Impacts of Climate Change on Urban Infrastructure & the Built Environment

A Toolbox

Tool 2.2.4: Inundation mapping of future high tides, sea level rise and storm surge

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1. Introduction

1.1 Background

Maps are extremely useful for visualising detailed spatial data. Overlaying spatial references such as coastlines, roads, rivers, and place names and including topography and/or semi-transparent hill shading adds to the identification of information and enhances the interpretability of the map. Inclusion of data layers (vector or raster) into a Geographic Information System (GIS) allows analysts to produce maps for specific purposes with multiple levels of information.

1.2 Purpose of Tool

The purpose of this tool is to demonstrate a simple GIS-based method for the spatial mapping of coastal inundation.

2. Methods

2.1 Derivation of present-day and future sea levels

The previous two tools in this Toolbox demonstrate methods that can be used to derive present-day and future levels of the sea using tidal harmonic analysis [Tool 2.2.2] and extreme value analysis [Tool 2.2.3] of sea level records to produce sea level estimates such as the mean high water springs (MHWS10) tide and the 100-year ARI storm tide. This tool shows how data from these statistical analyses can be used in combination with high resolution digital terrain data to produce useful maps of potential land inundation from the sea.

2.2 GIS based spatial mapping of sea levels

To generate detailed maps showing potential coastal inundation under the current climate and possible future climate scenarios, it is critical that high resolution elevation data is used. The extent of landward inundation can be derived by using such elevation data in combination with measured and modelled sea levels (see [Tool 2.2.2] and [Tool 2.2.3]) and a GIS software package.

The potential inundation is calculated by subtracting the sea level value from the elevation data using GIS software. All areas that are assigned a negative value represent land that potentially could be inundated and those areas with a positive value are unlikely to be inundated. The GIS software can also be used to derive a contour line showing the probable inundation limit.

An essential consideration is to ensure that the geographic datum used to set the sea level and extreme event (storm tide) information is the same as the datum used for the elevation data.

3. Case study example

3.1 Impact of sea level rise on storm surge inundation for Christchurch Estuary

The impact of sea level rise on storm surge inundation for the Christchurch Estuary case study investigated the following six sea level rise and extreme sea level event scenarios:

1. Mean high water springs 10 (current climate, 2010)
2. Mean high water springs 10 (including sea level rise to 2040)
3. Mean high water springs 10 (including sea level rise to 2090)
4. 100 year ARI storm tide (current climate, 2010)
5. 100 year ARI storm tide (including sea level rise to 2040)
6. 100-year ARI storm tide (including sea level rise to 2090)

The sea levels for the “present day” scenarios 1 and 4 were derived from Figure 2.1 in [Tool 2.2.2] and Table 1.2 in [Tool 2.2.3], respectively. Sea levels for the “future” scenarios were derived by adding 0.4 m (being an estimate of the sea level rise to 2040) and 0.8 m (being an estimate of the sea level rise to 2090) to these values (see Table 3.1, below).

Table 3.1: Scenarios and corresponding sea level in meters above datum for studying the impact of sea level rise on storm surge inundation for the Christchurch Estuary

Scenario	Sea level above datum[1]
Mean high water 2010	1.15m
Mean high water 2040	1.55m
Mean high water 2090	1.95m
100 year ARI storm tide	1.88m
100 year ARI storm tide 2040	2.28m
100-year ARI storm tide 2090	2.68m

[1] Lyttleton Vertical Datum 1937

For this case study, high resolution elevation data were obtained from the Christchurch City Council. The elevation data were collected using LiDAR technology (see 4.1 below) which gives closely spaced point elevations with decimetre vertical acccuracy. The data were supplied as ASCII text files providing easting, northing, elevation and intensity. The files were imported into an ArcGIS Personal Geodatabase as table data and then converted into point feature datasets using the easting and northing coordinates originally provided in the ASCII text files. The point feature datasets were then interpolated and converted to 1m resolution ArcGIS grid format datasets using the *Topo to Raster* tool located in the ArcGIS Toolbox. The *Topo to Raster* tool is an ArcGIS specific tool for interpolating hydrologically correct surfaces from point, line and polygon datasets. The resulting ArcGIS grid datasets were then combined using the *Mosaic* tool to give a 1m resolution ArcGIS grid dataset.

There are several alternative methodologies for performing this conversion from high accuracy irregularly spaced point elevations to a 1m resolution raster dataset and many other software packages to choose from.

Once the 1m elevation grid was completed, a map showing the potential land inundation from the sea for each scenario was generated by applying the sea level above datum categories in metres (see Table 3.1) to the elevation grid symbology properties in ArcGIS (see Figure 3.1). Individual grids showing the potential land inundation from the sea for each scenario were derived by subtracting the sea level above datum value (see Table 3.1) from the elevation data using the ArcGIS *raster* calculator. All areas that were assigned a negative value were considered to represent land that could be inundated and those areas with a positive value represent land that is unlikely to be inundated. These individual inundation grids were then used to calculate the total area of inundation for each scenario.

To complete a risk analysis and damage assessment, inundation depth information is required. The inundation depth ArcGIS grid datasets were generated by subtracting the sea level above datum value (see Table 3.1) from the elevation data, reclassifying all grid cell values greater than 0 to Null and multiplying the resulting grid by -1 using the ArcGIS *raster* calculator. These data were then provided to a risk assessment analyst to estimate the total building and infrastructure damage as well as the total repair costs [see Tool 3.3].

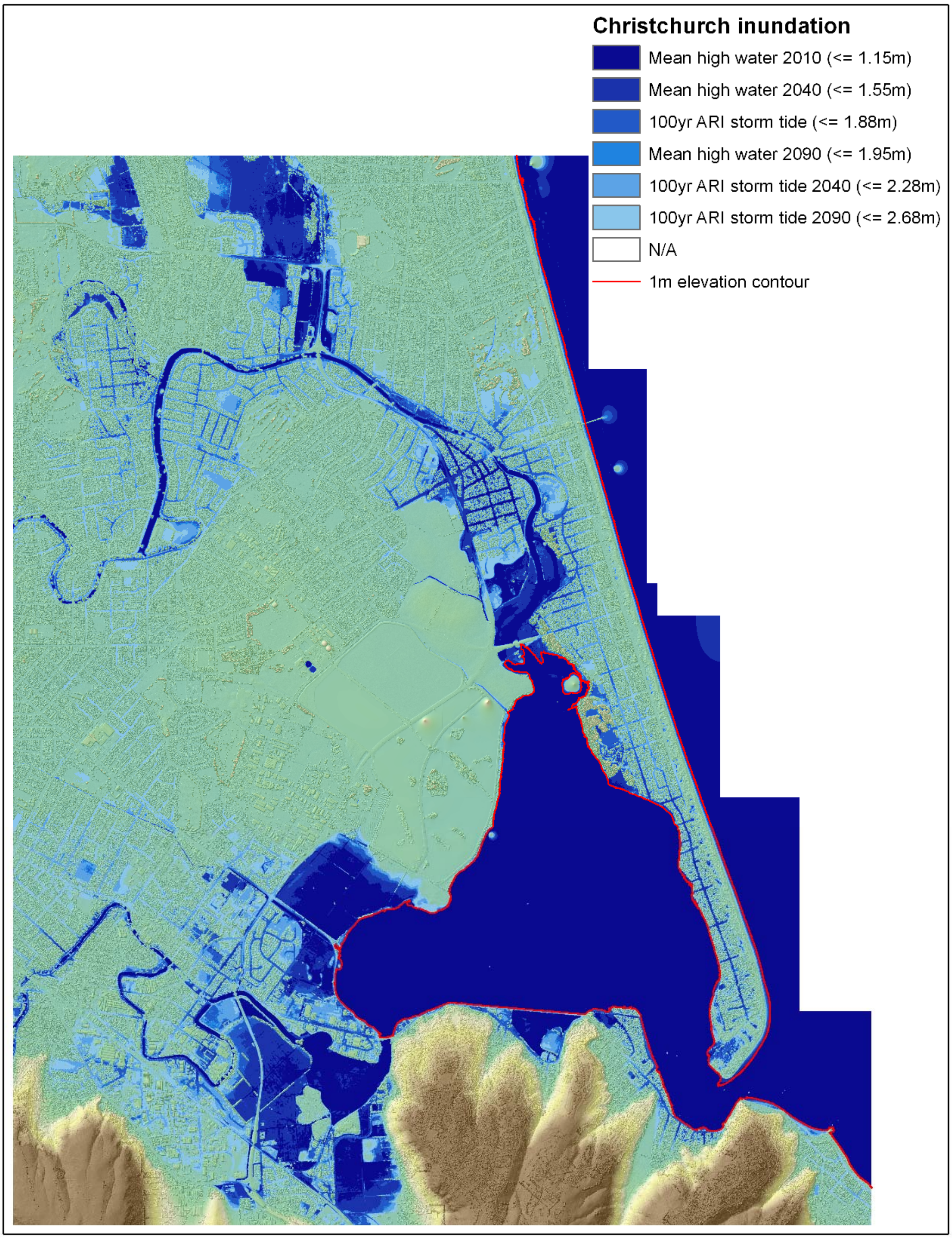

Figure 3.1: Sea water inundation around the Christchurch Estuary based on the current (2010) and future (2040 and 2090) mean high water springs tide exceeded 10% of the time, and the 100-year ARI storm tide. Inundation is based solely on (pre earthquake) land elevation above mean sea level and does not take into account hidden flow paths.

4. Data Needs

4.1 Lidar data

Airborne LiDAR (Light Detection and Ranging) is used for high resolution terrain modelling at medium to large scales. Several Australasian aerial mapping companies provide LiDAR services. An aircraft-mounted laser unit scans the target area and the travel time of the reflected beam is used to determine the precise location of ground "hits". Typical ground spacing of the hits is less than 1 metre. The change in the intensity of the reflected beam gives additional information on ground surface properties. GPS satellites are used to calculate LiDAR x, y and z co-ordinates and geoidal corrections are required to correct the elliptical orbit of the satellite to the match the earth's geometry and gravitational field. Where LiDAR data are to be used for inundation studies it is important that the provider of the data uses orthometric ground control points to correct for any local geoidal differences as water levels are determined by gravity.

4.2 Sea level and storm tide information

Deriving present-day and future levels of the sea using tidal harmonic analysis of sea level records is discussed in [Tool 2.2.2].

Deriving sea level as a result of extreme events such as the 100-year ARI storm tide is discussed in [Tool 2.2.3].

5. Assumptions and Limitations

The technique used with this tool simply assumes that a sea level at the coast will extend inland to the point where this level intersects the hydraulically connected ground surface. The tool does not necessarily account for hidden blockages or flow paths, nor for hydrodynamic effects such as wave run-up, flow resistance effects and conservation of volume. It is therefore recommended as an "assessment of the problem" tool rather than as a precise planning tool. It is not recommended that this technique be used for flood-inundation or tsunami studies.

The LiDAR data used with this tool were collected before the February 2011 Christchurch earthquake. As a result of the quake, northern parts of the study area appear to have sunk and southern parts may have been uplifted. The map in this tool should therefore be seen only as an example and not used for planning purposes.

6. References

ArcGIS 9.2 Desktop Help. http://webhelp.esri.com/