Jacobs — Challenging today. Reinventing tomorrow.

Hurunui District Council Coastal Hazards

Multi Flood Hazard Assessment

Amberley Beach

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Topics

- Need for assessment
- Flood mechanisms
- Flood probabilities
- Climate change and sea level rise
- Flood scenarios
- Flood model
- Results
- Summary
- Going forward

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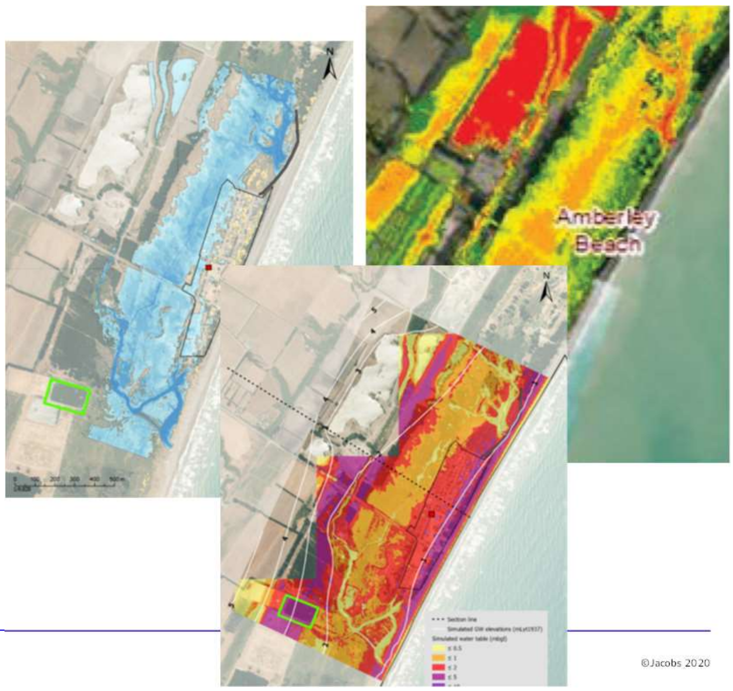
Need for assessment

Need for assessment

- Amberley Beach is susceptible to flooding from different sources:
  - Storm tides
    - Hurunui District Coastal Hazard and Risk Assessment (Jacobs, 2020)
  - High flow in the rivers and streams and heavy rain
    - Kowai River, Leithfield Beach and Amberley Beach flood (ECan, 2014)
  - High groundwater level
    - Hurunui District Coastal Hazard and Risk Assessment (Jacobs, 2020)



Need for assessment

- Amberley Beach is susceptible to flooding from different sources:
  - 31 July 2008 (ECan photos)

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Need for assessment

- To better understand the combined flood hazard from multiple sources
- To understand how this will change in the future with sea level rise and climate change
- To provide information to help develop appropriate adaptive pathway options for managing flood hazard in Amberley Beach

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Flood mechanisms

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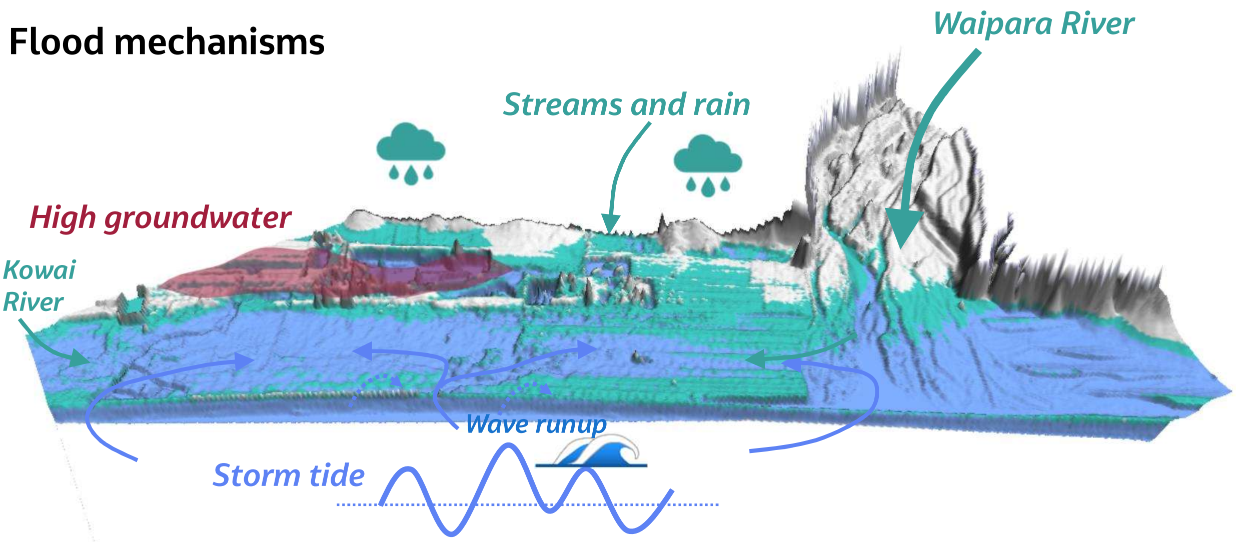
Flood mechanisms



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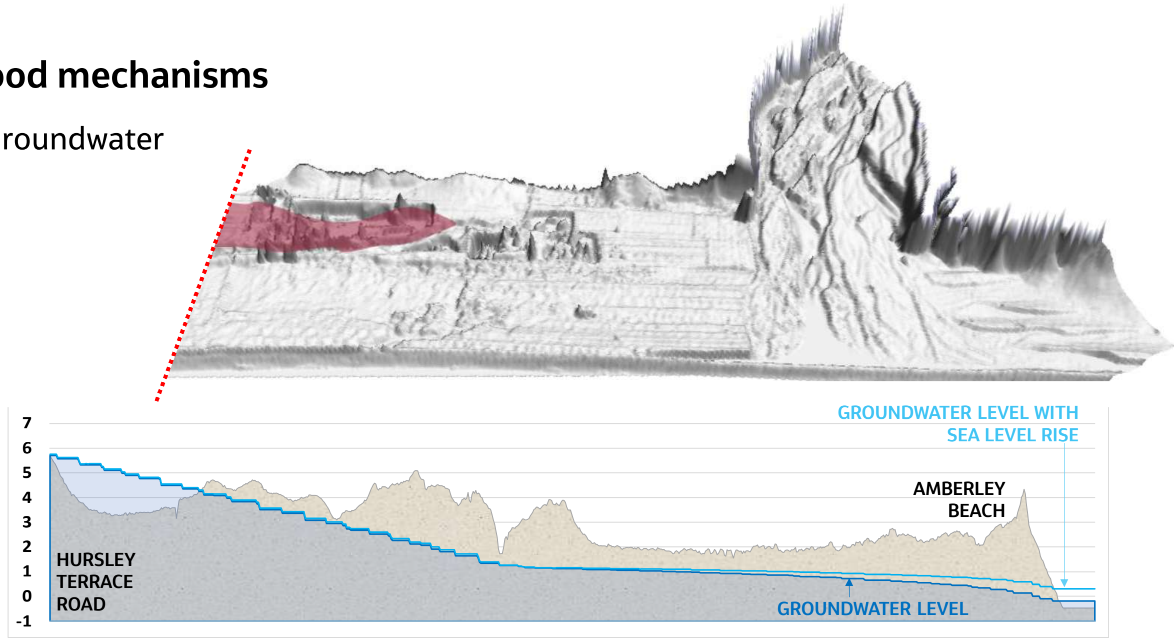
Flood mechanisms

- Groundwater



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Flood probabilities

Flood probabilities

- Average Recurrence Interval (ARI)
  - On average, <u>how often</u> will it happen – every 10 years?, every 100 years?
- Annual Exceedance Probability (AEP)
  - What's the chance it will happen <u>in any one year</u> – 10%?, 1%?

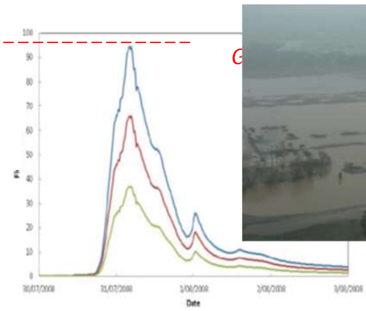
	ARI	AEP	What's the chance it will happen during a period of….		
			30 years?	60 years?	100 years?
"small flood"	5 years	20%	100%	100%	100%
↓	10 years	10%	96%	100%	100%
↓	20 years	5%	79%	95%	99%
↓	50 years	2%	45%	70%	87%
"big flood"	200 years	0.5%	14%	26%	39%

Flood probabilities

- Kowai River (ECan analysis)
  - Flood frequency at the North Branch gauge

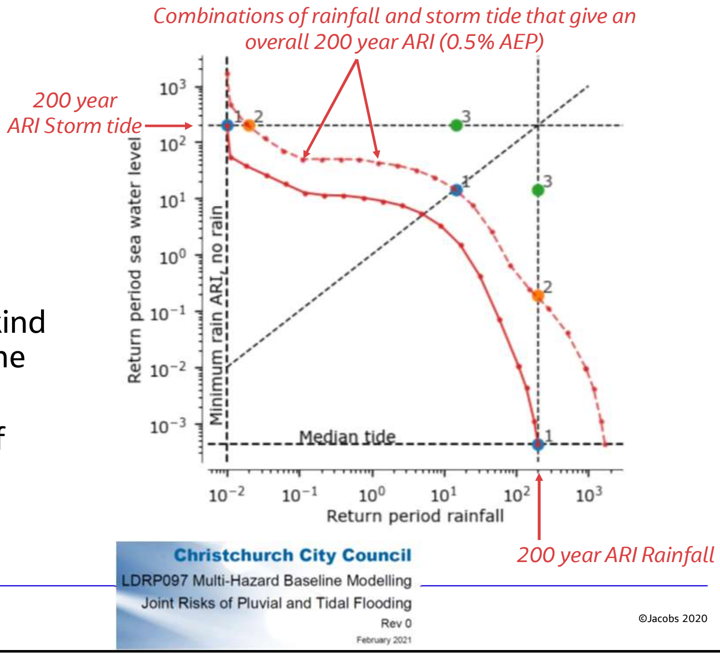
Design flows (m³/s)	North Branch
0.2 AEP (5 year ARI)	78
0.1 AEP (10 year ARI)	103
0.05 AEP (20 year ARI)	128
0.02 AEP (50 year ARI)	160
0.01 AEP (100 year ARI)	184
0.005 AEP (200 year ARI)	208
0.002 AEP (500 year ARI)	239

95 m^3/s between 5 year and 10 year ARI



Flood probabilities

- Joint probability
  - What's the chance of two things happening at the same time?
- Two main sources of flooding
  - Storm tide
  - High river flow and rain
- Weather systems that cause one kind of flooding are likely to cause some of the other kind as well
- But it's less likely that extremes of each kind of flooding will happen together



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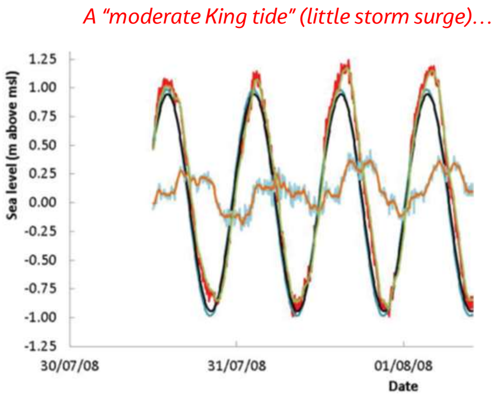
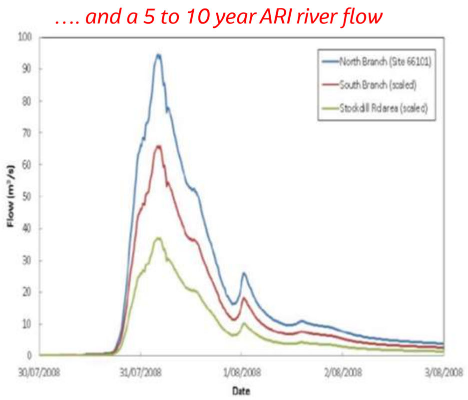
Flood probabilities

- Example: 31 July 2008





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Flood probabilities – what's the worst?

- Could look at lots of combinations of different probability storm tide and river flood events to find the combination that gives the worst flooding for one AEP – takes time
- Or choose a few combinations (often just two) which are "on the safe side" of estimating the worst flooding

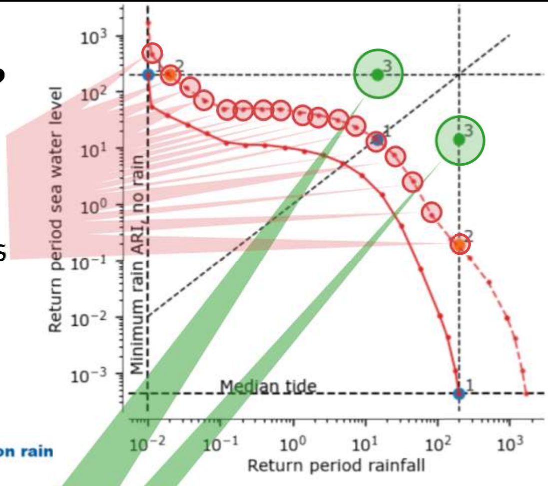


Table 1 Recommended rain/sea event ARI paired values for long duration rain events, compared to previous pairings

Joint Event ARI (years)	10 year	50 year	100 year	200 year
Historic (1/10th rule)	1	5	10	20
Now recommended for long duration (rain >= 6 hrs)	2	7	10	13

Flood probabilities

- For our assessment we have considered two overall probabilities of flooding:
  - 0.5% AEP (or 200 year ARI), a more extreme event – often considered for land use planning
  - 2% AEP (or 50 year ARI), a more frequent event – often considered for asset planning
- For each probability we have assessed the flooding for two combinations of storm tide and river flow + rainfall (the "1/10th rule"):

Flood probability (AEP)	Storm tide probability (AEP)	River flow and rainfall probability (AEP)
0.5%	0.5%	5%
	5%	0.5%
2%	2%	20%
	20%	2%

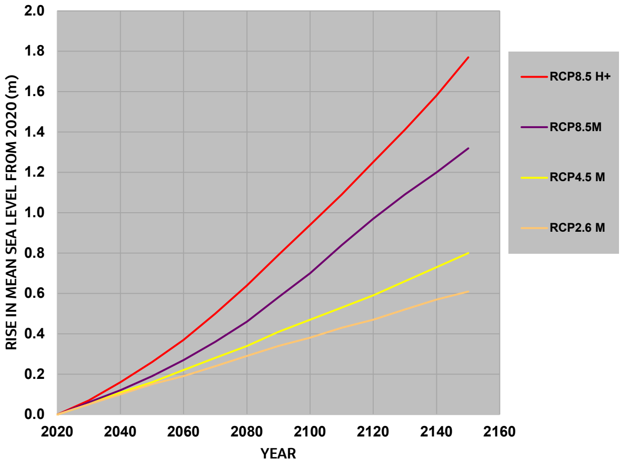
Climate change and sea level rise

Climate change and sea level rise

- Climate change is increasing flood hazard in Amberley Beach
- Two main factors:
  - Sea level rise (SLR)
    - The mean water level in the sea is rising and this means that storm tide levels are also rising by a similar amount
  - Increasing depths of rainfall in extreme rainfall events
    - The total amount of rain falling in storm events is expected to increase – this would mean more runoff and could result in higher flows in the streams and rivers
- Knock-on effects
  - Near the coast, groundwater level will likely rise as the sea level rises
  - Groundwater levels could also increase because of changes in rainfall patterns – more complex
- And… the ground may be sinking – 1 mm/year in Kaikoura?

Climate change and sea level rise

- Sea level rise
  - Ministry for Environment guidance (2017)
  - 0.5 m likely in the next ~50 years
  - 1 m possible in the next ~80 years



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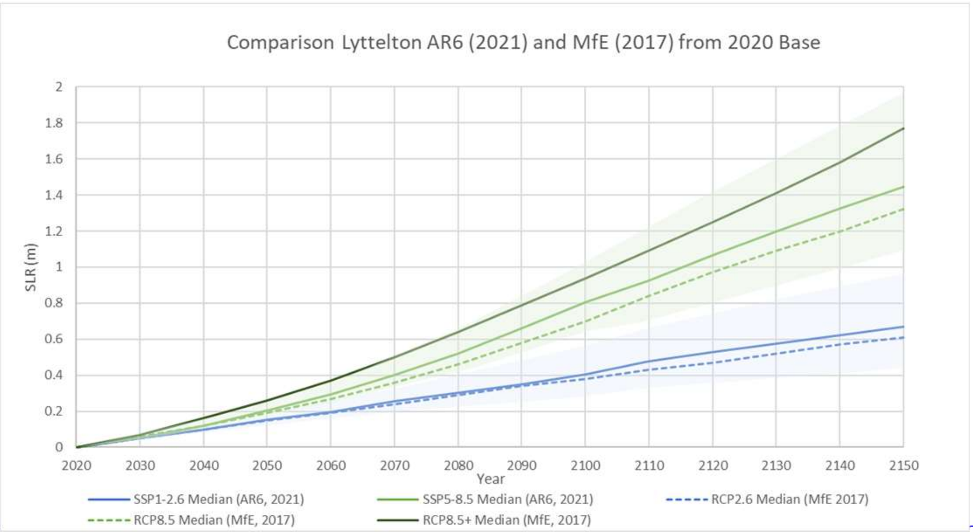
Climate change and sea level rise - IPCC AR6 (2021) and MfE 2017



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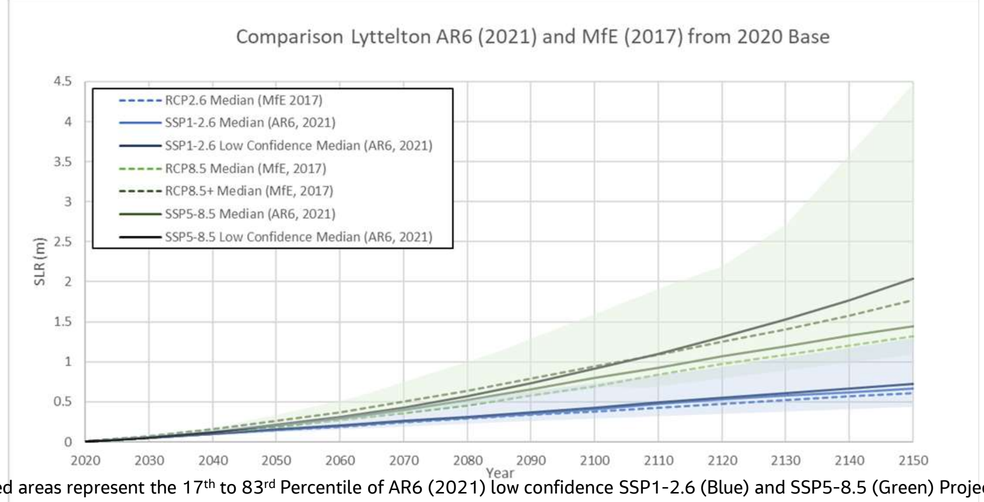
Shaded areas represent the 17th to 83rd Percentile of AR6 (2021) SSP1-2.6 (Blue) and SSP5-8.5 (Green) Projections

Climate change and sea level rise - IPCC AR6 (2021) and MfE 2017



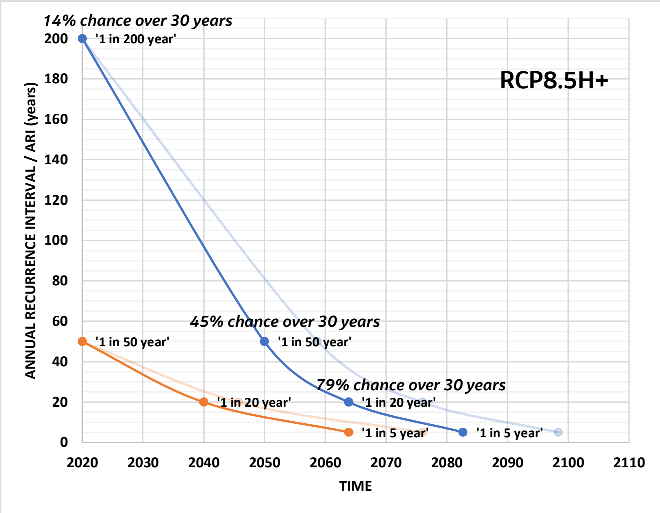
Shaded areas represent the 17th to 83rd Percentile of AR6 (2021) low confidence SSP1-2.6 (Blue) and SSP5-8.5 (Green) Projections

Climate change and sea level rise

- Extreme rainfall
  - Ministry for Environment guidance (2018)
  - 24 hour rainfall totals for storm events to increase by 8.5% per degree of rise in temperature
  - In the next 60 to 80 years rainfall totals could increase by 14% to 22% depending on how much the average temperature in New Zealand rises
  - River flows may not necessarily increase by the same amount, especially at the bottom of catchments, due to increased flooding upstream

Climate change and sea level rise

- Climate change affects the probability of flooding
  - The severity of more frequent events will become greater (flooding in the 10 year ARI will become as bad as the 20 year, for example)
  - or,
  - Severe events will become more frequent (the 50 year ARI event will occur every 20 years on average, for example)
- Change in probability of storm tides at Amberley Beach



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Flood scenarios

Flood scenarios

Flood probability	Sea level rise	Storm tide probability	River flow and rainfall probability
0.5% AEP (200 year ARI)	0 m	0.5%	5%
		5%	0.5%
	0.3 m	0.5%	5%
		5%	0.5%
	0.5 m	0.5%	5%
		5%	0.5%
	1 m	0.5%	5%
		5%	0.5%
2% AEP (50 year ARI)	0.5 m	2%	20%
		20%	2%

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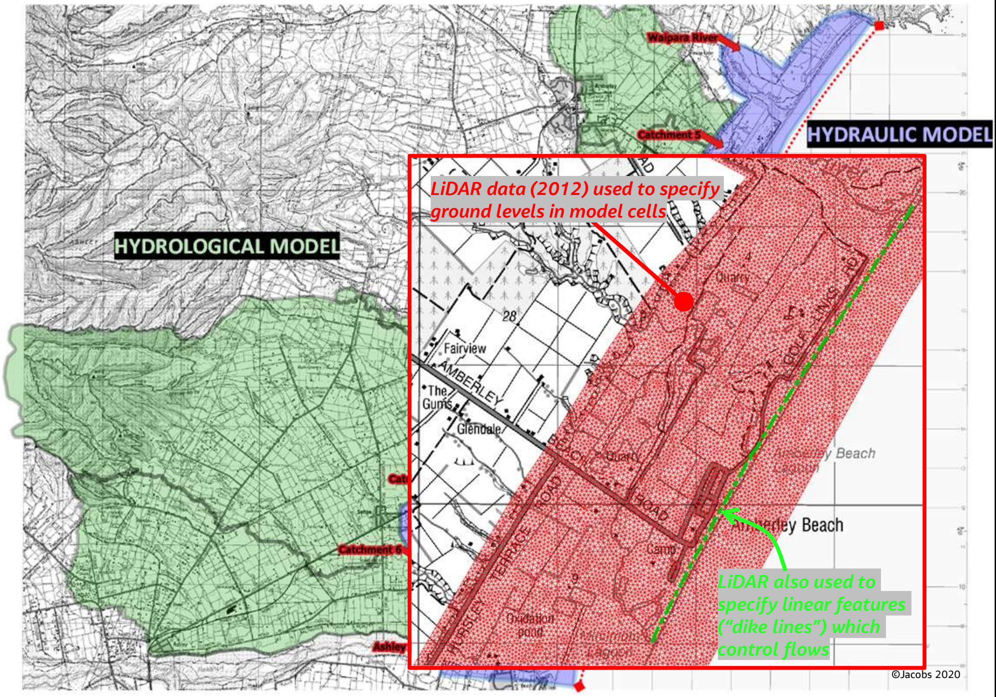
Flood model

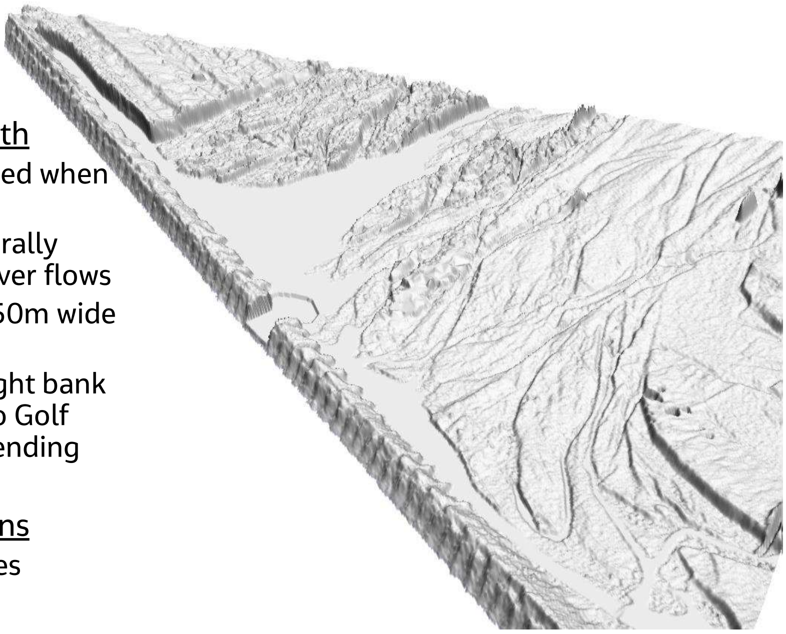
Flood model

- Hydraulic model
  - mesh of cells that calculate the movement of water across the ground
  - extends over the whole coastal plain to include all the flood flow paths that may affect communities



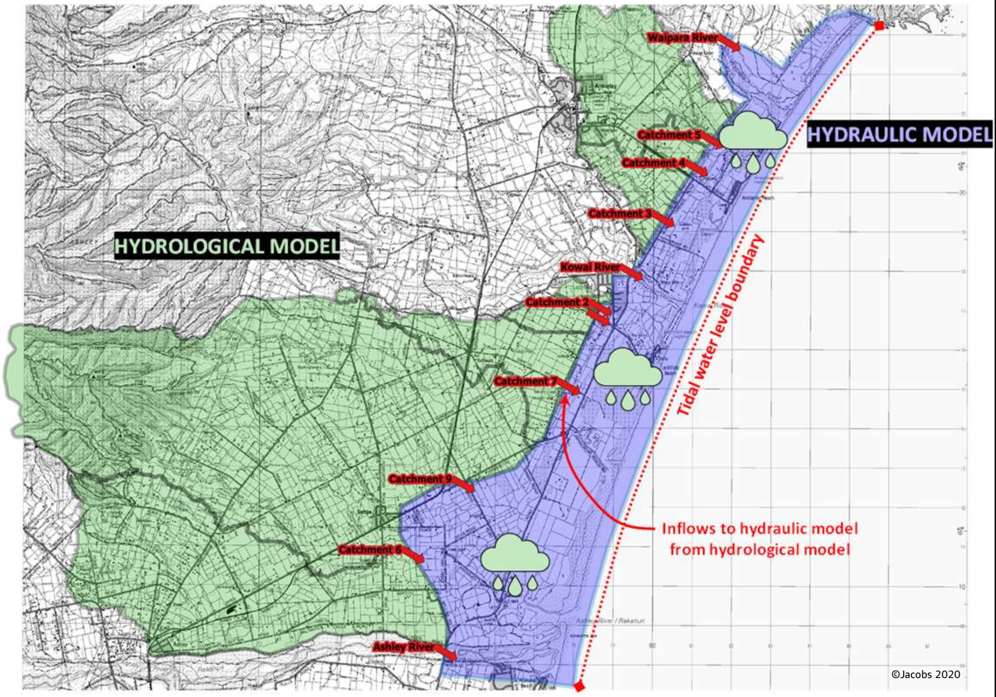
Flood model

- Waipara River mouth
  - LiDAR data collected when bar fully formed
  - Bar cut forms naturally under moderate river flows
  - Model includes a 50m wide cut
  - Overtopping on right bank of Waipara River to Golf Course varies depending on cut width
- Kowai River/Lagoons
  - LiDAR data includes openings



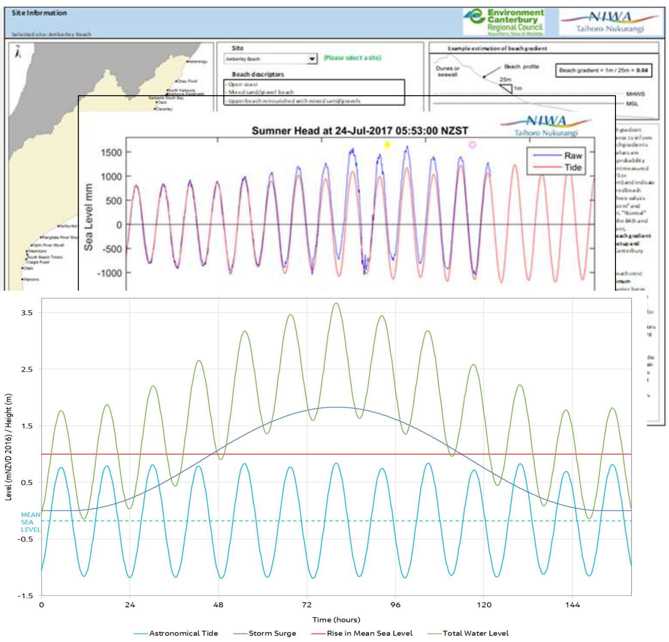
Flood model

- Hydrological model
  - Calculates the runoff flow from the inland catchments
  - Rainfall applied directly to hydraulic model
  - Flood frequency data for large rivers



Flood model

- Tidal water level boundary
  - Storm tide levels from ECan Coastal Calculator (to NZVD2016)
    - 20% AEP = 1.99 m
    - 5% AEP = 2.25 m
    - 2% AEP = 2.41 m
    - 0.5% AEP = 2.67 m
  - Typical storm surge adopted from example records
  - Water level time series composed of
    - typical astronomical tide
    - + storm surge to give storm tide level
    - + sea level rise

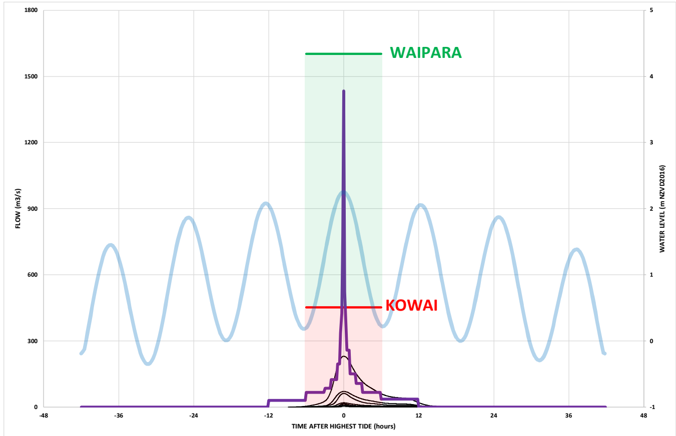


Flood model

- Flow boundaries
  - Runoff from local catchments
    - Rainfall-runoff flow (US Soil Conservation Service method)
    - Rainfall depths from NIWA High Intensity Design System (HiRDSv4)
    - 24-hour nested rainfall pattern
  - Large rivers (Waipara, Kowai, Ashely)
    - ECan flood frequency analyses
    - Long duration events, constant flow over peak tide (12-hour)
  - Direct rainfall onto hydraulic model
    - Same rainfall profile as for small catchments

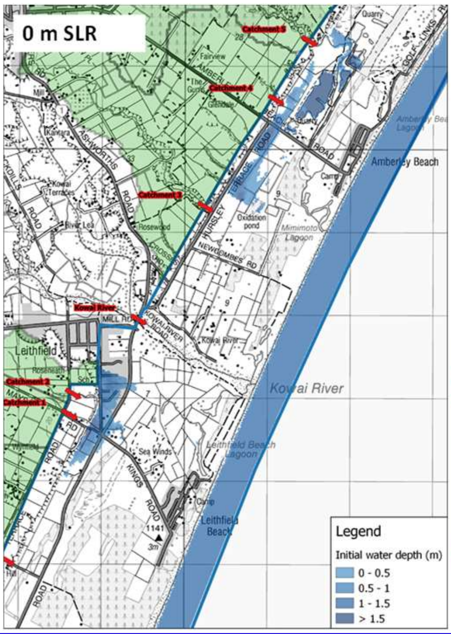
River Flow for Ashley River at RTB (Cones Rd)

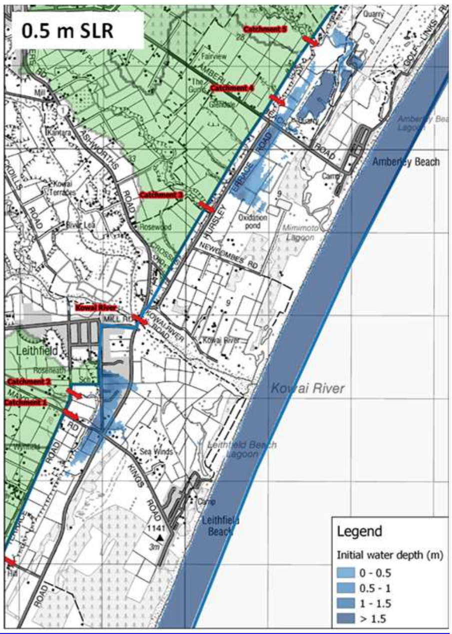
LAST SAMPLE (NZD STD TIME)	STAGE M	FLOW M3/S	CHANGE MM/H	7 DAY PEAK STAGE	7 DAY PEAK FLOW	7 DAY PEAK DATE	TEMP CELSIUS
08-Jun 07:00	0.798	86.476	2	2.659	1154.32	01-Jun 00:05	



Flood model

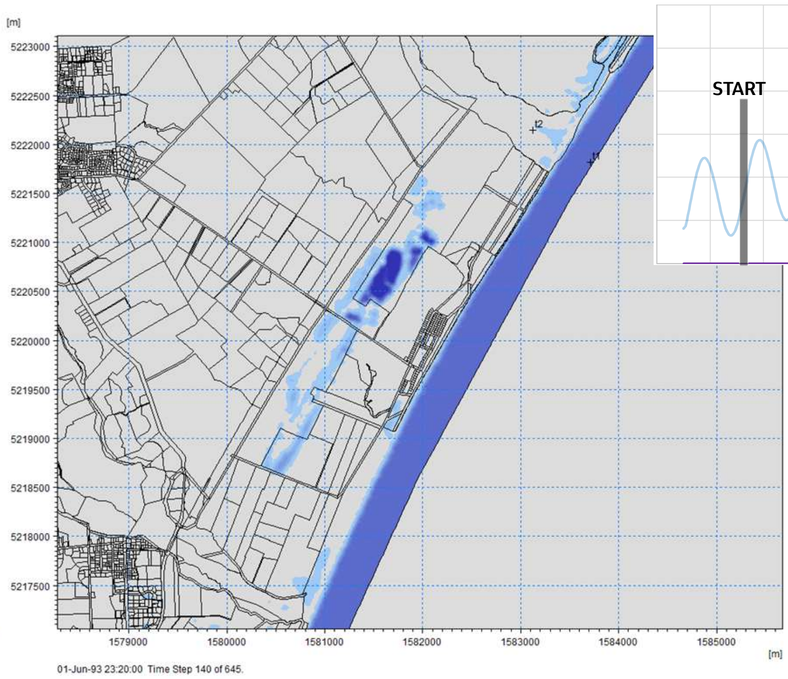
- Initial water levels
  - Include ponding from groundwater where the groundwater level exceeds the ground level
  - Groundwater levels were derived through modelling in the Coastal Hazard and Risk Assessment (Jacobs, 2020)

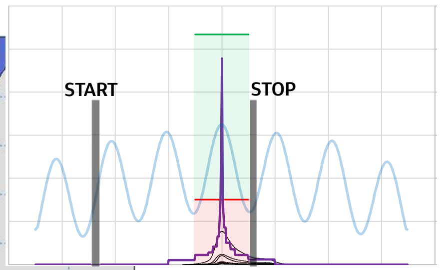




Results

Results

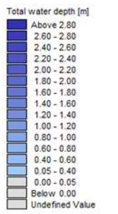




2% AEP (1 in 50-year)

Tidally dominated

- **2% AEP tide**
- **20% AEP fluvial**
- **0.5 m SLR**



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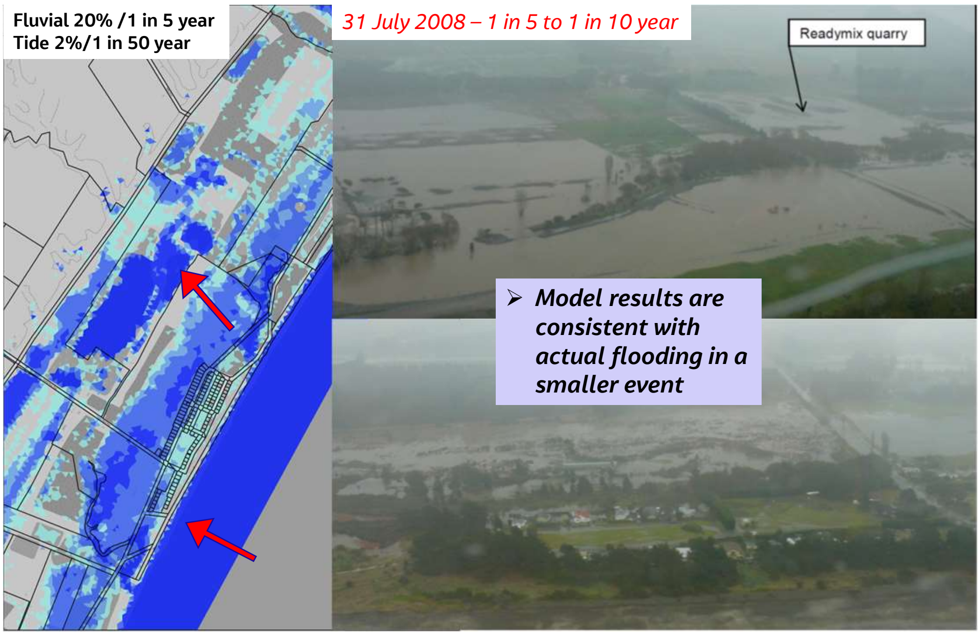
Results

- 2% AEP (1 in 50-year)
- 0.5 m SLR



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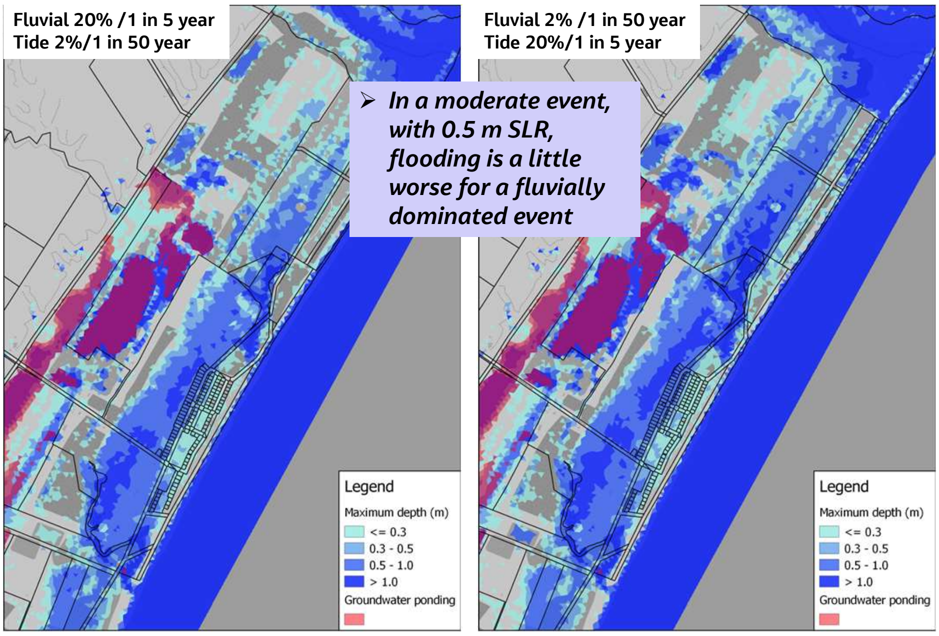
Results

- 2% AEP (1 in 50-year)
- 0.5 m SLR



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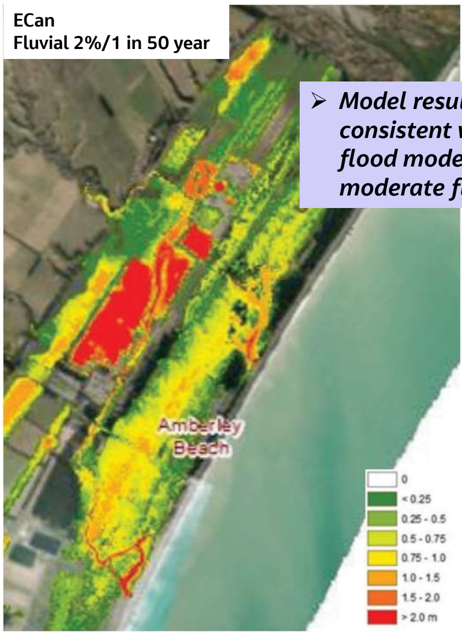
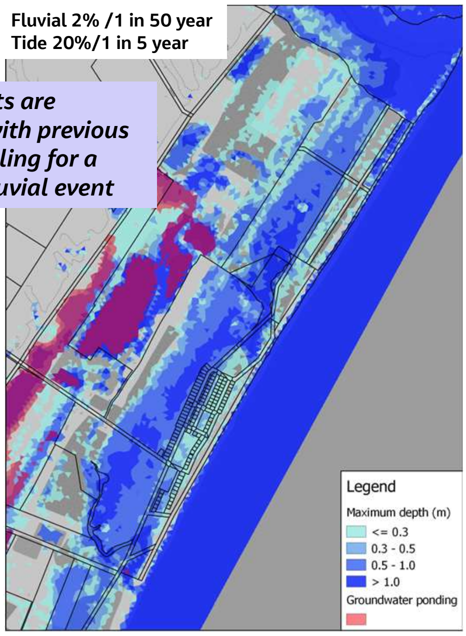
Results

- 2% AEP (1 in 50-year)
- 0.5 m SLR

ECan
Fluvial 2%/1 in 50 year

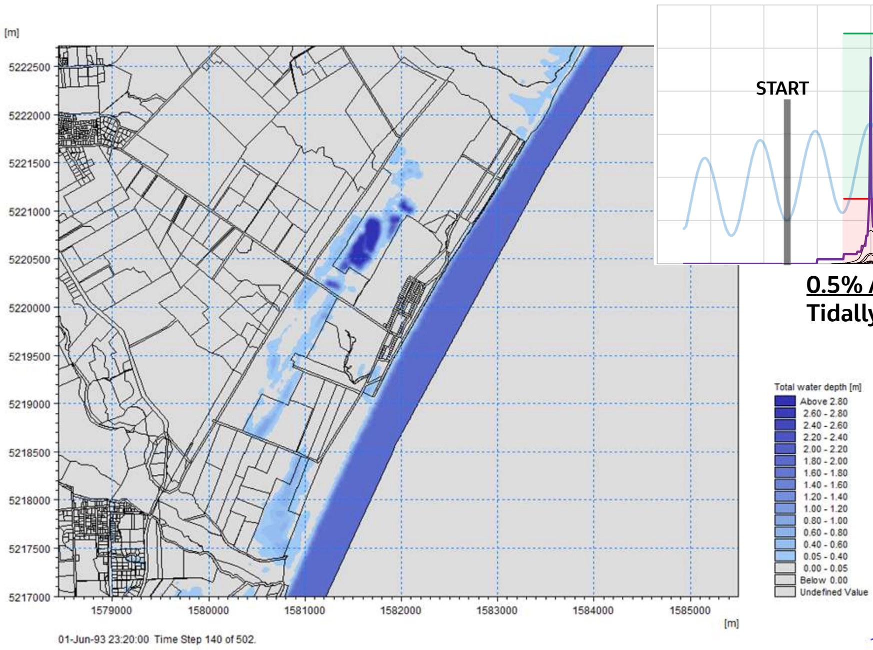


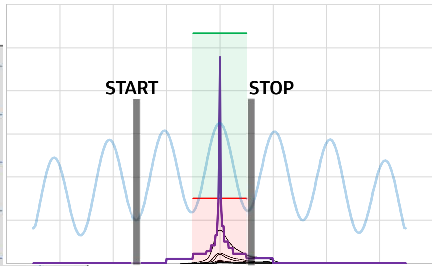
Fluvial 2% /1 in 50 year
Tide 20%/1 in 5 year



➢ *Model results are consistent with previous flood modelling for a moderate fluvial event*

Results



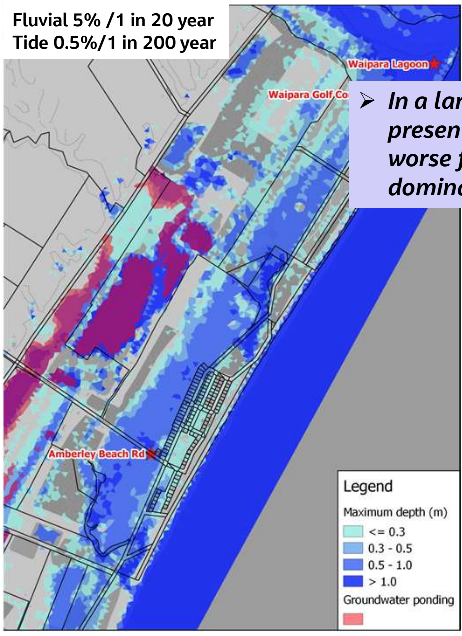


0.5% AEP (1 in 200-year)
Tidally dominated
- **0.5% AEP tide**
- **5% AEP fluvial**
- **0 m SLR**

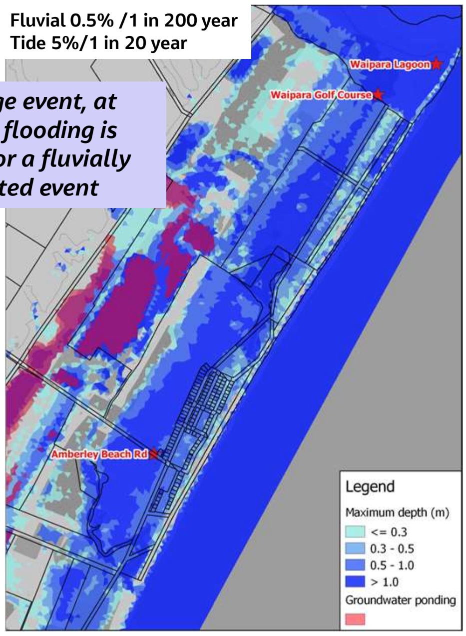
Results

- 0.5% AEP (1 in 200-year)
- 0 m SLR

Fluvial 5% /1 in 20 year
Tide 0.5%/1 in 200 year



Fluvial 0.5% /1 in 200 year
Tide 5%/1 in 20 year

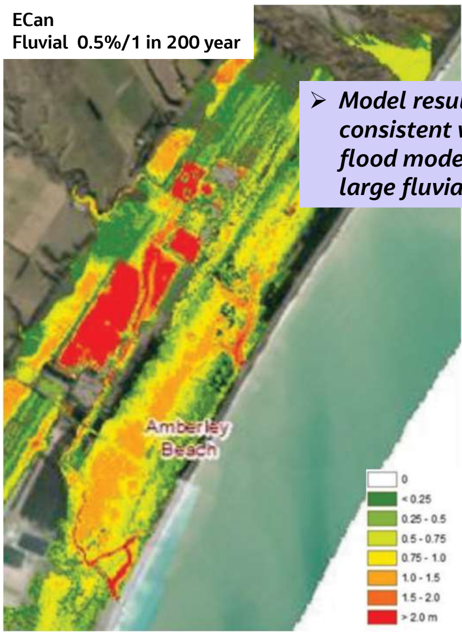


- ➢ *In a large event, at present flooding is worse for a fluvially dominated event*

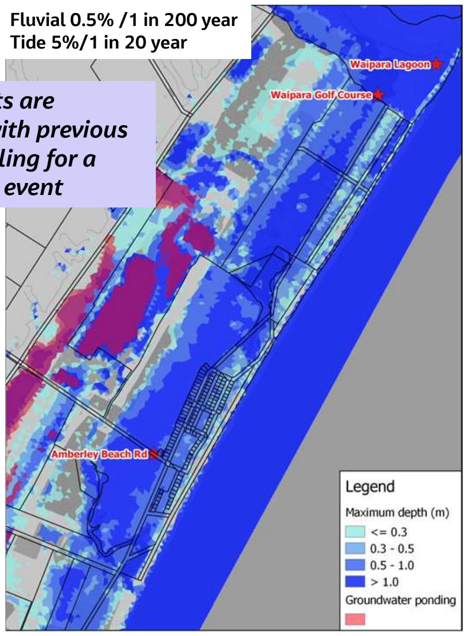
Results

- 0.5% AEP (1 in 200-year)
- 0 m SLR

ECan
Fluvial 0.5%/1 in 200 year

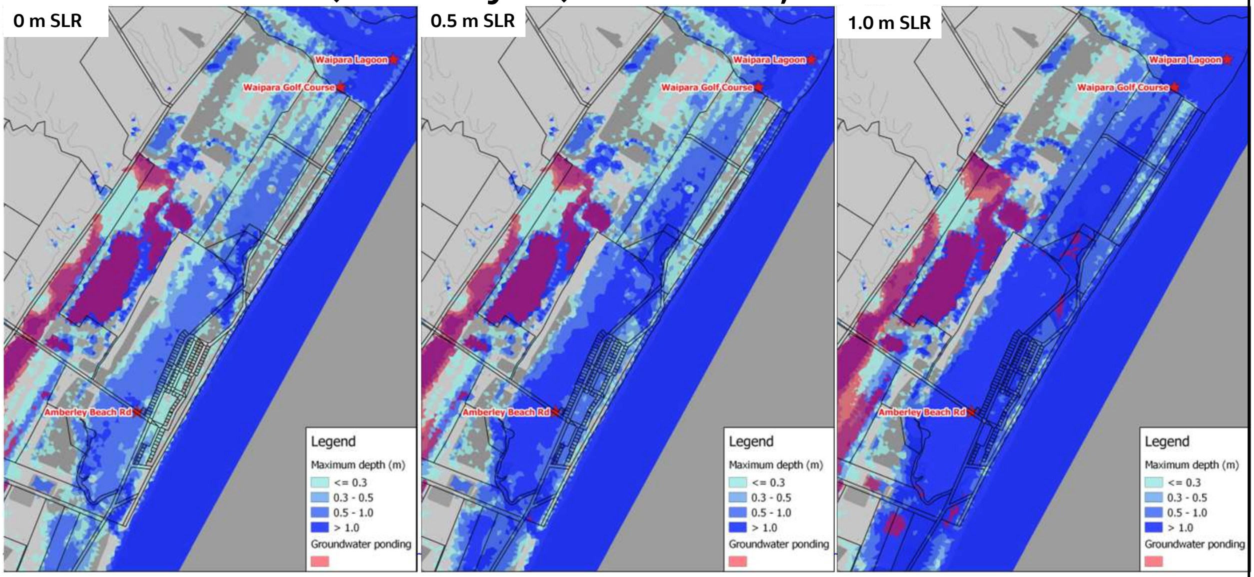


Fluvial 0.5% /1 in 200 year
Tide 5%/1 in 20 year



- ➢ *Model results are consistent with previous flood modelling for a large fluvial event*

Results : 0.5% AEP (1 in 200 year) – Tide 0.5%, Fluvial 5%



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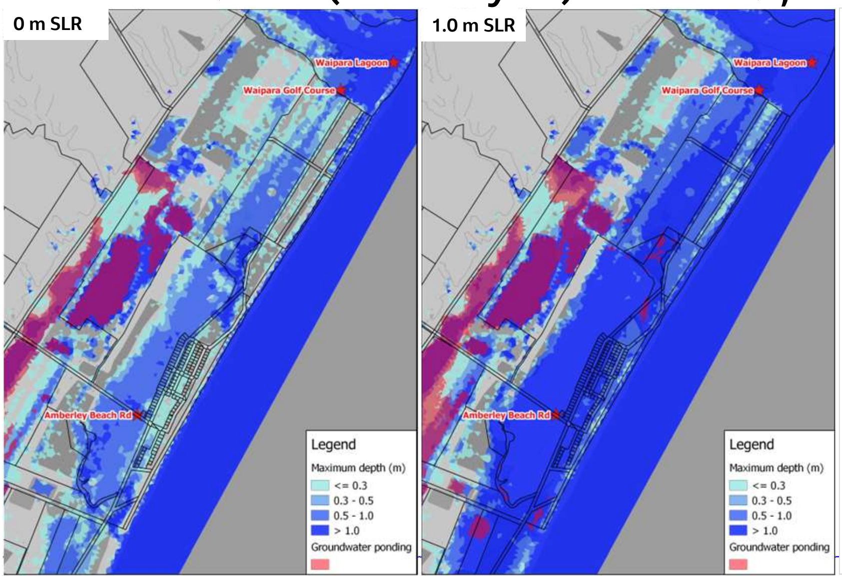
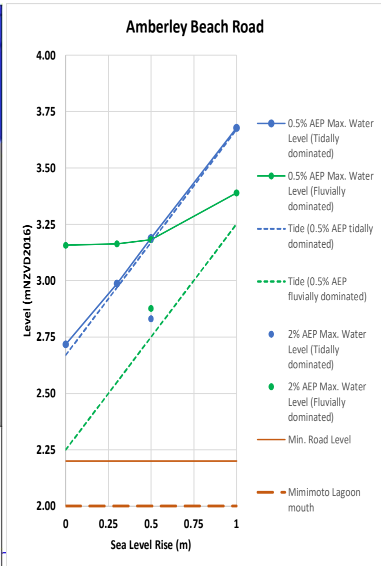
Results : 0.5% AEP (1 in 200 year) – Tide 0.5%, Fluvial 5%





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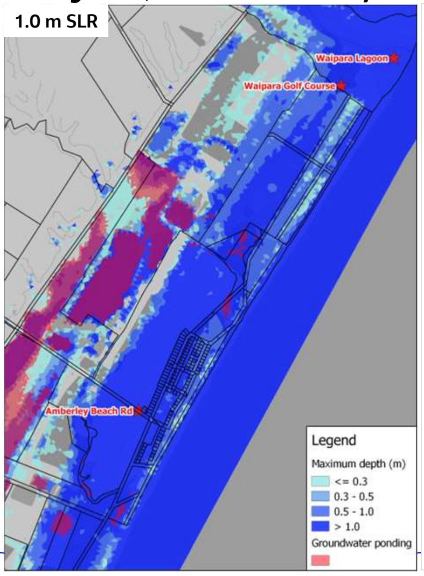
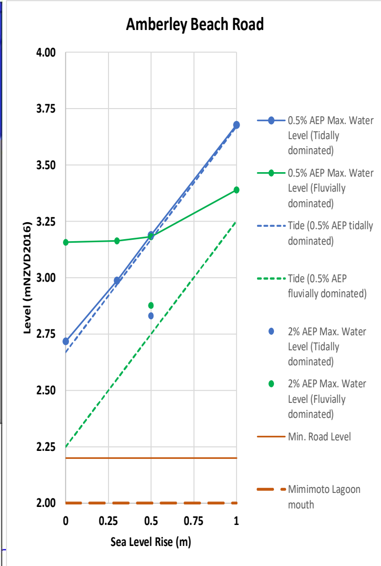
Results : 0.5% AEP (1 in 200 year) – Tide 0.5%, Fluvial 5%

- At present time, fluvial flooding worse than tidal for a given AEP
- As sea level rises, tidal becomes worse than fluvial at around 0.5 m SLR
- Potential for groundwater ponding increases a little with SLR but is mostly in the seep area below Hursley Terrace and lowest points around lagoons





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Results - uncertainties

- Waipara River
  - Flooding depends on the size of the opening that forms in the bar and flow in the river
  - But effects reduces for larger storm tides and as sea level rise (present day 0.5% AEP storm tide is just below the lowest point on the bank

  → less uncertainty in future flooding
- Other river mouths and lagoons
  - Modelled as per 2012 LiDAR – considered typical but these do vary with time (and can be artificially cut).
  - But mouths generally a lot lower relative to storm tide levels so less effect
- Model scale
  - Small features and drains not represented due to size of mesh but key raised features that control flooding are included separately

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Results - uncertainties

- River flows
  - Simplified flow duration for main rivers but not unrealistic
  - Flooded area fills rapidly in large events (small floodplain volume relative to river flow)
  - Flood extents and depths likely not very sensitive to duration
- Groundwater
  - Groundwater levels and the changes in level with SLR based on simpler modelling – less certainty in this source of hazard

Summary

Summary of Multi Flood Hazard Assessment for Amberley Beach

- Main sources of flood hazard are high river flow and storm tide
- Runoff from local catchments important in smaller events
- Probability of flooding is high
  - Widespread flooding for events more frequent than 1 in 50 year at present
  - Deepest flooding is in the lower land between Amberley Beach and Hursley Terrace – including the only access route via Amberley Beach Road
  - Flooding will become more frequent with climate change and sea level rise
- At present, flooding during large events is worse for high river flow events than for high storm tide events
- With rising mean sea level, flooding will be worse for storm tide events than for high river flow events after around 0.5 m SLR
- Less certainty in hazard from groundwater - modelling indicates this is mainly in the seep area below Hursley Terrace Road rather than in Amberley Beach itself and is less affected by sea level rise than tidal and fluvial flooding

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Going forward

Going forward