AQUIS RESORT AT THE GREAT BARRIER REEF PTY LTD

ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1

CHAPTER 9

FLOODING

9. FLOODING

9.1 EXISTING SITUATION

9.1.1 Overview

The site is situated at the seaward limit of the delta of the Barron River and is within several hundred metres of the Coral Sea. At a local level, the site lies within the sub-catchments of Richters Creek, Yorkeys Creek, and Half Moon Creek. Of these, Richters Creek is the largest of the waterways, being a distributary of the Barron River due to its connection via Thomatis Creek.

Further details are provided **Chapter 10** (Water Resources) where a range of broad surface hydrology and hydraulic matters are addressed. There is an unavoidable overlap in the issues required to be addressed under Flooding, Water Resources, and Water Quality and judgment has been used in where these are discussed. In particular, it has been decided to detail the following matters as described:

- flooding:
  - Barron River cat catchment and flood history
  - flooding of the Aquis Resort site
  - modelling of design flows
  - impacts of flooding on Aquis Resort and the impact of Aquis Resort mitigation on surrounding areas
- water resources:
  - surface water hydrology and hydraulics
  - groundwater hydrology and hydraulics
  - quality of groundwater
  - use of surface water
  - use of groundwater
  - surface water / groundwater interaction

Cross references between these chapters are provided where appropriate.

9.1.2 Barron River Catchment

The Barron River with its headwater located on the Atherton Tableland has a contributing area of 217,500 ha and drains into Trinity Bay (i.e. Coral Sea) north of Cairns and north of Trinity Inlet.

The catchment contains five major dams and / or weir(s) with an extensive irrigation network located in the upper reaches, before the river drops through the Barron Gorge and forms the Barron River delta. The delta is also extensively developed with agricultural activities and cane farming with fringing residential development, although this agricultural use is quickly being transformed by urban, commercial and industrial uses. The tidal limit of the Barron River is located some 7 km upstream of the site, at Kamerunga near where the Cairns Western Arterial Road crosses the river (refer to **Figure 9-1**).

The combined Thomatis / Richters Creek system is a major distributary of the Barron River, with the confluence being approximately 9.2 km upstream from the mouth of the Barron River. Tidal exchange occurs between Thomatis / Richters Creek and the Barron River.

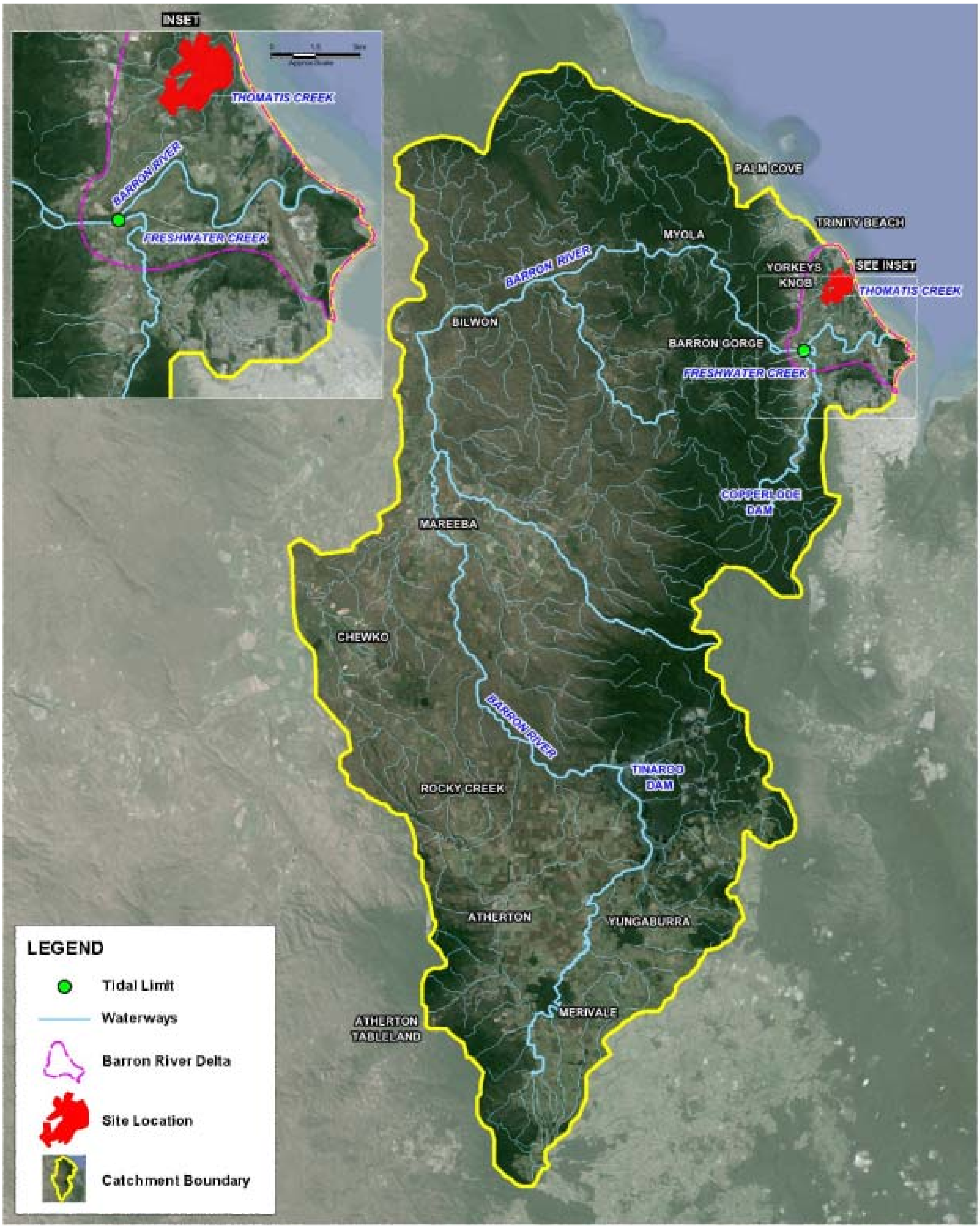

Figure 9-1 Barron River catchment.

Source: Appendix K (Figure 2-1).

9.1.3 Barron River Flooding

a) Terms used for Describing Probability

The probability of occurrence of an event (e.g. cyclone, flood, earthquake, tsunami) is expressed in terms of one or both of the following:

- **Average Recurrence Interval (ARI)** – the annual period between events of the specified magnitude, expressed in years (i.e. 100 year or 1,000 year ARI).
- **Annual Exceedance Probability (AEP)** – the probability that events of the specified magnitude occur in one year, expressed as a percent (i.e. 1% AEP or 0.1% AEP). This is the preferred terminology.

These are related concepts in that ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP (i.e. 100 year ARI = 0.1% AEP). Note that the old approach of referring to probability as, for example, the '1 in 100 year flood', while being statistically identical to 100 year ARI, is no longer in official usage as it implies that rare events are in some way separated by fixed periods of time. As noted above, the preferred terminology is AEP.

b) Flood History

The Barron River has a history of minor and major floods and most of the site itself is inundated during quite common floods (i.e. on average every couple of years). When the Barron River breaks its banks most of the delta floods and Richters Creek, Yorkeys Creek, and Half Moon Creek help convey flood waters around the Yorkeys Knob township (i.e. to the east and west of the natural divide formed by Yorkeys Knob Road (Varley Street)).

Based on long term stream gauge records at Myola, and the latest estimates for Freshwater Creek, design peak flood flows for the Barron River system are as shown in the flowing table.

TABLE 9-1 DESIGN PEAK FLOOD FLOWS IN THE BARRON RIVER

FREQUENCY		FLOW	
ARI1 (YEARS)	**AEP2 (%)**	**BARRON RIVER PEAK FLOW (MYOLA) (m3 / s)**	**FRESHWATER CREEK ENTERING THE DELTA (m3 / s)**
5	20	1,820	426
10	10	2,600	504
20	5	3,430	607
50	2	4,896	726
100	1	6,392	820
Possible Maximum Flood[3] (PMF)		25,255	2,124

Source: Appendix K (Table 2-1).

1: Average Recurrence Interval (see **Section 9.1.3a)** for an explanation of this terms).

2: Annual Exceedance Probability (see **Section 9.1.3a)** for an explanation of this term).

3. Probable Maximum Flood (PMF) is a very extreme theoretical flood that is used for dam design and emergency management planning. See below.

c) Probable Maximum Flood

According to the Bureau of Meteorology (2014), a Probable Maximum Flood (PMF) is 'the maximum flood that is reasonably estimated to not be exceeded'. This is derived from a 'Probable Maximum Precipitation (PMP) which is the maximum precipitation (rainfall) that is reasonably estimated to not be exceeded'. PMP is defined as:

> ..the theoretical maximum precipitation for a given duration under modern meteorological conditions.

BoM (2014) notes that:

> Hydrologists use a PMP magnitude, plus its spatial and temporal distributions, to calculate the PMF for the catchment of a dam. The PMF is used to design the dam.

In practical terms, a PMF is the largest conceivable flood for a given catchment.

9.1.4 Site Flooding History

The Aquis Resort site is generally flat and is flood-prone, with the entire site being affected by Barron River flooding for events less frequent than about 50% AEP. Key points regarding flooding on the site are summarised below:

- The largest recorded flood occurred in 1977 and resulted in flood depths of 1-2 m across the site with flood waters receding after about four days. This was estimated to have an AEP of about 2%.
- A similar sized event also occurred in 1979 (demonstrating that large events can occur more frequently than the calculated ARI).
- The Probable Maximum Flood (PMF) (i.e. a very extreme theoretical flood used for emergency management planning) results in an approximate peak water level of 7.5 m AHD at the southern part of the site.

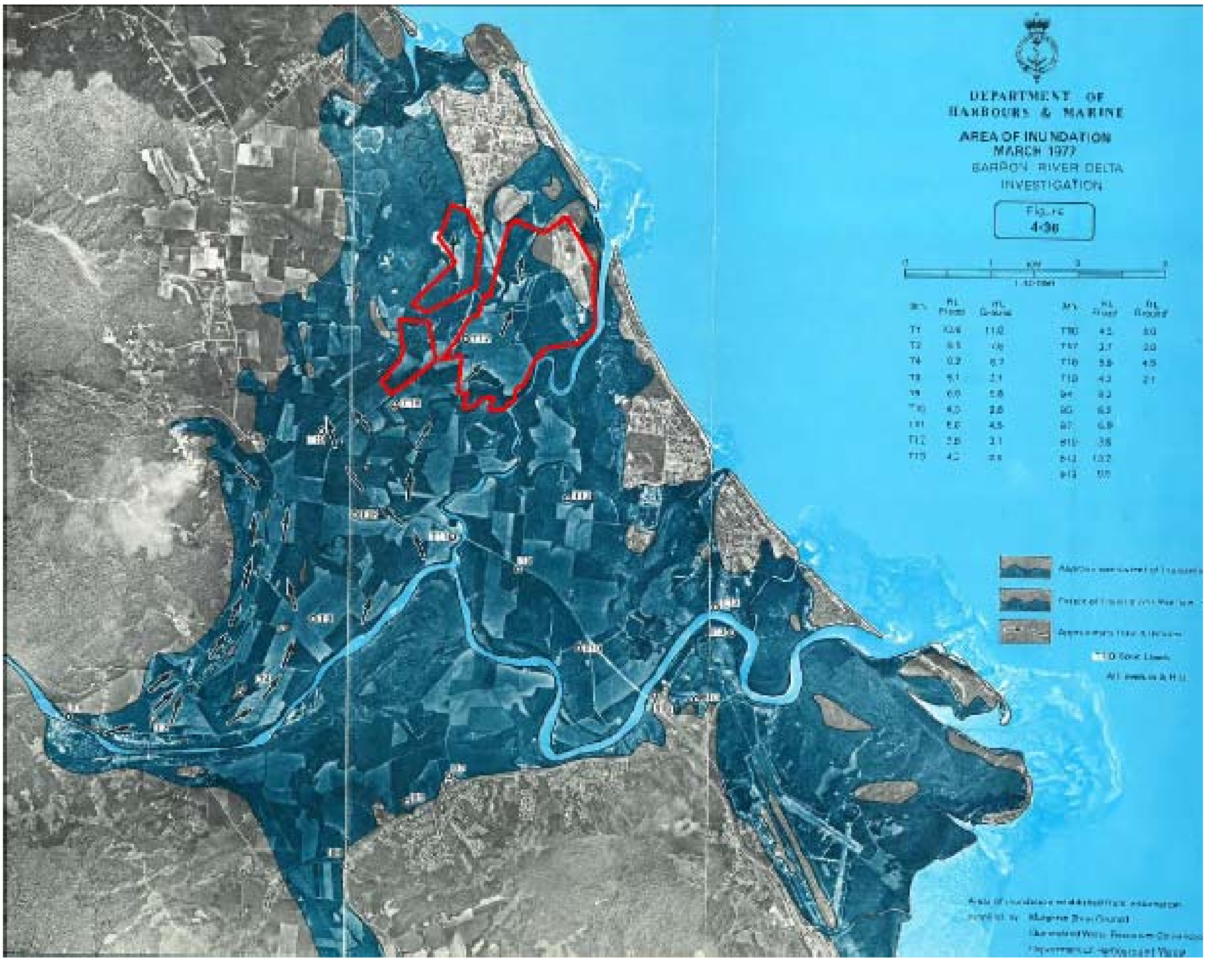

Figure 9-2. Inundation from March 1977 event.

Source: Department of Harbours and Marine (1981) reproduced in **Appendix K** (Figure 2-7).

Existing levels across the site typically vary from less than 1 m AHD to 5 m AHD but are generally between about 1 m and 3 m AHD. **Figure 9-3** and **Figure 9-4** show approximate flood levels and depths across the site for a 1% AEP flood and the PMF respectively. These figures have been produced using CRC's Barron River Delta Flood Model described in **Section 9.1.6**.

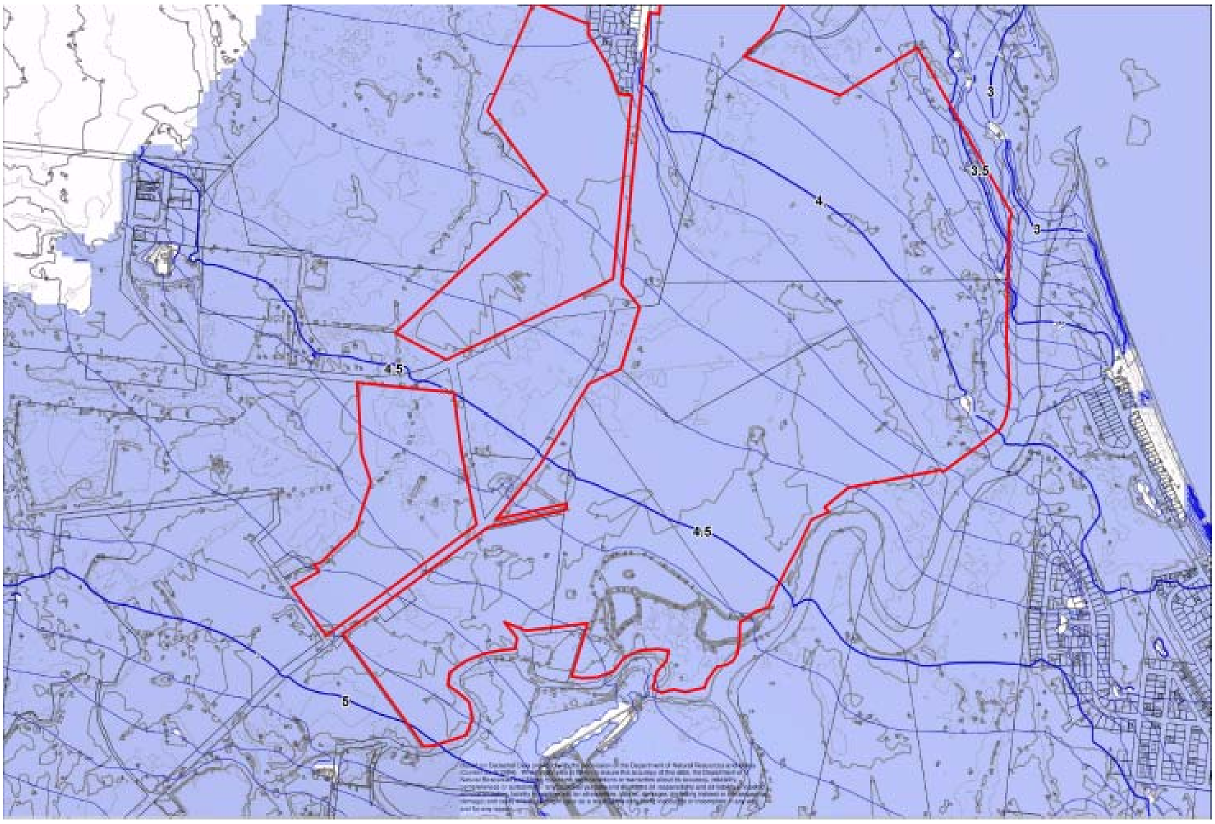

Figure 9-3 Approximate flood levels for a 1% AEP flood.

Source: Appendix K (Figure 2-10). Levels shown as grey contours and depths as blue contours.

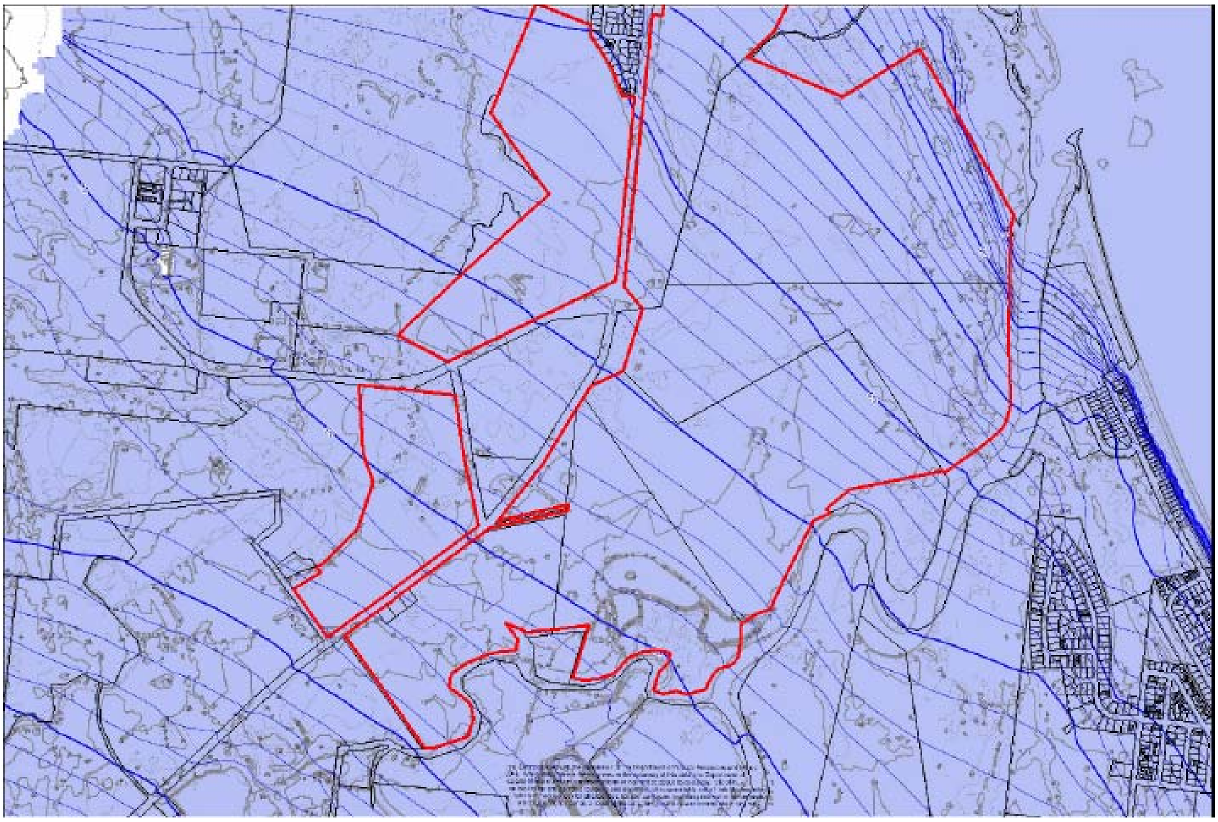

Figure 9-4 Approximate flood levels for a PMF.

Source: Appendix K (Figure 2-11). Levels shown as grey contours and depths as blue contours.

Table 9-2 shows flood levels based on detailed flood modelling for the undeveloped site for a range of events (20% AEP, 1% AEP and PMF), as well as 1% AEP with an allowance for climate change (see **Section 9.1.5**).

TABLE 9-2 GENERAL FLOOD LEVELS ACROSS THE SITE

Location	20% AEP		1% AEP		PMF	
	Level (m AHD)	Approx. depth (m)	Level (m AHD)	Approx. depth (m)	Level (m AHD)	Approx. depth (m)
South	3.0	0.6	4.5	2.5	7.5	5.5
Central	2.5	0.5 to 1.5	4.3	1.0 to 3.5	6.5	4.5 to 5.5
North	2.5	0.5	3.5	2.0	5.0	3.0 to 3.5
South (+ climate change)	Not modelled	Not modelled	4.55	3.0	Not modelled	Not modelled
Central (+ climate change)	Not modelled	Not modelled	4.35	1.5 to 4.0	Not modelled	Not modelled
North (+ climate change)	Not modelled	Not modelled	3.55	2.5	Not modelled	Not modelled

Source: Study team compilation based **Appendix K** (Table 2-3, 2-4, 2-5, and 2-6).

9.1.5 Climate Change

A discussion of the likely effects of climate change has been presented in **Section 3.6.6** and involves:

- sea level rise
- changes to intensity and frequency of extreme events (especially cyclones and rainfall).

Flood modelling has taken into account the 0.8 m predicted sea level rise. This shows that under such circumstances flood levels would be only marginally higher than currently considered because the frontal dune is the critical tailwater control in both the current and future cases.

9.1.6 Barron River Delta Flood Model

The Barron River Delta Flood Model is a dynamic two-dimensional hydraulic flood model (using the MIKE21 software package by the Danish Hydraulics Institute) of the Barron River delta developed originally by Connell Wagner on behalf of Cairns City Council to provide a comprehensive tool to represent the current flooding situation and to assist in planning and assessing future development within the Barron River delta. The model has the capability to predict design flood levels, depths, and velocities over the duration of a flood event that can occur within the delta.

Ground levels within the delta are represented within the model by a regular grid derived from numerous sources including aerial laser survey, ground survey, and bathymetric (below water) survey. In addition to the ground level elements, additional items such as roads, bridges and culverts can be included within the model. Flood flows are applied for a range of predicted flood events from which the model calculates the resulting flood levels, depths, and velocities. By modifying the grid (ground) levels and providing or modifying culverts etc., changes of landform within the delta can be represented by the flood model, allowing the effect on flood levels to be assessed.

Flood modelling within the delta commenced initially in 1981 with ongoing development occurring up until the last revision which occurred in 2007. Modifications to the model generally include:

- revision of ground levels based on revised or additional survey
- development within the delta that has progressively occurred
- refinement of flood flow estimates.

In order to ensure accuracy of the model, the flood model has been calibrated to several historical flood events, in particular the 1977 and 1979 Barron River flood events as these are amongst the largest for which reliable flow data exists. Consideration has also been given to the larger floods of 1911 and 1913.

The 2007 Mike21 Barron River Delta flood plain model was used as the basis for all Aquis Resort assessments as described in **Section 9.2.1f)**.

9.2 IMPACTS

9.2.1 Flood Levels and Velocities

Use of CRC's Barron River delta Flood Model and the local Aquis model shows that Barron River flooding impacts on parts of the site for floods with an AEP of less than 50% and the whole site for floods with an AEP of less than 20%. Yorkeys Knob Road has about the same immunity, i.e. less than 20% AEP.

A 1% AEP flood (as stipulated in CairnsPlan as the basis of design of habitable structures along with freeboard requirements) on the undeveloped site is characterised by the following:

- east of Yorkeys Knob Road, flood depths are typically 2.0 m
- west of the Yorkeys Knob Road, flood depths are greater due to lower elevation of the land and are typically over 3.0 m
- Yorkeys Knob Road itself would be inundated by several metres.

The design-related mitigation options to deal with site flooding are one or more of the following:

- adopting flood-tolerant land uses (e.g. golf courses) involving minimal earthworks that could affect external properties (see below), and accepting frequent inundation
- building habitable floors and important infrastructure above (at least) the 1% AEP level (plus freeboard) on piers such that floodwaters can pass beneath the development with no effect on external properties
- building habitable floors and important infrastructure above (at least) the 1% AEP level (plus freeboard) and provide compensatory waterways with appropriate flood plain storage (e.g. lake) to prevent floodwaters affecting external properties.

CairnsPlan requires that development should not result in adverse flooding impacts on off-site areas, namely:

- afflux (a rise in water level upstream of an obstruction due to damming effect) outside the property boundaries
- higher velocities or adverse flow paths outside the property boundaries.

Further, it is desirable that the flood immunity of Yorkeys Knob Road be increased to that of the Captain Cook Highway / Cairns Western Arterial Road link to improve its performance as an evacuation route.

a) Broad Flood Mitigation Solutions

A review of flooding reveals the following:

- A lake solution is suitable for the eastern lots (subject to coastal erosion, ecological considerations, and the ability to maintain acceptable water quality by seawater exchange).
- A lake solution is not suitable for the western lots due to excessive distance from waterbodies suitable for seawater water exchange.
- Pier solutions are suitable on all lots, subject to cost criteria.
- Flood-tolerant uses are suitable on all lots, but, of course, are limited in practicality for an integrated resort development.

b) Habitable Structures and Associated Areas

The Resort Complex Precinct (east of Yorkeys Knob Road) involves building habitable floors (and important infrastructure) on fill above the adopted flood levels. Impacts on external properties are to be mitigated using compensatory waterways with appropriate flood plain storage (e.g. a lake solution).

The adopted site development rules are that the resort should accommodate flooding and conform to the following design cases (with a check to make sure that storm tide and tsunami levels and forces are not higher):

- Lowest habitable floor: based on Barron River flooding (PMF) plus allowance for freeboard.
- Evacuation floor: based on Barron River flooding (PMF) plus allowance for freeboard.
- Design of habitable structures and provision of safe refuge: structural integrity, protection of critical infrastructure, and human safety criteria apply.
- No unacceptable afflux or velocity effects.

Recommended levels for habitable floors and safe refuge are provided in **Table 9-3**. This table shows that the recommended levels are based on flooding criteria. Although the minimum requirement for floor levels in the Barron River delta is based on a 1% AEP flood plus freeboard, the proponent has opted for the higher standard of PMF plus freeboard. This means that all habitable floor levels at the Aquis Resort will be above the necessary evacuation level.

Subject to detailed planning under the Integrated Emergency Management Plan (**Chapter 12** – Hazards), it is possible that the Aquis Resort refuge areas and associated emergency management infrastructure and services could be used by residents of Yorkeys Knob.

c) Flood-tolerant Uses

The golf course, infrastructure on the western lots, and all areas of natural vegetation and restoration (i.e. Sports & Recreation Precinct and Environmental Management & Conservation Precinct) are essentially flood-tolerant uses. They do not require substantial earthworks and will not result in adverse flooding impacts on off-site areas. The relevant performance requirement is:

- Design of car parking areas and areas where frequent flooding is not of concern: AEP (flooding) = 20%.
- The golf course and conservation areas could be at a lower level.
- Actual design levels have not yet been set.

d) Transport Infrastructure

Yorkeys Knob Road should be raised to provide additional flood immunity, namely:

- Design of Yorkeys Knob Road and connections to the Captain Cook Highway / Cairns Western Arterial Road: AEP (flooding) = 2%.
- Provide sufficient cross drainage to distribute flood flows.
- See **Table 9-4** for adopted design levels.

e) Design of Mitigation Solutions

<u>Aquis Resort Site</u>

The mitigation solution selected for addressing flood impacts on the site is a large lake designed to provide compensatory excavated waterways which also provide compensatory flood storage. The current form of the lake and overall landform were determined iteratively based on detailed flood modelling using CRC's Barron River Delta Flood Model (August 2007). This is a full two dimensional dynamic flow model and is the planning and assessment tool approved by CRC for flooding compliance assessments.

Design Considerations

In the modelling:

- filling was assumed to provide a minimum immunity to the 1% AEP flood or storm tide (whichever results in the greater level)
- higher filling levels for the Resort Complex were investigated as the design progressed
- compensatory waterways were iteratively designed until acceptable off-site impacts were obtained.

Issues associated with design of the lake as modelled are:

- The compensatory waterway has to be of an adequate cross sectional area to convey the design floods around the raised land of the Resort Complex Precinct without creating unacceptable afflux or velocities. From a purely hydraulic perspective, such a waterway:
  - needs to be of the width / configuration of the proposed lake
  - could have a bed level of 0.5 m AHD
  - does not need to be joined at the southern end (i.e. could be two parallel channels on either side of the Resort Complex Precinct with a connection across the northern end)
  - could be either 'always wet' or 'mostly dry' (see below).
- A bed level of about 0.5 m AHD is close to that of the dry season groundwater level (approximately 0.3 m AHD although this is seasonally variable). Thus there is an option to have a 'dry' channel that is perched above this level and that would only contain water during the wet season and especially during a flood. Modelling was undertaken to check the performance of such a channel and it was found to be acceptable in terms of flood mitigation. However, it was determined that such a waterway would have maintenance problems as it would be so close to local groundwater that it would be boggy and difficult to maintain in a healthy and aesthetically pleasing state. In the wet season, groundwater rises as high as RL 1.5 m AHD which could fill the lake. In particular:
  - lined options (e.g. concrete) were considered to be impractical and aesthetically undesirable and were therefore rejected
  - any natural vegetation established on the bed and banks would need to be tolerant to waterlogging – the end result would be an ephemeral wetland that would be predominantly fresh to brackish and that would pond shallow water for extended periods of time, leading to algal growth and die-off issues, periodic rotting vegetation, and a generally unacceptable aesthetic outcome
  - such vegetation would be difficult to mow and otherwise maintain as a waterway with acceptably low flood plain roughness such that it could convey the design flow
  - there would be health risks associated with standing water (mosquitos and midges) and the resulting environment would encourage birdlife, with associated additional bird strike risk.
- Having settled on an 'always wet' option, design decisions were made regarding:
  - width – determined by flooding performance (a width varying between 80 m and 160 m is required, with actual width at any point being optimised by hydraulic design)
  - depth – an optimum of 4 m depth was selected based on past experience with constructed waterbodies (this is a compromise between maximising water quality and minimising excavation volumes) – the important issue is to provide sufficient depth to reduce light penetration and algal growth on the bed
  - connections – water quality performance requires circulation and this means that the two channels need to be connected to form a lake where circulation could be achieved

- top water level – determined largely by aesthetic criteria once groundwater interaction issues were solved using a quarantining solution as described in **Chapter 10** (Water Resources) – this set water level at just below the natural ground (i.e. top water level of 1.5 m AHD)
- bed level – determined by depth and top water levels decisions above (adopted as -2.5 m AHD plus nominal allowance for sediment build-up)
- lake ecology – determined by water quality outcomes (water will be saline and will be similar in quality to Richters Creek or better)
- edge treatment – determined by structural, aesthetic, cost, ecological, health, and safety considerations (currently modelled with a vertical inner and outer edge although the outer edge could be changed if necessary).

Further details and an assessment of performance are provided in **Chapter 11** (Water Quality).

Floor Levels

Table 9-3 shows the recommended design floor levels for the development (based on flooding criteria).

TABLE 9-3 DESIGN FLOOR LEVELS

TYPE	ARI + FREEBOARD	RECOMMENDED DESIGN LEVEL (m AHD)		
		Upper (south of Resort Complex Precinct)	Mid (southern part of Resort Complex Precinct)	Lower (northern part of Resort Complex Precinct
Lowest habitable floor	PMF or Higher	7.5	7.5	7.5
Evacuation floor	PMF or Higher	7.5	7.5	7.5

Source: Appendix K (Table 2-7).

Refer to **Chapter 12** (Hazards) for consideration of other criteria (e.g. storm tide and tsunami). This shows that a minimum podium level of 7.5 m AHD has been set for the development resort hotels and facilities in the Resort Complex Precinct. Referring to **Table 9-2**, the recommended floor level provides between 1 and 2.5 m freeboard to the PMF for the 'mid' and 'lower' parts of the site (these are the areas covered by the Resort Complex Precinct).

Water quality considerations of the lake solution are important design matters and these are described in detail in **Chapter 11** (Water Quality). In summary, as an outcome of water quality design the lake will involve:

- a water body with an area of 33 ha and a depth of 4 m
- a volume of approximately 1.3 GL
- water exchange with the Coral Sea / Richters Creek such that the lake water will approximate the quality of water in Richters Creek.

Yorkeys Knob Road

The mitigation option selected for addressing poor flood immunity of Yorkeys Knob Road is to upgrade the road to a 2% AEP trafficable standard to match that of the Captain Cook Highway (north) and Cairns Western Arterial Road. Flood modelling also included consideration of the proposed Yorkeys Knob Road upgrade works (height and cross drainage).

Table 9-4 provides detailed recommendations for raising Yorkeys Knob Road to a 2% AEP immunity based on modelling described above.

TABLE 9-4 PROPOSED ROAD LEVELS AND CROSS DRAINAGE REQUIREMENTS

LOCATION	CHAINAGE (km)	ROAD LEVEL (m AHD	
		Existing	Proposed
Captain Cook Highway	0.0 - 0.5	N/A	4.9 m to 4.7 m
Yorkeys Knob Rd Roundabout	0.0 - 0.5	3.8 m to 4.4 m	N/A
Robinson Road South	0.5 – 1.0	3.0 m to 4.3 m	4.4 m to 4.6 m
Robinson Road North	1.0 - 1.5	2.75 m to 3.4 m	4.2 m to 4.5 m
Cattana Road	1.5 - 2.0	2.32 m to 3.3 m	4.0 m to 4.3 m
Morabito Road	2.0 - 2.5	2.2 m to 3.0 m	3.8 m to 4.0 m
Yorkeys Creek	2.5 - 3.0	2.8 m to 3.0 m	3.7 m to 3.8 m
Dunne Road	3.0 - 3.5	2.6 m to 3.2 m	3.6 m to 3.8 m
Yorkeys Knob	3.5 - 4.0	2.5 m and 4.4 m	3.5 m and 4.4 m

Source: Appendix K (Table 5-1).

f) Impacts of Mitigation Solutions

Planning Controls

Planning controls permit certain development in the delta but require compliance with a number of criteria related to minimum building levels, access provisions, prohibition on affecting other properties (afflux, velocities), and other matters covered in CairnsPlan's *Flood Management Code* and *Excavation and Filling Code.*

Impact assessment was necessary in order to demonstrate compliance with these codes. This assessment requires the use of the Barron River Delta Flood Model described in **Section 9.1.6** as explained below.

Flood Modelling

The 2007 Mike21 Barron River Delta flood plain model was used as the basis for all Aquis Resort assessments, but with a conversion and updating to a new TUFLOW two-dimensional flood model of the delta. TUFLOW is a two-dimensional hydraulic software package developed by BMT WBM and which is used world-wide. The development of a TUFLOW model was decided upon to utilise the flexible culvert modelling capabilities which are more accurate and more powerful than those of the MIKE21 modelling system, and also for speed of model runtimes.

Given the very large number of development refinements investigated, and the large number of design storm and storm tide events investigated, it was impractical to use the MIKE21 model within the limited timetable for the EIS. In converting the MIKE21 model to TUFLOW, where possible all of the features and data were directly transferred to TUFLOW. A comparison of flood levels was conducted between the two models to ensure consistency of results between the two models. As part of the subsequent design refinement stage of the project, it is proposed that the final development configuration will be tested back against the MIKE21 flood model.

To assess the proposed development, modifications to the model included:

- excavation representing the proposed lake
- filling to represent the resort platform and other various landforms
- high level access roads and bridges
- upgrading and duplication of Yorkeys Knob Road to be trafficable in a 2% AEP flood event (included raising of the road and additional culverts).

Resulting flood levels, velocities and flow patterns predicted for the development were compared to the pre-development flood conditions to provide the resultant predicted flood impacts. Flood impacts can represent either an increase in flood level or velocity a decrease in flood level or velocity or no change in flooding characteristics. Based on resulting flood impacts, the flood model can be utilised to test refinements of the development design to ensure that the proposed development does not adversely affect flooding within the delta.

Flood level impacts are represented below by graphical plots which are generated by subtracting the pre-development flood levels from the post-development flood levels. The coloured contour bands represent the difference in water level as a result. Negative values (blue colours) represent a decrease in flood level when compared to the pre-development flood levels and the positive values (green through to red) represent increases in flood level when compared to pre-development flood levels.

Peak flood levels, depths and velocities are also represented by coloured contour plots, with each colour band representing a range of values specific to each. Plots are provided for both pre- and post-development scenarios for a range of flood events.

Aquis Flooding Impacts

Figure 9-5 to **Figure 9-9** show modelling outputs for various AEPs, namely 20%, 10%, 5%, and 1%. A velocity profile for the 1% AEP is also included.

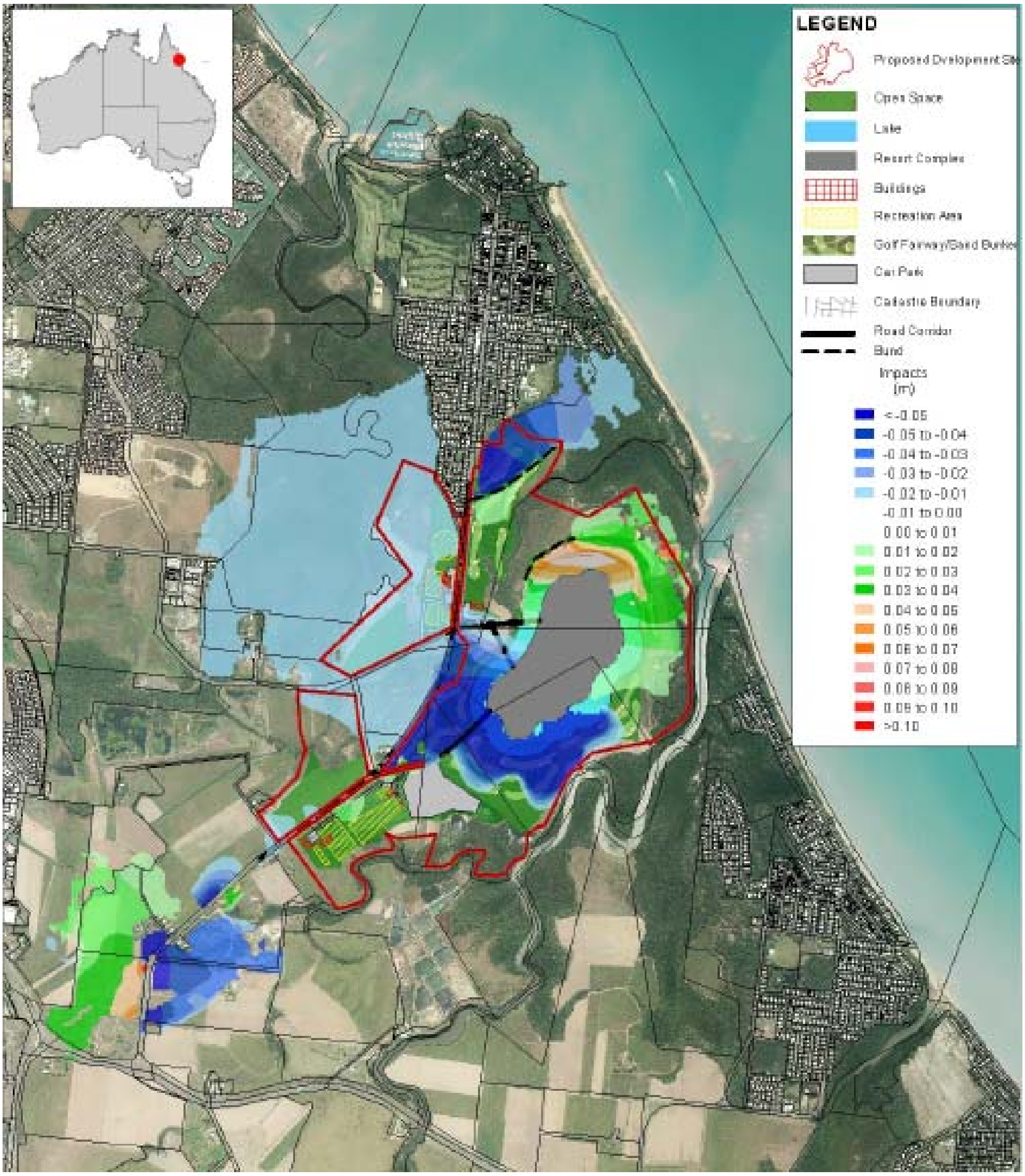

Figure 9-5 Flood modelling results of 20% AEP flood.

Source: Appendix K (Figure 5-3). Areas shown in blue shades will experience lower water levels with the Aquis project than previously. The converse applies for green / red colours.

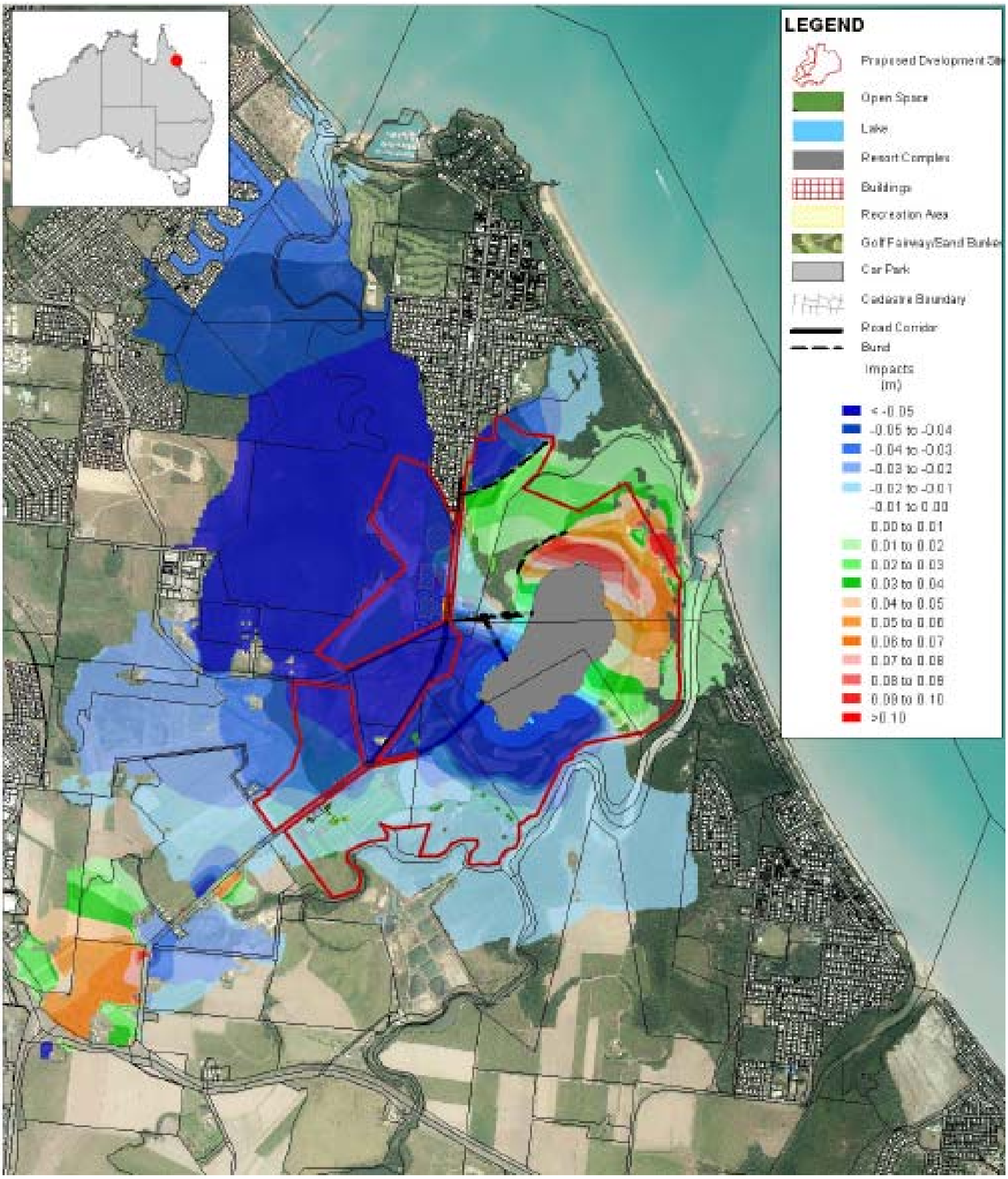

Figure 9-6 Flood modelling results of 10% AEP flood.

Source: Appendix K (Figure 5- 4).

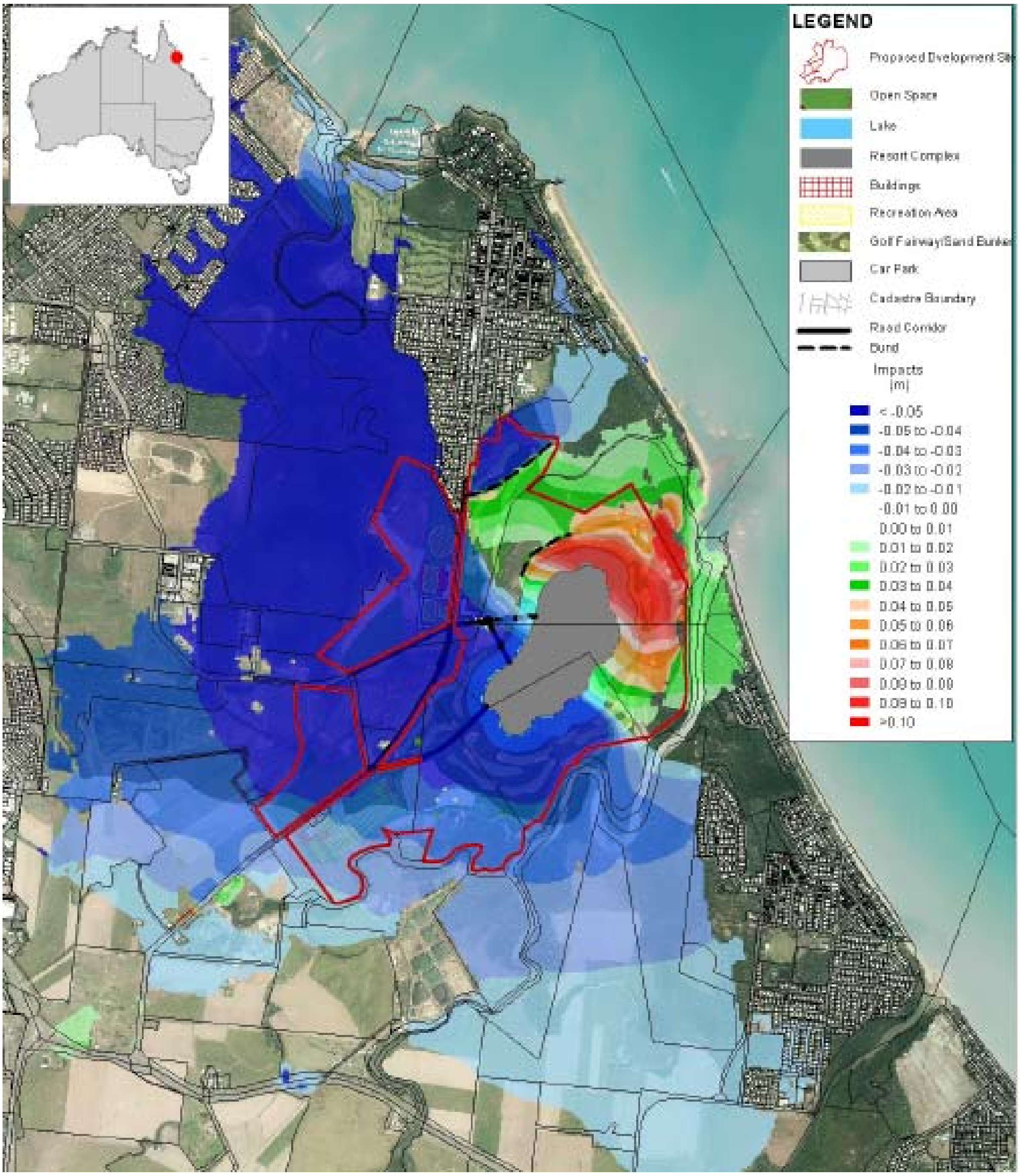

Figure 9-7 Flood modelling results of 5% AEP flood.

Source: Appendix K (Figure 5- 5).

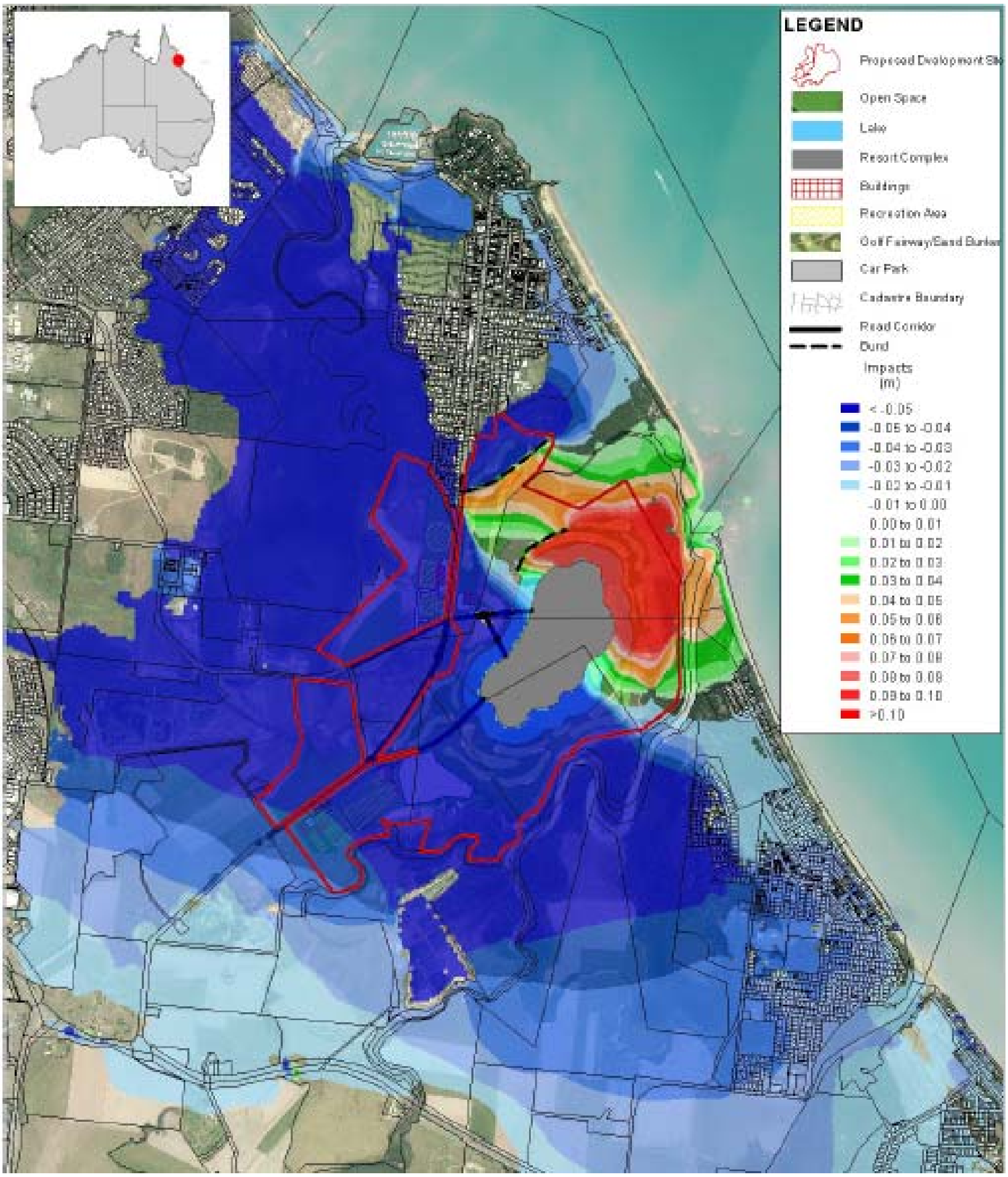

Figure 9-8 Flood modelling results of 1% AEP flood.

Source: Appendix K (Figure 5-1).

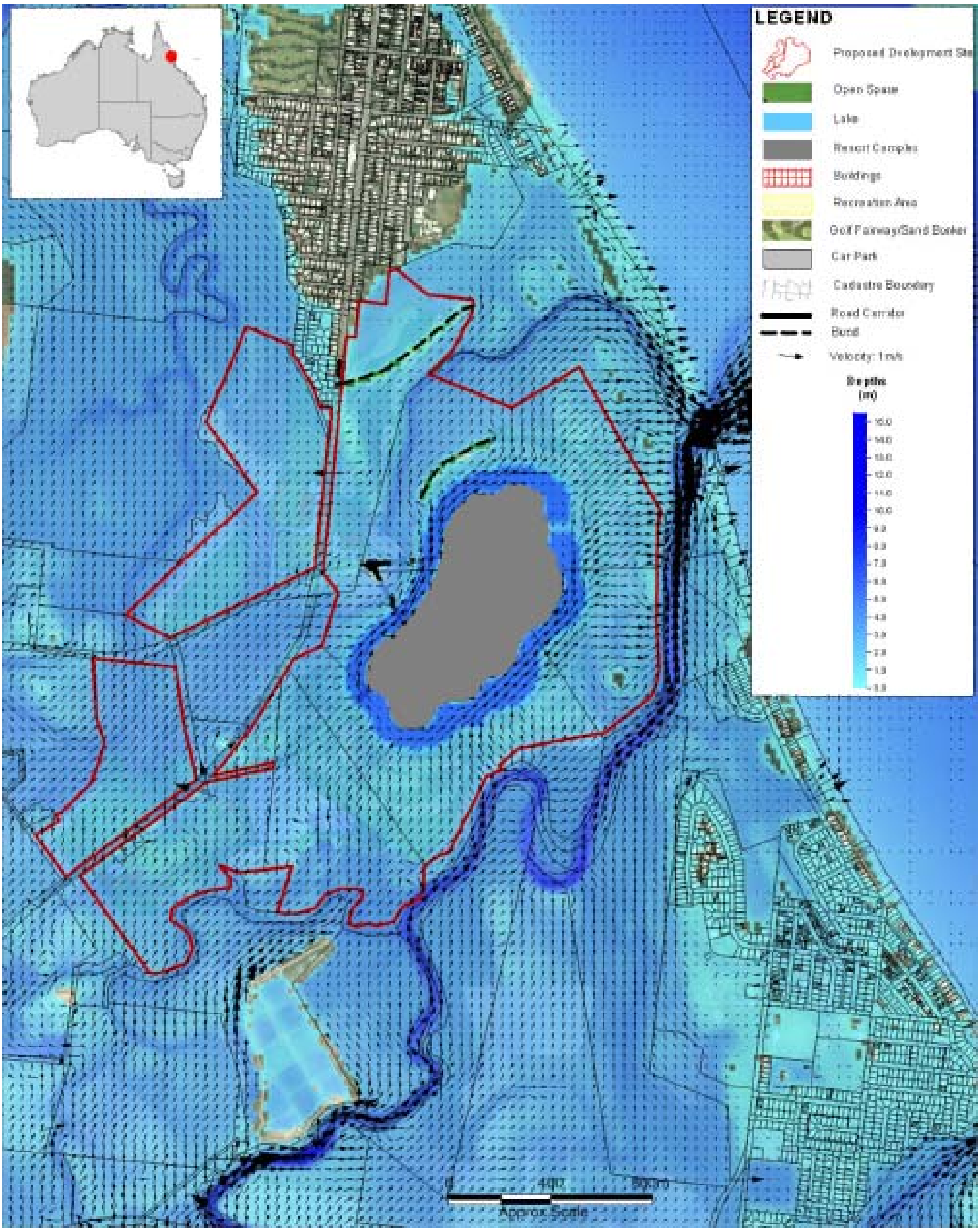

Figure 9-9 Velocity modelling results of 1% AEP flood.

Source: Appendix K (Figure 5-2). Arrows show the speed and direction of flow and colours indicate depth.

Assessment Against Flood and Filling Codes

The following describes an assessment of the project against the relevant CairnsPlan Code provisions.

Flood Management Code

An assessment of the proposed development against the relevant performance criteria and acceptable measures for this code is shown in **Table 9-5**.

TABLE 9-5 ASSESSMENT AGAINST FLOOD MANAGEMENT CODE

Performance criteria	Acceptable measures	Comment on compliance
P1. An acceptable level of flood immunity must be provided for new development	A1.1. Development satisfies the minimum levels set out in Table 1 below.	All hotels, apartments, casino, swimming lagoon, aquarium, and essential services will be provided a minimum of 500 mm above the ARI 100 year flood level, with safe refuge areas above the PMF, with suitable emergency services including independent power, water supply, sewerage and communications to support the safe refuge above the PMF.
P2. An acceptable level of flood immunity must be provided for the access to new development.	A2.1. Access to new development is in accordance with the Queensland Urban Drainage Manual.	With the proposed major upgrade to Yorkeys Knob Road, trafficable access to and from the site across and out of the delta will be achieved. The main access roads within the site will be to the same standard.
P3. Development on premises does not result in a significant impact on other premises.	A3.1. Excavation or filling in premises results in a not worsening on other premises both upstream and downstream of up to 20 mm; and A3.2. Development does not occur within the riparian corridor.	Flood modelling has demonstrated that, subject to suitable detailed design, no significant adverse impact of flooding will result from the proposed development and that impacts can be limited to no more than 20mm. No development other than the lake intake / outlet is proposed within the riparian corridor, and this will consist of a buried pipeline aligned with existing cleared site tracks.
P4. Drainage paths on premises are maintained free of obstruction to permit unimpeded flow of stormwater.	A4.1. Where premises contain waterway a drainage reserve or easement with a minimum width of 10 metres from the high bank of the waterway is provided; and A4.2. No excavation or filling of drainage paths are permitted.	All site areas will be free draining with the exception of the proposed site lake. No works are proposed within major waterways, except for the intake / outlet structure for the lake turn-over system which will be located within Richters Creek.

Performance criteria	Acceptable measures	Comment on compliance
P5. New development does not create an adverse impact on existing properties within Barron River delta as mapped on the Smithfield – Barron District Flood Inundation (ARI 100 year) Overlay Map.	A5.1. No acceptable measures are specified. Note: The Planning Scheme Policy, Reports and Information Council may request, provides a guide to the information which should be provided to demonstrate that the Performance Criteria is achieved.	The proposed development has been demonstrated to show that, subject to suitable detailed design, there will be no significant adverse impact in relation to flooding on existing properties within the Barron River delta.

Source: Appendix K (Section 6.3a).

TABLE 9-6 ASSESSMENT AGAINST FLOOD MANAGEMENT CODE (TABLE 1)

LAND USE	FILL LEVEL	FLOOR LEVEL
Residential Uses Tourist and Short-term Accommodation Uses Community Uses with a residential component	Immunity to 1 in 100 year ARI Flood	150 mm above 1 in 100 year ARI immunity
Retail Uses Business and Commercial Uses Industry and Associated Uses Community Uses involving access by the public Permanent residential car parking	Immunity to 1 in 100 ARI Flood	Immunity to 1 in 100 year ARI Flood Event
Temporary car parking	Immunity to 1 in 20 year ARI Flood	
Parks and open space	Immunity to 1 in 5 year ARI Flood	

Source: Appendix K (Section 6.3 – Table 1 from Flood Management Code).

Excavation and Filling Code

An assessment of the proposed development against the relevant performance criteria and acceptable measures for this code is shown in **Table 9-7**.

TABLE 9-7 ASSESSMENT AGAINST EXCAVATION AND FILLING CODE

Performance Criteria	Acceptable Measures	Comment On Compliance
P6. Excavation or filling must not adversely impact on other premises as a result of stormwater drainage flows or flooding.	A6.1. Stormwater drainage flows must be taken to a lawful point of discharge; and	The main resort precinct and all lands east of Yorkeys Knob Rd will drain directly to either the site lake or the Thomatis Richters Creek. Lake overflow will be to Yorkeys Creek within the site, and to Thomatis Richters Creek, the site properties west of Yorkeys Knob Rd are only proposed to be lightly developed, with no significant change in existing run-off characteristics, with existing farm drains off the site to be retained for site drainage. Hence, a lawful point of discharge can be achieved.
	A6.2. Excavation or filling must not result in: a) the ponding of water; or b) an erosive velocity of overland flow, on premises or adjacent premises; and	The site will be designed to be free draining, with the exception of the site lake. No significant adverse impacts on flood velocities are predicted beyond the site.
	A6.3 All berms must be: a) graded towards the upwards slope, and b) contain adequate drainage infrastructure to accommodate the changed drainage flows; and	Adequate drainage infrastructure is proposed as part of the development.
	A6.4. Excavation or filling must not result in an increase in the volume of water or concentration of water in: a) overland flow paths of the premises and other premises; and b) waterways; and	No increase in the volume of water or any significant concentration of water to other premises is proposed. Whilst the lake outlet is to Thomatis / Richters Creek, this does not result in adverse impact to other premises.
	A6.5. Excavation or filling must not occur: a) within a waterway; or b) within a riparian corridor; or c) below the 1 in 100 year flood line; and A6.6. Excavation or filling complies with the Design Guidelines set out in the Planning Scheme Policy Development Manual.	No filling or excavation is proposed within a waterway. No filling or excavation is proposed within the riparian corridor except for the installation of a buried pipeline for the lake intake / out falls, with these being situated within existing cleared farm access tracks.

Source: Appendix K (Section 6.3b).

Summary of Compliance

In summary, modelling demonstrates that the resort can feasibly be designed to achieve a no significant worsening impact on private land beyond the site, in terms of actionable damage and nuisance. In particular it shows that:

- upstream of the development, there are extensive areas of predicted flood level reduction and no unacceptable flood level increases
- downstream of the development, significant impacts are contained to non-urbanised areas
- predicted velocities across the site are generally less than 1 m/s and therefore are non-scouring for grassed areas and are not highly hazardous to people
- flood modelling and impact assessment has also been carried out for a range of events and this reveals that acceptable flooding impacts can be achieved across the full range of flood frequencies.

Overall, the impact is beneficial due to the lowering of flood levels on many Holloways Beach properties.

With rising sea levels, the frontal dune downstream of the site will act as a control weir to floods once they have overtopped the channels, thus resulting in flatter flood slopes upstream of the dunes and a steeper gradient to the ocean level downstream of the dunes. So, with SLR, there will be a significant effect seaward of the dunal system, but only a small effect upstream of the dunes, as the dunes are only just overtopped. Therefore impacts with a higher sea level will be smaller than those presented above.

Yorkeys Knob Road

The modelling described above is based on a design for Yorkeys Knob Road at the required level to provide the desired immunity with the necessary drainage structures to not create flooding problems. The flooding impact assessment therefore includes consideration of the impacts of the road upgrade. These were found to be acceptable.

9.2.2 Siltation from Sediment Inflow

a) Barron River Floods

During significant river flooding events greater than a 50% AEP event, floodplain break-out of flow occurs, with large suspended sediment loads carrying silts and fine sands across the delta, including across the site. Two alternate methods were used to estimate the likely sediment load.

- Based on the Barron River Delta Investigation (Department of Harbours and Marine 1981), suspended sediment loads of up to 1200 mg/L were recorded. Assuming this load exists for the duration of the 1% AEP flood (which is conservative), and using the numerical flood model of the delta to determine that over-bank flooding at the site occurs for 48 hours with an average flow of 500 m^3/s, this would result in 103,680 tonnes of sediment entering the site in suspension. If it is further assumed that all of this material was to settle, about 70,000 m^3 of material would be deposited (assuming a density of 1.5 t/m^3). Spreading this material over the 340 ha site would result in an average of 20 mm deposition. Even if all of the suspended sediment was deposited in the 33 ha lake, this equates to an average siltation depth of 250 mm or 6.25% of lake depth. These calculations are based on the conservative assumption that there is uniform and complete deposition across the lake. In reality, only a small proportion of sediment will fall out of suspension, so actual average sedimentation will be much less.

- An alternate method of estimating site siltation is by using annual sediment load for the Myola gauging station as documented in the Barron River Delta Investigation which estimates the highest annual load as being 281,000 tonnes for the period 1915 to 1929. Freshwater Creek will also contribute to the sediment load. However Freshwater Creek is regulated by Copperlode Dam and has a significantly smaller catchment than the Barron River. Therefore it is anticipated that Freshwater Creek will only have a minor load contribution compared to that of the Barron River. The report estimates that 39% of the river flow uses the Thomatis / Richters Creek system for minor floods, which results in 73,000 m^3 (assuming the above density). If it is assumed that all of this material were to fall out over the site, or just in the lake, this results in 20 mm and 220 mm siltation respectively.

These two methods consider the issue from different perspectives and yield similar results. That is, that the likely siltation will be, at worst, less than 6% of the lake depth if all of the sediments carried by a 1% AEP flood fall out in the lake.

b) Local Floodplain Erosion

An assessment of the likely siltation of the lake solution from soil eroded by an incoming flood was undertaken and this involved:

- interrogation of the TUFLOW flood model to assess likely bed shear stress (i.e. the force that the floodwaters exert on the ground over which they pass)
- reference to standard hydraulics theory to determine whether or not the resultant velocities are likely to result in significant erosion.

Without significant erosion of the land upstream of the lake there will not be significant deposition of sediments into the lake.

Findings are:

- As shown on **Figure 9-10**, the resulting peak velocity in the western portion of the development is less than 0.5 m/s. Vegetation is proposed in this western area (i.e. rehabilitated and/or golf course) which will further limit the potential for erosion.
- An increase in peak velocity is predicted to occur on the north side and southern ends of the proposed development. The increase is generally minor and in the order of 0.2 m/s and largely within the development boundary. The velocities in these regions are generally less than 1 m/s and similar to the western area will be either rehabilitated and/or covered with vegetation or hard surfaces, thereby limiting the erosion potential.
- Modelling (**Figure 9-11**) shows a bed shear stress less than 6 N/m^2 for the 1% AEP flood. It is important to note that the predicted bed shear stress plots are based on the average velocity vertically through the water column. In reality, the near bed velocity will be less than half the average velocity. That is, the actual bed shear stress will be less than 3 N/m^2 at the surface of the land.

Based on standard hydraulic theory, the threshold of movement for sandy clays (which is the main type of soil likely to be encountered) is around 10 N/m^2 for material in a natural state between 'loose' and 'compact'. This threshold is over three times that occurring on the site, meaning that there will be minimal re-suspension of sediments from the bed of the lake during both local and Barron River floods. It should also be noted that vegetation cover typically prevents erosion up to velocities of 1.5 m/s to 2.0 m/s and those likely to be encountered are in the range of 0.2 to 0.5 m/s.

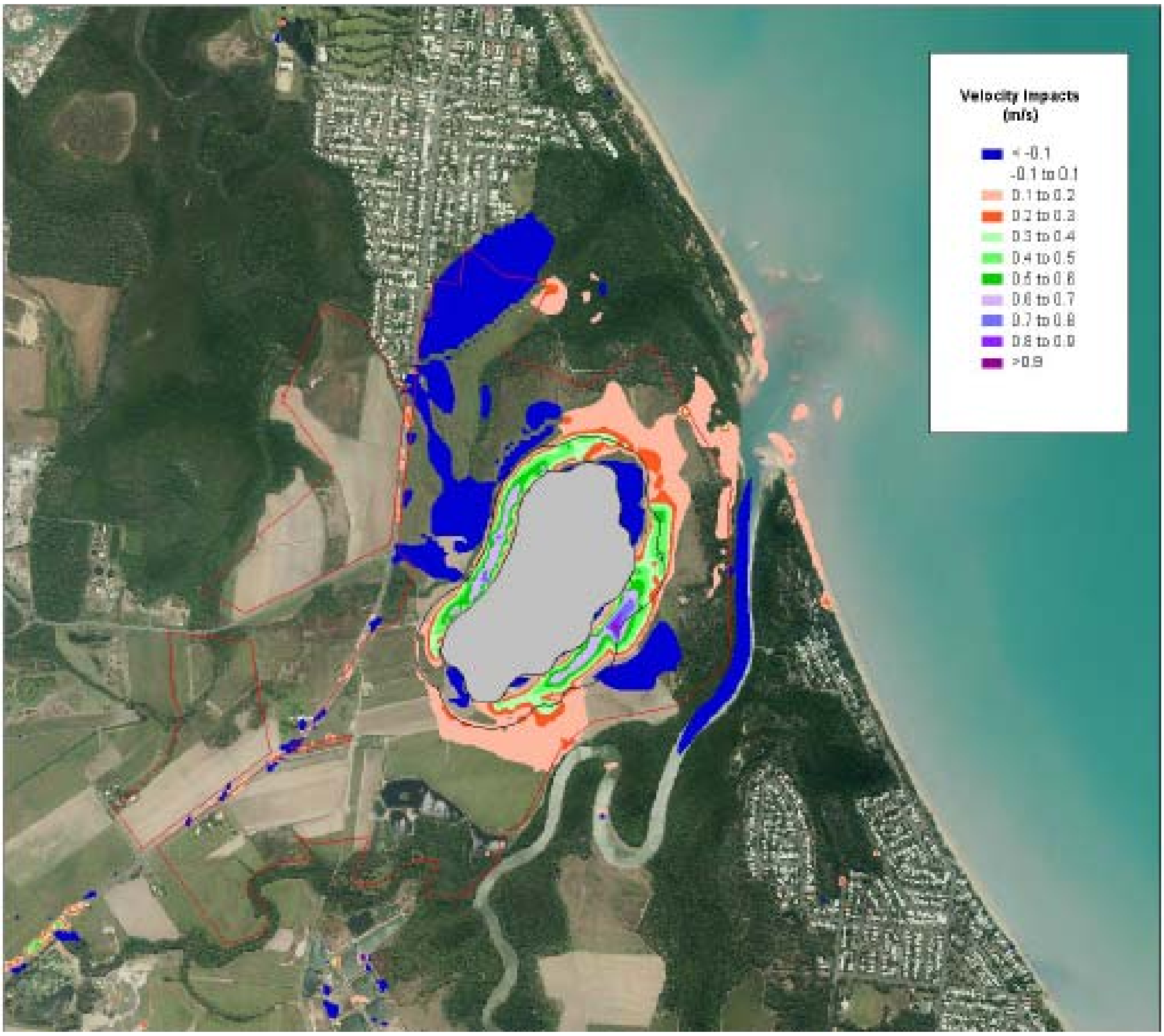

Figure 9-10 Velocities for a 1% AEP flood.

Source: Appendix K (Figure 5-10).

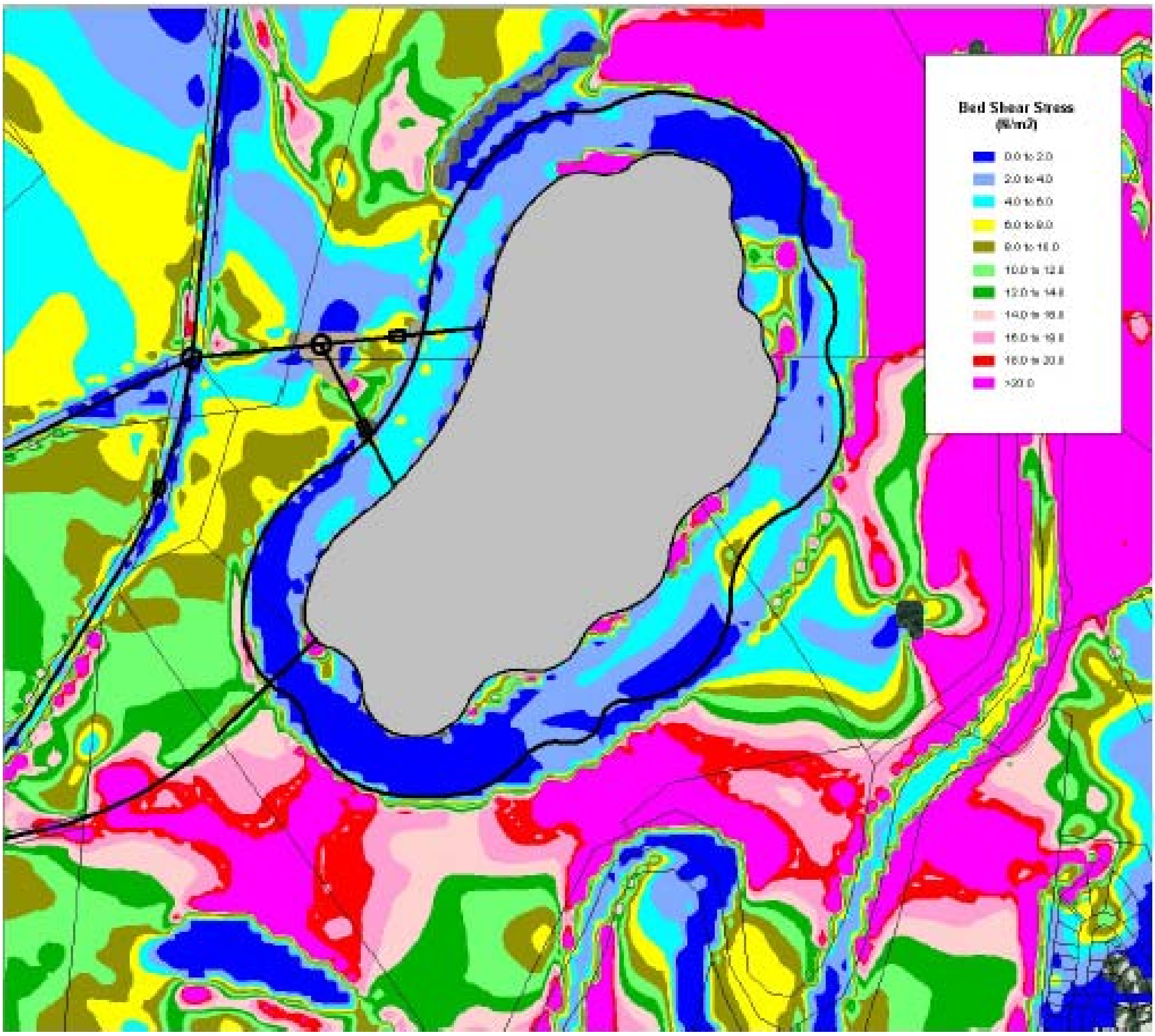

Figure 9-11 Bed shear stress for a 1% AEP flood.

Source: Appendix K (Figure 5-11).

9.2.3 Siltation from Lake Operations

In addition to potential siltation from river flood events, the lake inflow from tidal exchange with Richters Creek has the potential to ingest suspended sediments which may potentially settle in the lake.

Based on available water quality monitoring results, typical average wet and dry season suspended solids levels in Richters Creek are 50 mg/L and 10 mg/L respectively. Tidal hydrodynamic modelling shows that the lake tidal exchange system turns over 31,000 ML/annum. Making appropriate assumptions about the lengths of the wet and dry seasons and other factors results in an estimate of around 600 tonnes of suspended solids that could be ingested into the lake annually.

If it is conservatively assumed that all this suspended sediment is deposited in the lake, this equates to less than 2 mm/y average deposition across the lake.

This is considered insignificant. However, because of the need to be able to remove sediment arising from floods, it is recommended that equipment such as a suction dredge be available for maintenance as required.

9.2.4 Siltation from Storm Surge and Tsunami

It is not possible to predict the quantity of material likely to be deposited in the lake in the event of a tsunami or storm surge large enough to inundate the lake.

9.3 MITIGATION AND MANAGEMENT

9.3.1 Flood Levels

The modelling shows that the design meets the relevant CairnsPlan codes and therefore no mitigation is required. This is for the operational phase.

It is also necessary that no afflux or other adverse impacts of flooding occur during construction. This issue is considered in the preliminary construction methodology (**Chapter 4** – Description of Proposed Project). This notes that, until the lake is constructed to sufficient depth to convey flood, there will be a limit to the extent that earthworks and materials can be stockpiled on-site during high flood risk periods (January to May). Once the Resort Complex Precinct footprint is constructed and the lake is in place, the building works can be undertaken from within the podium footprint.

A detailed construction methodology will be developed to ensure that the site is secure from floods and does not impact on external areas at all times.

9.3.2 Siltation from Sediment Inflow

While the 6% of lake depth figure quoted in **Section 9.2.2** is likely to be an over-estimate of siltation, there will need to be clean-up after floods, and periodically, the lake may need to be de-silted. Based on the above, de-silting would be infrequent, and less than once every 10 years except for major events. On-site management of extracted material will be required and provision has been made in the Concept Land Use Plan for an appropriate silt disposal facility site. Annual lake bed surveys at selected cross sections will be required to monitor silt build-up over time.

Recommendations for management of sediments from all sources are included in the conceptual Sedimentation and Maintenance Dredging Plan described in **Chapter 11** (Water Quality).

9.3.3 Siltation from Lake Operations

The depth of sediment arising from lake operations is considered insignificant. However, because of the need to be able to remove sediment arising from floods, it is recommended that equipment such as a suction dredge be available for maintenance as required.

Recommendations for management of sediments from all sources are included in the conceptual Sedimentation and Maintenance Dredging Plan described in **Chapter 11** (Water Quality).

9.3.4 Siltation from Storm Surge and Tsunami

As noted above, it is not possible to predict the quantity of material likely to be deposited in the lake in the event of a tsunami or storm surge large enough to inundate the lake. A management response will be required that includes the use of a suction dredge to remove sediment and re-profile the lake.

Recommendations for management of sediments from all sources are included in the conceptual Sedimentation and Maintenance Dredging Plan described in **Chapter 11** (Water Quality).

9.4 RESIDUAL IMPACTS

9.4.1 Flood Levels

It is considered that the design levels adopted provided for the Resort Complex Precinct are adequate to provide a very high level of safety in the event of Barron River flood. At 7.5 m AHD, this level provides between 1 and 2.5 m freeboard to the PMF for the 'mid' and 'lower' parts of the site (these are the areas covered by the Resort Complex Precinct).

Structures will need to be designed for the loads induced by a major flood to guarantee the effectiveness of the adopted 'shelter in place' strategy and a range of emergency response measures will be required to be in place via the Integrated Emergency Management Plan.

The modelling shows that the design meets the relevant CairnsPlan codes and that the residual impacts (afflux and velocities) are acceptable and that the Aquis Resort response to this hazard will not have any adverse impact on the surrounding area.

A detailed construction methodology will be developed to ensure that the site is secure from floods and does not impact on external areas at all times.

9.4.2 Siltation from Sediment Inflow

The Sedimentation and Maintenance Dredging Plan will ensure that lake siltation from sediment inflow will not compromise lake function.

9.4.3 Siltation from Lake Operations

The Sedimentation and Maintenance Dredging Plan will ensure that the minor lake siltation from normal lake operation will not compromise lake function.

9.4.4 Siltation from Storm Surge and Tsunami

The Sedimentation and Maintenance Dredging Plan will ensure that any lake siltation from storm surge or tsunami will not compromise lake function.