

Methodology to Create Overland Flow Paths using Hydrological Modelling Tools in QGIS

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Last Revised: 02/11/2021

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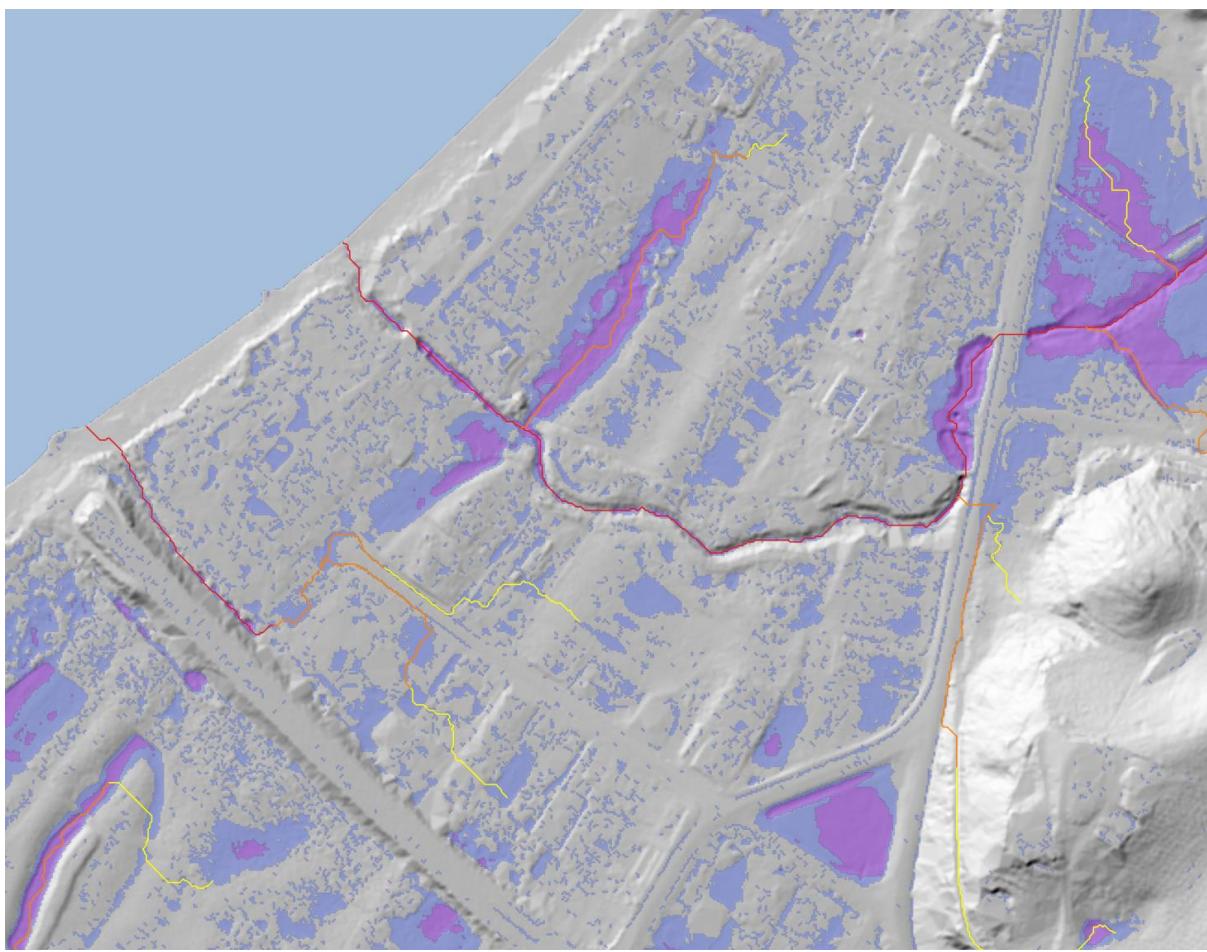
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1 Introduction

Overland flow paths are a common way of representing the predicted path of stormwater as it flows over the topography. Depression areas map the potential extent of stormwater ponding if the stormwater network is full or failure occurs within the network.

Overland flow paths require a Digital Elevation Model (DEM) that is representative of the ground surface. The DEM is obtained from LiDAR, a remote sensing technology that measures distance by illuminating a target with a laser and analysing the reflected light. LiDAR is typically recorded from an aircraft where the laser picks up multiple levels (deemed returns); the last return is usually taken to represent the ground surface. This return does not include building elevations, and above ground features are removed so as to not influence the topographical path of overland flow or ponding in depression areas.

This document describes the methodology used in QGIS to import a Digital Elevation Model (DEM), hydrologically correct it to ensure flow and then extract new vector lines from it that represent the overland flow paths across the DEM. In addition the methodology used to extract the depression areas from the DEM is detailed.



2 Project Setup

2.1 Processing Requirements

Data:

- Gridded DEM derived from 2020/2021 LiDAR Survey.
This dataset is supplied in GeoTIFF format.
An Airborne Laser Scanner survey was conducted over the Whanganui urban area and Whangaehu River area of interest totalling approximately 443 km². One of the deliverables from this survey is a Gridded ground surface (1 m separation grid) with hydro flattening and breaklines for water bodies, streams and rivers. The LiDAR survey was captured on the following dates: 8 September 2020, 2 December 2020, 4 January 2021, 27 January 2021, 3 February 2021



- All spatial data for this project provided in terms of New Zealand Transverse Mercator 2000 (NZTM2000) horizontal and New Zealand Vertical Datum (NZVD2016).

Software:

- QGIS Desktop Version 3.20.3 (64bit)
<https://qgis.org>
- WhiteboxTools Version 1.5.0
<https://www.whiteboxgeo.com/geospatial-software/>

Platform:

- Microsoft Windows 10 Enterprise
- HP Z2 Tower G4 Workstation
- 128Gb RAM
- Intel Xeon E-2136 CPU @ 3.30GHz (6 Cores, 12 Logical Processors)

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- NVidia Quadro P2000 GPU (5GB Dedicated RAM)

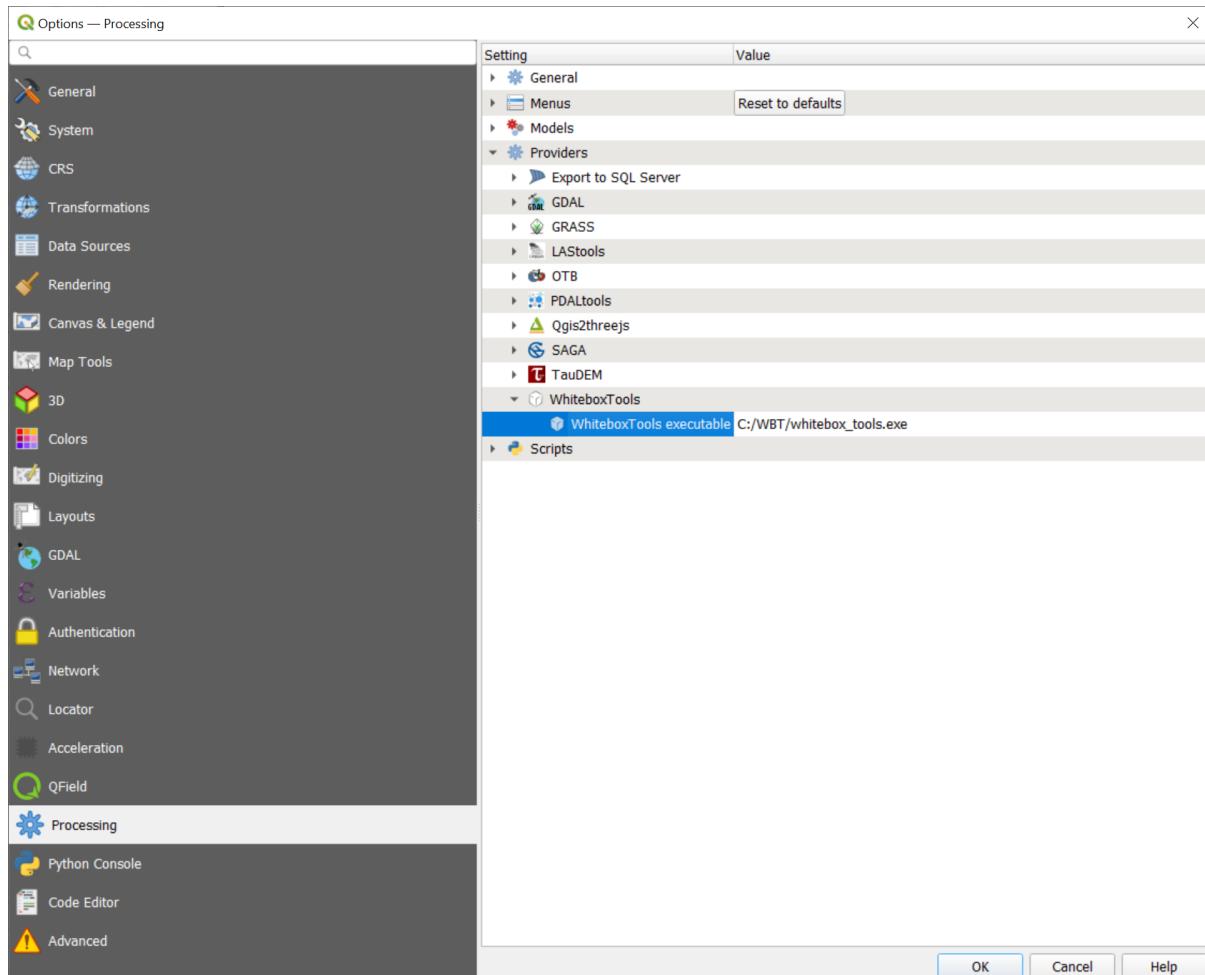
2.2 QGIS Setup

1. Download and Install Whitebox tools

<https://www.whiteboxgeo.com/download-whiteboxtools>

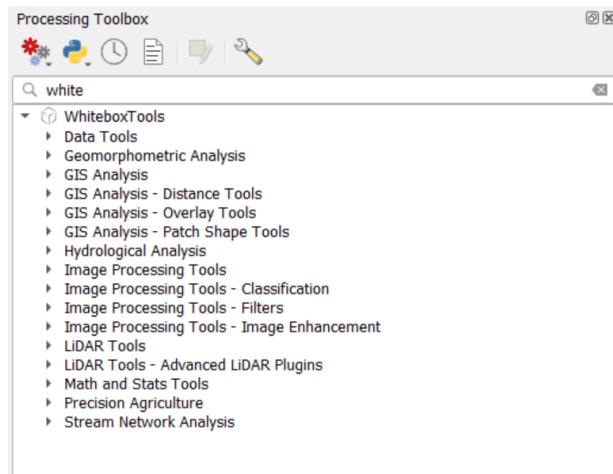
2. Setup Whitebox Processing Provider in QGIS

https://www.whiteboxgeo.com/manual/wbt_book/qgis_plugin.html



Additional Tools become available in the QGIS Processing Toolbox:

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3 Processing Steps

3.1 Overland Flow Paths

1. Identify Sinks
2. Breach Single Cell Pits
3. Breach Depressions (Method 1 – Least Cost)
4. Fill Remaining Depressions
5. Calculate Flow Accumulation and Flow Pointer
6. Extract Overland Flow Paths and Vectorise
 - a. Contributing Area $\geq 5\text{ha}$
 - b. Contributing Area $\geq 2\text{ha} < 5\text{ha}$
 - c. Contributing Area $\geq 1\text{ha} < 2\text{ha}$
7. Clip Vector results using Hydro Mask

3.2 Depression Areas

1. Calculate Depth in Sinks for original DEM
2. Calculate areas greater than or equal to 300mm and polygonise
3. Calculate areas less than 300mm and polygonise
4. Clip Vector results using Hydro Mask

4 Processing Algorithms Used

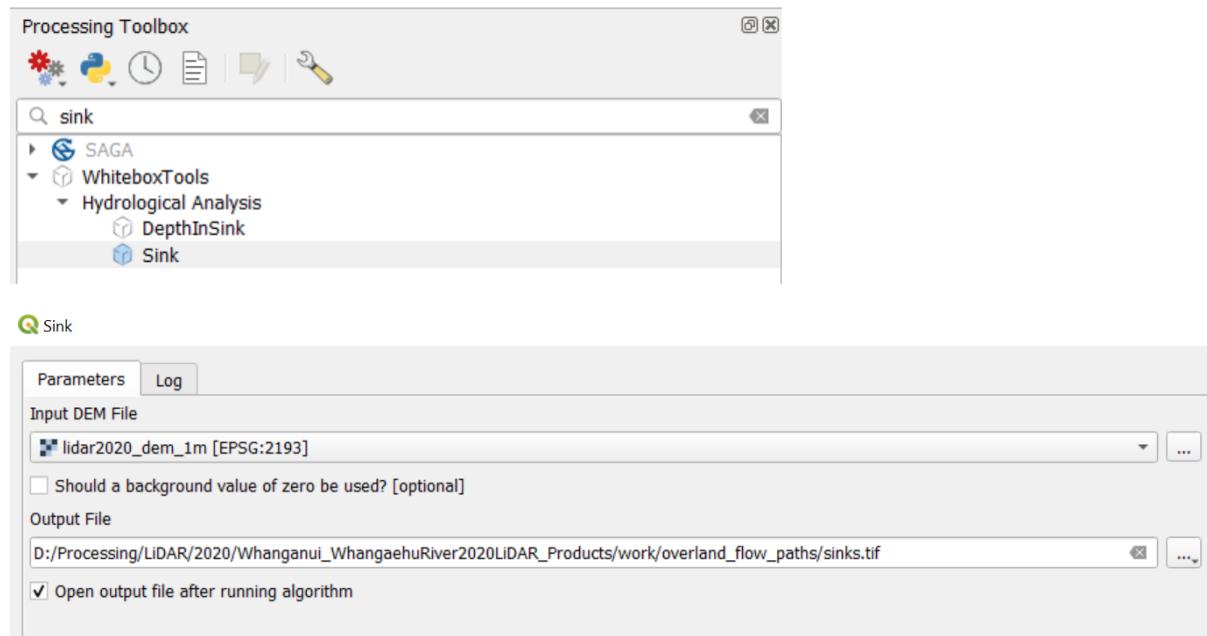
4.1 Investigate DEM for Sinks

Determine if the DEM is hydrologically enforced; does the DEM have sinks (i.e. topographic depressions).

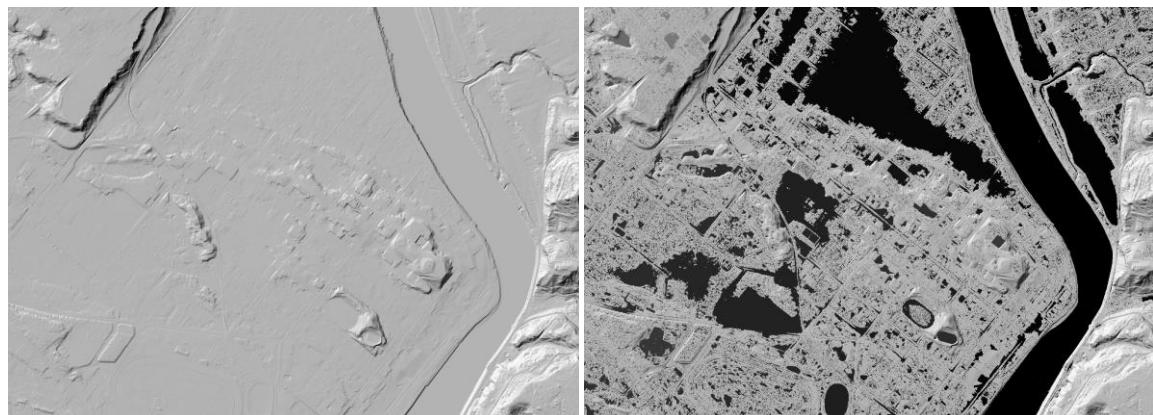
4.1.1 Identify Sinks

In QGIS, run the Whitebox **Sink** tool on the DEM, to identify each sink (i.e. topographic depression).

A sink, or depression, is a bowl-like landscape feature, which is characterized by interior drainage. Each identified sink in the input DEM is assigned a unique, non-zero, positive value in the output raster.



Execution completed in 91.91 seconds (1 minute 32 seconds)



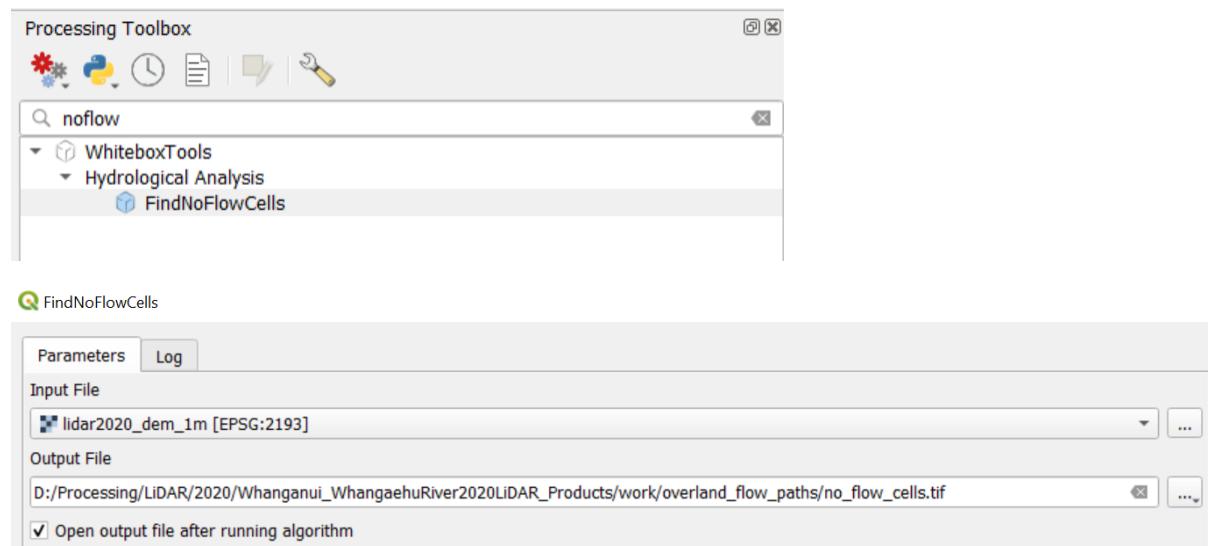
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WhiteboxTools command:

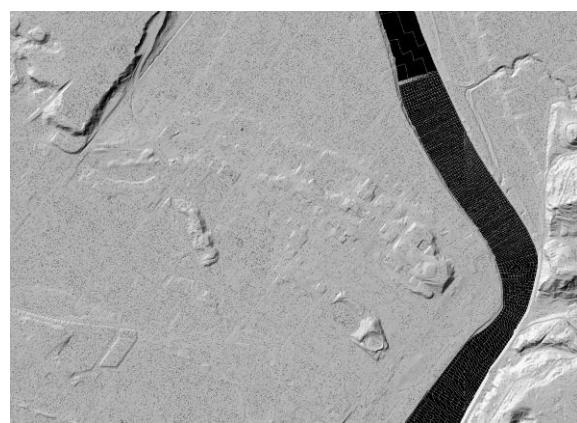
```
"C:/WBT/whitebox_tools.exe" -v --run=Sink --
dem="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\lidar2020_dem_1m.tif" --
zero_background="False" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\sinks.tif"
```

4.1.2 Find No Flow Cells

Finds grid cells with no downslope neighbours



Execution completed in 33.73 seconds



WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=FindNoFlowCells --
dem="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\lidar2020_dem_1m.tif" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\no_flow_cells.tif"
```

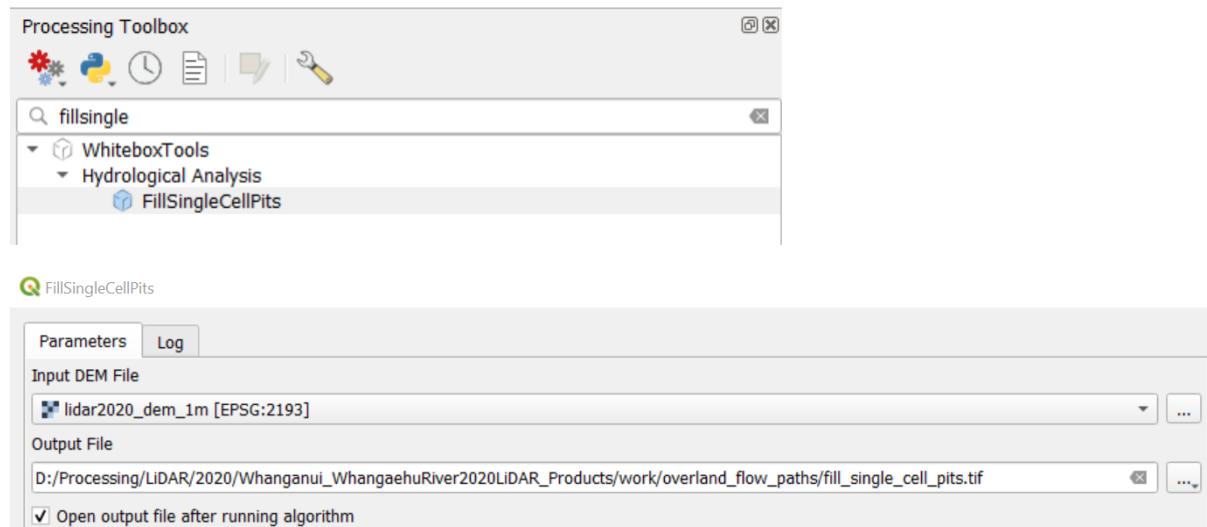
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4.2 Hydrological Enforcement using Fill Depressions methodology

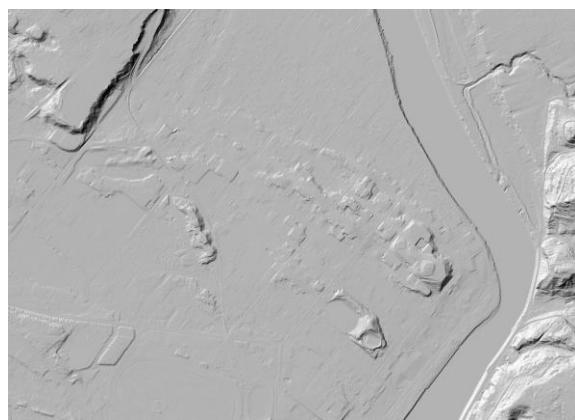
The DEM is not hydrologically enforced as there are many sinks within the DEM. We now have a decision to make on how to create the hydrologically enforced model. There is the typical **fill** approach which will increase the sink values until they are just a little bit lower than their neighbouring cells, or we can take the **breach** approach which will maintain the sink heights, but will build channels to cut through the DEM and make sure that all the depressions are connected so that every cell can flow into another cell. There is also a secondary type of breaching called **breach least cost** which as it says, will breach the DEM with more control parameters based on the cost to breach the depressions.

4.2.1 Fill Single Cell Pits

Raises pit cells to the elevation of their lowest neighbour



Execution completed in 84.56 seconds (1 minute 25 seconds)



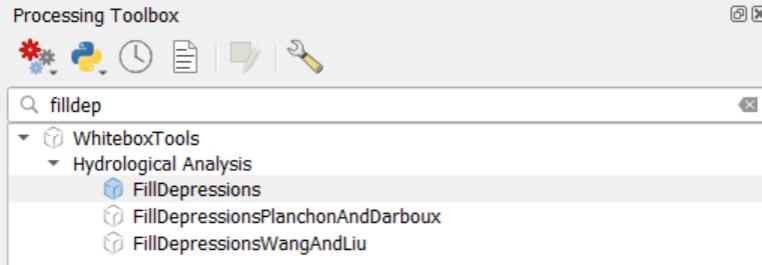
WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=FillSingleCellPits --
dem="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\lidar2020_dem_1m.tif" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\fill_single_cell_pits.tif"
```

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4.2.2 Fill Depressions

Fills all of the depressions in a DEM.



The screenshot shows the QGIS Processing Toolbox interface. A search bar at the top contains the text "filldep". Below the search bar, the "WhiteboxTools" group is expanded, and the "Hydrological Analysis" group is also expanded. Inside "Hydrological Analysis", the "FillDepressions" algorithm is highlighted with a gray selection bar. Other algorithms in this group include "FillDepressionsPlanchonAndDarboux" and "FillDepressionsWangAndLiu".



The dialog box for the "FillDepressions" algorithm has two tabs: "Parameters" (selected) and "Log".
Input DEM File: Set to "fill_single_cell_pits [EPSG:2193]".
Fix flat areas? [optional]: An unchecked checkbox.
Flat increment value (z units) [optional]: Set to "0.000100".
Maximum depth (z units) [optional]: Set to "Not set".
Output File: Set to "D:/Processing/LiDAR/2020/Whanganui_WhangaehuRiver2020LiDAR_Products/work/overland_flow_paths/fill_depressions.tif".
Open output file after running algorithm: A checked checkbox.

Note that we use **Fix flat areas** and we apply a very small **Flat increment value**. This will allow us to define a flow path across flat areas that more accurately follows the actual terrain (rather than a straight line directly across the flat area).

Execution completed in 119.76 seconds (1 minute 60 seconds)

WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=FillDepressions --
dem="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\
\fill_single_cell_pits.tif" --fix_flats="True" --flat_increment=0.0001 --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat-
hs\fill_depressions.tif"
```

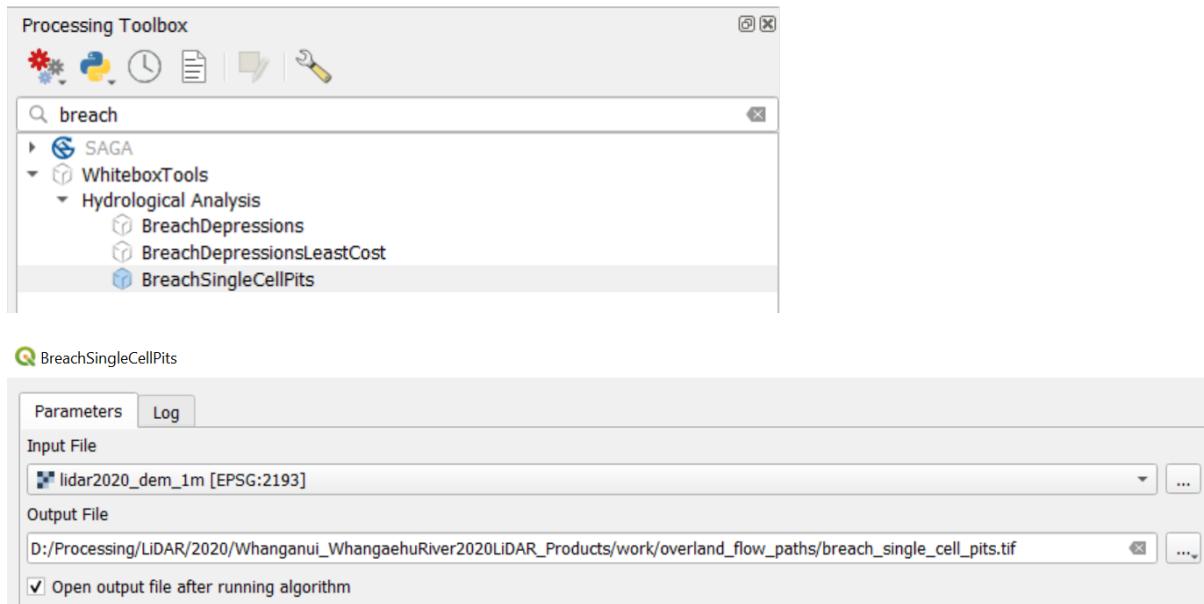
4.3 Hydrological Enforcement using Breaching methodology

4.3.1 Breach Single Cell Pits

First apply a breach action on individual pits. This acts to get rid of single cell depressions first before we breach depressions that are larger than one pixel in size.

Removes single-cell pits from an input DEM by breaching

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Execution completed in 90.24 seconds (1 minute 30 seconds)

WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=BreachSingleCellPits --
dem="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\lidar2020_dem_1m.tif" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat
hs\breach_single_cell_pits.tif"
```

4.3.2 Breach Depressions

4.3.2.1 Method 1 – Breach Depressions Least Cost

Breaches the depressions in a DEM using a least-cost pathway method.

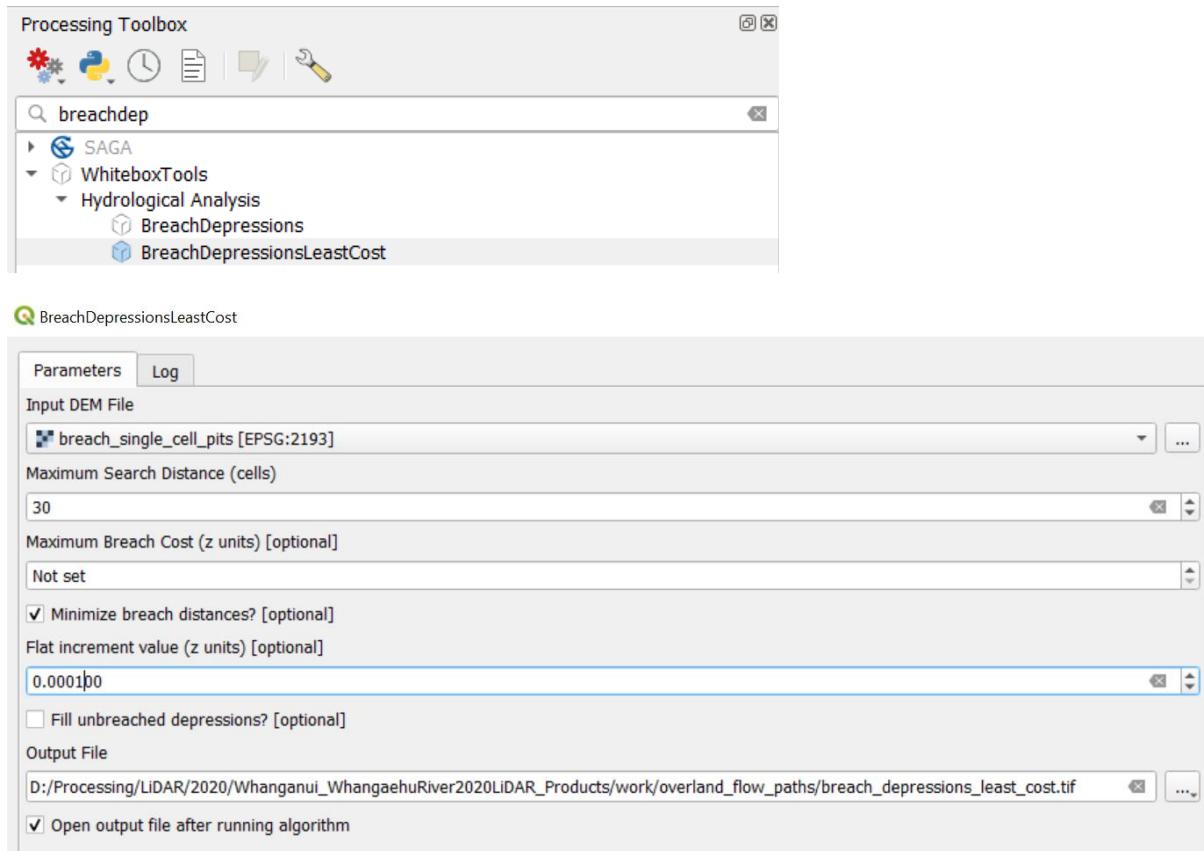
Using the **breach depressions least cost** algorithm we are able to effectively cut through road obstructions which would normally utilise culverts to channel water underneath them.

This tool is actually performing a least-cost based region growing operation centred on each of the pit cells contained in the input DEM. This operation grows outwardly from the pit until a target (lower) cell is identified, at which point a breach channel is carved, and which follows the least-cost path connecting the pit and target cell. This search distance parameter will effectively stop the region-growing operation when the current shortest potential least-cost path is longer than this radius parameter. This is probably the most important parameter for this tool, because breaching, when not constrained with a maximum breach length, can result in very long breach channels that dig through significant ridges.

Multiple Runs were carried out to determine which combinations of breaching parameters to use that best suited the Whanganui DC topology.

Most Suitable Run

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The screenshot shows the QGIS Processing Toolbox interface. In the search bar at the top, 'breachdep' is typed. Below the search bar, the 'WhiteboxTools' provider is expanded, showing the 'Hydrological Analysis' group. Inside this group, 'BreachDepressions' and 'BreachDepressionsLeastCost' are listed, with 'BreachDepressionsLeastCost' being the currently selected tool.

BreachDepressionsLeastCost

Parameters Log

Input DEM File: breach_single_cell_pits [EPSG:2193]

Maximum Search Distance (cells): 30

Maximum Breach Cost (z units) [optional]: Not set

Minimize breach distances? [optional]

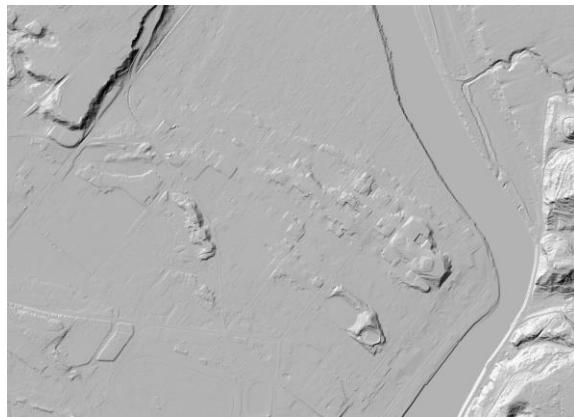
Flat increment value (z units) [optional]: 0.0001|0

Fill unbreached depressions? [optional]

Output File: D:/Processing/LiDAR/2020/Whanganui_WhangaehuRiver2020LiDAR_Products/work/overland_flow_paths/breach_depressions_least_cost.tif

Open output file after running algorithm

Execution completed in 3617.46 seconds (1 hour 0 minute 17 seconds)



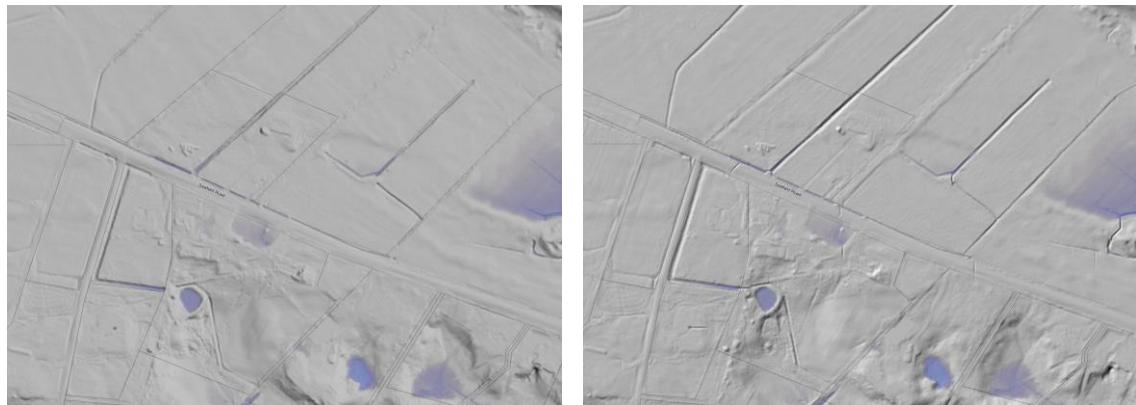
WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=BreachDepressionsLeastCost --
dem="D:/Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths
\breach_single_cell_pits.tif" --dist=30 --min_dist="True" --flat_increment=0.0001 --fill="False" --
output="D:/Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat
hs\breach_depressions_least_cost.tif"
< 03BreachDepressions_30cells_00002flatinc.tif
```

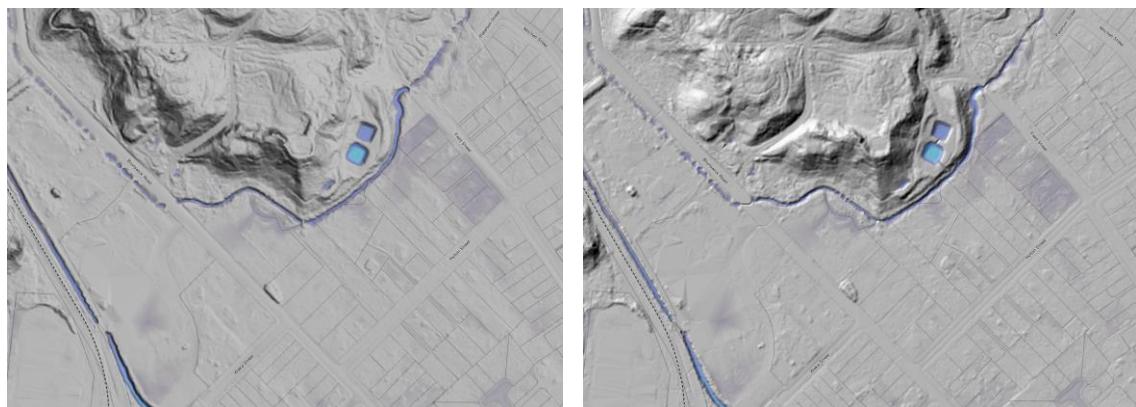
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Examples of the affect of using the breach depressions least cost algorithm, with original DEM on the left and breached DEM on the right

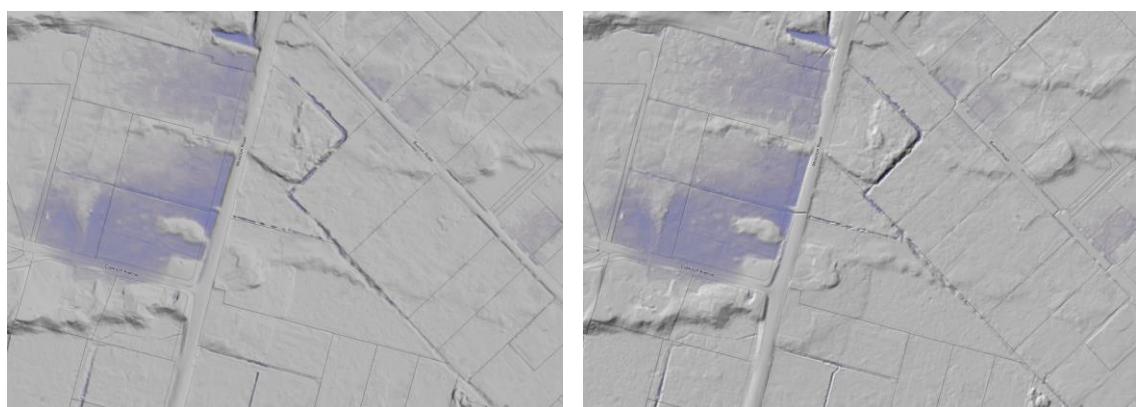
Seafield Road:



Brunswick Road:

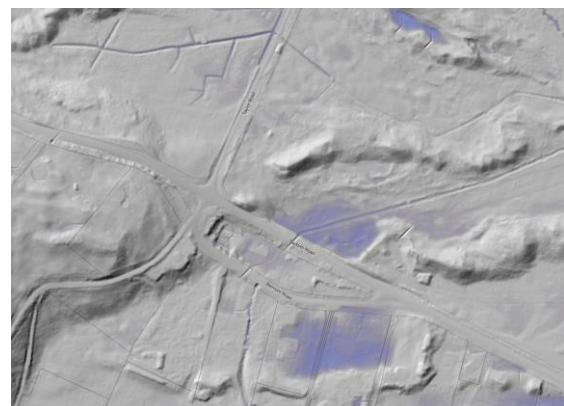
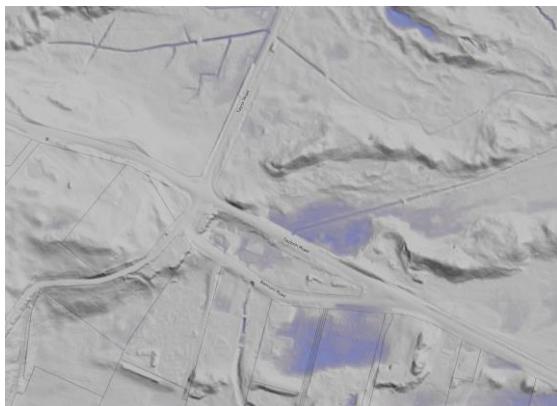


Mosston Road

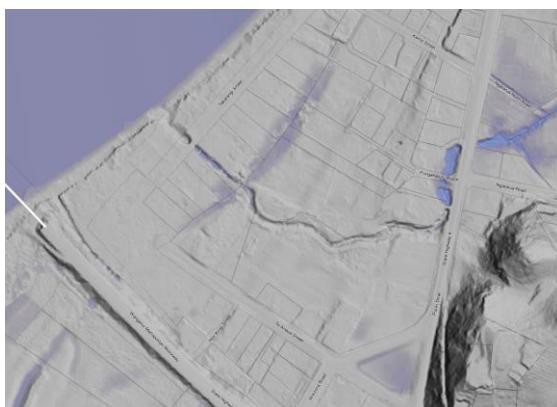


Tayforth Road

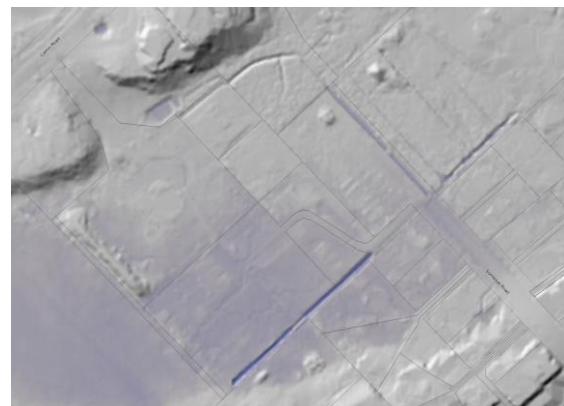
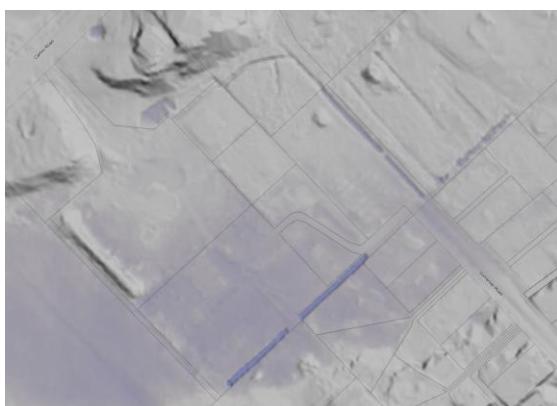
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Putiki



Somerset Road



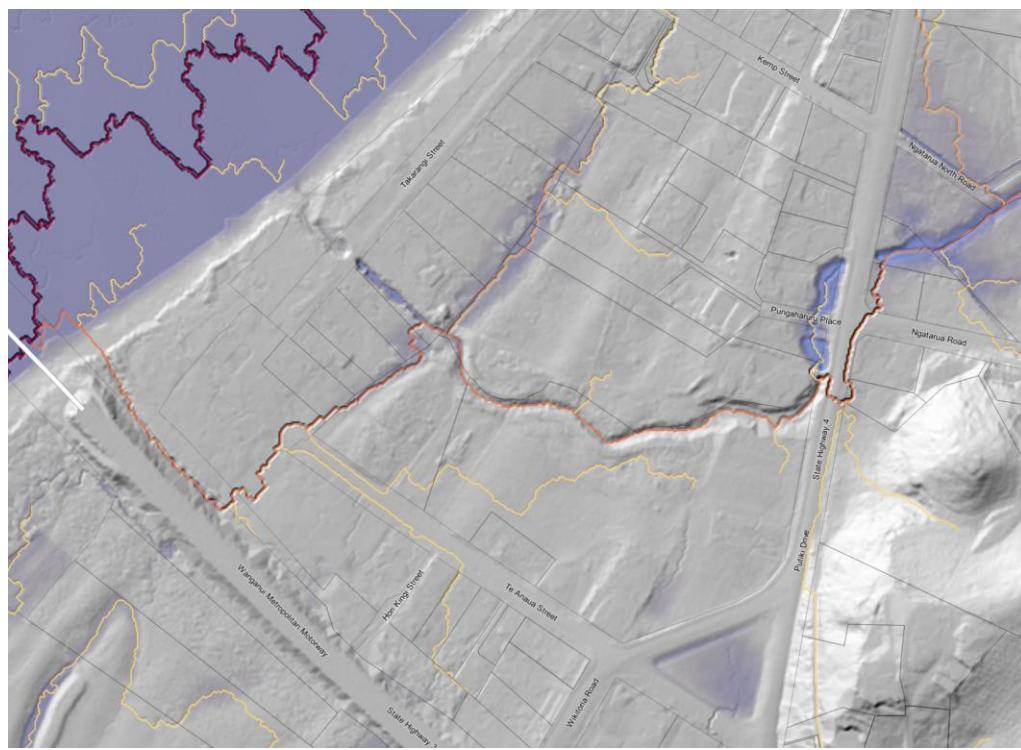
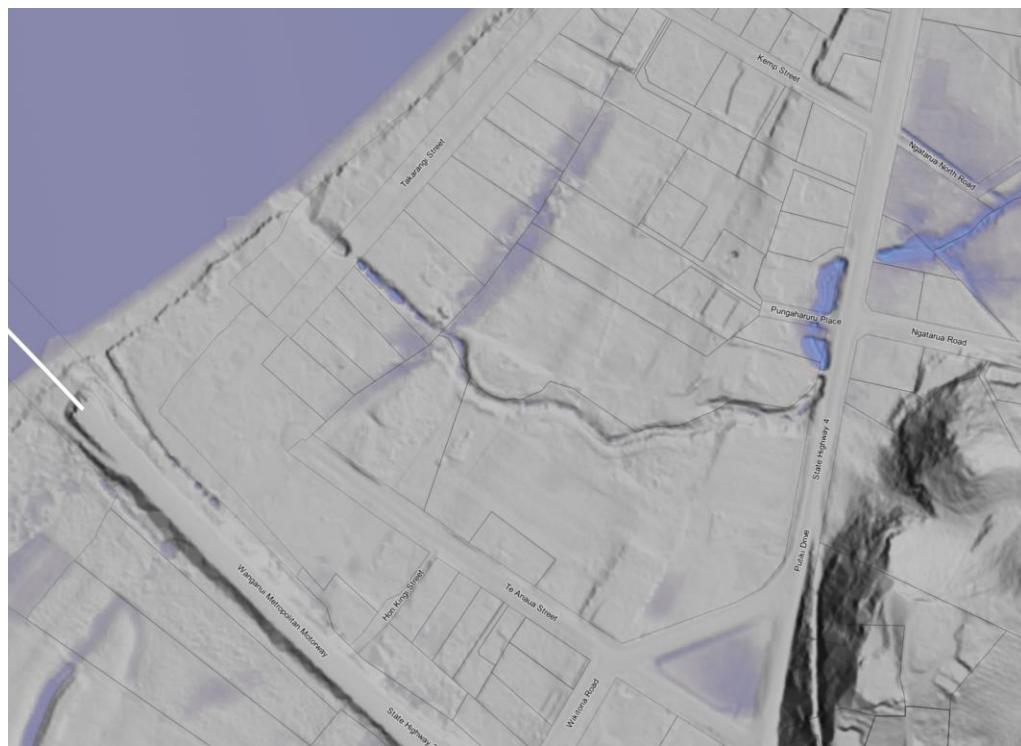
4.3.2.2 Method 2 – Breach Depressions

In comparison with the Breach Depressions Least Cost tool, this breaching method often provides a less satisfactory, higher impact, breaching solution and is often less efficient. It has been provided to users for legacy reasons and it is advisable that users try the Breach Depressions Least Cost tool to remove depressions from their DEMs first. The Breach Depressions Least Cost tool is particularly well suited to breaching through road embankments. Nonetheless, there are applications for which full depression filling using the Fill Depressions tool may be preferred.

This method can generate significant breaching errors.

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For example, the following images show the raw DEM for Putiki, followed by the DEM breached using this method...



Significant errors show up where the stream crosses Putiki Drive and for the location of the Stream outlet to the Whanganui River some 160m southwest of the actual outlet.

As a result this method was determined to be unsuitable for breaching depressions in the Whanganui DC topology.

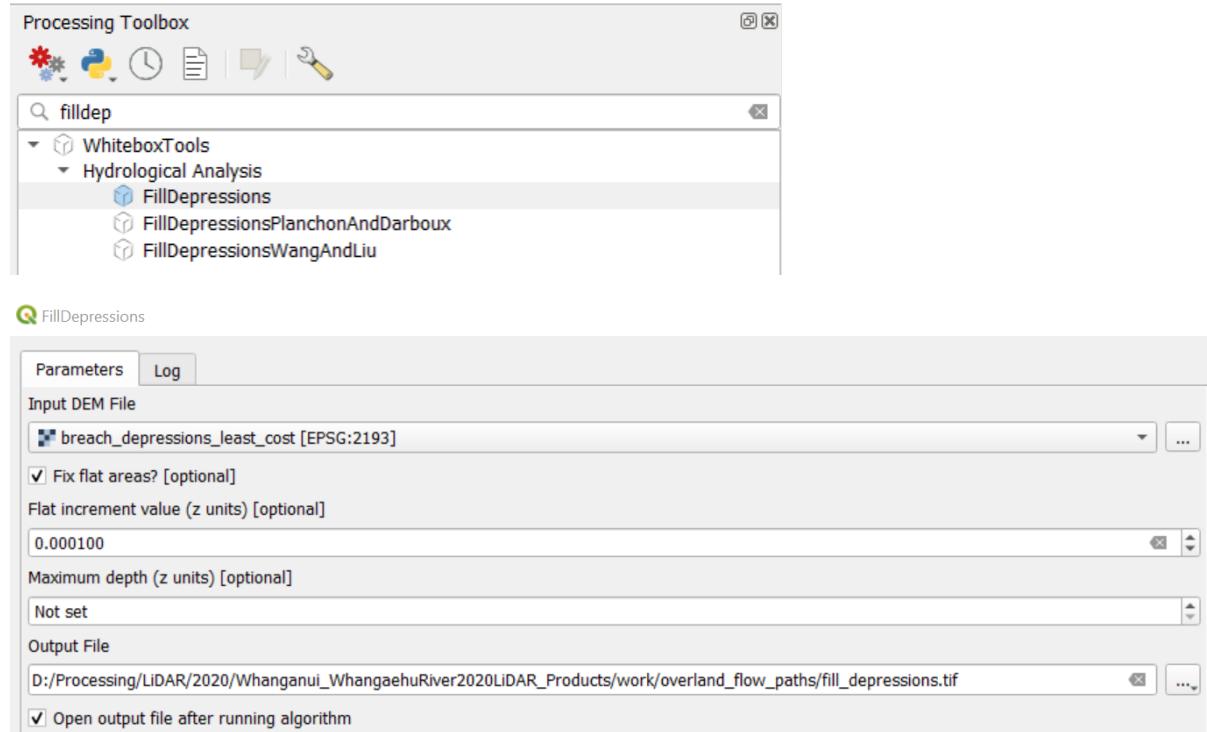
Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.4 Calculate Flow Accumulation and Flow Pointer

Generate a flow accumulation grid (i.e. catchment area). This algorithm is an example of single-flow-direction (SFD) method because the flow entering each grid cell is routed to only one downslope neighbour, i.e. flow divergence is not permitted.

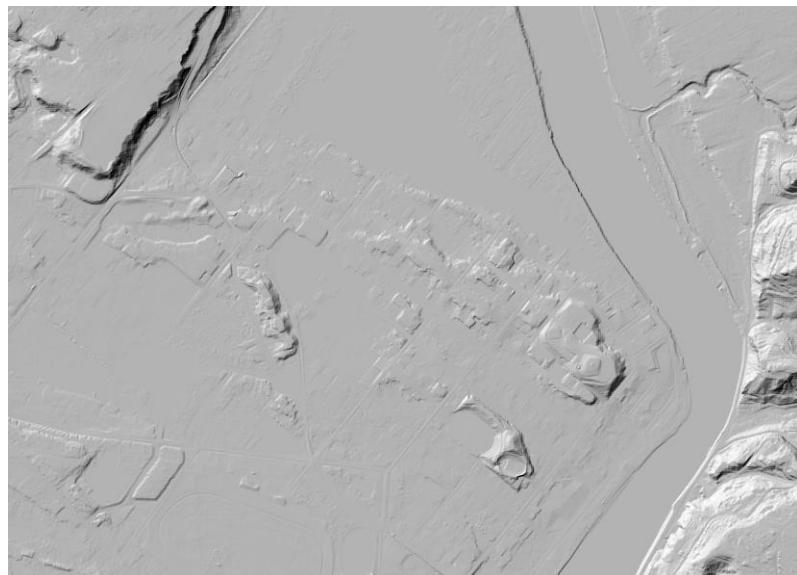
4.4.1 Fill Depressions

Fills all of the remaining depressions in the DEM.



Note that we use **Fix flat areas** and we apply a very small **Flat increment value**. This will allow us to define a flow path across flat areas that more accurately follows the actual terrain (rather than a straight line directly across the flat area).

Execution completed in 108.66 seconds (1 minute 49 seconds)



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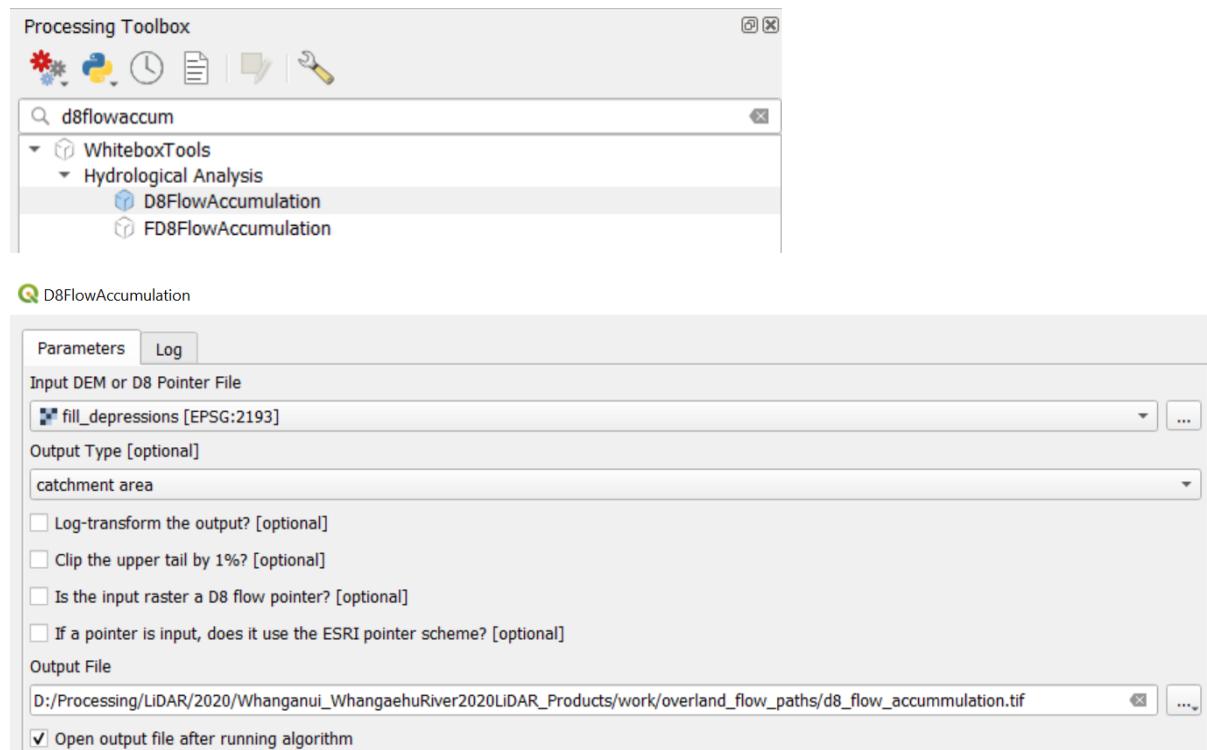
WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=FillDepressions --
dem="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\
\breach_depressions_least_cost.tif" --fix_flats="True" --flat_increment=0.0001 --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\fill_depressions.tif"
```

4.4.2 D8 Flow Accumulation

Calculates a D8 flow accumulation (i.e. catchment area) raster from an input DEM or flow pointer.

The output flow-accumulation is set to catchment area (i.e. the upslope area)



We use **Catchment area** as the **Output Type** so that we can extract out 1ha, 2ha and 5ha catchment overland flow paths later.

Execution completed in 198.04 seconds (3 minutes 18 seconds)

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WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=D8FlowAccumulation --
input="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\fill_depressions.tif" --out_type="catchment area" --log="False" --clip="False" --pntr="False" --esri_pntr="False"
--
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\d8_flow_accumulation.tif"
```

4.4.3 D8 Pointer Flow Direction

Now that we have created the accumulation raster's, we need to extract the pointer raster to determine flow direction of the raster.

Calculates a D8 flow pointer raster from an input DEM

The screenshot shows the QGIS Processing Toolbox. A search bar at the top contains the text "d8pointer". Below it, under the "WhiteboxTools" category, the "Hydrological Analysis" group is expanded, showing the "D8Pointer" algorithm. The "D8Pointer" dialog box is open in the foreground. It has two tabs: "Parameters" (which is selected) and "Log". The "Parameters" tab contains the following fields:

- Input DEM File:** A dropdown menu showing "fill_depressions [EPSG:2193]".
- Should the pointer file use the ESRI pointer scheme? [optional]:** An unchecked checkbox.
- Output File:** A text input field containing the path "D:/Processing/LiDAR/2020/Whanganui_WhangaehuRiver2020LiDAR_Products/work/overland_flow_paths/d8_pointer.tif".
- Open output file after running algorithm:** A checked checkbox.

Execution completed in 95.39 seconds (1 minute 35 seconds)

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WhiteboxTools command:

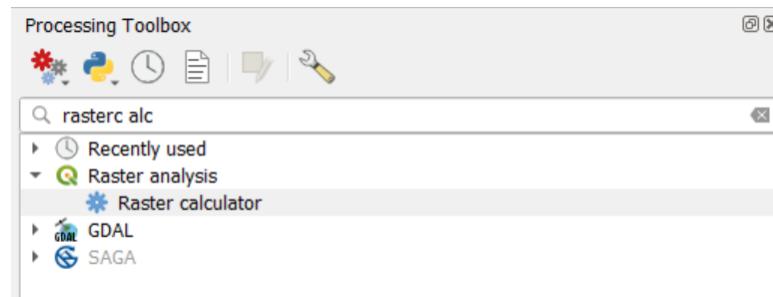
```
"C:/WBT/whitebox_tools.exe" -v --run=D8Pointer --
dem="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths
\fill_depressions.tif" --esri_pntr="False" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat
hs\d8_pointer.tif"
```

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4.5 Extract Overland Flow Paths

4.5.1 QGIS Raster Calculator

The QGIS Raster Calculator allows performing algebraic operations using raster layers. The resulting layer will have its values computed according to an expression.



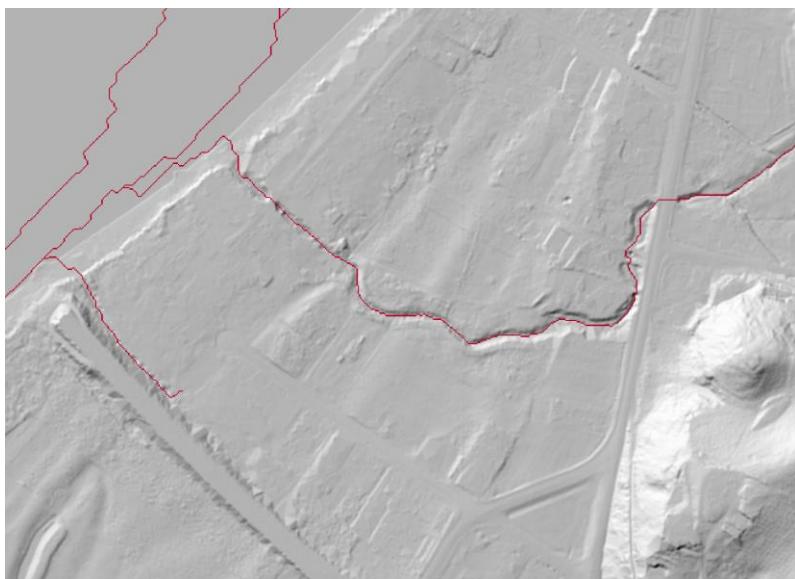
4.5.1.1 Contributing Area >= 5ha

Calculate overland flow path with a contributing area of greater than or equal to 5.0 ha

A screenshot of the Raster Calculator dialog box. The 'Parameters' tab is selected. In the 'Layers' section, several raster layers are listed, including 'breach_depressions_least_cost@1', 'd8_flow_accumulation@1', and 'lidar2020_dem_1m@1'. In the 'Operators' section, a grid of mathematical operators is shown. In the 'Expression' section, the expression '"d8_flow_accumulation@1" >= 50000' is entered. Below the expression, a green message 'Expression is valid' is displayed.

Execution completed in 86.02 seconds (1 minute 26 seconds)

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4.5.1.2 Contributing Area $\geq 2\text{ha} < 5\text{ha}$

Calculate overland flow path with a contributing area of greater than or equal to 2.0 ha and less than 5ha

Raster Calculator

Parameters Log

Expression

Layers

- 2021_overland_flow_path_2ha@1
- 2021_overland_flow_path_5ha@1
- breach_depressions_least_cost@1
- breach_single_cell_pits@1
- d8_flow_accumulation@1
- d8_pointer@1
- fill_depressions@1
- fill_single_cell_pits@1
- lidar2020_dem_1m@1
- no_flow_cells@1
- sinks@1

Operators

+	*	cos	sin	log10	AND
-	/	acos	asin	ln	OR
\wedge	sqrt	tan	atan	()
<	>	=	!=	\leq	\geq
abs	min	max			

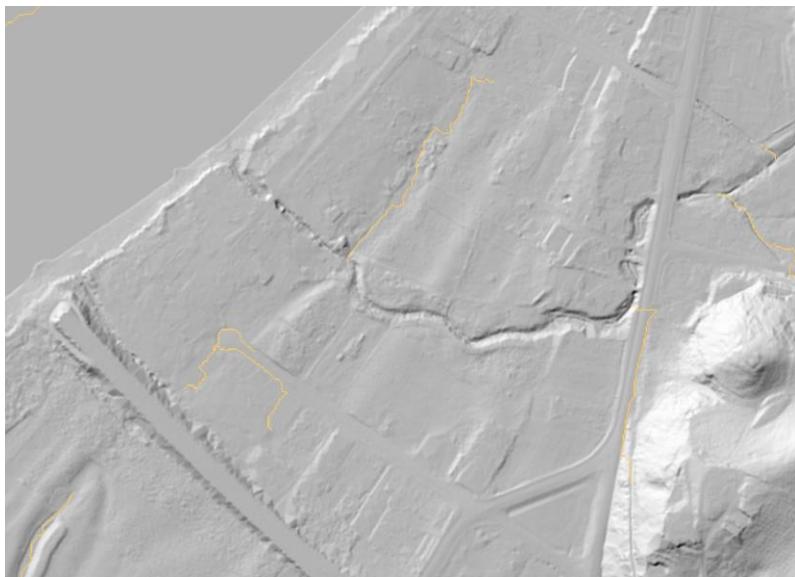
Expression

```
"d8_flow_accumulation@1" >= 20000 AND "d8_flow_accumulation@1" < 50000
```

Expression is valid

Execution completed in 108.47 seconds (1 minute 48 seconds)

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS



4.5.1.3 Contributing Area $\geq 1\text{ha} < 2\text{ha}$

Calculate overland flow path with a contributing area of greater than or equal to 1.0 ha and less than 2ha

Raster Calculator

Parameters Log

Expression

Layers

- 2021_overland_flow_path_2ha@1
- 2021_overland_flow_path_5ha@1
- breach_depressions_least_cost@1
- breach_single_cell_pits@1
- d8_flow_accumulation@1
- d8_pointer@1
- fill_depressions@1
- fill_single_cell_pits@1
- lidar2020_dem_1m@1
- no_flow_cells@1
- sinks@1

Operators

+	*	cos	sin	log10	AND
-	/	acos	asin	ln	OR
^	sqrt	tan	atan	()
<	>	=	!=	<=	\geq
abs	min	max			

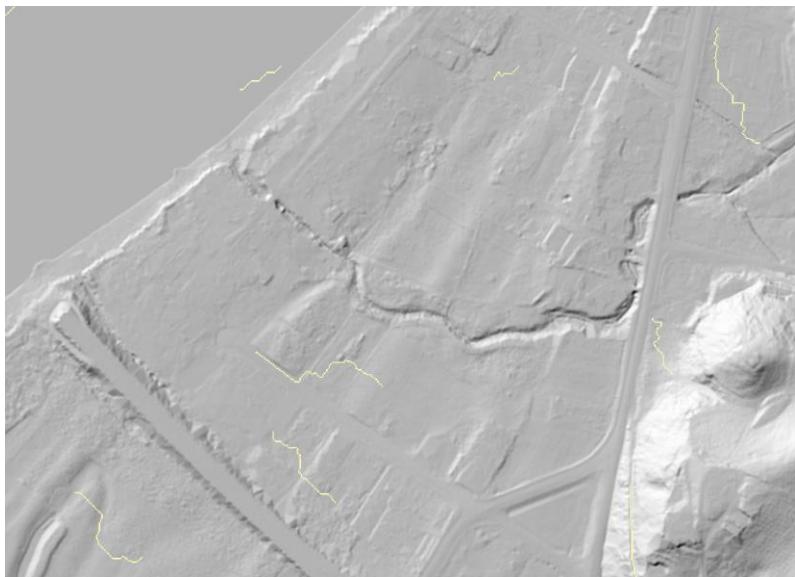
Expression

```
"d8_flow_accumulation@1" >= 10000 AND "d8_flow_accumulation@1" < 20000
```

Expression is valid

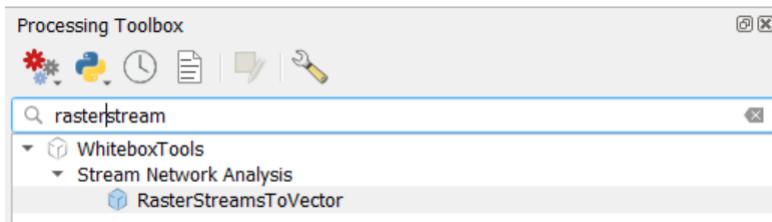
Execution completed in 96.99 seconds (1 minute 37 seconds)

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS



4.5.2 Convert Raster Streams to Vector

Convert the raster stream files into a vector files.



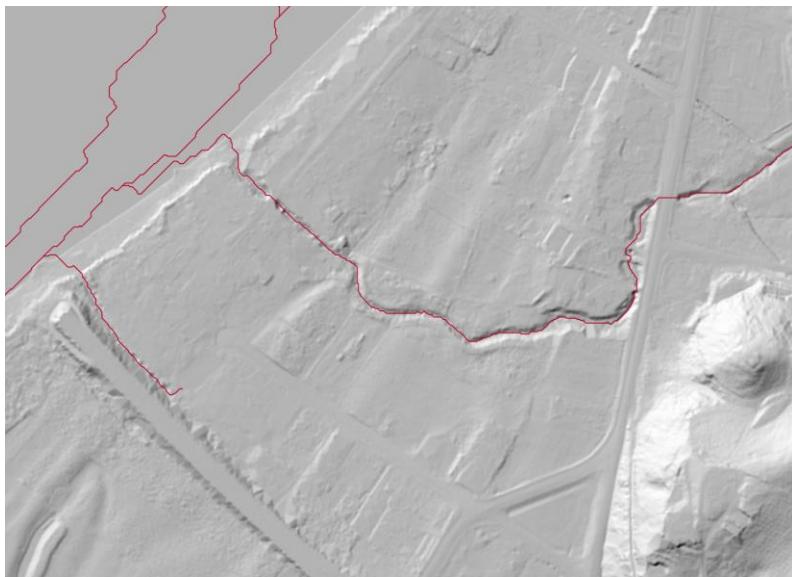
4.5.2.1 Contributing Area >= 5ha

Convert overland flow path with a contributing area of greater than or equal to 5.0 ha to vector



Execution completed in 27.36 seconds

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS



WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=RasterStreamsToVector --
streams="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pa
ths\2021_overland_flow_path_5ha.tif" --
d8_pntr="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_p
aths\d8_pointer.tif" --esri_pntr="False" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pa
ths\2021_overland_flow_path_5ha.shp"
```

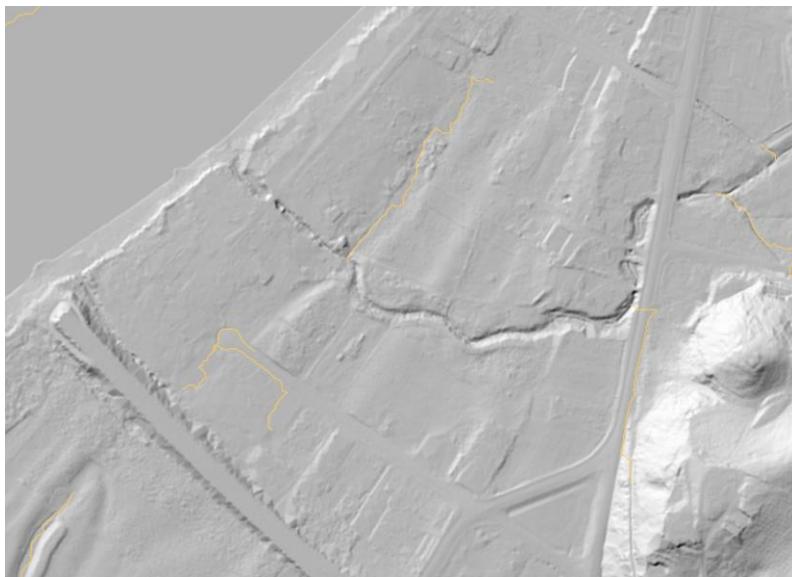
4.5.2.2 Contributing Area >= 2ha < 5ha

Convert overland flow path with a contributing area of greater than or equal to 2.0 ha and less than 5ha to vector



Execution completed in 27.18 seconds

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS



WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=RasterStreamsToVector --
streams="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pa
ths\2021_overland_flow_path_2ha.tif" --
d8_pntr="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_p
aths\d8_pointer.tif" --esri_pntr="False" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat
hs\2021_overland_flow_path_2ha.shp"
```

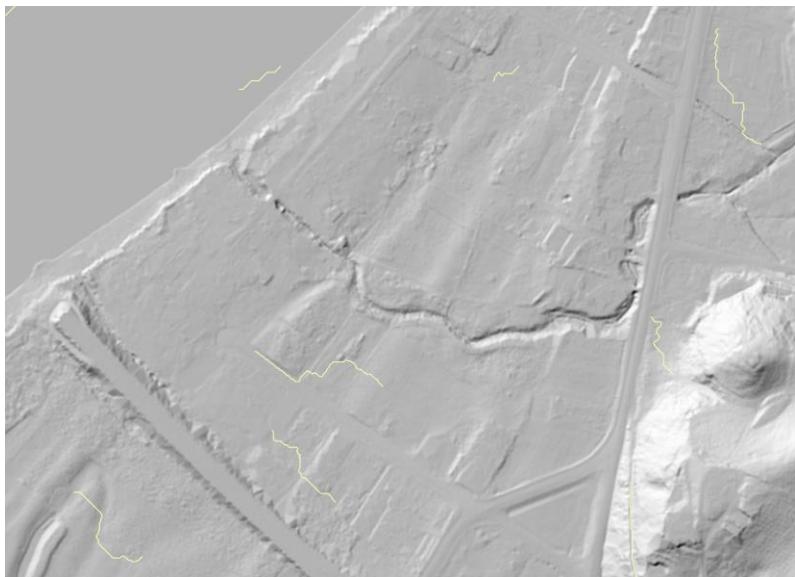
4.5.2.3 Contributing Area >= 1ha < 2ha

Convert overland flow path with a contributing area of greater than or equal to 1.0 ha and less than 2ha to vector



Execution completed in 53.53 seconds

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS



WhiteboxTools command:

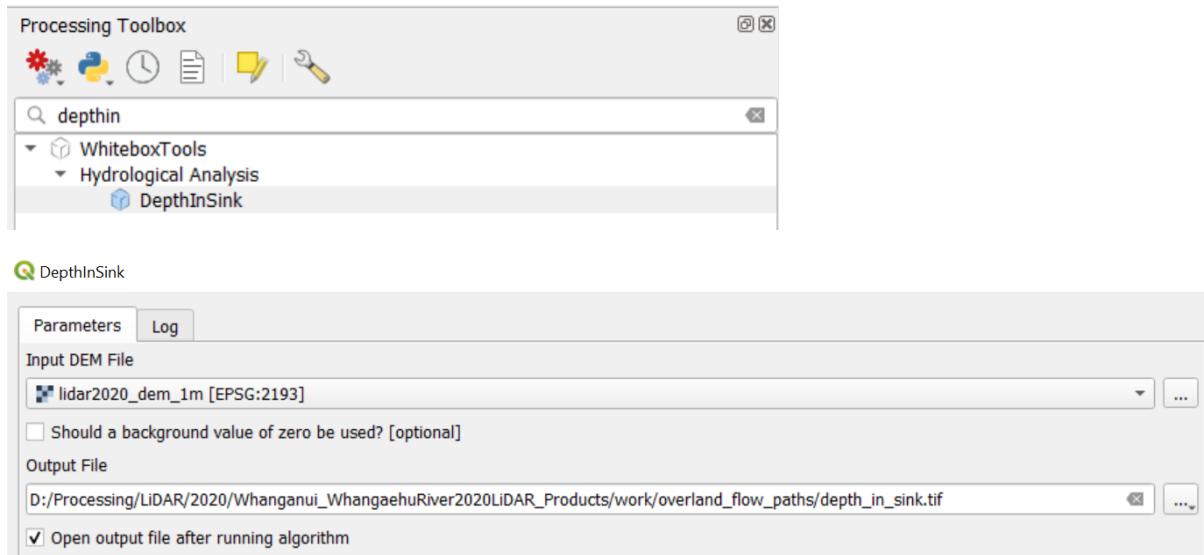
```
"C:/WBT/whitebox_tools.exe" -v --run=RasterStreamsToVector --
streams="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pa
ths\2021_overland_flow_path_1ha.tif" --
d8_pntr="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_p
aths\d8_pointer.tif" --esri_pntr="False" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat
hs\2021_overland_flow_path_1ha.shp"
```

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

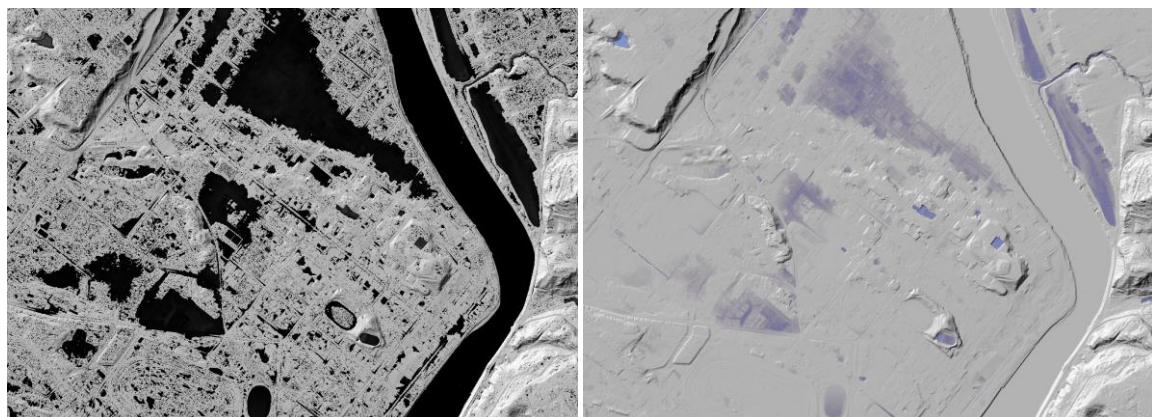
4.6 Depression Areas

4.6.1 Depth in Sink

Measures the depth of sinks (depressions) in a DEM



Execution completed in 104.75 seconds (1 minute 45 seconds)



WhiteboxTools command:

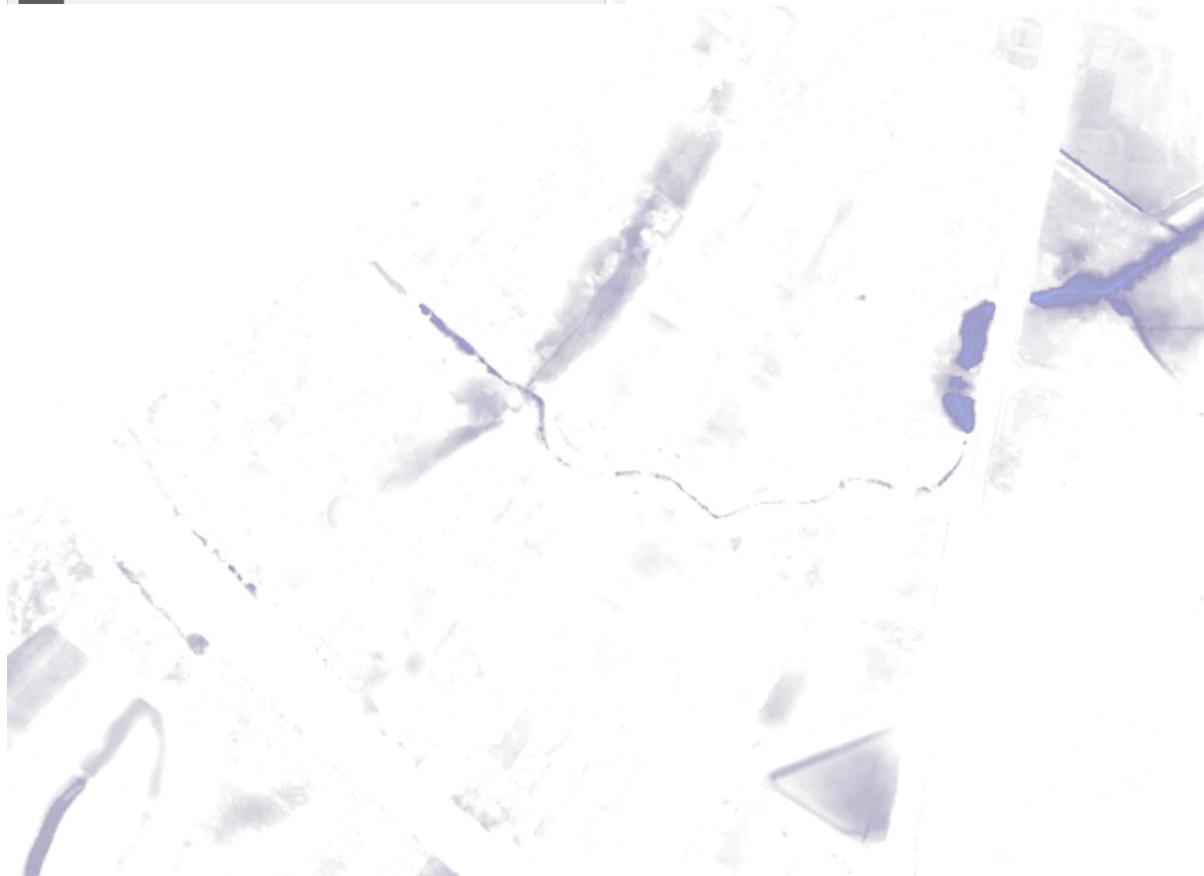
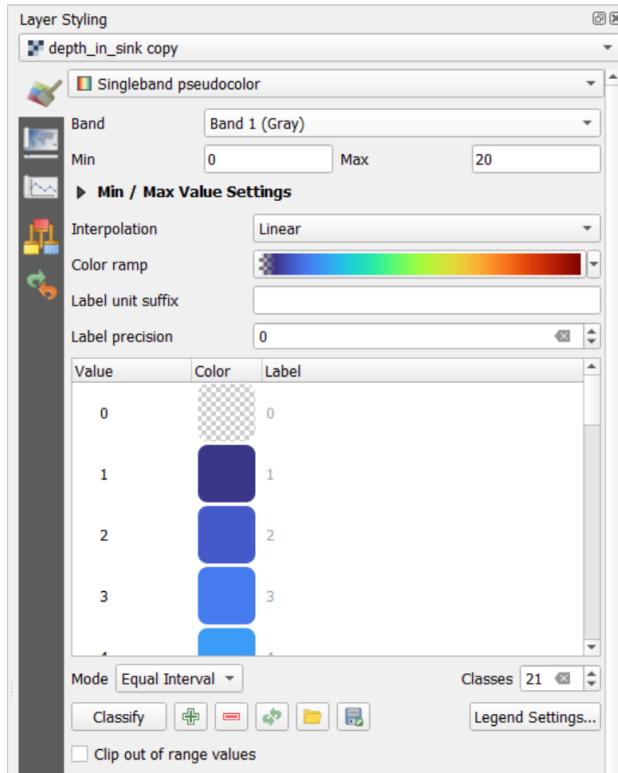
```
"C:/WBT/whitebox_tools.exe" -v --run=DepthInSink --
dem="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\lidar2020_dem_1m.tif" --
zero_background="False" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat-
hs\depth_in_sink.tif"
```

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.6.2 QGIS Raster Styling of Depression Areas

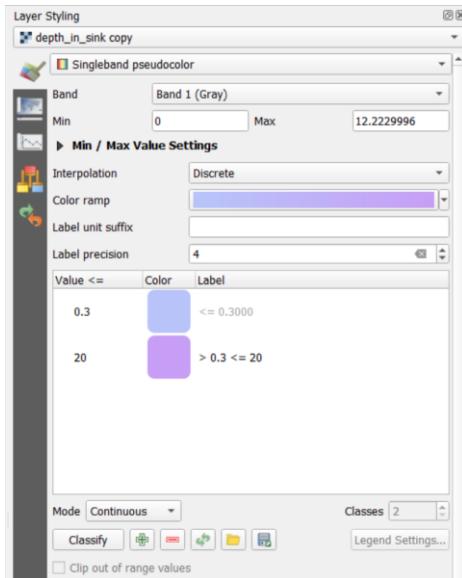
4.6.2.1 Linear range of classified values

This style allows better representation of the variable depth of a Depression Area.



4.6.2.2 Discrete Categories

This style allows the portrayal of defined value categories



Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.6.3 Polygonise Depression Areas <= 0.3m

4.6.3.1 Extract Depth <= 0.3m

Use QGIS Raster Calculator to extract Depression Areas with depth <= 0.3m

Q Raster Calculator

Parameters Log

Expression

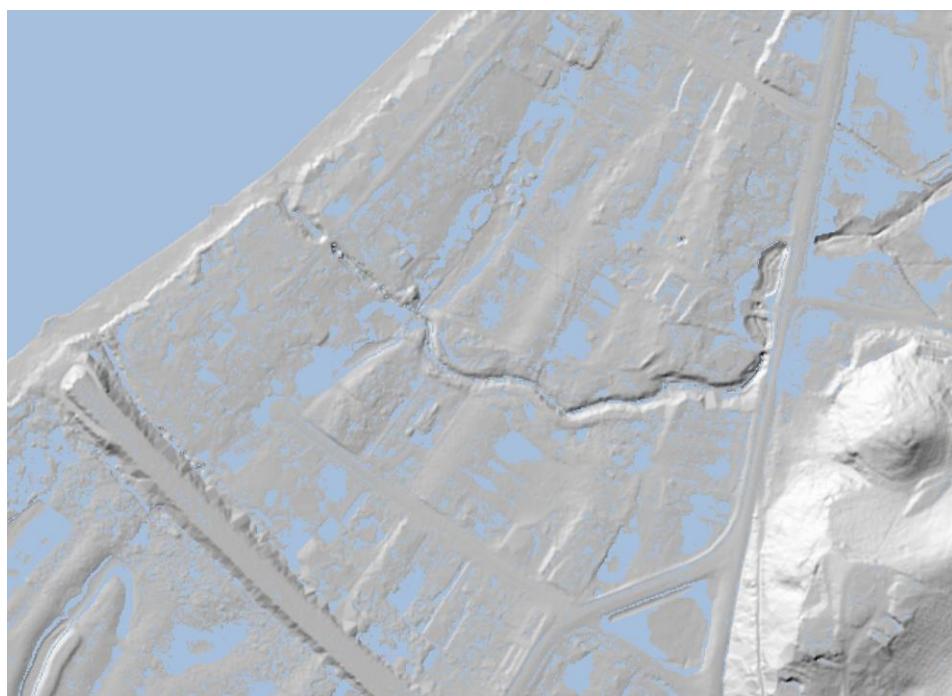
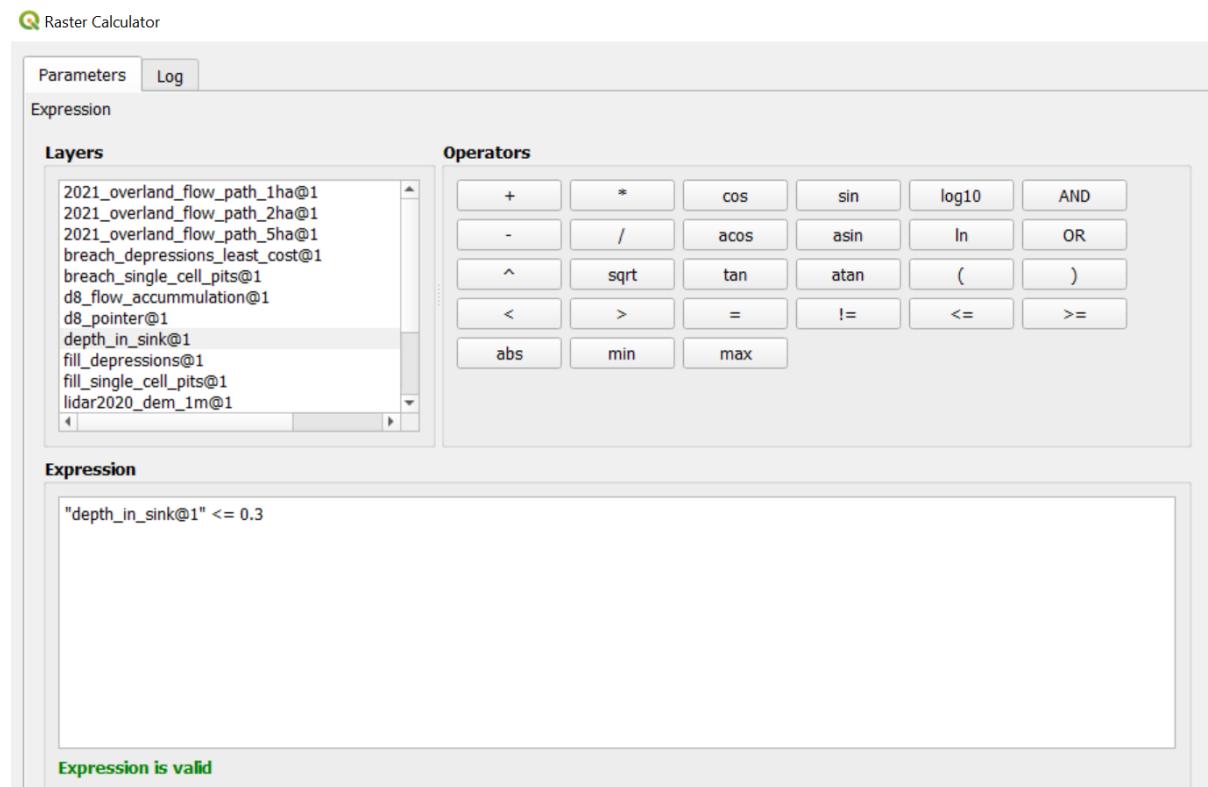
Layers Operators

2021_overland_flow_path_1ha@1 * cos sin log10 AND
2021_overland_flow_path_2ha@1 / acos asin ln OR
2021_overland_flow_path_5ha@1 ^ sqrt tan atan ()
breach_depressions_least_cost@1 < ! = <= >= AND
breach_single_cell_pits@1 d8_flow_accumulation@1
d8_pointer@1 depth_in_sink@1 fill_depressions@1 fill_single_cell_pits@1
lidar2020_dem_1m@1

Expression

"depth_in_sink@1" <= 0.3

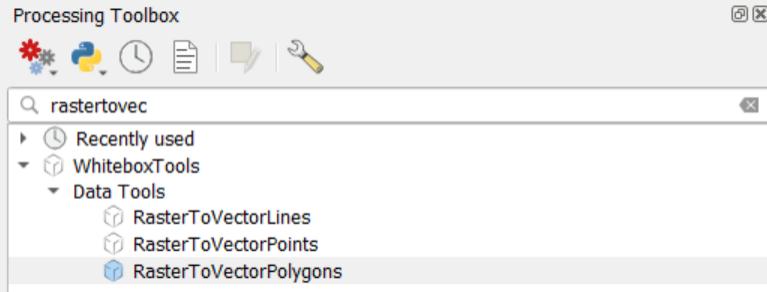
Expression is valid



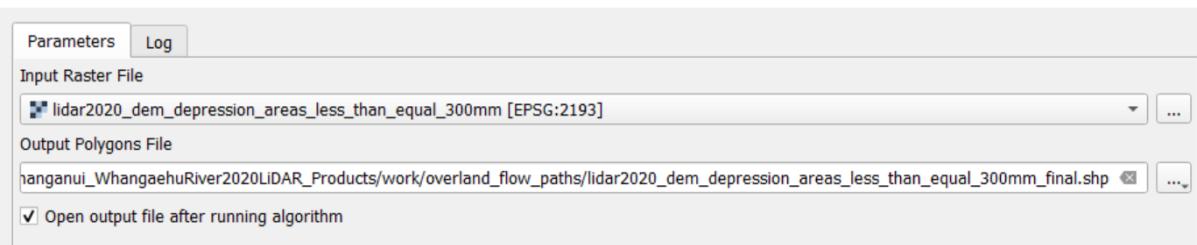
Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.6.3.2 Convert to Vector

Polygonise the result using the Whitebox **Raster to Vector Polygons** algorithm.



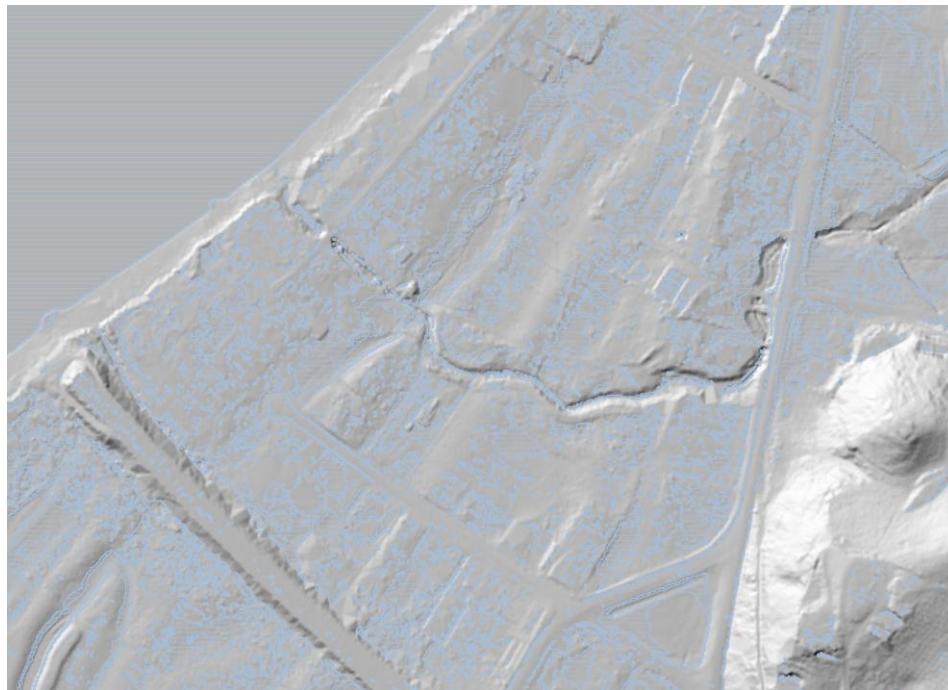
The screenshot shows the Processing Toolbox interface. A search bar at the top contains the text "rastertovec". Below it, the "Recently used" section is expanded, showing a list of recent tools. Under the "WhiteboxTools" category, the "Data Tools" section is expanded, showing three sub-tools: "RasterToVectorLines", "RasterToVectorPoints", and "RasterToVectorPolygons". The "RasterToVectorPolygons" tool is highlighted with a gray selection bar at the bottom of its list item.



The screenshot shows the "RasterToVectorPolygons" algorithm parameters dialog box. It has two tabs: "Parameters" (selected) and "Log".
Input Raster File: A dropdown menu containing "lidar2020_dem_depression_areas_less_equal_300mm [EPSG:2193]" with a checked checkbox.
Output Polygons File: A text input field containing "hanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\lidar2020_dem_depression_areas_less_equal_300mm_final.shp" with a checked checkbox.
Checkboxes:

- Open output file after running algorithm

Execution completed in 4294.95 seconds (1 hour 11 minutes 35 seconds)



WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=RasterToVectorPolygons --
input="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_path
s\lidar2020_dem_depression_areas_less_equal_300mm.tif" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat
hs\lidar2020_dem_depression_areas_less_equal_300mm_final.shp"
```

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.6.3.3 Fix Geometries

Select the lidar2020_dem_depression_areas_less_equal_300mm_final vector layer in the QGIS layer panel:



Enable the  **Edit features in place** tool

Run **Fix geometries**



Note that a progress bar is displayed along the top of the map



Save the changes 

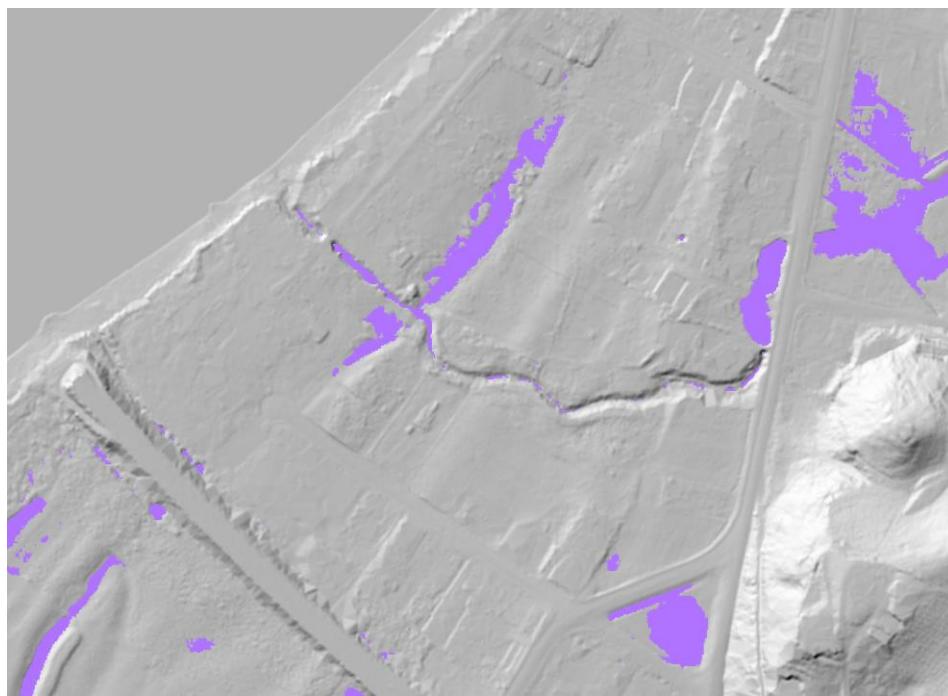
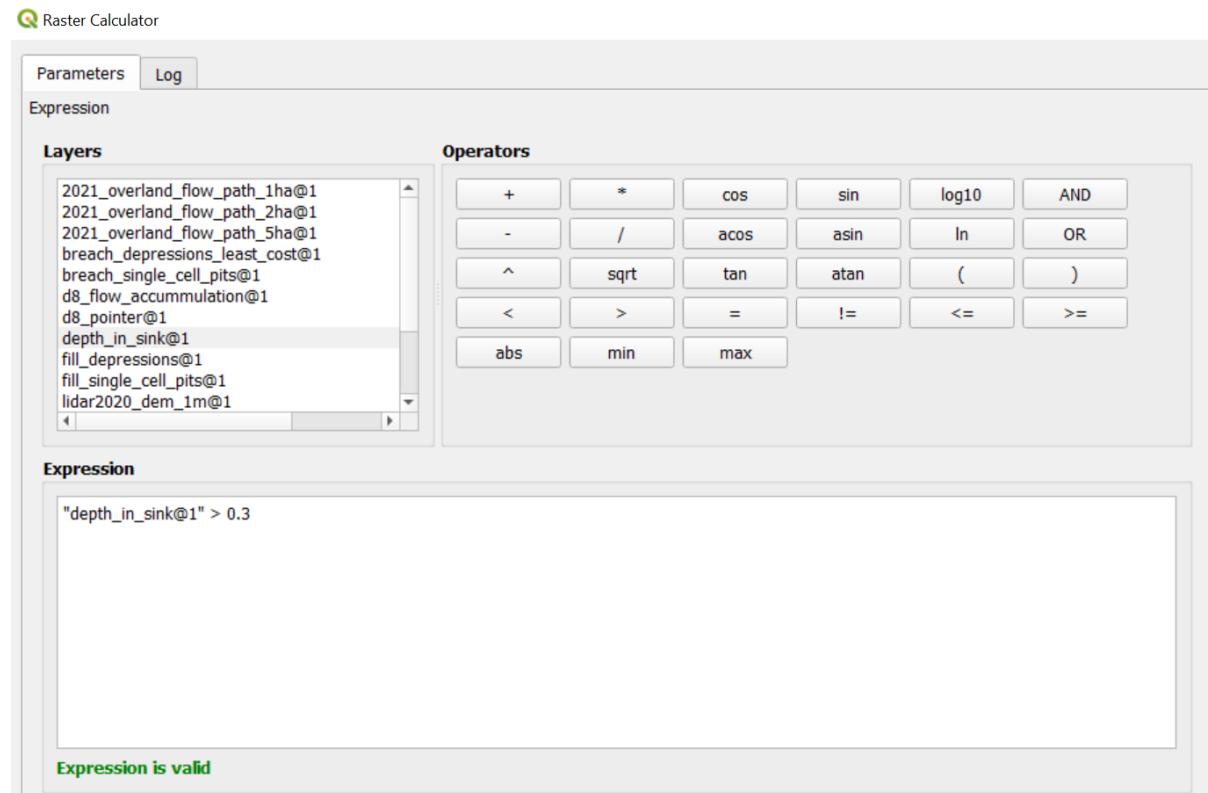
On completion, disable the  **Edit features in place** tool

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.6.4 Polygonise Depression Areas > 0.3m

4.6.4.1 Extract Depth > 0.3m

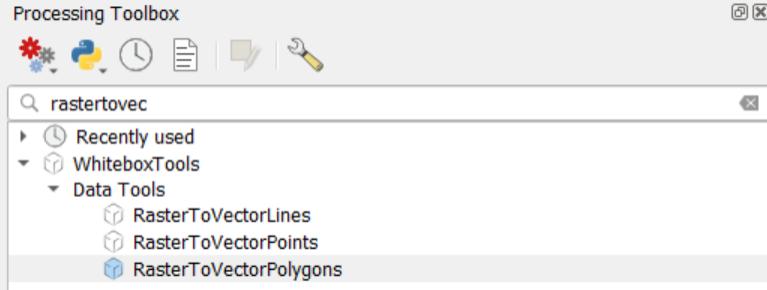
Use QGIS Raster Calculator to extract Depression Areas with depth > 0.3m



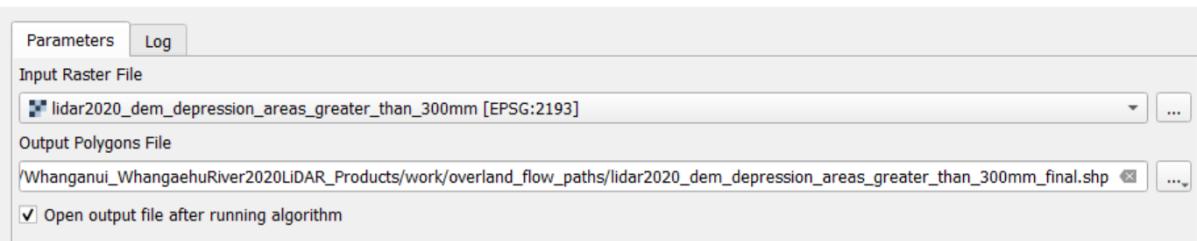
Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.6.4.2 Convert to Vector

Polygonise the result using the Whitebox **Raster to Vector Polygons** algorithm.

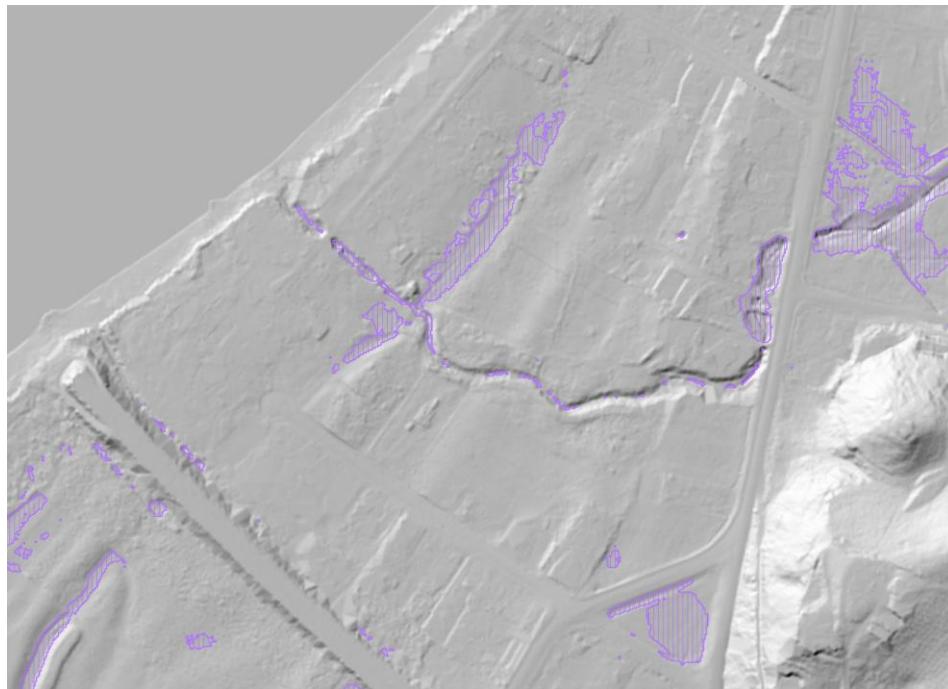


The screenshot shows the Processing Toolbox interface. A search bar at the top contains the text "rastertovec". Below it, the "Recently used" section is expanded, showing "WhiteboxTools" and "Data Tools". Under "Data Tools", three options are listed: "RasterToVectorLines", "RasterToVectorPoints", and "RasterToVectorPolygons". The "RasterToVectorPolygons" option is highlighted with a gray selection bar at the bottom of the list.



The dialog box for the "RasterToVectorPolygons" algorithm is open. It has two tabs: "Parameters" (selected) and "Log".
Input Raster File: Set to "lidar2020_dem_depression_areas_greater_than_300mm [EPSG:2193]" with a dropdown arrow and a "...".
Output Polygons File: Set to "/Whanganui_WhangaehuRiver2020LiDAR_Products/work/overland_flow_paths/lidar2020_dem_depression_areas_greater_than_300mm_final.shp" with a dropdown arrow and a "...".
Open output file after running algorithm: A checked checkbox.

Execution completed in 79.83 seconds (1 minute 20 seconds)



WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=RasterToVectorPolygons --
input="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\lidar2020_dem_depression_areas_greater_than_300mm.tif" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\lidar2020_dem_depression_areas_greater_than_300mm_final.shp"
```

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.6.4.3 Fix Geometries

Select the **lidar2020_dem_depression_areas_greater_than_300mm_final** vector layer in the QGIS layer panel:



Enable the  **Edit features in place** tool

Run **Fix geometries**



Note that a progress bar is displayed along the top of the map

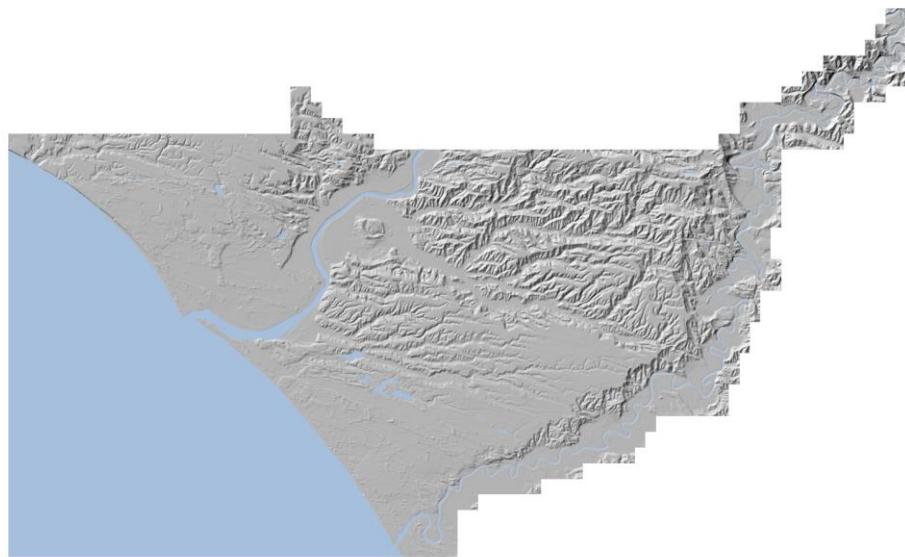
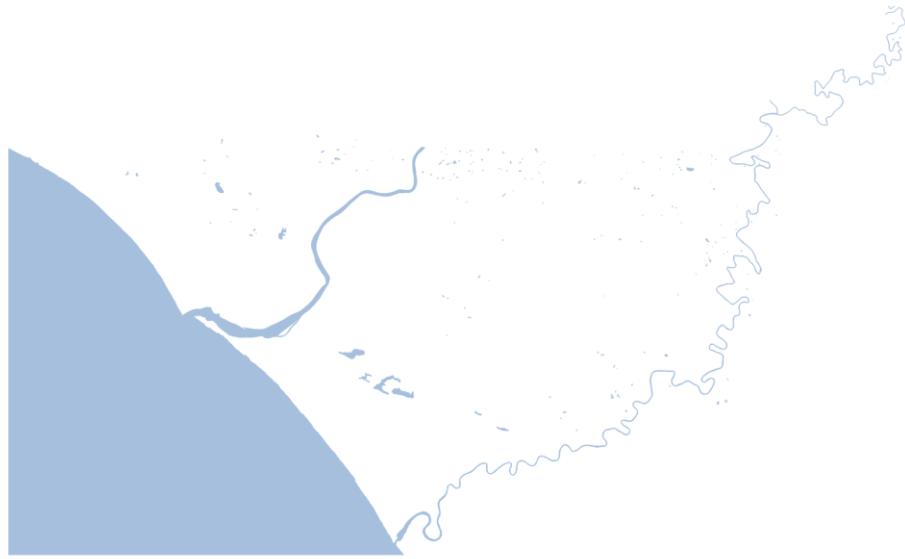


Save the changes 

On completion, disable the  **Edit features in place** tool

4.7 Hydro Clipping

A Hydro Mask polygon layer has been derived from the 2021 LIDAR Hydro Flattening Polygons and Breaklines.

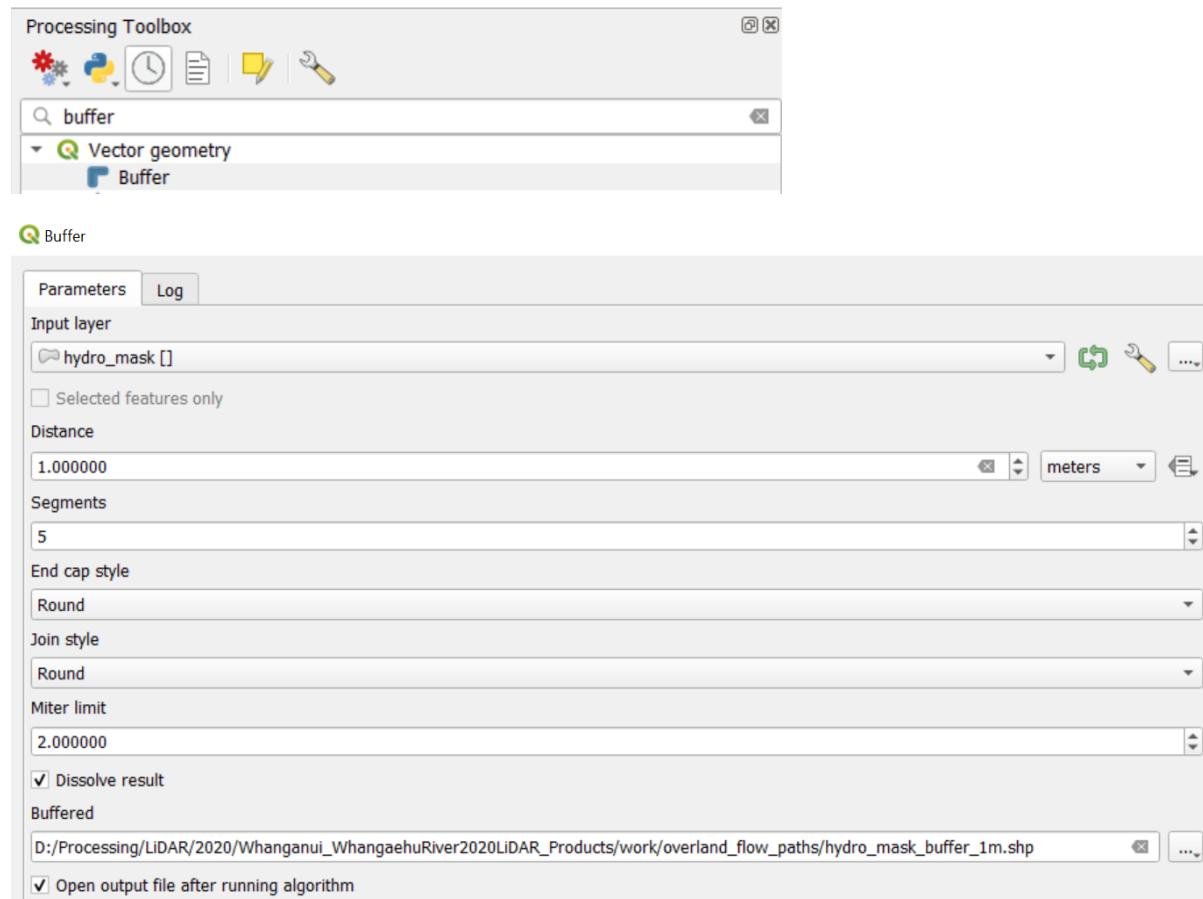


The Hydro Mask is used to remove the Overland Flow Path and Depression Area results from areas defined as hydro (e.g. Rivers, Lakes and Sea).

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.7.1 Buffer hydro mask

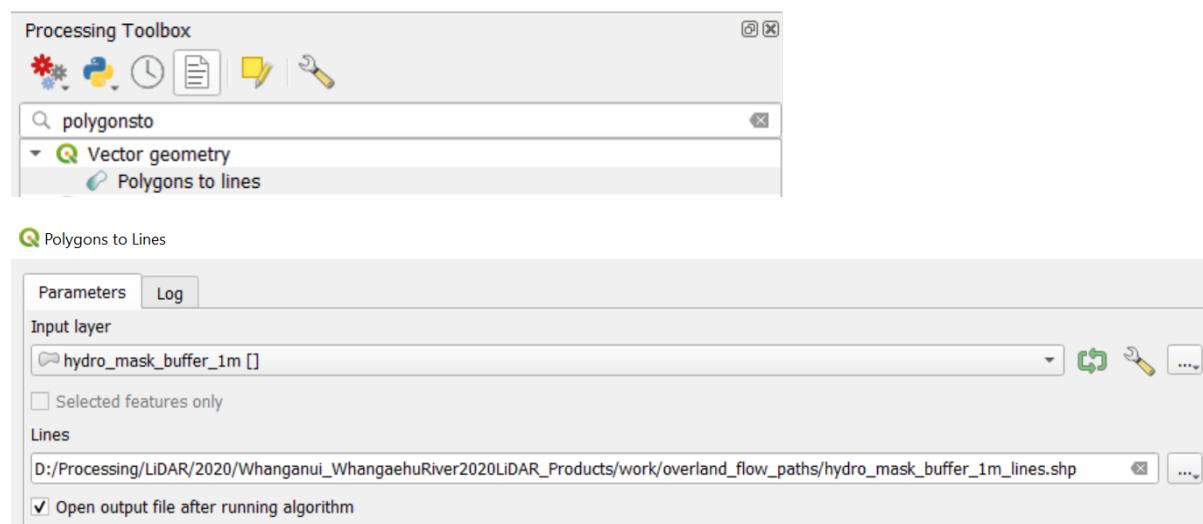
This algorithm computes a buffer area for all the features in an input layer, using a fixed or dynamic distance.



Execution completed in 0.44 seconds

4.7.2 Convert buffer to Lines

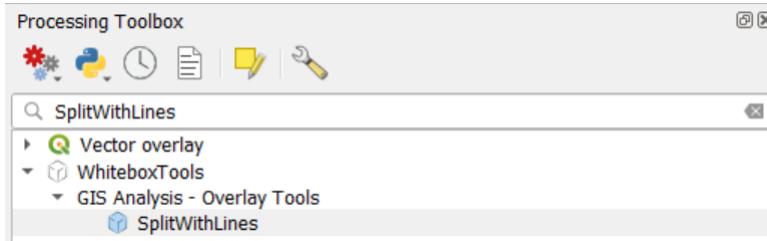
Converts polygons to lines



Execution completed in 0.39 seconds

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.7.3 Split each Overland Flow Path using Buffer Line



4.7.3.1 Contributing Area $\geq 5\text{ha}$

Split overland flow path with a contributing area of greater than or equal to 5ha using hydro mask buffer line



Execution completed in 571.63 seconds (9 minutes 32 seconds)

4.7.3.2 Contributing Area $\geq 2\text{ha} < 5\text{ha}$

Split overland flow path with a contributing area of greater than or equal to 2 ha and less than 5ha using hydro mask buffer line



Execution completed in 274.04 seconds (4 minutes 34 seconds)

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.7.3.3 Contributing Area $\geq 1\text{ha} < 2\text{ha}$

Split overland flow path with a contributing area of greater than or equal to 1 ha and less than 2ha using hydro mask buffer line



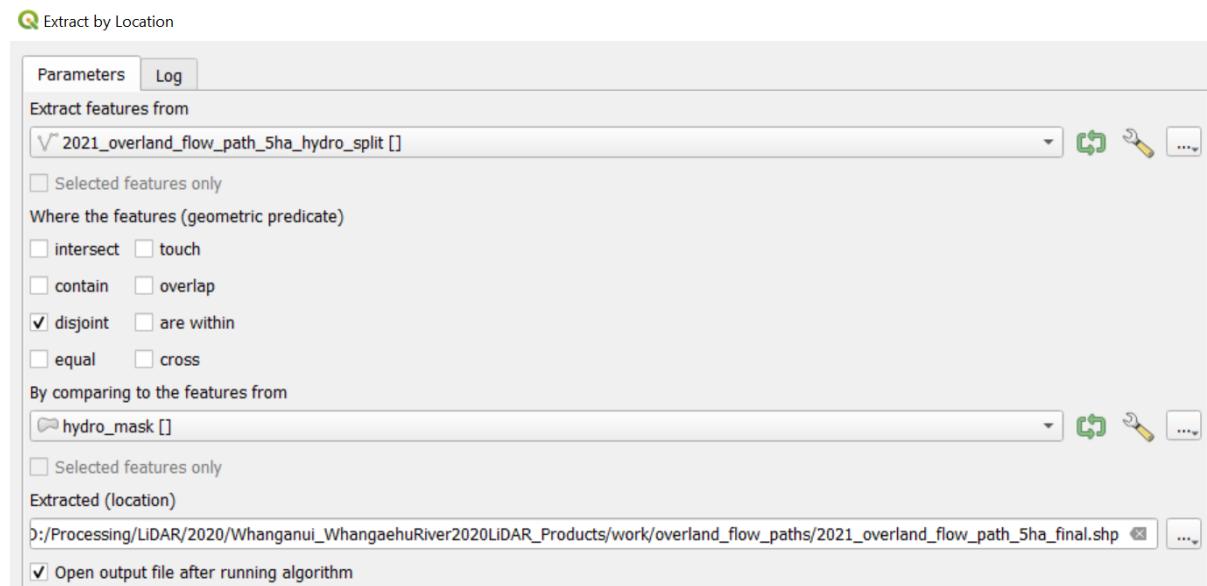
Execution completed in 291.47 seconds (4 minutes 51 seconds)

4.7.4 Extract Overland Flow Path Features that do not Intersect Hydro Mask

This algorithm creates a new vector layer that only contains matching features from an input layer. The criteria for adding features to the resulting layer is defined based on the spatial relationship between each feature and the features in an additional layer.



4.7.4.1 Contributing Area $\geq 5\text{ha}$



Execution completed in 2.82 seconds

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.7.4.2 Contributing Area $\geq 2\text{ha} < 5\text{ha}$

Extract by Location

The dialog shows the following settings:

- Extract features from:** 2021_overland_flow_path_2ha_hydro_split []
- Selected features only
- Where the features (geometric predicate):**
 - intersect
 - touch
 - contain
 - overlap
 - disjoint
 - are within
 - equal
 - cross
- By comparing to the features from:** hydro_mask []
- Selected features only
- Extracted (location):** D:/Processing/LiDAR/2020/Whanganui_WhangaehuRiver2020LiDAR_Products/work/overland_flow_paths/2021_overland_flow_path_2ha_final.shp
- Open output file after running algorithm

Execution completed in 1.68 seconds

4.7.4.3 Contributing Area $\geq 1\text{ha} < 2\text{ha}$

Extract by Location

The dialog shows the following settings:

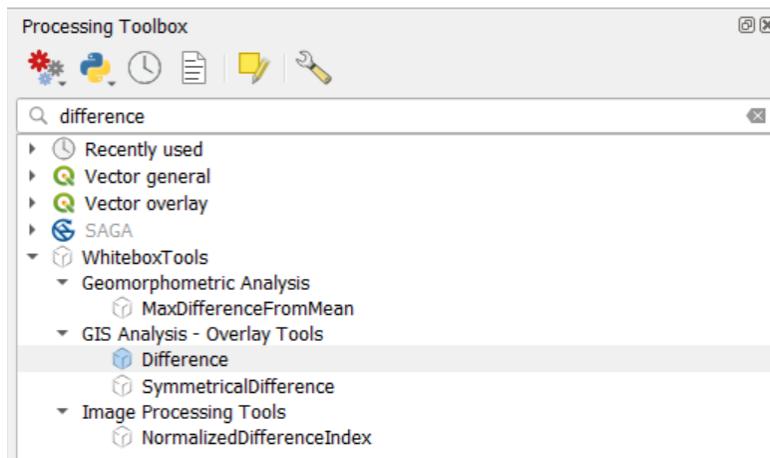
- Extract features from:** 2021_overland_flow_path_1ha_hydro_split []
- Selected features only
- Where the features (geometric predicate):**
 - intersect
 - touch
 - contain
 - overlap
 - disjoint
 - are within
 - equal
 - cross
- By comparing to the features from:** hydro_mask []
- Selected features only
- Extracted (location):** D:/Processing/LiDAR/2020/Whanganui_WhangaehuRiver2020LiDAR_Products/work/overland_flow_paths/2021_overland_flow_path_1ha_final.shp
- Open output file after running algorithm

Execution completed in 1.68 seconds

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.7.5 Extract Difference of each Vector Depression Area with Hydro Mask

The Whitebox Difference Algorithm outputs the features that occur in one of the two vector inputs but not both, i.e. no overlapping features.



4.7.5.1 Depression Area Depth > 0.3m



Execution completed in 731.59 seconds (12 minutes 12 seconds)



WhiteboxTools command:

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

```
"C:/WBT/whitebox_tools.exe" -v --run=Difference --
input="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_path
s\lidar2020_dem_depression_areas_greater_than_300mm_final.shp" --
overlay="C:\qgis_output\processing_ybtstw\fa9c8560e8a74e62af35cb459c0f39fa\overlay.shp" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat
hs\lidar2020_dem_depression_areas_greater_than_300mm_final_hydro_split.shp"
```

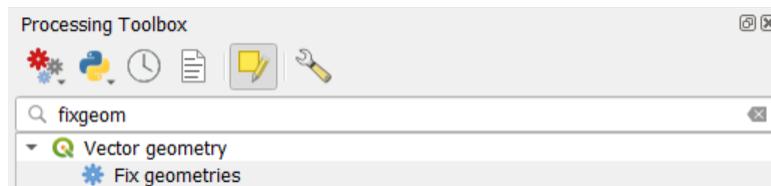
4.7.5.2 Fix Geometries

Select the **lidar2020_dem_depression_areas_greater_than_300mm_final_hydro_split** vector layer in the QGIS layer panel:



Enable the **Edit features in place** tool

Run **Fix geometries**



Note that a progress bar is displayed along the top of the map



Save the changes

On completion, disable the **Edit features in place** tool

Note – you may need to repopulate the **fid** column with the **row_number** to allow unique values if you intend to push this dataset to PostGIS or other spatial database and use the fid column as a primary key.

Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

4.7.5.3 Depression Area Depth <= 0.3m

Difference

Parameters Log

Input Vector File
lidar2020_dem_depression_areas_less_than_equal_300mm_final [EPSG:2193]    

Selected features only

Input Overlay Vector File
hydro_mask []    

Selected features only

Output Vector File
/Whanganui_WhangaehuRiver2020LiDAR_Products/work/overland_flow_paths/lidar2020_dem_depression_areas_less_than_equal_300mm_final_  

Open output file after running algorithm

Execution completed in 184553.77 seconds (51 hours 15 minutes 54 seconds)



WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=Difference --
input="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\lidar2020_dem_depression_areas_less_than_equal_300mm_final.shp" --
overlay="C:\qgis_output\processing_ybtstw\0c60de62cd64b1e8106e56915c8122a\overlay.shp" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_paths\lidar2020_dem_depression_areas_less_than_equal_300mm_final_hydro_split.shp"
```

4.7.5.4 Fix Geometries

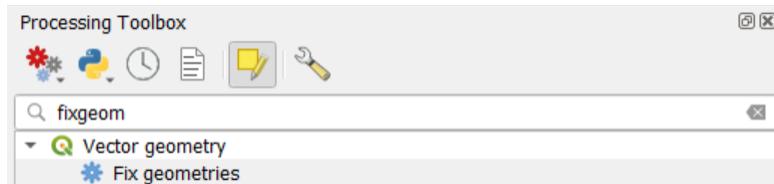
Select the **lidar2020_dem_depression_areas_less_than_equal_300mm_final_hydro_split** vector layer in the QGIS layer panel:



Methodology to Create Overland Flow Paths Using Hydrological Modelling Tools in QGIS

Enable the  **Edit features in place** tool

Run **Fix geometries**



Note that a progress bar is displayed along the top of the map



Save the changes 

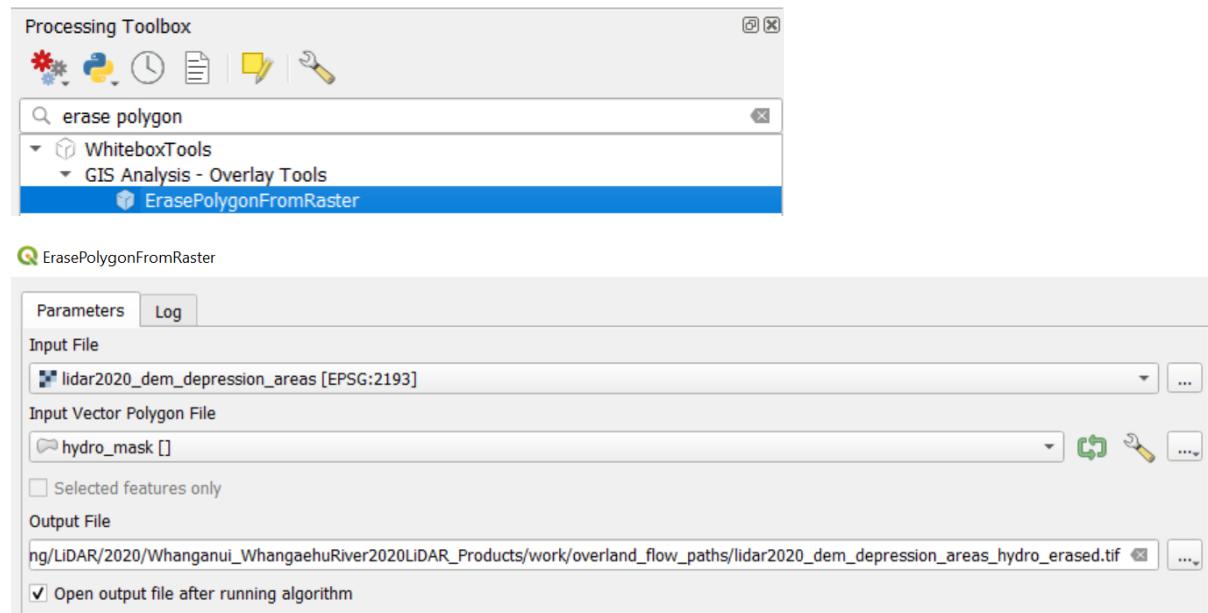
On completion, disable the  **Edit features in place** tool

Note – you may need to repopulate the **fid** column with the **row_number** to allow unique values if you intend to push this dataset to PostGIS or other spatial database and use the fid column as a primary key.

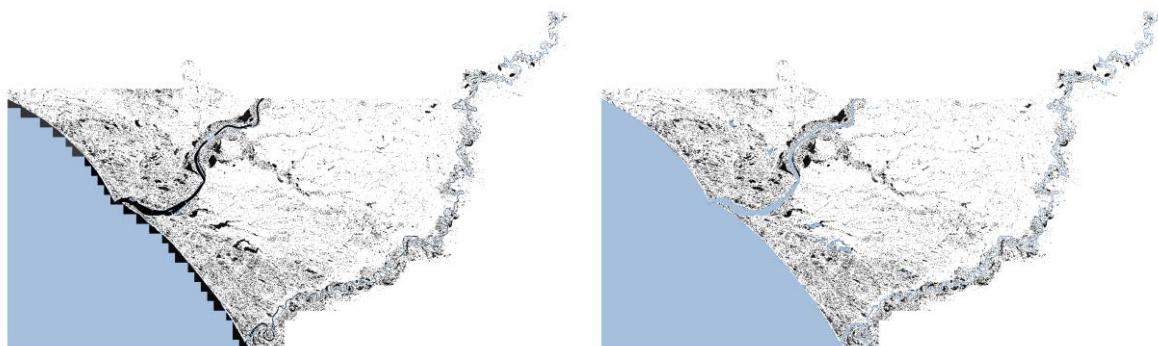
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4.7.6 Erase Hydro Mask polygon from Raster Vector Depression Area

Erases (cuts out) a vector polygon from a raster



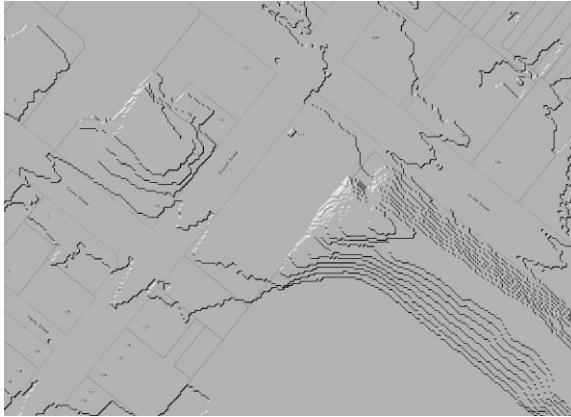
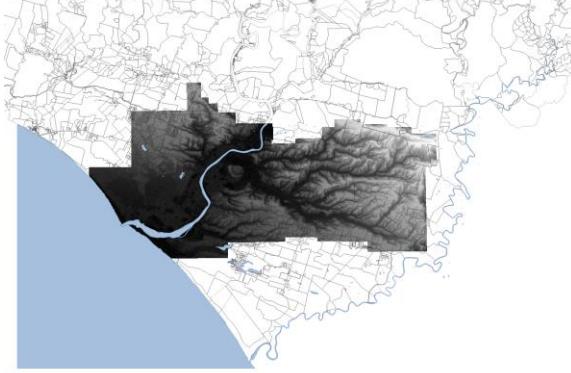
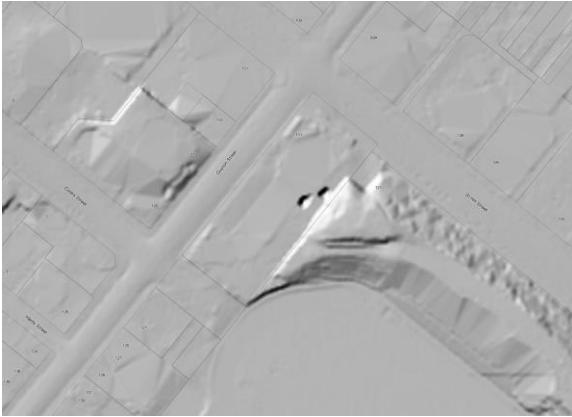
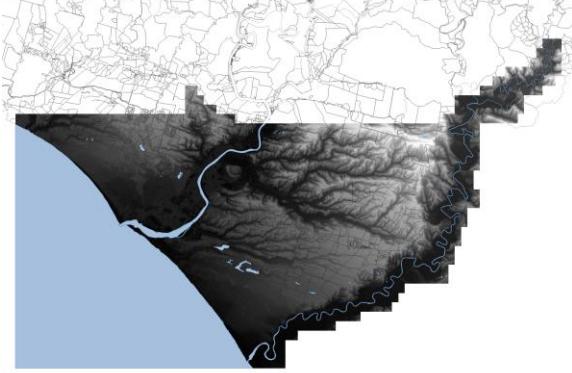
Execution completed in 13944.44 seconds (3 hours 52 minutes 24 seconds)



WhiteboxTools command:

```
"C:/WBT/whitebox_tools.exe" -v --run=ErasePolygonFromRaster --
input="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_path
s\lidar2020_dem_depression_areas.tif" --
polygons="C:\qgis_output\processing_VZsILO\aa151b9ae45645dca9c0b4dd8f651b5b\polygons.shp" --
output="D:\Processing\LiDAR\2020\Whanganui_WhangaehuRiver2020LiDAR_Products\work\overland_flow_pat
hs\lidar2020_dem_depression_areas_hydro_erased.tif"
```

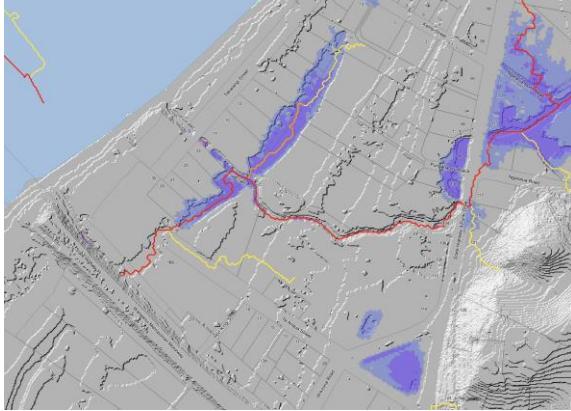
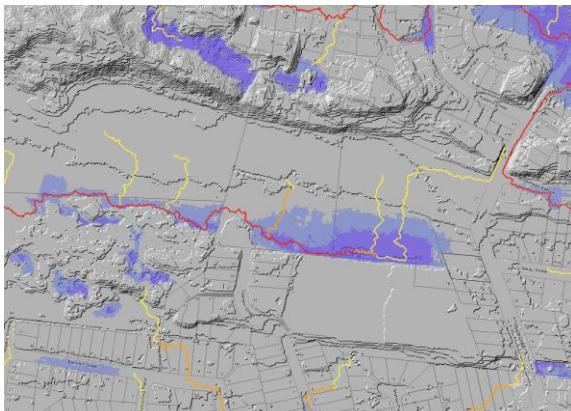
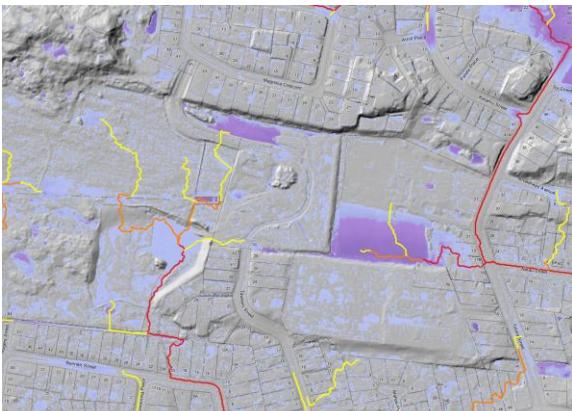
5 Comparison to previous Overland Flow Path Dataset

2013 Overland Flow Paths	2021 Overland Flow Paths
<p>In 2013, Wanganui District Council (WDC) commissioned Pattle Delamore Partners Ltd (PDP) to map overland flow paths for the Churton Creek catchment and other catchments in the Whanganui City area.</p> <p>https://hubble.whanganui.govt.nz/site/inf/waterm/Overland%20Flowpaths%20LiDAR%20Churton%20Creek.pdf</p>	<p>In-house mapping of overland flow paths and depression areas carried out Sept/Oct 2021 by GIS Lead.</p>
<p>Input:</p> <ul style="list-style-type: none"> • 2x2m DEM derived from LiDAR 2013  <ul style="list-style-type: none"> • Coverage area 258625806 m² 	<p>Input:</p> <ul style="list-style-type: none"> • 1x1m DEM derived from LiDAR 2021  <ul style="list-style-type: none"> • Coverage area 471271142 m² 
<p>Output:</p> <ul style="list-style-type: none"> • Three overland flow path series, generated from: <ul style="list-style-type: none"> ○ Contributing Area \geq 1ha < 2ha ○ Contributing Area \geq 2ha < 5ha ○ Contributing Area \geq 5ha • Depression areas: <ul style="list-style-type: none"> ○ Area exceeding 500 m² ○ Volume exceeding 50 m³ 	<p>Output:</p> <ul style="list-style-type: none"> • Three overland flow path series, generated from: <ul style="list-style-type: none"> ○ Contributing Area \geq 1ha < 2ha ○ Contributing Area \geq 2ha < 5ha ○ Contributing Area \geq 5ha • Depression areas: <ul style="list-style-type: none"> ○ Depth \leq 0.3m ○ Depth $>$ 0.3m

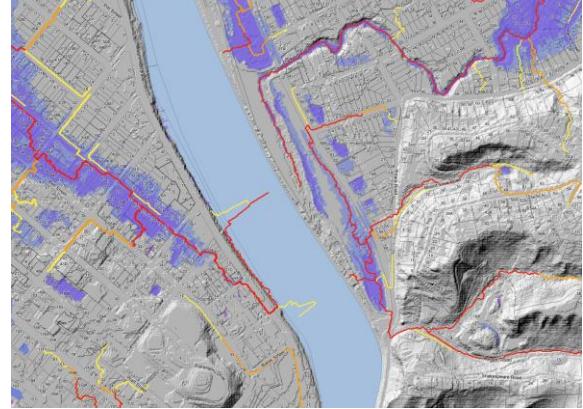
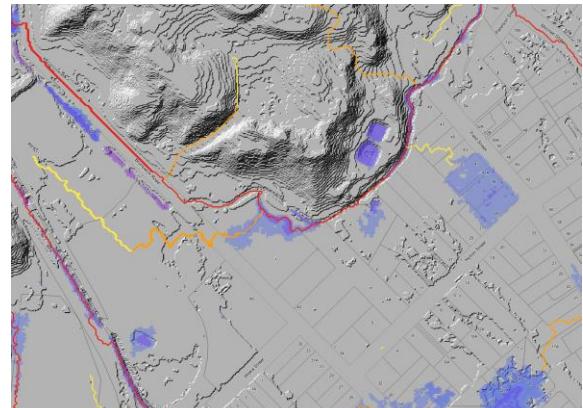
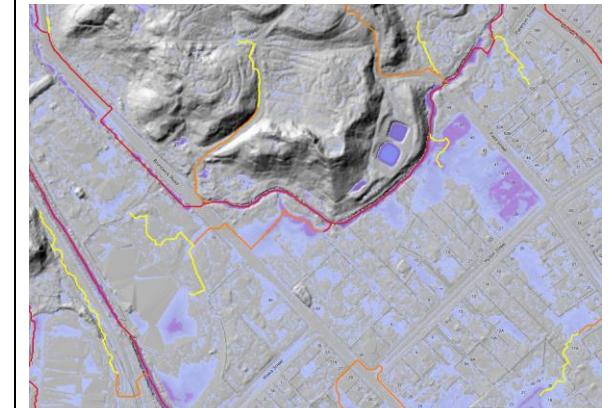
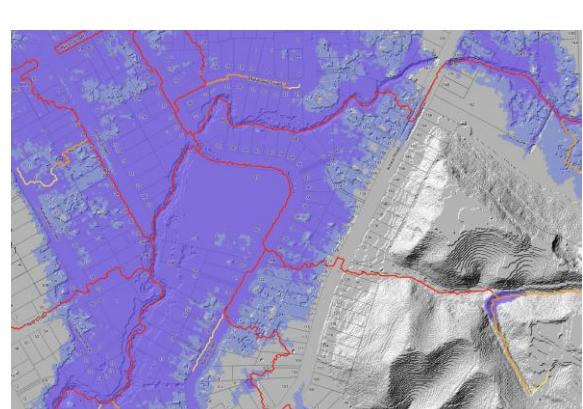
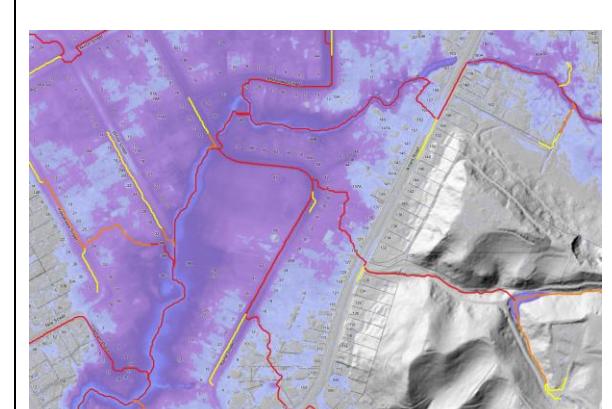
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<ul style="list-style-type: none"> ○ Max depth exceeding 0.3m 	
<p>Limitations: The following limitations apply to overland flow paths:</p> <ul style="list-style-type: none"> • Only the elevation of the topography is considered, there are no allowances for underground reticulation or land use. For example, stormwater reticulation may convey overland flow paths beneath the ground surface, and impervious areas are more likely to generate overland flow paths for pervious areas of a similar size; • Overland flow paths do not map the entire width of the flow, only what is likely to be its deepest point; • Velocity, depths and flows are not included; and • Buildings are not incorporated. <p>Limitations of depression area mapping include:</p> <ul style="list-style-type: none"> • Depressions have been mapped to their maximum extent. In some instances, the depressions may have a volume that exceeds that generated by a design storm event (such as the 1% AEP). The extent of fill for each generated depression area could be calculated, using design storm parameters and the catchment area raster; • No underground infrastructure has been included in the assessment, culverts would provide relief for depression areas; and, • Depression areas that intersect the physical house (not just the land parcel) may have a maximum potential depth of less than 300 mm and therefore may not be of concern. This could be addressed by checking each property listed to identify whether or not the physical house intersects the mapped depression area. 	<p>Limitations: The same limitations apply for both overland flow paths and depression areas to the 2021 dataset as were identified for the 2013 dataset.</p>
Comparisons	
Putiki	Putiki

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<p>The PDP 2013 Overland Flow Paths dataset does show potential errors.</p>	<p>Depression Areas are more clearly defined due to a higher resolution DEM</p>
<p>Tawhero Street</p> 	<p>Tawhero Street</p> 
	<p>The effect of development in this area is clearly displayed.</p>
<p>Anzac Parade 1</p> 	
	<p>Depression Areas are more clearly defined due to a higher resolution DEM</p>
<p>Anzac Parade 2</p>	<p>Anzac Parade 2</p>

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	 <p>Depression Areas are more clearly defined due to a higher resolution DEM</p>
<p>Brunswick Road</p> 	<p>Brunswick Road</p>  <p>Depression Areas and Overland Flow Paths are more clearly defined due to a higher resolution DEM</p>
<p>Ikitara Road</p> 	<p>Ikitara Road</p> 
<p>College Estate</p>	<p>College Estate</p>

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