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7.1.1 Methodology

7.1.1.1 Appropriateness of QUDM as a predictive tool

A submission suggested that Queensland Urban Drainage Manual (QUDM) is an inappropriate tool to use in the prediction of flows within the context of the EIS.

QUDM is a widely accepted standard across Queensland for the estimation of flows at the conceptual design stage of a project. In the absence of detailed lot layouts or road design, the Stormwater Management Plan (Appendix A7.2 of the EIS) proposed outline plans for quantity and quality treatment devices, and commits the Proponent to large areas of developable land to accommodate treatment infrastructure.

In the detailed design phase of the HHI Development, each zone will be subject to detailed analysis to exactly determine its quantity and quality measures. Hydrological runoff routing models such as XP-RAFTS will be used to assess the performance of detailed designs in a range of storms, and the MUSIC modelling will be repeated to ensure that detailed Water Sensitive Urban Design (WSUD) designs perform as planned.

It is standard practice to use QUDM at the concept design stage of a project. This methodology is considered very conservative and experience shows it generally works for a 1 in 100 year storm event.

7.1.1.2 Source of rainfall data

One submission queried the source of rainfall data used in the stormwater assessment.

The estimates of rainfall intensity at the site for storms of particular duration and average recurrence intervals have been compiled using an Intensity, Frequency and Duration (IFD) curve for the site. The method to produce an IFD curve for any location in Australia is described in 'Australian Rainfall and Runoff' (Institution of Engineers, Australia 1987). The use of IFD curves is standard practice by hydraulic engineers and government agencies.

IFD curves are statistically derived from meteorological data recorded by the Bureau of Meteorology from all over Australia.

7.1.1.3 Time of Concentration

Submitters have questioned the use of the same time of concentration for both undeveloped and developed catchments within the EIS.

In Appendix A7 of the EIS, the Time of Concentration, t_c, was shown in error, and appears as 20 minutes in both the existing (undeveloped) and proposed (developed) cases. The time of concentration for the proposed case should be shown as 15 minutes (according to QUDM for gently sloping urban residential areas). However, this value was used in the calculations, so the results were correct as published.

QUDM was subsequently updated with a change to the runoff coefficient. The updated results are presented in **Section 7.1.2.2**.

7.1.1.4 Detention volumes

Submitters have questioned the principles behind the calculation of proposed detention requirements for the HHI Development.

Drainage rates are controlled through the use of detention basins. Detention basins detain the increased stormwater volume generated from impervious areas and control the increased rate of runoff from peak flow events to match those of the existing case.

It is standard practice to use QUDM to determine the size of detention basins at the conceptual design stage of a project.

QUDM (2008) provides four methods of calculating detention requirements (see Culp, Boyd, Carroll and Basha retained in Section 5.05.1 of the newly-revised 2008 edition). It is standard practice to estimate the required detention volumes by using all four methods. The proposed detention requirements are determined by selecting the largest volume and multiplying it by a factor of two as a method for incorporating safety. This approach was used for the conceptual design of detention basins for the HHI Development. This methodology is considered very conservative but effective at the conceptual design stage of a project.

7.1.1.5 Overestimation of existing runoff from Hummock Hill Island

Submitters have suggested that calculations of existing stormwater runoff volumes and rates from Hummock Hill Island are grossly exaggerated.

As stated in **Section 7.1.1.1**, QUDM is a widely accepted standard across Queensland for the estimation of flows at the concept design stage of a project. The detention measures proposed in the Stormwater Management Plan were sized correctly according to the industry standard guidance at the time of writing.

QUDM (1992) was updated in late 2008. Although most of the methods for the calculation of stormwater runoff remain as before, a change has been made to the calculation of green-field runoff rates, by suggesting alternatives to the C_{10} runoff coefficient which reflect soil and vegetation type. These changes would serve to decrease most of the calculated flows in the existing case and leave the proposed case flows unchanged. The detention requirements would therefore increase. The updated results are presented in **Section 7.1.2.2**.

7.1.1.6 Assumptions used for MUSIC and Sednet Models

Submitters have requested clarification of the assumptions used for Music and Sednet modelling.

The following assumptions/guidelines were used for MUSIC modelling:

- modelling was undertaken in accordance with Brisbane City Council's Guidelines for Pollutant Export Modelling in Brisbane Version 7 (Draft, October 2003);

- study area was divided into eight drainage zones based on the site topography and development layout (each of these zones is described in detail in Appendix A.7.2 of the EIS);
- the developed area within each zone was modelled using the appropriate source nodes (urban residential, commercial and forest) as given in the guidelines;
- baseflow and stormflow concentration parameters were obtained from a City Design report to Gladstone City Council to reflect the local conditions (e.g. total annual load of suspended sediments from a 50% impervious node is 813 kg/ha per annum);
- rainfall and evaporation data is for Rockhampton (using a six minute time interval between 1985 and 1995); and
- daily rainfall values for Hummock Hill Island were interpolated from the records of nearby meteorological stations. This data verified the Rockhampton data, resulting in a similar yearly average.

The SedNet results for Colosseum inlet reported in Section 8 of the EIS were reported on the OzCoasts website (formerly OzEstuaries). These results are available at http://www.ozcoasts.org.au/search_data/detail_result.jsp

7.1.1.7 Catchments

Some submitters noted that the overall surface water system concept and design methodology put forward in the EIS were appropriate however, more detail of each catchment would be required for checking purposes.

The study area was divided into eight drainage zones (catchments) based on the site topography and development layout (each of these zones is described in detail in Appendix A.7.2 of the EIS).

The assessment of surface water runoff has been undertaken using the concept plans described in Section 3.3 of the EIS. This level of detail enabled careful estimates of impervious area; the road areas were derived from CAD drawings, but roof and hardstand areas were estimated from experience. The conceptual design of the treatment devices were sized according to these estimates.

As the designs are progressed, there will be an opportunity to refine the sizing of the water quality treatment train. In particular, rainwater tanks will be sized according to roof areas at an individual property level, and bio-retention swales or basins will be sized to serve a small number of allotments, such as the Eco-Homesites ‘pods’.

7.1.2 Modelling Results

7.1.2.1 Detailed Modelling Results

One submission requested the results of the ‘detailed’ modelling showing the potential changes in both flows and water quality.

Detailed outputs from MUSIC modelling were presented in Appendix A.7.2 of the EIS. The treatment train has been designed to match nutrient and suspended solids in existing and post-development scenarios. The model will therefore show no changes in water quality. The development will increase impervious area leading to an increase in runoff. The treatment train has been designed so the peak flowrates for existing and post-development scenarios are the same.

In the detailed design phase of the HHI Development, each catchment zone will be subject to detailed analysis to exactly determine its quantity and quality treatment measures. Hydrological runoff routing models such as XP-RAFTS will be used to assess the performance of detailed designs in a range of storms, and the MUSIC modelling will be repeated to ensure that detailed Water Sensitive Urban Design (WSUD) designs perform as planned.

7.1.2.2 Updated Runoff Calculations

QUDM was updated in late 2008 since preparation of the Stormwater Management Report. Although most of the methods for the calculation of stormwater runoff remain as before, a change has been made to the calculation of green-field runoff rates by suggesting alternatives to the C_{10} runoff coefficient which reflect soil and vegetation type. The updated peak flows prior to development and post development are presented in **Table 7-1** and **Table 7-2** respectively.

Table 7-1 – 100-year peak flows prior to development

<table>
<tr><th>Zone</th><th>Developed Area (ha)</th><th>F, impervious (%)</th><th>Intensity $^{1hr}I_{10yr}$ (mm)</th><th>C_{10}</th><th>F_{100}</th><th>C_{100}</th><th>Time of Conc, t_c (min)</th><th>Intensity $^{tc}I_{100yr}$ (mm)</th><th>Peak Flow (m^3/s)</th></tr>
<tr><td>Lagoon</td><td>98.29</td><td rowspan="8">0</td><td rowspan="8">67</td><td rowspan="8">0.33</td><td rowspan="8">1.2</td><td rowspan="8">0.4</td><td rowspan="8">20</td><td rowspan="8">184</td><td>19.89</td></tr>
<tr><td>Bay</td><td>8.18</td><td>1.66</td></tr>
<tr><td>Town</td><td>26.45</td><td>5.35</td></tr>
<tr><td>Headland</td><td>22.79</td><td>4.61</td></tr>
<tr><td>Hummock</td><td>31.19</td><td>6.31</td></tr>
<tr><td>Boyne Hill</td><td>24.51</td><td>4.96</td></tr>
<tr><td>Boyne East</td><td>34.70</td><td>7.02</td></tr>
<tr><td>Boyne West</td><td>25.13</td><td>5.09</td></tr>
</table>

The updated peak flows post development is presented in **Table 7-2**.

Table 7-2 – 100-year peak flows following development

Zone	Developed Area (ha)	F, impervious (%)	Intensity $^{1hr}I_{10yr}$ (mm)	C_{10}	F_{100}	C_{100}	Time of Conc, t_c (min)	Intensity $^{tc}I_{100yr}$ (mm)	Peak Flow (m^3/s)
Lagoon	98.29	0.36	67	0.75	1.2	0.90	15	211	51.85
Bay	8.18	0.32		0.74		0.89			4.26
Town	26.45	0.95		0.89		1.00			15.50
Headland	22.79	0.47		0.77		0.93			12.41
Hummock	31.19	0.32		0.74		0.89			16.23
Boyne Hill	24.51	0.32		0.74		0.89			12.76
Boyne East	34.70	0.42		0.76		0.92			18.65
Boyne West	25.13	0.42		0.76		0.92			13.50

Revisions to the runoff calculations from completely pervious areas (i.e. Hummock Hill Island's existing case) now take into account soil and vegetation types. These changes would decrease most of the calculated flows in the existing case and leave the proposed case flows unchanged. The detention requirements would therefore increase. The calculations of the required detention volumes for each zone are presented in **Table 7-3**. The dimensions for each of the detention volumes for each zone are presented in **Table 7-4**.

Table 7-3 – Derivation of required detention volumes

Zone	Peak IN (m^3/s)	Peak OUT (m^3/s)	IN Volume (QUDM)	Ratio 'r'	Culp (m^3)	Boyd (m^3)	Carroll (m^3)	Basha (m^3)	Maximum Estimate (m^3)	Factor of safety	Storage, V_s (m^3)
Lagoon	51.85	19.89	62216	0.62	28536	38344	29149	33440	38344	2	76688
Bay	4.26	1.66	5111	0.61	2314	3123	2364	2719	3123	2	6247
Town	15.50	5.35	18603	0.65	9375	12179	9550	10777	12179	2	24358
Headland	12.41	4.61	14890	0.63	7035	9354	7180	8195	9354	2	18708
Hummock	16.23	6.31	19480	0.61	8818	11905	9011	10361	11905	2	23809
Boyne Hill	12.76	4.96	15308	0.61	6930	9355	7081	8143	9355	2	18711
Boyne E	18.65	7.02	22375	0.62	10445	13947	10664	12196	13947	2	27895
Boyne W	13.50	5.09	16205	0.62	7565	10101	7723	8833	10101	2	20202

Table 7-4 – Detention Sizing

Zone	Storage, V_s (m^3)	Base Area (m^2)	Top Area (m^2)	Volume (m^3)	Check	% Development Area
Lagoon	76688	60319	67600	76752	OK	6.9
Bay	6247	4173	6241	6248	OK	7.6
Town	24358	18387	22500	24532	OK	8.5
Headland	18708	13830	17424	18752	OK	7.6
Hummock	23809	17849	21904	21904	OK	7.0
Boyne Hill	18711	13830	17424	17424	OK	7.1
Boyne East	27895	21199	25600	25600	OK	7.4
Boyne West	20202	15031	18769	18769	OK	7.5

7.1.3 Design Issues

7.1.3.1 Updated WSUD Guidelines

Submissions have highlighted the fact that the load based objectives from WSUD have been updated and the load based criterion Stormwater Quality Management is only one of three assessment criteria in the document – Water Sensitive Urban Design – Developing design objectives for water sensitive urban design development in south East Queensland (2006). The design of stormwater management systems should also be based on the criteria for Frequent Flow Management and Waterway Stability.

The first of the objectives, to capture and manage the first 10 mm (in most cases) of runoff from the site in each event was not addressed in the Stormwater Management Report. This objective is based on the desire to control the increased frequency and volume of the lower discharges due to the increase in impervious area and can be achieved by promoting infiltration. However, in order to protect the quality of the groundwater resource on Hummock Hill Island infiltration is not the preferred option for the management of stormwater flows, at this stage of design.

The detention basins were designed in late 2005 and early 2006 using the methods outlined in QUDM. The largest of the volumes calculated using four equations is doubled to account for batter slopes in the final design, and because the basin must match the proposed flows with existing in all storms, and not just the 100-year event.

At the detailed design stage, basins will be modelled in XP-RAFTS software to ensure that they detain runoff from the 1, 2, 5, 10, 20, 50 and 100 year events to match those of the existing case. The diameter of the outlet pipe is which one of the key design parameters has been selected to limit outflows from the one-year event (whereas basin volume is dependent on the storage needed for the 100-year event).

This detention of flows in all rainfall events, including the one-year event, meets the second of the three Healthy Waterways design objectives (with the third being the percentage pollutant reductions) outlined in its '*WSUD: Developing Design Objectives for Water Sensitive Urban Development in South East Queensland'* document of October 2006.

7.1.3.2 Minimum Design Criteria for WSUD Devices

Submitters have requested that the Proponent provide a clear commitment to the minimum design criteria for WSUD devices and provide evidence of the effectiveness of this minimum design standard for the rainfall pattern in the Gladstone region compared with South East Queensland. Furthermore, it has been suggested that the minimum design standards for the sediment control systems should be stated in sufficient detail to allow inclusion in conditions of approval under the SDPWO Act and subsequently by Gladstone Regional Council.

Section 8.2.15 of the EIS outlined the load-based WSUD design criteria from Healthy Waterways (2006). These require achievement of following objectives when compared to unmitigated urban development:

- an 80% reduction in annual suspended solid loads;

- a 60% reduction in annual Total Phosphorus loads;
- a 45% reduction in annual Total Nitrogen loads; and
- a 90% reduction in annual gross pollutant loads.

The treatment train has been designed to match nutrient and suspended solids in existing and post-development scenarios. Modelling results from MUSIC show the conceptual stormwater treatment train will achieve the WSUD design criteria in all zones.

MUSIC uses local rainfall data, and is not dependent on conditions in South East Queensland.

Details of sediment control systems will be provided for each stage of development in an Erosion and sediment Control Plan, for Gladstone Regional Council's approval, prior to construction of the stage.

7.1.3.3 Design Criteria for WSUD Devices in a World Heritage Area

One submission stated that that the high ecological value areas of the estuarine and marine areas had design implications for the stormwater system.

The stormwater treatment train is designed to trap both sediment and nutrients and to attenuate peak flows to prevent erosion of gullies. The treatment train has been designed to match nutrient and suspended solids in existing and post-development scenarios. The effective design and operation of the proposed stormwater treatment train will means the existing estuarine and marine areas will not be affected by stormwater from HHI Development.

7.1.3.4 Stormwater Treatment Train

Submitters have requested clarification of the rationale and processes behind the proposed stormwater treatment train.

The stormwater treatment train is designed to trap both sediment and nutrients and to attenuate peak flows to prevent erosion of gullies. The system has been designed to replicate natural water system without the requirement for large infrastructure intensive treatment methods.

All runoff from developed areas will pass through a stormwater treatment train which to varying degrees has a removal effect on all pollutants. The stormwater treatment train consists of:

- rainwater tanks;
- grassed swales;
- bioretention devices; and
- lake for final polishing in some catchments.

A conceptual stormwater treatment train has been designed to meet and exceed the WSUD guidelines.

7.1.3.5 Adequacy of stormwater treatment train

Submitters expressed concern regarding the adequacy and appropriateness of the proposed stormwater treatment system for use on a greenfield site.

The stormwater treatment train is designed to trap both sediment and nutrients and to attenuate peak flows to prevent erosion of gullies. The system has been designed to replicate natural water system without the requirement for large infrastructure intensive treatment methods. It is an appropriate stormwater treatment system for use on a greenfield site.

7.1.3.6 Use of Recycled Stormwater

The EIS states that recycled stormwater may be used for irrigation and submitters have questioned this commitment given that the water supply report identified a combination of potable water, rainwater tanks and recycled wastewater and preferred water sources of the HHI Development.

There are stormwater retention basins located in the golf course. The intention is to maxmimise the use of effluent for irrigation purposes. If treated effluent is not available captured stormwater in the retention basins on the golf course will be used for irrigation.

7.1.3.7 Allowance for Climate Change

Submitters have requested that the Proponent provide sufficient information to support the statement that the proposed treatments in Table 8-10 and Table 8-11 of the EIS could accommodate any potential storm flow changes associated with climate change, or withdraw the statement.

Climate change may affect the intensity, frequency or duration of rainfall in future. The potential impacts of climate change on the stormwater management system are presented in **Table 7-5** along with the design features to help mitigate against climate change.

Table 7-5 – Impact of Climate Change on Stormwater Management System

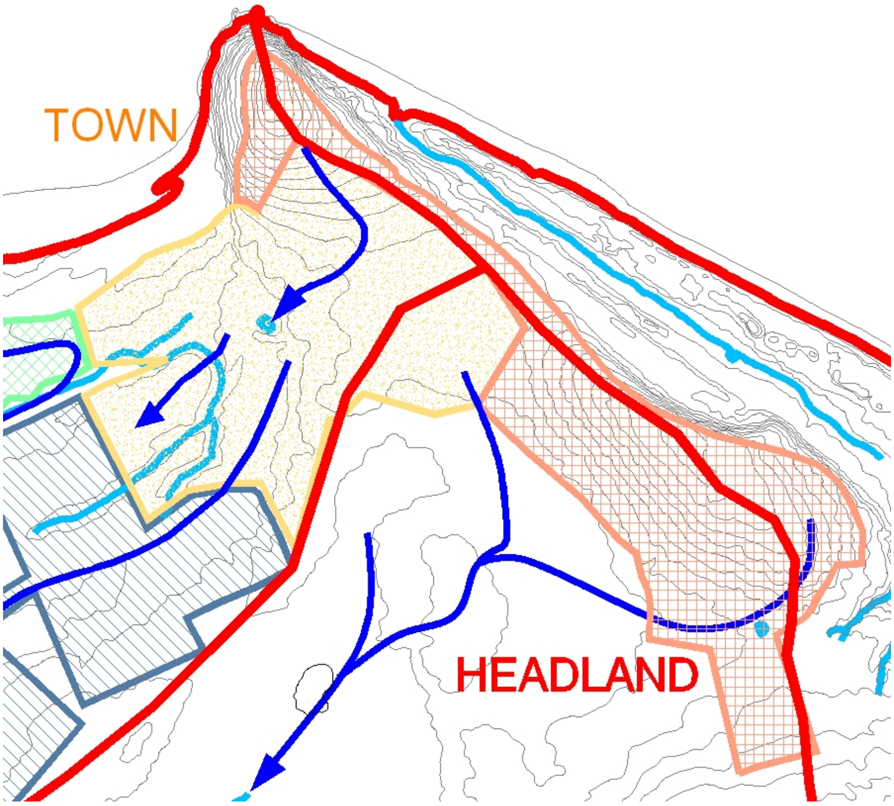
Climate Parameter	Impact on Stormwater Management System	Mitigation measures included in design
Increase/decrease in rainfall intensity	Increase in rainfall intensity may cause the system to overtop more frequently Decrease in rainfall intensity will not affect the system	▪ Include a freeboard on all basins of at least 300 mm over the 1 in a 100-year level ▪ A wide overflow spillway
Increase/decrease in rainfall frequency	No impact – system will operate in same manner, just on a more/less regular basis	None required
Increase/decrease in rainfall duration	MUSIC modelling results show the system performance improves with an increase in rainfall	Design includes a wet zone, beneath the filter outlet, is included to stop the filter drying out completely in dry conditions

7.1.4 Potential Impacts

7.1.4.1 Release to North Beach

Several submissions expressed concerns around the potential impacts on sensitive coastal dune systems and on coral reefs just offshore from the headland as a result of construction and operation of a stormwater outlet structure at the north beach.

The proposed stormwater discharge at North Beach has been rerouted, and will now flow in a southerly direction into the Lagoon Zone and the dedicated detention there. This removes any discharge into the 'North Beach', Bay and Headland Zones and avoids any impacts to the coastal dune and coral reefs. The figure on page 17 of the Stormwater Management Report has been updated to show the following:



7.1.4.2 Release to Colosseum Inlet

Several submissions suggested that the HHI Development will release untreated stormwater to receiving environments.

There will be no releases of untreated stormwater (or even minimally-treated stormwater) from any developed area on any part of Hummock Hill Island. All urban runoff from events of up to the three-month average recurrence interval will pass through a WSUD treatment train that will improve its quality to meet the water quality objectives for the site. Stormwater from undeveloped areas will remain untreated as is the currently the case.

7.1.4.3 Potential Impacts of the Golf Course

Several submissions expressed concern around the potential for the proposed golf course development to impact on the environmental values of Hummock Hill Island and in particular groundwater aquifers.

Operation of the proposed golf course will be based on current and future best management practices including the AGCSA (2001) Guidelines. To mitigate potential impacts associated with the golf course, the proponent will develop and implement a Golf Course management Plan in accordance with AGCSA (2001) Guidelines that will include:

- Integrated Turf Management Plans (ITMPs) as recommended by the Improving the Eco-efficiency of Golf Courses in Queensland (AGCSA & Qld EPA, 2001);
- Use of recycled waste water for irrigation of turf using in ground sensors to control application; and
- Integrated Pest Management Plan in accordance with AGCSA requirements for the golf course will required prior to commission.

The aim of the golf course management plans is to ensure zero runoff, and such careful application would also ensure nothing is lost to the substrata.

The Proponent has committed to the use of these guidelines, ensuring best current practice. Perhaps most importantly, Hummock Hill Island's golf course will be 'wild', retaining as much native vegetation as possible and dramatically reducing the need for chemical applications as a consequence.

Submitters also raised concerns in relation to the magnitude of impact from the golf course on the environmental values of the receiving environment, particularly the Great Barrier Reef World Heritage Area.

No runoff will be created from irrigation practices, as stated above, and so none of the fertilisers should reach a watercourse at the time of their application. Because the possibility exists that runoff from natural rainfall would re-entrain applied chemicals, the golf course will be designed in order to limit this (through the use of slopes, etc.). Any overland flow that does result from rainfall events would be directed towards WSUD devices such as buffer strips. These areas of vegetation allow plants a final chance to strip the runoff of its nutrients.

It should be noted that, in addition to the eagerness of all parties to protect the natural environment, it is not in the golf course operator's interest to apply expensive chemicals to the land to allow them to then be lost to runoff (necessitating a second application). The effective environmental management of the golf course is also in the operator's financial interest.

7.1.5 Sediment and Erosion Control

Submitters have requested that details of proposed sediment control measures be provided in the form of objective and auditable comments to design and management.

The HHI Development is at a conceptual stage and it is not possible to formulate detailed Erosion and Sediment Control Plans (ESCPs) without detailed design plans. The development of ESCPs is normally undertaken following detailed design and prior to any works occurring on site.

The Proponent has committed to manage erosion and sediment through the development of ESCPs or each stage of the construction, which comply with erosion and sediment control guidelines for Queensland Construction Sites (Witheridge and Walker, 1996) as discussed in **Section 5.1.2** of the EIS.

The use of the Guidelines will ensure that adverse impacts are minimised during the construction phase. The bio-retention devices suggested for water quality treatment in the operational phase are very sensitive to sediment loading, which could blanket the device and smother plant growth. During the construction phase they serve as sedimentation basins, already positioned as they are in appropriate downstream locations. Following the re-establishment of vegetation at the end of the construction phase, the basins are cleaned of their deposits and the filter media installed and planted. The basin then assumes its long-term role as a bio-retention device.

7.2 Groundwater Resources

7.2.1 Groundwater Quality

Several submissions raised the issue of potential groundwater contamination as a result of infiltration of untreated runoff from developed areas.

The EIS recognises the values of groundwater resource on Hummock Hill Island is of value and the need to protect them from contamination. It was not thought that the resource would be denied any significant inflows following adoption of this plan, as development is proposed for only a fraction of Hummock Hill Island and, in the main, is of a low impervious fraction.

Many of the upstream quality devices such as porous pavements and bio-retention basins encourage stormwater to infiltrate below the surface and into a storage or filter material. To prevent runoff infiltrating further into the substrata, it is proposed that these devices be lined with an impermeable layer. This may take the form of clay or geomembranes, as is deemed appropriate at the detailed design stage, and outlets would be provided from the media to return runoff to surface flowpaths.

7.2.2 Groundwater Recharge

Submitters have suggested that there may be some benefit in promoting concentration infiltration to groundwater in some areas and furthermore that denying infiltration may have adverse affects on existing vegetation.

Moreover, some groundwater dependent ecosystems have been identified at the break of slope of low hills in the southern areas of Hummock Hill Island, such as melaleuca stands. Development will not occur in or near these areas, further reducing any potential impacts.

7.2.3 Impacts to Groundwater Resources

One submission stated that impacts to groundwater dependant ecosystems during construction should be avoided at all costs. Section 8.4.2 of the EIS identified that clearing and earthmoving in groundwater recharge and discharge zones may impact shallow groundwater hydrology leading to increased surface salination and soil scalding, however these potential impacts could be mitigated by minimising clearing of vegetation on upslope recharge areas and slope break discharge areas and maintaining existing vegetation in low density lots and golf course buffer strips.

Another submission requested information regarding the management of groundwater resources and the prevention of possible interference. The Proponent does not intend to use any form of groundwater during the construction or operation of the HHI Development. Management of groundwater resources is not considered an enforceable commitment of the Proponent.

Residents of Hummock Hill Island must obtain relevant permits from the Department of Environment and Resource Management if they wish to utilise groundwater resources.

7.3 Flooding

7.3.1 Infrastructure

One submission, identified that infrastructure on Hummock Hill Island and Clarks Road and Turkey Beach Road should be designed with flood immunity to at least the 1 in 50 year average recurrence interval event and preferably the 1in 100 year level.

The detailed design of the access roads to Hummock Hill Island have not been undertaken at this stage of the Project. It is during the detailed design phase that specifications for the road will be made, including flood immunity.

Detailed design of the roads should also ensure that current drainage routes and potential flood routes in extreme events are not impeded by development. Appropriate buffers would be needed around any drainage paths to ensure flood immunity for dwellings.