Flooding

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Chapter 19 - Table of Contents

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19.1 Introduction

This chapter of the EIS provides a flood assessment for the proposed resort, including a revised Dam Failure Impact Assessment for Gap Creek Dam. Catchments contributing to the resort and Gap Creek Dam extend over the south-western part of Lindeman Island and are proposed to be amended by increasing the size of Gap Creek Dam to cater for predicted demand as outlined in **Chapter 18 – Water Resources**. Temporal patterns and rainfall intensities for Lindeman Island were determined in accordance with Australian Rainfall and Runoff (AR&R). A rainfall on grid TUFLOW model was initially developed for the study area to determine the key flow paths on the island, especially in the flatter areas in the tableland at the top of the island. The rainfall on grid model was also used to confirm catchment boundaries and inflow points with the total size of the catchment in the study area calculated as approximately 189 hectares. As the proposed expansion of Lindeman Island Resort involves an increase in the number of lodgings, it is necessary to revisit the dam failure impact assessment also associated with Gap Creek Dam.

The flood assessment was based on the *Australian Rainfall and Runoff – Volume 1: Design Guide (2016)* and *Guidelines for Failure Impact Assessment of Water Dams (2012)*. Further supporting information including parameters used by Cardno for the calibration of the WBNM and TUFLOW models is available from **Appendix Q - Flood Study.**

Addendum: *This EIS was initially prepared assuming that the safe harbour was to be part of the Lindeman Great Barrier Reef Resort Project. With the commencement of the Great Barrier Reef Marine Park Authority's (GBRMPA) Dredging Coral Reef Habitat Policy (2016), further impacts on Great Barrier Reef coral reef habitats from yet more bleaching, and the recent impacts from Tropical Cyclone Debbie, the proponent no longer seeks assessment and approval to construct a safe harbour at Lindeman Island. Instead the proponent seeks assessment and approval for upgrades to the existing jetty and additional moorings in sheltered locations around the island to enable the resort's marine craft to obtain safe shelter under a range of wind and wave conditions. Accordingly, remaining references to, and images of, a safe harbour on various figures and maps in the EIS are no longer current.*

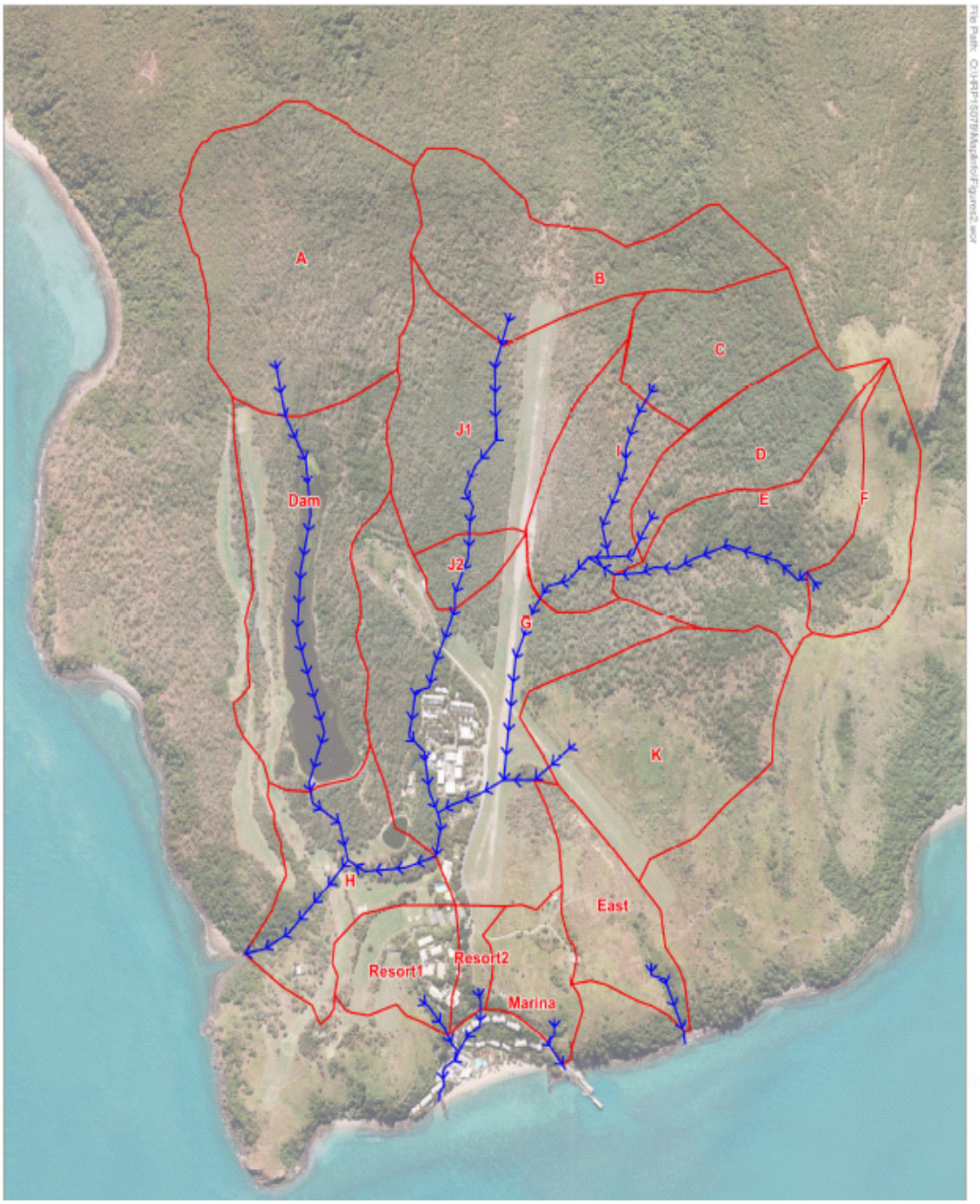
19.2 Gap Creek Dam Catchment

19.2.1 Existing Dam

The existing dam and catchments is shown in **Figure 19-1** and **Figure 19-3**. The total catchment area of Gap Creek Dam is approximately 43 hectares. The slope of the catchment in its upper reaches is approximately 45%. Survey and topographic data of the island is contained in **Appendix Q - Flood Study**, and the existing topography. The creek is mostly narrow and contained within well-defined banks. Downstream of the dam, Gap Creek opens up into the relatively flat area in the vicinity of the existing golf course, before discharging to a steep sloping gully which outlets into the ocean. The majority of the catchment comprises very dense vegetation. There are some areas of open grass, in particular the existing golf course. There are no impervious areas in the catchment which discharge to the dam. Within the golf course, there is a small culvert which conveys low flows to the steep gully (which outlets into the ocean). This culvert has not been included in the

flood modelling of the site as the small diameter of the culvert could easily become blocked during a flood event. A ridge is located between two fairways in the existing golf course. This ridge forms the watershed between the Gap Creek catchment and the catchment which discharges to the south towards the existing resort. However, in a dam-break scenario, the sudden release of a large volume of water from the dam has the potential to overtop this ridge, allowing flow to discharge towards the resort area. For this reason, a dam break analysis was carried out to determine whether the height or extent of this ridge needed to be increased.

Figure 19-1. Existing Catchment Plan.



19.2.2 Proposed Dam and Catchment

The proposed extension to the dam will increase the catchment area contributing to the dam (refer to **Table 19-1**, **Figure 19-2** and **Figure 19-4**). However, all of the runoff from the additional catchment area will not be able to be diverted into the dam due to environmental restrictions on works in this area. During small rainfall events, a new waterway will direct flow contained in the main channel of the creek to the extension of the dam. During medium to large rainfall events, some of the runoff from the additional catchment will be directed to the dam, but the remainder will continue in a southerly direction along the existing floodplain.

Figure 19-2. Proposed Catchment Plan.

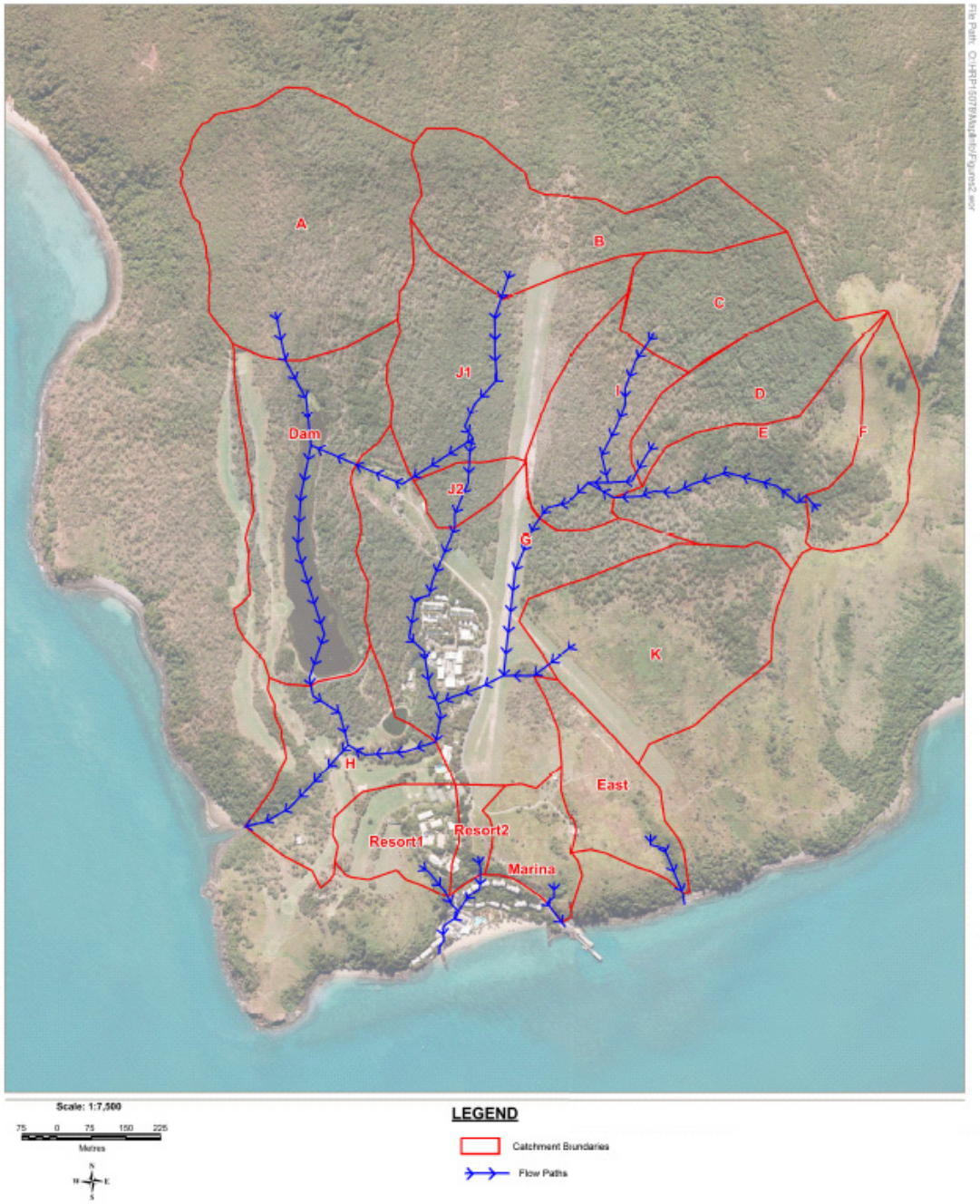


Figure 19-3. Existing Dam Extent.

Figure 19-4. Proposed Dam Extent (with mitigation bund location).

Table 19-1. Dam characteristics (existing and proposed).

Parameter	Units	Existing Dam	Proposed Dam
Type of Dam		Earth fill with riprap protection on upstream and downstream sides	Earth fill with riprap protection on upstream and downstream sides
Elevation at base of embankment	m AHD	48.5	48.5
Length	m	170	170
Crest Elevation	m AHD	51.33	51.33
Crest Width	m	3	3
Purpose of Storage		supply water for domestic and industrial use to the nearby resort	supply water for domestic and industrial use to the nearby resort
Dam Capacity to FSL	ML	199.6	207.3
Dam Capacity to DCL	ML	279.75	292.9
Dam Surface Area at FSL	ha	5.85	6.25

Details of the spillway outflow from Gap Creek Dam are shown in the following **Table 19-2**. The spillway is not affected by the proposed change in the dam catchment.

Table 19-2. Spillway Details.

Parameter	Units	Value
Spillway description		Unlined channel with a steel lip control structure
Spillway Crest Length	m	8.48
Spillway Level Below Dam Crest	m	1.4
Spillway Capacity (Dam Crest Flood)	m^3/s	24

19.3 Flood Assessment

19.3.1 Data

The following data was collected to contribute to the hydrologic and hydraulic models used to complete the flood modelling for Lindeman Island:

(a) Topography
- *Lidar data was used to form the existing topography. The Lidar was captured in 2009 as part of the Tropical Coast Lidar capture project;*
- *Detailed survey of the existing dam;*
- *Design TIN of the proposed extension to the dam;*

(b) Aerial images;
(c) IFD data as available from the Bureau of Meteorology;
(d) Dam stage storage relationship derived from detailed survey information; and
(e) DNRM dam break spread sheet.

19.3.2 Hydrology

The hydrologic analysis for Lindeman Island was carried out using Watershed Bounded Network Model (WBNM). The catchments contributing to flow into the dam and Lindeman Island resort extend over the south-western part of Lindeman Island. The WBNM catchment plan is shown in **Figure 19-1**.

The runoff from the eastern part of the study area generally flows in a southerly or westerly direction to the existing airplane runway and staff accommodation areas. The waterway then has its confluence with the outflow from Gap Creek Dam, near the golf course. The combined flow then discharges to the western coast of the island. Small catchment areas discharge runoff to the southern coastline of the island. Temporal patterns and rainfall intensities for Lindeman Island were determined in accordance with Australian Rainfall and Runoff (AR&R). A rainfall on grid TUFLOW model was initially developed for the study area to determine the key flow paths on the island, especially in the flatter areas in the tableland at the top of the island. The rainfall on grid model was also used to confirm catchment boundaries and inflow points. The total size of the catchment in the study area is approximately 189 hectares. The percentage impervious for each sub-catchment was determined based on aerial photography and site inspection and totals approximately 4.93%.

The 1% AEP event was analysed for a range of storm durations to determine the range of critical durations throughout the catchment. Due to the variety of conditions over the catchment, including steep upper catchments and flat inland catchments, the critical duration varies throughout the study area. Hydrographs were exported from the WBNM model for use in the TUFLOW model, for the existing and post development cases. A constant tail water level at the ocean outlets of 2.66 mAHD (equal to Highest Astronomical Tide, or HAT) was adopted. Due to the large difference in elevation between the ground levels in the study area and the tide level, the tailwater level boundary did not affect the calculated flood levels. The WBNM derived local hydrographs were applied locally towards the downstream end of each subcatchment.

19.3.3 Results

19.3.3.1 Existing Conditions

The existing case 1% AEP flood levels and depths are presented in **Figure 19-5** and **Figure 19-6** respectively. The results show that the flood flow is conveyed in the steep valley which discharges towards the existing resort. At the downstream end of this valley, the flow is diverted to an underground pipe drainage network. However, some overflow occurs during the 1% AEP event, causing flooding to some existing buildings. Thus, the detailed design of the future stormwater drainage system in this area will need to take this into account so that all future buildings are immune to flooding in the 1% AEP event.

Figure 19-5. Existing 1% AEP Water Level.

Legend:

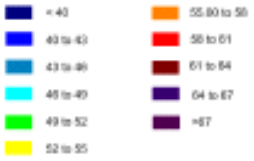
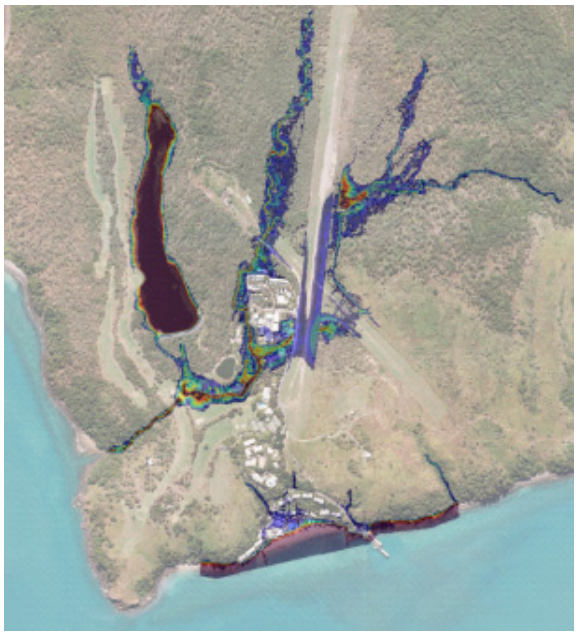


Figure 19-6. Existing 1% AEP Depth.



Legend:

19.3.3.2 Developed Case

The developed case 1% AEP flood levels and depths are presented in **Figure 19-7** and **Figure 19-8** respectively. The results are similar to those discussed above. There is also flooding in the vicinity of some of the proposed buildings. The buildings that could be affected are the aircraft hangers, and a small part of the tourist villa district located east of the runway. These issues will need to be addressed during the detailed design of the site. In summary, the results of the flood model indicate that some stormwater drainage upgrades will be required as part of the proposed redevelopment of the Lindeman Island Resort.

Figure 19-7. Proposed 1% AEP Water Level.

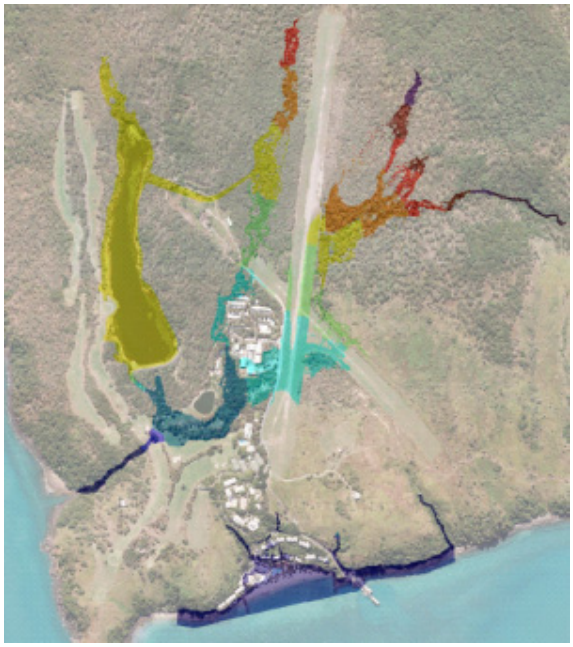


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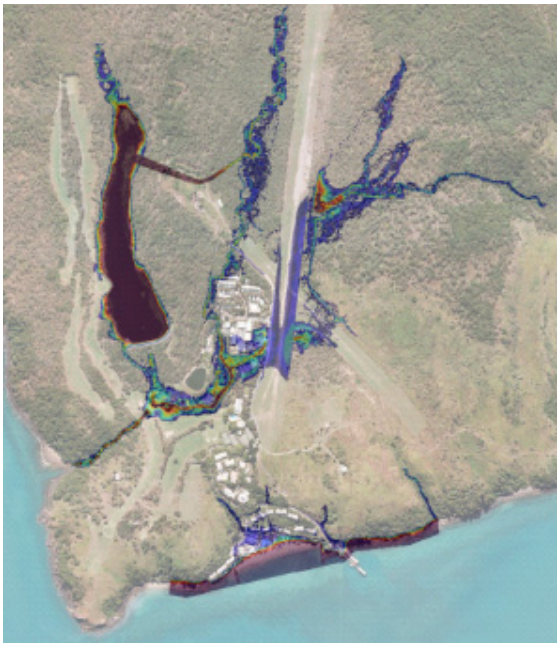
Figure 19-8. Proposed 1% AEP Depth.



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19.4 Dam Break Analysis

As the proposed expansion of Lindeman Island Resort involves a substantial increase in the number of lodgings, it is necessary to revisit the dam failure impact assessment associated with Lindeman Island's water supply dam, Gap Creek Dam. It is also proposed to increase the storage capacity of the dam by extending the dam. The existing and proposed dam extents are shown in **Figure 19-3** and **Figure 19-4** respectively. The catchment contributing to Gap Creek Dam is relatively small, limiting the amount of flow running off into the dam during rainfall events. Runoff from the Gap Creek Dam catchment in the 1% AEP flood event discharges to the ocean outfall to the west of the island. However, in a dam break scenario, the discharge from the dam may be too large to be conveyed to the western ocean outfall, resulting in flow overtopping the existing ridgeline in the golf course and discharging through the resort area to the ocean on the southern side of the island.

Consequently, a dam break analysis was carried out to determine if any mitigation measures were required as part of the proposed redevelopment to control the flow during such an event. The dam failure impact assessment (FIA) was conducted in accordance with the Queensland Government's Department of Energy and Water Supply's *Guidelines for Failure Impact Assessment of Water Dams, 2012*. According to the guidelines, an FIA isn't automatically required for this dam. An FIA is required if the height and storage criteria specified in the *Water Act 2000* are exceeded. These criteria specify that an FIA is required if the dam currently, or after construction will be:

- More than eight metres in height with a storage capacity of more than 500 ML; or
- More than eight metres in height with a storage capacity of more than 250 ML and a catchment area that is more than three times its maximum surface area at full supply level.

These criteria do not apply to the Gap Creek Dam. However, as an FIA has been prepared for the dam in the past, and it is proposed to extend the current dam, it was considered appropriate to complete an FIA for the proposed resort.

19.4.1 Previous Reporting

A dam failure impact assessment for the Gap Creek Dam was carried out previously by MRG Water Consulting Pty Ltd. A copy of the Dam Failure Impact Assessment Report (2013) is contained in **Appendix Q - Flood Study**. A stage one and two Preliminary Flood Impact Analysis was undertaken by the Department of Natural Resources and Water in 2004. This assessment included RORB and MIKE11 modelling, the files from which were provided to MRG to complete the full assessment. Some of the files were missing however and so were not used. In 2013, it was found that there were inaccuracies in the breach hydrograph used dating possibly back to the initial assessments conducted by the Department of Energy and Water Supply. The inaccuracies were traced back to the dam storage curve, batter slopes of the embankment and the catchment hydrology. The original estimates calculated an approximate peak discharge of 390 m^3/s for a Dam Crest Failure event. The revised breach hydrography had a peak of 220 m^3/s. Due to this reduction in the peak flow calculation, the 2013 report found that the dam break flow did not overtop the existing ridge in the golf course. However, a review of this report has found some further areas for methodology improvement. The previous reporting did not include a coincident flood event downstream of the dam for the Dam Crest Failure event. Some levels used also seem to be approximately 2 metres different to recent survey data. As it is proposed to significantly expand the resort, a comprehensive assessment was undertaken to ensure the increased population of the island is safe during a dam failure event.

19.4.2 Dam Failure Scenarios

The TUFLOW model developed for the flood assessment assessed the impact of dam failure scenarios for both the existing and proposed conditions. The model was also used to determine what, if any, mitigation measures were required to ensure the dam is not a referable dam and does not provide a population at risk in the event of a failure. Both Sunny Day Failure (SDF) of the dam and a Dam Crest Failure (DCF) (i.e. dam failure due to overtopping of the dam embankment during a flood event) were considered. In order to determine if the dam is referable, it is necessary to calculate the number of people potentially at risk should a dam failure occur. As a sunny day failure occurs with no coincident flooding, every person at risk due to the dam failure flood is considered a person at risk. In a dam failure during a flood, only those people who would not have already been at risk due to the coincident flooding are counted as population at risk. The dam break parameters were calculated using DNRM's breaching spreadsheet. The breaching spreadsheet also calculates a dam breach hydrograph. This hydrograph can then be used directly as an inflow into a hydraulic model directly downstream of the dam breach location in order to simulate a breach flood. However, this method produced a less conservative flood level than directly modelling the dam failure within the TUFLOW model (using a variable z-shape function). The breach shape and time to develop can be calculated using the breaching spreadsheet, and the failure can be triggered to start based on time or water levels within the TUFLOW model. The TUFLOW method was adopted as initial sensitivity testing showed higher water levels being produced by this method, and it was therefore deemed the more conservative option.

A probability cannot be assigned to the dam failure scenarios, with the dam failure impact assessment undertaken in accordance with the *Guidelines for Failure Impact Assessment of Water Dams, 2012.*

19.4.3 Sunny Day Failure

A sunny day failure describes a dam failure that occurs at full supply level without any concurrent flood event. In this scenario, since there is no simultaneous flood event, nobody would be at risk of flooding if the dam did not break. Therefore, any persons at risk due to the dam break flood contribute towards population at risk calculations to determine if the dam is referable. The dam break parameters were calculated using DNRM's breaching spreadsheet.

19.4.3.1 Existing Conditions

The existing case sunny day failure is a failure of the dam in its existing condition, starting with the dam at its full supply level. The peak flood levels and depths due to the existing case sunny day failure case are presented in **Figure 19-9** and **Figure 19-10** respectively. The flood extent does not break out of the Gap Creek valley into the resort area. Hence, there are no persons at risk from a sunny day dam failure under existing conditions.

Figure 19-9. Existing Case Sunny Day Failure Water Level.

Legend:

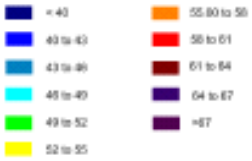


Figure 19-10.Existing Case Sunny Day Failure Depth.

Legend:

19.4.3.2 Proposed Redevelopment

The peak flood levels and depths due to the sunny day failure with the proposed dam arrangement are presented in **Figure 19-11** and **Figure 19-12** respectively. Similar to existing conditions, the flood extent does not break out of the Gap Creek valley into the resort area. Hence, there are no persons at risk from a sunny day dam failure under developed conditions.

Figure 19-11. Proposed Case Sunny Day Failure Water level.

Legend:

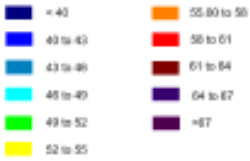
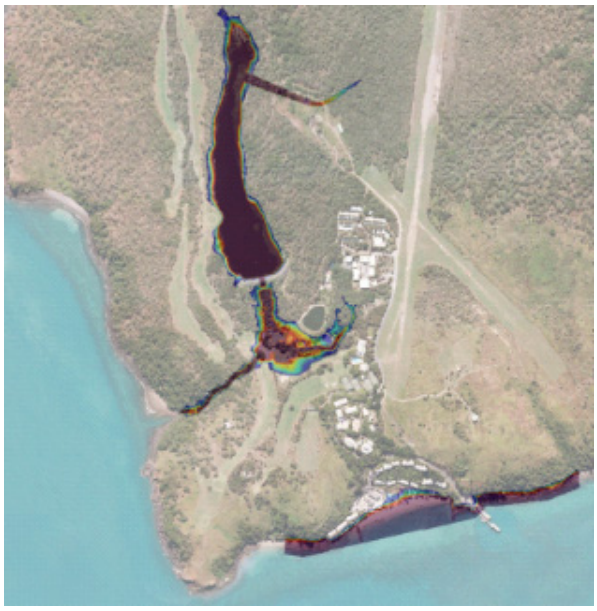


Figure 19-12. Proposed Case Sunny Day Failure Depth.



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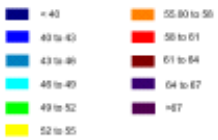


19.4.4 Dam Failure during a Flood

A dam failure event during a flood occurs due to overtopping or piping failure of the dam wall during a large flood event. It is assumed the dam fails with the water level at the crest of the embankment or at the probable maximum flood level if the dam does not overtop. As per the *Guidelines for Failure Impact Assessment of Water Dams*, the relevant flood event is a PMF event in the catchments upstream of the dam and a coincident 1% AEP flood event in the other catchments. The dam break parameters were calculated using DNRM's breaching spreadsheet.

19.4.4.1 Existing Conditions

As discussed above, the relevant flood event is a PMF event in the catchments upstream of the dam and a coincident 1% AEP flood event in the other catchments. Because the proposed dam case has different upstream catchments (due to the proposed diversion), these catchments were also modelled with PMF input for the existing case. This is both a conservative and consistent approach, and allows like for like comparison between cases. The peak flood levels and depths due to the existing dam crest failure case are presented in **Figure 19-13** and **Figure 19-14** respectively. The results show that the dam break flood is not contained within the Gap Creek valley, but overflows the existing ridge and discharges towards the resort area. Left unmitigated, there is potential for there to be persons at risk during this type of dam failure event.

Figure 19-13. Existing Dam Failure during a Flood Water Level.

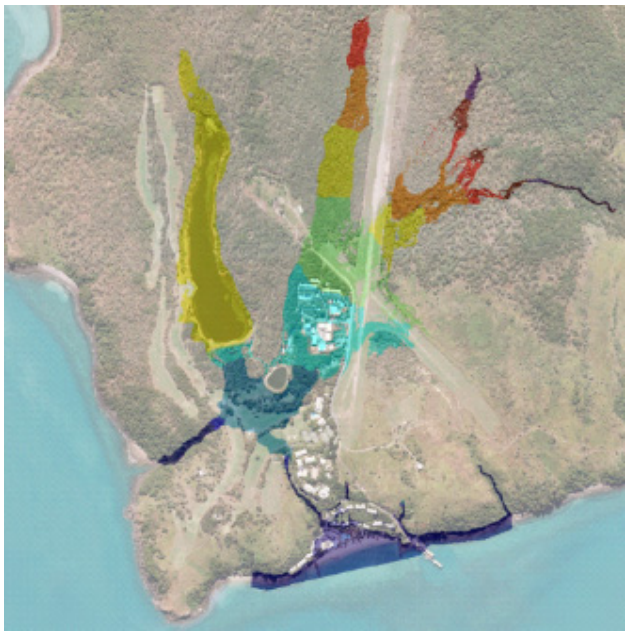
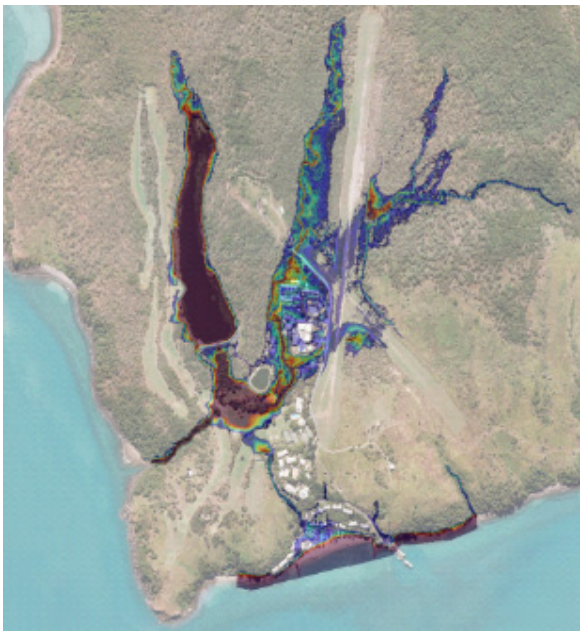


Figure 19-14. Existing Dam Failure During a Flood Depth.



19.4.4.2 Proposed Redevelopment

The peak flood levels and depths due to the developed scenario dam crest failure case are presented in **Figure 19-15** and **Figure 19-16** respectively. The results are similar to the existing case results, and show that the flow breaches the existing ridge and discharges towards the resort area.

Figure 19-15. Proposed Dam Failure during a Flood Water Level.

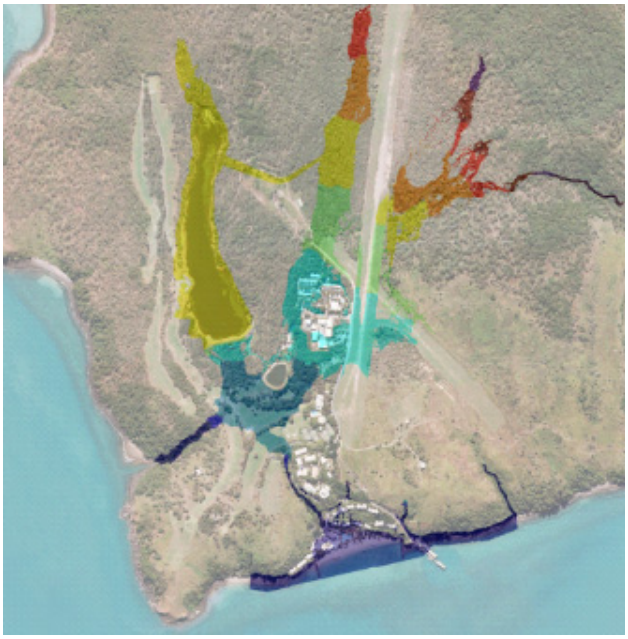


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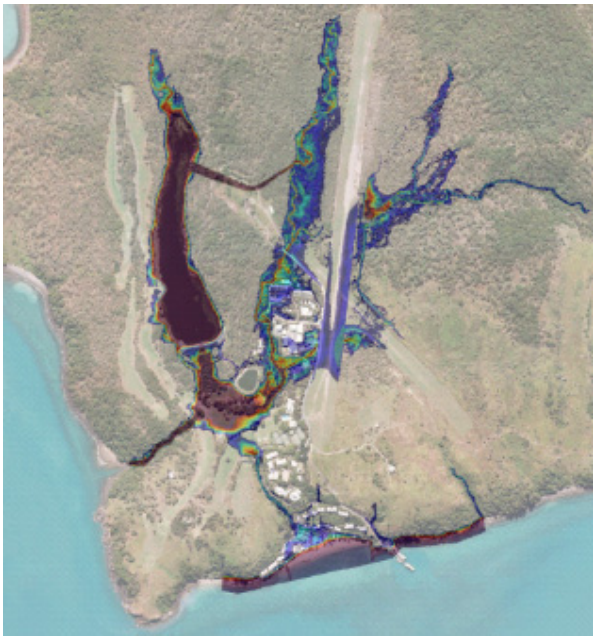
Figure 19-16. Proposed Dam Failure During a Flood Depth.



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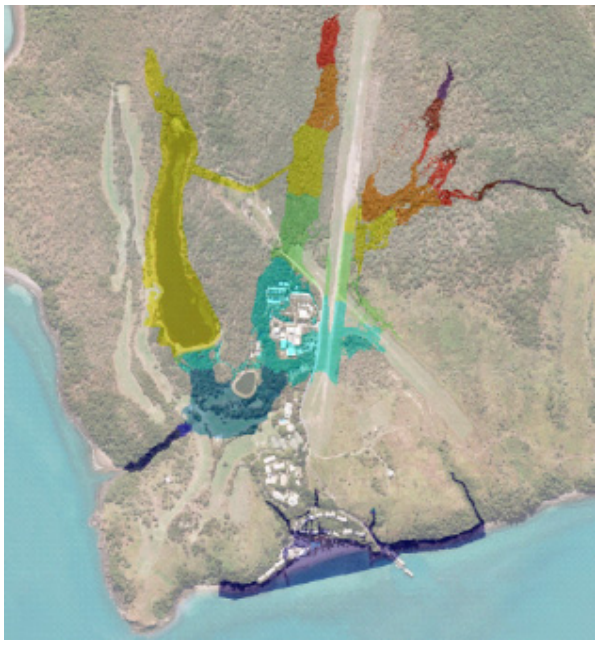
19.5 Proposed Redevelopment with Mitigation Measures

The existing ridge line is overtopped during the dam failure event. The ridge is overtopped by a maximum depth of approximately 350 mm. It is therefore proposed to increase the height of this ridge (through minor earthworks) by 500 mm and to not locate any building within the area expected to be flooded from a dam failure event. The peak flood levels and depths due to the developed scenario dam crest failure case with the mitigation measure in place are presented in **Figure 19-17** and **Figure 19-18** respectively. These results show that the increased level of the ridge is sufficient to exclude the floodwaters from entering the resort area with the water flowing into Gap Creek. Despite this an Evacuation and Emergency Management and Response Plan is proposed to be prepared which addresses procedures and contact numbers in the event of a dam failure (refer to **Chapter 28 – Environmental Management Plan**).

Figure 19-17. Proposed Mitigated Dam Failure during a Flood Water Level.



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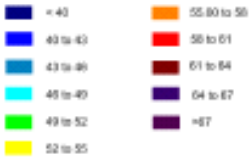
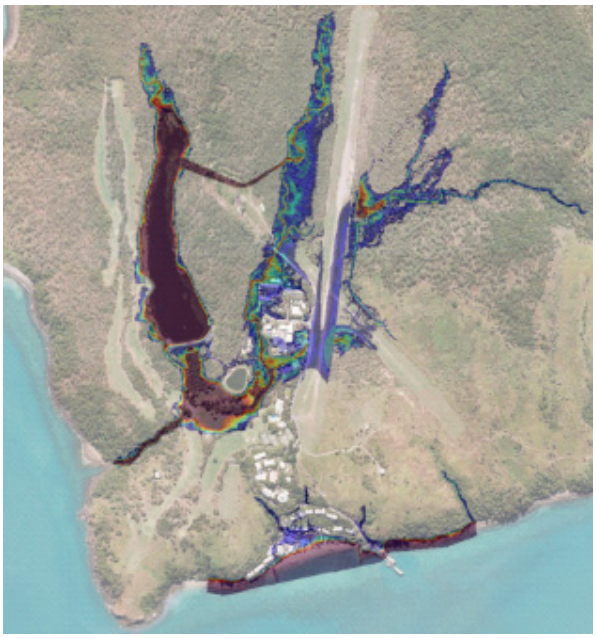


Figure 19-18. Proposed Mitigated Dam Failure During a Flood Depth.



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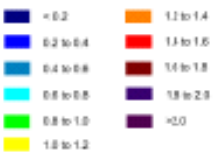

Detailed hydraulic modelling of the Gap Creek Dam determined:

- A sunny day failure would not cause inundation of the main resort area; and
- A dam crest failure event has the potential to cause floodwaters to discharge through the resort area.

Consequently, it is recommended that the elevation of the existing ridge be raised by 500 mm to protect the resort area and divert the flow to the western coastline via Gap Creek and that no development be located within the area potentially affected by a dam failure event.

19.6 Impacts arising from climate change

The potential impacts of climate change in the Mackay Whitsunday region are summarised in the *2014-2021 Water Quality Improvement Plan.* The climate change trends for the Mackay Whitsunday region relevant to flooding include:

- Annual rainfall is not expected to change, however the intensity of extreme events is expected to increase (Hilbert et al. 2014). Projections for the Mackay Whitsunday region indicate baseline (1995) 1 in 100 year rainfall events may occur every 70 years by 2030 and every 60 years by 2050 (RPS 2014);
- The intensity (not frequency) of tropical cyclones is expected to increase (Hilbert et al. 2014); and
- Although the average annual rainfall is not expected to change, the increases in rainfall intensity during the wet season, likely reductions in rainfall intensity in dry seasons and increases in evapotranspiration indicate that an overall reduction in runoff is likely.

The flood assessment included an analysis of the Probable Maximum Flood Event, which is not affected by climate change.

19.7 Potential Impacts and Mitigation Measures

The following table provides an assessment of potential impacts and mitigation measures associated with flooding.

Table 19-3. Risk assessment matrix – flooding.

Potential Impact	Significance of Impact: Unmitigated	Mitigation Measure			Significance of Impact: Mitigated
		Design	Construction	Operation	
Discharge of floodwaters through the resort area associated with dam cress failure or sunny day failure.	Medium (10)	• Two-Dimensional Unsteady Flow (TUFLOW) modelling indicates the flood extent will not break out of the Gap Creek valley under existing and proposed conditions creating a low residual risk profile. • Masterplan does not include any building within the area expected to be flooded from a dam failure event.	• Increase the elevation of the earth bund by 500 mm to protect the resort area and divert the flow to the western coastline.	• Maintain dam wall and earth bund. • Develop and maintain an Evacuation and Emergency Management and Response Plan (refer to **Chapter 28**) which addresses procedures and contact numbers in the event of a dam failure.	Low (2)
Localised flooding from overland flows associated with rainfall events (including potential impacts associated with climate change) exceeding capacity of stormwater design systems.	High (15)	• Stormwater infrastructure to be sized for ultimate development layout and predicted increases in rainfall intensity associated with climate change.	• Increase the elevation of the earth bund by 500 mm to protect the resort area and divert the flow to the western coastline	• Detention storage provided to contain peak flows during for the 63% Annual Exceedance Probability (AEP) rainfall event. • Storage will be a combination of, bio-retention basins, and wetland gardens, with additional storage within rainwater tanks where required. • Minimum floor levels to be set based on results of flood study, with inclusion of sufficient freeboard.	Medium (6)

19.8 Summary

A hydrologic analysis for Lindeman Island was carried out using Watershed Bounded Network Model (WBNM). The catchments contributing to flow into the dam and Lindeman Island resort extend over the south-western part of Lindeman Island. The runoff from the eastern part of the study area generally flows in a southerly or westerly direction to the existing airplane runway and staff accommodation areas. The waterway then has its confluence with the outflow from Gap Creek Dam, near the golf course. The combined flow then discharges to the western coast of the island. Small catchment areas discharge runoff to the southern coastline of the island. Temporal patterns and rainfall intensities for Lindeman Island were determined in accordance with Australian Rainfall and Runoff (AR&R). A rainfall on grid TUFLOW model was initially developed for the study area to determine the key flow paths on the island, especially in the flatter areas in the tableland at the top of the island. The rainfall on grid model was also used to confirm catchment boundaries and inflow points. The total size of the catchment in the study area is approximately 189 hectares. The percentage impervious for each sub-catchment was determined based on aerial photography and site inspection and totals approximately 4.93%. The 1% AEP event was analysed for a range of storm durations to determine the range of critical durations throughout the catchment.

Detailed hydrologic and hydraulic modelling shows that for the proposed development the 1% AEP flood event in the Gap Creek catchment there is flooding in the vicinity of some of the proposed buildings including the aircraft hangers, and a small part of the tourist villa district located east of the runway. These issues will need to be addressed during the detailed design of the site.

The proposed extension to Gap Creek Dam will increase the catchment area contributing to the dam but not all inflows will be diverted into the dam due to environmental restrictions on works in this area. During small rainfall events, a new waterway will direct flow contained in the main channel of the creek to the extension of the dam. During medium to large rainfall events, some of the runoff from the additional catchment will be directed to the dam, but the remainder will continue in a southerly direction along the existing floodplain.

The flood assessment also included a dam break analysis. In a dam-break scenario the sudden release of a large volume of water from the dam has the potential to overtop the existing ridge near the golf course, allowing flow to discharge towards the resort area. A dam crest failure has the potential to increase the population at risk, therefore it is recommended that the elevation of the existing earth bund be raised through earthworks by 500 mm and that no buildings be sited in the area that would be inundated during a dam failure event.

Average annual rainfall is not likely to change as a consequence of climate change, however there is likely to be an increase in rainfall intensity during the wet season and likely reductions in rainfall intensity in dry seasons. The flood assessment included an analysis of the Probable Maximum Flood Event, which is not affected by climate change.