

# Coastal Inundation Tool Guidance

## 1 Overview

The Coastal Inundation Tool provides users with a tool to quickly understand the susceptibility of coastal areas to coastal inundation due to [tides](#), [storms](#) and [projected sea level rise](#) at a regional scale. The tool is not intended to provide specific information that could be used to define actual coastal inundation hazards or minimum floor levels for specific properties.

Using the Coastal Inundation Tool consists of two components:

1. Choosing a water level scenario,
2. Mapping the inundation that might occur.

The user can either choose a predefined water level scenario, or choose to create their own.

The tool is intended to identify areas where further work should be undertaken, if required, to better quantify the coastal inundation hazard, both currently and in the future. The tool only shows 'static' water levels and does not include the effects of currents, friction, waves or other hydraulic processes that affect water movement or inundation.

The tool shows:

- **Connected inundation** (blue shaded areas), which represent areas where water could directly flow to the sea for a chosen water level.
- **Disconnected inundation** (green areas), which represent areas that are at or below a chosen water level, but may have no direct flow path to the sea. Disconnected areas may still be affected by coastal inundation in some way, e.g. via groundwater.

The very first mapped water level for all locations shows the area that is likely to be inundated with a high tide (generally 0.2 m below the MHWS water level). All higher mapped water levels only show areas that would not normally be inundated by a high tide.

All water levels and land elevations are provided relative to Moturiki Vertical Datum 1953, both in the Coastal Inundation Tool and also as referred to in the text and tables of this guidance document.

## 2 How do I use the Coastal Inundation Tool?

The Coastal Inundation Tool allows the user to choose a water level scenario for a specific location. As water levels vary around the WRC coastline, water level values are required that best represent the specific location.

The process to use the Coastal inundation tool is (Refer figure 2.1):

- Zoom to the area of interest in the map
- Choose a water level [scenario](#) (or scenarios) for the area of interest.

- Choose the nearest water level on the slider in the map to the chosen water level scenario, (note, the mapped water levels are at 0.2 m intervals)
- Explore the 'sensitivity' of the area by observing the mapped water levels above and below your water level scenario.

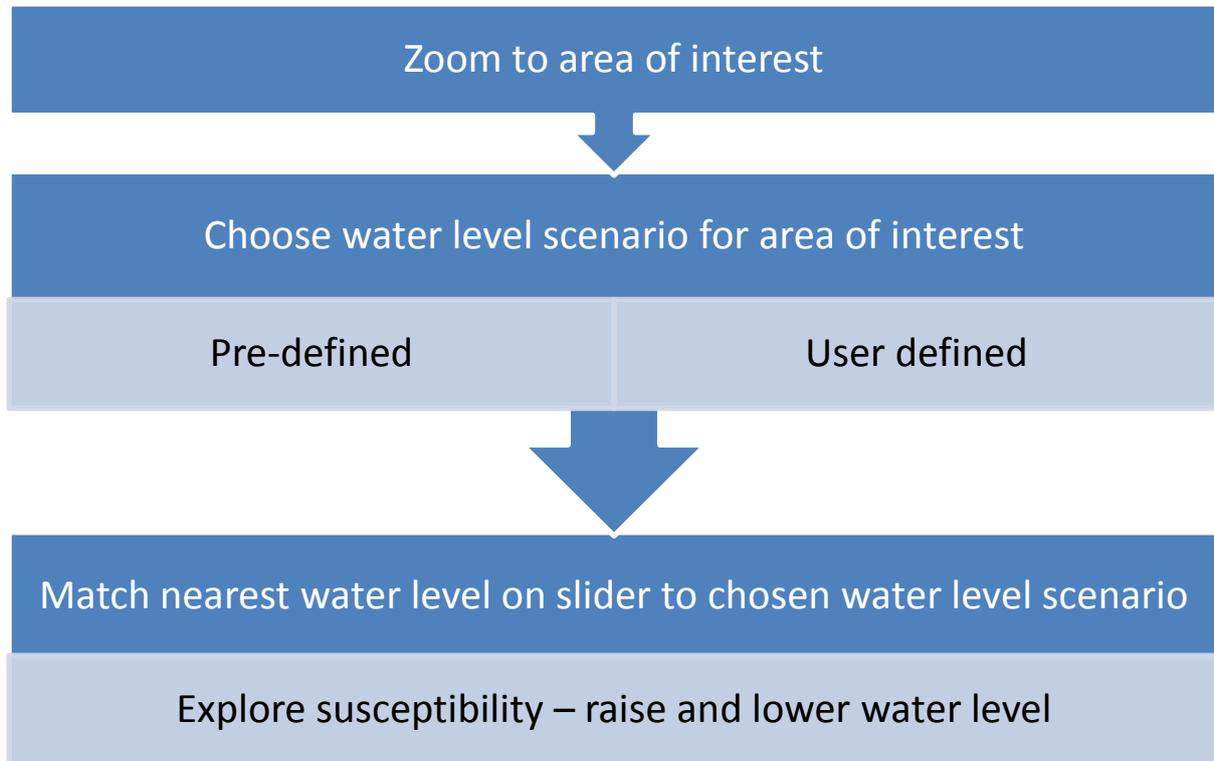


Figure 2.1 Coastal Inundation Tool process.

## 2.1 Predefined Water Level Scenario

Predefined Water Level scenarios provide the user with a quick reference to commonly used water levels. The user can also define their own water level scenarios if required, refer to [Section 2.2](#).

Water-level scenarios for specific areas around the WRC coastline have been provided based on [tide levels](#), [storm tides](#) and [projected sea level rise](#).

The predefined water level scenarios provide water level estimates for the present day and with future projected sea-level rise. The present day coastal water levels are valid for the next approximately 10 years representing:

- Mean High Water Spring Tide (MHWS)
- Maximum High Tide (Max Tide)
- Lower Storm Tide
- Upper Storm Tide

Refer to [Section 3](#) for descriptions on how the values were derived.

The Future Projected water levels simply include the addition of 0.5 m and 1.0 m to the Present Day levels. The predefined water levels do not include Sea-Level Anomaly.

Predefined water level scenarios are provided below for specific areas (all values relative to Moturiki Vertical Datum 1953):

Area			Coromandel East Coast						
Location			Whiritoa Beach	Opoutere Beach	Tairua and Pauanui	Hahei Beach	Mercury Bay	Matarangi and Whangapoua	
<b>Present Day</b>	<b>MHWS (m)</b>		1.07	1.07	1.08	1.08	1.10	1.16	
	<b>Max Tide (m)</b>		1.26	1.26	1.27	1.27	1.29	1.37	
	<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	1.37	1.37	1.38	1.38	1.40	1.46	
		<b>Upper (m)</b>	2.07	2.07	2.08	2.08	2.10	2.18	
<b>Future Projected</b>	<b>0.5 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		1.57	1.57	1.58	1.58	1.60	1.66
		<b>Max Tide (m)</b>		1.76	1.76	1.77	1.77	1.79	1.87
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	1.87	1.87	1.88	1.88	1.90	1.96
			<b>Upper (m)</b>	2.57	2.57	2.58	2.58	2.60	2.68
	<b>1.0 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.07	2.07	2.08	2.08	2.10	2.16
		<b>Max Tide (m)</b>		2.26	2.26	2.27	2.27	2.29	2.37
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.37	2.37	2.38	2.38	2.40	2.46
			<b>Upper (m)</b>	3.07	3.07	3.08	3.08	3.10	3.18

Area			Coromandel East Coast						
Location			Opito Bay	Whangamata	Onemana Beach	Hot Water Beach	Shakespeare Bay	Whitianga (Wharf)	
<b>Present Day</b>	<b>MHWS (m)</b>		1.11	1.07	1.07	1.08	1.10	0.98	
	<b>Max Tide (m)</b>		1.31	1.26	1.26	1.27	1.30	1.18	
	<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	1.41	1.37	1.37	1.38	1.40	1.28	
		<b>Upper (m)</b>	2.12	2.07	2.07	2.08	2.11	1.99	
<b>Future Projected</b>	<b>0.5 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		1.61	1.57	1.57	1.58	1.60	1.48
		<b>Max Tide (m)</b>		1.81	1.76	1.76	1.77	1.80	1.68
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	1.91	1.87	1.87	1.88	1.90	1.78
			<b>Upper (m)</b>	2.62	2.57	2.57	2.58	2.61	2.49
	<b>1.0 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.11	2.07	2.07	2.08	2.10	1.98
		<b>Max Tide (m)</b>		2.31	2.26	2.26	2.27	2.30	2.18
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.41	2.37	2.37	2.38	2.40	2.28
			<b>Upper (m)</b>	3.12	3.07	3.07	3.08	3.11	2.99

Area			Coromandel East Coast					
Location			Otama Beach	Kuaotunu	Kennedy Bay	Port Charles and Sandy Bay	Stony Bay	
<b>Present Day</b>	<b>MHWS (m)</b>		1.13	1.15	1.17	1.24	1.26	
	<b>Max Tide (m)</b>		1.33	1.36	1.38	1.46	1.48	
	<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	1.43	1.45	1.47	1.54	1.56	
		<b>Upper (m)</b>	2.14	2.17	2.19	2.27	2.29	
<b>Future Projected</b>	<b>0.5 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		1.63	1.65	1.67	1.74	1.76
		<b>Max Tide (m)</b>		1.83	1.86	1.88	1.96	1.98
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	1.93	1.95	1.97	2.04	2.06
			<b>Upper (m)</b>	2.64	2.67	2.69	2.77	2.79
	<b>1.0 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.13	2.15	2.17	2.24	2.26
		<b>Max Tide (m)</b>		2.33	2.36	2.38	2.46	2.48
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.43	2.45	2.47	2.54	2.56
			<b>Upper (m)</b>	3.14	3.17	3.19	3.27	3.29

Area			Coromandel West Coast						
Location			Coromandel Harbour	Amodeo Bay	Port Jackson	Port Jackson Road	Colville Bay	Te Kouma Harbour and Manaia Harbour	
<b>Present Day</b>	<b>MHWS (m)</b>		1.58	1.53	1.39	1.48	1.51	1.60	
	<b>Max Tide (m)</b>		1.86	1.80	1.63	1.72	1.78	1.88	
	<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	1.88	1.83	1.69	1.78	1.81	1.90	
		<b>Upper (m)</b>	2.67	2.61	2.44	2.53	2.59	2.69	
<b>Future Projected</b>	<b>0.5 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.08	2.03	1.89	1.98	2.01	2.10
		<b>Max Tide (m)</b>		2.36	2.30	2.13	2.22	2.28	2.38
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.38	2.33	2.19	2.28	2.31	2.40
			<b>Upper (m)</b>	3.17	3.11	2.94	3.03	3.09	3.19
	<b>1.0 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.58	2.53	2.39	2.48	2.51	2.60
		<b>Max Tide (m)</b>		2.86	2.80	2.63	2.72	2.78	2.88
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.88	2.83	2.69	2.78	2.81	2.90
			<b>Upper (m)</b>	3.67	3.61	3.44	3.53	3.59	3.69

Area		Firth of Thames									
Location		Miranda	Thames (Tararu)	Kaiaua	Wharekawa	Te Puru	Waikawau/Te Mata/Tapu	Kereta	Hauraki Plains		
<b>Present Day</b>	<b>MHWS (m)</b>		1.80	1.79	1.77	1.73	1.75	1.71	1.66	1.80	
	<b>Max Tide (m)</b>		2.12	2.11	2.09	2.04	2.06	2.02	1.95	2.12	
	<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.21	2.20	2.18	2.14	2.16	2.12	2.07	2.21	
		<b>Upper (m)</b>	3.23	3.22	3.20	3.15	3.17	3.13	3.06	3.23	
<b>Future Projected</b>	<b>0.5 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.30	2.29	2.27	2.23	2.25	2.21	2.16	2.30
		<b>Max Tide (m)</b>		2.62	2.61	2.59	2.54	2.56	2.52	2.45	2.62
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.71	2.70	2.68	2.64	2.66	2.62	2.57	2.71
			<b>Upper (m)</b>	3.73	3.72	3.70	3.65	3.67	3.63	3.56	3.73
	<b>1.0 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.80	2.79	2.77	2.73	2.75	2.71	2.66	2.80
		<b>Max Tide (m)</b>		3.12	3.11	3.09	3.04	3.06	3.02	2.95	3.12
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	3.21	3.20	3.18	3.14	3.16	3.12	3.07	3.21
			<b>Upper (m)</b>	4.23	4.22	4.20	4.15	4.17	4.13	4.06	4.23

Area		West Coast							
Location		Mokau River	Waikato River	Raglan Harbour	Marakopa River	Kawhia Harbour	Aotea Harbour		
<b>Present Day</b>	<b>MHWS (m)</b>		1.82	1.69	1.72	1.76	1.74	1.73	
	<b>Max Tide (m)</b>		2.17	2.02	2.06	2.10	2.08	2.07	
	<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.36	2.23	2.26	2.30	2.28	2.27	
		<b>Upper (m)</b>	3.23	3.08	3.12	3.16	3.14	3.13	
<b>Future Projected</b>	<b>0.5 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.32	2.19	2.22	2.26	2.24	2.23
		<b>Max Tide (m)</b>		2.67	2.52	2.56	2.60	2.58	2.57
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	2.86	2.73	2.76	2.80	2.78	2.77
			<b>Upper (m)</b>	3.73	3.58	3.62	3.66	3.64	3.63
	<b>1.0 m projected Sea Level Rise</b>	<b>MHWS (m)</b>		2.82	2.69	2.72	2.76	2.74	2.73
		<b>Max Tide (m)</b>		3.17	3.02	3.06	3.10	3.08	3.07
		<b>Storm Tide Range (Estimate)</b>	<b>Lower (m)</b>	3.36	3.23	3.26	3.30	3.28	3.27
			<b>Upper (m)</b>	4.23	4.08	4.12	4.16	4.14	4.13

## 2.2 User Defined Water Level Scenario

The simplest way of determining a user defined water level scenario is to use the 'building block' approach. Starting with a base water level, various components can be added to provide a 'ballpark' water level. The basic components or 'blocks' to use are:

- [Tide Level](#) -varies along the WRC coastline
- [Sea Level Anomaly](#) – varies over time
- [Storm surge \(added to Tide level\) or Storm Tide](#) – varies along the WRC coastline
- [Projected Sea Level Rise](#) – constant along the WRC coastline, but there are different Sea Level Rise Scenarios

A combination of the above components will derive a specific water level scenario. Here are some water level scenario examples:

***Present day tide levels = Tide Level***

***Present day storm-tide water level = Tide Level + Storm Surge or  
= Storm Tide level***

***Future tide level with 1.0 m sea level rise = Tide Level + Projected Sea level Rise (1.0 m)***

***Future Storm tide water level with 1.0 m sea level rise = Storm Tide level + Projected Sea level Rise (1.0 m).***

If in doubt on what water level scenario to use for a particular application, it is suggested to consult WRC or a coastal expert.

## 3 Water level Components

### 3.1 Tide Levels

Tide levels vary around the Waikato Region's coasts. NIWA has provided tide levels for the Waikato region based on a national tide model, which have been adjusted with local tide gauge readings where available. The tide levels supplied for the Coastal Inundation Tool are:

- Mean High Water Springs (MHWS)
- Maximum Tide (MaxHT).

There are various definitions of MHWS, we have used a level that the highest 10% of all tides exceed, called MHWS10. The maximum tide level is the maximum tide level predicted over a 100 year period (not including projected sea level rise). Refer to Table 6.2 in [Section 6.2](#) for other tide markers.

All tide levels provided for the Coastal Inundation Tool are for open coast areas. Tide levels and ranges generally vary inland up rivers and estuaries/harbours. Therefore, the tide levels provided may not be applicable to some inland coastal water ways.

All tide levels and ground elevations are relative to Moturiki Vertical Datum 1953. Refer to [Section 6.1](#) for datum offsets.

## 3.2 Sea Level Anomaly

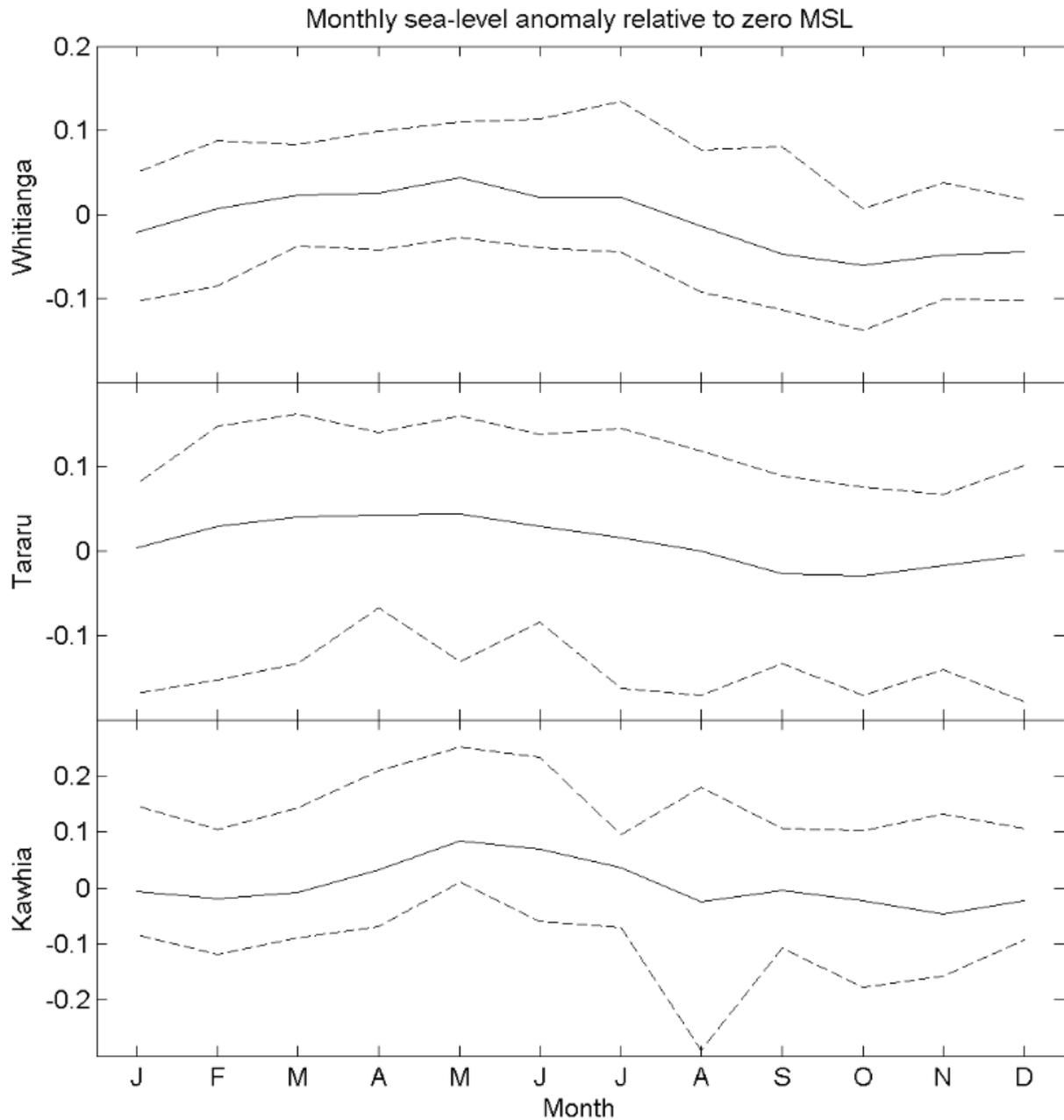
The sea-level 'anomaly' describes the variation of the non-tidal sea level on time scales ranging from month to month, through an annual sea-level cycle, up to decades due to climate variability. The variations in sea level along the coast are due primarily to changes in water temperature and wind patterns.

As water gets warmer it expands and sea levels rise. Persistent winds can also 'push' water towards the coast (increasing sea levels) or away from the coast (decreasing sea levels). The sea level variations occur at time periods over a year (seasonal changes), several years (El Niño and La Nina Climate Cycles) and over decades (Pacific Decadal Oscillation).

Therefore, while tide levels can be accurately predicted, the actual sea level at any given location is likely to differ from the predicted tide.

The sea-level anomaly is not provided for in the pre-defined water level scenarios in the coastal inundation tool. The range of sea level anomaly at all tide gauge sites is generally up to +/- 0.2 m (NIWA 2015). To account for the effects of sea-level anomaly on a water level scenario, a sensitivity assessment is suggested by increasing/decreasing the water level by a 0.2 m increment.

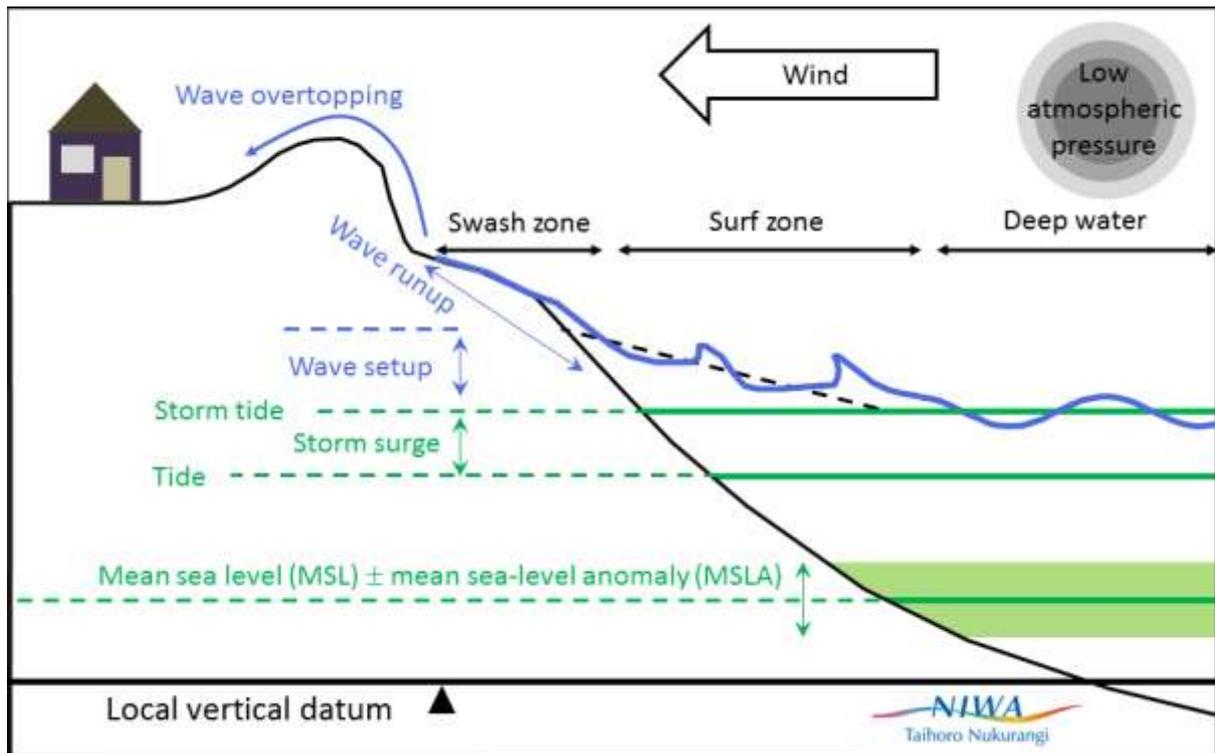
The Figure 2.1 below shows the monthly sea-level anomaly for three tide gauges at Whitianga Wharf, Tararu on the Firth of Thames and at Kawhia Wharf.



**Figure 2.1 Monthly Sea level Anomaly for three tides gauges. For each tide gauge the dashed top and bottom lines are the maximum and minimum values respectively. The solid middle line is the mean value. (Source: NIWA 2015)**

### 3.3 Storms

Storms affect the water level along coasts in a number of ways. Figure 2.2 below shows the components that cause coastal water levels to increase due to storm effects.



**Figure 2.2 Components causing increased water levels along the coast during a storm event.**

An explanation of the components is provided below:

- Storm Tide includes the following components:
  - Tides –astronomical tides (largest storm tides generally occur during a spring tide)
  - Storm Surge:
    - Inverted Barometer - a decrease in atmospheric pressure causes the water to rise (approximately 1 cm water level for every 1hPa drop in pressure)
    - Onshore winds ‘push’ water from deep water towards the coastline
- Monthly Mean Sea Level Variation = Sea Level Anomaly
- Wave ‘setup’ along the surf zone **(no information on wave set up provided for in the Coastal Inundation Tool)**
- Wave ‘run up’ along the shoreline **(no information on wave run up provided for in the Coastal Inundation Tool)**

The characteristics of storm surge, the tide height, and the resulting storm tide level varies along the Waikato coastline.

For the Coastal Inundation Tool, a lower and upper storm tide level for each location is provided in the pre-defined water level scenarios. The storm tide ranges for each location are representative only, but are derived from storm-tide analysis of actual data recorded by WRC tide gauges (NIWA 2015, refer to Section 6 for summaries).

For each tide gauge, storm surge levels were calculated from the difference between the tide value and storm tide value. The lower storm surge value is the difference between the MHWS10 tide value and the 39% AEP storm tide value (which represents a “biannual” event). The upper storm surge value is the difference between the maximum high tide value and the maximum storm tide value.

As the largest component of a storm tide is the astronomical tide (refer to [Section 6.3](#)), which varies around the Waikato region in a known way, the storm surge component derived from the nearest tide gauge was added to the tide at each location.

The lower storm tide value is the lower storm-surge value added to the MHWS value at each location. The upper storm tide value is the upper storm surge value added to the maximum high tide value at each location.

Table 3.1 below shows the lower and upper storm-surge components for each tide gauge, which were added to the tide values of the representative areas.

	Tararu	Whitianga (open coast)	Kawhia Harbour
<b>MHWS (m – MVD-53)</b>	1.79	1.11	1.74
<b>Maximum Tide (m– MVD-53)</b>	2.10	1.32	2.07
<b>39% AEP Storm Tide (m– MVD-53)</b>	2.20	1.41	2.28
<b>Maximum Storm tide (m– MVD-53)</b>	3.21	2.13	3.13
<b>Lower SS component (m)</b>	0.41	0.30	0.54
<b>Upper SS component (m)</b>	1.11	0.81	1.06
<b>Areas SS components used</b>	Firth of Thames	Coromandel East and West Coast	West Coast

**Table 3.1 showing lower and upper storm surge components and the areas they are applied to**

There is no reliable available information on long term water levels for the Coromandel West Coast (which we took to extend as far south as Te Kouma and Manaia Harbours). Therefore, the Whitianga tide gauge was used to provide an estimate on storm surge. South of Te Kouma and Mania Harbour is regarded as the Firth of Thames.

Further information on tides and storm tides based on analysis of tide gauges at Whitianga Wharf, Tararu and Kawhia Harbour can be found in [Section 6](#).

### 3.3.1 Waves

The predefined water level scenarios do not make any allowances for wave (wind and/or swell) effects. However, if a property is adjacent to either the open coast or within an estuary or harbour, a comprehensive coastal hazard assessment would need to include wave effects.

Wave effects are very site specific and require detailed assessments to quantify localised inundation. As a guide, if a property is within approximately 40 m of the landward extent of the water level scenario along the open coast, wave effects are possible. Along estuaries and enclosed harbours wave effects are generally much less and so may only affect areas within approximately 20 m from the landward extent of the water level scenario.

## 3.4 Projected Sea level Rise

Current guidance on Projected Sea Level Rise for New Zealand is provided by NIWA and Ministry for the Environment.

Current guidance suggests:

- 0.5 m projected sea level rise over the next 50 years
- 1.0 m projected sea level rise over the next 100 years

The sea level rise projections were simply added to present day tide/storm tide water levels. Further information on climate change and sea level rise can be found in the following links:

- <http://www.pce.parliament.nz/publications/all-publications/changing-climate-and-rising-seas-understanding-the-science/>
- <http://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-manual-local-government-ne-0>

## 4 Ground Elevations

All ground levels used to map the water level scenario have been derived by LiDAR aerial surveys and compiled into a Digital Elevation Model (DEM), relative to Moturiki Vertical Datum 1953 (MVD-53). The LiDAR information is generally accurate to around  $\pm 0.2$  m vertically; some areas are less or more accurate.

The LiDAR information is a 'snapshot' of the ground elevation at the time of the survey, so any changes to ground elevation since the LiDAR survey will not be captured. The DEM ground elevations are the most up to date currently available from WRC. The following table shows the year when LiDAR was captured.

Area	DEM grid cell size	Year of LiDAR capture
Coromandel Peninsula (West and East coast)	1 m	2012
Hauraki Plains	2 m	2007/2015
Kaiaua/Miranda	2 m	2007/2010
Port Waikato	1 m	2010
Raglan, Aotea and Kawhia Harbours	1 m	2007/2008
Other West Coast areas	1 m	2015

**Table 4.1 showing LiDAR survey year and horizontal resolution of DEM .**

The LiDAR survey does not identify all features that either allows water to flow through, such as culverts, or barriers to water flow such as flood walls or sheet piling.

Therefore, manual modification of the DEM for specific areas was undertaken to ensure the DEM generally represented the hydraulic regime, especially for areas with flood protection, such as the Hauraki Plains.

Therefore, the green disconnected inundation areas may or may not be 'real' and could actually be connected inundation areas. The disconnected inundation areas should still be regarded as areas that could be affected by coastal inundation.

Flood protection assets such as stop banks or flood walls are provided as a layer in the tool. Therefore, disconnected (green) areas behind identified stop banks/flood walls are assumed to be protected from coastal inundation up to the design crest level. Connected inundation (blue) areas behind identified stop banks/flood walls show that the flood protection has been overtopped.

## 5 Tsunami

Assessments on tsunami risk for several sites have been undertaken, with Tsunami Hazard classification extents for a maximum credible event provided in the Coastal Inundation Tool. Simply turn off or on the tsunami layer in the tool.

Locations where WRC has undertaken tsunami hazard assessments include:

- Tairua /Pauanui
- Whangamata/Whiritoa/Onemana
- Whangapoua/Matarangi/Kennedy Bay/Kuaotunu/Opito Bay

More information on tsunami can be found [here](#) on the WRC website

## 6 Tide Gauge Analysis for Whitianga Wharf, Tararu and Kawhia Wharf

All sea-level data used in the Coastal Inundation tool is based on analysis of tide gauges at Whitianga Wharf (Coromandel East Coast), Tararu (Firth of Thames) and Kawhia Wharf (West Coast). The tide-gauge analyses are strictly only accurate at the specific location of the tide gauge. However, the sea-level data provides the best available coastal water level information, and a tide model was used to transfer information from the tide gauges to other areas.

An analysis of water levels for the three tide gauges was undertaken by NIWA in 2015.

The following sections contain information used to calculate the water level used in the pre-defined water levels and provides information for the user to derive their own water level scenario. The full tide gauge analysis report is in DM#3460508.

## 6.1 Mean sea level offsets to Moturiki Vertical Datum 1953 (MVD-53)

Location	Mean sea-level offset relative to MVD-53 (m)		
	MSL Averaging Period 2008–2014 (Kawhia record duration)	MSL Averaging Period 1999-2014 (Whitianga record duration)	MSL Averaging Period 2005-2014 (Recent decade)
Auckland	0.16	0.14	0.15
Moturiki	0.12	0.11	0.11
Whitianga	0.14	0.11	0.13
Tararu	0.18	0.19	0.18
Kawhia	0.13		

Table 6.1 showing MSL offsets to MVD-53 datum at Auckland, Moturiki, Whitianga, Tararu and Kawhia. MSL epoch averages were calculated from annual means. The highlighted values have been adopted by WRC.

## 6.2 Tide markers

Tide Marker	Whitianga		Kawhia	Tararu
	Wharf	Open coast		
Minimum high water (m)	0.52	0.64	0.69	0.91
MHWPS (m)	1.00	1.13	1.85	1.88
MHWS-6 (m)	1.01	1.14	1.81	1.85
MHWS-10 (m)	0.98	1.11	1.74	1.79
Maximum water (m)	1.19	1.32	2.07	2.10

Table 6.2 . Analysis of high waters at Whitianga (wharf and open coast), Kawhia and Tararu relative to MVD-53. MHWS-6 = mean high water spring height exceeded by 6% of all tides, MHWS-10 = mean high water spring height exceeded by 10% of all tides, MHWPS = mean high water perigean spring (M2 +S2 + N2). The MHWS elevations presented here are given in meters relative to MVD-53.

Note: The Whitianga tide gauge is located at the wharf in the throat of the harbour entrance. Based on a comparison of water levels between the wharf and offshore, the location of the tide gauge in the throat of the entrance is recording water levels 0.13 m lower than outside the entrance. The reduced water levels are due to attenuation of the tidal wave as it moves into Whitianga Harbour.

## 6.3 Storm Tides

Tables 6.3 to 6.6 summarise extreme storm tide distributions for each tide gauge based on a Monte Carlo joint-probability analysis.

The probability is represented in both Annual Exceedance Probability (AEP) and Annual Return Interval (ARI).

### 6.3.1 Tararu tide gauge extreme storm-tide distribution

AEP (%)	ARI (years)	Median (mm)	Lower 95% C.I (mm)	Upper 95% C.I (mm)
39	2	2.196	2.193	2.198
18	5	2.275	2.269	2.28
10	10	2.348	2.34	2.359
5	20	2.431	2.417	2.446
2	50	2.538	2.519	2.561
1	100	2.62	2.589	2.658
0.5	200	2.706	2.662	2.759

**Table 6.3** Extreme storm-tide distribution at Tararu. Elevations for the median and 95% confidence bounds are based on a Monte Carlo joint-probability analysis of sea level data at Tararu. The storm-tide elevations presented here are given relative to MVD-53.

### 6.3.2 Whitianga Wharf tide gauge and Open Coast extreme storm-tide distribution

AEP (%)	ARI (years)	Median (mm)	Lower 95% C.I (mm)	Upper 95% C.I (mm)
39	2	1.282	1.28	1.285
18	5	1.345	1.34	1.35
10	10	1.396	1.389	1.403
5	20	1.452	1.442	1.462
2	50	1.532	1.514	1.547
1	100	1.601	1.575	1.636
0.5	200	1.685	1.639	1.737

**Table 6.4** Extreme storm-tide distribution at Whitianga WHARF. Elevations for the median and 95% confidence bounds are based on a Monte Carlo joint-probability analysis of sea level data at Whitianga Wharf. The storm-tide elevations presented here are given relative to MVD-53.

AEP (%)	ARI (years)	Median (m)	Lower 95% C.I (m)	Upper 95% C.I (m)
39	2	1.442	1.44	1.445
18	5	1.505	1.5	1.51
10	10	1.556	1.549	1.563
5	20	1.612	1.602	1.622
2	50	1.692	1.674	1.707
1	100	1.761	1.735	1.796
0.5	200	1.845	1.799	1.897

**Table 6.5 Extreme storm-tide distribution at Whitianga OPEN COAST. Elevations for the median and 95% confidence bounds are based on a Monte Carlo joint-probability analysis of sea level data at Whitianga Wharf. An offset of 0.16 m is added to account for tide attenuation at the tide gauge. The storm-tide elevations presented here are given relative to MVD-53.**

As mentioned in Section 6.2, the Whitianga Tide gauge is located inside the harbour, and the tide attenuates as it passes through the harbour entrance; the tide elevation is about 0.13 m lower than outside the harbour. Similarly, storm-tide levels are also likely to be reduced compared to the open coast areas with Mercury Bay.

To account for the tide attenuation at Whitianga WHARF, extreme storm-tide distribution values for the Whitianga OPEN COAST have simply had 0.13 m added. Considering astronomical tides are the largest component of storm tides, the additional 0.13 m is a reasonable approximation to account for the attenuation. However, the exact amount of storm tide attenuation through the harbour entrance is unknown.

### 6.3.3 Kawhia Wharf tide gauge extreme storm-tide distribution

AEP (%)	ARI (years)	Median (m)	Lower 95% C.I (m)	Upper 95% C.I (m)
39	2	2.271	2.267	2.276
18	5	2.374	2.366	2.382
10	10	2.458	2.447	2.47
5	20	2.548	2.533	2.565
2	50	2.665	2.643	2.692
1	100	2.757	2.719	2.803
0.5	200	2.864	2.802	2.957

**Table 6.6 Extreme storm-tide distribution at Kawhia Wharf. Elevations for the median and 95% confidence bounds are based on a Monte Carlo joint-probability analysis of sea level data at Kawhia Wharf. The storm-tide elevations presented here are given relative to MVD-53.**

The Kawhia wharf is situated inside Kawhia Harbour, so the tide gauge measurements do not represent the open coast tide and storm tide regime, nor the effect of the energetic west-coast wave climate. Storm-tide levels measured at Kawhia are likely to be amplified relative to the open coast, due to tidal amplification and wind set up effects within the harbour.

### 6.3.4 Storm tide composition

Figures 6.1, 6.2 and 6.3 show the composition of the largest 20 storm tides for each tide gauge.

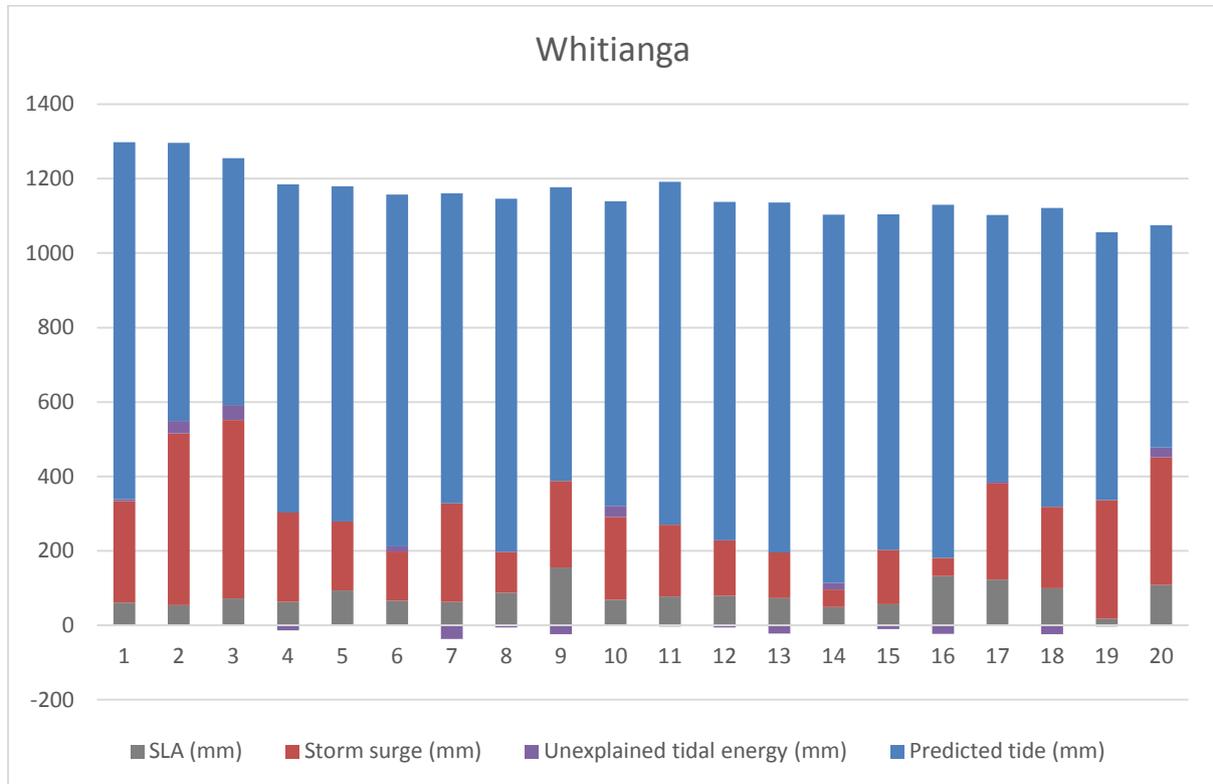
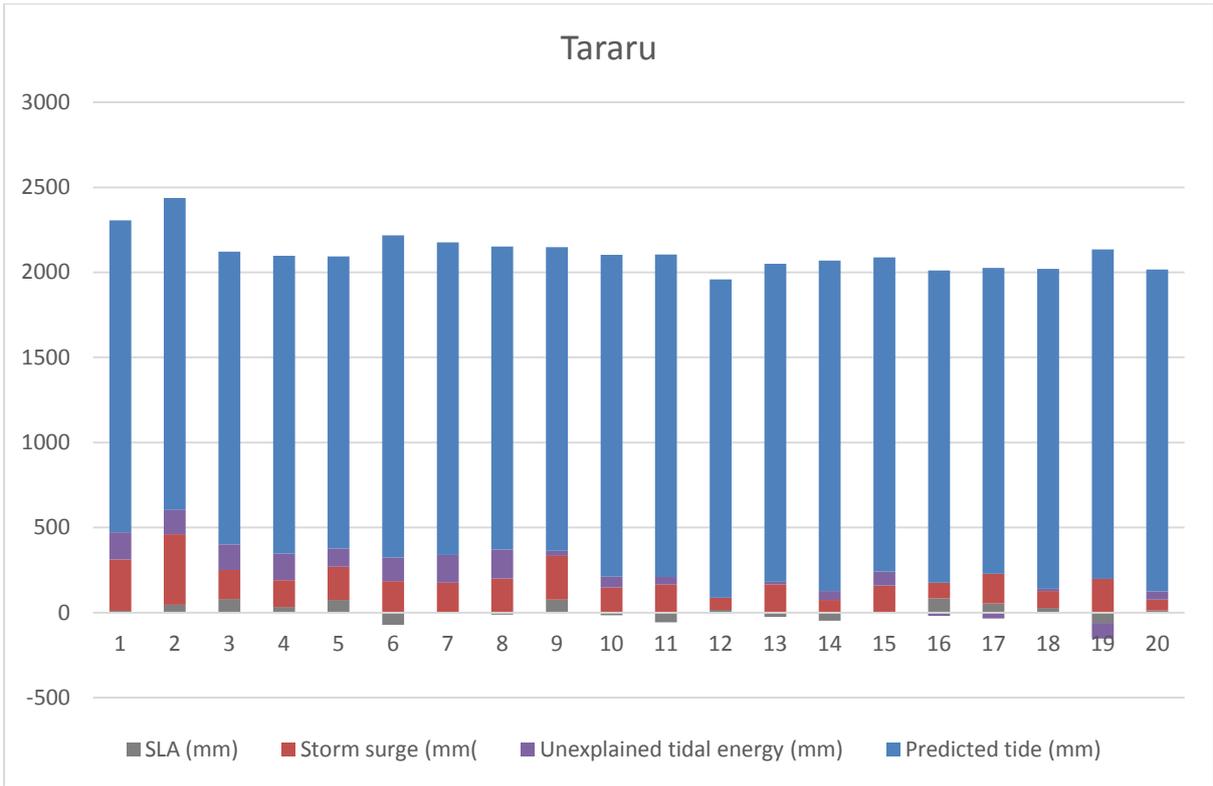
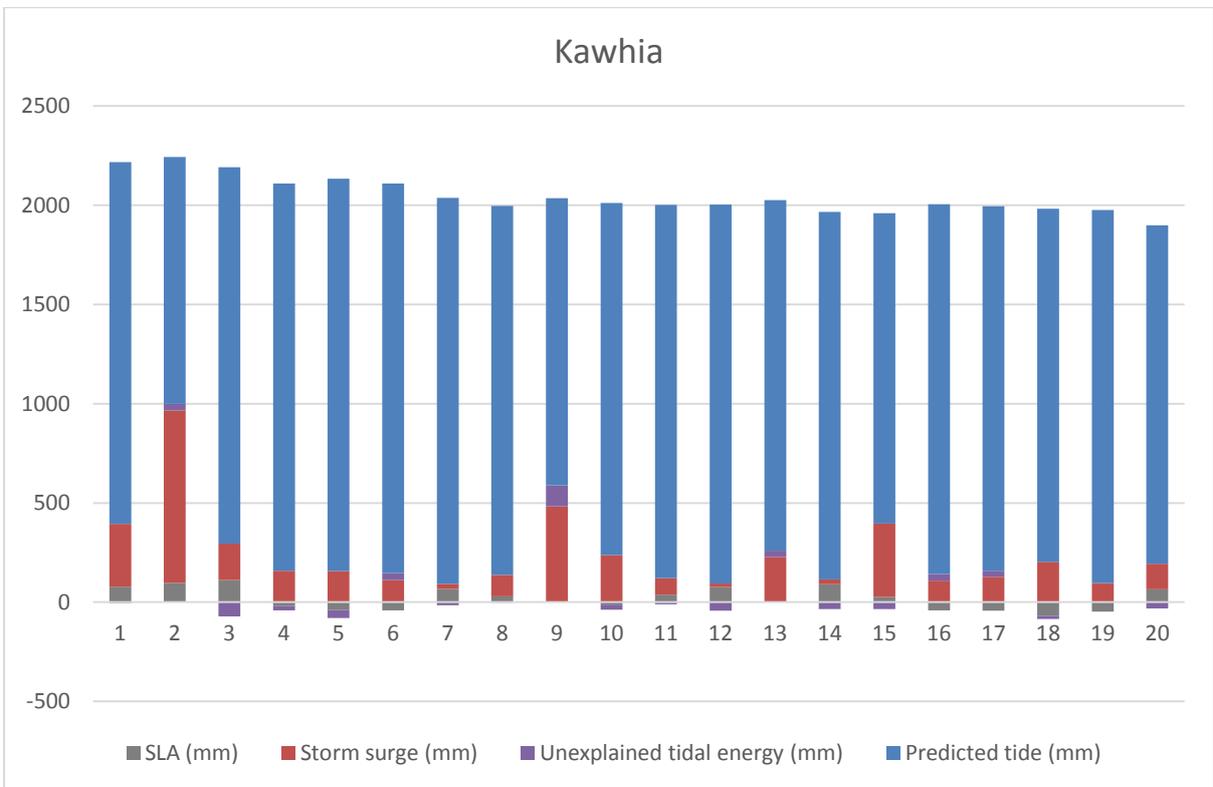


Figure 6.1 Storm tide composition for Whitianga Tide Gauge



**Figure 6.2 Storm tide composition for Tararu Tide Gauge**



**Figure 6.1 Storm tide composition for Kawhia Tide Gauge**

### 6.3.5 Maximum Storm Tide Estimates

The Table 6.7 provides estimates of a ‘worst case’ storm tide scenario where maximum water level components coincide. The probability of such an event occurring is unknown and extremely low, but possible.

Location	Tide	Storm surge	SLA	Sum
Whitianga Wharf	1.19	0.63	0.18	2.00
Whitianga Open Coast	1.32	0.63	0.18	2.13
Tararu	2.10	0.97	0.14	3.21
Kawhia	2.07	0.90	0.16	3.13

Table 6.7 Maximum Storm tide estimates for the 3 tide gauges.

## 7 Further information

The following links provide further information:

Coastal storm Inundation - NIWA

<https://www.niwa.co.nz/natural-hazards/hazards/coastal-storm-inundation>

Coastal Hazards and Climate Change Guidance – Ministry for the Environment

<http://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-manual-local-government-ne-0>

NIWA (Stephens et al.) 2015: Analysis of Whitianga, Tararu and Kawhia sea-level records to 2014. NIWA Client Report to Waikato Regional Council HAM2015-046, 98p.

## 8 Frequently Asked Questions

### How accurate is this inundation mapping information?

The Coastal Inundation tool is intended to provide a ‘ballpark estimate’ on the inundation extent for a particular water level scenario. The mapping tool does not include all the components (i.e. does not map wave effects) that contribute to coastal inundation, and does not substitute for a coastal hazard assessment by a qualified specialist. However, the tool is designed to alert people of a property’s susceptibility to coastal inundation.

There are two things that affect the accuracy of mapping coastal inundation extent.

The first is the accuracy of the water-level scenario. The water-level scenarios are based on work undertaken by NIWA (2015) that used the best-available water-level information and models, and are accurate to within a few centimetres.

Secondly is the accuracy of the ground elevations used to map the water level scenarios. All ground levels used to map the water-level scenarios have been derived from LiDAR aerial surveys. The LiDAR information is generally accurate to around  $\pm 0.2$  m vertically relative to Moturiki vertical datum.

The LiDAR information is a ‘snapshot’ of the ground elevation at the time of the survey, so any changes to ground elevation since the LiDAR survey will not be captured (refer to Table 4.1 for LiDAR capture dates).

The effect of these uncertainties on coastal inundation can be explored, by adjusting the water-level slider within the coastal-inundation tool.

**The mapping of the MHWS10 level shows inundation of areas that I know do not get inundated during even a king tide, is the information wrong?**

All MHWS10 values are based on a tide model (NIWA) along the open coast. As the tides enter an enclosed water body such as an estuary or enclosed harbour, the tide range and high-tide levels change. In areas where the MHWS value is overestimating the tide, it is suggested that the water level that best matches the expected tide inundation on the map is used as the starting water level elevation.

**Will the coastal inundation tool devalue my property?**

The coastal inundation tool does not provide a coastal hazard assessment. Therefore, the tool itself is unlikely to and unintended to devalue a property. The tool can alert people that a property is more or less susceptible to coastal inundation and where further investigation could be undertaken as part of due diligence for a property purchase.

As the information used in the coastal inundation tool has been available for some time, a proper due diligence process would likely include similar information whether this tool existed or not.

**Will showing this coastal inundation extent cause issues for my insurance?**

Insurance companies should not be using this tool to ascertain coastal-inundation risk for any specific property, although they may use the tool to identify areas that should require further assessment.

**I own a property that is inundated using a water level scenario, what should I do now?**

In most cases, nothing. However, if you are looking to develop or sell the property then you or another party may need to provide/seek further information as to the risk of coastal inundation. Any further information would likely to have been required whether the coastline inundation tool was used or not.

However, if the property is inundated with a present day scenario, then having an evacuation plan, should a storm event occur, is advised.

**Can I use the coastal inundation tool as part of information for a consent application?**

No. A site-specific assessment on coastal hazards is likely to be required. However, the tool can be used as a 'first cut' assessment to ascertain if a site-specific coastal hazard assessment is required, prior to lodging consent.