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Review & Assessment of GHD Preliminary Hydraulic Report and Floodplain Management Issues Relating to PP2016/126

Location: **Gellibrand Estuary, Old Coach Road, Princetown** Date**: 27th September 2019**

About the Author

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Foreword

The Princetown Wetlands & Estuary Preservation Group (PWEP) are opposed to planning permit PP2016/126 for a large tourism resort complex located in the Gellibrand Estuary at Princetown, due to concerns about flooding hazards and the impacts of development on the ecology of the estuary flood marshes. The permit was issued despite the PWEP's concerns being raised with the responsible authorities. The services of an independent floodplain management consultant have been engaged to address their concerns and lend some authority to their cause.

PWEP are concerned that:

- The floods witnessed by the Princetown Community, and those reported by previous generations are much worse than the flood examined in the GHD Preliminary Hydraulic Report. The Princetown Community believe that Gellibrand Estuary is not safe for the intensive use allowed by planning permit PP2016/126.
- The planning provisions that protect public safety and environmental assets such as the Gellibrand Estuary have not been effective in this case.

Accordingly, PWEP have commissioned an independent review the GHD Preliminary Hydraulic Report and floodplain management related issues associated with planning permit PP2016/126.

The review of GHD's Preliminary Hydraulic Report focuses on its quality and appropriateness for use in risk assessments and planning purposes. It reviews the application of analysis and modelling methods and the value of their findings with reference to industry guidelines.

The Floodplain Management review comments on floodplain management issues associated with planning processes. It reviews the planning permit with reference to Ministerial Direction, Planning Practice Notes, the Victoria Planning Provisions and relevant strategies that were available in 2016.

An early draft of this report was used to obtain legal advice. Any revisions to that draft were made in the interests of clarity only.

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1 Executive Summary

1.1 Review of GHD's Preliminary Hydraulic Report

GHD's Preliminary Hydraulic Report is provided to inform the preliminary design of the development and to respond to the Corangamite Catchment Management Authority's request for a preliminary assessment of specific flood scenarios.

GHD's report employs rapid assessment methodologies suitable for a quick preliminary assessment, and its finding are indicative only. The modelling shows how flood water disperses around the floodplain under the conditions defined by the modelling scenarios. However, 1% AEP flood levels are assumed, and 1% AEP flood flows are estimated based on a small sample of the available data and assumed hydrology and are thus indicative only. The modelling scenarios also rely heavily on assumptions that reduce the complexity of the estuary system to a rough approximation, and so the findings are also a rough approximation of flooding in the Gellibrand Estuary and unsuitable for planning, design or emergency management considerations.

The 1% AEP flood level is assumed and unrealistically low. The 1% AEP flood flow is very low and much larger flows are indicated by a regional assessment. The modelling shows that flood levels at Princetown are sensitive to tidal conditions and that a 1% AEP flood level over 3 metres is likely.

1.2 Review of Floodplain Management

Public safety demands careful analysis of potential hazards and this is provided for in planning policies that are designed to prevent decisions based upon assumptions. In the case of PP2016/126 no guarantee of public safety is provided because the decision was based upon assumptions about flood hazards. Furthermore, evidence indicates that actual flood hazards are far worse than the assumed flood hazards.

Key steps in the regulation process do not appear to have been undertaken with due care.

1. The directions of Victoria Planning Provisions Clause 13, Environmental Risks are not followed.
2. The directions of Victoria Planning Provisions Clause 13.01-1, Coastal inundation and erosion are only partially followed.
3. The directions of Victoria Planning Provisions Clause 13.02-1 Floodplain Management are only partially followed.
4. Ministerial Direction-13, Managing Coastal Hazards and the Coastal Impacts of Climate Change is not followed.
5. Planning Practice Note 53, Managing coastal hazards and the coastal impacts of climate change is only partially followed.
6. The aims of the CCMA Floodplain Management Strategy are not addressed.
7. The requirements outlined in the Victorian Floodplain Management Strategy are not satisfied by the GHD Preliminary Hydraulic Report.
8. The objectives of the Victorian Coastal Strategy are not achieved.
9. Corangamite CMA's commitment to preserve and protect the Gellibrand Estuary is not honoured.

1.3 Discussion

Planning policies and floodplain management guidelines require best practice in flood estimation. Best practice requires analysis of all the available data as well as a detailed analysis of catchment hydrology. There are records from 25 flow gauges on the Gellibrand River and its tributaries, and from 19 rainfall gauges dispersed over the catchment (details are provided as an appendix to this document). Data from these gauges indicates that some of the most significant rainfall events coincide with reports of flooding provided by the Princetown Community. The evidence of the local community indicates that flood levels recorded at the Princetown gauge since 2008 were exceeded many times in previous years, including in 1984. Gauge records show that 1984 was a significant catchment flood event but smaller than the largest recorded flood of 2010 when flood levels were not high. It is important to find out why the smaller flood caused more flooding in the Gellibrand Estuary than the larger one.

A detailed hydrological study of the Gellibrand catchment is required to test the assumptions made in the GHD Preliminary Hydraulic Report and gain insight into the drivers of flooding at Princetown. Extensive rainfall and river flow records covering much of the Gellibrand River catchment make possible a detailed and authoritative hydrological assessment. It is uncommon to find so much hydrological data in such a small rural catchment and it would be a mistake to trust in assumed hydrology when there is an opportunity to verify catchment hydrology and determine reliable estimations for the full range of likely flood conditions.

The coastal hazards associated with the river mouth are well known and documented in Council proceedings since early settlement. Many attempts have been made to control the sand bar which naturally forms at the river mouth using breakwaters, a tunnel, and by artificially opening it. In 1881 there are reports in local news of a rockfall close to the river mouth:

> *A gigantic piece of the rock has become detached & fallen into the river, which is very narrow at that particular spot. The huge mass almost completely fills up the passage, and the consequence is that the flood water cannot get away freely. For the benefit of the selectors the Government should, by blasting or some other means, remove this obstruction*[1]

The complex coastal hazards present in the Gellibrand Estuary are increasing due to rising sea levels and climate change yet remain little understood. A coastal hazard assessment of the Gellibrand Estuary is urgently required so that public safety issues can be addressed.

The findings of the GHD Preliminary Hydraulic Report are not a detailed coastal hazard assessment as required by the Victorian Coastal Strategy. The modelling scenarios presented in the GHD report do not accurately represent conditions in the estuary and at the river mouth and offer little insight into their effects on flooding in the estuary or the effects of climate change on existing hazards.

Floodplain management in Victoria relies very heavily on flood overlays in planning schemes to guide the decision process and achieve effective planning controls. However, where no overlays exist the decision process falters. The only available instructions about standards for flood estimation apply specifically to government funded projects, and this creates a loophole through which flood estimation projects not funded by government can pass. Best practice is expensive

[1] Camperdown Chronicle Saturday 1st Oct. 1881

and without specific regulations to refer to it is difficult to demand such high standards from the private sector, especially in connection with a speculative development application.

Floodplain management practices and decisions are centred on flood overlays based on theoretical 1% AEP flood conditions, whose determination is undertaken by commercial agents with vested interests in the outcomes, without oversight and in the absence of codes of practice. When commercial agents can determine the parameters for development it is incumbent on the responsible authorities to ensure their authenticity.

These are systemic problems that stem from weak floodplain management structures. Legislation is minimal and the power of Floodplain Management Authorities to influence planning decisions has been eroded, while development pressure and flood hazard are increasing. A stronger regulatory framework should be considered.

1.4 Conclusions

GHD's Preliminary Hydraulic Report comes with appropriate caveats and is not suitable to support a planning permit application or as the basis for emergency planning. State Planning Policies direct development away from hazardous floodplain areas and seek to preserve natural assets such as the Gellibrand Estuary.

Had State Policy been properly applied all decisions would be based on detailed and reliable investigations of present and future flood hazards, using in all the data and the evidence of the local community. The evidence and concerns of the Princetown Community are relevant and must inform any flood estimation in the Gellibrand Estuary.

The Princetown Community's role in raising concerns is recognised by the Victorian Floodplain Management Strategy vision:

> *Victorian communities, businesses and government agencies are aware of flooding and are actively taking measures to manage their flood risks to minimise the consequences to life, property, community wellbeing and the economy.*

2 The GHD Preliminary Hydraulic Report

2.1 Background – Flood Estimation

Flood estimation is a science-based discipline founded on the need to live safely with flooding. Decades of research, practice and technological advances have produced suites of high-tech tools and methods, and today flood estimation is a thriving industry with strong academic and institutional support. There is no code of practice but the Australian Rainfall and Runoff Guide to Flood Estimation (ARR) provides a comprehensive and authoritative guide to current best practice.

Flood estimation is not an exact science and the reliability of an investigation is determined by the methods used and the quality of the available data. There can be several components of a flood estimation project which are selected and combined according to the purpose of the investigation. Each component may be undertaken using a variety of methods and tools, each with strengths and weaknesses, and the selection is guided by the purpose of the job and available data.

Regarding the applicability of the different methods, ARR notes:

… it should be recognised that there is considerable overlap in their ranges of applicability and it is strongly advised to apply more than one method to any given design situation. The comparison of different methods yields insights about errors or assumptions that might otherwise be missed, and the process of reconciling the different assessments provides valuable information that aids adoption of a final "best estimate"[2]*.*

2.2 Review of the GHD Preliminary Hydraulic Report

The purpose of the GHD Preliminary Hydraulic Report is to provide a preliminary assessment of flooding from a range of rainfall events and various closed estuary scenarios, with emphasis on the determination of 1% AEP flood conditions. It is intended to inform preliminary concept and feasibility work and to address specific questions set by Corangamite CMA. The GHD reports documents a rapid assessment and not an in-depth investigation, which is demonstrated by many assumptions, shortcuts and approximations. Appropriately, the report comes with a caution: *the resultant outputs should only be interpreted for the current stated purposes and only relied upon by those with a good understanding of their uncertainty and limitations.*

The GHD Preliminary Hydraulic Report has five main components

1. Analysis of peak flood levels at Princetown
2. Flood frequency analysis – to determine peak flows
3. Flood hydrograph estimation – to determine the build-up and dissipation of peak flows
4. Hydraulics Modelling – to determine flows and levels around the floodplain.
5. Discussion of results

[2] ARR Book 1, Chapter 3.4 Selection of Approach

2.2.1 Analysis of Peak Flood Levels at Princetown

An analysis of flood levels at Princetown is presented based on eight years of data from a gauge located at the bridge on the Old Coach Road at Princetown that collects water level data at 15-minute intervals and has been in operation since 2008. One of the key assumptions underlying the GHD report is *that recent years are representative of long-term averages*. This is a proposition whose likelihood increases with the number of years sampled and is extremely low on eight years. Eight years is a very small sample and there is little confidence in the accuracy of estimated long-term averages thus determined. This lack of confidence is indicated by 5% and 95% confidence limits which range from approximately 1.8 to 3 metres, suggesting that flood levels over 3 metres are highly unlikely. These confidence limits indicate far greater accuracy than is possible from the available data and 1% AEP flood levels greater than 3 metres are well with the bounds of probability.

According to ARR, flood frequency analysis

> *is not generally applied to flood level maxima as the manner in which flood levels increase with flood magnitude is heavily dependent on channel geometry and is thus not suited to statistical exploration*[3].

The estimated 1% AEP flood level has no empirical or scientific basis and no attempt is made to verify its accuracy. Much higher flood levels are reported by the Princetown Community from a range of flood events, and this empirical evidence has far greater value than the findings presented in the report.

The relationship between flood levels and flood magnitude in the Gellibrand Estuary is unusual in that peak flood levels do not necessarily coincide with peak flood magnitude. Flood levels are also heavily dependent on conditions at the river mouth and are frequently high as a result of storm surge, or prolonged river mouth closure. Given that the two highest flood levels recorded at Princetown occurred when the river mouth was closed and were influenced by storm surge, their use for estimating a 1% AEP flood level is dubious.

Best practice for the determination of 1% AEP flood levels usually follows a detailed hydrological analysis of catchment flows and uses hydraulic modelling and statistical analysis to make reliable estimates. The GHD Preliminary Hydraulic Report assumes the 1% AEP flood level of 2.3m AHD without any supporting evidence or hydraulic modelling and maintains its appropriateness throughout. Confidence in this finding is very low and there are strong indications that it is underestimated. Reports of much higher peak flood levels that predate the Princetown gauge are supported by rainfall and river gauge data not examined in the GHD report (examples are provided as an appendix to this review).

The use of assumed flood levels for planning purposes is unheard of in my experience of the industry. It is unnecessary given the availability of reliable tools, unsafe given that the underestimation of flood levels may result in poor planning decisions, and open to abuse given ineffective safeguards.

[3] ARR Book 1, Chapter 3.2.2 Flood Frequency Techniques

In order to make confident predictions about the behaviour of a system it is necessary to first understand it by testing assumptions, checking integrity and considering where errors might have occurred that could influence the outcome. In this case there are several critical reasons why such checks and tests need to be applied:

1. Best practice flood estimation requires rigorous analysis of the available data to ensure public safety. Accurate flood levels are the principal output of flood estimation projects and are essential indicators of flood hazards and the limits of development. Reliable estimates of flood hazards are essential for flood risk assessment and assumed flood levels are inadequate for this purpose.
2. The flood frequency analysis is unsuitable for the determination of 1% AEP flood levels.
3. The highest flood levels recorded at the Princetown gauge occurred during seasonal river mouth closure events and not from catchment flooding.
4. The peak flood level recorded during the largest flood event has been exceeded by small flood events.
5. There are numerous reports of higher peak water levels from local people and media.
6. Previous modelling undertaken for Corangamite Catchment Management Authority in 2008[4] confirms that high flood levels are possible from moderate flood events.
7. The use of assumed flood levels for planning purposes is unnecessary, unsafe, and open to abuse.

There is no certainly in GHD's 1% AEP peak flood level at Princetown. It should not be used for planning purposes or risk assessment and use should be limited by extreme caution. The evidence indicates that 1% AEP flood levels above 3 metres should be considered in planning decisions for the Gellibrand Estuary.

2.2.2 Flood Frequency Analysis

The flood frequency analysis is based on an analysis of 46 years of data from the flow gauge at Burrupa, approximately 20km upstream of Princetown. One of the key assumptions underlying the GHD report is *that recent years are representative of long-term averages*, a hypothesis which carries considerable uncertainty. A graphical analysis is presented which indicates that the 1% AEP peak flood flow at Burrupa would be approximately 320 cumecs. No confidence limits are provided for this estimate nor any discussion of uncertainty or limitations.

The graphic shows the 2010 flood peak is at a point well above the trend line and appearing separate to the lesser peaks which are all close to the trend line. This could indicate a data anomaly or a poor fit of the trend line to the data. A similar analysis of annual maximum flows from the Burrupa gauge is presented in Figure 1 and shows the broad range of possible 1% AEP peak flood flows that are indicated by the Burrupa gauge data.

[4] Environmental Water Requirements of the Gellibrand Estuary: Final Estuary FLOWs Report by Lloyd Environmental Pty Ltd

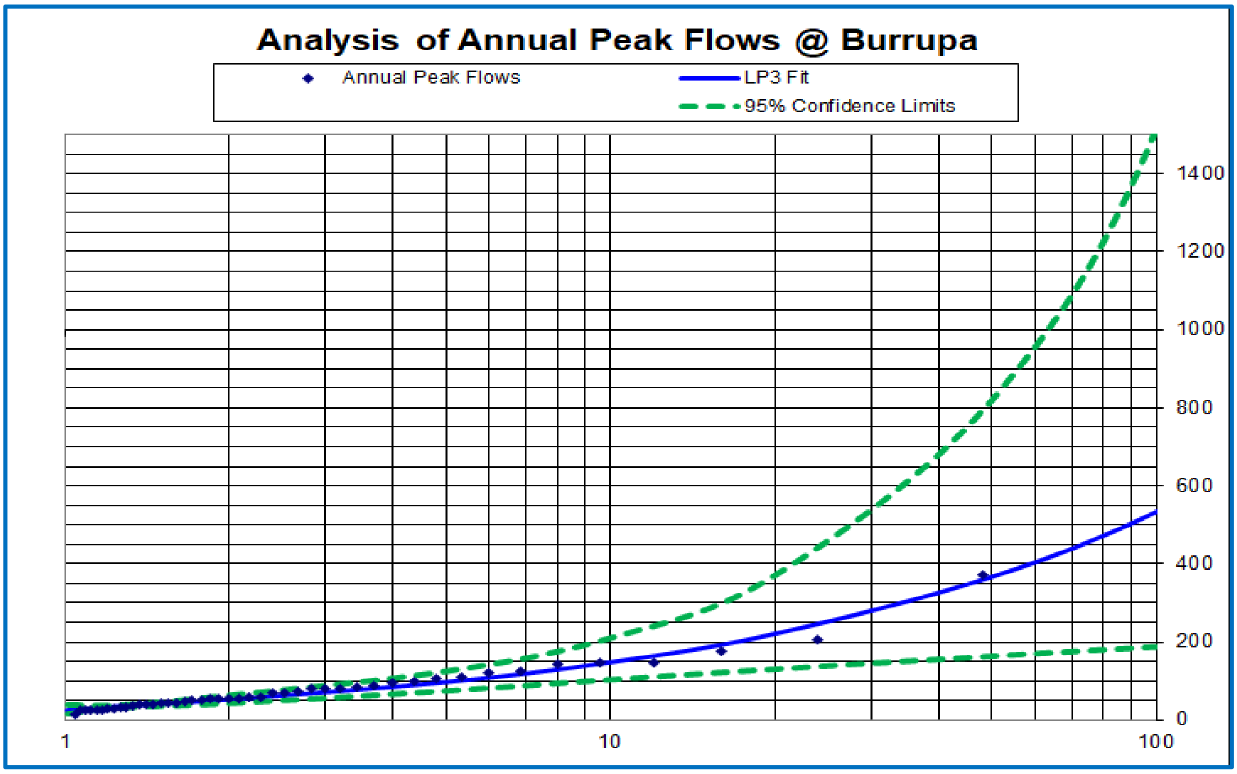

Figure 1: Analysis of Annual Peak flows at Burrupa

The trend line in Figure 1 is a good fit to the data and indicates a 1% AEP peak flood flow of approximately 550 cumecs, with broad confidence limits indicating the low certainty from using this method alone. Similar confidence limits should apply to the GHD analysis.

ARR provide an online tool for flood frequency estimation[5] that uses regional information and catchment data to estimate flood frequency. Results for the Gellibrand River at Burrupa are provided in Figure 2.

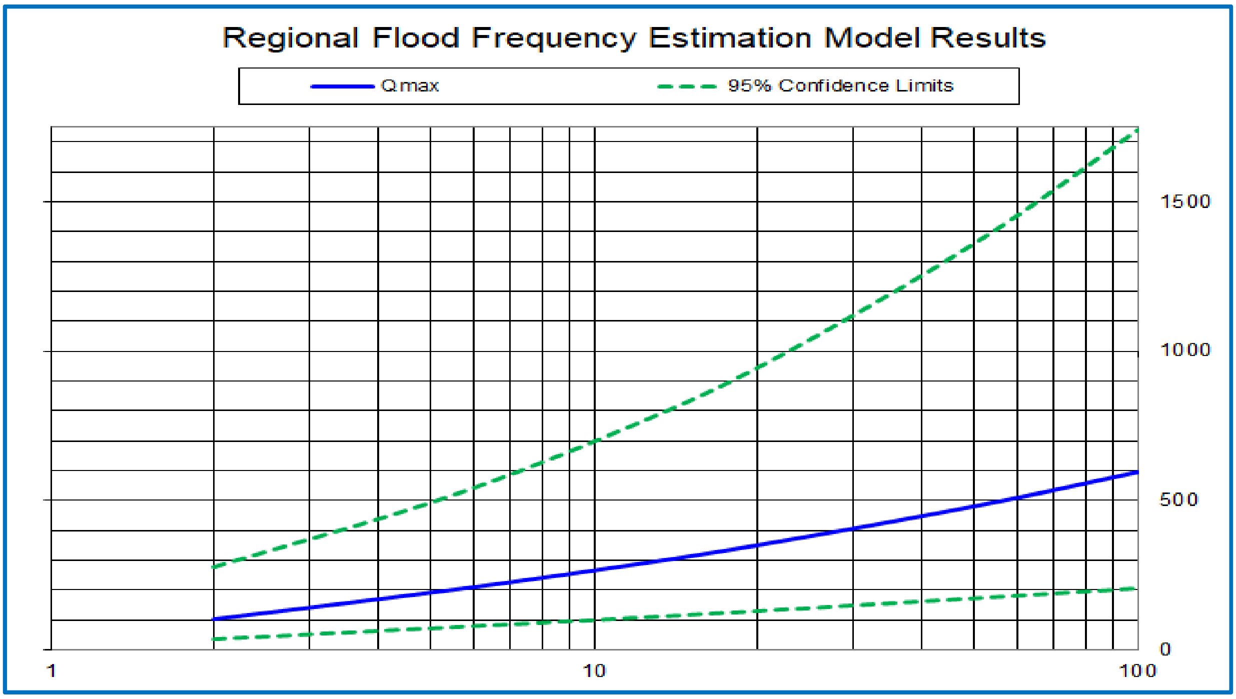

Figure 2: Regional Flood Frequency Estimation Model Results for the Gellibrand River at Burrupa

[5] ARR Regional Flood Frequency Estimation Model 2015 - https://rffe.arr-software.org/

The regional analysis of catchment flows shown in Figure 2 indicates a 1% AEP peak flood flow of approximately 600 cumecs with similar confidence limits to Figure 1, indicating the low level of certainty that may be obtained from rapid assessment methods. However, the available catchment rainfall data indicates that large floods predating the Burrupa gauge are likely, and this is a further indication that 1% AEP peak flood flow is significantly underestimated in the GHD report. An in-depth analysis of catchment hydrology is necessary in order to determine accurate and reliable 1% AEP flood flows.

ARR notes:

> *A flood may have occurred before the period of gauged record and known to be the largest flood, or flood of other known rank, over a period longer than that of the gauged record. Such floods can provide valuable information and should be included in the analysis if possible[6].*

Flood estimation is not an exact science and every analysis comes with confidence limits that reflect the quality of the method and the data used. Confidence limits are necessary in order to understand the level of uncertainty and appropriate limitations on the use of such findings. However, the GHD report omits confidence limits in the estimation of 1% AEP peak flood flow, thus obscuring the level of uncertainty and appropriate limitations on the use of their findings. Appropriate confidence limits are indicated by Figures 1 & 2 above.

In order to be confident in the findings of an analysis it is necessary to apply checks and tests, and to consider where errors might have occurred that could influence the outcome. In this case there are several critical reasons why such checks and tests need to be applied:

1. Best practice in flood estimation requires analysis of all the available data as well as a detailed analysis of catchment hydrology.
2. There are numerous records of significant flood events that predate the Burrupa gauge. Princetown locals report higher flood levels in past decades than have recently been observed. Although much of this evidence lacks detail it is of great value as a signal to beware and further investigation may yield useful data.
3. Rainfall records have been collected in and around the Gellibrand catchment for over 100 years. There appear to have been numerous rainfall events that could have caused flooding in the Gellibrand Estuary. The data for August 2010 does not stand out from other significant rainfall events recorded in the catchment, and there are indications that larger floods than 2010 may have occurred. A brief summary of the available data is presented as an appendix to this review.
4. A larger flood than the estimated 1% AEP flood was recorded at the Burrupa gauge in August 2010, when the peak flow is estimated to have reached 372 cumecs. While it is possible that this event exceeded a 1% AEP flood, it cannot be stated with great confidence based on only 46 years of data. If the August 2010 event was not greater than a 1% AEP flood, then peak flood flow may be greatly underestimated.
5. Analysis of data from the Burrupa gauge indicates a 1% AEP peak flood flow of 550 cumecs.

[6] ARR Book 3, Chapter 2.3.8. Historical and Paleo Flood Information

6. A Regional Flood Frequency Estimation from ARR indicates a 1% AEP peak flood flow of 600 cumecs.
7. It is possible that more rigorous analysis would yield a much higher peak flood flow for 1% AEP events, which could make the Gellibrand Estuary unsafe for development.

There is very low certainly in GHD's estimation of 1% AEP flood flow at Burrupa. It should not be used for planning purposes or risk assessment and use should be limited by extreme caution. Best practice requires flood estimation based on a detailed analysis of catchment hydrology, in the absence of which the best estimate of 1% AEP peak flood flow is 550 - 600 cumecs.

2.2.3 Flood Hydrograph estimation

Flood hydrograph estimation in the GHD Hydraulic Report is achieved by scaling a hydrograph from the largest flood event recorded at the Burrupa gauge in August 2010. One of the key assumptions underlying the GHD report is *inflow hydrographs*, a convenient shortcut which carries considerable uncertainty. No confidence limits are provided for use of this shortcut, nor any discussion of uncertainty or limitations.

Flood hydrographs show peak flood flows at a catchment outlet over the duration of a storm event, and thus the volume of a flood. Flood hydrographs represents the catchment component of a flood event; during storm events, some catchment rainfall flows to the river, some is stored by plants, soils, wetlands and aquifers and some is lost to evaporation. These losses affect the timing, magnitude and duration of a flood event and are reflected in the shape of a flood hydrograph.

In flood estimation, a flood hydrograph is designed to represent the characteristics of the catchment response to rainfall that most influence flood levels at given location for a predetermined probability of occurrence. Building in the floodplain comes at the cost of high exposure to risk of damage resulting from flooding. The planning system attempts to limit the risk to a statistically tolerable level by ensuring that development is safe from hazardous flooding conditions with a 1% probability of occurrence or Annual Exceedance Probability (AEP). The determination of a reliable 1% AEP flood hydrograph is central to flood estimation and flood risk mitigation.

If peak flood levels arise due to catchment flood flows then it's common practice to assume a hydrograph from the largest recorded flood event, however in the case of the Gellibrand Estuary 1% AEP peak flood levels arise due to a combination of factors:

1. Tidal conditions (lunar cycles, atmospheric conditions, weather and sea bed)
2. Catchment flooding conditions (peak flood flow, flood volume and flood duration)
3. Estuary channel morphology (Channel capacity and scour)

Tidal conditions vary and are not affected by catchment flooding or estuary morphology. Similarly, catchment flooding is independent of tidal conditions and channel morphology. However, estuary channel morphology varies according to tidal conditions and catchment flood flows. Therefore, the selection of flood hydrographs should be informed by a good understanding of the dynamics of the Gellibrand Estuary and the manner in which flood levels at Princetown are influenced by sea levels at the river mouth.

In flood estimation, the selection of 1% AEP peak flood flow is influenced by all factors affecting flood flows and levels and their impacts at the project location, including:

- Estuary channel morphology
- Tidal conditions
- Social and economic factors relating to the project purpose.

The 1% AEP peak flood flow is typically estimated from detailed analysis of catchment hydrology and may be increased by a safety margin to compensate for uncertainties, and to treat social and economic considerations such as public safety and the integrity of community infrastructure. The GHD Preliminary Hydraulic Report assumes a 1% AEP flood hydrograph by scaling *down* the largest recorded flood event, leaving no safety margin to compensate for all the uncertainties in their methods, and making no allowance for public safety.

The highest recorded peak flood flow in 2010 did not cause high flood levels at Princetown, demonstrating that significant catchment flood events can drain through the estuary under low flood levels. In the 46 years of records from the Burrupa gauge the 1984 flood event ranks highest after the 2010 flood event but the Princetown Community remembers very high flood levels during the 1984 event. It would therefore be appropriate to consider the 1984 flood as a signature catchment flooding event and to assess the causes of elevated flood levels at Princetown at that time. Flood hydrographs from these two events could be used for hydraulic modelling to compare flood responses, test the 1% AEP flood hydrograph and learn about the catchment conditions that most effect flood levels.

Very little is learned from only one inflow hydrograph and in order to verify its suitability it is necessary to try others and make comparisons. In order to be confident in the findings of an analysis it is necessary to apply checks and tests, and to consider where errors might have occurred that could influence the outcome. In this case there are several critical reasons why such checks and tests need to be applied:

1. The flood of August 2010, reached a maximum height of 1.828m at the Princetown gauge and has been exceeded twice although it was a larger flood than the estimated 1% AEP flood. This indicates that the hydrograph may not represent the catchment characteristics that most influence flood levels at Princetown.
2. The highest flood levels recorded at the Princetown gauge were recorded during seasonal river mouth closure events.
3. According to the Princetown Community a flood event in 1984 caused very high flood levels although it is known to have been a smaller catchment flood event than in 2010. It is necessary to examine the causes of the highest flood levels in order to understand nature of the catchment contribution to flooding in the estuary.
4. In order to understand the uncertainty and limitations around the design hydrographs it is necessary to test other hydrographs and examine the flood response in greater depth.
5. The selection of flood hydrographs should be informed by a good understanding of the relationship between flood levels and dynamics of the Gellibrand Estuary.
6. The selection of flood hydrographs should include a safety margin to compensate for uncertainties and as a public safety measure.

Best practice requires flood estimation based on a detailed analysis of the interactions between catchment hydrology and estuarine processes that affect flood levels. There is low certainly in GHD's flood hydrograph estimation and use of the findings should be limited by caution.

2.2.4 Hydraulic Modelling

The hydraulic model uses a 25m grid over the study area, with a 5m grid over areas of interest. The ARR notes:

> *Clearly, the smallest feature that can be resolved will be one grid or mesh cell wide. However, if realistic simulation of flow separation and eddy formation behind structures such as bridge abutments is required, then these structures will need to be resolved by a minimum of 6 to 8 grid or mesh cells[7].*

The use of a 5m grid at areas of interest such as the development site, access road and bridge abutments limits the accuracy of findings from hydraulic modelling. Detailed modelling of shallow water flooding is essential for designing cross-drainage and flood-safe infrastructure, and for managing construction around flooding and understanding the impacts of development on fragile aquatic ecosystems.

Hydraulic modelling was undertaken for a set of scenarios using scaled down hydrographs from the 2010 flood event and predetermined 1% AEP flood levels. The modelling assumes fixed riverbed bathymetry and boundary conditions to approximate the more complex dynamic conditions in the Gellibrand Estuary and the Bass Strait.

2.2.4.1 Model Calibration

The hydraulic model was calibrated and validated by simulating the 2010 flood event and adjusting scour parameters in the model to obtain a "best-fit". Two cases were assessed, a Moderate Scour Case and an Increased Scour Case. The moderate scour case was seen to overestimate the peak flood level observed in 2010 and eliminate the tidal variation in the flood level at Princetown. The increased scour case resulted in a significantly lower flood level at Princetown although the observed tidal variation is present. The moderate scour case was adopted for the open estuary mouth modelling scenarios. Neither case is a good match for the calibration event and with an error of 0.6m the model is not well calibrated.

Increasing scour in the model lowered the flood level at Princetown by 0.8 metres and caused the flood level to vary with the tide. These are clear indicators of an important model parameter, but further investigation of scour is not discussed. The link between scour and flood flow is well established in the report and results confirm that a scour function linked with flood flow is required in the model in order to accurately represent the likely range of flood events.

The tidally varying downstream boundary condition was used in the validation process but not for any of the modelled scenarios. The effect of this alteration of boundary conditions from the verification run is not discussed and the unrealistic steady state downstream boundary levels further reduce the reliability of the modelled findings.

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[7] ARR Book 6, Section 4.7.7 Specific Model Development

ARR notes:

> *Model calibration is the process of comparing model results against measured flood levels and extents and adjusting model parameters to obtain a "best-fit". For flood studies, model calibration is typically carried out on the largest flood for which reliable water level data is available. In studies where more frequent flooding may be important, the model should also be calibrated against measurements taken from a more frequent flood event.*[8]

Calibration and validation of the model was only partially achieved, and it was not calibrated against the frequent flooding that is such an important feature of the Gellibrand estuary. As the model was not calibrated for frequent flood events the uncertainty in these model scenarios is high, and low accuracy must be assumed, which puts severe limitations on use of these findings.

2.4.2.2 Modelled Scenarios

The modelled scenarios have some value because they provide an indication of how floods behave in the Gellibrand Estuary and the impact of the development in the floodplain. In particular, the scenarios demonstrate the sensitivity of the model to the downstream boundary conditions, giving rise to a large range of flood levels at Princetown. However, accuracy is compromised by incomplete validation and the use of unrealistic boundary conditions, including the omission of tidal variations at the downstream boundary. Observations regarding the scenarios are presented in Table 1.

Scenario ID	Peak Flow (cumecs)	D/S boundary conditions	Discussion of results Flood levels are AHD
Validation Moderate Scour Case	372	Tidal variation based on Portland tides during the 2010 flood event.	Modelled flood level at Princetown approximately 2.4m. This is 0.6m higher than the recorded level and does not vary with the tide.
Validation Increased Scour Case	372	Tidal variation based on Portland tides during the 2010 flood event.	Modelled flood level at Princetown approximately 1.6m. This is 0.2m lower than the recorded level and varies with the level of the tide. Increasing scour in the model lowers the modelled flood levels at Princetown by 0.8 metres. Slightly less scour might have produced a better fit to the observed data.
1A	320	1.95m AHD (10% AEP storm surge in 2100). River mouth open.	Modelled flood level at Princetown approximately 2.5m. This is the highest sea level boundary condition modelled with 1% AEP flood flows, but the results show lower flood levels than scenario 1B, where the sea level is 1.15m lower. This anomaly is not discussed.
1B	320	0.8m AHD	Modelled flood level at Princetown

[8] ARR Book 6, Chapter 4.3.2. Model Calibration and Validation

		(mean sea level in 2100). River mouth partially closed by 0.8m sand bar.	approximately 2.9m. This scenario could represent a present-day situation during a moderate storm surge event and is probably the best estimation of 1% AEP flood levels provided by this study. A tide level of 1.096m AHD was recorded at Portland on 28th June 2014, although it is unlikely that this level would coincide with a 1% AEP flood event. An analysis of their joint probability would provide some confidence in the appropriate sea level boundary conditions.
2A	Base flow	River mouth closed by 1.8m sand bar.	In 2015 the flood level peaked at 2.019m at the Princetown gauge due to storm surge overtopping the sand bar and minor catchment flooding. A simulation of this event could have been used to calibrate the model for floods of this kind.
2B	Base flow	River mouth closed by 1.4m sand bar.	The model was not calibrated for this kind of frequent flood event, which indicates present-day average depths and extents during typical closed estuary events.
3A	145	2.9m AHD (1% AEP storm surge in 2100). River mouth partially closed by 0.8m sand bar.	Modelled flood level at Princetown approximately 2.9m. This scenario demonstrates that very high flood levels are possible from moderate flood events, a finding that is confirmed by previous modelling undertaken for Corangamite Catchment Management Authority in 2008[9].
4E-100 4P1-100 4P2-100	320	Sea level constant at 0.0m AHD. River mouth open.	Modelled flood level at Princetown approximately 2.2m 0.2m lower than the calibration scenario, where the peak flow is higher by 52 cumecs and mean sea level is higher by approximately 0.1m 0.7m lower than scenario 1B, where mean sea level is higher by 0.8m
4E-010 4P1-010 4P2-010	145	Sea level constant at 0.0m AHD. River mouth open.	These scenarios show that raising the Old Coach Road diverts flood flows from significant areas of floodplain. This problem is acute during more frequent flood events, when some parts of the estuary marshes will be prevented from flooding.

Table 1 – Observations on the Modelled Scenarios

The results from the number 4 scenarios indicate flood level afflux in 4mm ranges which is well beyond the tolerance of the modelling approach. Use of these findings should be limited by extreme caution.

[9] Environmental Water Requirements of the Gellibrand Estuary: Final Estuary FLOWs Report by Lloyd Environmental Pty Ltd

The GHD report does not discuss modelling of the likely range of flood events or attempt to verify a 1% AEP flood level of 2.3m AHD. No analysis is provided to support the assumption of this flood level, although the findings from the modelled scenarios do not support it: Scenario 1B, uses the estimated 1% AEP flood flow and a downstream boundary representing a sand bar and sea level of 0.8m AHD. Although it's unlikely that a sand bar would be present under such conditions it makes little difference because the inertia of the ocean is an effective barrier at the river mouth. In this scenario the flood level at Princetown is 2.9m AHD, demonstrating that much higher flood levels can be caused by smaller floods than occurred in 2010 if the tidal conditions are unfavourable.

The modelling shows that flood flow is not the only factor affecting flood levels at Princetown, the effects of scour and variations in sea level are also very significant. The modelled scenarios show flood levels at Princetown varying by 0.7m in 1% AEP flood events due to variations in sea level, and 0.8m due to variations in scour. The GHD report does not examine the combinations of these factors that influence flood levels and conditions at Princetown.

A tide level of 1.096m AHD was recorded at Portland on 28th June 2014, although it is unlikely that this level would coincide with a 1% AEP flood event. An analysis of their joint probability would provide some confidence in the appropriate sea level boundary conditions. The ARR Guide to Flood Estimation provides advice on flood estimation in estuarine areas where flood levels are influenced jointly by flood flow and sea level conditions, and notes that the range of possible flood levels is significantly increased in the joint probability zone[10]. This is not reflected in the GHD report, which assumes that 1% AEP flood levels are not influenced by sea levels. The ARR guidelines provide advice on appropriate methods for flood estimation in the joint probability zone[11] which is not followed in the GHD report.

In present-day conditions it is not uncommon for the tide to remain above 0.8m AHD at Princetown for several hours. Under these conditions, according to the modelling of Scenario 1B the flood height at the Princetown reaches approximately 2.9m AHD. With larger flood flows such as the 600 cumecs indicated by the Regional Flood Frequency Estimation, 1% AEP flood levels over 3 metres are to be expected which make the Gellibrand Estuary unsafe for development.

2.2.5 Contentions

1. In order to make confident predictions about flooding in the Gellibrand estuary it is necessary to first understand it. However, investigating the complex relationships between catchment rainfall, intermittent river mouth closures, scour, variations in sea level and other oceanic forces that give rise to peak flood levels is ***not*** the purpose of the GHD report. Its purpose is to provide a preliminary assessment of flooding from a set of scenarios including a range of flood events and various closed estuary conditions, with emphasis on the determination of 1% AEP flood conditions.

2. The highest flood level in the eight years recorded at the Princetown gauge occurred while the river mouth was closed, and the largest magnitude flood in 50 years of flow

[10] ARR Book 6, Chapter 5.1. Interaction of Coastal and Catchment Flooding
[11] ARR Book 6, Section 5.3. Flood Estimation Approaches for the Joint Probability Zone

gauging does not stand out in the Princetown flood level record. These erratic signals indicate a highly irregular system, and a difficult one to model. By modelling aspects of the system as discreet scenarios the complexity that defines and regulates the system is lost. The conditions that define the scenarios do not accurately represent the system, so the findings of modelling are inherently unreliable estimates of system trends.

3. Flood estimation and modelling use numerical methods which provide opportunities for bias to affect project outcomes. It is sometimes easy to overlook and dismiss evidence that does not support a guiding hypothesis or that runs counter to any underlying assumptions. The assumptions used in the GHD report render unnecessary much examination of evidence, and evidence of higher flood levels at Princetown and larger historic floods was overlooked. The use of such profound assumptions is common practice for rapid assessment projects but is not considered good practice where safety is a consideration. The ARR notes:

   > *…the primary criterion for the selection of the methods recommended in ARR is that the methods should be based on observed flood data in the region of interest and have been peer reviewed by the profession.*
   >
   > *In early editions of Australian Rainfall and Runoff, application of this criterion was not always possible because of the paucity of observed flood data technology limitations and the limited analysis of the available data. Hence it was necessary to recommend many arbitrary methods based purely on engineering judgement.*
   >
   > *For significant portions of Australia, this is no longer the case, and data are available for the development of techniques that have undergone review by the profession from both a scientific and a practical perspective. In these regions, the continued use of arbitrary design methods and information cannot be justified*[12].

   GHD's 1% AEP flood estimation is based on limited hydrological data although there are extensive records including more than a hundred years of rainfall data indicating that the 1% AEP flood conditions are likely to be underestimated (refer to the Appendix for details).

4. In the design of a 1% AEP flood hydrograph it is common practice to use the hydrograph from the largest recorded flood event as a template. Typically, the hydrograph is scaled up to compensate for uncertainties in the methods used and a safety factor is added to ensure public safety and protect community infrastructure. However, in the case of the GHD report the 1% AEP flood hydrograph is assumed by scaling *down* the hydrograph from a flood that did not produce significant flood levels at Princetown, with no safety margin to compensate for the many uncertainties in the methods used and making no allowance for public safety.

5. Construction of the proposed roadways, car parks, buildings and landscaping will significantly alter the dynamics of the floodplain by diverting flood flows, particularly during frequent shallow water flooding events. Managing flood flows around the proposed infrastructure and construction sites will require careful drainage designs to protect against the corrosive effects of frequent flooding and avoidable environmental

[12] ARR Book 3, Chapter 1.3 Selection of Method

damage. A more detailed examination of shallow water flooding is required in order to accurately assess and manage the environmental impacts of the development.

6. The GHD modelling appears to support the evidence of history in finding that large flood flows can result in much higher flood levels than have so far been recorded at the Princetown gauge. This finding is further supported by a previous investigation undertaken for the Corangamite Catchment Management Authority in 2008[13], which indicates that flood levels at the location of the Princetown gauge can reach over 2.5m AHD due to moderate flood flows.

7. The intermittent closure of the river mouth and morphological changes in the estuary during flood events are critical in determining peak flood levels. Scour in the estuary and at the river mouth increases with flood flow and modifies the channel, which can significantly impact peak flood levels. It is important to understand the seasonal geomorphology of the river mouth and estuary channels, to identify trends in their behaviour due to gradual changes in sea level and to accurately predict the likely impacts of climate change and long-term sea level rise so that the hazards of developing in the estuary are known prior to construction.

8. The effects of climate change are discussed in the GHD Preliminary Hydraulic Report and addressed by elevating habitable building. However, the nature of present and future flood hazards in the Gellibrand Estuary remains largely unknown and the risks are increasing due to climate change. There are significant gaps in current knowledge about the Gellibrand Estuary, including channel morphology, shoreline recession and landslide risk (Gellibrand is identified as a high-risk area by the Corangamite CMA[14]) combined with the effects of higher sea levels. The estuary is very vulnerable to the impacts of climate change and this vulnerability must be addressed for safe development in the estuary.

[13] Environmental Water Requirements of the Gellibrand Estuary: Final Estuary FLOWs Report by Lloyd Environmental Pty Ltd
[14] CCMA Landslide and Erosion Database, 2005

3 Floodplain Management

3.1 Background to Floodplain Management

The mission of floodplain management is to live safely with flooding. Flooding is a common occurrence in Australia, its effects are known to most Australians and we rely on the execution of good governance to keep risk and exposure to acceptable levels. Effective floodplain management balances the social benefits of occupying the floodplain with environmental benefits of flooding while limiting the impacts of flooding on the community.

Floodplain Management in Australia is guided by Australian Institute for Disaster Resilience *Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*, and other guidelines produced by State and local governments.

Handbook 7

This handbook aims to encourage practice that works towards the following vision for flood risk management in Australia.

Floodplains are strategically managed for the sustainable long-term benefit of the community and the environment, and to improve community resilience to floods.

Best practice requires the consideration and management of flood impacts to existing and future development within the community. It aims to improve community flood resilience using a broad risk management hierarchy of avoidance, minimisation and mitigation to:

- limit the health, social and financial costs of occupying the floodplain
- increase the sustainable benefits of using the floodplain
- improve or maintain floodplain ecosystems dependent on flood inundation.

Best practice promotes understanding flood behaviour so that the full range of flood risk to the community can be understood, effectively communicated and, where practical and justifiable, mitigated. It facilitates informed decisions on the management of this risk, and economic investment in development and infrastructure on the floodplain.

Best practice floodplain management involves all the affected community, all emergency response personnel, and all levels of government, supported by sound science and in alliance with competent industry professionals.

In Victoria, floodplain management is coordinated and regulated by the planning system and refers to Catchment Management Authorities for flood advice. Local planning schemes include flood overlays to trigger referrals and development controls, and where flood overlays are absent the Catchment Management Authorities assist in the determination of appropriate development controls.

The Victoria Planning Provisions are the regulatory framework for the implementation of State, regional and local policies affecting land use and development. The relevant flood provisions current in 2016 are referred to for this review.

3.2 Review of Floodplain Management

Public safety demands careful analysis of potential hazards and this is provided for in planning policies that are designed to prevent decisions based upon assumptions. In the case of PP2016/126 no guarantee of public safety is provided because the decision was based upon assumptions about flood hazards. Furthermore, evidence indicates that actual flood hazards are far worse than the assumed flood hazards and development would jeopardise public safety and endanger the lives of emergency services personnel. This case has not achieved best practice floodplain management and is a far cry from the vision for Australian flood risk management.

Key steps in the regulation process do not appear to have been undertaken with due care.

1. The directions of Victoria Planning Provisions Clause 13, Environmental Risks are not followed.
2. The directions of Victoria Planning Provisions Clause 13.01-1, Coastal inundation and erosion are only partially followed.
3. The directions of Victoria Planning Provisions Clause 13.02-1 Floodplain Management are only partially followed.
4. Ministerial Direction-13, Managing Coastal Hazards and the Coastal Impacts of Climate Change is not followed.
5. Planning Practice Note 53, Managing coastal hazards and the coastal impacts of climate change is only partially followed.
6. The aims of the CCMA Floodplain Management Strategy are not addressed.
7. The requirements outlined in the Victorian Floodplain Management Strategy & industry best practice guidelines are not satisfied by the GHD Preliminary Hydraulic Report.
8. The objectives of the Victorian Coastal Strategy are not achieved.
9. Corangamite CMA's commitment to preserve and protect the Gellibrand Estuary is not honoured.

3.2.1 VPP Clause 13, Environmental Risks

> Planning should adopt a best practice environmental management and risk management approach which aims to avoid or minimise environmental degradation and hazards. Planning should identify and manage the potential for the environment, and environmental changes, to impact upon the economic, environmental or social well-being of society.

In the case of PP2016/126, no attempt has been made to achieve best practice environmental management and risk management. The consideration of risks associated with flooding, coastal hazards and climate change is done lightly, and not in the manner required by this policy.

In order to satisfy this policy a detailed flood study is required, based on catchment hydrology and including dynamic modelling of the river mouth and estuary channels. The flood study would discover why flood levels at Princetown during the largest recorded flood were so much lower than flood levels from smaller floods and quantify the effects of sea level variations and intermittent river mouth closures. The flood study would inform a coastal hazard vulnerability assessment examining the likely impacts of changing environmental conditions and hazard consequences in order to ensure public safety into the future. The rapid assessment used in the case of PP2016/126 provides little insight into the present and future flood hazards in the Gellibrand Estuary and does not satisfy this policy.

3.2.2 VPP Clause 13.01-1, Coastal Inundation and Erosion

Objective

To plan for and manage the potential coastal impacts of climate change.

Strategies

In planning for possible sea level rise, an increase of 0.2 metres over current 1 in 100 year flood levels by 2040 may be used for new development in close proximity to existing development (urban infill).

Plan for possible sea level rise of 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology when assessing risks and coastal impacts associated with climate change.

Consider the risks associated with climate change in planning and management decision making processes.

For new greenfield development outside of town boundaries, plan for not less than 0.8 metre sea level rise by 2100.

Ensure that land subject to coastal hazards are identified and appropriately managed to ensure that future development is not at risk.

Ensure that development or protective works seeking to respond to coastal hazard risks avoids detrimental impacts on coastal processes.

Avoid development in identified coastal hazard areas susceptible to inundation (both river and coastal), erosion, landslip/landslide, acid sulfate soils, bushfire and geotechnical risk.

Policy guidelines

Planning must consider as relevant:

- *The Victorian Coastal Strategy* (Victorian Coastal Council, 2008).
- Any relevant coastal action plan or management plan approved under *the Coastal Management Act 1995* or National Parks Act 1975.
- Any relevant Land Conservation Council recommendations.

In the case of PP2016/126 some of the requirements of this policy are observed by the designs outlined in the GHD Preliminary Hydraulic Report, but no provision is made for future risk, and the impacts of climate change on this development are uncertain. The direction to avoid development in identified coastal hazard areas is not followed.

Coastal hazards associated with the Gellibrand Estuary are identified in the Corangamite Regional Floodplain Management Strategy but have not yet been assessed. The Strategy notes as a Priority Risk Area:

> *Major risks relate to the potential coastal inundation of the Great Ocean Road at Princetown (this could occur in combination with riverine flooding from the Gellibrand River).*

The Strategy lists as a medium priority action:

> *Seek funding to investigate the berm dynamics for the lower Gellibrand River estuary. This action needs to link in with any Coastal Hazard Assessment and could include recommendations for planning controls in estuarine areas.*

The policy requirement is to ensure that coastal hazards are appropriately managed and to avoid development in identified coastal hazard areas. In the case of PP2016/126, a permit has been issued to develop in an identified coastal hazard area in opposition to the requirements of this policy.

Guidelines for Coastal Catchment Management Authorities: Assessing development in relation to sea level rise, published by the Department of Sustainability and Environment in June 2012, is intended to provide instructions regarding the application of Clause 13.01 of the State Planning Policy Framework. The guidelines explain the coastal inundation and erosion policy and as an additional strategy requires CMAs to:

> *Apply the precautionary principle to planning and management decision-making when considering the risks associated with climate change.*

It also advises:

> *Development should be avoided in wetlands and areas which in the opinion of the CMA pose an unacceptable flood hazard. These areas should be preserved for recreational or other low-intensity passive uses that promote environmental values.*

The guidelines do not appear to have been applied in the case of PP2016/126.

In order to satisfy this policy a coastal hazard vulnerability assessment is required, augmenting a detailed flood study and including dynamic modelling of the river mouth and estuary channels under future climate scenarios. The assessment would quantify the effects of the changing climate on existing and future hazards in the estuary and at the river mouth and determine hazard management strategies to ensure public safety into the future. The rapid assessment used in the case of PP2016/126 does not satisfy this policy.

3.2.3 VPP Clause 13.02-1 Floodplain Management

Objective

To assist the protection of:

- Life, property and community infrastructure from flood hazard.
- The natural flood carrying capacity of rivers, streams and floodways.
- The flood storage function of floodplains and waterways.
- Floodplain areas of environmental significance or of importance to river health.

Strategies

Identify land affected by flooding, including floodway areas, as verified by the relevant floodplain management authority, in planning scheme maps. Land affected by flooding is land inundate by the 1 in 100 year flood event or as determined by the floodplain management authority.

Avoid intensifying the impacts of flooding through inappropriately located uses and developments.

Locate emergency and community facilities (including hospitals, ambulance stations, police stations, fire stations, residential aged care facilities, communication facilities, transport facilities, community shelters and schools) outside the 1 in 100 year floodplain and, where possible, at levels above the height of the probable maximum flood.

Locate developments and uses which involve the storage or disposal of environmentally hazardous industrial and agricultural chemicals or wastes and other dangerous goods (including intensive animal industries and sewage treatment plants) must not be located on floodplains unless site design and management is such that potential contact between such substances and floodwaters is prevented, without affecting the flood carrying and flood storage functions of the floodplain.

Policy guidelines

Planning must consider as relevant:

- *State Environment Protection Policy (Waters of Victoria).*
- Regional catchment strategies and special area plans approved by the Minister for Environment and Climate Change.
- Any floodplain management manual of policy and practice, or catchment management, river health, wetland or floodplain management strategy adopted by the relevant responsible floodplain management authority.
- Any best practice environmental management guidelines for stormwater adopted by the Environment Protection Authority.
- *Victoria Floodplain Management Strategy* (Department of Natural Resources and Environment, 1998).

This policy seeks to protect floodplains from inappropriate uses, such as a very large restaurant and hotel facility and the storage and handling of large volumes of raw sewage. In the case of PP2016/126, the requirement of this policy to identify flood affected land is only partially accomplished by rapid appraisal methods with very low reliability.

The policy and guidelines require best practice standards in the estimation of 1% AEP flood conditions and this has not been achieved in the GHD Preliminary Hydraulic Report; the estimated 1% AEP flood flow is very low compared with a Regional Flood Frequency Estimation for the catchment, and the 1% AEP flood level is assumed and very low compared with the available evidence. The flood modelling is undertaken using a poorly calibrated model and the influence of sea level variations and intermittent river mouth closures is not analysed. The findings of the study have very low certainty and use should be limited by extreme caution.

In order to satisfy this policy a detailed flood study is required, based on catchment hydrology and including dynamic modelling of the river mouth and estuary channels. The flood study would discover why flood levels at Princetown during the largest recorded flood were so much lower than flood levels from smaller floods and quantify the effects of sea level variations and intermittent river mouth closures. The rapid assessment used in the case of PP2016/126 does not satisfy this policy.

Planning Practice Note 12, *Applying the Flood Provisions in Planning Schemes: A Guide for Councils*, was introduced by the Department of Environment, Land, Water and Planning in June 2015 and is a clear guide to the requirements and standards that are to be applied to flood prone land. In particular PPN12 notes:

> *Where adequate flood maps have not been prepared for a particular area, all available local knowledge should be documented and a flood mapping investigation should be initiated.*
>
> *If detailed information on flooding is not available, in the interim the floodplain management authority should identify land known to be subject to inundation as best it can and the LSIO should be applied, even if the LSIO boundary is based on limited information. The boundary should be adjusted, and floodway provisions included if necessary, after detailed flood mapping has been completed.*

That advice was not followed.

VPP Clause 13.02-1 Floodplain Management also seeks to protect floodplain areas of environmental significance or of importance to river health such as the Gellibrand Estuary, but this was not accomplished in the case of PP2016/126. The available guidance for planners regarding the interpretation of this policy does not discus environmental significance or river health and these aspects of the policy are frequently overlooked.

3.2.4 Ministerial Direction-13, Managing Coastal Hazards and the Coastal Impacts of Climate Change

Purpose

The purpose of this Direction is to set out the general requirements for consideration of the impacts of climate change within coastal Victoria as part of an amendment which would have the effect of allowing non-urban land to be used for an urban use and development.

Application

This Direction applies to any planning scheme amendment that provides for the rezoning of non-urban land for urban use and development of all land:

- Abutting the coastline or a coastal reserve.
- Less than 5 metres Australian Height Datum within one kilometre of the coastline including the Gippsland Lakes.

Definition

In this Direction:
Coastline means the line of the low water mark off the sea coast which includes any bay, inlet, estuary and any waters within the ebb and flow of the tide.
Coastal hazard means an occurrence of an event within coastal Victoria which includes the individual or combined effects of inundation by the sea, the effects of storm tides, river flooding, coastal erosion, landslip/landslide and sand drift which adversely affects or may adversely affect human life, property or aspects of the environment.

Requirements to be met

In preparing an amendment which would have the effect of rezoning non-urban land for urban use or development, a planning authority must include in the explanatory report how the proposed amendment:

- Is consistent with the planning policies, objectives and strategies for coastal Victoria as outlined in state planning policies (including regional planning policies) in the Planning Policy Framework.
- Addresses the current and future risks and impacts associated with projected sea level rise and the individual and/or combined effects of storm surges, tides, river flooding and coastal erosion.
- Is based on an evaluation of the potential risks and presents an outcome that seeks to avoid or minimise exposing future development to projected coastal hazards.
- Ensures that new development will be located, designed and protected from potential coastal hazards to the extent practicable and how future management arrangements will ensure ongoing risk minimisation.
- Considers the views of the relevant floodplain manager and relevant Victorian Government department.

This Direction from the Minister for Planning requires an explanatory report examining coastal hazards and demonstrating sustainability for any proposed development in the Gellibrand Estuary. This direction has not been followed.

3.2.5 Planning Practice Note 53, Managing Coastal Hazards and the Coastal Impacts of Climate Change

PPN 53 recommends that development proposals in coastal zones be informed by a coastal vulnerability assessment in order to *ensure risk minimisation and effective long term management of new use and development.*

In order to ensure that developments in coastal zones are safe into the future these considerations require a detailed understanding of the coastal processes active at the river mouth and the impacts of rising sea levels and climate change on flooding and geomorphology in the estuary system. It is beyond the scope and purpose of the GHD Preliminary Hydraulic Report to use its findings as a substitute for the coastal hazard assessment required by Planning Practice Note 53. This requirement has not been properly applied to development in the Gellibrand Estuary.

3.2.6 CCMA Floodplain Management Strategy

The Corangamite CMA's Regional Floodplain Management Strategy aims to:

- Build flood resilience – by sharing information about flood behaviour;
- Reduce flood risks – through emergency management, flood mitigation infrastructure works and risk management;
- Avoid future flood risks – through land use planning and building controls;
- Manage residual flood risks – through flood insurance, sharing flood risk information and integrated flood emergency management.
- Protect floodplains for their ecological and cultural values – by integrating the management of flood risks with protecting the environmental and cultural values of natural floodplains.

And identifies Possible Flood Mitigation Actions including:

> *Seek funding to investigate the berm dynamics for the lower Gellibrand River estuary. This action needs to link in with any Coastal Hazard Assessment and could include recommendations for planning controls in estuarine areas (Corangamite CMA to lead)*

The Corangamite CMA's Regional Floodplain Management Strategy appears to have been overlooked in planning permit PP2016/126.

3.2.7 Victorian Floodplain Management Strategy

The Victorian Floodplain Management Strategy 2016, Section 11.1 outlines the requirements for flood studies:

Flood studies must consider all sources of flooding in the study area, as well as the interactions between them. They must seek to:

- model the hydrologic inputs – including rainfall and runoff – that lead to floods of different sizes and calibrate these models against historic floods

- model the hydraulic behaviour of floods – including flood heights, extents and velocities as they vary with time – and calibrate these models against historical floods
- understand the varying hydraulic nature of the floodplain being studied
- understand the varying flood hazards within the floodplain
- assess the scale of potential flood damages for the existing community
- assess the potential for flood damage on areas of the floodplain that may be considered for future development
- analyse risk treatment options
- consult with local communities to take advantage of local knowledge
- consult with local Aboriginal communities to ensure cultural values are considered in assessing and mapping flood risks
- assess the consequences of floods of different sizes
- capture the local community's experience and knowledge of floods.

These requirements are not met by the GHD report and it is the role of the responsible authorities to demanded them.

3.2.8 Victorian Coastal Strategy

The Victorian Coastal Strategy sets out the Victorian Government's long-term vision for Victoria's coasts and is the foundation of planning policies and guidance notes relating to coastal zones. It promotes best practice sustainable development, safety and environment protection.

The Victorian Coastal Strategy sets out the required standards for managing the coastal zone and applies to all Victorian estuaries. The strategy includes policies for decision makers that are echoed in the Victoria Planning Provisions and direct planners to avoid development in coastal zones and undertake rigorous examination of risks.

The objectives of the Victorian Coastal Strategy are not achieved in planning permit PP2016/126.

3.2.9 Gellibrand Estuary Management Plan

Corangamite CMA's Gellibrand Estuary Management Plan identifies the estuary as a valuable environmental asset to be preserved and protected. In it the CMA gives a commitment to *work with the Victorian Government, the Victorian Coastal Council, Coastal Boards and regional partner organisations within the framework of the Victorian Water Management Strategy and the Victorian Coastal Strategy to effectively manage the environmental condition of estuaries within the Corangamite region*.

That commitment is not honoured in planning permit PP2016/126.

4. Discussions

1. GHD's Preliminary Hydraulic Report comes with a warning:

   The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

   Many of the assumptions described in the report are simplistic and inaccurate and no attempt has been made to verify them. Unexamined historic evidence of flooding indicates that it's highly likely that these assumptions are incorrect. Under such conditions it is not appropriate for the findings of this report to be adopted as a benchmark for planning purposes. Planning policy requires best practice and not assumptions.

2. In a floodplain area characterised by frequent and unpredictable flooding, and where very large floods have been reported the safety of visitors requires a great deal of care and attention. The GHD report discusses safety indicating that the provision of management plans, a well-stocked refuge, controlled access, and egress paths to higher ground will improve safety. However, it is well established that mitigation of risk through planning measures can only be successful with the full cooperation of the affected community. This presupposes a level of understanding of the risks that visitors are unlikely to possess, and with visitors numbering in the hundreds, the likelihood of human error in very high.

   The Gellibrand Estuary is not safe during flood events and local people know to avoid flood hazards. Three visitors were drowned in the Gellibrand river near Burrupa during a flood in the 1980s. Worse floods are remembered by the Princetown Community.

3. The intermittent closure of the river mouth and morphological changes in the estuary during flood events are critical in determining design peak flood levels. Scour in the estuary and at the river mouth increases with flood flow and modifies the channel, which can significantly impact peak flood levels. It is important to understand the seasonal geomorphology of the river mouth and estuary channels, to identify trends in their behaviour due to gradual changes in sea level and to accurately predict the likely impacts of climate change and long-term sea level rise so that the hazards of developing in the estuary are known prior to construction.

4. The requirement for a coastal hazard assessment is triggered by identification of coastal hazards and there is a risk that where such hazards exist that have not been 'identified' development permits may be issued. This problem might be remedied if all areas subject to coastal hazards were clearly identified by the Victoria Government.

5. Floodplain management in Victoria relies very heavily on flood overlays in planning schemes to guide decision processes and achieve best practice standards. However, where no overlays exist the decision process falters and the guidance for decision makers about standards applies specifically to flood estimation projects funded by the Government. This creates a loophole through which flood estimation projects not funded by the Government may pass. Best practice is expensive and without specific regulations

to refer to it is difficult to demand such high standards from the private sector, especially in connection with a speculative development application. This problem might be remedied by the release of a Practice Note providing clear directions regarding admissible standards in flood estimation for planning purposes.

6. Floodplain management practices and decisions are centred on flood overlays based on theoretical 1% AEP flood conditions, whose determination is undertaken by commercial agents with vested interests in the outcomes, without oversight and in the absence of codes of practice. Best practice is unlikely under these circumstances and the threat to public safety is at a very high level.

7. VPP Clause 13.02-1 Floodplain Management puts the protection of floodplain areas of environmental significance or of importance to river health at the centre of best practice floodplain management. However, the available guidance for planners regarding the interpretation of this policy does not discus environmental significance or river health and these aspects of the policy are frequently overlooked. This problem might be remedied by the release of a Practice Note focussed on the protection of environmental assets such as the Gellibrand Estuary.

6. Conclusions

The level of uncertainty in the findings of the GHD Preliminary Hydraulic Report is extremely high. No confidence limits are provided on the estimation of 1% AEP flood conditions, although flows and levels are likely to be underestimated. Uncertainties in the findings of this report put severe limitations on their usefulness. The findings of this report are indicative only, and not sufficiently robust for risk assessments, emergency planning or managing construction around flood events. Further investigations are necessary in order to understand the nature of flooding in the Gellibrand Estuary and are essential before committing to development at this location.

The 1% AEP flood level is assumed and unrealistically low. The 1% AEP flood flow is very low and much larger flows are indicated by a regional assessment. The 1% AEP flood hydrograph represents a flood that caused exceptionally low flood levels. The model is poorly validated. The importance of the scour function and tidal variations are overlooked. The modelling shows that flood levels at Princetown are sensitive to tidal conditions and that a 1% AEP flood level over 3 metres is likely.

The GHD report does not meet the industry best practice standards that are required to ensure the integrity of planning decisions. It addresses the wrong questions, is founded on false assumptions, uses inappropriate methods, omits quality controls and draws implausible conclusions. It overlooks the concerns of the Princetown Community and presents inconclusive findings with expert rhetoric in a report that has been relied upon for purposes beyond its stated scope and limitations.

The ARR Guide to Flood Estimation (ARR) provides a comprehensive and authoritative guide to current Australian best practice and Victoria Government guidelines outline the standards and requirements of State regulators. Further guidelines are published by the Australian Institute for Disaster Resilience and there is broad agreement that appropriate standards must be maintained across the flood estimation industry. However, the required standards are not upheld in the GHD Preliminary Hydraulic Report and due to so many approximations in the analysis methods used its findings are approximate only.

These are systemic problems that stem from weak floodplain management structures. Legislation is minimal and the power of Floodplain Management Authorities to influence planning decisions has been eroded, while development pressure and flood hazards are increasing. A stronger regulatory framework should be considered.

The Gellibrand Estuary is a rare and precious natural asset that is by nature hazardous to people due to very frequent flooding. PP2016/126 allows an environmentally destructive development that would expose hundreds of visitors to uncertain flood hazards, endangering life, property and community infrastructure.

Appendix

A Brief Examination of Hydrological Data overlooked in the Preliminary Hydraulic Report

Best practice in flood estimation requires analysis of all the available data as well as a detailed analysis of catchment hydrology. In the GHD Preliminary Hydraulic Report, catchment hydrology is assumed based on river flow measured at a single point, the Burrupa gauge approximately 20km upstream of Princetown. 1% AEP peak flood flows are derived from a brief analysis of 46 years of flow data and the selection of the highest recorded flow event, August 2010, as the basis for design of the flood hydrographs. 1% AEP flood levels are assumed based on a dubious analysis of river level data recorded at the Princetown gauge. The Princetown gauge data shows that the 2010 flood level was exceeded in 2015 and 2016 during seasonal river mouth closure events.

The Princetown Community believe that higher flood levels have occurred at Princetown that predate the Princetown gauge. In particular, the floods of 1984 and 1952 are well remembered, with further major floods reported in the 1930s and earlier. This evidence was not considered in the GHD Preliminary Hydraulic Report, although it is supported by the available rainfall records.

There are records from 25 river gauges on the Gellibrand River and its tributaries, only 2 of which are referred to in the GHD Preliminary Hydraulic Report. A list of the river gauges is presented in Table 1 below. Data from these gauges is available from the DELWP Water Measurement Information System at http://data.water.vic.gov.au/.

Label	Gauge Ref.	Location	Coordinates		Years Active
			ºS	ºE	
1	235269	Gellibrand River @ Princetown	38.697	143.155	2008 - 2019
2	235224	Gellibrand River @ Burrupa	38.702	143.248	1969 - 2018
3	235211	Kennedys Creek @ Kennedys Creek	38.589	143.257	1964 - 2018
4	235258	Gellibrand River @ d/s Otway Pumps Bridge	38.634	143.264	1998 - 2018
5	235213	Skinner Creek @ Chapple Vale	38.642	143.307	1964 - 1971
6	235212	Chapple Creek @ Chapple Vale	38.632	143.323	1968 - 1988
7	235208	Gellibrand River @ Carlisle	38.585	143.328	1964 - 1990
8	235225	Gellibrand River @ Carlisle River Pumping Station	38.559	143.368	1998 - 2018
9	235200	Carlisle River @ Carlisle River	38.558	143.395	1930 - 1969
10	235206	Sandy Creek (Left Branch) @ Wylangta	38.645	143.418	1959 - 1966
11	235207	Sandy Creek (Right Branch) @ Wylangta	38.651	143.418	1949 - 1966
12	235205	Arkins Creek @ Wyelangta	38.64	143.443	1958 - 2018
13	235227	Gellibrand River @ Bunkers Hill	38.524	143.483	1970 - 2018
14	235210	Lardner Creek @ Gellibrand	38.534	143.544	1964 - 2018
15	235228	Gellibrand River @ Gellibrand	38.533	143.55	1970 - 1989
16	235234	Love Creek @ Gellibrand	38.483	143.572	1979 - 2018
17	235240	Yahoo Creek @ Kawarren	38.48	143.582	1985 - 1993
18	235239	Ten Mile Creek @ Kawarren	38.46	143.597	1985 - 2008
19	235236	Gellibrand River @ d/s of Dam Site G5A	38.53	143.601	1980 - 1990
20	235241	Porcupine Creek @ Kawarren	38.479	143.606	1986 - 2008

21	235249	West Gellibrand Reservoir @ Spillway	38.599	143.653	1999 - 2019
22	235266	Gellibrand River @ d/s West Gellibrand Dam	38.593	143.654	2005 - 2018
23	235202	Gellibrand River at Upper Gellibrand	38.563	143.656	1949 - 2018
24	235267	Olangolah Creek @ d/s Olangolah Reservoir	38.609	143.68	2005 - 2018
25	235250	Olangolah Weir @ Spillway	38.612	143.682	2000 - 2007

Table 1 - River Gauges in the Gellibrand River Catchment

Rainfall gauge records for the Gellibrand River catchment are available from the Bureau of Meteorology. The available records begin in 1884 and cover much of the catchment area, although there are gaps in some data records. Table 2 lists the available rain gauge records and Figure 1 shows the gauge locations in and around the catchment. None of this data is referred to in the GHD Preliminary Hydraulic Report.

Label	Gauge Number	Gauge Name	Coordinates		Years Active
			oS	oE	
1	90071	Princetown	38.69	143.16	1901 – 2016
2	90165	Simpson South	38.56	143.17	1968 – 2019
3	90073	Princetown (Rivernook)	38.75	143.20	1901 – 1946
4	90042	Gellibrand River West	38.62	143.28	1915 – 2019
5	90052	Lavers Hill	38.70	143.40	1914 – 1965
6	90089	Tirrengower	38.40	143.40	1884 – 1965
7	90138	Irrewillipe (Tomahawk Creek)	38.44	143.44	1965 – 2019
8	90086	Wyelangta	38.65	143.45	1913 – 1950
9	90087	Wyelangta	38.66	143.45	1936 – 2019
10	90090	Tomahawk Creek North Startion	38.40	143.45	1934 – 1968
11	90179	Burtons Lookout	38.45	143.47	1990 – 2005
12	90041	Gellibrand River East (Lovat)	38.50	143.50	1898 – 1960
13	90128	Tomahawk Creek (Irrewillipe East)	38.40	143.50	1890 – 1945
14	90083	Weeaproinah	38.64	143.51	1901 – 2012
15	90134	Gellibrand River Forestry	38.53	143.54	1956 – 2015
16	90006	Beech Forest	38.62	143.56	1887 – 2017
17	90007	Beech Forest State Forest	38.70	143.58	1949 – 1956
18	90003	Barramunga	38.60	143.70	1891 – 1980
19	90040	Forrest State Forest	38.52	143.72	1898 – 2019

Table 2 - Rainfall Gauges in and around the Gellibrand River Catchment

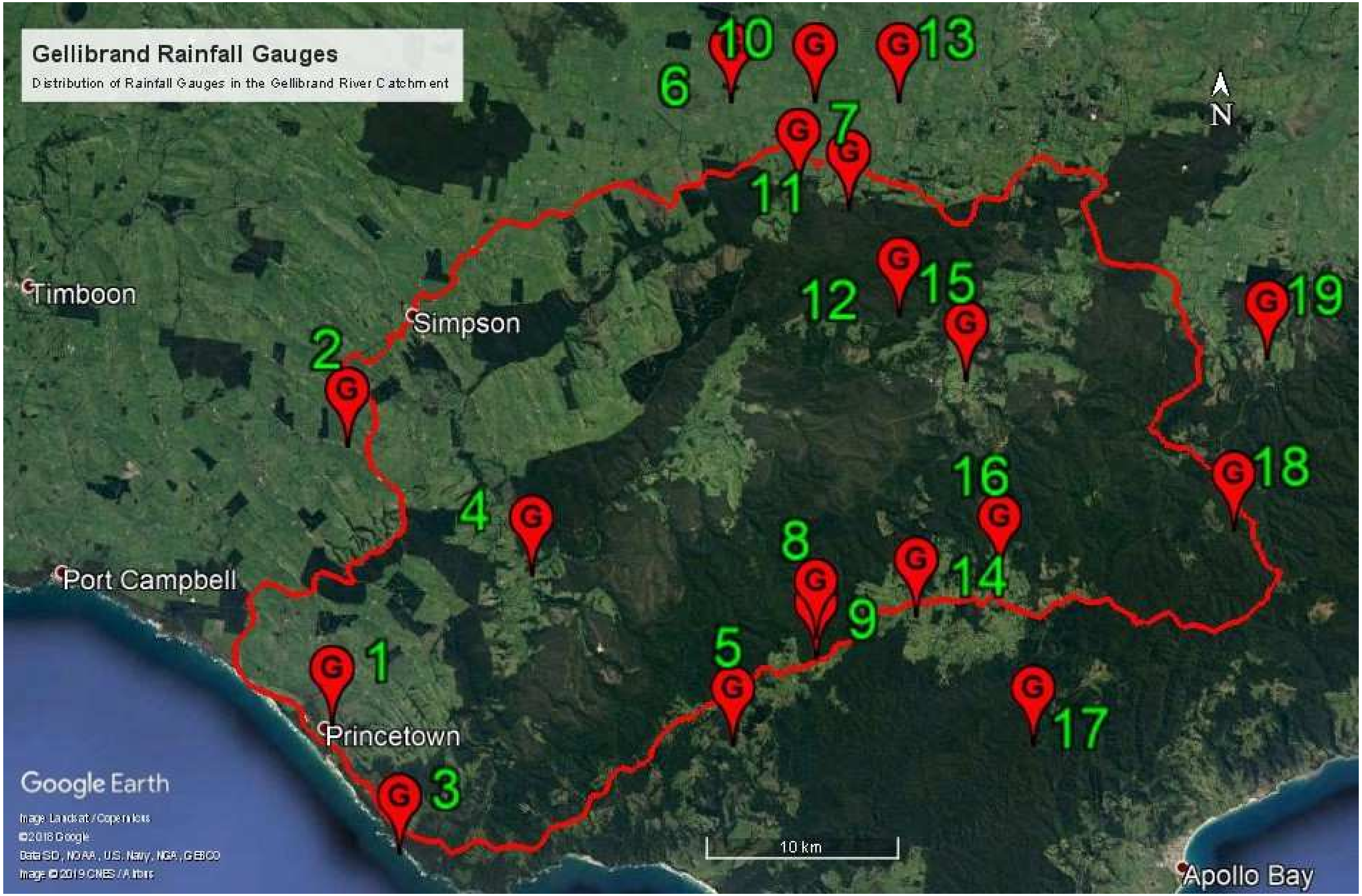

Figure 1 – Distribution of Rain Gauges around the Gellibrand River Catchment

A lot may be learned about catchment hydrology from rainfall records. The rain gauge records show numerous significant falls dispersed around the catchment occurring throughout the period of record. A superficial comparison of a small selection of rainfall events is presented in Table 2, using 3-day rainfall totals in millimetres; cells are graded from yellow to red as the totals increase and are blank where data in not available. A thorough examination of all the data is required to learn how rainfalls dispersed around the catchment combine to cause flooding.

Gauge	Label	1925	1932	1946	1946	1951	1951	1952	1978	1984	1990	2001	2005	2010
Princetown (90071)	1	27.2	149.9	114	44.2	30	76.2	22.8	23.9	47.4	113.4	57.5	46.4	45
Simpson South (90165)	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.7	74.4	167.4	58.2	92.8	97.4
Princetown – Rivernook (90073)	3	53.4	146.1	114	70.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gellibrand River West (90042)	4	23.8	170.2	116	51.3	38.1	53.8	10.2	9.4	76.6	158.2	38	115.8	137
Lavers Hill (90052)	5	158.3	172	211.8	168.5	107.2	126.2	113.8	N/A	N/A	N/A	N/A	N/A	N/A
Irrewillipe – Tomahawk Creek (90138)	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22.6	44.4	125.4	39.2	60.6	87.4
Wyelangta (90086 & 90087)	9	147.1	228.6	146	190	157.5	N/A	189.5	169.2	226	314.6	209.4	201.4	214
Gellibrand River East – Lovat (90041)	12	40.6	92.7	75.7	56.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Weeaproinah (90083)	14	177.8	230.8	75.9	167.9	200.7	164.9	139.2	203.4	229.6	215.6	215.6	185.2	215
Gellibrand River Forestry (90134)	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	47.6	60.4	71.8	65.4	116.2	91.9
Beech Forest (90006)	16	214.1	219.5	134	175.8	236.9	226.3	265.3	270.6	N/A	N/A	N/A	N/A	N/A
Barramunga (90003)	18	N/A	157.7	N/A	N/A	N/A	N/A	250.9	287	N/A	N/A	N/A	N/A	N/A
Forrest State Forest (90040)	19	118.6	65.5	74.2	59.5	182.2	173.5	211.6	205.7	93.2	87.2	176.2	182.6	98

Table 2 – Three Day Totals in mm for a Selection of Rainfall Events at Selected Gauges (from BoM Climate Data)

This comparison confirms that there have been numerous significant rainfall events in recorded history that are relevant to flood estimation at Princetown. Significant rainfall events covering much of the catchment are recorded in 1932, 1951, 1952 and 1990, and incomplete records indicate that further significant events occurred in 1946, 1978, 1984, 2005 and 2010. The 2010 event does not stand out in the sample presented, and the possibility of higher flows predating the Burrupa gauge (active since 1969) cannot be dismissed.

A detailed hydrological study of the Gellibrand catchment is required to test the assumptions made in the GHD Preliminary Hydraulic Report and gain insight into the drivers of flooding at Princetown. Extensive rainfall and river flow records covering much of the Gellibrand River catchment make possible a detailed and authoritative hydrological assessment. It is uncommon to find so much hydrological data in such a small rural catchment and it would be a mistake to trust in assumed hydrology when there is an opportunity to verify catchment hydrology and determine reliable estimations for the full range of likely flood conditions.