the holder of the Registration Certificate became aware of the release;
- The suspected cause of the release;
- An initial assessment of the environmental harm and or environmental nuisance caused, threatened, or suspected to be caused by the release; and
- Actions taken to prevent any further release and mitigate any environmental harm and / or environmental nuisance caused by the release.

The Resort Manager will also be responsible for notifying emergency response services (e.g. fire services) as soon as practicable after becoming aware of any emergency or incident resulting in the release of contaminants not in accordance with conditions of the approval.

An incident form is to be completed by the Resort Manager for all incidents. Corrective actions should be initiated immediately and will be determined by the Resort Manager in consultation with the WWTP Operations Manager, Grounds Maintenance Manager and relevant authorities.

6. ENVIRONMENTAL COMPLAINTS

6.1 GENERAL

As part of sound environmental practice, it is important to maintain relationships with the community and minimise environmental impacts associated with site operations. In this regard, it is essential that any written or verbal complaints made by members of the public or organisations are dealt with immediately, particularly those that relate to issues which have potential to cause environmental harm. All complaints must be documented and measures taken to investigate and address the offending matter as quickly as possible. This procedure details the requirements associated with the investigation, reporting, corrective action, and follow-up actions associated with public complaints.

6.2 REQUIREMENTS

An Environmental Complaints Register shall be established and maintained for the recycled water irrigation scheme by the Resort Manager .

All public complaints received shall be addressed in the following manner:

- All complaints shall be registered immediately with the following details:
    - Time, date and nature of complaint;
    - Type of communication (telephone, letter, personal etc);
    - Name, contact address and contact telephone number of complainant (Note: if the complainant does not wish to be identified then “Not Identified” to be recorded);
    - Response and investigation undertaken as a result of the complaint;
    - Name of person responsible for investigating complaint; and
    - Action taken as a result of the complaint investigation and signature of responsible person.

- The Resort Manager shall initiate an investigation to determine the nature and cause of the complaint;

- The Resort Manager in consultation with the WWTP Operations Manager and Grounds Maintenance Manager shall initiate action to correct any procedure, work practice or condition, which resulted in the complaint being made. Any complaint that has a potential for significant adverse effect on the environment shall be dealt with immediately;

- The Resort Manager shall report back to the complainant within 2 business days of the complaint or the initial findings of the investigations, the action to be taken and the expected completion date;

- The Resort Manager shall advise the complainant when all investigations and corrective actions are complete, and update the Environmental Complaint Register; and

- Records of all complaints received shall be kept for a minimum of five (5) years.

7. STAFF TRAINING & AWARENESS

The IMP will only be successful if those responsible for operation of the recycled water irrigation scheme are aware of the potential impacts, requirements and mitigation procedures necessary to minimise environmental impact.

The Resort Manager shall be responsible for ensuring that initial and ongoing training is provided to ensure all personnel involved in the operation and maintenance of the recycled water irrigation scheme are aware of their environmental obligations, in particular the following:

- Awareness of environmental issues relevant to the site and recycled water irrigation scheme;
- Obligations under the *Environmental Protection Act 1994* and associated legislation;
- Specific conditions of development approval relating to the site; and
- Incident and complaint reporting procedures detailed in this IMP.

Records shall be maintained of all training undertaken by personnel involved in operation of the recycled water irrigation scheme.

APPENDIX I

MEDLI Summary Output Data

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SUMMARY OUTPUT
MEDLI Version 1.30

Data Set: 110824 GKI Scenario Baseline
Run Date: 25/08/11 Time:08:22:34.42

****

GENERAL INFORMATION

Title: GKI Resort Revitalisation Plan
Subject: Scenario Baseline
Client: GKI Resorts Pty Ltd
User: Mark Farrey
Time: Thu Aug 25 08:21:50 2011
Comments: Dry Run - 31ha

RUN PERIOD

Starting Date 1/ 1/1957
Ending Date 31/12/2009
Run Length 53 years 0 days

CLIMATE INFORMATION

Enterprise site: Great Keppel Island -23.2 deg S 150.9 deg E
Weather station: keppel_23.20S_150.95E (Interpola

ANNUAL TOTALS	10 Percentile	50 percentile	90 Percentile
Rainfall mm/year	688.	1062.	1478.
Pan Evap mm/year	1715.	1837.	1997.

MONTHLY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	154	170	133	95	93	59	44	39	27	45	68	120	1045
Pan Evap (mm)	198	166	169	138	111	92	100	122	155	191	199	208	1848
Ave Max Temp DegC	29	29	28	26	24	22	21	22	24	26	28	29	25
Ave Min Temp DegC	23	23	22	19	16	14	12	13	16	19	21	22	18
Rad (MJ/m2/day)	22	21	20	18	15	14	15	18	21	23	24	24	19

MONTHLY IRRIGATION

Irrigation (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0

SOIL PROPERTIES

Soil type: Great Keppel Island Sand

SOIL WATER PROPERTIES

		Layer 1	Layer 2	Layer 3	Layer 4
Bulk Density	(g/cm3)	1.3	1.5	1.5	1.5
Porosity	(mm/layer)	50.6	213.2	264.9	130.2
Saturated Water Content	(mm/layer)	50.1	211.5	261.6	129.3
Drained Upper Limit	(mm/layer)	10.9	68.0	82.8	27.3
Lower Storage Limit	(mm/layer)	4.0	32.0	45.0	18.0
Air Dry Moisture Content	(mm/layer)	4.0			
Layer Thickness	(mm)	100.0	500.0	600.0	300.0

		Profile	Max Rootzone
Total Saturated Water Content	(mm)	652.5	348.6
Total Drained Upper Limit	(mm)	189.0	106.4
Total Lower Storage Limit	(mm)	99.0	51.0
Total Air Dry Moisture Content	(mm)	5.4	4.7
Total Depth	(mm)	1500.0	799.5

Maximum Plant Available Water Capacity 55.5
Saturated Hydraulic Conductivity
At Surface (mm/hr) 100.0

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               Limiting              (mm/hr)   20.0

RUNOFF

Runoff curve No II                             70.0

SOIL EVAPORATION

CONA                            (mm/day^0.5)    4.5
URITCH                                  (mm)   10.0
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AVERAGE WASTE STREAM
********************

Other waste stream
(All values relate to influent after any screening and recycling, if applicable).

Inflow Volume                      (ML/year)  157.7
Nitrogen                        (tonne/year)    3.2
Phosphorus                      (tonne/year)    1.1
Salinity                        (tonne/year)  431.7

Nitrogen Concentration                (mg/L)   20.0
Phosphorus Concentration              (mg/L)    7.0
Salinity                              (mg/L) 2738.4
Salinity                              (dS/m)    4.3

WASTE STREAM DETAILS (for last inflow event):
Nitrogen Concentration                (mg/L)   20.0
Phosphorus Concentration              (mg/L)    7.0
TDS Concentration                     (mg/L) 1000.0
Salinity                              (dS/m)    1.6
```

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IRRIGATION WATER
****************

Irrigation triggered every   1 days
Irrigating upto upper storage limit +   0 mm

AREA

Total Irrigation Area                   (ha)   31.0

VOLUMES

Total Irrigation                   (ML/year)    0.0
Minimum Volume Irrigated by Pump (ML/ha/day)    0.0
Maximum Volume Irrigated by Pump (ML/ha/day)    0.0
Maximum Vol. Available For Shandying (ML/yr)    0.0

IRRIGATION CONCENTRATIONS

Average salinity of Irrigation        (dS/m)    0.0
Average salinity of Irrigation        (mg/L)    0.0
Average Nitrogen Conc of Irrigation
                Before ammonia loss   (mg/L)    0.0
                After ammonia loss    (mg/L)    0.0
Average Phosphorus Conc of Irrigation (mg/L)    0.0
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FRESH WATER USAGE
*****************

Irrigation (shandying) water         (ML/yr)   0.00

Avg volume of fresh water used       (ML/yr)   0.00

Annual allocation                    (ML/yr)    N/A


POND INFORMATION
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****************

POND GEOMETRY
                                                 Pond 1

Final pond volume                      (ML)        37.0
Final liquid volume                    (ML)        37.0
Final sludge volume                    (ML)         0.0
Average pond volume                    (ML)        36.9
Average active volume                  (ML)        36.9
Maximum pond volume                    (ML)        37.0
Minimum allowable pond volume          (ML)         0.0
Average pond depth                      (m)         3.0
Pond depth at outlet                    (m)         3.0
Maximum water surface area      (m2 x1000)         13.0
Pond catchment area             (m2 x1000)         13.5
Pond footprint length                   (m)       116.0
Pond footprint width                    (m)       116.0

POND WATER BALANCE

Inflow of Effluent to pond system    (ML/yr)  157.7
Recycle Volume from pond system      (ML/yr)    0.0
Rain water added to pond system      (ML/yr)   14.1
Evaporation loss from pond system    (ML/yr)   16.8
Seepage loss from pond system        (ML/yr)    0.5
Irrigation from last pond            (ML/yr)    0.0
Volume of overtopping                (ML/yr)  153.7
Sludge accumulated                   (ML/yr)    0.0
    Sludge accumulated             (t DM/yr)    0.0
Sludge removed                       (ML/yr)    0.0
No of desludging events every 10 years          0.0
Increase in pond water volume        (ML/yr)    0.7

OVERTOPPING EVENTS

Volume of overtopping                (ML/yr)  153.74
No. of days pond overtops per 10 years       3638.54
Average Length of overtopping events  (days)19284.00
% Reuse                                         0.00
No. of overtopping events every 10 years
          >  0.000 ML         0.19
          >  0.013 ML*        0.00
          >  1.000 ML         0.00
          >  2.000 ML         0.00
          >  5.000 ML         0.00
          > 10.000 ML         0.00
          > 20.000 ML         0.00
          > 50.000 ML         0.00
* Volume equivalent to 1 mm depth of water
No. periods/year without irrigable effluent     0.0
Average Length of such periods        (days)    0.0

POND NITROGEN BALANCE

Nitrogen Added by Effluent        (tonne/yr)    3.2   Irrig. from pond (ML/yr)    0.0
Nitrogen removed by Irrigation    (tonne/yr)    0.0
Nitrogen removed by Volatilisation(tonne/yr)    0.9
Nitrogen removed by Seepage       (tonne/yr)    0.0
Nitrogen accumulated in Sludge    (tonne/yr)    0.0
Nitrogen lost by Overtopping      (tonne/yr)    2.2
Nitrogen involved in Recycling    (tonne/yr)    0.0
Increase in pond Nitrogen         (tonne/yr)    0.0

POND PHOSPHORUS BALANCE

Phosphorus Added by Effluent      (tonne/yr)    1.1   Irrig. from pond (ML/yr)    0.0
Phosphorus removed by Irrigation  (tonne/yr)    0.0
Phosphorus removed by Seepage     (tonne/yr)    0.0
Phosphorus accumulated in Sludge  (tonne/yr)    0.0
Phosphorus lost by Overtopping    (tonne/yr)    1.1
Phosphorus involved in Recycling  (tonne/yr)    0.0
Increase in pond Phosphorus       (tonne/yr)    0.0

POND SALINITY BALANCE
```

Salinity Added by Effluent	(tonne/yr)	431.7
Salinity removed by Irrigation	(tonne/yr)	0.0
Salinity removed by Seepage	(tonne/yr)	1.3
Salinity lost by Overtopping	(tonne/yr)	428.7
Salinity involved in Recycling	(tonne/yr)	0.0
Increase in pond Salinity	(tonne/yr)	1.7

POND CONCENTRATIONS

		Pond 1
Average Nitrogen Conc of Pond Liquid	(mg/L)	14.0
Average Phosphorus Conc of Pond Liquid	(mg/L)	7.1
Average TDS Conc of Pond Liquid	(mg/L)	2825.5
Average Salinity of Pond Liquid	(dS/m)	4.4
Average Potassium Conc of Pond Liquid	(mg/L)	0.0

(On final day of simulation)

Nitrogen Conc of Pond Liquid	(mg/L)	15.7
Phosphorus Conc of Pond Liquid	(mg/L)	7.6
TDS Conc of Pond Liquid	(mg/L)	2394.2
EC of Pond Liquid	(dS/m)	3.7
Potassium Conc of Pond Liquid	(mg/L)	0.0

REMOVED SLUDGE - NUTRIENT & SALT CONCENTRATIONS

Nitrogen in removed Sludge (db)	(kg/tonne)	0.0
Phosphorus in removed Sludge (db)	(kg/tonne)	0.0
Salt in removed Sludge (db)	(kg/tonne)	0.0
Potassium in removed Sludge (db)	(kg/tonne)	0.0

REMOVED SLUDGE - NUTRIENT & SALT MASSES

Nitrogen in removed Sludge	(tonne/yr)	0.0
Phosphorus in removed Sludge	(tonne/yr)	0.0
Salt in removed Sludge (mass bal.)	(tonne/yr)	0.0
Salt in removed Sludge	(tonne/yr)	0.0
Potm. in removed Sludge (mass bal.)	(tonne/yr	0.0
Potassium in removed Sludge	(tonne/yr)	0.0

LAND DISPOSAL AREA
****

WATER BALANCE

(Initial soil water assumed to be at field capacity)
(Irrigated up to 0.00% of field capacity)

Rainfall	(mm/year)	1045.9	Irrigation Area	(ha)	31.0
Irrigation	(mm/year)	0.0			
Soil Evaporation	(mm/year)	273.8			
Transpiration	(mm/year)	325.8			
Runoff	(mm/year)	19.8			
Drainage	(mm/year)	426.2			
Change in soil moisture	(mm/year)	0.3			

ANNUAL TOTALS

Year	Rain (mm)	Irrig (mm)	Sevap (mm)	Trans (mm)	Runoff (mm)	Drain (mm)	Change (mm)
1957	492.0	0.0	184.5	200.3	0.0	129.5	-22.4
1958	1106.0	0.0	164.3	518.8	0.0	415.3	7.7
1959	1050.0	0.0	298.3	408.5	4.6	335.7	2.9
1960	1074.0	0.0	218.8	355.7	30.2	454.8	14.6
1961	1324.0	0.0	279.5	315.3	162.2	579.5	-12.6
1962	1108.0	0.0	220.4	416.7	10.0	318.0	142.9
1963	1080.0	0.0	244.8	442.8	2.1	585.6	-195.4
1964	908.0	0.0	232.7	436.7	14.6	223.2	0.8
1965	696.0	0.0	239.7	146.8	3.9	252.3	53.4
1966	1184.0	0.0	230.4	536.0	7.0	415.3	-4.7
1967	1260.0	0.0	246.2	484.5	0.0	525.7	3.6
1968	1080.0	0.0	158.1	496.6	2.9	443.4	-21.0
1969	1275.0	0.0	345.7	216.0	66.8	623.8	22.7
1970	950.0	0.0	329.1	262.8	0.0	345.1	13.0
1971	1572.0	0.0	131.6	594.8	31.4	827.4	-13.2

1972	800.0	0.0	261.0	317.2	2.6	292.1	-72.9
1973	1693.0	0.0	345.5	413.0	80.4	782.1	72.1
1974	1272.0	0.0	255.4	344.6	32.1	604.0	35.9
1975	1090.0	0.0	98.4	772.8	13.1	222.9	-17.2
1976	1240.0	0.0	382.5	319.1	20.1	544.8	-26.5
1977	1176.0	0.0	94.8	480.8	9.0	584.1	7.3
1978	1146.0	0.0	291.5	292.1	28.2	535.9	-1.8
1979	658.0	0.0	127.9	441.6	0.0	132.2	-43.6
1980	1121.0	0.0	324.6	167.7	26.4	523.2	79.0
1981	1488.0	0.0	148.9	531.0	47.0	798.2	-37.2
1982	713.0	0.0	151.9	509.3	0.0	67.5	-15.7
1983	1756.0	0.0	396.1	230.9	155.1	958.4	15.5
1984	1030.0	0.0	261.9	397.4	8.1	333.7	29.0
1985	1013.0	0.0	140.5	545.4	3.1	359.5	-35.5
1986	1258.0	0.0	267.0	483.9	3.3	526.3	-22.5
1987	826.0	0.0	355.0	149.5	0.5	273.6	47.5
1988	1336.0	0.0	204.5	629.6	5.0	511.0	-14.1
1989	1468.0	0.0	276.2	299.8	3.4	897.2	-8.6
1990	1707.0	0.0	180.4	321.0	108.3	947.6	149.8
1991	1003.0	0.0	368.3	245.5	11.2	519.0	-140.9
1992	1196.0	0.0	313.7	290.0	50.0	552.1	-9.9
1993	956.0	0.0	376.0	136.7	42.9	390.8	9.7
1994	753.0	0.0	301.5	227.3	0.7	257.9	-34.4
1995	1042.0	0.0	404.0	211.5	2.2	418.1	6.2
1996	943.0	0.0	296.0	233.1	19.2	364.4	30.2
1997	677.0	0.0	329.4	160.6	0.0	154.7	32.4
1998	962.0	0.0	442.5	233.4	0.4	348.9	-63.2
1999	882.0	0.0	399.9	150.0	6.8	296.7	28.5
2000	1084.0	0.0	324.8	221.7	3.9	458.5	75.1
2001	477.0	0.0	212.1	236.6	0.0	103.1	-74.8
2002	743.0	0.0	278.0	172.3	5.5	306.8	-19.6
2003	842.0	0.0	326.9	129.4	7.1	358.7	19.8
2004	611.0	0.0	366.4	180.3	0.0	97.3	-33.0
2005	679.0	0.0	338.9	152.1	0.0	156.5	31.5
2006	840.0	0.0	351.8	217.5	0.9	279.9	-10.0
2007	909.0	0.0	358.4	190.2	0.3	346.4	13.7
2008	1110.0	0.0	301.9	250.8	6.1	571.0	-19.7
2009	773.0	0.0	332.6	147.3	11.6	238.1	43.4

NUTRIENT BALANCE

NITROGEN

Total N irrigated from ponds	(kg/ha/year)	0.0	% of Total as ammonium	80.0
Nitrogn lost by ammonia volat.	(kg/ha/year)	0.0	Deep Drainage (mm/year)	426.2
Nitrogen added in irrigation	(kg/ha/year)	0.0		
Nitrogen added in seed	(kg/ha/year)	0.8		
Nitrogen removed by crop	(kg/ha/year)	31.7		
Denitrification	(kg/ha/year)	0.3		
Leached NO3-N	(kg/ha/year)	6.9		
Change in soil organic-N	(kg/ha/year)	-35.2		
Change in soil solution NH4-N	(kg/ha/year)	0.0		
Change in soil solution NO3-N	(kg/ha/year)	-2.9		
Change in adsorbed NH4-N	(kg/ha/year)	0.0		
Initial soil organic-N	(kg/ha)	1957.5		
Final soil organic-N	(kg/ha)	89.3		
Initial soil inorganic-N	(kg/ha)	156.0		
Final soil inorganic-N	(kg/ha)	2.8		
Average NO3-N conc in the root zone	(mg/L)	1.6		
Average NO3-N conc below root zone	(mg/L)	2.2		
Average NO3-N conc of deep drainage	(mg/L)	1.6		

PHOSPHORUS

Phosphorus added in irrigatn	(kg/ha/year)	0.0	% of Total as phosphate	100.0
Phosphorus added in seed	(kg/ha/year)	0.1		
Phosphorus removed by crop	(kg/ha/year)	0.1		
Leached PO4-P	(kg/ha/year)	0.0		
Change in dissolved PO4-P	(kg/ha/year)	0.0		
Change in adsorbed PO4-P	(kg/ha/year)	0.0		
Average PO4-P conc in the root zone	(mg/L)	0.0		
Average PO4-P conc below root zone	(mg/L)	0.0		

SOIL P STORAGE LIFE

Year	YearNo.	Tot P stored kg/ha	P leached in year kg/ha
1957	1	365.5	0.0
1958	2	365.5	0.0
1959	3	365.4	0.0
1960	4	366.4	0.0
1961	5	365.3	0.1
1962	6	365.3	0.0
1963	7	365.2	0.1
1964	8	366.2	0.0
1965	9	365.2	0.0
1966	10	365.1	0.0
1967	11	365.1	0.1
1968	12	366.0	0.0
1969	13	365.0	0.1
1970	14	365.0	0.0
1971	15	364.9	0.1
1972	16	365.8	0.0
1973	17	364.8	0.1
1974	18	364.7	0.1
1975	19	364.7	0.0
1976	20	365.6	0.1
1977	21	364.6	0.1
1978	22	364.5	0.1
1979	23	364.5	0.0
1980	24	365.4	0.1
1981	25	364.4	0.1
1982	26	364.3	0.0
1983	27	364.3	0.1
1984	28	365.2	0.0
1985	29	364.2	0.0
1986	30	364.1	0.1
1987	31	364.1	0.0
1988	32	365.1	0.1
1989	33	364.0	0.1
1990	34	363.9	0.1
1991	35	363.8	0.1
1992	36	364.8	0.1
1993	37	363.7	0.0
1994	38	363.7	0.0
1995	39	363.7	0.0
1996	40	364.6	0.0
1997	41	363.6	0.0
1998	42	363.6	0.0
1999	43	363.5	0.0
2000	44	364.5	0.0
2001	45	363.5	0.0
2002	46	363.4	0.0
2003	47	363.4	0.0
2004	48	364.4	0.0
2005	49	363.4	0.0
2006	50	363.4	0.0
2007	51	363.3	0.0
2008	52	364.3	0.1
2009	53	363.2	0.0

PLANT

Plant species: Coastal couch grass (Cynodon dac

PLANT WATER USE

Irrigation	(mm/year)	0.	Totl Irrigation Area(ha)	31.0
Pan coefficient	(%)	1.0		
Maximum crop coefficient	(%)	0.8		
Average Plant Cover	(%)	34.		
Average Plant Total Cover	(%)	47.		
Average Plant Rootdepth	(mm)	334.		
Average Plant Available Water Capacity	(mm)	45.		

Average Plant Available Water	(mm)	26.	
Yield produced per unit transp.	(kg/ha/mm)	9.	

PLANT NUTRIENT UPTAKE

Dry Matter Yield (Shoots)	(kg/ha/yr)	3031.			
Net nitrogen removed by plant	(kg/ha/yr)	31.	Shoot Concn	(%DM)	1.02
Net phosphorus removed by plant	(kg/ha/yr)	0.	Shoot Concn	(%DM)	0.00

AVERAGE MONTHLY GROWTH STRESS (0=no stress, 1=full stress)

Month	Yield kg/ha	Nitr	Temp	Water Defic	Water Logging
1	312.	0.3	0.0	0.2	0.0
2	353.	0.4	0.0	0.2	0.0
3	464.	0.4	0.0	0.2	0.0
4	405.	0.5	0.0	0.2	0.0
5	306.	0.4	0.2	0.2	0.0
6	189.	0.4	0.5	0.2	0.0
7	138.	0.3	0.7	0.3	0.0
8	168.	0.3	0.5	0.3	0.0
9	174.	0.3	0.2	0.3	0.0
10	138.	0.2	0.0	0.3	0.0
11	163.	0.3	0.0	0.2	0.0
12	220.	0.3	0.0	0.3	0.0

>>> NO-PLANT EVENTS <<<

%Days due to temperature stress	0.9
%Days due to water stress	15.6
%Days due to nitrogen stress	2.3
No. of forced harvests per year	1.3
No. of normal harvests per year	0.7

SALINITY

Salt tolerance - plant species: tolerant

Average EC of Irrigation Water	(dS/m)	0.0	Irrigation	(mm/year)	0.0
Average EC of Rainwater	(dS/m x10)	0.3	Rainfall	(mm/year)	1045.9

>>>No salinity calculations<<<
No. of years chosen for running averages 5

GROUNDWATER
****

Average Groundwater Recharge	(m3/day)	361.7
Average Nitrate-N Conc of Recharge	(mg/L)	1.6

Thickness of the Aquifer	(m)	10.0
Distance (m) from Irrigation Area to where Nitrate-N Conc in Groundwater is Calculated		1000.0

Concentration of NITRATE-N in Groundwater (mg/L)

Year	Depth Below Water Table Surface 0.0 m	5.0 m	9.0 m
1961	0.4	0.4	0.4
1966	0.8	0.8	0.8
1971	1.1	1.1	1.1
1976	1.2	1.2	1.2
1981	1.3	1.3	1.3
1986	1.3	1.3	1.3
1991	1.4	1.4	1.4
1996	1.4	1.4	1.4
2001	1.4	1.4	1.4
2006	1.4	1.4	1.4

```
Last   2009        1.4       1.4       1.4
```

ACKNOWLEDGMENTS
****
This run brought to you courtesy of:

MEDLIEXE.EXE : 1300468 bytes Fri Mar 12 10:26:56 1999

CRCPROJ.EXE   : 1286656 bytes Wed Apr 28 15:18:26 1999

GRAPHS.EXE: No details found
GRAPHS.EXE   :   2617 bytes Wed Apr 28 15:18:26 1999

OTHER INDUSTRY INPUT PARAMETERS - DATA SUMMARY

Nature of Industry: STP wastestream

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>>> Dryland run! <<<        1 file(s) copied
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UNCONDITIONAL FINISH

****

SUMMARY OUTPUT
MEDLI Version 1.30

Data Set: 110824 GKI Scenario 1a-95% 2mm 31ha
Run Date: 25/08/11 Time:08:54:45.77

****

GENERAL INFORMATION

Title: GKI Resort Revitalisation Plan
Subject: Scenario 1a - 2mm Irrigation
Client: GKI Resorts Pty Ltd
User: Mark Farrey
Time: Thu Aug 25 08:50:50 2011
Comments: 2mm/day . Irrigation Area = 31ha. Wet Weather Storage = 0.6ML (95% reuse). N = 20mg/L, P = 7mg/L.

RUN PERIOD

Starting Date 1/ 1/1957
Ending Date 31/12/2009
Run Length 53 years 0 days

CLIMATE INFORMATION

Enterprise site: Great Keppel Island -23.2 deg S 150.9 deg E
Weather station: keppel_23.20S_150.95E (Interpola

ANNUAL TOTALS	10 Percentile	50 percentile	90 Percentile
Rainfall mm/year	688.	1062.	1478.
Pan Evap mm/year	1715.	1837.	1997.

MONTHLY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	154	170	133	95	93	59	44	39	27	45	68	120	1045
Pan Evap (mm)	198	166	169	138	111	92	100	122	155	191	199	208	1848
Ave Max Temp DegC	29	29	28	26	24	22	21	22	24	26	28	29	25
Ave Min Temp DegC	23	23	22	19	16	14	12	13	16	19	21	22	18
Rad (MJ/m2/day)	22	21	20	18	15	14	15	18	21	23	24	24	19

MONTHLY IRRIGATION

Irrigation (mm)	60	31	37	41	21	23	33	31	58	45	45	60	485

SOIL PROPERTIES

Soil type: Great Keppel Island Sand

SOIL WATER PROPERTIES

		Layer 1	Layer 2	Layer 3	Layer 4
Bulk Density	(g/cm3)	1.3	1.5	1.5	1.5
Porosity	(mm/layer)	50.6	213.2	264.9	130.2
Saturated Water Content	(mm/layer)	50.1	211.5	261.6	129.3
Drained Upper Limit	(mm/layer)	10.9	68.0	82.8	27.3
Lower Storage Limit	(mm/layer)	4.0	32.0	45.0	18.0
Air Dry Moisture Content	(mm/layer)	4.0			
Layer Thickness	(mm)	100.0	500.0	600.0	300.0

		Profile	Max Rootzone
Total Saturated Water Content	(mm)	652.5	348.8
Total Drained Upper Limit	(mm)	189.0	106.5
Total Lower Storage Limit	(mm)	99.0	51.0
Total Air Dry Moisture Content	(mm)	5.4	4.7
Total Depth	(mm)	1500.0	800.0

Maximum Plant Available Water Capacity 55.5
Saturated Hydraulic Conductivity

At Surface	(mm/hr)	100.0
Limiting	(mm/hr)	20.0

RUNOFF

Runoff curve No II		70.0

SOIL EVAPORATION

CONA	(mm/day^0.5)	4.5
URITCH	(mm)	10.0

AVERAGE WASTE STREAM
****

Other waste stream
(All values relate to influent after any screening and recycling, if applicable).

Inflow Volume	(ML/year)	157.7
Nitrogen	(tonne/year)	3.2
Phosphorus	(tonne/year)	1.1
Salinity	(tonne/year)	431.7
Nitrogen Concentration	(mg/L)	20.0
Phosphorus Concentration	(mg/L)	7.0
Salinity	(mg/L)	2738.4
Salinity	(dS/m)	4.3

WASTE STREAM DETAILS (for last inflow event):

Nitrogen Concentration	(mg/L)	20.0
Phosphorus Concentration	(mg/L)	7.0
TDS Concentration	(mg/L)	1000.0
Salinity	(dS/m)	1.6

IRRIGATION WATER
****

Irrigation triggered every 1 days
Irrigating a fixed amount of 2 mm

AREA

Total Irrigation Area	(ha)	31.0

VOLUMES

Total Irrigation	(ML/year)	150.6
Minimum Volume Irrigated by Pump	(ML/ha/day)	0.0
Maximum Volume must be full irrig. requiremt		
Maximum Vol. Available For Shandying	(ML/yr)	0.0

IRRIGATION CONCENTRATIONS

Average salinity of Irrigation	(dS/m)	4.3
Average salinity of Irrigation	(mg/L)	2750.2
Average Nitrogen Conc of Irrigation		
Before ammonia loss	(mg/L)	20.0
After ammonia loss	(mg/L)	16.8
Average Phosphorus Conc of Irrigation	(mg/L)	7.0

FRESH WATER USAGE
****

Irrigation (shandying) water	(ML/yr)	0.00
Avg volume of fresh water used	(ML/yr)	0.00
Annual allocation	(ML/yr)	N/A

POND INFORMATION
****

POND GEOMETRY

		Pond 1
Final pond volume	(ML)	0.0
Final liquid volume	(ML)	0.0
Final sludge volume	(ML)	0.0
Average pond volume	(ML)	0.0
Average active volume	(ML)	0.0
Maximum pond volume	(ML)	0.6
Minimum allowable pond volume	(ML)	0.0
Average pond depth	(m)	2.3
Pond depth at outlet	(m)	3.0
Maximum water surface area	(m2 x1000)	0.3
Pond catchment area	(m2 x1000)	0.4
Pond footprint length	(m)	19.0
Pond footprint width	(m)	19.0

POND WATER BALANCE

Inflow of Effluent to pond system	(ML/yr)	157.7
Recycle Volume from pond system	(ML/yr)	0.0
Rain water added to pond system	(ML/yr)	0.4
Evaporation loss from pond system	(ML/yr)	0.3
Seepage loss from pond system	(ML/yr)	0.0
Irrigation from last pond	(ML/yr)	150.6
Volume of overtopping	(ML/yr)	7.1
Sludge accumulated	(ML/yr)	0.0
Sludge accumulated	(t DM/yr)	0.0
Sludge removed	(ML/yr)	0.0
No of desludging events every 10 years		0.0
Increase in pond water volume	(ML/yr)	0.0

OVERTOPPING EVENTS

Volume of overtopping	(ML/yr)	7.15
No. of days pond overtops per 10 years		922.46
Average Length of overtopping events	(days)	45.69
% Reuse		95.46

No. of overtopping events every 10 years

> 0.000 ML	20.19
> 0.000 ML*	20.00
> 1.000 ML	10.00
> 2.000 ML	10.00
> 5.000 ML	9.81
> 10.000 ML	0.00
> 20.000 ML	0.00
> 50.000 ML	0.00

* Volume equivalent to 1 mm depth of water

No. periods/year without irrigable effluent		0.0
Average Length of such periods	(days)	0.0

POND NITROGEN BALANCE

Nitrogen Added by Effluent	(tonne/yr)	3.2	Irrig. from pond (ML/yr) 150.6
Nitrogen removed by Irrigation	(tonne/yr)	3.0	
Nitrogen removed by Volatilisation	(tonne/yr)	0.0	
Nitrogen removed by Seepage	(tonne/yr)	0.0	
Nitrogen accumulated in Sludge	(tonne/yr)	0.0	
Nitrogen lost by Overtopping	(tonne/yr)	0.1	
Nitrogen involved in Recycling	(tonne/yr)	0.0	
Increase in pond Nitrogen	(tonne/yr)	0.0	

POND PHOSPHORUS BALANCE

Phosphorus Added by Effluent	(tonne/yr)	1.1	Irrig. from pond (ML/yr) 150.6
Phosphorus removed by Irrigation	(tonne/yr)	1.1	
Phosphorus removed by Seepage	(tonne/yr)	0.0	
Phosphorus accumulated in Sludge	(tonne/yr)	0.0	
Phosphorus lost by Overtopping	(tonne/yr)	0.1	
Phosphorus involved in Recycling	(tonne/yr)	0.0	
Increase in pond Phosphorus	(tonne/yr)	0.0	

POND SALINITY BALANCE

Salinity Added by Effluent	(tonne/yr)	431.7
Salinity removed by Irrigation	(tonne/yr)	414.1
Salinity removed by Seepage	(tonne/yr)	0.0
Salinity lost by Overtopping	(tonne/yr)	17.7
Salinity involved in Recycling	(tonne/yr)	0.0
Increase in pond Salinity	(tonne/yr)	0.0

POND CONCENTRATIONS

		Pond 1
Average Nitrogen Conc of Pond Liquid	(mg/L)	4.0
Average Phosphorus Conc of Pond Liquid	(mg/L)	7.0
Average TDS Conc of Pond Liquid	(mg/L)	2827.6
Average Salinity of Pond Liquid	(dS/m)	4.4
Average Potassium Conc of Pond Liquid	(mg/L)	0.0

(On final day of simulation)

Nitrogen Conc of Pond Liquid	(mg/L)	4.0
Phosphorus Conc of Pond Liquid	(mg/L)	7.0
TDS Conc of Pond Liquid	(mg/L)	999.4
EC of Pond Liquid	(dS/m)	1.6
Potassium Conc of Pond Liquid	(mg/L)	0.0

REMOVED SLUDGE - NUTRIENT & SALT CONCENTRATIONS

Nitrogen in removed Sludge (db)	(kg/tonne)	0.0
Phosphorus in removed Sludge (db)	(kg/tonne)	0.0
Salt in removed Sludge (db)	(kg/tonne)	0.0
Potassium in removed Sludge (db)	(kg/tonne)	0.0

REMOVED SLUDGE - NUTRIENT & SALT MASSES

Nitrogen in removed Sludge	(tonne/yr)	0.0
Phosphorus in removed Sludge	(tonne/yr)	0.0
Salt in removed Sludge (mass bal.)	(tonne/yr)	0.0
Salt in removed Sludge	(tonne/yr)	0.0
Potm. in removed Sludge (mass bal.)	(tonne/yr	0.0
Potassium in removed Sludge	(tonne/yr)	0.0

LAND DISPOSAL AREA
****

WATER BALANCE

(Initial soil water assumed to be at field capacity)
(Irrigated up to 3.53% of field capacity)

Rainfall	(mm/year)	1045.9	Irrigation Area	(ha)	31.0
Irrigation	(mm/year)	485.7			
Soil Evaporation	(mm/year)	53.7			
Transpiration	(mm/year)	1026.0			
Runoff	(mm/year)	6.1			
Drainage	(mm/year)	446.2			
Change in soil moisture	(mm/year)	-0.4			

ANNUAL TOTALS

Year	Rain (mm)	Irrig (mm)	Sevap (mm)	Trans (mm)	Runoff (mm)	Drain (mm)	Change (mm)
1957	492.0	484.8	403.0	491.0	0.0	161.6	-78.8
1958	1106.0	485.4	0.0	997.3	0.0	540.5	53.7
1959	1050.0	485.1	0.0	1179.0	0.0	335.7	20.3
1960	1074.0	487.0	0.0	1019.7	3.6	554.0	-16.4
1961	1324.0	485.7	0.0	1116.4	85.2	639.8	-31.7
1962	1108.0	485.1	0.0	1071.2	0.7	314.7	206.5
1963	1080.0	485.2	287.9	742.2	0.0	742.5	-207.5
1964	908.0	487.0	1.3	1189.3	1.3	194.1	9.2
1965	696.0	484.8	0.0	965.4	0.0	191.6	23.8
1966	1184.0	485.3	0.0	1298.6	0.0	404.4	-33.6
1967	1260.0	485.4	0.0	1169.6	0.0	530.7	45.1
1968	1080.0	487.3	0.0	1052.6	3.1	529.5	-17.9
1969	1275.0	485.6	0.0	1046.8	8.4	687.2	18.2
1970	950.0	484.9	0.0	1168.1	0.0	239.3	27.5

1971	1572.0	485.6	0.0	1154.6	31.6	897.2	-25.7
1972	800.0	487.1	0.0	1093.0	0.0	265.4	-71.4
1973	1693.0	485.4	0.0	1133.8	8.7	964.6	71.3
1974	1272.0	485.0	300.8	626.0	6.9	781.5	41.8
1975	1090.0	485.1	300.8	782.7	0.5	496.6	-5.5
1976	1240.0	487.4	0.0	1168.7	2.9	599.9	-44.2
1977	1176.0	485.5	0.0	955.8	9.4	724.5	-28.3
1978	1146.0	485.2	0.0	1130.4	1.6	444.5	54.8
1979	658.0	485.0	0.0	948.5	0.0	271.7	-77.2
1980	1121.0	487.1	0.0	1082.1	2.0	432.6	91.4
1981	1488.0	485.6	0.0	1081.7	27.0	914.5	-49.5
1982	713.0	484.8	0.0	1079.1	0.0	138.2	-19.5
1983	1756.0	486.1	0.0	1135.3	57.5	1035.8	13.4
1984	1030.0	487.0	324.4	738.3	0.5	411.5	42.4
1985	1013.0	485.4	0.7	1167.5	3.2	414.6	-87.7
1986	1258.0	485.4	334.9	762.0	0.1	641.5	4.9
1987	826.0	485.0	0.2	1184.1	0.0	75.9	50.9
1988	1336.0	487.4	0.0	1150.3	0.5	659.1	13.5
1989	1468.0	486.0	270.1	685.2	3.5	1054.5	-59.3
1990	1707.0	485.9	10.9	842.6	36.8	1072.4	230.1
1991	1003.0	485.0	0.0	1026.7	0.0	643.7	-182.4
1992	1196.0	487.5	0.0	1090.7	14.4	624.5	-46.0
1993	956.0	484.8	0.0	1129.4	9.7	255.0	46.7
1994	753.0	484.9	0.0	1085.4	0.0	210.0	-57.5
1995	1042.0	485.2	0.0	1220.1	0.0	268.8	38.3
1996	943.0	486.8	0.0	1043.9	1.0	387.3	-2.5
1997	677.0	484.8	0.0	1059.7	0.0	41.7	60.4
1998	962.0	485.2	0.0	1219.5	0.0	310.6	-82.9
1999	882.0	484.9	0.0	1111.6	0.1	197.3	57.9
2000	1084.0	487.3	0.0	1109.3	0.0	385.6	76.4
2001	477.0	484.6	0.0	996.7	0.0	83.2	-118.3
2002	743.0	484.8	0.0	1049.2	0.0	194.2	-15.6
2003	842.0	485.1	0.0	1042.4	0.0	244.9	39.8
2004	611.0	486.7	0.0	1096.3	0.0	44.0	-42.6
2005	679.0	484.8	0.0	1120.1	0.0	58.7	-15.1
2006	840.0	484.9	0.0	1122.2	0.0	171.1	31.6
2007	909.0	485.1	309.9	756.2	0.0	286.3	41.7
2008	1110.0	487.3	287.7	742.5	0.3	622.2	-55.3
2009	773.0	484.9	13.5	945.7	1.7	256.9	40.1

NUTRIENT BALANCE

NITROGEN

Total N irrigated from ponds	(kg/ha/year)	97.1	% of Total as ammonium	80.0
Nitrogn lost by ammonia volat.	(kg/ha/year)	15.5	Deep Drainage (mm/year)	446.2
Nitrogen added in irrigation	(kg/ha/year)	81.6		
Nitrogen added in seed	(kg/ha/year)	0.1		
Nitrogen removed by crop	(kg/ha/year)	116.7		
Denitrification	(kg/ha/year)	0.1		
Leached NO3-N	(kg/ha/year)	2.8		
Change in soil organic-N	(kg/ha/year)	-35.0		
Change in soil solution NH4-N	(kg/ha/year)	0.0		
Change in soil solution NO3-N	(kg/ha/year)	-2.9		
Change in adsorbed NH4-N	(kg/ha/year)	0.0		
Initial soil organic-N	(kg/ha)	1957.5		
Final soil organic-N	(kg/ha)	101.5		
Initial soil inorganic-N	(kg/ha)	156.0		
Final soil inorganic-N	(kg/ha)	0.0		
Average NO3-N conc in the root zone	(mg/L)	0.4		
Average NO3-N conc below root zone	(mg/L)	1.8		
Average NO3-N conc of deep drainage	(mg/L)	0.6		

PHOSPHORUS

Phosphorus added in irrigatn	(kg/ha/year)	34.0	% of Total as phosphate	100.0
Phosphorus added in seed	(kg/ha/year)	0.0		
Phosphorus removed by crop	(kg/ha/year)	26.1		
Leached PO4-P	(kg/ha/year)	0.1		
Change in dissolved PO4-P	(kg/ha/year)	0.0		
Change in adsorbed PO4-P	(kg/ha/year)	7.9		
Average PO4-P conc in the root zone	(mg/L)	0.2		
Average PO4-P conc below root zone	(mg/L)	0.0		

SOIL P STORAGE LIFE

Year	YearNo.	Tot P stored kg/ha	P leached in year kg/ha
1957	1	381.5	0.0
1958	2	410.4	0.1
1959	3	429.8	0.0
1960	4	443.2	0.1
1961	5	450.0	0.1
1962	6	454.4	0.0
1963	7	460.6	0.1
1964	8	470.5	0.0
1965	9	470.8	0.0
1966	10	472.5	0.0
1967	11	474.9	0.1
1968	12	480.4	0.1
1969	13	482.9	0.1
1970	14	485.7	0.0
1971	15	489.0	0.1
1972	16	494.2	0.0
1973	17	496.2	0.1
1974	18	502.7	0.1
1975	19	522.6	0.1
1976	20	526.4	0.1
1977	21	528.8	0.1
1978	22	534.4	0.1
1979	23	539.4	0.0
1980	24	546.1	0.1
1981	25	549.5	0.1
1982	26	554.8	0.0
1983	27	561.1	0.1
1984	28	570.5	0.0
1985	29	577.3	0.0
1986	30	585.2	0.1
1987	31	594.4	0.0
1988	32	601.1	0.1
1989	33	608.4	0.1
1990	34	619.3	0.2
1991	35	625.5	0.1
1992	36	633.4	0.1
1993	37	638.4	0.0
1994	38	645.3	0.0
1995	39	653.4	0.0
1996	40	662.6	0.1
1997	41	668.3	0.0
1998	42	675.8	0.0
1999	43	683.3	0.0
2000	44	694.1	0.1
2001	45	700.6	0.0
2002	46	709.1	0.0
2003	47	718.1	0.0
2004	48	728.1	0.0
2005	49	734.7	0.0
2006	50	742.7	0.0
2007	51	753.6	0.0
2008	52	768.9	0.2
2009	53	777.6	0.0

PLANT

Plant species: Coastal couch grass (Cynodon dac

PLANT WATER USE

Irrigation	(mm/year)	486.	Totl Irrigation Area(ha)	31.0
Pan coefficient	(%)	1.0		
Maximum crop coefficient	(%)	0.8		
Average Plant Cover	(%)	81.		
Average Plant Total Cover	(%)	94.		
Average Plant Rootdepth	(mm)	754.		

Average Plant Available Water Capacity	(mm)	54.
Average Plant Available Water	(mm)	35.
Yield produced per unit transp.	(kg/ha/mm)	9.

PLANT NUTRIENT UPTAKE

Dry Matter Yield (Shoots)	(kg/ha/yr)	9415.			
Net nitrogen removed by plant	(kg/ha/yr)	117.	Shoot Concn	(%DM)	1.24
Net phosphorus removed by plant	(kg/ha/yr)	26.	Shoot Concn	(%DM)	0.28

AVERAGE MONTHLY GROWTH STRESS (0=no stress, 1=full stress)

Month	Yield kg/ha	Nitr	Temp	Water Defic	Water Logging
1	1091.	0.4	0.0	0.1	0.0
2	881.	0.5	0.0	0.1	0.0
3	873.	0.5	0.0	0.1	0.0
4	787.	0.5	0.0	0.1	0.0
5	654.	0.5	0.2	0.1	0.0
6	416.	0.4	0.5	0.0	0.0
7	346.	0.4	0.7	0.1	0.0
8	553.	0.3	0.5	0.1	0.0
9	894.	0.3	0.2	0.2	0.0
10	903.	0.4	0.0	0.3	0.0
11	921.	0.5	0.0	0.3	0.0
12	1095.	0.5	0.0	0.2	0.0

>>> NO-PLANT EVENTS <<<

%Days due to temperature stress	0.2
%Days due to water stress	0.4
%Days due to nitrogen stress	0.0
No. of forced harvests per year	0.2
No. of normal harvests per year	6.4

SALINITY

Salt tolerance - plant species: tolerant

Average EC of Irrigation Water	(dS/m)	4.3	Irrigation	(mm/year)	485.7
Average EC of Rainwater	(dS/m x10)	0.3	Rainfall	(mm/year)	1045.9
Average EC of Infiltrated water	(dS/m)	1.4			
Av. water-upt-weightd rootzone EC(dS/m s.e.)		1.4			
EC soil soln (FC) at base of rootzone	(dS/m)	5.8	Deep Drainage	(mm/year)	446.2
Reduction in Crop yield due to Salinity	(%)	0.0			
Percentage of yrs that crop yld falls below 90% of potential because of soil salinity		0.0			

Period	ECrootzone sat ext (dS/m)	ECbase in situ (dS/m)	Rel Yield (%)
1957 - 1961	1.35	4.74	100.
1958 - 1962	1.20	4.30	100.
1959 - 1963	1.19	4.10	100.
1960 - 1964	1.24	4.33	100.
1961 - 1965	1.38	5.08	100.
1962 - 1966	1.46	5.73	100.
1963 - 1967	1.39	5.33	100.
1964 - 1968	1.43	5.72	100.
1965 - 1969	1.24	4.52	100.
1966 - 1970	1.20	4.41	100.
1967 - 1971	1.08	3.68	100.
1968 - 1972	1.17	4.05	100.
1969 - 1973	1.03	3.48	100.
1970 - 1974	1.02	3.37	100.
1971 - 1975	0.98	3.11	100.
1972 - 1976	1.04	3.42	100.
1973 - 1977	0.95	2.98	100.
1974 - 1978	1.07	3.48	100.
1975 - 1979	1.23	4.17	100.

1976 - 1980	1.23	4.32	100.
1977 - 1981	1.14	3.80	100.
1978 - 1982	1.32	4.81	100.
1979 - 1983	1.13	3.80	100.
1980 - 1984	1.07	3.62	100.
1981 - 1985	1.09	3.64	100.
1982 - 1986	1.17	4.01	100.
1983 - 1987	1.17	4.11	100.
1984 - 1988	1.30	4.81	100.
1985 - 1989	1.11	3.73	100.
1986 - 1990	0.94	2.95	100.
1987 - 1991	0.97	3.03	100.
1988 - 1992	0.88	2.62	100.
1989 - 1993	0.95	2.91	100.
1990 - 1994	1.14	3.78	100.
1991 - 1995	1.45	5.57	100.
1992 - 1996	1.51	6.06	100.
1993 - 1997	1.86	9.09	100.
1994 - 1998	1.85	8.67	100.
1995 - 1999	1.81	8.76	100.
1996 - 2000	1.70	7.78	100.
1997 - 2001	2.04	10.37	100.
1998 - 2002	1.95	9.02	100.
1999 - 2003	2.01	9.55	100.
2000 - 2004	2.24	11.09	100.
2001 - 2005	2.90	17.91	100.
2002 - 2006	2.49	14.80	100.
2003 - 2007	2.32	13.11	100.
2004 - 2008	1.94	8.93	100.
2005 - 2009	1.78	7.57	100.

GROUNDWATER
****

Average Groundwater Recharge (m3/day) 378.7
Average Nitrate-N Conc of Recharge (mg/L) 0.6

Thickness of the Aquifer (m) 10.0
Distance (m) from Irrigation Area to where
Nitrate-N Conc in Groundwater is Calculated 1000.0

Concentration of NITRATE-N in Groundwater (mg/L)

	Year	Depth Below Water Table Surface 0.0 m	5.0 m	9.0 m
	1961	0.2	0.2	0.2
	1966	0.3	0.3	0.3
	1971	0.4	0.4	0.4
	1976	0.5	0.5	0.5
	1981	0.5	0.5	0.5
	1986	0.5	0.5	0.5
	1991	0.5	0.5	0.5
	1996	0.5	0.5	0.5
	2001	0.5	0.5	0.5
	2006	0.6	0.6	0.6
Last	2009	0.6	0.6	0.6

ACKNOWLEDGMENTS
****
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OTHER INDUSTRY INPUT PARAMETERS - DATA SUMMARY

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UNCONDITIONAL FINISH

****
SUMMARY OUTPUT
MEDLI Version 1.30

Data Set: 110824 GKI Scenario 1b-100% 2mm 31ha
Run Date: 25/08/11 Time:09:05:09.94
****

GENERAL INFORMATION

Title: GKI Resort Revitalisation Plan
Subject: Scenario 1b - 2mm Irrigation
Client: GKI Resorts Pty Ltd
User: Mark Farrey
Time: Thu Aug 25 08:57:44 2011
Comments: 2mm/day . Irrigation Area = 31ha. Wet Weather Storage = 9ML (100% reuse). N = 20mg/L, P = 7mg/L.

RUN PERIOD

Starting Date 1/ 1/1957
Ending Date 31/12/2009
Run Length 53 years 0 days

CLIMATE INFORMATION

Enterprise site: Great Keppel Island -23.2 deg S 150.9 deg E
Weather station: keppel_23.20S_150.95E (Interpola

ANNUAL TOTALS	10 Percentile	50 percentile	90 Percentile
Rainfall mm/year	688.	1062.	1478.
Pan Evap mm/year	1715.	1837.	1997.

MONTHLY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	154	170	133	95	93	59	44	39	27	45	68	120	1045
Pan Evap (mm)	198	166	169	138	111	92	100	122	155	191	199	208	1848
Ave Max Temp DegC	29	29	28	26	24	22	21	22	24	26	28	29	25
Ave Min Temp DegC	23	23	22	19	16	14	12	13	16	19	21	22	18
Rad (MJ/m2/day)	22	21	20	18	15	14	15	18	21	23	24	24	19

MONTHLY IRRIGATION

Irrigation (mm)	62	49	38	42	21	23	33	31	59	44	44	62	508

SOIL PROPERTIES

Soil type: Great Keppel Island Sand

SOIL WATER PROPERTIES

		Layer 1	Layer 2	Layer 3	Layer 4
Bulk Density	(g/cm3)	1.3	1.5	1.5	1.5
Porosity	(mm/layer)	50.6	213.2	264.9	130.2
Saturated Water Content	(mm/layer)	50.1	211.5	261.6	129.3
Drained Upper Limit	(mm/layer)	10.9	68.0	82.8	27.3
Lower Storage Limit	(mm/layer)	4.0	32.0	45.0	18.0
Air Dry Moisture Content	(mm/layer)	4.0			
Layer Thickness	(mm)	100.0	500.0	600.0	300.0

		Profile	Max Rootzone
Total Saturated Water Content	(mm)	652.5	348.8
Total Drained Upper Limit	(mm)	189.0	106.5
Total Lower Storage Limit	(mm)	99.0	51.0
Total Air Dry Moisture Content	(mm)	5.4	4.7
Total Depth	(mm)	1500.0	800.0

Maximum Plant Available Water Capacity 55.5
Saturated Hydraulic Conductivity

At Surface	(mm/hr)	100.0
Limiting	(mm/hr)	20.0

RUNOFF

Runoff curve No II		70.0

SOIL EVAPORATION

CONA	(mm/day^0.5)	4.5
URITCH	(mm)	10.0

AVERAGE WASTE STREAM
****

Other waste stream
(All values relate to influent after any screening and recycling, if applicable).

Inflow Volume	(ML/year)	157.7
Nitrogen	(tonne/year)	3.2
Phosphorus	(tonne/year)	1.1
Salinity	(tonne/year)	431.7
Nitrogen Concentration	(mg/L)	20.0
Phosphorus Concentration	(mg/L)	7.0
Salinity	(mg/L)	2738.4
Salinity	(dS/m)	4.3

WASTE STREAM DETAILS (for last inflow event):

Nitrogen Concentration	(mg/L)	20.0
Phosphorus Concentration	(mg/L)	7.0
TDS Concentration	(mg/L)	1000.0
Salinity	(dS/m)	1.6

IRRIGATION WATER
****

Irrigation triggered every 1 days
Irrigating a fixed amount of 2 mm

AREA

Total Irrigation Area	(ha)	31.0

VOLUMES

Total Irrigation	(ML/year)	157.7
Minimum Volume Irrigated by Pump	(ML/ha/day)	0.0
Maximum Volume must be full irrig. requiremt		
Maximum Vol. Available For Shandying	(ML/yr)	0.0

IRRIGATION CONCENTRATIONS

Average salinity of Irrigation	(dS/m)	4.3
Average salinity of Irrigation	(mg/L)	2735.8
Average Nitrogen Conc of Irrigation		
Before ammonia loss	(mg/L)	19.6
After ammonia loss	(mg/L)	16.4
Average Phosphorus Conc of Irrigation	(mg/L)	7.0

FRESH WATER USAGE
****

Irrigation (shandying) water	(ML/yr)	0.00
Avg volume of fresh water used	(ML/yr)	0.00
Annual allocation	(ML/yr)	N/A

POND INFORMATION
****

POND GEOMETRY

		Pond 1
Final pond volume	(ML)	1.1
Final liquid volume	(ML)	1.1
Final sludge volume	(ML)	0.0
Average pond volume	(ML)	0.5
Average active volume	(ML)	0.5
Maximum pond volume	(ML)	9.0
Minimum allowable pond volume	(ML)	0.0
Average pond depth	(m)	0.3
Pond depth at outlet	(m)	3.0
Maximum water surface area	(m2 x1000)	3.3
Pond catchment area	(m2 x1000)	3.6
Pond footprint length	(m)	59.7
Pond footprint width	(m)	59.7

POND WATER BALANCE

Inflow of Effluent to pond system	(ML/yr)	157.7
Recycle Volume from pond system	(ML/yr)	0.0
Rain water added to pond system	(ML/yr)	3.7
Evaporation loss from pond system	(ML/yr)	3.6
Seepage loss from pond system	(ML/yr)	0.1
Irrigation from last pond	(ML/yr)	157.7
Volume of overtopping	(ML/yr)	0.0
Sludge accumulated	(ML/yr)	0.0
Sludge accumulated	(t DM/yr)	0.0
Sludge removed	(ML/yr)	0.0
No of desludging events every 10 years		0.0
Increase in pond water volume	(ML/yr)	0.0

OVERTOPPING EVENTS

Volume of overtopping	(ML/year)	0.00
Average Length of overtopping events	(days)	0.00
% Reuse		0.00
No. of overtopping events per 10 years		0.00
No. periods/year without irrigable effluent		0.0
Average Length of such periods	(days)	0.0

POND NITROGEN BALANCE

Nitrogen Added by Effluent	(tonne/yr)	3.2	Irrig. from pond (ML/yr)	157.7
Nitrogen removed by Irrigation	(tonne/yr)	3.1		
Nitrogen removed by Volatilisation	(tonne/yr)	0.1		
Nitrogen removed by Seepage	(tonne/yr)	0.0		
Nitrogen accumulated in Sludge	(tonne/yr)	0.0		
Nitrogen lost by Overtopping	(tonne/yr)	0.0		
Nitrogen involved in Recycling	(tonne/yr)	0.0		
Increase in pond Nitrogen	(tonne/yr)	0.0		

POND PHOSPHORUS BALANCE

Phosphorus Added by Effluent	(tonne/yr)	1.1	Irrig. from pond (ML/yr)	157.7
Phosphorus removed by Irrigation	(tonne/yr)	1.1		
Phosphorus removed by Seepage	(tonne/yr)	0.0		
Phosphorus accumulated in Sludge	(tonne/yr)	0.0		
Phosphorus lost by Overtopping	(tonne/yr)	0.0		
Phosphorus involved in Recycling	(tonne/yr)	0.0		
Increase in pond Phosphorus	(tonne/yr)	0.0		

POND SALINITY BALANCE

Salinity Added by Effluent	(tonne/yr)	431.7
Salinity removed by Irrigation	(tonne/yr)	431.4
Salinity removed by Seepage	(tonne/yr)	0.3
Salinity lost by Overtopping	(tonne/yr)	0.0
Salinity involved in Recycling	(tonne/yr)	0.0
Increase in pond Salinity	(tonne/yr)	0.0

POND CONCENTRATIONS

Pond 1

Average Nitrogen Conc of Pond Liquid	(mg/L)	18.2
Average Phosphorus Conc of Pond Liquid	(mg/L)	6.9
Average TDS Conc of Pond Liquid	(mg/L)	2706.8
Average Salinity of Pond Liquid	(dS/m)	4.2
Average Potassium Conc of Pond Liquid	(mg/L)	0.0

(On final day of simulation)

Nitrogen Conc of Pond Liquid	(mg/L)	17.7
Phosphorus Conc of Pond Liquid	(mg/L)	6.8
TDS Conc of Pond Liquid	(mg/L)	972.0
EC of Pond Liquid	(dS/m)	1.5
Potassium Conc of Pond Liquid	(mg/L)	0.0

REMOVED SLUDGE - NUTRIENT & SALT CONCENTRATIONS

Nitrogen in removed Sludge (db)	(kg/tonne)	0.0
Phosphorus in removed Sludge (db)	(kg/tonne)	0.0
Salt in removed Sludge (db)	(kg/tonne)	0.0
Potassium in removed Sludge (db)	(kg/tonne)	0.0

REMOVED SLUDGE - NUTRIENT & SALT MASSES

Nitrogen in removed Sludge	(tonne/yr)	0.0
Phosphorus in removed Sludge	(tonne/yr)	0.0
Salt in removed Sludge (mass bal.)	(tonne/yr)	0.0
Salt in removed Sludge	(tonne/yr)	0.0
Potm. in removed Sludge (mass bal.)	(tonne/yr	0.0
Potassium in removed Sludge	(tonne/yr)	0.0

LAND DISPOSAL AREA
****

WATER BALANCE

(Initial soil water assumed to be at field capacity)
(Irrigated up to 3.65% of field capacity)

Rainfall	(mm/year)	1045.9	Irrigation Area	(ha)	31.0
Irrigation	(mm/year)	508.7			
Soil Evaporation	(mm/year)	54.1			
Transpiration	(mm/year)	1031.5			
Runoff	(mm/year)	6.1			
Drainage	(mm/year)	463.3			
Change in soil moisture	(mm/year)	-0.4			

ANNUAL TOTALS

Year	Rain (mm)	Irrig (mm)	Sevap (mm)	Trans (mm)	Runoff (mm)	Drain (mm)	Change (mm)
1957	492.0	499.3	411.5	492.3	0.0	166.3	-78.7
1958	1106.0	508.1	0.0	997.2	0.0	562.3	54.6
1959	1050.0	508.0	0.0	1175.4	0.0	363.4	19.2
1960	1074.0	511.3	0.0	1020.9	3.6	576.5	-15.7
1961	1324.0	512.2	0.0	1117.6	85.3	665.7	-32.4
1962	1108.0	506.1	0.0	1069.7	0.7	337.0	206.7
1963	1080.0	511.6	287.1	742.6	0.0	766.8	-204.9
1964	908.0	508.3	1.3	1208.9	1.3	200.2	4.7
1965	696.0	502.6	0.0	976.0	0.0	200.4	22.3
1966	1184.0	510.6	0.0	1301.1	0.0	427.1	-33.6
1967	1260.0	509.9	0.0	1168.1	0.0	555.0	46.8
1968	1080.0	511.4	0.0	1058.3	3.1	551.6	-21.6
1969	1275.0	510.3	0.0	1064.4	8.4	691.8	20.6
1970	950.0	506.8	0.0	1175.2	0.0	249.9	31.7
1971	1572.0	515.1	0.0	1156.8	31.7	924.1	-25.4
1972	800.0	509.3	0.0	1097.9	0.0	284.2	-72.9
1973	1693.0	512.5	0.0	1137.4	8.7	987.0	72.3
1974	1272.0	515.4	302.1	628.7	6.9	808.8	41.0
1975	1090.0	508.0	316.2	785.3	0.5	501.5	-5.5
1976	1240.0	513.7	0.0	1168.2	2.9	626.5	-44.0
1977	1176.0	511.7	0.0	953.3	9.5	752.1	-27.1
1978	1146.0	509.6	0.0	1146.6	1.6	453.5	53.8
1979	658.0	505.1	0.0	950.9	0.0	290.2	-78.0
1980	1121.0	509.4	0.0	1084.9	2.2	455.8	87.4

1981	1488.0	515.8	0.0	1084.1	26.9	935.8	-43.0
1982	713.0	504.1	0.0	1074.6	0.0	155.7	-13.1
1983	1756.0	517.7	0.0	1165.9	57.5	1049.2	1.1
1984	1030.0	510.1	323.1	733.4	0.5	436.2	46.9
1985	1013.0	510.0	0.7	1167.7	3.3	438.2	-86.9
1986	1258.0	509.7	333.7	763.9	0.2	666.7	3.2
1987	826.0	506.1	0.2	1204.4	0.0	76.5	51.1
1988	1336.0	511.8	0.0	1160.7	0.5	673.5	13.1
1989	1468.0	516.7	270.0	687.1	3.5	1083.2	-59.1
1990	1707.0	512.2	10.3	856.8	36.7	1085.3	230.2
1991	1003.0	510.0	0.0	1029.7	0.0	666.1	-182.8
1992	1196.0	513.7	0.0	1092.1	14.3	644.3	-41.0
1993	956.0	506.1	0.0	1155.4	9.7	256.0	40.9
1994	753.0	504.3	0.0	1078.1	0.0	235.3	-56.0
1995	1042.0	506.6	0.0	1216.0	0.0	286.6	45.9
1996	943.0	508.8	0.0	1064.1	1.0	397.8	-11.1
1997	677.0	503.2	0.0	1074.3	0.0	49.6	56.2
1998	962.0	508.3	0.0	1233.6	0.0	311.9	-75.2
1999	882.0	504.5	0.0	1108.1	0.2	222.7	55.5
2000	1084.0	511.4	0.0	1104.4	0.0	415.0	76.0
2001	477.0	501.8	0.0	1011.5	0.0	84.3	-117.0
2002	743.0	503.7	0.0	1065.9	0.0	197.8	-16.9
2003	842.0	503.3	0.0	1049.8	0.0	257.4	38.1
2004	611.0	505.1	0.0	1092.4	0.0	65.3	-41.5
2005	679.0	503.2	0.0	1127.4	0.0	69.2	-14.4
2006	840.0	504.9	0.0	1146.8	0.0	164.2	33.9
2007	909.0	505.8	309.3	755.7	0.0	309.5	40.4
2008	1110.0	512.3	287.8	747.5	0.3	645.0	-58.2
2009	773.0	503.9	12.9	942.0	1.8	277.8	42.3

NUTRIENT BALANCE

NITROGEN

Total N irrigated from ponds	(kg/ha/year)	99.5	% of Total as ammonium	80.0
Nitrogn lost by ammonia volat.	(kg/ha/year)	15.9	Deep Drainage (mm/year)	463.3
Nitrogen added in irrigation	(kg/ha/year)	83.6		
Nitrogen added in seed	(kg/ha/year)	0.1		
Nitrogen removed by crop	(kg/ha/year)	118.7		
Denitrification	(kg/ha/year)	0.1		
Leached NO3-N	(kg/ha/year)	2.8		
Change in soil organic-N	(kg/ha/year)	-35.0		
Change in soil solution NH4-N	(kg/ha/year)	0.0		
Change in soil solution NO3-N	(kg/ha/year)	-2.9		
Change in adsorbed NH4-N	(kg/ha/year)	0.0		
Initial soil organic-N	(kg/ha)	1957.5		
Final soil organic-N	(kg/ha)	101.6		
Initial soil inorganic-N	(kg/ha)	156.0		
Final soil inorganic-N	(kg/ha)	0.0		
Average N03-N conc in the root zone	(mg/L)	0.4		
Average N03-N conc below root zone	(mg/L)	1.8		
Average N03-N conc of deep drainage	(mg/L)	0.6		

PHOSPHORUS

Phosphorus added in irrigatn	(kg/ha/year)	35.6	% of Total as phosphate	100.0
Phosphorus added in seed	(kg/ha/year)	0.0		
Phosphorus removed by crop	(kg/ha/year)	26.7		
Leached PO4-P	(kg/ha/year)	0.1		
Change in dissolved PO4-P	(kg/ha/year)	0.0		
Change in adsorbed PO4-P	(kg/ha/year)	8.9		
Average P04-P conc in the root zone	(mg/L)	0.2		
Average P04-P conc below root zone	(mg/L)	0.0		

SOIL P STORAGE LIFE

Year	YearNo.	Tot P stored kg/ha	P leached in year kg/ha
1957	1	382.4	0.0
1958	2	412.5	0.1
1959	3	432.2	0.0
1960	4	445.9	0.1

1961	5	452.9	0.1
1962	6	457.3	0.0
1963	7	464.0	0.1
1964	8	474.2	0.0
1965	9	474.7	0.0
1966	10	477.0	0.0
1967	11	480.0	0.1
1968	12	486.2	0.1
1969	13	489.3	0.1
1970	14	493.0	0.0
1971	15	497.4	0.1
1972	16	503.8	0.0
1973	17	506.8	0.1
1974	18	514.5	0.1
1975	19	535.8	0.1
1976	20	540.9	0.1
1977	21	544.8	0.1
1978	22	551.5	0.1
1979	23	558.0	0.0
1980	24	566.1	0.1
1981	25	570.8	0.1
1982	26	577.1	0.0
1983	27	584.5	0.2
1984	28	595.3	0.0
1985	29	603.3	0.1
1986	30	612.5	0.1
1987	31	622.6	0.0
1988	32	630.7	0.1
1989	33	639.3	0.1
1990	34	651.2	0.2
1991	35	658.7	0.1
1992	36	668.0	0.1
1993	37	673.9	0.0
1994	38	682.1	0.0
1995	39	691.2	0.0
1996	40	701.7	0.1
1997	41	708.7	0.0
1998	42	717.4	0.0
1999	43	726.0	0.0
2000	44	738.1	0.1
2001	45	745.6	0.0
2002	46	755.1	0.0
2003	47	765.1	0.0
2004	48	776.2	0.0
2005	49	783.9	0.0
2006	50	793.1	0.0
2007	51	805.1	0.0
2008	52	821.9	0.2
2009	53	831.5	0.0

PLANT

Plant species: Coastal couch grass (Cynodon dac

PLANT WATER USE

Irrigation	(mm/year)	509.	Totl Irrigation Area(ha)	31.0
Pan coefficient	(%)	1.0		
Maximum crop coefficient	(%)	0.8		
Average Plant Cover	(%)	81.		
Average Plant Total Cover	(%)	94.		
Average Plant Rootdepth	(mm)	754.		
Average Plant Available Water Capacity	(mm)	54.		
Average Plant Available Water	(mm)	35.		
Yield produced per unit transp.	(kg/ha/mm)	9.		

PLANT NUTRIENT UPTAKE

Dry Matter Yield (Shoots)	(kg/ha/yr)	9515.			
Net nitrogen removed by plant	(kg/ha/yr)	119.	Shoot Concn	(%DM)	1.25
Net phosphorus removed by plant	(kg/ha/yr)	27.	Shoot Concn	(%DM)	0.28

AVERAGE MONTHLY GROWTH STRESS (0=no stress, 1=full stress)

Month	Yield kg/ha	Nitr	Temp	Water Defic	Water Logging
1	1089.	0.4	0.0	0.1	0.0
2	927.	0.4	0.0	0.1	0.0
3	913.	0.5	0.0	0.1	0.0
4	794.	0.5	0.0	0.1	0.0
5	655.	0.5	0.2	0.1	0.0
6	417.	0.4	0.5	0.0	0.0
7	346.	0.3	0.7	0.1	0.0
8	550.	0.3	0.5	0.1	0.0
9	897.	0.3	0.2	0.2	0.0
10	905.	0.4	0.0	0.3	0.0
11	917.	0.4	0.0	0.3	0.0
12	1103.	0.5	0.0	0.2	0.0

>>> NO-PLANT EVENTS <<<

%Days due to temperature stress	0.2
%Days due to water stress	0.4
%Days due to nitrogen stress	0.0
No. of forced harvests per year	0.2
No. of normal harvests per year	6.5

SALINITY

Salt tolerance - plant species: tolerant

Average EC of Irrigation Water	(dS/m)	4.3	Irrigation	(mm/year)	508.7
Average EC of Rainwater	(dS/m x10)	0.3	Rainfall	(mm/year)	1045.9
Average EC of Infiltrated water	(dS/m)	1.4			
Av. water-upt-weightd rootzone EC(dS/m s.e.)		1.4			
EC soil soln (FC) at base of rootzone	(dS/m)	5.8	Deep Drainage	(mm/year)	463.3
Reduction in Crop yield due to Salinity	(%)	0.0			
Percentage of yrs that crop yld falls below 90% of potential because of soil salinity		0.0			

Period	ECrootzone sat ext (dS/m)	ECbase in situ (dS/m)	Rel Yield (%)
1957 - 1961	1.36	4.72	100.
1958 - 1962	1.21	4.27	100.
1959 - 1963	1.20	4.07	100.
1960 - 1964	1.26	4.34	100.
1961 - 1965	1.39	5.08	100.
1962 - 1966	1.47	5.71	100.
1963 - 1967	1.41	5.32	100.
1964 - 1968	1.45	5.70	100.
1965 - 1969	1.26	4.55	100.
1966 - 1970	1.22	4.44	100.
1967 - 1971	1.09	3.72	100.
1968 - 1972	1.19	4.09	100.
1969 - 1973	1.05	3.52	100.
1970 - 1974	1.04	3.40	100.
1971 - 1975	1.00	3.15	100.
1972 - 1976	1.06	3.45	100.
1973 - 1977	0.97	3.01	100.
1974 - 1978	1.09	3.52	100.
1975 - 1979	1.24	4.20	100.
1976 - 1980	1.25	4.31	100.
1977 - 1981	1.15	3.82	100.
1978 - 1982	1.33	4.81	100.
1979 - 1983	1.15	3.83	100.
1980 - 1984	1.09	3.65	100.
1981 - 1985	1.10	3.67	100.
1982 - 1986	1.18	4.02	100.
1983 - 1987	1.19	4.14	100.
1984 - 1988	1.31	4.82	100.
1985 - 1989	1.13	3.76	100.

1986 - 1990	0.96	3.00	100.
1987 - 1991	0.99	3.09	100.
1988 - 1992	0.90	2.67	100.
1989 - 1993	0.97	2.96	100.
1990 - 1994	1.16	3.82	100.
1991 - 1995	1.46	5.55	100.
1992 - 1996	1.53	6.06	100.
1993 - 1997	1.88	8.98	100.
1994 - 1998	1.87	8.59	100.
1995 - 1999	1.82	8.67	100.
1996 - 2000	1.72	7.68	100.
1997 - 2001	2.05	10.15	100.
1998 - 2002	1.96	8.93	100.
1999 - 2003	2.02	9.34	100.
2000 - 2004	2.24	10.78	100.
2001 - 2005	2.89	17.22	100.
2002 - 2006	2.51	14.57	100.
2003 - 2007	2.32	12.69	100.
2004 - 2008	1.95	8.78	100.
2005 - 2009	1.80	7.51	100.

GROUNDWATER
****

Average Groundwater Recharge (m3/day) 393.2
Average Nitrate-N Conc of Recharge (mg/L) 0.6

Thickness of the Aquifer (m) 10.0
Distance (m) from Irrigation Area to where
Nitrate-N Conc in Groundwater is Calculated 1000.0

Concentration of NITRATE-N in Groundwater (mg/L)

	Year	Depth Below Water Table Surface 0.0 m	5.0 m	9.0 m
	1961	0.2	0.2	0.2
	1966	0.3	0.3	0.3
	1971	0.4	0.4	0.4
	1976	0.5	0.5	0.5
	1981	0.5	0.5	0.5
	1986	0.5	0.5	0.5
	1991	0.5	0.5	0.5
	1996	0.5	0.5	0.5
	2001	0.5	0.5	0.5
	2006	0.5	0.5	0.5
Last	2009	0.5	0.5	0.5

ACKNOWLEDGMENTS
****
This run brought to you courtesy of:

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OTHER INDUSTRY INPUT PARAMETERS - DATA SUMMARY

Nature of Industry: STP wastestream

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UNCONDITIONAL FINISH

****
SUMMARY OUTPUT
MEDLI Version 1.30

Data Set: 110824 GKI Scenario 2a-95% PAWC 31ha
Run Date: 25/08/11 Time:08:02:04.14
****

GENERAL INFORMATION
****
Title: GKI Resort Revitalisation Plan
Subject: Scenario 2a - 80% PAWC Irrigatio
Client: GKI Resorts Pty Ltd
User: Mark Farrey
Time: Thu Aug 25 08:01:11 2011
Comments: 80%PAWC-5mm beyond DUL. Irrigation Area = 31ha. Wet Weather Storage = 13ML (95% reuse). N = 20mg/L, P = 7mg/L.

RUN PERIOD
****

Starting Date 1/ 1/1957
Ending Date 31/12/2009
Run Length 53 years 0 days

CLIMATE INFORMATION
****

Enterprise site: Great Keppel Island -23.2 deg S 150.9 deg E
Weather station: keppel_23.20S_150.95E (Interpola

ANNUAL TOTALS	10 Percentile	50 percentile	90 Percentile
Rainfall mm/year	688.	1062.	1478.
Pan Evap mm/year	1715.	1837.	1997.

MONTHLY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	154	170	133	95	93	59	44	39	27	45	68	120	1045
Pan Evap (mm)	198	166	169	138	111	92	100	122	155	191	199	208	1848
Ave Max Temp DegC	29	29	28	26	24	22	21	22	24	26	28	29	25
Ave Min Temp DegC	23	23	22	19	16	14	12	13	16	19	21	22	18
Rad (MJ/m2/day)	22	21	20	18	15	14	15	18	21	23	24	24	19

MONTHLY IRRIGATION
****

Irrigation (mm)	58	34	42	39	23	25	31	28	52	45	45	60	483

SOIL PROPERTIES
****

Soil type: Great Keppel Island Sand

SOIL WATER PROPERTIES

		Layer 1	Layer 2	Layer 3	Layer 4
Bulk Density	(g/cm3)	1.3	1.5	1.5	1.5
Porosity	(mm/layer)	50.6	213.2	264.9	130.2
Saturated Water Content	(mm/layer)	50.1	211.5	261.6	129.3
Drained Upper Limit	(mm/layer)	10.9	68.0	82.8	27.3
Lower Storage Limit	(mm/layer)	4.0	32.0	45.0	18.0
Air Dry Moisture Content	(mm/layer)	4.0			
Layer Thickness	(mm)	100.0	500.0	600.0	300.0

		Profile	Max Rootzone
Total Saturated Water Content	(mm)	652.5	348.8
Total Drained Upper Limit	(mm)	189.0	106.5
Total Lower Storage Limit	(mm)	99.0	51.0
Total Air Dry Moisture Content	(mm)	5.4	4.7
Total Depth	(mm)	1500.0	800.0

Maximum Plant Available Water Capacity 55.5
Saturated Hydraulic Conductivity

At Surface	(mm/hr)	100.0
Limiting	(mm/hr)	20.0

RUNOFF

Runoff curve No II		70.0

SOIL EVAPORATION

CONA	(mm/day^0.5)	4.5
URITCH	(mm)	10.0

AVERAGE WASTE STREAM
****

Other waste stream
(All values relate to influent after any screening and recycling, if applicable).

Inflow Volume	(ML/year)	157.7
Nitrogen	(tonne/year)	3.2
Phosphorus	(tonne/year)	1.1
Salinity	(tonne/year)	431.7
Nitrogen Concentration	(mg/L)	20.0
Phosphorus Concentration	(mg/L)	7.0
Salinity	(mg/L)	2738.4
Salinity	(dS/m)	4.3

WASTE STREAM DETAILS (for last inflow event):

Nitrogen Concentration	(mg/L)	20.0
Phosphorus Concentration	(mg/L)	7.0
TDS Concentration	(mg/L)	1000.0
Salinity	(dS/m)	1.6

IRRIGATION WATER
****

Irrigation triggered when plant available water falls to (%PAWC) 80.0
Irrigating upto upper storage limit + 5 mm

AREA

Total Irrigation Area	(ha)	31.0

VOLUMES

Total Irrigation	(ML/year)	149.9
Minimum Volume Irrigated by Pump	(ML/ha/day)	0.0
Maximum Volume must be full irrig. requiremt		
Maximum Vol. Available For Shandying	(ML/yr)	0.0

IRRIGATION CONCENTRATIONS

Average salinity of Irrigation	(dS/m)	4.3
Average salinity of Irrigation	(mg/L)	2738.2
Average Nitrogen Conc of Irrigation		
Before ammonia loss	(mg/L)	18.6
After ammonia loss	(mg/L)	15.7
Average Phosphorus Conc of Irrigation	(mg/L)	7.0

FRESH WATER USAGE
****

Irrigation (shandying) water	(ML/yr)	0.00
Avg volume of fresh water used	(ML/yr)	0.00
Annual allocation	(ML/yr)	N/A

POND INFORMATION
****

POND GEOMETRY

		Pond 1
Final pond volume	(ML)	3.5
Final liquid volume	(ML)	3.5
Final sludge volume	(ML)	0.0
Average pond volume	(ML)	2.7
Average active volume	(ML)	2.7
Maximum pond volume	(ML)	13.0
Minimum allowable pond volume	(ML)	0.0
Average pond depth	(m)	0.8
Pond depth at outlet	(m)	3.0
Maximum water surface area	(m2 x1000)	4.7
Pond catchment area	(m2 x1000)	5.0
Pond footprint length	(m)	70.8
Pond footprint width	(m)	70.8

POND WATER BALANCE

Inflow of Effluent to pond system	(ML/yr)	157.7
Recycle Volume from pond system	(ML/yr)	0.0
Rain water added to pond system	(ML/yr)	5.2
Evaporation loss from pond system	(ML/yr)	5.4
Seepage loss from pond system	(ML/yr)	0.2
Irrigation from last pond	(ML/yr)	149.9
Volume of overtopping	(ML/yr)	7.4
Sludge accumulated	(ML/yr)	0.0
Sludge accumulated	(t DM/yr)	0.0
Sludge removed	(ML/yr)	0.0
No of desludging events every 10 years		0.0
Increase in pond water volume	(ML/yr)	0.1

OVERTOPPING EVENTS

Volume of overtopping	(ML/yr)	7.41
No. of days pond overtops per 10 years		167.55
Average Length of overtopping events	(days)	12.16
% Reuse		95.20

No. of overtopping events every 10 years

> 0.000 ML	13.77
> 0.005 ML*	13.77
> 1.000 ML	11.70
> 2.000 ML	8.68
> 5.000 ML	4.53
> 10.000 ML	1.70
> 20.000 ML	1.13
> 50.000 ML	0.00

* Volume equivalent to 1 mm depth of water

>>> NO-IRRIGATION EVENTS <<<

%Days rain prevents irrigation		26.5
%Days water demand too small to trigger irr.		32.3
No. periods/year without irrigable effluent		0.0
Average Length of such periods	(days)	0.0

POND NITROGEN BALANCE

Nitrogen Added by Effluent	(tonne/yr)	3.2	Irrig. from pond (ML/yr)	149.9
Nitrogen removed by Irrigation	(tonne/yr)	2.8		
Nitrogen removed by Volatilisation	(tonne/yr)	0.2		
Nitrogen removed by Seepage	(tonne/yr)	0.0		
Nitrogen accumulated in Sludge	(tonne/yr)	0.0		
Nitrogen lost by Overtopping	(tonne/yr)	0.1		
Nitrogen involved in Recycling	(tonne/yr)	0.0		
Increase in pond Nitrogen	(tonne/yr)	0.0		

POND PHOSPHORUS BALANCE

Phosphorus Added by Effluent	(tonne/yr)	1.1	Irrig. from pond (ML/yr)	149.9
Phosphorus removed by Irrigation	(tonne/yr)	1.1		
Phosphorus removed by Seepage	(tonne/yr)	0.0		
Phosphorus accumulated in Sludge	(tonne/yr)	0.0		

Phosphorus lost by Overtopping	(tonne/yr)	0.0
Phosphorus involved in Recycling	(tonne/yr)	0.0
Increase in pond Phosphorus	(tonne/yr)	0.0

POND SALINITY BALANCE

Salinity Added by Effluent	(tonne/yr)	431.7
Salinity removed by Irrigation	(tonne/yr)	410.5
Salinity removed by Seepage	(tonne/yr)	0.4
Salinity lost by Overtopping	(tonne/yr)	20.7
Salinity involved in Recycling	(tonne/yr)	0.0
Increase in pond Salinity	(tonne/yr)	0.1

POND CONCENTRATIONS

		Pond 1
Average Nitrogen Conc of Pond Liquid	(mg/L)	16.6
Average Phosphorus Conc of Pond Liquid	(mg/L)	6.7
Average TDS Conc of Pond Liquid	(mg/L)	2729.8
Average Salinity of Pond Liquid	(dS/m)	4.3
Average Potassium Conc of Pond Liquid	(mg/L)	0.0

(On final day of simulation)

Nitrogen Conc of Pond Liquid	(mg/L)	17.5
Phosphorus Conc of Pond Liquid	(mg/L)	6.6
TDS Conc of Pond Liquid	(mg/L)	947.7
EC of Pond Liquid	(dS/m)	1.5
Potassium Conc of Pond Liquid	(mg/L)	0.0

REMOVED SLUDGE - NUTRIENT & SALT CONCENTRATIONS

Nitrogen in removed Sludge (db)	(kg/tonne)	0.0
Phosphorus in removed Sludge (db)	(kg/tonne)	0.0
Salt in removed Sludge (db)	(kg/tonne)	0.0
Potassium in removed Sludge (db)	(kg/tonne)	0.0

REMOVED SLUDGE - NUTRIENT & SALT MASSES

Nitrogen in removed Sludge	(tonne/yr)	0.0
Phosphorus in removed Sludge	(tonne/yr)	0.0
Salt in removed Sludge (mass bal.)	(tonne/yr)	0.0
Salt in removed Sludge	(tonne/yr)	0.0
Potm. in removed Sludge (mass bal.)	(tonne/yr	0.0
Potassium in removed Sludge	(tonne/yr)	0.0

LAND DISPOSAL AREA
****

WATER BALANCE

(Initial soil water assumed to be at field capacity)
(Irrigated up to 40.90% of field capacity)

Rainfall	(mm/year)	1045.9	Irrigation Area	(ha)	31.0
Irrigation	(mm/year)	483.6			
Soil Evaporation	(mm/year)	35.7			
Transpiration	(mm/year)	1055.7			
Runoff	(mm/year)	6.0			
Drainage	(mm/year)	432.6			
Change in soil moisture	(mm/year)	-0.5			

ANNUAL TOTALS

Year	Rain (mm)	Irrig (mm)	Sevap (mm)	Trans (mm)	Runoff (mm)	Drain (mm)	Change (mm)
1957	492.0	416.6	302.5	550.0	0.0	134.6	-78.5
1958	1106.0	500.1	0.0	1007.8	0.0	546.1	52.2
1959	1050.0	474.3	0.0	1200.2	0.0	312.4	11.8
1960	1074.0	496.1	0.0	1043.2	3.6	538.2	-14.9
1961	1324.0	523.3	0.0	1136.2	83.8	638.3	-10.9
1962	1108.0	483.0	0.0	1082.8	0.6	319.3	188.2
1963	1080.0	452.3	202.6	807.0	0.0	718.1	-195.4
1964	908.0	498.3	0.0	1210.9	1.3	195.6	-1.5
1965	696.0	497.4	0.0	991.1	0.0	161.6	40.7

1966	1184.0	519.2	0.0	1306.1	0.0	438.1	-41.0
1967	1260.0	503.4	0.0	1172.3	0.0	544.2	46.8
1968	1080.0	515.9	0.0	1065.5	3.2	549.6	-22.4
1969	1275.0	496.6	0.0	1076.8	8.3	665.1	21.5
1970	950.0	488.7	0.0	1197.4	0.0	227.3	14.0
1971	1572.0	455.0	0.0	1167.7	31.5	852.3	-24.4
1972	800.0	518.6	0.0	1120.9	0.0	262.5	-64.8
1973	1693.0	449.2	0.0	1154.3	8.5	918.8	60.6
1974	1272.0	371.7	214.3	669.5	6.8	720.6	32.4
1975	1090.0	482.2	11.5	1168.9	0.5	387.1	4.2
1976	1240.0	463.1	0.0	1178.0	2.4	549.4	-26.6
1977	1176.0	520.5	0.0	984.0	9.4	739.5	-36.3
1978	1146.0	486.2	0.0	1148.1	1.6	439.2	43.3
1979	658.0	495.3	0.0	969.0	0.0	245.5	-61.2
1980	1121.0	505.5	0.0	1107.7	2.1	433.9	82.7
1981	1488.0	498.1	0.0	1078.6	26.9	915.5	-34.9
1982	713.0	504.3	0.0	1099.5	0.0	142.1	-24.3
1983	1756.0	505.4	0.0	1170.6	57.3	1014.8	18.8
1984	1030.0	444.5	233.3	762.9	0.5	436.5	41.4
1985	1013.0	514.9	0.9	1169.0	3.2	442.6	-87.8
1986	1258.0	405.0	239.8	812.0	0.1	615.2	-4.1
1987	826.0	498.8	1.0	1194.1	0.0	70.8	58.8
1988	1336.0	478.1	0.0	1187.4	0.6	633.8	-7.7
1989	1468.0	406.5	193.4	719.0	3.4	1001.2	-42.5
1990	1707.0	473.4	5.1	886.3	37.2	1033.7	218.0
1991	1003.0	435.3	0.0	1038.2	0.0	578.1	-177.9
1992	1196.0	533.2	0.0	1139.9	15.1	615.1	-40.8
1993	956.0	481.1	0.0	1149.0	9.5	227.5	51.2
1994	753.0	501.8	0.0	1092.8	0.0	222.7	-60.7
1995	1042.0	500.2	0.0	1229.6	0.0	257.2	55.4
1996	943.0	505.0	0.0	1083.0	1.0	379.0	-15.0
1997	677.0	493.7	0.0	1087.6	0.0	35.6	47.5
1998	962.0	474.3	0.0	1255.2	0.0	247.8	-66.7
1999	882.0	494.3	0.0	1120.1	0.1	214.2	41.9
2000	1084.0	508.8	0.0	1126.0	0.0	388.1	78.8
2001	477.0	505.8	0.0	1005.7	0.0	83.9	-106.8
2002	743.0	501.7	0.0	1077.0	0.0	188.6	-21.0
2003	842.0	492.3	0.0	1059.2	0.0	229.1	46.0
2004	611.0	511.4	0.0	1121.2	0.0	48.8	-47.7
2005	679.0	500.2	0.0	1128.5	0.0	69.8	-19.1
2006	840.0	503.2	0.0	1149.5	0.0	159.9	33.8
2007	909.0	420.4	240.9	789.9	0.0	269.3	29.3
2008	1110.0	436.8	227.9	757.2	0.3	606.4	-45.0
2009	773.0	490.6	17.0	947.7	1.8	261.0	36.1

NUTRIENT BALANCE

NITROGEN

Total N irrigated from ponds	(kg/ha/year)	90.1	% of Total as ammonium	80.0
Nitrogn lost by ammonia volat.	(kg/ha/year)	14.4	Deep Drainage (mm/year)	432.6
Nitrogen added in irrigation	(kg/ha/year)	75.7		
Nitrogen added in seed	(kg/ha/year)	0.1		
Nitrogen removed by crop	(kg/ha/year)	111.7		
Denitrification	(kg/ha/year)	0.1		
Leached NO3-N	(kg/ha/year)	2.1		
Change in soil organic-N	(kg/ha/year)	-35.1		
Change in soil solution NH4-N	(kg/ha/year)	0.0		
Change in soil solution NO3-N	(kg/ha/year)	-2.9		
Change in adsorbed NH4-N	(kg/ha/year)	0.0		
Initial soil organic-N	(kg/ha)	1957.5		
Final soil organic-N	(kg/ha)	96.9		
Initial soil inorganic-N	(kg/ha)	156.0		
Final soil inorganic-N	(kg/ha)	0.0		
Average NO3-N conc in the root zone	(mg/L)	0.2		
Average NO3-N conc below root zone	(mg/L)	1.6		
Average NO3-N conc of deep drainage	(mg/L)	0.5		

PHOSPHORUS

Phosphorus added in irrigatn	(kg/ha/year)	33.9	% of Total as phosphate	100.0
Phosphorus added in seed	(kg/ha/year)	0.0		
Phosphorus removed by crop	(kg/ha/year)	24.9		

Leached PO4-P	(kg/ha/year)	0.1
Change in dissolved PO4-P	(kg/ha/year)	0.0
Change in adsorbed PO4-P	(kg/ha/year)	9.0
Average PO4-P conc in the root zone	(mg/L)	0.2
Average PO4-P conc below root zone	(mg/L)	0.0

SOIL P STORAGE LIFE

Year	YearNo.	Tot P stored kg/ha	P leached in year kg/ha
1957	1	376.6	0.0
1958	2	408.4	0.1
1959	3	432.0	0.0
1960	4	450.9	0.1
1961	5	462.6	0.1
1962	6	472.1	0.0
1963	7	479.7	0.1
1964	8	491.0	0.0
1965	9	495.1	0.0
1966	10	499.7	0.0
1967	11	506.3	0.1
1968	12	515.3	0.1
1969	13	519.5	0.1
1970	14	524.7	0.0
1971	15	528.2	0.1
1972	16	536.1	0.0
1973	17	538.8	0.1
1974	18	541.5	0.1
1975	19	549.8	0.0
1976	20	555.1	0.1
1977	21	561.3	0.1
1978	22	569.3	0.1
1979	23	575.2	0.0
1980	24	584.7	0.1
1981	25	589.0	0.1
1982	26	596.6	0.0
1983	27	604.4	0.1
1984	28	614.6	0.0
1985	29	621.9	0.1
1986	30	628.3	0.1
1987	31	635.9	0.0
1988	32	644.4	0.1
1989	33	648.5	0.1
1990	34	657.3	0.2
1991	35	663.5	0.1
1992	36	673.4	0.1
1993	37	680.6	0.0
1994	38	689.1	0.0
1995	39	698.8	0.0
1996	40	709.9	0.1
1997	41	717.6	0.0
1998	42	726.1	0.0
1999	43	735.0	0.0
2000	44	747.7	0.1
2001	45	756.0	0.0
2002	46	765.9	0.0
2003	47	776.4	0.0
2004	48	788.2	0.0
2005	49	796.3	0.0
2006	50	805.9	0.0
2007	51	816.3	0.0
2008	52	828.9	0.2
2009	53	838.3	0.0

PLANT

Plant species: Coastal couch grass (Cynodon dac

PLANT WATER USE

Irrigation (mm/year) 484. Totl Irrigation Area(ha) 31.0

Pan coefficient	(%)	1.0
Maximum crop coefficient	(%)	0.8
Average Plant Cover	(%)	81.
Average Plant Total Cover	(%)	95.
Average Plant Rootdepth	(mm)	759.
Average Plant Available Water Capacity	(mm)	55.
Average Plant Available Water	(mm)	38.
Yield produced per unit transp.	(kg/ha/mm)	9.

PLANT NUTRIENT UPTAKE

Dry Matter Yield (Shoots)	(kg/ha/yr)	9263.			
Net nitrogen removed by plant	(kg/ha/yr)	112.	Shoot Concn	(%DM)	1.20
Net phosphorus removed by plant	(kg/ha/yr)	25.	Shoot Concn	(%DM)	0.27

AVERAGE MONTHLY GROWTH STRESS (0=no stress, 1=full stress)

Month	Yield kg/ha	Nitr	Temp	Water Defic	Water Logging
1	1079.	0.5	0.0	0.1	0.0
2	883.	0.5	0.0	0.1	0.0
3	867.	0.5	0.0	0.1	0.0
4	768.	0.5	0.0	0.1	0.0
5	628.	0.5	0.2	0.0	0.0
6	403.	0.5	0.5	0.0	0.0
7	336.	0.4	0.7	0.0	0.0
8	538.	0.3	0.5	0.1	0.0
9	865.	0.4	0.2	0.1	0.0
10	893.	0.4	0.0	0.3	0.0
11	912.	0.5	0.0	0.3	0.0
12	1092.	0.5	0.0	0.1	0.0

>>> NO-PLANT EVENTS <<<

%Days due to temperature stress	0.2
%Days due to water stress	0.6
%Days due to nitrogen stress	0.0
No. of forced harvests per year	0.2
No. of normal harvests per year	6.3

SALINITY

Salt tolerance - plant species: tolerant

Average EC of Irrigation Water	(dS/m)	4.3	Irrigation	(mm/year)	483.6
Average EC of Rainwater	(dS/m x10)	0.3	Rainfall	(mm/year)	1045.9
Average EC of Infiltrated water	(dS/m)	1.4			
Av. water-upt-weightd rootzone EC(dS/m s.e.)		1.4			
EC soil soln (FC) at base of rootzone	(dS/m)	6.0	Deep Drainage	(mm/year)	432.6
Reduction in Crop yield due to Salinity	(%)	0.0			
Percentage of yrs that crop yld falls below 90% of potential because of soil salinity		0.0			

Period	ECrootzone sat ext (dS/m)	ECbase in situ (dS/m)	Rel Yield (%)
1957 - 1961	1.33	4.82	100.
1958 - 1962	1.22	4.45	100.
1959 - 1963	1.17	4.16	100.
1960 - 1964	1.23	4.40	100.
1961 - 1965	1.38	5.25	100.
1962 - 1966	1.45	5.82	100.
1963 - 1967	1.38	5.39	100.
1964 - 1968	1.44	5.83	100.
1965 - 1969	1.26	4.67	100.
1966 - 1970	1.21	4.50	100.
1967 - 1971	1.08	3.78	100.
1968 - 1972	1.17	4.19	100.
1969 - 1973	1.03	3.59	100.
1970 - 1974	0.97	3.32	100.

1971 - 1975	0.94	3.15	100.
1972 - 1976	1.00	3.48	100.
1973 - 1977	0.91	2.99	100.
1974 - 1978	1.03	3.55	100.
1975 - 1979	1.23	4.48	100.
1976 - 1980	1.24	4.46	100.
1977 - 1981	1.15	3.91	100.
1978 - 1982	1.33	4.97	100.
1979 - 1983	1.14	3.93	100.
1980 - 1984	1.05	3.61	100.
1981 - 1985	1.06	3.60	100.
1982 - 1986	1.10	3.85	100.
1983 - 1987	1.11	3.96	100.
1984 - 1988	1.23	4.64	100.
1985 - 1989	1.05	3.58	100.
1986 - 1990	0.89	2.83	100.
1987 - 1991	0.94	3.03	100.
1988 - 1992	0.85	2.61	100.
1989 - 1993	0.92	2.91	100.
1990 - 1994	1.16	3.95	100.
1991 - 1995	1.47	5.92	100.
1992 - 1996	1.53	6.40	100.
1993 - 1997	1.91	9.67	100.
1994 - 1998	1.89	9.42	100.
1995 - 1999	1.85	9.52	100.
1996 - 2000	1.74	8.29	100.
1997 - 2001	2.08	11.14	100.
1998 - 2002	1.98	9.63	100.
1999 - 2003	2.04	9.92	100.
2000 - 2004	2.28	11.70	100.
2001 - 2005	2.95	18.83	100.
2002 - 2006	2.56	15.78	100.
2003 - 2007	2.33	13.68	100.
2004 - 2008	1.90	8.91	100.
2005 - 2009	1.74	7.50	100.

GROUNDWATER
****

Average Groundwater Recharge (m3/day) 367.1
Average Nitrate-N Conc of Recharge (mg/L) 0.5

Thickness of the Aquifer (m) 10.0
Distance (m) from Irrigation Area to where
Nitrate-N Conc in Groundwater is Calculated 1000.0

Concentration of NITRATE-N in Groundwater (mg/L)

	Year	Depth Below Water Table Surface 0.0 m	5.0 m	9.0 m
	1961	0.1	0.1	0.1
	1966	0.3	0.3	0.3
	1971	0.3	0.3	0.3
	1976	0.4	0.4	0.4
	1981	0.4	0.4	0.4
	1986	0.4	0.4	0.4
	1991	0.4	0.4	0.4
	1996	0.4	0.4	0.4
	2001	0.4	0.4	0.4
	2006	0.4	0.4	0.4
Last	2009	0.4	0.4	0.4

ACKNOWLEDGMENTS
****
This run brought to you courtesy of:

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OTHER INDUSTRY INPUT PARAMETERS - DATA SUMMARY

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UNCONDITIONAL FINISH

****
SUMMARY OUTPUT
MEDLI Version 1.30

Data Set: 110824 GKI Scenario 2b-100% PAWC 31ha
Run Date: 29/08/11 Time:15:20:49.44
****

GENERAL INFORMATION
****

Title: GKI Resort Revitalisation Plan
Subject: Scenario 2b - 80% PAWC Irrigatio
Client: GKI Resorts Pty Ltd
User: Mark Farrey
Time: Mon Aug 29 15:18:23 2011
Comments: 80%PAWC-5mm beyond DUL. Irrigation Area = 31ha. Wet Weather Storage = 75ML (100% reuse) . N = 20mg/L, P = 7mg/L.

RUN PERIOD
****

Starting Date 1/ 1/1957
Ending Date 31/12/2009
Run Length 53 years 0 days

CLIMATE INFORMATION
****

Enterprise site: Great Keppel Island -23.2 deg S 150.9 deg E
Weather station: keppel_23.20S_150.95E (Interpola

ANNUAL TOTALS	10 Percentile	50 percentile	90 Percentile
Rainfall mm/year	688.	1062.	1478.
Pan Evap mm/year	1715.	1837.	1997.

MONTHLY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	154	170	133	95	93	59	44	39	27	45	68	120	1045
Pan Evap (mm)	198	166	169	138	111	92	100	122	155	191	199	208	1848
Ave Max Temp DegC	29	29	28	26	24	22	21	22	24	26	28	29	25
Ave Min Temp DegC	23	23	22	19	16	14	12	13	16	19	21	22	18
Rad (MJ/m2/day)	22	21	20	18	15	14	15	18	21	23	24	24	19

MONTHLY IRRIGATION
****

Irrigation (mm)	58	35	47	39	28	28	32	29	49	43	43	62	493

SOIL PROPERTIES
****

Soil type: Great Keppel Island Sand

SOIL WATER PROPERTIES

		Layer 1	Layer 2	Layer 3	Layer 4
Bulk Density	(g/cm3)	1.3	1.5	1.5	1.5
Porosity	(mm/layer)	50.6	213.2	264.9	130.2
Saturated Water Content	(mm/layer)	50.1	211.5	261.6	129.3
Drained Upper Limit	(mm/layer)	10.9	68.0	82.8	27.3
Lower Storage Limit	(mm/layer)	4.0	32.0	45.0	18.0
Air Dry Moisture Content	(mm/layer)	4.0			
Layer Thickness	(mm)	100.0	500.0	600.0	300.0

		Profile	Max Rootzone
Total Saturated Water Content	(mm)	652.5	348.8
Total Drained Upper Limit	(mm)	189.0	106.5
Total Lower Storage Limit	(mm)	99.0	51.0
Total Air Dry Moisture Content	(mm)	5.4	4.7
Total Depth	(mm)	1500.0	800.0

Maximum Plant Available Water Capacity 55.5
Saturated Hydraulic Conductivity

```
               At Surface          (mm/hr)  100.0
               Limiting            (mm/hr)   20.0

RUNOFF

Runoff curve No II                            70.0

SOIL EVAPORATION

CONA                          (mm/day^0.5)    4.5
URITCH                                (mm)   10.0
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AVERAGE WASTE STREAM
********************

Other waste stream
(All values relate to influent after any screening and recycling, if applicable).

Inflow Volume                    (ML/year)  157.7
Nitrogen                      (tonne/year)    3.2
Phosphorus                    (tonne/year)    1.1
Salinity                      (tonne/year)  157.7

Nitrogen Concentration              (mg/L)   20.0
Phosphorus Concentration            (mg/L)    7.0
Salinity                            (mg/L) 1000.0
Salinity                            (dS/m)    1.6

WASTE STREAM DETAILS (for last inflow event):
Nitrogen Concentration              (mg/L)   20.0
Phosphorus Concentration            (mg/L)    7.0
TDS Concentration                   (mg/L) 1000.0
Salinity                            (dS/m)    1.6
```

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IRRIGATION WATER
****************

Irrigation triggered when plant available water falls to (%PAWC)   80.0
Irrigating upto upper storage limit +   5 mm

AREA

Total Irrigation Area                 (ha)   31.0

VOLUMES

Total Irrigation                 (ML/year)  153.1
Minimum Volume Irrigated by Pump (ML/ha/day)    0.0
Maximum Volume must be full irrig. requiremt
Maximum Vol. Available For Shandying (ML/yr)    0.0

IRRIGATION CONCENTRATIONS

Average salinity of Irrigation        (dS/m)    1.6
Average salinity of Irrigation        (mg/L) 1023.4
Average Nitrogen Conc of Irrigation
                Before ammonia loss   (mg/L)   14.7
                After ammonia loss    (mg/L)   12.3
Average Phosphorus Conc of Irrigation (mg/L)    7.2
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FRESH WATER USAGE
*****************

Irrigation (shandying) water         (ML/yr)   0.00

Avg volume of fresh water used       (ML/yr)   0.00

Annual allocation                    (ML/yr)    N/A
```

POND INFORMATION
****

POND GEOMETRY

		Pond 1
Final pond volume	(ML)	4.2
Final liquid volume	(ML)	4.2
Final sludge volume	(ML)	0.0
Average pond volume	(ML)	7.6
Average active volume	(ML)	7.6
Maximum pond volume	(ML)	75.0
Minimum allowable pond volume	(ML)	0.0
Average pond depth	(m)	0.3
Pond depth at outlet	(m)	3.0
Maximum water surface area	(m2 x1000)	26.0
Pond catchment area	(m2 x1000)	26.6
Pond footprint length	(m)	163.1
Pond footprint width	(m)	163.1

POND WATER BALANCE

Inflow of Effluent to pond system	(ML/yr)	157.7
Recycle Volume from pond system	(ML/yr)	0.0
Rain water added to pond system	(ML/yr)	27.8
Evaporation loss from pond system	(ML/yr)	31.4
Seepage loss from pond system	(ML/yr)	0.9
Irrigation from last pond	(ML/yr)	153.1
Volume of overtopping	(ML/yr)	0.0
Sludge accumulated	(ML/yr)	0.0
Sludge accumulated	(t DM/yr)	0.0
Sludge removed	(ML/yr)	0.0
No of desludging events every 10 years		0.0
Increase in pond water volume	(ML/yr)	0.1

OVERTOPPING EVENTS

Volume of overtopping	(ML/year)	0.00
Average Length of overtopping events	(days)	0.00
% Reuse		0.00
No. of overtopping events per 10 years		0.00

>>> NO-IRRIGATION EVENTS <<<

%Days rain prevents irrigation		26.5
%Days water demand too small to trigger irr.		36.3
No. periods/year without irrigable effluent		0.0
Average Length of such periods	(days)	0.0

POND NITROGEN BALANCE

Nitrogen Added by Effluent	(tonne/yr)	3.2	Irrig. from pond (ML/yr) 153.1
Nitrogen removed by Irrigation	(tonne/yr)	2.2	
Nitrogen removed by Volatilisation	(tonne/yr)	0.9	
Nitrogen removed by Seepage	(tonne/yr)	0.0	
Nitrogen accumulated in Sludge	(tonne/yr)	0.0	
Nitrogen lost by Overtopping	(tonne/yr)	0.0	
Nitrogen involved in Recycling	(tonne/yr)	0.0	
Increase in pond Nitrogen	(tonne/yr)	0.0	

POND PHOSPHORUS BALANCE

Phosphorus Added by Effluent	(tonne/yr)	1.1	Irrig. from pond (ML/yr) 153.1
Phosphorus removed by Irrigation	(tonne/yr)	1.1	
Phosphorus removed by Seepage	(tonne/yr)	0.0	
Phosphorus accumulated in Sludge	(tonne/yr)	0.0	
Phosphorus lost by Overtopping	(tonne/yr)	0.0	
Phosphorus involved in Recycling	(tonne/yr)	0.0	
Increase in pond Phosphorus	(tonne/yr)	0.0	

POND SALINITY BALANCE

Salinity Added by Effluent	(tonne/yr)	157.7
Salinity removed by Irrigation	(tonne/yr)	156.7
Salinity removed by Seepage	(tonne/yr)	0.9
Salinity lost by Overtopping	(tonne/yr)	0.0

Salinity involved in Recycling	(tonne/yr)	0.0
Increase in pond Salinity	(tonne/yr)	0.1

POND CONCENTRATIONS

		Pond 1
Average Nitrogen Conc of Pond Liquid	(mg/L)	9.8
Average Phosphorus Conc of Pond Liquid	(mg/L)	5.9
Average TDS Conc of Pond Liquid	(mg/L)	843.2
Average Salinity of Pond Liquid	(dS/m)	1.3
Average Potassium Conc of Pond Liquid	(mg/L)	0.0

(On final day of simulation)

Nitrogen Conc of Pond Liquid	(mg/L)	10.6
Phosphorus Conc of Pond Liquid	(mg/L)	5.5
TDS Conc of Pond Liquid	(mg/L)	781.7
EC of Pond Liquid	(dS/m)	1.2
Potassium Conc of Pond Liquid	(mg/L)	0.0

REMOVED SLUDGE - NUTRIENT & SALT CONCENTRATIONS

Nitrogen in removed Sludge (db)	(kg/tonne)	0.0
Phosphorus in removed Sludge (db)	(kg/tonne)	0.0
Salt in removed Sludge (db)	(kg/tonne)	0.0
Potassium in removed Sludge (db)	(kg/tonne)	0.0

REMOVED SLUDGE - NUTRIENT & SALT MASSES

Nitrogen in removed Sludge	(tonne/yr)	0.0
Phosphorus in removed Sludge	(tonne/yr)	0.0
Salt in removed Sludge (mass bal.)	(tonne/yr)	0.0
Salt in removed Sludge	(tonne/yr)	0.0
Potm. in removed Sludge (mass bal.)	(tonne/yr	0.0
Potassium in removed Sludge	(tonne/yr)	0.0

LAND DISPOSAL AREA
****

WATER BALANCE

(Initial soil water assumed to be at field capacity)
(Irrigated up to 40.59% of field capacity)

Rainfall	(mm/year)	1045.9	Irrigation Area	(ha)	31.0
Irrigation	(mm/year)	494.0			
Soil Evaporation	(mm/year)	37.2			
Transpiration	(mm/year)	1048.1			
Runoff	(mm/year)	6.1			
Drainage	(mm/year)	448.9			
Change in soil moisture	(mm/year)	-0.5			

ANNUAL TOTALS

Year	Rain (mm)	Irrig (mm)	Sevap (mm)	Trans (mm)	Runoff (mm)	Drain (mm)	Change (mm)
1957	492.0	444.5	315.0	529.4	0.0	171.1	-78.9
1958	1106.0	492.5	0.0	1012.0	0.0	532.3	54.2
1959	1050.0	479.5	0.0	1196.1	0.0	324.2	9.2
1960	1074.0	510.9	0.0	1038.0	3.7	560.6	-17.3
1961	1324.0	534.0	0.0	1118.3	83.9	662.4	-6.7
1962	1108.0	461.3	0.0	1056.2	0.6	325.7	186.8
1963	1080.0	537.3	227.7	842.6	0.0	730.1	-183.2
1964	908.0	472.7	0.0	1200.1	1.3	193.7	-14.5
1965	696.0	453.0	0.0	941.2	0.0	165.9	41.8
1966	1184.0	516.6	0.0	1302.3	0.0	443.1	-44.7
1967	1260.0	503.7	0.0	1167.8	0.0	545.1	50.7
1968	1080.0	513.0	0.0	1047.2	3.2	569.7	-27.1
1969	1275.0	489.3	0.0	1056.5	8.3	673.1	26.4
1970	950.0	484.0	0.0	1171.7	0.0	247.2	15.1
1971	1572.0	531.0	0.0	1207.8	31.5	889.5	-25.8
1972	800.0	510.9	0.0	1091.4	0.0	284.6	-65.1
1973	1693.0	501.1	0.0	1152.5	8.5	971.6	61.5
1974	1272.0	481.7	214.8	683.5	6.8	770.4	78.2
1975	1090.0	573.8	9.3	1170.9	0.5	523.9	-40.8

1976	1240.0	526.1	0.0	1174.5	2.4	617.6	-28.3
1977	1176.0	526.8	0.0	1005.7	9.4	718.9	-31.2
1978	1146.0	482.9	0.0	1156.9	1.6	432.5	37.9
1979	658.0	487.7	0.0	963.3	0.0	244.8	-62.3
1980	1121.0	492.2	0.0	1114.7	2.1	416.6	79.8
1981	1488.0	552.4	0.0	1090.9	27.1	944.5	-22.0
1982	713.0	467.3	0.0	1056.0	0.0	149.9	-25.5
1983	1756.0	549.0	0.0	1167.9	57.3	1063.7	16.2
1984	1030.0	485.3	238.1	767.1	0.5	477.1	32.5
1985	1013.0	526.3	1.9	1156.1	3.2	469.4	-91.3
1986	1258.0	505.3	252.0	814.2	0.1	648.6	48.4
1987	826.0	474.8	1.1	1224.4	0.0	73.8	1.5
1988	1336.0	479.3	0.0	1165.7	0.6	630.4	18.6
1989	1468.0	446.3	198.1	707.4	3.4	1014.5	-9.2
1990	1707.0	648.6	10.9	1064.9	37.3	1071.2	171.4
1991	1003.0	491.6	0.0	1064.1	0.0	609.1	-178.6
1992	1196.0	550.0	0.0	1147.6	15.1	623.7	-40.4
1993	956.0	466.5	0.0	1142.9	9.5	218.7	51.5
1994	753.0	474.2	0.0	1050.5	0.0	239.3	-62.7
1995	1042.0	482.2	0.0	1217.4	0.0	250.8	56.0
1996	943.0	484.9	0.0	1050.5	1.0	393.1	-16.7
1997	677.0	447.0	0.0	1046.6	0.0	27.4	50.0
1998	962.0	495.0	0.0	1243.3	0.0	247.6	-33.9
1999	882.0	461.5	0.0	1097.1	0.1	236.6	9.7
2000	1084.0	500.8	0.0	1110.8	0.0	395.6	78.3
2001	477.0	461.3	0.0	952.2	0.0	87.9	-101.8
2002	743.0	451.0	0.0	1026.3	0.0	193.8	-26.1
2003	842.0	457.7	0.0	1017.3	0.0	235.2	47.1
2004	611.0	458.7	0.0	1065.7	0.0	54.7	-50.7
2005	679.0	452.8	0.0	1079.8	0.0	69.1	-17.1
2006	840.0	471.2	0.0	1130.6	0.0	145.1	35.6
2007	909.0	458.2	242.1	776.1	0.0	308.3	40.7
2008	1110.0	525.0	241.8	800.2	0.3	636.5	-43.9
2009	773.0	449.2	19.8	917.2	1.8	263.7	19.7

NUTRIENT BALANCE

NITROGEN

Total N irrigated from ponds	(kg/ha/year)	72.6	% of Total as ammonium	80.0
Nitrogn lost by ammonia volat.	(kg/ha/year)	11.6	Deep Drainage (mm/year)	448.9
Nitrogen added in irrigation	(kg/ha/year)	60.9		
Nitrogen added in seed	(kg/ha/year)	0.1		
Nitrogen removed by crop	(kg/ha/year)	96.8		
Denitrification	(kg/ha/year)	0.1		
Leached NO3-N	(kg/ha/year)	2.3		
Change in soil organic-N	(kg/ha/year)	-35.2		
Change in soil solution NH4-N	(kg/ha/year)	0.0		
Change in soil solution NO3-N	(kg/ha/year)	-2.9		
Change in adsorbed NH4-N	(kg/ha/year)	0.0		
Initial soil organic-N	(kg/ha)	1957.5		
Final soil organic-N	(kg/ha)	93.2		
Initial soil inorganic-N	(kg/ha)	156.0		
Final soil inorganic-N	(kg/ha)	0.0		
Average NO3-N conc in the root zone	(mg/L)	0.2		
Average NO3-N conc below root zone	(mg/L)	1.4		
Average NO3-N conc of deep drainage	(mg/L)	0.5		

PHOSPHORUS

Phosphorus added in irrigatn	(kg/ha/year)	35.4	% of Total as phosphate	100.0
Phosphorus added in seed	(kg/ha/year)	0.0		
Phosphorus removed by crop	(kg/ha/year)	23.3		
Leached PO4-P	(kg/ha/year)	0.1		
Change in dissolved PO4-P	(kg/ha/year)	0.0		
Change in adsorbed PO4-P	(kg/ha/year)	12.0		
Average PO4-P conc in the root zone	(mg/L)	0.3		
Average PO4-P conc below root zone	(mg/L)	0.0		

SOIL P STORAGE LIFE

Year	YearNo.	Tot P stored kg/ha	P leached in year kg/ha

1957	1	380.0	0.0
1958	2	412.5	0.1
1959	3	436.7	0.0
1960	4	457.5	0.1
1961	5	469.6	0.1
1962	6	479.3	0.0
1963	7	487.0	0.1
1964	8	502.4	0.0
1965	9	507.0	0.0
1966	10	511.9	0.0
1967	11	518.4	0.1
1968	12	528.1	0.1
1969	13	533.2	0.1
1970	14	540.5	0.0
1971	15	545.3	0.1
1972	16	557.7	0.0
1973	17	563.4	0.1
1974	18	568.9	0.1
1975	19	586.9	0.1
1976	20	597.9	0.1
1977	21	606.2	0.1
1978	22	616.7	0.1
1979	23	625.9	0.0
1980	24	637.4	0.1
1981	25	644.4	0.1
1982	26	655.3	0.0
1983	27	664.4	0.2
1984	28	679.2	0.1
1985	29	692.1	0.1
1986	30	701.6	0.1
1987	31	717.2	0.0
1988	32	728.4	0.1
1989	33	733.8	0.2
1990	34	753.4	0.2
1991	35	765.0	0.1
1992	36	779.7	0.1
1993	37	790.5	0.0
1994	38	802.4	0.0
1995	39	814.6	0.0
1996	40	829.0	0.1
1997	41	838.9	0.0
1998	42	850.1	0.0
1999	43	864.6	0.0
2000	44	880.0	0.1
2001	45	890.8	0.0
2002	46	902.6	0.0
2003	47	914.9	0.0
2004	48	929.2	0.0
2005	49	937.6	0.0
2006	50	948.8	0.0
2007	51	960.7	0.1
2008	52	980.3	0.3
2009	53	995.9	0.0

PLANT

Plant species: Coastal couch grass (Cynodon dac

PLANT WATER USE

Irrigation	(mm/year)	494.	Totl Irrigation Area(ha)	31.0
Pan coefficient	(%)	1.0		
Maximum crop coefficient	(%)	0.8		
Average Plant Cover	(%)	82.		
Average Plant Total Cover	(%)	95.		
Average Plant Rootdepth	(mm)	759.		
Average Plant Available Water Capacity	(mm)	55.		
Average Plant Available Water	(mm)	39.		
Yield produced per unit transp.	(kg/ha/mm)	8.		

PLANT NUTRIENT UPTAKE

Dry Matter Yield (Shoots)	(kg/ha/yr)	8515.			
Net nitrogen removed by plant	(kg/ha/yr)	97.	Shoot Concn	(%DM)	1.14
Net phosphorus removed by plant	(kg/ha/yr)	23.	Shoot Concn	(%DM)	0.27

AVERAGE MONTHLY GROWTH STRESS (0=no stress, 1=full stress)

Month	Yield kg/ha	Nitr	Temp	Water Defic	Water Logging
1	1007.	0.5	0.0	0.1	0.0
2	803.	0.5	0.0	0.1	0.0
3	797.	0.5	0.0	0.1	0.0
4	696.	0.5	0.0	0.1	0.0
5	578.	0.5	0.2	0.0	0.0
6	379.	0.5	0.5	0.0	0.0
7	315.	0.5	0.7	0.0	0.0
8	498.	0.4	0.5	0.1	0.0
9	785.	0.4	0.2	0.2	0.0
10	803.	0.4	0.0	0.3	0.0
11	837.	0.5	0.0	0.3	0.0
12	1017.	0.5	0.0	0.2	0.0

>>> NO-PLANT EVENTS <<<

%Days due to temperature stress	0.2
%Days due to water stress	0.4
%Days due to nitrogen stress	0.0
No. of forced harvests per year	0.2
No. of normal harvests per year	5.8

SALINITY

Salt tolerance - plant species: tolerant

Average EC of Irrigation Water	(dS/m)	1.6	Irrigation	(mm/year)	494.0
Average EC of Rainwater	(dS/m x10)	0.3	Rainfall	(mm/year)	1045.9
Average EC of Infiltrated water	(dS/m)	0.5			
Av. water-upt-weightd rootzone EC	(dS/m s.e.)	0.5			
EC soil soln (FC) at base of rootzone	(dS/m)	2.2	Deep Drainage	(mm/year)	448.9
Reduction in Crop yield due to Salinity	(%)	0.0			
Percentage of yrs that crop yld falls below 90% of potential because of soil salinity		0.0			

Period	ECrootzone sat ext (dS/m)	ECbase in situ (dS/m)	Rel Yield (%)
1957 - 1961	0.51	1.82	100.
1958 - 1962	0.45	1.65	100.
1959 - 1963	0.45	1.59	100.
1960 - 1964	0.47	1.67	100.
1961 - 1965	0.52	1.97	100.
1962 - 1966	0.55	2.20	100.
1963 - 1967	0.53	2.05	100.
1964 - 1968	0.53	2.14	100.
1965 - 1969	0.46	1.71	100.
1966 - 1970	0.45	1.66	100.
1967 - 1971	0.40	1.40	100.
1968 - 1972	0.44	1.55	100.
1969 - 1973	0.39	1.33	100.
1970 - 1974	0.37	1.26	100.
1971 - 1975	0.36	1.20	100.
1972 - 1976	0.39	1.31	100.
1973 - 1977	0.36	1.15	100.
1974 - 1978	0.40	1.35	100.
1975 - 1979	0.47	1.69	100.
1976 - 1980	0.47	1.71	100.
1977 - 1981	0.43	1.50	100.
1978 - 1982	0.50	1.87	100.
1979 - 1983	0.43	1.47	100.
1980 - 1984	0.39	1.34	100.

1981 - 1985	0.40	1.33	100.
1982 - 1986	0.43	1.46	100.
1983 - 1987	0.43	1.51	100.
1984 - 1988	0.48	1.77	100.
1985 - 1989	0.41	1.39	100.
1986 - 1990	0.36	1.17	100.
1987 - 1991	0.37	1.21	100.
1988 - 1992	0.34	1.05	100.
1989 - 1993	0.37	1.18	100.
1990 - 1994	0.45	1.57	100.
1991 - 1995	0.55	2.23	100.
1992 - 1996	0.58	2.41	100.
1993 - 1997	0.71	3.60	100.
1994 - 1998	0.72	3.54	100.
1995 - 1999	0.69	3.52	100.
1996 - 2000	0.65	3.05	100.
1997 - 2001	0.78	4.09	100.
1998 - 2002	0.74	3.52	100.
1999 - 2003	0.75	3.53	100.
2000 - 2004	0.85	4.22	100.
2001 - 2005	1.09	6.74	100.
2002 - 2006	0.96	5.82	100.
2003 - 2007	0.87	4.95	100.
2004 - 2008	0.73	3.37	100.
2005 - 2009	0.67	2.86	100.

GROUNDWATER
****

Average Groundwater Recharge (m3/day) 381.0
Average Nitrate-N Conc of Recharge (mg/L) 0.5

Thickness of the Aquifer (m) 10.0
Distance (m) from Irrigation Area to where
Nitrate-N Conc in Groundwater is Calculated 1000.0

Concentration of NITRATE-N in Groundwater (mg/L)

Year	Depth Below Water Table Surface 0.0 m	5.0 m	9.0 m
1961	0.1	0.1	0.1
1966	0.3	0.3	0.3
1971	0.3	0.3	0.3
1976	0.4	0.4	0.4
1981	0.4	0.4	0.4
1986	0.4	0.4	0.4
1991	0.4	0.4	0.4
1996	0.4	0.4	0.4
2001	0.4	0.4	0.4
2006	0.4	0.4	0.4
Last 2009	0.5	0.5	0.5

ACKNOWLEDGMENTS
****
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OTHER INDUSTRY INPUT PARAMETERS - DATA SUMMARY

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UNCONDITIONAL FINISH

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SUMMARY OUTPUT

MEDLI Version 1.30

Data Set: 110824 GKI Scenario 2d- PAWC 31ha 1in10
Run Date: 25/08/11 Time:08:09:49.03

****

GENERAL INFORMATION

Title: GKI Resort Revitalisation Plan
Subject: Scenario 2d - 80% PAWC Irrigatio
Client: GKI Resorts Pty Ltd
User: Mark Farrey
Time: Thu Aug 25 08:08:30 2011
Comments: 80%PAWC-5mm beyond DUL. Irrigation Area = 31ha. Wet Weather Storage = 37ML (1in10year overflow). N = 20mg/L, P = 7mg/L.

RUN PERIOD

Starting Date 1/ 1/1957
Ending Date 31/12/2009
Run Length 53 years 0 days

CLIMATE INFORMATION

Enterprise site: Great Keppel Island -23.2 deg S 150.9 deg E
Weather station: keppel_23.20S_150.95E (Interpola

ANNUAL TOTALS	10 Percentile	50 percentile	90 Percentile
Rainfall mm/year	688.	1062.	1478.
Pan Evap mm/year	1715.	1837.	1997.

MONTHLY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	154	170	133	95	93	59	44	39	27	45	68	120	1045
Pan Evap (mm)	198	166	169	138	111	92	100	122	155	191	199	208	1848
Ave Max Temp DegC	29	29	28	26	24	22	21	22	24	26	28	29	25
Ave Min Temp DegC	23	23	22	19	16	14	12	13	16	19	21	22	18
Rad (MJ/m2/day)	22	21	20	18	15	14	15	18	21	23	24	24	19

MONTHLY IRRIGATION

Irrigation (mm)	58	34	44	41	27	28	33	29	51	45	46	64	500

SOIL PROPERTIES

Soil type: Great Keppel Island Sand

SOIL WATER PROPERTIES

		Layer 1	Layer 2	Layer 3	Layer 4
Bulk Density	(g/cm3)	1.3	1.5	1.5	1.5
Porosity	(mm/layer)	50.6	213.2	264.9	130.2
Saturated Water Content	(mm/layer)	50.1	211.5	261.6	129.3
Drained Upper Limit	(mm/layer)	10.9	68.0	82.8	27.3
Lower Storage Limit	(mm/layer)	4.0	32.0	45.0	18.0
Air Dry Moisture Content	(mm/layer)	4.0			
Layer Thickness	(mm)	100.0	500.0	600.0	300.0

		Profile	Max Rootzone
Total Saturated Water Content	(mm)	652.5	348.8
Total Drained Upper Limit	(mm)	189.0	106.5
Total Lower Storage Limit	(mm)	99.0	51.0
Total Air Dry Moisture Content	(mm)	5.4	4.7
Total Depth	(mm)	1500.0	800.0

Maximum Plant Available Water Capacity 55.5
Saturated Hydraulic Conductivity

At Surface	(mm/hr)	100.0
Limiting	(mm/hr)	20.0

RUNOFF

Runoff curve No II		70.0

SOIL EVAPORATION

CONA	(mm/day^0.5)	4.5
URITCH	(mm)	10.0

AVERAGE WASTE STREAM
****

Other waste stream
(All values relate to influent after any screening and recycling, if applicable).

Inflow Volume	(ML/year)	157.7
Nitrogen	(tonne/year)	3.2
Phosphorus	(tonne/year)	1.1
Salinity	(tonne/year)	431.7
Nitrogen Concentration	(mg/L)	20.0
Phosphorus Concentration	(mg/L)	7.0
Salinity	(mg/L)	2738.4
Salinity	(dS/m)	4.3

WASTE STREAM DETAILS (for last inflow event):

Nitrogen Concentration	(mg/L)	20.0
Phosphorus Concentration	(mg/L)	7.0
TDS Concentration	(mg/L)	1000.0
Salinity	(dS/m)	1.6

IRRIGATION WATER
****

Irrigation triggered when plant available water falls to (%PAWC) 80.0
Irrigating upto upper storage limit + 5 mm

AREA

Total Irrigation Area	(ha)	31.0

VOLUMES

Total Irrigation	(ML/year)	155.1
Minimum Volume Irrigated by Pump	(ML/ha/day)	0.0
Maximum Volume must be full irrig. requiremt		
Maximum Vol. Available For Shandying	(ML/yr)	0.0

IRRIGATION CONCENTRATIONS

Average salinity of Irrigation	(dS/m)	4.3
Average salinity of Irrigation	(mg/L)	2763.0
Average Nitrogen Conc of Irrigation		
Before ammonia loss	(mg/L)	16.6
After ammonia loss	(mg/L)	13.9
Average Phosphorus Conc of Irrigation	(mg/L)	7.1

FRESH WATER USAGE
****

Irrigation (shandying) water	(ML/yr)	0.00
Avg volume of fresh water used	(ML/yr)	0.00
Annual allocation	(ML/yr)	N/A

POND INFORMATION
****

POND GEOMETRY

		Pond 1
Final pond volume	(ML)	3.8
Final liquid volume	(ML)	3.8
Final sludge volume	(ML)	0.0
Average pond volume	(ML)	5.7
Average active volume	(ML)	5.7
Maximum pond volume	(ML)	37.0
Minimum allowable pond volume	(ML)	0.0
Average pond depth	(m)	0.5
Pond depth at outlet	(m)	3.0
Maximum water surface area	(m2 x1000)	13.0
Pond catchment area	(m2 x1000)	13.5
Pond footprint length	(m)	116.0
Pond footprint width	(m)	116.0

POND WATER BALANCE

Inflow of Effluent to pond system	(ML/yr)	157.7
Recycle Volume from pond system	(ML/yr)	0.0
Rain water added to pond system	(ML/yr)	14.1
Evaporation loss from pond system	(ML/yr)	15.4
Seepage loss from pond system	(ML/yr)	0.4
Irrigation from last pond	(ML/yr)	155.1
Volume of overtopping	(ML/yr)	0.8
Sludge accumulated	(ML/yr)	0.0
Sludge accumulated	(t DM/yr)	0.0
Sludge removed	(ML/yr)	0.0
No of desludging events every 10 years		0.0
Increase in pond water volume	(ML/yr)	0.1

OVERTOPPING EVENTS

Volume of overtopping	(ML/yr)	0.76
No. of days pond overtops per 10 years		17.17
Average Length of overtopping events	(days)	10.11
% Reuse		99.24

No. of overtopping events every 10 years

> 0.000 ML	1.70
> 0.013 ML*	1.70
> 1.000 ML	0.94
> 2.000 ML	0.94
> 5.000 ML	0.38
> 10.000 ML	0.19
> 20.000 ML	0.19
> 50.000 ML	0.00

* Volume equivalent to 1 mm depth of water

>>> NO-IRRIGATION EVENTS <<<

%Days rain prevents irrigation		26.5
%Days water demand too small to trigger irr.		35.8
No. periods/year without irrigable effluent		0.0
Average Length of such periods	(days)	0.0

POND NITROGEN BALANCE

Nitrogen Added by Effluent	(tonne/yr)	3.2	Irrig. from pond (ML/yr) 155.1
Nitrogen removed by Irrigation	(tonne/yr)	2.6	
Nitrogen removed by Volatilisation	(tonne/yr)	0.6	
Nitrogen removed by Seepage	(tonne/yr)	0.0	
Nitrogen accumulated in Sludge	(tonne/yr)	0.0	
Nitrogen lost by Overtopping	(tonne/yr)	0.0	
Nitrogen involved in Recycling	(tonne/yr)	0.0	
Increase in pond Nitrogen	(tonne/yr)	0.0	

POND PHOSPHORUS BALANCE

Phosphorus Added by Effluent	(tonne/yr)	1.1	Irrig. from pond (ML/yr) 155.1
Phosphorus removed by Irrigation	(tonne/yr)	1.1	
Phosphorus removed by Seepage	(tonne/yr)	0.0	
Phosphorus accumulated in Sludge	(tonne/yr)	0.0	

Phosphorus lost by Overtopping	(tonne/yr)	0.0
Phosphorus involved in Recycling	(tonne/yr)	0.0
Increase in pond Phosphorus	(tonne/yr)	0.0

POND SALINITY BALANCE

Salinity Added by Effluent	(tonne/yr)	431.7
Salinity removed by Irrigation	(tonne/yr)	428.5
Salinity removed by Seepage	(tonne/yr)	1.2
Salinity lost by Overtopping	(tonne/yr)	2.0
Salinity involved in Recycling	(tonne/yr)	0.0
Increase in pond Salinity	(tonne/yr)	0.1

POND CONCENTRATIONS

		Pond 1
Average Nitrogen Conc of Pond Liquid	(mg/L)	13.1
Average Phosphorus Conc of Pond Liquid	(mg/L)	6.4
Average TDS Conc of Pond Liquid	(mg/L)	2616.3
Average Salinity of Pond Liquid	(dS/m)	4.1
Average Potassium Conc of Pond Liquid	(mg/L)	0.0

(On final day of simulation)

Nitrogen Conc of Pond Liquid	(mg/L)	14.1
Phosphorus Conc of Pond Liquid	(mg/L)	6.1
TDS Conc of Pond Liquid	(mg/L)	874.3
EC of Pond Liquid	(dS/m)	1.4
Potassium Conc of Pond Liquid	(mg/L)	0.0

REMOVED SLUDGE - NUTRIENT & SALT CONCENTRATIONS

Nitrogen in removed Sludge (db)	(kg/tonne)	0.0
Phosphorus in removed Sludge (db)	(kg/tonne)	0.0
Salt in removed Sludge (db)	(kg/tonne)	0.0
Potassium in removed Sludge (db)	(kg/tonne)	0.0

REMOVED SLUDGE - NUTRIENT & SALT MASSES

Nitrogen in removed Sludge	(tonne/yr)	0.0
Phosphorus in removed Sludge	(tonne/yr)	0.0
Salt in removed Sludge (mass bal.)	(tonne/yr)	0.0
Salt in removed Sludge	(tonne/yr)	0.0
Potm. in removed Sludge (mass bal.)	(tonne/yr	0.0
Potassium in removed Sludge	(tonne/yr)	0.0

LAND DISPOSAL AREA
****

WATER BALANCE

(Initial soil water assumed to be at field capacity)
(Irrigated up to 47.53% of field capacity)

Rainfall	(mm/year)	1045.9	Irrigation Area	(ha)	31.0
Irrigation	(mm/year)	500.3			
Soil Evaporation	(mm/year)	35.6			
Transpiration	(mm/year)	1058.9			
Runoff	(mm/year)	6.0			
Drainage	(mm/year)	446.1			
Change in soil moisture	(mm/year)	-0.5			

ANNUAL TOTALS

Year	Rain (mm)	Irrig (mm)	Sevap (mm)	Trans (mm)	Runoff (mm)	Drain (mm)	Change (mm)
1957	492.0	476.4	318.5	548.7	0.0	179.8	-78.6
1958	1106.0	497.8	0.0	1017.4	0.0	536.7	49.8
1959	1050.0	488.7	0.0	1198.4	0.0	327.6	12.6
1960	1074.0	517.7	0.0	1053.2	3.7	549.5	-14.7
1961	1324.0	528.2	0.0	1130.2	83.7	646.9	-8.6
1962	1108.0	476.8	0.0	1073.7	0.6	324.1	186.3
1963	1080.0	529.0	201.2	823.9	0.0	755.1	-171.2
1964	908.0	492.9	0.0	1226.4	1.3	197.5	-24.4
1965	696.0	481.1	0.0	977.7	0.0	158.6	40.8

1966	1184.0	518.6	0.0	1307.4	0.0	441.0	-45.7
1967	1260.0	508.7	0.0	1170.3	0.0	547.7	50.8
1968	1080.0	509.6	0.0	1057.5	3.2	553.4	-24.4
1969	1275.0	498.1	0.0	1055.8	8.3	686.6	22.5
1970	950.0	496.7	0.0	1185.3	0.0	244.7	16.7
1971	1572.0	515.4	0.0	1200.9	31.5	881.9	-26.8
1972	800.0	524.8	0.0	1114.8	0.0	274.0	-63.9
1973	1693.0	491.3	0.0	1153.0	8.5	961.7	61.2
1974	1272.0	517.5	212.7	720.4	6.6	780.3	69.4
1975	1090.0	499.2	1.9	1168.6	0.5	451.9	-33.7
1976	1240.0	520.7	0.0	1179.6	2.3	604.5	-25.8
1977	1176.0	523.5	0.0	1027.0	9.1	696.1	-32.7
1978	1146.0	485.6	0.0	1159.2	1.6	434.1	36.7
1979	658.0	510.7	0.0	989.2	0.0	238.7	-59.1
1980	1121.0	500.9	0.0	1120.0	2.1	416.4	83.3
1981	1488.0	532.7	0.0	1077.3	27.1	952.6	-36.2
1982	713.0	490.9	0.0	1069.3	0.0	147.9	-13.3
1983	1756.0	532.5	0.0	1175.1	57.2	1040.1	16.1
1984	1030.0	476.8	233.9	775.2	0.5	467.2	30.0
1985	1013.0	538.7	0.4	1162.4	3.2	469.5	-83.8
1986	1258.0	486.0	243.9	824.9	0.1	653.7	21.5
1987	826.0	486.2	0.0	1215.4	0.0	65.0	31.8
1988	1336.0	478.9	0.0	1171.0	0.6	635.3	8.1
1989	1468.0	456.1	193.3	715.8	3.4	1033.7	-22.1
1990	1707.0	543.7	5.6	984.8	37.2	1039.4	183.7
1991	1003.0	488.5	0.0	1048.4	0.0	619.6	-176.5
1992	1196.0	549.3	0.0	1160.7	15.1	608.5	-39.0
1993	956.0	481.2	0.0	1153.6	9.5	227.0	47.0
1994	753.0	501.8	0.0	1078.9	0.0	237.5	-61.6
1995	1042.0	493.9	0.0	1232.3	0.0	252.8	50.8
1996	943.0	501.5	0.0	1075.7	1.0	381.9	-14.1
1997	677.0	476.1	0.0	1064.6	0.0	34.4	54.1
1998	962.0	490.6	0.0	1251.4	0.0	244.0	-42.8
1999	882.0	496.6	0.0	1118.9	0.1	243.0	16.6
2000	1084.0	512.3	0.0	1119.8	0.0	396.9	79.5
2001	477.0	486.9	0.0	991.1	0.0	79.0	-106.2
2002	743.0	482.7	0.0	1057.2	0.0	191.8	-23.3
2003	842.0	479.4	0.0	1046.0	0.0	228.7	46.8
2004	611.0	491.7	0.0	1096.1	0.0	52.9	-46.3
2005	679.0	482.3	0.0	1111.5	0.0	69.7	-19.9
2006	840.0	491.4	0.0	1148.4	0.0	149.0	34.0
2007	909.0	469.1	236.5	788.1	0.0	311.2	42.4
2008	1110.0	533.1	226.9	798.4	0.3	644.2	-26.7
2009	773.0	474.9	13.7	950.6	1.8	279.6	2.2

NUTRIENT BALANCE

NITROGEN

Total N irrigated from ponds	(kg/ha/year)	82.9	% of Total as ammonium	80.0
Nitrogn lost by ammonia volat.	(kg/ha/year)	13.3	Deep Drainage (mm/year)	446.1
Nitrogen added in irrigation	(kg/ha/year)	69.6		
Nitrogen added in seed	(kg/ha/year)	0.1		
Nitrogen removed by crop	(kg/ha/year)	105.4		
Denitrification	(kg/ha/year)	0.1		
Leached NO3-N	(kg/ha/year)	2.4		
Change in soil organic-N	(kg/ha/year)	-35.1		
Change in soil solution NH4-N	(kg/ha/year)	0.0		
Change in soil solution NO3-N	(kg/ha/year)	-2.9		
Change in adsorbed NH4-N	(kg/ha/year)	0.0		
Initial soil organic-N	(kg/ha)	1957.5		
Final soil organic-N	(kg/ha)	95.0		
Initial soil inorganic-N	(kg/ha)	156.0		
Final soil inorganic-N	(kg/ha)	0.0		
Average NO3-N conc in the root zone	(mg/L)	0.2		
Average NO3-N conc below root zone	(mg/L)	1.4		
Average NO3-N conc of deep drainage	(mg/L)	0.5		

PHOSPHORUS

Phosphorus added in irrigatn	(kg/ha/year)	35.3	% of Total as phosphate	100.0
Phosphorus added in seed	(kg/ha/year)	0.0		
Phosphorus removed by crop	(kg/ha/year)	24.4		

Leached PO4-P	(kg/ha/year)	0.1
Change in dissolved PO4-P	(kg/ha/year)	0.0
Change in adsorbed PO4-P	(kg/ha/year)	10.9
Average PO4-P conc in the root zone	(mg/L)	0.2
Average PO4-P conc below root zone	(mg/L)	0.0

SOIL P STORAGE LIFE

Year	YearNo.	Tot P stored kg/ha	P leached in year kg/ha
1957	1	379.9	0.0
1958	2	413.0	0.1
1959	3	436.6	0.0
1960	4	456.9	0.1
1961	5	468.4	0.1
1962	6	477.9	0.0
1963	7	485.8	0.1
1964	8	501.0	0.0
1965	9	504.8	0.0
1966	10	509.6	0.0
1967	11	516.1	0.1
1968	12	525.2	0.1
1969	13	530.0	0.1
1970	14	536.0	0.0
1971	15	540.4	0.1
1972	16	551.5	0.0
1973	17	556.4	0.1
1974	18	562.6	0.1
1975	19	577.0	0.0
1976	20	584.9	0.1
1977	21	593.0	0.1
1978	22	602.9	0.1
1979	23	610.6	0.0
1980	24	621.6	0.1
1981	25	627.7	0.1
1982	26	636.4	0.0
1983	27	644.6	0.2
1984	28	656.9	0.1
1985	29	668.0	0.1
1986	30	676.3	0.1
1987	31	688.6	0.0
1988	32	698.5	0.1
1989	33	704.3	0.2
1990	34	717.9	0.2
1991	35	727.7	0.1
1992	36	740.1	0.1
1993	37	749.6	0.0
1994	38	760.2	0.0
1995	39	771.2	0.0
1996	40	784.4	0.1
1997	41	793.2	0.0
1998	42	803.0	0.0
1999	43	816.0	0.0
2000	44	830.0	0.1
2001	45	839.8	0.0
2002	46	850.4	0.0
2003	47	861.5	0.0
2004	48	874.7	0.0
2005	49	883.5	0.0
2006	50	894.1	0.0
2007	51	905.9	0.1
2008	52	924.4	0.2
2009	53	938.2	0.0

PLANT

Plant species: Coastal couch grass (Cynodon dac

PLANT WATER USE

Irrigation (mm/year) 500. Totl Irrigation Area(ha) 31.0

Pan coefficient	(%)	1.0
Maximum crop coefficient	(%)	0.8
Average Plant Cover	(%)	82.
Average Plant Total Cover	(%)	95.
Average Plant Rootdepth	(mm)	760.
Average Plant Available Water Capacity	(mm)	55.
Average Plant Available Water	(mm)	39.
Yield produced per unit transp.	(kg/ha/mm)	8.

PLANT NUTRIENT UPTAKE

Dry Matter Yield (Shoots)	(kg/ha/yr)	8962.			
Net nitrogen removed by plant	(kg/ha/yr)	105.	Shoot Concn	(%DM)	1.17
Net phosphorus removed by plant	(kg/ha/yr)	24.	Shoot Concn	(%DM)	0.27

AVERAGE MONTHLY GROWTH STRESS (0=no stress, 1=full stress)

Month	Yield kg/ha	Nitr	Temp	Water Defic	Water Logging
1	1048.	0.5	0.0	0.1	0.0
2	845.	0.5	0.0	0.1	0.0
3	832.	0.5	0.0	0.1	0.0
4	737.	0.5	0.0	0.1	0.0
5	606.	0.5	0.2	0.0	0.0
6	392.	0.5	0.5	0.0	0.0
7	326.	0.4	0.7	0.0	0.0
8	525.	0.4	0.5	0.1	0.0
9	833.	0.4	0.2	0.1	0.0
10	858.	0.4	0.0	0.3	0.0
11	878.	0.5	0.0	0.3	0.0
12	1081.	0.5	0.0	0.1	0.0

>>> NO-PLANT EVENTS <<<

%Days due to temperature stress	0.2
%Days due to water stress	0.4
%Days due to nitrogen stress	0.0
No. of forced harvests per year	0.2
No. of normal harvests per year	6.1

SALINITY

Salt tolerance - plant species: tolerant

Average EC of Irrigation Water	(dS/m)	4.3	Irrigation	(mm/year)	500.3
Average EC of Rainwater	(dS/m x10)	0.3	Rainfall	(mm/year)	1045.9
Average EC of Infiltrated water	(dS/m)	1.4			
Av. water-upt-weightd rootzone EC	(dS/m s.e.)	1.4			
EC soil soln (FC) at base of rootzone	(dS/m)	6.0	Deep Drainage	(mm/year)	446.1
Reduction in Crop yield due to Salinity	(%)	0.0			
Percentage of yrs that crop yld falls below 90% of potential because of soil salinity		0.0			

Period	ECrootzone sat ext (dS/m)	ECbase in situ (dS/m)	Rel Yield (%)
1957 - 1961	1.37	4.91	100.
1958 - 1962	1.22	4.47	100.
1959 - 1963	1.20	4.23	100.
1960 - 1964	1.25	4.46	100.
1961 - 1965	1.39	5.28	100.
1962 - 1966	1.46	5.86	100.
1963 - 1967	1.40	5.44	100.
1964 - 1968	1.43	5.80	100.
1965 - 1969	1.25	4.61	100.
1966 - 1970	1.20	4.44	100.
1967 - 1971	1.08	3.77	100.
1968 - 1972	1.18	4.18	100.
1969 - 1973	1.05	3.61	100.
1970 - 1974	1.02	3.48	100.

1971 - 1975	0.98	3.27	100.
1972 - 1976	1.04	3.57	100.
1973 - 1977	0.96	3.14	100.
1974 - 1978	1.08	3.69	100.
1975 - 1979	1.25	4.56	100.
1976 - 1980	1.26	4.64	100.
1977 - 1981	1.17	4.03	100.
1978 - 1982	1.34	5.02	100.
1979 - 1983	1.14	3.95	100.
1980 - 1984	1.06	3.63	100.
1981 - 1985	1.07	3.59	100.
1982 - 1986	1.14	3.92	100.
1983 - 1987	1.15	4.04	100.
1984 - 1988	1.27	4.73	100.
1985 - 1989	1.08	3.69	100.
1986 - 1990	0.93	3.00	100.
1987 - 1991	0.97	3.15	100.
1988 - 1992	0.88	2.73	100.
1989 - 1993	0.96	3.05	100.
1990 - 1994	1.18	4.07	100.
1991 - 1995	1.48	5.96	100.
1992 - 1996	1.55	6.47	100.
1993 - 1997	1.92	9.68	100.
1994 - 1998	1.91	9.54	100.
1995 - 1999	1.86	9.48	100.
1996 - 2000	1.74	8.21	100.
1997 - 2001	2.08	11.00	100.
1998 - 2002	1.98	9.51	100.
1999 - 2003	2.02	9.65	100.
2000 - 2004	2.28	11.57	100.
2001 - 2005	2.96	18.74	100.
2002 - 2006	2.57	15.84	100.
2003 - 2007	2.34	13.42	100.
2004 - 2008	1.95	8.96	100.
2005 - 2009	1.78	7.54	100.

GROUNDWATER
****

Average Groundwater Recharge (m3/day) 378.6
Average Nitrate-N Conc of Recharge (mg/L) 0.5

Thickness of the Aquifer (m) 10.0
Distance (m) from Irrigation Area to where
Nitrate-N Conc in Groundwater is Calculated 1000.0

Concentration of NITRATE-N in Groundwater (mg/L)

	Year	Depth Below Water Table Surface 0.0 m	5.0 m	9.0 m
	1961	0.1	0.1	0.1
	1966	0.3	0.3	0.3
	1971	0.4	0.4	0.4
	1976	0.4	0.4	0.4
	1981	0.4	0.4	0.4
	1986	0.4	0.4	0.4
	1991	0.5	0.5	0.5
	1996	0.5	0.5	0.5
	2001	0.5	0.5	0.5
	2006	0.5	0.5	0.5
Last	2009	0.5	0.5	0.5

ACKNOWLEDGMENTS
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APPENDIX J

Stormwater Quantity Analysis

J.1 SURFACE FLOW RATES

J.1.1 Analysis

Peak surface flow rates were calculated using the Rational Method, generally as outlined in Book 4 Section 1 of Australian Rainfall and Run-Off.

Intensity/frequency/duration curves were generated using the algebraic procedures outlined in Book II of Australian Rainfall and Run-Off. Statistical parameters were extracted from the detailed maps in Australian Rainfall and Run-off, Volume 2.

Adopted parameters are as follows:

- ${}^{2}i_{1}$ = 48.98
- ${}^{2}i_{12}$ = 9.67
- ${}^{2}i_{72}$ = 3.27
- ${}^{50}i_{1}$ = 92.14
- ${}^{50}i_{12}$ = 22.14
- ${}^{50}i_{72}$ = 8.99
- G = 0.21
- F2 = 4.24
- F50 = 17.94

Times of concentration in each catchment were estimated using the Bransby-Williams equation and confirmed using estimated average stream velocities. Table J1.1.1 below details the adopted time of concentration for each catchment. Due to the extensive vegetated areas in each catchment, it is not currently anticipated that post-development times of concentration will vary from predevelopment values.

Table J1.1.1 – Times of Concentration

Catchment	Catchment length (km)	Adopted time of concentration (minutes)
9	1.83	65
11	3.10	97
5	0.65	20
7	0.70	22
8	1.10	32

Run-off coefficients were estimated using the methods outlined in the Queensland Urban Drainage Manual based on the respective fractions impervious of each catchment. Table J1.1.2 below details the adopted run-off coefficients (both predevelopment and post-development) for each catchment.

Table J1.1.2 – Fractions Impervious

Catchment	Catchment area (Ha)	Fraction impervious	
		Predevelopment	Post-development
9	92.26	0.024	0.215
11	324.47	0.004	0.019
5	66.78	0.000	0.001
7	65.60	0.003	0.050
8	57.90	0.090	0.174

Tables J1.1.3 to J1.1.7 below outline the existing peak surface flow rates in the various catchments.

Table J1.1.3 – Catchment 5 (peak flow rates from catchment to Clam Bay)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)
1	3.22
2	4.42
5	6.34
10	7.58
20	9.24
50	12.02
100	14.11

Table J1.1.4 – Catchment 7 (peak flow rates to Long Beach from GKI land and catchments downstream)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)
1	3.08
2	4.23
5	6.05
10	7.24
20	8.82
50	11.48
100	13.47

Table J1.1.5 – Catchment 8 (peak flow rates to Fisherman's Beach from GKI land)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)
1	3.37
2	4.63
5	6.63
10	7.91
20	9.64
50	12.53
100	14.69

Table J1.1.6 – Catchment 9 (peak flow rates at the mouth of Putney Creek)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)
1	3.46
2	4.75
5	6.77
10	8.07
20	9.82
50	12.75
100	14.93

Table J1.1.7 – Catchment 11 (peak flow rates at the mouth of Leeke's Creek)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)
1	7.03
2	9.68
5	13.99
10	16.81
20	20.57
50	26.88
100	31.64

J.1.2 Mitigation

The analyses showed that the proposed development would potentially increase peak flow rates by amounts ranging from 0.5% (Catchment 5 – Clam Bay) to 90.2% (Catchment 9 – Putney Creek).

The waterway stability objective of SPP 4/10 requires that a development manage flows such that the post-development one-year ARI event discharge within the downstream waterway is no greater than the predevelopment peak one-year ARI event discharge. Generally, detention of surface run-off is necessary to achieve this objective.

A number of areas within the development have been identified as suitable sites for detention structures. Routing analyses have been undertaken to determine preliminary sizes of detention structures to mitigate post-development peak flow rates to pre-development levels.

Detention structures will be low impact designs utilising relatively low grassed or vegetated mounds enclosing open space.

Structures will be sited so that run-off from storm events exceeding the detention basin design event can bypass safely around the outside of the structure. Civil designs (building pads, roads, surface flow paths and piped networks) will direct run-off from catchments to the relevant detention basins.

Drawing number R03 identifies approximate locations of suitable detention structures. Typical details are provided in drawing number R02.

Table J1.2.1 below outlines the estimated size (volume and surface area) of each basin. The flooding has been based on a maximum basin depth (Q100) of 1.2m. The nominated basins mitigate all runoff events up to the 100 year recurrence interval (which is significantly more than is required by SPP 4/10).

Catchment 8 discharges directly to the ocean at Fishermans Beach and there is no downstream waterway which might be impacted by discharge rate increases. No detention is proposed in that catchment.

Table A1.2.1 – Detention Basins

Catchment	Basin Volume (ML)	Basin Surface Area (Ha)
9	13.5	1.1
11	8.1	0.7
5	1.8	0.2
7	5.5	0.5

Although specific details of infrastructure layouts and the like are not yet available, the modelling shows that detention requirements to mitigate post-development peak flow rates to, or below, pre-development levels are relatively small. It is not anticipated that any siting difficulties will be identified during detailed design.

Calculated mitigated post-development peak flow rates in the various catchments are outlined in Tables J1.2.2 to J1.2.6 below.

Table J1.2.2 – Catchment 5 (peak flow rates from catchment to Clam Bay)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)	Post-development peak discharge - unmitigated (m^3/s)	Post-development peak discharge - mitigated (m^3/s)	% reduction in peak flow	"No worsening" achieved?
1	3.22	3.23	3.19	0.9	yes
2	4.42	4.44	4.37	1.1	yes
5	6.34	6.37	6.29	0.8	yes
10	7.58	7.61	7.51	0.9	yes
20	9.24	9.28	8.98	2.8	yes
50	12.02	12.08	11.36	5.5	yes
100	14.11	14.18	13.14	6.9	yes

Table J1.2.3 – Catchment 7 (peak flow rates to Long Beach from GKI land and catchments downstream)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)	Post-development peak discharge - unmitigated (m^3/s)	Post-development peak discharge - mitigated (m^3/s)	% reduction in peak flow	"No worsening" achieved?
1	3.08	3.89	2.62	14.9	yes
2	4.23	5.34	3.89	8.0	yes
5	6.05	7.65	5.91	2.3	yes
10	7.24	9.14	7.21	0.4	yes
20	8.82	11.14	8.64	2.0	yes
50	11.48	14.50	10.65	7.2	yes
100	13.47	17.02	12.20	9.4	yes

Table J1.2.4 – Catchment 8 (peak flow rates to Fisherman's Beach from GKI land). Note that these flows are distributed over a wide beach frontage and are not concentrated at specific points.

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)	Post-development peak discharge - unmitigated (m^3/s)
1	3.37	4.44
2	4.63	6.09
5	6.63	8.72
10	7.91	10.41
20	9.64	12.68
50	12.53	16.48
100	14.69	19.33

Table J1.2.5 – Catchment 9 (peak flow rates at the mouth of Putney Creek)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)	Post-development peak discharge - unmitigated (m^3/s)	Post-development peak discharge - mitigated (m^3/s)	% reduction in peak flow	"No worsening" achieved?
1	3.46	6.58	2.60	25.3	yes
2	4.75	9.03	3.97	16.4	yes
5	6.77	12.88	6.28	7.2	yes
10	8.07	15.35	7.76	3.8	yes
20	9.82	18.68	9.18	6.5	yes
50	12.75	24.24	11.79	7.5	yes
100	14.93	28.40	13.54	9.3	yes

Table J1.2.6 – Catchment 11 (peak flow rates at the mouth of Leeke's Creek)

Average recurrence interval (years)	Pre-development peak discharge (m^3/s)	Post-development peak discharge - unmitigated (m^3/s)	Post-development peak discharge - mitigated (m^3/s)	% reduction in peak flow	"No worsening" achieved?
1	7.03	7.61	6.59	6.3	yes
2	9.68	10.49	9.31	3.8	yes
5	13.99	15.16	13.79	1.4	yes
10	16.81	18.20	16.46	2.1	yes
20	20.57	22.27	19.45	5.4	yes
50	26.88	29.11	24.33	9.5	yes
100	31.64	34.27	28.23	10.8	yes

J.2 RUN-OFF VOLUMES

Annual run-off volumes, and particularly the distribution of rainfall to surface flow and groundwater, have been analysed using continuous simulation analysis in the hydrologic module of MUSIC software. The algorithm adopted in MUSIC to generate runoff is based on a simplified rainfall-runoff model developed by Chiew et al. (1997). The model is described in general terms below (an extract from the MUSIC manual).

All rainfall on the impervious area becomes runoff once a small storage capacity or initial loss is exceeded. The initial loss storage is emptied each day.

Pervious areas are modelled using one soil moisture store and one groundwater store. Rainfall on the pervious part of the catchment is subject to infiltration, with the infiltration rate of the soil being defined as an exponential *function of the soil moisture storage. The infiltration rate is at a maximum when the soil moisture store is empty, and gradually decreases to a minimum when the soil moisture store is full.*

Runoff from the pervious area occurs when the rainfall exceeds the infiltration rate of the soil (infiltration excess runoff) and when the soil moisture store has reached its maximum capacity (soil saturation excess runoff).

Evapotranspiration is subtracted from the soil moisture store. It is dependent on the amount of water in the soil store and the areal potential evapotranspiration rate.

Soil moisture recharges groundwater whenever the soil moisture store exceeds field capacity. Recharge is calculated as a constant percentage of the storage above field capacity. Baseflow from groundwater is simulated using a linear recession of the groundwater store.

Table J2.1 below outlines the anticipated changes in annual run-off volumes in the various catchments as a result of the proposed development.

Table J2.1 – Average Annual Volumes

Catchment	Average annual volume to surface run-off (ML per year)		Average annual volume to groundwater (ML per year)		Average annual volume to evapotranspiration (ML per year)		Average annual volume harvested from the roof water (ML per year)
	Pre-development	Post-development	Pre-development	Post-development	Pre-development	Post-development	Post-development
9	21.3	85.7	133.4	184.7	687.7	570.6	2.0
11	19.1	33.1	398.7	410.9	2051.4	2024.3	9.4
5	2.2	2.4	82.4	82.3	423.7	423.6	0.2
7	3.3	13.4	80.7	87.5	415.3	398.2	2.1
8	37.6	40.7	55.0	85.6	337.8	313.8	5.2

J.2.1 Mitigation

The modelling suggests that the main impact will be increases in surface run-off and groundwater recharge volumes in some catchments. The modelling suggests that rainwater tanks capturing roof water for reuse will remove some 19 ML per annum from the volume which would otherwise become surface run-off.

If necessary, additional surface storage (harvesting rainwater for irrigation purposes) or infiltration zones to direct surface stormwater run-off to groundwater could be provided.

Note that these calculations ignore infiltration losses in the surface drainage and detention basin network. Given the relatively high permeability of the sandy soils on the island, it can be expected that actual surface runoff volumes discharging to the main waterways will be less than the modelling suggests.

J3 FREQUENT FLOW MANAGEMENT

To protect in-stream ecology of ephemeral freshwater waterways, the SPP 4/10 requires development to manage the increase in the number of small runoff events which occur from impervious surfaces compared to natural vegetated surfaces. The objective is satisfied by capturing and managing the first 10mm of runoff from impervious surfaces each day.

The geotechnical testing has shown that Great Keppel Island soils are very sandy, with high permeability, typically exceeding 100mm/day.

Only two of the catchments impacted by the development discharge to ephemeral freshwater streams – Catchment 9 to Putney Creek, and Catchment 11 to Leeke's Creek.

The proposed bio-retention and detention structures in these two catchments intercept all runoff from impervious surfaces before it reaches the respective defined waterways. In both catchments, the daily infiltration capacity of the treatment structures far exceeds the volume of the first 10mm of rainfall on the respective impervious surfaces.

Table 11.3.1 below compares the required capture and dispose volume with the infiltration capacity of the treatment structures in each catchment. The comparison amply demonstrates the capacity of the water sensitive designs proposed to manage frequent flows in accordance with the SPP.

Table 11.3.1 – Frequent Flow Management - Comparison of capture and dispose volume with infiltration capacity.

Catchment	Total impervious area (Ha)	Required daily capture and dispose volume (ML)	Area of bio-retention and detention structures (Ha)	Daily disposal capacity (ML)	Ratio of disposal capacity to requirement
9 – Putney Creek	23.8	2.3	1.7	39.9	17.3
11 – Leeke's Creek	6.2	0.7	1.4	32.4	46.3

Note that this tabulation is conservative as it ignores the additional infiltration of the surface drainage network.

APPENDIX K

Stormwater Quality Analysis

K1. WATER QUALITY OBJECTIVES

Environmental values and water quality objectives for the area are generally outlined in "Water Quality Guidelines for the Great Barrier Reef Marine Park", published by the Great Barrier Reef Marine Park Authority (2009). The Queensland Water Quality Guidelines 2009 outline trigger values for a number of physico-chemical indicators for subregional coastal areas.

Within that guideline, the section relevant to Great Keppel Island is that relating to the Central Coast Queensland region. Table 3.2.1b details specific regional guideline values for waters of that region within the Great Barrier Reef Marine Park.

Nominated values are:

- Amm N: 0.004mg/L
- Oxid N: 0.003mg/L
- Particulate N: 0.020mg/L
- Total N: 0.140mg/L
- FiltR P: 0.006mg/L
- Particulate P: 0.0028mg/L
- Total P: 0.020mg/L
- Chl-a: 0.00045mg/L
- TSS: 2.0mg/L
- Turb: 1 NTU
- Secchi: 10m
- pH: 8.1 - 8.4
- DO: 95 - 105 (% sat)

Typically, EVs and WQOs form the basis for defining the required water quality in receiving waters. However, they are guideline or trigger values and most are not something which can be readily modelled or predicted.

In recent years, significant research effort has been applied to develop modelling methods which can estimate the level of stormwater quality improvement necessary for a site to ensure that receiving water WQOs can be met and EVs protected. Currently, surface water quality modelling tools are only able to model and predict TSS, TP, TN and GP.

In Queensland, available research and model development has culminated in the implementation of State Planning Policy 4/10 Healthy Waters (May 2011) and the draft "Urban Stormwater - Queensland Best Practice Environment Management Guidelines 2009".

SPP 4/10 (and supporting documents) nominates specific minimum stormwater pollutant load reductions required to be met by development in areas throughout Queensland. The nominated minimums have been based on research and modelling work undertaken by number of Australian organisations.

The target load reductions were derived using a "diminishing returns" analysis balancing incremental community costs against improved environmental benefits. Whilst the target load reductions are not necessarily the maximum which can possibly be achieved, they have been derived following rigorous analysis. The analysis outlined in detail below demonstrates that the methods proposed to achieve the nominated load reductions will also reduce modelled pollutant concentrations in run-off below those which presently exist.

Adopting predictive modelling techniques to quantify estimates of stormwater pollutant concentrations and loads from urban land surfaces, and the pollutant removal efficacy of current best practice stormwater treatment infrastructure is now an accepted method for establishing best practice stormwater management complying with SPP 4/10.

K2. ANALYSIS METHODS

Surface water quality impacts have been examined using MUSIC modelling software to quantify stormwater pollutant concentrations and average annual loads and to assess and establish appropriate stormwater management methods. MUSIC is state of the art modelling software, widely adopted in the industry and well accepted by assessing authorities.

Design stormwater quality improvement objectives were taken from the draft Queensland Best Practice Environmental Management Guidelines (Table 2.1b). For the relevant region (Central Coast South), minimum target reductions in mean annual loads for the modelled pollutants are as follows:

- suspended solids (TSS) - 85%
- total phosphorus (TP) - 70%
- total nitrogen (TN) - 45%
- gross pollutants (GP) - 90%.

K3. MODEL NETWORK

Subcatchment details are available in Tables K5.1 and K5.2. These should be read together with Drawing R01.

K4. MODEL PARAMETERS

K4.1 Meteorological data from the Bureau of Meteorology recording station nearest the site (39083 Rockhampton) has been used. The rainfall data sequence adopted is that required by the Urban Stormwater – Queensland Best Practice Environmental Management Guidelines 2009 (1980 – 1989 at 6 minute time steps).

K4.2 Evapotranspiration data for Great Keppel Island was obtained from the Bureau of Meteorology. The following table outlines the evapotranspiration data adopted for the MUSIC model.

Table K4.2.1 – Evapotranspiration Data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evapotranspiration (mm/month)	204	165	178	131	99	84	85	107	133	178	193	200

K4.3 Soil characteristics were calibrated for the soils present at Great Keppel Island. The calibration was undertaken using *MUSIC calibration based on soil conditions* by Andrew Macleod. The following soil characteristics were adopted from the technical paper for a sandy soil texture and included in the MUSIC model.

Table K4.3.1 – Soil Characteristics

Soil Characteristic	Calibrated Input
Soil Storage Capacity	175 mm
Field Capacity	75 mm
Infiltration Capacity Coefficient - a	200
Infiltration Capacity Exponent - b	0.5
Initial Depth	50 mm
Daily Recharge Rate	75%
Daily Baseflow Rate	50%
Daily Deep Seepage Rate	0%

K4.4 Where rainwater tanks are provided, toilet flush was estimated using the MUSIC Modelling Guidelines for South East Queensland. The facilities were assumed to incorporate full water saving devices with the following water usage:

- 25L per person per day; and
- a seven day week.

The following shows the daily number of staff, patrons and guests used in the toilet flush estimation:

Eco Villas

- 938 staff, patrons and guests

K4.5 Landscape usage was estimated using the Brisbane City Council Landscape Irrigation Design Guideline.

K4.6 Model parameters for source node pollutant generation and treatment node characteristics were taken directly from the appropriate sections of the MUSIC modelling Guidelines without modification.

The parameters recommended in the guideline originated from testing of stormwater run-off sampled in "normal" mainland urban areas. Since Great Keppel Island has no nearby industry and few hydrocarbon powered vehicles (which are the main sources of airborne pollution in mainland urban areas) these pollutant generation parameters will be very conservative for the Great Keppel Island MUSIC model.

It is likely therefore that stormwater quality modelling (particularly that of pollutant concentrations) will predict higher values than those which will actually occur.

K4.7 Specific parameters used in the "developed" model scenario are summarised in Table K4.7.1 below.

Table K4.7.1 – MUSIC node parameters (developed scenario)

Catchment	Catchment Name:	N-B0160.00 GKI Resort Developed
	Rainfall Station:	39083 ROCKHAMPTON
	ET Station:	User-defined monthly PET
	Start Date:	01/01/1980 12:00 AM
	End Date:	01/12/1989 11:54 PM
	Modelling Time Step:	6 Minutes
Roads 2	Total Area (ha):	0.345
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00

Roads 3	Total Area (ha):	0.360
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 4	Total Area (ha):	0.180
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	

	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 5	Total Area (ha):	0.736
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39

	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 7	Total Area (ha):	0.482
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28

	Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roads 8 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	2.511 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roads 8 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm):	0.351 100 1.00 175 10 75

	Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roads 9 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP	15.977 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00

	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 9 Other Land	Total Area (ha):	0.966
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	

	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 11	Total Area (ha):	3.606
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated

	R squared:	0.00
Roads 14	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.141 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Pervious Ground 5	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%):	0.768 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00

	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Pervious Ground 7	Total Area (ha):	5.602
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52

	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Pervious Ground 8 GKI Land	Total Area (ha):	11.765
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56

	Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Pervious Ground 8 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.955 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Pervious Ground 9 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity):	3.745 0 1.00 175 10

	Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Pervious Ground 9 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	2.782 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00

	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Pervious Ground 11	Total Area (ha):	29.108
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	

	TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Impervious Ground 9 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L):	3.600 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.78 0.39 Stochastically Generated 0.00 -0.60 0.50 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00 2.16 0.38 Stochastically Generated 0.00 -0.39 0.34 Stochastically Generated 0.00 0.37 0.34

	Estimation Method: R squared:	Stochastically Generated 0.00
Roof Not Tanked 3	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.001 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00

Roof Tanked 5	Total Area (ha):	0.032
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Tanked 7	Total Area (ha):	0.328
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	

	TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roof Tanked 8 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L):	0.816 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39

	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Not Tanked 8 GKI Land	Total Area (ha):	6.217
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28

	Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roof Tanked 8 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.165 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00

Roof Tanked 9 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.324 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roof Not Tanked 9 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters	1.886 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00

	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Tanked 9 Other Land	Total Area (ha):	1.018
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39

	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Tanked 11	Total Area (ha):	1.500
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28

	Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roof Not Tanked 11	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	1.082 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00

Roof Not Tanked 14	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	2.118 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Ocean 14	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters	9.600 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00

	TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Rainwater Tank 5	Low Flow Bypass (m3/sec): High Flow Bypass (m3/sec): Volume Below Overflow (kL): Depth Above Overflow (m): Surface Area (m2): Overflow Pipe Diameter (mm): Use Stored Water: Annual Demand (kL/yr) scaled by daily (PET – Rain): Daily Demand (kL/day): Orifice Discharge Coeff.: Number of CSTR Cells: TSS k (m/yr): TSS C* (mg/L): TP k (m/yr): TP C* (mg/L): TN k (m/yr): TN C* (mg/L):	0.0000 10000.00 24.00 0.2 10.857 100 Yes 4632.576 0.250 0.6 2 400 12.000 300 0.130 40 1.400
Rainwater Tank 7	Low Flow Bypass (m3/sec): High Flow Bypass (m3/sec): Volume Below Overflow (kL): Depth Above Overflow (m): Surface Area (m2): Overflow Pipe Diameter (mm): Use Stored Water: Annual Demand (kL/yr) scaled by daily (PET –	0.0000 10000.00 246.000 0.2 111.288 100 Yes

	Rain):	33791.264
	Daily Demand (kL/day):	2.564
	Orifice Discharge Coeff.:	0.6
	Number of CSTR Cells:	2
	TSS k (m/yr):	400
	TSS C* (mg/L):	12.000
	TP k (m/yr):	300
	TP C* (mg/L):	0.130
	TN k (m/yr):	40
	TN C* (mg/L):	1.400
Rainwater Tank 8	Low Flow Bypass (m3/sec):	0.0000
	High Flow Bypass (m3/sec):	10000.000
	Volume Below Overflow (kL):	612.000
	Depth Above Overflow (m):	0.2
	Surface Area (m2):	276.862
	Overflow Pipe Diameter (mm):	100
	Use Stored Water:	Yes
	Annual Demand (kL/yr) scaled by daily (PET – Rain):	70967.646
	Daily Demand (kL/day):	30.895
	Orifice Discharge Coeff.:	0.6
	Number of CSTR Cells:	2
	TSS k (m/yr):	400
	TSS C* (mg/L):	12.000
	TP k (m/yr):	300
	TP C* (mg/L):	0.130
	TN k (m/yr):	40
	TN C* (mg/L):	1.400
Rainwater Tank 9	Low Flow Bypass (m3/sec):	0.0000
	High Flow Bypass (m3/sec):	10000.000
	Volume Below Overflow (kL):	243.000
	Depth Above Overflow (m):	0.2
	Surface Area (m2):	109.931
	Overflow Pipe Diameter (mm):	100
	Use Stored Water:	Yes
	Annual Demand (kL/yr) scaled by daily (PET – Rain):	22591.147
	Daily Demand (kL/day):	5.242
	Orifice Discharge Coeff.:	0.6
	Number of CSTR Cells:	2
	TSS k (m/yr):	400
	TSS C* (mg/L):	12.000
	TP k (m/yr):	300
	TP C* (mg/L):	0.130
	TN k (m/yr):	40
	TN C* (mg/L):	1.400
Rainwater Tank 11	Low Flow Bypass (m3/sec):	0.0000
	High Flow Bypass (m3/sec):	10000.000
	Volume Below Overflow (kL):	1125.000
	Depth Above Overflow (m):	0.2
	Surface Area (m2):	508.938
	Overflow Pipe Diameter (mm):	100
	Use Stored Water:	Yes
	Annual Demand (kL/yr) scaled by daily (PET – Rain):	175579.215
	Daily Demand (kL/day):	11.725
	Orifice Discharge Coeff.:	0.6
	Number of CSTR Cells:	2
	TSS k (m/yr):	400

	TSS C* (mg/L):	12.000
	TP k (m/yr):	300
	TP C* (mg/L):	0.130
	TN k (m/yr):	40
	TN C* (mg/L):	1.400
Bioretention 5	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	2.49
	Filter Area (m2):	0.49
	Unlined Filter Media Perimeter (m):	4.15
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	2.49
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 5A	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	3.20
	Filter Area (m2):	0.64
	Unlined Filter Media Perimeter (m):	4.31
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	3.20
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000

	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 5B	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	76.80
	Filter Area (m2):	15.36
	Unlined Filter Media Perimeter (m):	20.66
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	76.80
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 7	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	586.00
	Filter Area (m2):	73.25
	Unlined Filter Media Perimeter (m):	84.98
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	293.00
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000

	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 7A	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	65.60
	Filter Area (m2):	8.20
	Unlined Filter Media Perimeter (m):	12.71
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	32.80
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 7B	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	1120.40
	Filter Area (m2):	140.05
	Unlined Filter Media Perimeter (m):	159.21
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	560.20
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130

	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 8	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	502.20
	Filter Area (m2):	251.10
	Unlined Filter Media Perimeter (m):	282.60
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	251.1
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 8A	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	1406.62
	Filter Area (m2):	703.31
	Unlined Filter Media Perimeter (m):	785.05
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	703.31
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500

	TN C* (mg/L):	1.400
Bioretention 8B	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	2353.03
	Filter Area (m2):	1176.51
	Unlined Filter Media Perimeter (m):	1310.84
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	1176.51
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 9	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	3514.87
	Filter Area (m2):	798.83
	Unlined Filter Media Perimeter (m):	891.19
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	1597.67
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400

Bioretention 9A	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	486.284
	Filter Area (m2):	110.519
	Unlined Filter Media Perimeter (m):	126.399
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	221.038
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 9B	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	823.948
	Filter Area (m2):	187.261
	Unlined Filter Media Perimeter (m):	211.668
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	374.522
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 9C	Low Flow Bypass (m3/sec):	0.000

	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	792.000
	Filter Area (m2):	180.000
	Unlined Filter Media Perimeter (m):	203.600
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	360.00
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 11	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	685.07
	Filter Area (m2):	72.11
	Unlined Filter Media Perimeter (m):	83.72
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	360.56
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 11A	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000

	Extended Detention Depth (m):	0.10
	Surface Area (m2):	490.66
	Filter Area (m2):	51.64
	Unlined Filter Media Perimeter (m):	60.98
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	258.24
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 11B	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	5530.51
	Filter Area (m2):	582.15
	Unlined Filter Media Perimeter (m):	650.44
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	No
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	2910.79
	Underdrain Present:	No
	Submerged Zone With Carbon Present:	Yes
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	100.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 14	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10

	Surface Area (m2):	56.44
	Filter Area (m2):	31.04
	Unlined Filter Media Perimeter (m):	38.09
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	Yes
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	14.11
	Underdrain Present:	Yes
	Submerged Zone With Carbon Present:	No
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	000.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 14A	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	847.00
	Filter Area (m2):	465.85
	Unlined Filter Media Perimeter (m):	521.21
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	Yes
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	211.75
	Underdrain Present:	Yes
	Submerged Zone With Carbon Present:	No
	Submerged Zone Depth (m):	0.00
	Exfiltration Rate (mm/hr):	000.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Bioretention 14B	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	2307.59

	Filter Area (m2):	1269.17
	Unlined Filter Media Perimeter (m):	1413.79
	Filter Depth (m):	0.60
	TN Content of Filter Media (mg/kg):	800
	Sat. Hydraulic Con. (mm/hr):	100.00
	Proportion of Organic Material in Filter (%):	<5%
	Orthophosphate Content of Filter Media (mg/kg):	<55
	Is basin lined?	Yes
	Vegetated with effective nutrient removal plants?	Yes
	Overflow Weir Width (m):	576.89
	Underdrain Present:	Yes
	Submerged Zone With Carbon Present:	No
	Submerged Zone Depth (m):	000.00
	Exfiltration Rate (mm/hr):	000.00
	Weir Coefficient:	1.70
	Voids Ratio:	0.35
	Number of CSTR Cells:	3
	TSS k (m/yr):	8000
	TSS C* (mg/L):	20.000
	TP k (m/yr):	6000
	TP C* (mg/L):	0.130
	TN k (m/yr):	500
	TN C* (mg/L):	1.400
Pond 14	Low Flow Bypass (m3/sec):	0.000
	High Flow Bypass (m3/sec):	10000.000
	Extended Detention Depth (m):	0.10
	Surface Area (m2):	96000.0
	Permanent Pool Volume (cubic meters):	288000.0
	Exfiltration Rate (mm/hr):	0.00
	Evaporative Loss as % of PET:	100.00
	Equivalent Pipe Diameter (mm):	12361
	Overflow Weir Width (m):	40.0
	Orifice Discharge Coefficient:	0.60
	Weir Coefficient:	1.70
	Number of CSTR Cells:	2
	TSS k (m/yr):	400
	TSS C* (mg/L):	12.000
	TP k (m/yr):	300
	TP C* (mg/L):	0.090
	TN k (m/yr):	40
	TN C* (mg/L):	1.000
Forest 1	Total Area (ha):	13.716
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	

	Mean (log mg/L):	0.510
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.790
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.590
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	1.900
	Std Dev (log mg/L):	0.200
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.100
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.075
	Std Dev (log mg/L):	0.240
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Forest 2	Total Area (ha):	177.959
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.510
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.790
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.590
	Std Dev (log mg/L):	0.220

	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	1.900
	Std Dev (log mg/L):	0.200
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.100
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.075
	Std Dev (log mg/L):	0.240
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Forest 3	Total Area (ha):	86.379
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.510
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.790
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.590
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	1.900
	Std Dev (log mg/L):	0.200
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.100
	Std Dev (log mg/L):	0.220

	Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 4	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	86.654 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 5	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity):	65.956 0 1.00 175 10

	Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 6	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L):	7.473 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510

	Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 7 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method:	30.240 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated

	R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 7 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method:	26.500 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated

	R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 8 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	9.991 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 8 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm):	25.129 0 1.00 175 10 75

	Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 9 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L):	54.671 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280

	Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 9 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	25.731 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00

	Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 10	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.284 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00

	TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 -0.075 0.240 Stochastically Generated 0.00
Forest 11	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	289.151 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 12	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a:	13.716 0 1.00 175 10 75 200.0

	Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 13	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method:	12.391 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated

	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.790
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.590
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	1.900
	Std Dev (log mg/L):	0.200
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.100
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.075
	Std Dev (log mg/L):	0.240
	Estimation Method:	Stochastically Generated
	R squared:	0.00

K4.8 Specific parameters used in the "existing" model scenario are summarised in Table K4 below.

Table K4 – MUSIC node parameters (existing scenario)

Catchment	Catchment Name:	N-B0160.00 GKI Resort Existing
	Rainfall Station:	39083 ROCKHAMPTON
	ET Station:	User-defined monthly PET
	Start Date:	01/01/1980 12:00 AM
	End Date:	01/12/1989 11:54 PM
	Modelling Time Step:	6 Minutes
Roads 2	Total Area (ha):	0.345
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54

	Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roads 3	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L):	0.360 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26

	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 4	Total Area (ha):	0.180
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00

Roads 5	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.030 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roads 7	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters	0.195 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00

	TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roads 8 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L):	2.664 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39

	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 8 Other Land	Total Area (ha):	0.351
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28

	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 9 GKI Land	Total Area (ha):	0.495
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roads 9 Other Land	Total Area (ha):	0.966
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75

	Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roads 11	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP	1.359 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00

	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Pervious Ground 8 GKI Land	Total Area (ha):	18.036
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	

	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Pervious Ground 8 Other Land	Total Area (ha):	0.955
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated

	R squared:	0.00
Pervious Ground 9 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.955 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Pervious Ground 9 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%):	2.782 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00

	Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Pervious Ground 11	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L):	0.315 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52

	Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roof Not Tanked 3	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L):	0.001 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56

	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Not Tanked 7	Total Area (ha):	0.010
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Not Tanked 8 GKI Land	Total Area (ha):	2.056
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10

	Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00 -1.54 0.38 Stochastically Generated 0.00 -0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Roof Not Tanked 8 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.165 100 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.53 0.24 Stochastically Generated 0.00

	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Not Tanked 9 GKI Land	Total Area (ha):	0.159
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	

	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Not Tanked 9 Other Land	Total Area (ha):	1.018
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30

	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Not Tanked 11	Total Area (ha):	0.026
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Roof Tanked 11	Total Area (ha):	0.009
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00

	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.52
	Std Dev (log mg/L):	0.39
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	2.26
	Std Dev (log mg/L):	0.51
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-0.56
	Std Dev (log mg/L):	0.28
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	0.32
	Std Dev (log mg/L):	0.30
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Ocean 14	Total Area (ha):	14.578
	Impervious (%):	100
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.53
	Std Dev (log mg/L):	0.24
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.54
	Std Dev (log mg/L):	0.38
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	

	Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	-0.52 0.39 Stochastically Generated 0.00 2.26 0.51 Stochastically Generated 0.00 -0.56 0.28 Stochastically Generated 0.00 0.32 0.30 Stochastically Generated 0.00
Pond 14	Low Flow Bypass (m3/sec): High Flow Bypass (m3/sec): Extended Detention Depth (m): Surface Area (m2): Permanent Pool Volume (cubic meters): Exfiltration Rate (mm/hr): Evaporative Loss as % of PET: Equivalent Pipe Diameter (mm): Overflow Weir Width (m): Orifice Discharge Coefficient: Weir Coefficient: Number of CSTR Cells: TSS k (m/yr): TSS C* (mg/L): TP k (m/yr): TP C* (mg/L): TN k (m/yr): TN C* (mg/L):	0.000 10000.000 0.10 145780.0 437340.0 0.00 100.00 19544 100.0 0.60 1.70 2 400 12.000 300 0.090 40 1.000
Rainwater Tank 11	Low Flow Bypass (m3/sec): High Flow Bypass (m3/sec): Volume Below Overflow (kL): Depth Above Overflow (m): Surface Area (m2): Overflow Pipe Diameter (mm): Use Stored Water: Annual Demand (kL/yr): Daily Demand (kL/day): Orifice Discharge Coeff.: Number of CSTR Cells: TSS k (m/yr): TSS C* (mg/L): TP k (m/yr): TP C* (mg/L): TN k (m/yr): TN C* (mg/L):	0.0000 100.000 9.00 0.20 4.70 100 No 0.000 0.000 0.6 2 400 12.000 300 0.130 40 1.400
Forest 1	Total Area (ha): Impervious (%):	13.716 0

	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.510
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.790
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.590
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	1.900
	Std Dev (log mg/L):	0.200
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.100
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.075
	Std Dev (log mg/L):	0.240
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Forest 2	Total Area (ha):	177.959
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00

	Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 3	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN	86.379 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00

	Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	-0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 4	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP	86.654 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00

	Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	-1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 5	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	66.751 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 6	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day):	7.473 0 1.00

	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.510
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.790
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.590
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	1.900
	Std Dev (log mg/L):	0.200
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.100
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.075
	Std Dev (log mg/L):	0.240
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Forest 7 GKI Land	Total Area (ha):	38.895
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	

	TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 7 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L):	26.500 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590

	Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 8 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L):	8.544 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100

	Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 8 Other Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	25.129 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 9 GKI Land	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm):	64.253 0 1.00 175

	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	
	Mean (log mg/L):	0.510
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.790
	Std Dev (log mg/L):	0.280
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.590
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	Stormflow Conc. Parameters	
	TSS	
	Mean (log mg/L):	1.900
	Std Dev (log mg/L):	0.200
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TP	
	Mean (log mg/L):	-1.100
	Std Dev (log mg/L):	0.220
	Estimation Method:	Stochastically Generated
	R squared:	0.00
	TN	
	Mean (log mg/L):	-0.075
	Std Dev (log mg/L):	0.240
	Estimation Method:	Stochastically Generated
	R squared:	0.00
Forest 9 Other Land	Total Area (ha):	40.072
	Impervious (%):	0
	Rainfall Threshold (mm/day):	1.00
	Soil Storage Capacity (mm):	175
	Initial Storage (% of Capacity):	10
	Field Capacity (mm):	75
	Infiltration Capacity Coeff. – a:	200.0
	Infiltration Capacity Exp. – b:	0.5
	Initial Depth (mm):	50
	Daily Recharge Rate (%):	75.00
	Daily Baseflow Rate (%):	50.00
	Daily Deep Seepage Rate (%):	0.00
	Base Flow Conc. Parameters	
	TSS	

	Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 10	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L):	0.284 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220

	Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 11	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L):	322.738 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220

	Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 12	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	13.716 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 13	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity):	12.391 0 1.00 175 10

	Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	75 200.0 0.5 50 75.00 50.00 0.00 0.510 0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00
Forest 14	Total Area (ha): Impervious (%): Rainfall Threshold (mm/day): Soil Storage Capacity (mm): Initial Storage (% of Capacity): Field Capacity (mm): Infiltration Capacity Coeff. – a: Infiltration Capacity Exp. – b: Initial Depth (mm): Daily Recharge Rate (%): Daily Baseflow Rate (%): Daily Deep Seepage Rate (%): Base Flow Conc. Parameters TSS Mean (log mg/L):	3.050 0 1.00 175 10 75 200.0 0.5 50 75.00 50.00 0.00 0.510

	Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: Stormflow Conc. Parameters TSS Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TP Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared: TN Mean (log mg/L): Std Dev (log mg/L): Estimation Method: R squared:	0.280 Stochastically Generated 0.00 -1.790 0.280 Stochastically Generated 0.00 -0.590 0.220 Stochastically Generated 0.00 1.900 0.200 Stochastically Generated 0.00 -1.100 0.220 Stochastically Generated 0.00 -0.075 0.240 Stochastically Generated 0.00

K5. Catchments

The following tabulations set out the subcatchment details.

Table K5.1 – MUSIC subcatchment details - Developed case scenario

Subcatchment	Total area (ha)	Impervious area (ha)	Fraction Impervious
Forest 1	13.716	0.000	0%
Forest 2	177.959	0.000	0%
Forest 3	86.379	0.000	0%
Forest 4	86.654	0.000	0%
Forest 5	65.956	0.000	0%
Forest 6	7.473	0.000	0%
Forest 7GKI Land	30.240	0.000	0%
Forest 7 Other Land	26.500	0.000	0%
Forest 8 GKI Land	9.991	0.000	0%
Forest 8 Other Land	25.129	0.000	0%
Forest 9 GKI Land	54.671	0.000	0%
Forest 9 Other land	25.731	0.000	0%
Forest 10	0.284	0.000	0%
Forest 11	289.151	0.000	0%
Forest 12	13.716	0.000	0%
Forest 13	12.391	0.000	0%
Roads 2	0.345	0.345	100%
Roads 3	0.360	0.360	100%
Roads 4	0.180	0.180	100%

Subcatchment	Total area (ha)	Impervious area (ha)	Fraction Impervious
Roads 5	0.736	0.736	100%
Roads 7	0.482	0.782	100%
Roads 8 GKI Land	2.511	2.511	100%
Roads 8 Other Land	0.351	0.351	100%
Roads 9 GKI Land	15.977	15.977	100%
Roads 9 Other Land	0.966	0.966	100%
Roads 11	3.606	3.606	100%
Roads 14	0.141	0.141	100%
Roof Not Tanked 3	0.001	0.001	100%
Roof Tanked 5	0.032	0.032	100%
Roof Tanked 7	0.328	0.328	100%
Roof Tanked 8 GKI Land	0.816	0.816	100%
Roof Not Tanked 8 GKI Land	6.217	6.217	100%
Roof Tanked 8 Other Land	0.165	0.165	100%
Roof Tanked 9 GKI Land	0.324	0.324	100%
Roof Not Tanked 9 GKI Land	1.886	1.886	100%
Roof Tanked 9 Other Land	1.018	1.018	100%
Roof Tanked 11	1.500	1.500	100%
Roof Not Tanked 11	1.082	1.082	100%
Roof Not Tanked 14	2.118	2.118	100%
Ocean 14	9.600	9.600	100%
Pervious Ground 5	0.768	0.000	0%
Pervious Ground 7	5.602	0.000	0%
Pervious Ground 8 GKI Land	11.765	0.000	0%
Pervious Ground 8 Other Land	0.955	0.000	0%
Pervious Ground 9 GKI Land	3.745	0.000	0%
Pervious Ground 9 Other Land	2.782	0.000	0%
Pervious Ground 11	29.108	0.000	0%
Impervious Ground 9 GKI Land	3.600	3.600	100%

Table K5.2 – MUSIC subcatchment details – existing case scenario

Subcatchment	Total area (ha)	Impervious area (ha)	Fraction impervious
Forest 1	13.716	0.000	0%
Forest 2	177.959	0.000	0%
Forest 3	86.380	0.000	0%
Forest 4	86.654	0.000	0%
Forest 5	66.751	0.000	0%
Forest 6	7.473	0.000	0%
Forest 7 GKI Land	38.895	0.000	0%
Forest 7 Other Land	26.500	0.000	0%
Forest 8 GKI Land	8.544	0.000	0%
Forest 8 Other Land	25.129	0.000	0%
Forest 9 GKI Land	64.253	0.000	0%
Forest 9 Other Land	40.072	0.000	0%
Forest 10	0.284	0.000	0%
Forest 11	322.738	0.000	0%
Forest 12	13.716	0.000	0%
Forest 13	12.391	0.000	0%
Forest 14	3.050	0.000	0%
Roads 2	0.345	0.345	100%
Roads 3	0.360	0.360	100%
Roads 4	0.180	0.180	100%
Roads 5	0.030	0.030	100%
Roads 7	0.195	0.195	100%
Roads 8 GKI Land	2.664	2.664	100%
Roads 8 Other Land	0.351	0.351	100%
Roads 9 GKI Land	0.495	0.495	100%
Roads 9 Other Land	0.966	0.966	100%
Roads 11	1.359	1.359	100%
Roof Not Tanked 3	0.001	0.001	100%
Roof Not Tanked 7	0.010	0.010	100%
Roof Not Tanked 8 GKI Land	2.056	2.056	100%
Roof Not Tanked 8 Other Land	0.165	0.165	100%
Roof Not Tanked 9 GKI Land	0.159	0.159	100%
Roof Not Tanked 9 Other Land	1.018	1.018	100%
Roof Not Tanked 11	0.026	0.026	100%
Roof Tanked 11	0.009	0.009	100%
Ocean 14	14.578	14.578	100%
Pervious Ground 8 GKI Land	18.036	0.000	0%
Pervious Ground 8 Other Land	0.955	0.000	0%
Pervious Ground 9 GKI Land	0.955	0.000	0%
Pervious Ground 9 Other Land	2.782	0.000	0%
Pervious Ground 11	0.315	0.000	0%

Table K5.3 below shows estimated demand from the roof subcatchments for toilet flushing and landscaping.

Table K5.3 – MUSIC- roof harvest reuse (developed case scenario)

Subcatchment	Roof area (ha)	Estimated annual usage toilet flush (kL/year)	Estimated annual usage landscape irrigation (kL/year)
Roof Tanked 5	0.032	91.3	4632.6
Roof Tanked 7	0.328	935.8	33791.3
Roof Tanked 8 GKI Land	0.816	11276.7	70967.6
Roof Tanked 9 GKI Land	0.324	1913.3	22591.1
Roof Tanked 11	1.500	4279.6	175579.2

K.6 Bio-retention Basin Details

Typical details of the proposed stormwater quality improvement structures are illustrated on drawing number R02 in Appendix C.

Table K6.1 below details minimum sizing (area and depth) for stormwater quality management in the various catchments.

To enhance the overall environmental benefits, it is strongly recommended that a distributed or decentralised network of smaller bio retention "cells" should be provided, rather than larger, centralised catchment scale structures.

Accordingly, sizing details are provided in a "per unit" format and should be prorated to suit the specific contributing catchment areas as the detailed architectural, landscaping and civil engineering designs are developed. It is anticipated that specific structures will be located in a distributed fashion throughout the developed areas to suit surface flow patterns and to enhance local landscaping.

Table K6.1 – Stormwater Quality Improvement Devices - minimum sizing requirements

Area	Bio-retention Basin Details per 1000m^2 of Catchment Area		
	Filter Area (m^2)	Surface Area (m^2)	Extended Detention (m)
5	2.5	20	0.1
7	2.5	20	0.1
8	10.0	20	0.1
9	5.0	22	0.1
11	2.0	19	0.1
14	22.0	40	0.1

To ensure that actual operational performance matches the modelling and preliminary sizing, relevant components of the stormwater quality improvement devices must be detailed generally in accordance with details and specifications contained in the Water Sensitive Urban Design Guidelines for South East Queensland (Healthy Waterways - Version 1 June 2006).

K7. Results

K7.1 Average annual pollutant load reductions

The analysis shows that the load-based treatment objectives outlined in SPP 4/10 are exceeded.

A comparative summary of the mean annual load reduction results is detailed below in Table K9.

Table K7.1.1 – Average Annual Pollutant Load Reduction

Area	Indicator	Percent reduction target	No treatment - mean annual load (kg year^{-1})	Treated - mean annual load (kg year^{-1})	Percent reduction modelled	Complies?
5	TSS	≥85%	152.0	21.2	86.1%	Yes
	TP	≥70%	0.181	0.0422	76.7%	Yes
	TN	≥45%	1.51	0.401	73.3%	Yes
	GP	≥90%	9.91	0.0	100.0%	Yes
7	TSS	≥85%	7870.0	1040.0	86.8%	Yes
	TP	≥70%	8.00	2.00	75.0%	Yes
	TN	≥45%	63.5	23.7	62.7%	Yes
	GP	≥90%	566.0	0.0	100.0%	Yes
8	TSS	≥85%	24400	3530	85.6%	Yes
	TP	≥70%	22.6	5.84	74.1%	Yes
	TN	≥45%	180.0	72.8	59.6%	Yes
	GP	≥90%	1660.0	0.0	100.0%	Yes
9	TSS	≥85%	50100.0	7460.0	85.1%	Yes
	TP	≥70%	56.4	14.5	74.3%	Yes
	TN	≥45%	419.0	170.0	59.5%	Yes
	GP	≥90%	3790.0	0.0	100.0%	Yes
11	TSS	≥85%	16100.0	1930.0	88.0%	Yes
	TP	≥70%	16.4	3.11	81.0%	Yes
	TN	≥45%	132.0	37.4	71.7%	Yes
	GP	≥90%	1080.0	0.0	100.0%	Yes
14	TSS	≥85%	19400.0	1700.0	91.2%	Yes
	TP	≥70%	18.7	5.41	71.1%	Yes
	TN	≥45%	146.0	80.2	45.1%	Yes
	GP	≥90%	1400.0	0.0	100.0%	Yes

K7.2 Pollutant concentrations

The MUSIC engine can also report modelled pollutant concentrations at each time step. However, MUSIC concentration results cannot be compared directly to defined receiving water WQOs.

Receiving water WQOs are mean or median values of discrete samples in a continuum which is always present - the ocean.

By comparison, stormwater run-off is an intermittent occurrence interspersed with longer periods of zero flow. Modelled pollutant concentrations are mean or median values occurring during these discrete, and relatively rare, flow events within the confines of the waterway and prior to dilution at a receiving water (in this case, the ocean).

Modelled concentration results should be read with caution and are best viewed comparing pre-development and post-development (mitigated) concentrations. The following tabulation provides that comparison. (In calculating modelled means or medians, time steps with zero flow have been excluded.)

Table K7.2.1 – Modelled Runoff Concentrations

Catchment	Indicator	Existing (undeveloped) (mg/L)	Developed (mitigated) (mg/L)	Post-development concentrations are equal to or lower than existing?
5	TSS (annual mean)	31.20	6.12	Yes
	TP (annual median)	0.018	0.017	Yes
	TN (annual median)	0.273	0.262	Yes
	GP (annual median)	0.0005	0.0000	Yes
7	TSS (annual mean)	48.90	5.74	Yes
	TP (annual median)	0.020	0.018	Yes
	TN (annual median)	0.295	0.279	Yes
	GP (annual median)	0.0034	0.0000	Yes
8	TSS (annual mean)	65.80	54.20	Yes
	TP (annual median)	0.028	0.021	Yes
	TN (annual median)	0.354	0.310	Yes
	GP (annual median)	0.0866	0.0000	Yes
9	TSS (annual mean)	57.80	52.80	Yes
	TP (annual median)	0.021	0.021	Yes
	TN (annual median)	0.308	0.307	Yes
	GP (annual median)	0.0407	0.0000	Yes
11	TSS (annual mean)	48.70	5.35	Yes
	TP (annual median)	0.019	0.017	Yes
	TN (annual median)	0.289	0.263	Yes
	GP (annual median)	0.0196	0.0000	Yes
14	TSS (annual mean)	12.50	12.50	Yes
	TP (annual median)	0.091	0.091	Yes
	TN (annual median)	1.020	1.010	Yes
	GP (annual median)	0.0000	0.0000	Yes

K8. Conclusions

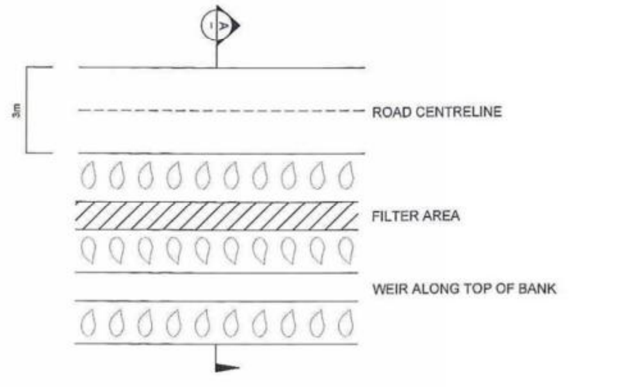
The modelling and analysis results demonstrate that the proposed mitigation measures achieve two key results:

- reductions in mean annual loads for modelled pollutants which **exceed (ie are better than)** the target values defined in SPP 4/10 Healthy Waters; and
- modelled post-development pollutant concentrations at the point of discharge to the receiving waters during flow events which are **equal to or lower** than the modelled concentrations at the same discharge points under the existing conditions.

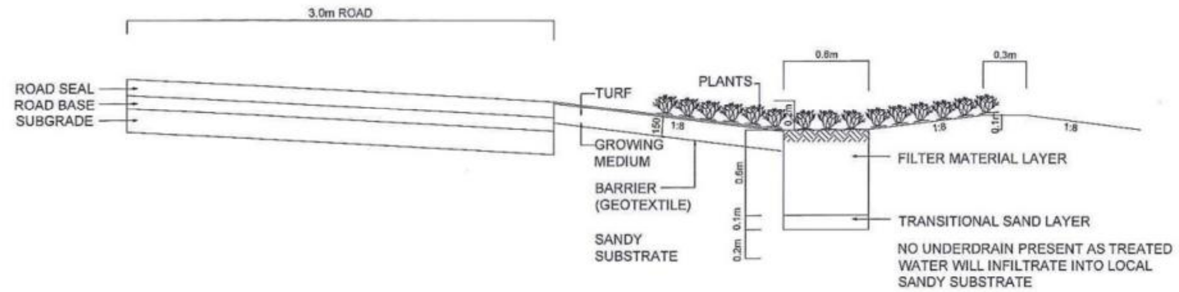
APPENDIX L

Stormwater Drawings

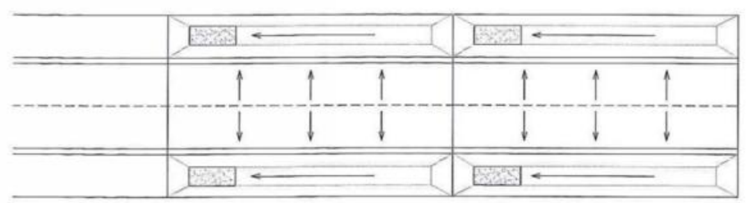

LEGEND
CATCHMENT BOUNDARY
AREA NUMBER
DEVELOPED WHARF AREA
MARINA PRECINCT
CLAM BAY PRECINCT
FISHERMAN'S BEACH PRECINCT
SECRET BEACH
BUTTERFISH BAY
LITTLE PENINSULA
SANDHILL BEACH
SVENDSEN'S BEACH
WRECK BEACH
WRECK BAY
LITTLE WRECK BEACH
BALD ROCK POINT
RED BEACH
CLAM BAY
WYNDHAM COVE
LONG BEACH
LITTLE MONKEY POINT
MONKEY POINT
MONKEY BEACH
SHELVING BEACH
FISHERMAN'S BEACH
PUTNEY BEACH
PUTNEY POINT
CHOCOLATE ROCKS
LEEKE'S BEACH
PRELIMINARY
Original Sheet Size A1 [841x594]
Plot Date
1:10000 @ A1
0 100 200 300 400 500 600 700 800 900 1000 m
OPUS
Toowoomba Office
PO Box 2279
Toowoomba QLD 4350
Australia
+61 7 4639 9500
Drawn EJP
Designed AEL
Approved AEL
Revision Date 05/07/2011
Project No. N-B0160
Scale 1:10000 at A1
Project GREAT KEPPEL ISLAND
Sheet CATCHMENT BOUNDARIES - PROPOSED
Drawing No. N-B0160.00
Sheet No. R01
Revision R0



PLAN VIEW OF PROPOSED ROAD BIORETENTION SYSTEM
SCALE 1:100



SECTION A-A
SCALE 1:20



PLAN VIEW OF PROPOSED RUNWAY BIORETENTION SYSTEM
SCALE 1:100

LEGEND
- FLOW DIRECTIONS
- BIO-RETENTION BASIN
- CATCHMENT BOUNDARIES

PRELIMINARY

OPUS Toowoomba Office
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Drawn	Designed	Approved	Revision Date
EJP	AEL	AEL	06/07/2011

Project No.	Scale
N-B0160	AS SHOWN

Project: GREAT KEPPELL ISLAND

Sheet: PROPOSED BIO-RETENTION SYSTEMS - DETAILS

Drawing No.	Sheet No.	Revision
N-B0160	R02	R0

Original Sheet Size A1 [841x594] Plot Date


LEGEND
CATCHMENT BOUNDARY
AREA NUMBER
POTENTIAL DETENTION BASIN LOCATIONS
DEVELOPED WHARF AREA
MARINA PRECINCT
FISHERMAN'S BEACH PRECINCT
CLAM BAY PRECINCT
SECRET BEACH
BUTTERFISH BAY
LITTLE PENINSULA
SANDHILL BEACH
SVENDSEN'S BEACH
WRECK BEACH
WRECK BAY
LITTLE WRECK BEACH
BALD ROCK POINT
RED BEACH
CLAM BAY
WYNDHAM COVE
LONG BEACH
LITTLE MONKEY POINT
MONKEY POINT
MONKEY BEACH
SHELVING BEACH
FISHERMAN'S BEACH
PUTNEY BEACH
PUTNEY POINT
CHOCOLATE ROCKS
LEEKE'S BEACH
PRELIMINARY
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PO Box 2279
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Australia
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GREAT KEPPEL ISLAND
DETENTION BASIN LOCATION
- PROPOSED
EJP
AEL
AEL
02/08/2011
N-B0160
1:10000 at A1
N-B0160.00
R03
R0
Original Sheet Size A1 [841x594]
Plot Date 02/08/11 @ 15:07
1:10000 @ A1

APPENDIX M

Preliminary Hazardous Substance Management Plan

Great Keppel Island Resort Revitalisation Plan

Preliminary Hazardous Substance Management Plan

For GKI Resort Pty Ltd

Revision A

15 September 2011

Opus International Consultants (PCA) Pty Ltd
ABN 89 096 110 262

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Preliminary Hazardous Substance Management Plan

Great Keppel Island Resort Revitalisation Plan

Revision A

TABLE OF CONTENTS

DOCUMENT HISTORY

REVISION / ISSUE RECORD

DATE	DESCRIPTION	REV	AUTHOR	VERIFIED
15/9/2011	Approval	A	MF	TB

DISTRIBUTION RECORD

	REVISION No. / Qty Issued				
RECIPIENT	**A**	**B**	**C**	**D**	**E**
GKI Resort Pty Ltd	1				

Prepared By:

MARK FARREY
Environmental Consultant

Approved for Issue:

for **Tracey Birt**
Work Group Manager ~ Environmental & Planning

1. GENERAL

The spillage or leakage of hazardous substances transported, used, stored or disposed of during the construction and operational phases of the GKI Resort Revitalisation Plan has the potential to contaminate soils, surface waters and groundwater and impact on vegetation, fauna, soil and water quality.

Hazardous substances likely to be stored on site will vary throughout construction and operational phases of the project, and may include:

1.1 Construction

- Diesel for use in generators, construction vehicles, plant and equipment;
- Other fuels and oils used in vehicles and equipment; and,
- Waste oils, batteries, paints, thinners and solvents.

1.2 Operation

- Diesel (or biodiesel) for standby generators;
- Other fuels and oil for use in resort vehicles (including tour boats, maintenance vehicles) and for maintenance and operation of aircraft associated with the new runway and airport facilities;
- Chemicals used in the operation of the wastewater treatment plant(s);
- Chemicals and fertilisers used for maintenance of the golf course, sporting fields and landscaped areas;
- Paints, solvents, thinners etc used during general resort maintenance; and
- Chemicals used for cleaning during operation of the resort

2. Objectives

The objectives of this Hazardous Substance Management Plan are:

- To prevent the degradation of water quality as a result of storage, handling and disposal of hazardous substances (including chemicals and fuel); and
- To prevent the contamination of soil as a result of storage, handling and disposal of hazardous substances (including chemicals and fuel).

3. Management Measures

- Hazardous substances (including dangerous goods and hazardous materials) present inherent environmental risks in storage, use and disposal. Wherever possible, non-hazardous alternatives shall be used;
- Only the minimum essential stocks of items such as chemicals and fuels are to be stored on site at any one time;
- Refuelling of vehicles during construction and operation of the resort shall occur only within a designated bunded hardstand area provided with a stormwater containment system to prevent discharge of any leaks of spills to surrounding soil or water bodies;

- Spill kits shall be kept on site at all times. Spill kits are to be located where hazardous substances are stored and used. All site personnel (including contractors) are to be trained in the use of spill kits;
- The Material Safety Data Sheets (MSDS) for all hazardous substances stored or handled on site are to be kept on site and are to be made readily available to personnel. MSDS shall be kept up-to-date at all times. Hazardous substances and materials must only be handled by trained personnel and in accordance with the relevant MSDS;
- All hazardous substances and materials must be stored and transported in accordance with the relevant MSDS and relevant Australian Standards and Dangerous Goods regulations, if applicable;
- All hazardous substances and materials shall be stored in a manner that prevents or minimises the impact of any accidental spills or releases. Hazardous substance storage areas shall be designed and constructed in accordance with AS1940:2004 – Storage and Handling of Flammable and Combustible Liquids;
- Any stormwater captured within bunded areas used for the storage or handling of wastes or other hazardous materials shall be pumped out and disposed of at an appropriately licensed facility. Regular inspections shall be undertaken for stormwater drainage systems in areas used for the storage or handling of wastes and other hazardous materials to ensure all drains are free of litter and operating at optimum efficiency;
- All hazardous substance storage areas shall be located at least 50 metres from any watercourse or drainage line;
- If any potentially dangerous wastes (ie. hazardous materials, soils contaminated by paints, fuels, oil, etc) are encountered during the project, the location and details of the waste must be reported to the Project Manager (Construction) or Resort Manager (Operation);
- Where hazardous waste is to be removed from the site, the waste must only be transported by an operator licensed under the Environmental Protection Act 1994. Waste tracking documentation must be completed upon dispatch of the waste off-site and records kept on file;
- Any leakage or spillage of hazardous substances will trigger immediate spill response and clean up procedures, and repair or improvement of storage areas and/or equipment;
- Where the storage or handling of hazardous substances does not comply with this Plan, additional training shall be provided to site personnel involved;
- Any complaint and/or environmental incident will trigger corrective actions immediately; and,
- All corrective actions shall be approved by the Project Manager (Construction) or Resort Manager (Operation) and shall be developed in consultation with the relevant regulatory authorities where appropriate.

4. Responsibility

- The Project Manager shall be responsible for implementation and enforcement of the Hazardous Substance Management Plan during construction, with compliance to be audited on a regular basis; and
- The Resort Manager shall be responsible for implementation and enforcement of the Hazardous Substance Management Plan during operation of the resort facilities.

5. Monitoring & Reporting

5.1 General

All complaints or environmental incidents relating to the storage, handling and disposal of hazardous substances must be recorded in an appropriate complaints register, which shall be kept for inspection by DERM and GBRMPA on request.

5.2 Construction

Daily inspections of the construction site shall be undertaken by the Site Supervisor to ensure hazardous substances are being stored and used in accordance with this Plan and applicable MSDS. Records of inspections shall be provided to the Project Manager and kept for inspection by DERM and GBRMPA on request.

5.3 Operation

Weekly inspections of the hazardous substance storage areas shall be undertaken by the Resort Manager, or a delegated person, to ensure hazardous substances are being stored and used in accordance with this EMP and applicable MSDS. Records of inspections shall be kept for inspection by DERM and GBRMPA on request.

APPENDIX N

Preliminary Stormwater Quality Maintenance Plan

Great Keppel Island Resort EIS

For GKI Resort Pty Ltd

Stormwater Quality Maintenance Plan

30 August 2011

Opus International Consultants (PCA) Pty Ltd

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Report

Great Keppel Island Resort EIS

Stormwater Quality Maintenance Plan

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Prepared By: **Joshua Goodall**
Civil Engineer

Approved for Issue: **Tony Loveday**
Work Group Manager ~ Environmental

1. GENERAL

The spillage or leakage of hazardous substances transported, used, stored or disposed of during the construction and operational phases of the GKI Resort Revitalisation Plan has the potential to contaminate soils, surface waters and groundwater and impact on vegetation, fauna, soil and water quality.

Hazardous substances likely to be stored on site will vary throughout construction and operational phases of the project, and may include:

1.1 CONSTRUCTION

- Diesel for use in generators, construction vehicles, plant and equipment;
- Other fuels and oils used in vehicles and equipment; and,
- Waste oils, batteries, paints, thinners and solvents.

1.2 OPERATION

- Diesel (or biodiesel) for standby generators;
- Other fuels and oil for use in resort vehicles (including tour boats, maintenance vehicles) and for maintenance and operation of aircraft associated with the new runway and airport facilities;
- Chemicals used in the operation of the wastewater treatment plant(s);
- Chemicals and fertilisers used for maintenance of the golf course, sporting fields and landscaped areas;
- Paints, solvents, thinners etc used during general resort maintenance; and
- Chemicals used for cleaning during operation of the resort

2. OBJECTIVES

The objectives of this Hazardous Substance Management Plan are:

- To prevent the degradation of water quality as a result of storage, handling and disposal of hazardous substances (including chemicals and fuel); and
- To prevent the contamination of soil as a result of storage, handling and disposal of hazardous substances (including chemicals and fuel).

3. MANAGEMENT MEASURES

- Hazardous substances (including dangerous goods and hazardous materials) present inherent environmental risks in storage, use and disposal. Wherever possible, non-hazardous alternatives shall be used;
- Only the minimum essential stocks of items such as chemicals and fuels are to be stored on site at any one time;
- Refuelling of vehicles during construction and operation of the resort shall occur only within a designated bunded hardstand area provided with a stormwater containment system to prevent discharge of any leaks of spills to surrounding soil or water bodies;

- Spill kits shall be kept on site at all times. Spill kits are to be located where hazardous substances are stored and used. All site personnel (including contractors) are to be trained in the use of spill kits;
- The Material Safety Data Sheets (MSDS) for all hazardous substances stored or handled on site are to be kept on site and are to be made readily available to personnel. MSDS shall be kept up-to-date at all times. Hazardous substances and materials must only be handled by trained personnel and in accordance with the relevant MSDS;
- All hazardous substances and materials must be stored and transported in accordance with the relevant MSDS and relevant Australian Standards and Dangerous Goods regulations, if applicable;
- All hazardous substances and materials shall be stored in a manner that prevents or minimises the impact of any accidental spills or releases. Hazardous substance storage areas shall be designed and constructed in accordance with AS1940:2004 – Storage and Handling of Flammable and Combustible Liquids;
- Any stormwater captured within bunded areas used for the storage or handling of wastes or other hazardous materials shall be pumped out and disposed of at an appropriately licensed facility. Regular inspections shall be undertaken for stormwater drainage systems in areas used for the storage or handling of wastes and other hazardous materials to ensure all drains are free of litter and operating at optimum efficiency;
- All hazardous substance storage areas shall be located at least 50 metres from any watercourse or drainage line;
- If any potentially dangerous wastes (ie. hazardous materials, soils contaminated by paints, fuels, oil, etc) are encountered during the project, the location and details of the waste must be reported to the Project Manager (Construction) or Resort Manager (Operation);
- Where hazardous waste is to be removed from the site, the waste must only be transported by an operator licensed under the Environmental Protection Act 1994. Waste tracking documentation must be completed upon dispatch of the waste off-site and records kept on file;
- Any leakage or spillage of hazardous substances will trigger immediate spill response and clean up procedures, and repair or improvement of storage areas and/or equipment;
- Where the storage or handling of hazardous substances does not comply with this Plan, additional training shall be provided to site personnel involved;
- Any complaint and/or environmental incident will trigger corrective actions immediately; and,
- All corrective actions shall be approved by the Project Manager (Construction) or Resort Manager (Operation) and shall be developed in consultation with the relevant regulatory authorities where appropriate.

4. RESPONSIBILITY

- The Project Manager shall be responsible for implementation and enforcement of the Hazardous Substance Management Plan during construction, with compliance to be audited on a regular basis; and
- The Resort Manager shall be responsible for implementation and enforcement of the Hazardous Substance Management Plan during operation of the resort facilities.

5. MONITORING & REPORTING

5.1 GENERAL

All complaints or environmental incidents relating to the storage, handling and disposal of hazardous substances must be recorded in an appropriate complaints register, which shall be kept for inspection by DERM and GBRMPA on request.

5.2 CONSTRUCTION

Daily inspections of the construction site shall be undertaken by the Site Supervisor to ensure hazardous substances are being stored and used in accordance with this Plan and applicable MSDS. Records of inspections shall be provided to the Project Manager and kept for inspection by DERM and GBRMPA on request.

5.3 OPERATION

Weekly inspections of the hazardous substance storage areas shall be undertaken by the Resort Manager, or a delegated person, to ensure hazardous substances are being stored and used in accordance with this EMP and applicable MSDS. Records of inspections shall be kept for inspection by DERM and GBRMPA on request.

1. GENERAL

1.1 AIMS AND OBJECTIVES

The stormwater quality maintenance plan is to ensure that the stormwater quality improvement devices and techniques adopted for this site perform as anticipated throughout the life of the Project.

1.2 DISTINCT PHASES

Stormwater quality management for this site has two distinct phases - construction and operation. This maintenance plan addresses the management of the quality improvement devices in each phase.

1.3 CONSTRUCTION

During the construction phase, the most significant water quality objective is the management of suspended solids. Temporary erosion and sediment control such as silt fences and sediment basins, if required, will be utilised during the construction phase.

Additional stormwater quality improvement devices to manage the operational phase will be constructed as part of the proposed development. It is important that these devices are either not constructed, or are constructed and blanked off, until after completion of all the ground disturbing activities. Post construction stormwater quality improvement devices are not intended to deal with the high sediment loads typically encountered in storm events during the construction phase.

Catch drains and silt fences will be constructed and moved as required during the ground disturbing activities on site to ensure that any sediment laden run-off is contained and redirected. Silt fences should be placed along catch drains to slow flow, reduce scour and capture sediment.

Silt fences must be installed downstream of all disturbed areas and stockpile sites.

The Preliminary Erosion & Sediment Control Guideline in Appendix H addresses the construction phase in further detail.

1.4 OPERATION

During the operational phase, the most significant pollutants for a tourist resort development of this type are litter, nutrients and fine solids from erosion.

2. MAINTENANCE ACTIONS

2.1 CONSTRUCTION PHASE

Maintenance revolves around ensuring inlet erosion protection (where provided) is operating as designed and monitoring sediment and debris accumulation.

Sand bags are to be placed around any gully inlets to stop silt entering gullies until construction phase activities are complete.

Debris removal is an ongoing maintenance function. Inspection and removal of debris should be done regularly, but debris should be removed whenever it is observed on the site.

Silt fences and other erosion control measures must be inspected after all significant rainfall events. Collected material should be removed and any damaged areas or control measures should be replaced or repaired immediately.

2.2 OPERATIONAL PHASE

2.2.1 Bio-retention Basins

Bio-retention basins treat run-off by filtering it through vegetation and then passing run-off vertically through a filtration media which filters the run-off. Surface flows are conveyed through overflow pits or bypass paths to protect the filter media surface from high velocities that can dislodge collected pollutants or scour vegetation. On this site, bio-retention basin outlets will generally be to the porous sub-soils.

Besides vegetative filtration, treatment relies upon detention and soil filtration. Vegetation is the key to maintaining the porosity of the soil media in the bio-retention system and a strong healthy growth of vegetation is critical to its performance. The potential for riling and erosion along the basin component of the system needs to be carefully monitored during the establishment stage of the system.

The most intensive period of maintenance is during plant establishment (first one to two years) when weed removal and replanting may be required. It is also the time when large loads of sediments could affect plant growth. Other components of the system that require careful consideration are the inlet points. These can be prone to scour and build up of litter. Any field inlet pits require routine inspections to ensure structural integrity and that they are free of blockages with debris.

Sediment accumulation needs to be monitored. Should excessive sediment build up, it will affect plant health and require removal before it reduces the infiltration rate of the filter media.

Similarly, debris removal is an ongoing maintenance function. Inspection and removal of debris should be done regularly, but debris should be removed whenever it is observed on the site.

Maintenance of basin areas includes:

- Removal of sediment build-up;
- Removal of debris;
- Repairing any damage to basin surface profiles resulting from scour or rill erosion;
- Regular watering/irrigation of vegetation until plants are established and actively growing;
- Vegetation pest monitoring and control;
- Removal and management of invasive weeds and removal and replacement of plants that may have died.

Resetting (i.e. complete reconstruction) of bio-retention basins will be required if the system fails to drain adequately after tilling of the surface. Inspections are recommended following large storm events to check for scour and other damage.

3. MAINTENANCE SCHEDULE

3.1 BIO-REMEDIATION BASINS

The bio-reremediation basin maintenance checklist should be used whenever an inspection is conducted and to be kept as a record of the asset condition and quantity of removed pollutants over time. A copy of such a check list is included in Attachment 1 and repeated below for ease of reference.

BIO-REREMEDIATION BASIN MAINTENANCE CHECK LIST

Inspection frequency:	**1-6 monthly**	**Date of visit:**		
Location:				
Description:				
Site visit by:				
Inspection items:		Y	N	Action required (details)
Sediment accumulation at inflow points?				
Litter within basin?				
Erosion at inlet or other key structures?				
Traffic damage present?				
Evidence of dumping (eg building waste)?				
Vegetation condition satisfactory (density, weeds etc)?				
Watering of vegetation required?				
Replanting required?				

Trimming/weeding required?			
Clogging of drainage points (sediment or debris)?			
Evidence of ponding?			
Damage/vandalism to structures present?			
Surface clogging visible?			
Resetting of system required?			
Comments:			

Bio-remediation basins should be checked after any significant run-off event, at least monthly until vegetation has fully established, and at least six monthly after that.

4. MANAGEMENT STRUCTURE

Management of the Stormwater Quality Maintenance Plan will be the responsibility of the following people:

- Site Manager;
- Site Staff (Reporting to the Site Manager);
- Subcontractors (Reporting to the Site Manager).

5. RESPONSIBILITIES

The Site Manager has overall responsibility for all operational aspects on site. The Manager will ensure that the requirements of the Stormwater Quality Maintenance Plan are implemented. The Manager will ensure that all site staff are familiar with the Stormwater Quality Maintenance Plan and their responsibilities contained within the plan. The Site Manager will also ensure that resources are allocated to meet the requirements of the maintenance plan.

Site staff will undertake site inspections and identify any potential maintenance issues. They will identify resources required for the implementation of the maintenance plan and let the Site Manager know what they are. Site staff will be required to implement control actions as necessary and will be allocated resources as required. Site staff will co-ordinate and refer any environmentally related issues or complaints to the Site Manager.

Audits of the maintenance plan will be undertaken by the site staff on behalf of the Site Manager and reports prepared on relevant issues. Compliance or non-compliance with the maintenance plan will be reported to all personnel and subcontractors engaged in the Project.

6. ONGOING MONITORING

Internal audits will be carried out to verify compliance with the stormwater quality maintenance program defined by this plan. The audit will also encompass work carried out by suppliers and subcontractors. The audit program will be managed by the Site Manager who will either undertake the audit personally or make arrangements for the audits to be carried out by appropriately trained site staff.

The Site Manager will maintain a forward schedule of all audits planned, maintain records of audits, and ensure that corrective actions are properly implemented. Audits will, among other things, determine whether periodic inspections and monitoring are being undertaken and if there are any issues with meeting specified guidelines. Audits will be carried out at approximately annual intervals.

7. RECORD KEEPING AND REPORTING

The Site Manager will maintain a record of all audits undertaken.

The site staff who undertake the regular maintenance inspections will complete inspection check sheets to show that inspections have taken place and as a record of any non-conformances which had been noted. Check sheets will be filed and archived.

8. NON-COMPLIANCE PROCEDURES

As soon as it is recognised that any stormwater quality management device is defective and requires repair or reinstatement, the inspecting staff member will advise the Site Manager who will inspect the defective item to review the extent of repair or rectification required. Repairs will then be carried out as required.

A register of non-conformances will be established for active and resolved non-conformances.

9. PERSONNEL TRAINING

All personnel who will be involved in the maintenance of the stormwater quality management devices or who will be carrying out activities which might impact adversely on the devices will undergo an environmental management training session. The session will be run by the Site Manager before staff commence work on site or before they commence activities which might impact on the stormwater quality devices.

The initial session will be introductory only and will not deal with specific activities. Its intent is to ensure that everyone is aware of the purpose of the stormwater quality management devices and the potential consequences of damage or inadequate maintenance.

An additional detailed session will be held for those staff specifically engaged in the maintenance of the stormwater quality management devices. This session will review in detail the work to be carried out in maintaining and monitoring the condition of the stormwater quality improvement devices.

10. WASTE MANAGEMENT

Debris and litter will be disposed of in accordance with the Waste Management Plan. Contaminated sediments will be removed and disposed of by an approved waste disposal contractor in accordance with the Waste Management Plan.

11. REVIEW AND UPDATE

This maintenance plan will be reviewed and updated as required. Record sheets from the regular internal audits will be used to identify any part of the maintenance plan which needs to be modified or updated.

ATTACHMENT 1

Bio-Retention Basin Maintenance Checklist

BIO-REMEDIATION BASIN MAINTENANCE CHECK LIST

Inspection frequency:	**1 to 6 monthly**	**Date of visit:**	
Location:			
Description:			
Site visit by:			
Inspection Items	Y	N	Action required (details)
Sediment accumulation at inflow points?			
Litter within basin?			
Erosion at inlet or other key structures?			
Traffic damage present?			
Evidence of dumping (eg building waste)?			
Vegetation condition satisfactory (density, weeds etc)?			
Watering of vegetation required?			
Replanting required?			
Trimming/weeding required?			
Clogging of drainage points (sediment or debris)?			
Evidence of ponding?			
Damage/vandalism to structures present?			
Surface clogging visible?			
Resetting of system required?			
Comments:			

APPENDIX O

Preliminary Erosion and Sediment Control Management Plan

Great Keppel Island Resort Revitalisation Plan

Preliminary Erosion and Sediment Control Management Plan

For GKI Resort Pty Ltd

Revision A

15 September 2011

Opus International Consultants (PCA) Pty Ltd

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Preliminary Erosion and Sediment Control Management Plan

Great Keppel Island Resort Revitalisation Plan

Revision A

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Prepared By: **Tony Loveday**
Work Group Manager ~ Environmental

Approved for Issue: **George Chen**
Senior Civil Engineer

APPENDIX O: PRELIMINARY EROSION AND SEDIMENT CONTROL MANAGEMENT PLAN

1.1 PURPOSE

The following conceptual Erosion and Sediment Control Management Plan has been prepared as part of an environmental impact statement (EIS) for the GKI Resort Revitalisation Plan at Great Keppel Island. The aim of this management plan is to address water quality and sediment runoff issues during the construction phase of the development. It will also aim to provide a description of the techniques to manage the impact of erosion and sediment run-off on the sensitive receiving environment.

1.2 SITE DESCRIPTION

1.2.1 Site Drainage & Topography

At the time of writing this report, no detailed level survey was available. However, the general relief of the Island is shown with the background contours on drawings R01 and R03 in Appendix L – Water Cycle Management Report. The following is an extract from the preliminary geotechnical assessment prepared by Douglas Partners:

"The overall topography of Great Keppel Island is relatively steep and is dominated by two south-east to north-west trending ridges with a maximum elevation of approximately 175m AHD. Leeke's, Putney and Blackall creeks drain these ridges to the west of the island and there are some tidal wetlands behind Putney Beach and Leeke's Beach. Other minor, perennial creeks are relatively short and flow directly to the ocean. A flat to undulating topography is present in the dune sand areas in the north-east and south-west regions of the island. The topography becomes slightly undulating on the eastern side of the island towards Wreck Bay."

1.2.2 Soils

A preliminary geotechnical assessment has been carried out and report prepared by Douglas Partners (December 2010). The report describes the subsurface conditions as predominantly silty sand and sand. Results of the laboratory testing indicate an Emerson Class Number of 6 and soils with a medium potential for erosion. Further information in the report indicates fine granular soils, but several other factors need to be assessed to determine the complete erosion hazard assessment prior to construction.

1.2.3 Disturbance Area

The disturbance area of the proposed development should be confined to the works areas only and the disturbance should be limited to a maximum of 2ha in order to minimise the potential for erosion. If the proposed work results in a larger area, staging should be implemented to limit the disturbance area.

1.3 GENERAL

All erosion and sediment control measures should be in accordance with the following guidelines:

- International Erosion Control Association (IECA) Best Management Practices (2008);
- the latest version of the Institution of Engineers (QLD) 'Soil Erosion and Sediment Control – Engineering Guidelines for Queensland Construction Sites';
- EPA's Best Practice Urban Stormwater Management: Erosion and Sediment Control Guideline; and,
- Great Barrier Reef Marine Park Authority – Water Quality Guidelines (2010), Great Barrier Reef Marine Park Act 1975 and the Reef Water Quality Protection Plan 2009.

All erosion and sediment control devices implemented onsite should represent current best management practices and all practical measures applicable to the site. These best management practices are to be applied to all stages of the project including construction, operation, and management of the control measures including maintenance and monitoring of the devices.

1.4 ENVIRONMENTAL DUTY

In accordance with the *Environmental Protection Act (EPA) 1994* all personnel are to comply with the general environmental controls under Sections 319 and 320.

According to Section 319 of the EPA, all persons involved in the project, from design to construction, are to have a responsibility to comply with the 'general environmental duty'. This requires all reasonable and practicable measures to be adopted to prevent or minimise environmental harm. Consequently, any erosion and sediment control devices proposed or implemented on site must represent current best management practices and all practical measures applicable to the site.

Further, under Section 320 of the EPA, all personnel have a duty to notify their employer, the Local Regulatory Authority and the Environmental Protection Agency (QLD) should they become aware of a potential or actual incident of environmental harm. As such, it is the Principal Contractor's responsibility to ensure all site Contractors and site personnel are aware of and understand their environmental duties.

1.5 RESPONSIBILITY

In addition to the general environmental duty which applies to all persons, it is the Contractor's responsibility to implement and maintain all the erosion and sediment control measures on site, until all disturbed areas are reinstated. This management plan present concepts only. The contractor is at all times responsible for the establishment, management and maintenance of the erosion and sediment control measures to ensure minimal environmental harm and best management practices.

1.6 EROSION AND SEDIMENT

1.6.1 Erosion Risk Assessment

The Revised Universal Soil Loss Equation (RUSLE) is to be utilised to predict the total soil loss, in tonnes (t), from both sheet and rill erosion from the construction sites. The RUSLE equation is shown below:

Soil Loss (t) = RUSLE x Area of disturbance (ha) x duration of disturbance (years)

RUSLE = Computed Soil Loss (t/ha/yr) = (R x K x LS x P x C)
R = rainfall erosivity factor
K = soil erodibility factor
LS = slope length/gradient factor
P = erosion control practice
C = ground cover and management factor

As shown above, there are several contributing factors that are required to undertake an erosion hazard assessment prior to construction. These factors include:

- the extent of site disturbance (ha);
- the duration of site disturbance (years);
- the rainfall erosivity factor during site disturbance (R);
- a representative soil erodibility factor (K);
- the average slope of the site;
- the area of external catchments (ha).

In accordance with the IECA Best Management Practice Guidelines, a soil loss of less than 150 tonnes corresponds to a 'low erosion risk' site and a soil loss of more than 150 tonnes corresponds to a 'high erosion risk' site. Due to the sensitive nature of this project and the pristine receiving environment, it is recommended that a Major Erosion & Sediment Control Management Plan be prepared. Each stage of the construction should be assessed and mitigating measures should be implemented accordingly.

Where large areas of land are being cleared, issues of biodiversity conservation will arise that need to be considered by the proponent and the relevant approving authority (QLD EPA). All consultants and contractors involved in preparing the major E&SCP should liaise closely to identify the planning needs, constraints and choice of best management practices (BMPs).

The various development design processes should integrate engineering and soil and water management planning. The major E&SCP should be prepared at the same time as engineering design for all construction works and included as part of the final engineering plans. Cross referencing soil and water management planning with site rehabilitation will also need to be considered.

1.6.2 Sediment Basin Requirement

Once the subject site has been assessed utilising RUSLE and the erosion risk identified, the need for a sedimentation basin can be determined. Sedimentation basins are usually implemented as part of major

E&SCP's and where the soils are predominantly dispersive. Sediment basins are required for the capture and control of sediment laden site runoff during the construction stage.

The sediment basin should be designed in accordance with the IECA's Best Practice Erosion & Sediment Control Guidelines. Further reference can be made to the 'Maroochy Manual for Erosion and Sediment Control' (Version 1.2), and Brisbane City Councils 'Sediment Basin Design, Construction and Maintenance Guidelines' (2001). The 'Maroochy Manual for Erosion and Sediment Control' is based on the NSW 'Managing Urban Stormwater: Soils and Construction' (2004), with amendments to suit the current Queensland legislative and planning framework and the local environment. The sediment basin would be rehabilitated once upstream construction is complete and all built-up sediments removed from the sediment basins.

Initial soil testing (*Douglas Partners Preliminary Geotechnical Assessment, Dec 2010*) indicates site soils are sandy corresponding to a Type C soil, although medium to high levels of dispersion has been noted in the laboratory test results. Due to the sensitive environment in which construction work will take place, it is recommended that a Type D basin may be appropriate for the site in accordance with the design objectives detailed in the table below. Further investigation and detailed design is required prior to operational works to establish the most appropriate basin type for each stage of the work.

Table 1: Sediment Basin Design Objectives

Basin Type	***Design Objectives***
Type C	• Coarse grained soils, < 33% finer then 0.02mm. • Type C basins allow rapid settling in wet or dry basins, without the use of flocculants. • The settling zone volume is calculated to provide capacity for the design particle to settle in the peak flow expected from the design storm, Q3month (half 1 year ARI). • Storage zone volume either 100% of the settling zone capacity (soil loss class 1-4) or 2-month soil loss (soil loss class 5-7) calculated by the RUSLE equation (see section 1.6). • Minimum depth 0.6m.
Type F	• Fine grained soils, > 33% finer then 0.02mm. • Type F basins require longer residence time (then type C basins) for fine sediment to settle. • The settling zone volume is calculated to provide capacity to contain all runoff expected from the 80th percentile, 5 day total runoff depth. • Storage zone volume either 50% of the settling zone capacity (soil loss class 1-4) or 2-month soil loss (soil loss class 5-7) calculated by the RUSLE equation (see section 1.6). • Average depth 0.6m.
Type D	• Contain a significant proportion of fine (<0.005mm) dispersible materials that will only settle if flocculated. Dispersible soils have >10% of soil materials dispersible. • The settling zone volume is calculated to provide capacity to contain all runoff expected from the 80th percentile, 5 day total runoff depth. • Storage zone volume either 50% of the settling zone capacity (soil loss class 1-4) or 2-month soil loss (soil loss class 5-7) calculated by the RUSLE equation (see section 1.6).

	• Average depth 0.6m.

The basin should be designed to ensure the water quality discharge criteria (50mg/L Total Suspended Solids) is met for the design storm. However the basin structure and outlets should be designed to ensure stability in the peak flow event (at least 10 year ARI). The sediment basin shape should be designed in accordance with a minimum length to width ratio of 3:1, to reduce short circuiting and average batter slopes of 1 in 3 for ease of maintenance.

1.6.3 Sediment Basin Discharge Criteria

All water discharged from the site must comply with the construction phase performance criteria below. These construction phase criteria are discharge standards and as such are applicable to runoff events or any pumped discharges from the sediment basins:

- Total Suspended Sediment: 90th percentile <50mg/L;
- pH close to that of the receiving water;
- Dissolved Oxygen: 90th percentile >80% saturation or 6mg/L;
- Hydrocarbons: No Visible sheen on receiving waters;
- Litter: No visible litter washed from site.

1.6.4 Water Quality Testing

Water quality testing should be undertaken onsite in accordance, as a minimum, with the procedure detailed below. Water quality monitoring is required to ensure compliance with the sediment discharge criteria and is the responsibility of the contractor.

Any monitoring undertaken should occur at least on a weekly basis and always before basin discharge. All water quality testing should be undertaken by a suitably qualified person.

Table 2: Water Quality Monitoring Procedure

Site/Soil Type	Criteria	Testing Method
Type C Soils	• No visible sediment, hydrocarbons, oils or anthropogenic gross pollutants discharging from site or entering receiving environment	• Visual inspection of site erosion management and sediment control measures/devices. • Visual inspection of drainage discharge points and prior to basin discharge. • Inspections conducted at least on a weekly basis.
Type F Soils	• Discharge turbidity no greater than 10% more than turbidity of receiving water • No visible sediment, hydrocarbons, oils or anthropogenic gross pollutants discharging from site or entering	• Manual turbidity recordings on a weekly basis and prior to basin discharge. • Visual inspection of site erosion management and sediment control measures/devices, at least on a weekly basis. • Visual inspection of drainage discharge

	receiving environment	points, at least on a weekly basis.
Type D Soils (Dispersive)	• TSS < 50mg/L • Discharge turbidity no greater than 10% more than turbidity of receiving water • pH values between 6.5-8.5 • No visible sediment, hydrocarbons, oils or anthropogenic gross pollutants discharging from site or entering receiving environment	• Field samples collected for TSS by suitably qualified professional, for testing at a NATA accredited laboratory prior to basin discharge. • Manual turbidity and pH recordings on a weekly basis and prior to basin discharge. • Visual inspection of site erosion management and sediment control measures/devices at least weekly. • Visual inspection of drainage discharge points, at least weekly.
Major Risk Sites / Sensitive receiving environments	• Water quality monitoring regime undertaken to establish base flows and water quality of receiving environment prior to works commencing. • TSS < 50mg/L • Discharge turbidity no greater than 10% more than turbidity of receiving water • pH values between 6.5-8.5 • No visible sediment, hydrocarbons, oils or anthropogenic gross pollutants discharging from site or entering receiving environment	• Base flow monitoring undertaken by suitably qualified professional, for testing at a NATA accredited laboratory. • Field samples collected for TSS by suitably qualified professional, for testing at a NATA accredited laboratory prior to basin discharge. • Manual turbidity and pH recordings on a weekly basis and prior to basin discharge. • Visual inspection of site erosion management and sediment control measures/devices at least weekly. • Visual inspection of drainage discharge points, at least weekly.

1.7 INSTREAM WORKS

1.7.1 General

Unless adequately managed, instream construction activities can represent a significant environmental hazard. Instream works and works within tidal waters will require approval from the Department of Environment and Resource Management (DERM) and may also require approval by the Department of Primary Industries and Fisheries.

Sediment released from a work site into a waterway or water body can cause an increase in both turbidity and bed load sediment. Turbidity consists of the clay and fine silt particles that generally do not settle until they reach quiescent or saline waters. Bed load sediment consists of the coarse silts, sands and gravels that move along, or close to, the bed of a watercourse.

Unnaturally high turbidity levels can cause adverse affects on aquatic life, such as:

- damage to fish gill membranes;
- reduced ability for aquatic life to feed by sighting food;

- general altering of aquatic habitat and behaviour;
- increased susceptibility to disease caused by stress; and,
- health problems associated with the transportation of pollutants attached to sediment particles such as nutrients, metals and pesticides.

Some of the potential impacts likely to result from unnaturally high bed-load sediment concentrations are listed below:

- Fine sediments that enter tidal waterways can be constantly resuspended into the water column by tidal movement resulting in increased turbidity levels;
- High water colum turbidity can reduce habitat diversity;
- Settled bed load sediment can increase local flooding problems and reduce the navigational limits of the waterways;
- Coarse sediment can smother aquatic vegetation and bed habitats; and,
- Fine sediments can settle as a fine dusting over the seabed, causing loss of seagrass through reduced photosynthesis and damage to coral habitats.

1.7.2 Key Management Principles

The key management principles for instream erosion and sediment control are:

- Appropriately plan and organise the work activities;
- Minimise channel or waterway disturbance;
- Control the movement of the water;
- Minimise soil erosion;
- Minimise the release of sediment and sediment-laden water; and,
- Promptly rehabilitate disturbed areas.

The choice of instream sediment control technique depends on a number of variables including flow rate, water depth, undisturbed water quality and the duration of the works. Further investigation is required prior to construction to identify the most appropriate techniques to manage instream works. Recommended site controls may include floating silt curtains or isolation barriers.

1.8 PROPOSED CONTROL MEASURES

The extent and position of the erosion and sediment control devices should be determined on site by the design consultant and contractors to suit the construction program.

1.8.1 Basic Concepts

The following fundamental concepts will form the foundation of the erosion and sediment control for the Project and should be reflected in the measures implemented:

- Erosion control measures favoured over sediment control devices, that is, any exposed surfaces should be stabilised as soon as practicable and sediment control devices used as a last defence;

- Limit disturbance by only clearing and disturbing areas necessary for works, disturbance should only extend 2-5m from necessary works areas;
- Minimise the extent and duration of disturbance by staging the works. Disturbed areas should be kept to workable areas, generally less than, say, 2ha; and,
- Divert all upstream stormwater runoff around the site and disturbed areas. Collect all stormwater from disturbed work areas for treatment as necessary.

1.8.2 Implementation sequence

All erosion and sediment control measures are required to be installed and functional prior to works commencing. The following implementation sequence should be adopted where practicable. Plans are to be updated and measures moved and reinstated to reflect site stages and progression of the works. The following implementation sequence is proposed:

Phase 1 – Prior to Works Commencing – Stripping and Bulk Earthworks

- Prior to any demolition, stripping or bulk earthworks on site, all required erosion and sediment control measures should be installed and operational.
- Provide a stabilised site access, either wash down area or shake down device at the construction site entrance to minimise the amount of sediment being tracked off the site. Generally, only a single site access point is to be provided, unless specific circumstances warrant additional access points.
- Sediment fences (or appropriate barrier fencing) are to be installed adjacent to the access point to confine ingress to and egress from the site to the established stabilised point.
- The wash down area/shake down device is to be drained to a suitable sediment capture device such as a sediment fence installed downstream of the construction entry.
- Inlet protection is to be provided to all gully pits, field or kerb inlets on all adjoining roads.
- All ‘clean’ upstream water is to be diverted around disturbed areas and stockpiles to minimise the amount of water flowing through the site, the amount of sediment mobilised and the amount of water requiring treatment.
- ‘No-go’ (restricted access) zones are to be established around areas of native vegetation to be retained and any areas which do not require disturbance, to limit the area of exposed soil.
- Earth banks are to be installed at intervals < 80 metres along slope contours to limit slope lengths.
- Sediment fences are to be installed 2-5 metres downstream of all works areas, including along the downstream property boundaries, downstream of batters and stockpiles, prior to stripping and throughout earthworks operations. All sediment fences are to be monitored and maintained throughout the duration of works.
- All nominated sediment basins and sediment traps are to be constructed with appropriately stabilised diversion structures and emergency spillways.

Phase 2 – Duration of Works

- Works are to be staged so that disturbed areas are kept to workable sizes and exposed for a short a period as practicable.
- All disturbance areas and clearing are to extend no more than 5 metres (preferably 2 metres) from essential works areas to minimise amount of exposed surface. Land outside the essential works areas

should remain undisturbed and in its natural condition, ensuring topsoil remains in place. These areas are to be protected by barrier fencing, if applicable.

- Topsoil is to be stripped and stockpiled for later use onsite. Sediment fences should be established downstream of all topsoil stockpiles.
- Native vegetation required and approved for clearing should be mulched and stockpiled for later use in landscaping, stabilisation and/or site rehabilitation works.
- Any stockpiles remaining on site for more than 10 days must be stabilised. Additionally, all disturbed areas are to be progressively grass seeded and stabilised using mulch, hydroseeding or hardstand to achieve 70% ground coverage within 20 days of inactivity or completion of works (even if works may continue later) for protection against both wind and water erosion.
- During windy and dry weather, any unprotected areas are to have sufficient dust control measures implemented including watering, roughening or wind barrier fencing.
- Acceptable receptors and appropriate waste disposal practices should be used for concrete and mortar slurries, paints, acid washers, litter and general waste materials.
- All vehicles departing from the site should be managed to ensure no sediment is being carried or transported off site. Regular inspection of public roads adjacent to the site should be conducted and any sediment deposits manually removed (not washed down).
- Any vehicle or equipment washing and/or refuelling conducted onsite should be conducted in specific bunded areas away from concentrated flow paths and the stormwater system.

Phase 3 – Finishing Works & Defects Liability Period

- All erosion and sediment control measures, including sediment fences and inlet traps are to be maintained until completion of surface finishes including landscaping and turfing and only removed once the site is stabilised.
- At construction completion, all temporary earth structures including soil stockpiles are to be track rolled and seeded to achieve 70% strike rate within 20 days.
- Final site landscaping is to be conducted as soon as possible and generally within 10 working days of construction completion.

1.9 INSPECTION AND MAINTENANCE

Inspection and maintenance of the Erosion and Sediment Control devices is necessary to ensure the proper and continued function of the measures.

Inspections should be conducted by the site contractor on a regular basis as part of the general site inspections. As a minimum, specific Erosion and Sediment Control inspections should occur as follows:

- Immediately before site closure (eg. Weekend/ Holiday closures);
- Prior to predicted large storm events;
- Following significant storm events (> 5mm rainfall);
- Or at least on a weekly basis.

All inspections are to be conducted, as a minimum, in such a way to include the following.

- Record type and location of device/control measure;
- Record condition of each control measure;

- Record sediment volumes removed from the devices/control measures (if required);
- Record details of sediment basin treatment and cleanout;
- Record sediment disposal procedures and location.

A Site Inspection Checklist and suggested inspection guidelines are included in Attachment A as examples.

All repair, maintenance and replacement of the devices/ control measures including non-structural measures, structural measures, sediment basins and diversion drains should be conducted as required by the site contractor or as instructed by the Local Authority.

Detailed and legible records of all inspection and maintenance conducted on the Erosion and Sediment control devices are to be kept on site by the site contractor.

1.9.1 Sediment Basin Maintenance

The sediment basins should remain operational until the site is stabilised and should only be decommissioned once the upstream earthworks have been completed and the other stormwater quality controls have been implemented. A maintenance marker post is to be installed in the sediment basin to clearly identify the level above which the design capacity is available.

The sediment basins should be dewatered, utilising a floating inlet pump or similar, and any built up sediment removed from the basin once accumulation of sediment reaches 70% of the storage capacity.

Maintenance of the sediment basins should consist of flocculation, dewatering, sediment cleanout and repair of any scour damage. Regular inspection of the basins should dictate the frequency at which maintenance is required and preformed. A sediment basin inspection check sheet is included in Attachment A as an example. As a minimum, sediment basin inspections and reporting should be conducted in accordance with this check sheet.

1.9.2 Sediment Disposal

At completion of the construction phase, with all disturbed areas having been stabilised, the sedimentation basins are to be removed and rehabilitated. Accumulated sediment removed from the sediment basin should be disposed of in a proper manner.

The proper, lawful and environmentally responsible disposal of the waste, including general rubbish and accumulated sediment from the control measures is essential. All site waste is to be dealt with and disposed of in accordance with the *Environmental Protection (Waste Management) Policy 2000 and Environmental Protection (Waste Management) Regulation 2000*. The disposal of any accumulated sediment shall be conducted to ensure pollution to the downstream waterway does not occur.

Accumulated sediment removed from the sediment basin can be mixed with onsite soil for disposal. Sediment must not be disposed of onsite in concentrated flows or where it can be re-entrained. Additionally, accumulated sediment from the basin dosed with Alum should not be disposed of onsite where the pH of the receiving waterways is < 5.5. At low pH values (< 5.5) alum becomes soluble in water, having the potential to cause aluminium toxicity and damage the aquatic ecosystem of the receiving waterways.

1.10 STABILISATION

Any exposed batters, embankments or fill areas should be stabilised, using hydromulch, hydroseeding, direct seeding or turfing to provide 70% coverage within 20 days of works being completed (even if works will continue later).

The following factors should be considered before applying hydroseeding, direct seeding or turfing to disturbed areas:

- The seed mix should consist of seeds suitable to the native environment of Great Keppel Island. It should be considered that native seeds (i.e. coastal grasses) can be costly and can take up to 12 months to germinate. The typical hydroseeding seed mixes containing Green Couch, Japanese Millet and Rye seeds will germinate quickly given suitable conditions and are less costly.
- Based on discussions with a local supplier of hydroseeding (Jimboomba Turf), the typical seed mix containing Green Couch, Japanese Millet and Rye have been used successfully on Moreton Island for stabilisation after construction, without ecological issues.
- In selecting the seeds to be used for stabilisation, the pH of the soil should be taken into account.
- Select a liquid organic fertiliser to reduce the impact on sensitive receiving waters.
- Select a reputable supplier with trained personnel to apply the chosen method of stabilisation.

1.11 REVIEW AND UPDATE

The approved Erosion and Sediment Control Plan must be updated by the Contractor as and when required to reflect construction activities including which modification of site circumstances or construction sequence and/or where objectives/targets are not being met.

Any updates required must reflect current standards, Council Guidelines and current Best Management Practice. All necessary updates should ensure that a reduction in overall control does not result.

If any updates or modifications are likely to result in a potential increase in environmental impacts, the contractor must notify Council/EPA under the *Environmental Protection Act 1994* general environmental duty and duty to notify.

REFERENCES

Brisbane City Council (2001). Sediment Basin Design, Construction and Maintenance Guidelines.

Institute of Engineers, Australia Queensland (1996). Soil Erosion and Sediment Control: Engineering Guidelines for Construction Sites.

International Erosion Control Association (IECA) Australasia (2008). Best Practice Erosion and Sediment Control.

Environmental Protection Agency. Best Practice Urban Stormwater Management: Erosion and Sediment Control Guideline

Sunshine Coast Regional Council. Maroochy Manual for Erosion and Sediment Control, Version 1.2.

Sunshine Coast Regional Council March (2008). Contract Standards for Erosion and Sediment Control on Construction Sites, Version 1.0.

Department of Sustainability, Environment, Water, Population and Communitites – Coasts and Marine (National Oceans Office, 2001). Impact from the ocean/land interface

Great Barrier Reef Marine Park Authority, Townsville (2010). Water Quality Guidelines for the Great Barrier Reef Marine Park

Great Barrier Reef Marine Park Authority, Townsville (2010). Great Barrier Reef Marine Park Act 1975

Australian Government and Queensland Government. Reef Water Quality Protection Plan 2009

Attachemnt A

Example Inspection Sheets

EROSION & SEDIMENT CONTROL – SITE INSPECTION CHECK SHEET

Project:									
Site Location:									
Date:									
Inspected By::	**Name:**						**Signature:**		
Site Coverage (%):									
Rainfall Over Past 24 hrs:									
BMP	**Condition**	**Maintenance Required**		**Maintenance Preformed**			**Sediment Volume Removed**	**Sediment Disposal Procedure/Location**	
		Y/N	**Type**	**Y/N**	**By**	**Date**			
Example: *Sediment Fence*	*Poor, fence no longer upright, sediment accumulated*	*Y*	*Sediment cleanout and fence replacement*	*Y*			*10kg*	*Added to existing onsite stockpile*	

RECOMMENDED MINIMUM INSPECTION GUIDELINES FOR STRUCTURAL MEASURES

Sediment Retention Basins	
	▪ Has sediment settling zone sufficient capacity? ▪ Is the outflow structure installed as illustrated in the E&SCP? ▪ Are the embankments protected against erosion?
Sediment Filters	
Straw Bales	▪ Are they installed in trenches? ▪ Are they tightly abutting, with material stuffed between the bales? ▪ Are they staked? ▪ Has backfill material been laced on the upstream side? ▪ Is runoff water running around, below or between the bales?
Sediment Fences	▪ Is the filter fabric buried in a trench and backfilled? ▪ Are the stakes installed correctly with proper spacing? ▪ Has sediment accumulated to within 300mm of the top? ▪ Is runoff water running around, below or between the bales?
Continuous Berms	▪ Have the berms been installed correctly? ▪ Is the fabric adequately stapled?
Other	▪ Are barriers causing local flooding problems?

Check Dams	
Straw Bales	▪ Are the bales staked and tight with each other? ▪ Have the bales been installed in a trench and backfilled? ▪ Will water be forced to run over a centre bale and not around the end bales? ▪ Is the ground below where water flows over the bales eroding?
Rock	▪ Is the correct size rock being used? ▪ Will water flow over the middle instead of around the edges? ▪ Has movement of the rock occurred?
Drains / Inlet Protection	
Straw Bales	▪ Are the bales staked and tight with each other? ▪ Have the bales been installed in a trench and backfilled? ▪ Will water be forced to run over a centre bale and not around the end bales? ▪ Is the ground below where water flows over the bales eroding?
Filter Fabric	▪ Is the filter fabric buried in a trench and backfilled? ▪ Is it staked correctly with proper spacing? ▪ Has sediment accumulated to within 300mm of the top? ▪ Is runoff water running around, below or between the fabric joins?
Inserts	▪ Has the insert been installed correctly? ▪ Will the insert prevent runoff water from entering the stormwater system? ▪ Has sediment filled the structure? When will the sediment be removed?

RECOMMENDED MINIMUM INSPECTION GUIDELINES FOR NON-STRUCTURAL MEASURES

Diversion and Containment Banks

- Are they protected against erosion?
- Have they been constructed to control and divert anticipated flows?
- Should the bottom be lined with any material to prevent erosion?

Slope Drains

- Will runoff water be diverted into the pipe?
- Does sufficient protection exist to prevent failure of piping?
- Is the pipe anchored?
- Does erosion protection exist where water charges?
- Are they functioning in the manner they were designed?

Staging of Construction Activities

- Does all the ground need to be disturbed?
- How much land is being disturbed and how much can remain in vegetation?

Planting of Perennial Seed

- Are drill marks evident that are parallel or perpendicular to land contours?
- Has seed tag been checked and the mixture verified?
- If seed was applied hydraulically, how much was used?
- If seed was broadcast, was the ground raked?
- What time of year was the seed planted?
- Are weeds becoming established?

Planting of Temporary, Nursery or Cover Crop
▪ What type of seed was used? ▪ How long will the vegetation be in place before planting perennial grass? ▪ When was the seed planted?
Dry / Hydraulic Mulch
▪ Does the mulch cover 80-100% of the bare ground? ▪ If dry mulch is applied, how is it held in place? ▪ Has wind removed the dry mulch and is this a problem?
Soil Binder
▪ What type of material was used? ▪ When was it applied? ▪ Does the material still control erosion?
Hillside Protection
▪ Is the material properly installed at the top? ▪ Are sufficient staples used? ▪ Does the material overlap along the edges? ▪ Does the material need to be repaired?
Channel Protection
▪ Is the material properly installed at the top? ▪ Are sufficient staples used? ▪ Is the material properly stapled or trenched along the edges?

- Should a rock check structure be installed on top of the material?

Soil Roughening

- How deep are the furrows?
- Are the furrows filling up with soil?
- Are the furrows perpendicular to the prevailing wind?

Wind Barriers

- Have they been installed perpendicular to what is accepted as the prevailing wind direction?
- Are they in need of repair or replacement?
- Have the structures been placed where maximum deposition of wind-borne particles can occur?

Vegetation

- Is the ground bare?
- How tall and / or dense is the vegetation?

Hydraulic Mulch / Soil Binder

- Is the ground bare?
- How tall and / or dense is the vegetation?
- Has sufficient material been applied?
- How long will the material be expected to control erosion?
- Has the material broken down and is it still effective?

*** Reference: Maroochy Manual for Erosion & Sediment Control, Chapter 8, Version 1.0, December 2007*

EROSION & SEDIMENT CONTROL – SEDIMENT BASIN INSPECTION CHECK SHEET

Project:			
Site Location:			
Date Inspected:			
Inspected By	**Name:**	**Signature:**	
Site Coverage (%):			
Rainfall over last 24 hrs:	mm	(from site rain gauge)	
Basin Volume:	m^3	(approximate from basin indicator post)	
Dewatering Required	YES / NO	(required at 50% basin capacity)	
Date of Flocculation:			
Flocculating Agent:			
Flocculating Dosage:	kg		
Water Quality Parameters	**Results**	**Release Criteria**	**Complies**
Suspended Solids	mg/L	< 50 mg/L	YES / NO
pH	pH Units	6.5 - 8.5	YES / NO
Visual Amenity		No Visible Plume	YES / NO
Dewatering Approved By	Name:	Signature:	
Date of Dewatering:			
Accumulated Sediment Volume:	m^3	(approximate from basin indicator post)	
Removal Required	YES / NO	(at sediment storage capacity)	
Disposal of sediment:			
Sediment basin and diversion drains protected:			YES / NO
Emergency spillway stabilised with appropriate erosion protection:			YES / NO