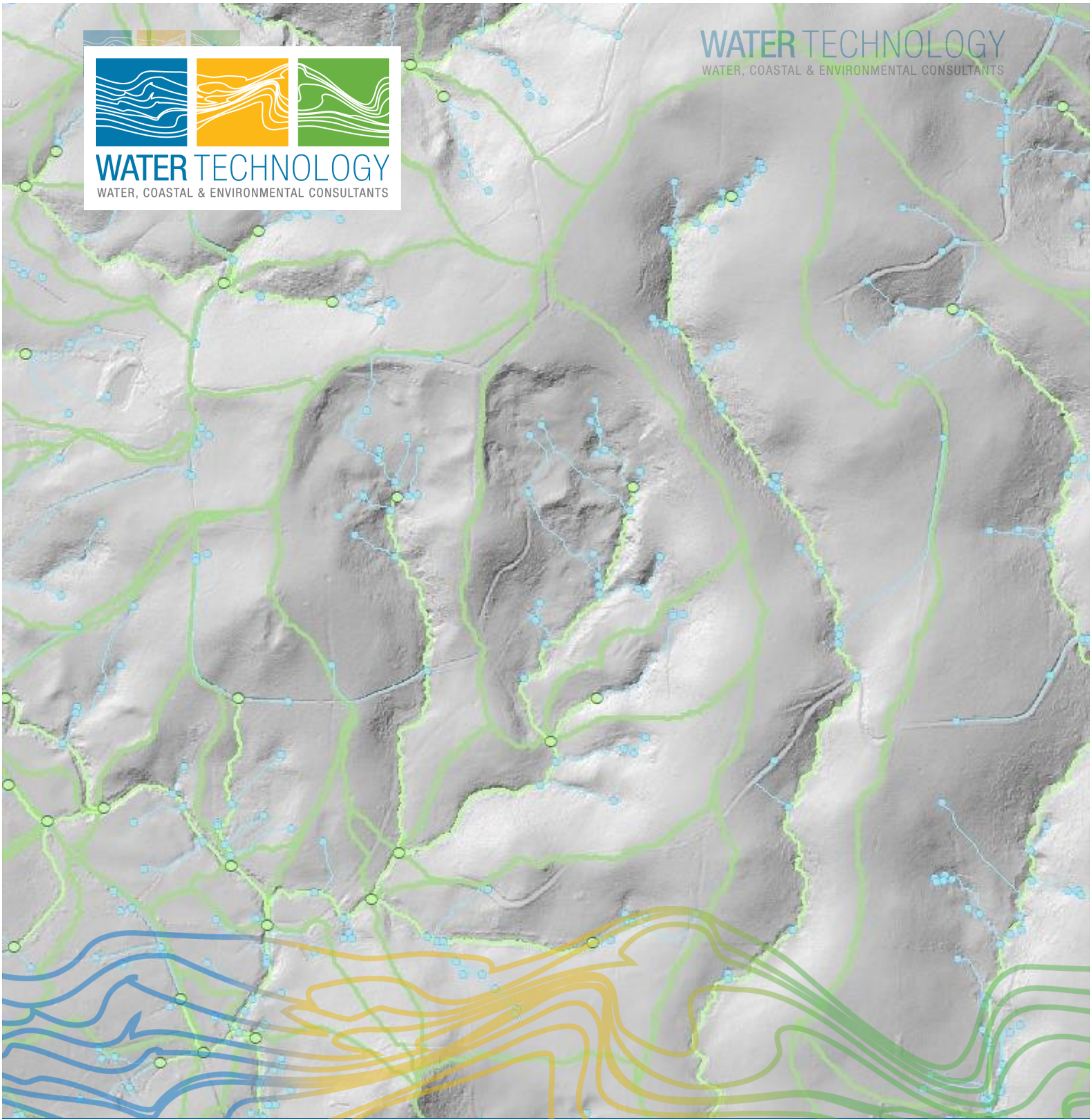

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High-Resolution Digital River Network for Northland

A GIS-based river network model derived from regional LiDAR

Prepared for Northland Regional Council

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	DRAFT	B SALMI	B SALMI	26.10.2022
V02	FINAL	B SALMI	B SALMI	18.01.2023

Project Details

Project Name	A GIS-based river network model derived from regional LiDAR
Client	Prepared for Northland Regional Council
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Document Number	22010283_R01V02.docx

RECOMMENDED CITATION

Charles, C 2023. High-resolution Digital River Network for Northland. A GIS-based river network model derived from regional LiDAR. Prepared for Northland Regional Council. Water Technology Report Number 22010283_R01V02.

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EXECUTIVE SUMMARY

A GIS-based digital river network model (DRN) has been produced for each of the thirteen Freshwater Management Units (FMU) which cover the Northland region of New Zealand. The intent of the DRN is to be used by Northland Regional Council (NRC) staff as the most accurate and detailed representation of the waterway network in Northland.

The DRN has been produced by conducting a catchment and drainage line analysis on a digital elevation model (DEM), at both 2ha and 0.2ha catchment size thresholds.

The DEM is based on recent (2020) LiDAR captured across the entire Northland region. Prior to the catchment analysis, the DEM was modified with 'burning' of hydraulic blockages to produce a *hydrologically-enforced DEM* (HE-DEM), which ensures that the delineated drainage lines follow their correct path as often as possible.

A suite of data attributes has been added into the key DRN GIS layers to make them useful for a range of analysis and modelling purposes in Northland. A quality assessment (QA/QC) process was developed and undertaken to assess the accuracy and suitability of the DRN. The QA/QC results indicate that the DRN data is within the 10% error limits, as sought for accuracy by NRC project team.

Having been derived from 1m-resolution LiDAR DEM data, the DRN represents a significant jump in scale, accuracy and detail compared to the existing River Environment Classification (REC) a national river network dataset. To provide an indication of the change in scale, Table 1-1 shows a comparison of the count of DRN catchments (2ha and 0.2ha) compared to the REC catchments, for each of the thirteen FMUs.

Table 1-1 Comparison of the number of REC versus DRN catchments for each FMU

FMU Name	REC Catchments	DRN Catchments (2ha)	DRN Catchments (0.2ha)
Aupōuri	1,981	29,645	277,522
Awanui	1,398	24,321	188,307
Bay of Islands	2,995	41,210	370,904
Bream Bay	1,006	15,018	113,236
Doubtless Bay	1,337	18,031	155,008
Herekino and Whāngāpē	1,422	20,297	176,473
Hokianga	3,789	53,197	459,648
Northern Wairoa	11,050	145,558	1,288,720
Poutō	651	13,542	87,321
Waipoua	873	12,044	97,732
Whananaki Coast	1,311	17,980	147,943
Whangārei	658	12,113	86,506
Whangaroa	1,087	14,982	128,455

For the 2ha DRN catchments, this equates to roughly a fifteenfold increase (one order of magnitude greater) in the number of catchments when compared to the REC network, or over a hundredfold increase (two orders of magnitude greater) when considering the 0.2ha DRN catchments.

A visual comparison of the existing REC river network, and the new DRN is shown in Figure 1-1.

The DRN data clearly provides a significantly higher level of spatial resolution, detail and accuracy when compared to the REC network.

In this figure there are eight 2ha DRN catchments (and many more 0.2ha catchments, not shown) within a single REC catchment, and the DRN waterways clearly follow the drainage lines in a much more accurate manner than the REC river lines. The REC catchment boundary also erroneously cuts across the middle of a gully in the Northeast part of the map.

This report describes the processing steps and data sources that have been used to produce the DRN, with the intention that the DRN could be updated in the future, by following the processing steps outlined in this report in combination with new or improved input data sources.

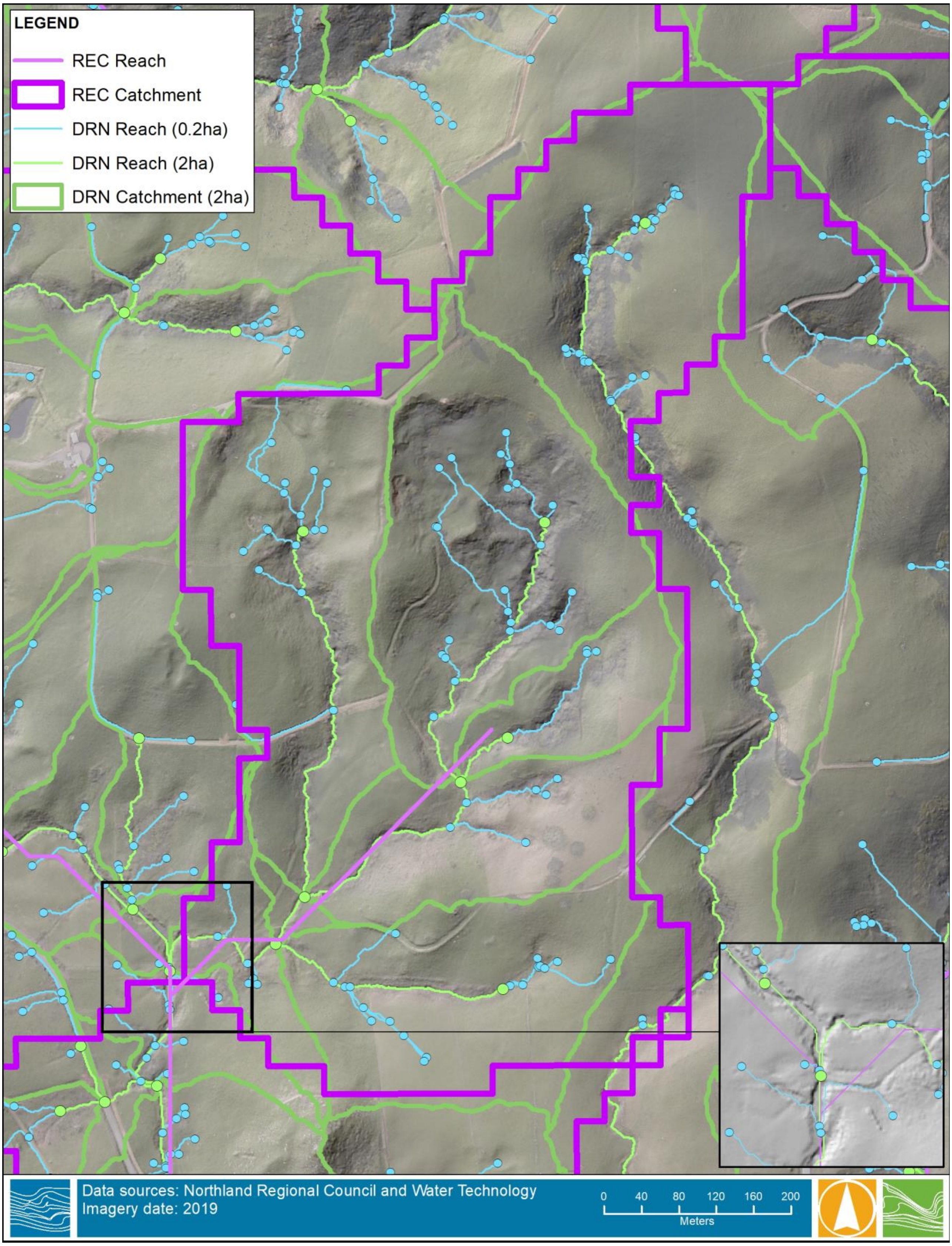

Figure 1-1 Comparison of DRN and REC catchments and waterways

GLOSSARY

Term	Definition
Burn line	A line used to create an artificial channel in a DEM through a blockage such as a culvert. Burn lines are used in the process of creating a HE-DEM.
Catchment	The area of upstream land draining into a particular location. A catchment can be delineated at any location, and at varying scales. For example, a catchment could refer to an entire river basin made up of multiple watersheds, or it could refer to any particular point along a waterway network. The terms ‘catchment’ and ‘watershed’ are somewhat interchangeable as they can at times refer to the same area.
DEM	A Digital Elevation Model (DEM) is a digital representation of a surface (usually the land) in the form of a regular grid of cells or pixels.
Drainage divide	The boundary between watershed areas.
Depression area	An area within a DEM which is lower than the surrounding cells, also referred to as a ‘sink’ or ‘pit’.
Drainage line	A digital line feature representing a waterway.
HE-DEM	Also referred to as HydroDEM. This is a ‘hydrologically-enforced’ DEM, which is a terrain model such as a LiDAR DEM, which has been modified to enable hydrologic models to simulate flow under bridges, through culverts and through other artificial ‘blockages’ in the DEM.
Hillshade	A method of displaying a DEM which uses an assumed position of the sun to display shadows and highlights that help the viewer visualize the DEM surface as a 3D representation.
Junction point	A start or end point of a waterway reach, or a confluence point where two reaches converge.
LiDAR	Light Detection And Ranging (LiDAR) is a measurement technology which can be used to determine land heights via aerial survey. The height measurements taken by a LiDAR sensor can be converted to a gridded digital elevation model dataset for use in modelling and mapping of terrain.
MHWS	Mean High Water Springs (MHWS) is an average high tide height throughout the year. Specifically, it is the long-term mean of the heights of 2 successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of tide is greatest, during full and new moon.
Reach	A single segment of a waterway, between one junction point and another.
Watershed	The area of land draining into a particular stream, river, or lake. The terms ‘catchment’ and ‘watershed’ are somewhat interchangeable as they can at times refer to the same area.

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1 INTRODUCTION

Water Technology has developed for the Northland Regional Council a GIS-based river network with a higher spatial resolution compared to the existing River Environment Classification (REC) model originally developed by NIWA for entire New Zealand. This Northland Digital River Network (DRN) comprises of watersheds and stream reaches delineated at both 2ha and 0.2ha drainage area thresholds and has been developed using a Hydro-Enforced Digital Elevation Model (HE-DEM) based on recent LiDAR capture for the Northland Region.

This report describes the processing steps and data sources that have been used to produce the DRN, with the intention that the DRN could be updated at an appropriate time in the future, by following the processing steps outlined in this report in combination with new or improved input data sources.

1.1 Background

The existing REC river network is based on national scale topographic data and is coarse, outdated and often erroneous. The National Environmental Standard for Freshwater (NES-F) and National Policy Statement for Freshwater Management (NPS-FM) require Regional Councils to undertake freshwater accounting (for allocation and water quality). This requires the use of digital river network for GIS-based modelling with less uncertainly at catchment and/or sub-catchment level. Freshwater accounting based on the existing REC river network data would result in a high level of uncertainty. The outputs from the DRN project would have the potential to improve the accuracy of existing models and provide useful tools for implementing land management mitigation measures at farm scale.

Use of the DRN will increase:

a. the accuracy of GIS-based water quantity and quality models and therefore increase users' confidence in setting water quality limits for the Regional Plan change,

b. assistance with planning of land management mitigation measures for improved water quality,

c. assistance with catchment delineation, and

d. assistance with the implementation of the NPS-FM.

1.2 General processing steps for producing the DRN

The DRN has been produced in the ArcGIS software suite using the following general steps:

1. Development of a Hydro-Enforced Digital Elevation Model (HE-DEM) for the entire NRC region by 'burning' of hydraulic blockages in the LiDAR.
2. Initial catchment analysis for delineation of accurate Freshwater Management Unit or FMU boundaries and splitting the HE-DEM by each FMU for processing of DRN spatial dataset.
3. Processing of catchments, drainage lines and junction points at both 2ha and 0.2ha catchment thresholds, for each FMU.
4. Processing of additional reference spatial datasets to add required attributes to the DRN layers.
5. Performance measurement (QA/QC) of the DRN.

2 DEVELOPMENT OF HE-DEM

The ArcGIS ArcHydro package of tools was used for the DEM processing. ArcHydro is a package of tools and techniques used within the ArcGIS software which is specifically designed for catchment analysis and DEM terrain processing tasks such as creating HE-DEMs and generating attribute-linked watershed and river networks.

2.1 LiDAR data

The DRN has been produced using LiDAR data flown across the entire Northland region in May 2020. Prior to commencement of the DRN processing, the latest version of the LiDAR DEM data was passed from NRC to Water Technology to ensure the very latest data was being used. Approximately 40,000 1km x1km LiDAR tiles were mosaicked together to produce a single DEM file.

2.2 Depression areas

A 'depression evaluation' was processed on raw 1m LiDAR DEM file. This is a single ArcHydro tool which produces a GIS polygon layer of depressions in the terrain (sometimes referred to as 'sinks' or 'pits'). Depressions are a group of DEM cells which are surrounded by cells of a higher elevation (such as the bottom of a farm dam), and thus a flow direction cannot be determined. Depressions can occur in a LiDAR DEM where there are natural lakes, constructed dams, or on the upstream side of an embankment such as a levee, road or railway embankment.

To ensure a flow direction can be determined and a continuous drainage network can be delineated, all depression areas within a DEM need to be 'filled', prior to determining flow direction and accumulation. This process results in a 'hydro-flattened' DEM, where all depression areas are 'filled' up to the level of their lowest surrounding cell. This cell will thus become the 'outflow' location for the depression area, and enable a continuous drainage network to be determined across the depression area, and onwards downstream.

At a regional scale, the filling of minor depressions does not greatly affect the suitability of a GIS-generated stream network, however the filling of major depression areas can pose a problem, because the location of the outflow point (lowest surrounding cell), may not be located where the flow would actually exit that area. The output depression area GIS layer includes key characteristics such as 2D area, volume, bottom level, fill level, sink depth etc. This output was used to classify all 'major' depression areas using the following criteria: >0.5m depth AND >5,000m^3 volume, OR >20,000m^2 2D area.

Figure 2-1 shows an example of a major depression area (purple polygon, with key characteristics labelled) which was present in the raw LiDAR DEM on the upstream side of a major culvert. The figure shows the improvement in delineated drainage lines (blue lines) when a burn line has been created for that culvert, resulting in the depression area being drained (not filled) in the HE-DEM. The green lines represent the drainage lines if the burn line is not created, and the depression area is filled (not drained). The outflow point is clearly not in the correct location as shown in the inset map of the Figure 2-1. The inset map shows that the burn line has been placed in the true culvert location, where the waterway goes under the road.

Thousands of 'major' depression areas were identified across the Northland region, and a process of creating burn lines to 'unblock' the major depression areas, along with other potential blockages at bridges and culverts, was undertaken prior to processing the DRN streams and catchments. It should be noted that it is not feasible to create burn lines for all major depression areas, so priority was given to those which were the largest, which were not existing waterbodies, or were deemed to have the greatest impact on the suitability and accuracy of the drainage network.

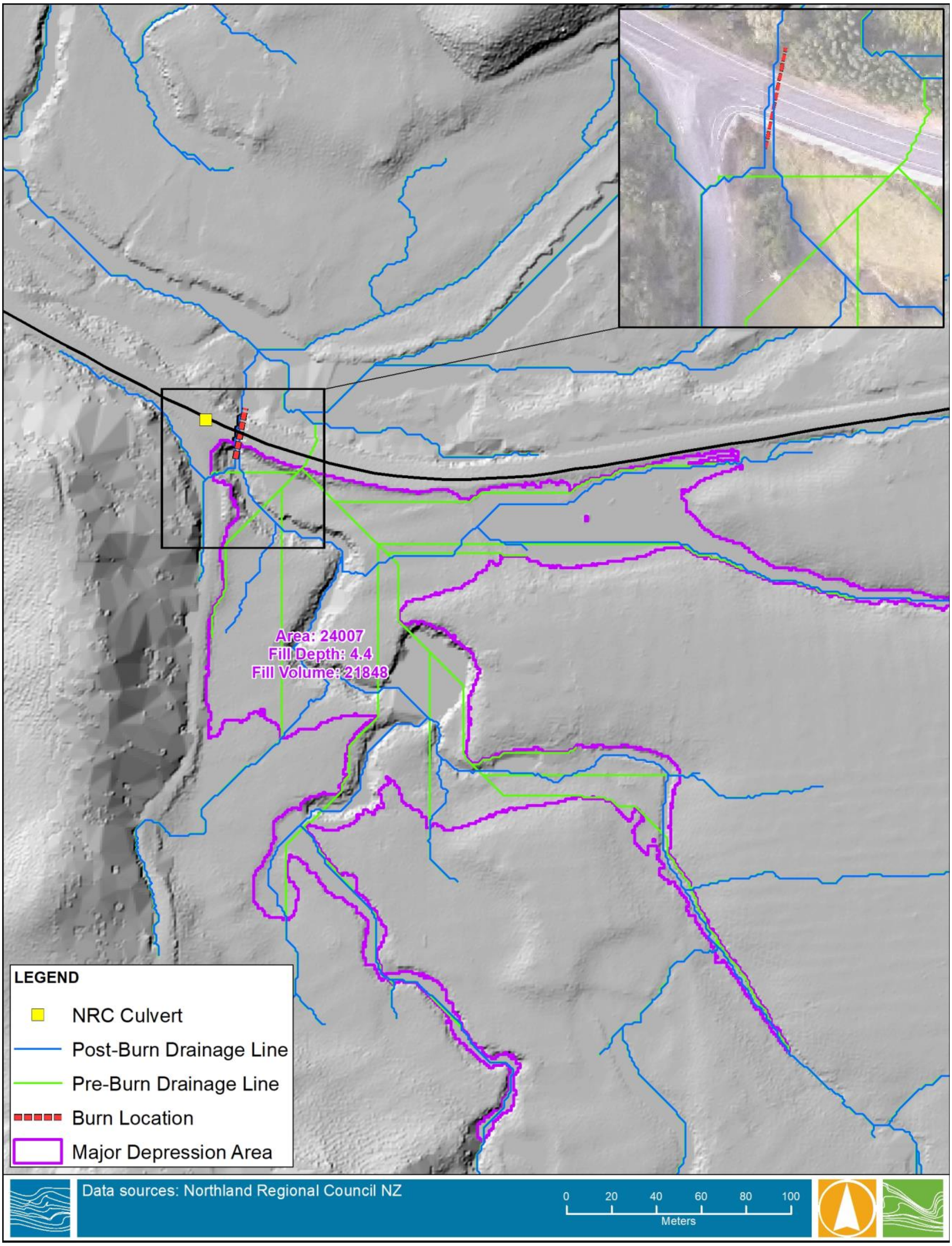


Figure 2-1 Depression area and improved drainage lines after creating a burn line at the culvert under the road.

2.3 Burn lines

As many 3D burn lines as possible (28,000+) were then subsequently created across all thirteen FMUs for the following scenarios:

- To drain the 'major' depression areas; and
- At locations of known hydraulic structures (as per spatial data provided by NRC) which create an upstream blockage, noting that:
  - Structure dimensions were not present in the Northland Transportation Alliance (NTA) and New Zealand Transport Agency (NZTA) data provided.
  - Burn lines were set at 2m or 5m width, based on visual interpretation of the waterway width.
  - Priority was given to NZTA major culvert locations and low-lying floodplain areas.

Burn lines were digitised in the GIS and then used in the ArcHydro package to create a 'burnt' version of the LiDAR DEM, where a 10m deep artificial channel is burnt into the LiDAR DEM along the burn line. The effect of creating the 10m deep channel is that the depression area or blockage is removed, and the flow direction and accumulation will be forced to follow the correct outflow point of the depression area or blockage.

Burn lines are only placed if the correct outflow location can be identified. A hillshaded version of the LiDAR DEM, existing 1:50K NZ river lines, structure data from NRC, and 25cm-resolution aerial photos from 2019 were all used to identify the correct outflow locations where burn lines were placed.

An example of some hydraulic structures (culverts) where 'burning' was undertaken is shown in Figure 2-2, and the resulting burnt DEM and output DRN drainage lines is shown in Figure 2-3.

In the first image, a hillshade version of the original LiDAR DEM has been shown underneath the aerial photo, and it's clear that these culverts would create a blockage when delineating a drainage network. The red arrows show where the burn lines would be drawn to 'unblock' these blockages.

In the second image, the 'burnt' version of the DEM is shown. The artificial channel created by the burn lines is clearly visible, and the resulting DRN drainage lines clearly follow the correct flow path under the roads and onwards downstream.

Figure 2-2 Culverts where burning is required

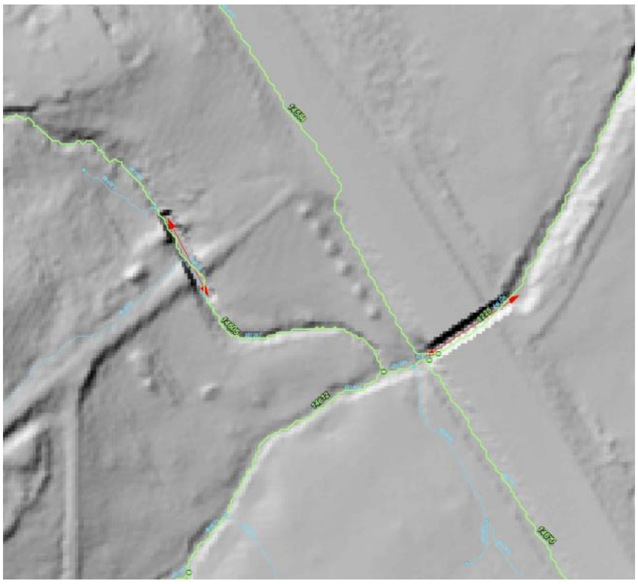


Figure 2-3 Burnt culverts and resulting DRN

2.4 River centrelines

In addition to the blockage burn lines, over 400 waterway centrelines were digitised along major (wide) waterways and used as burn lines in the HE-DEM, to ensure that the DRN waterway lines were delineated down the centre of the river. This is demonstrated in Figure 2-4, where the processed DRN drainage lines can be seen along the middle centreline of the river area.

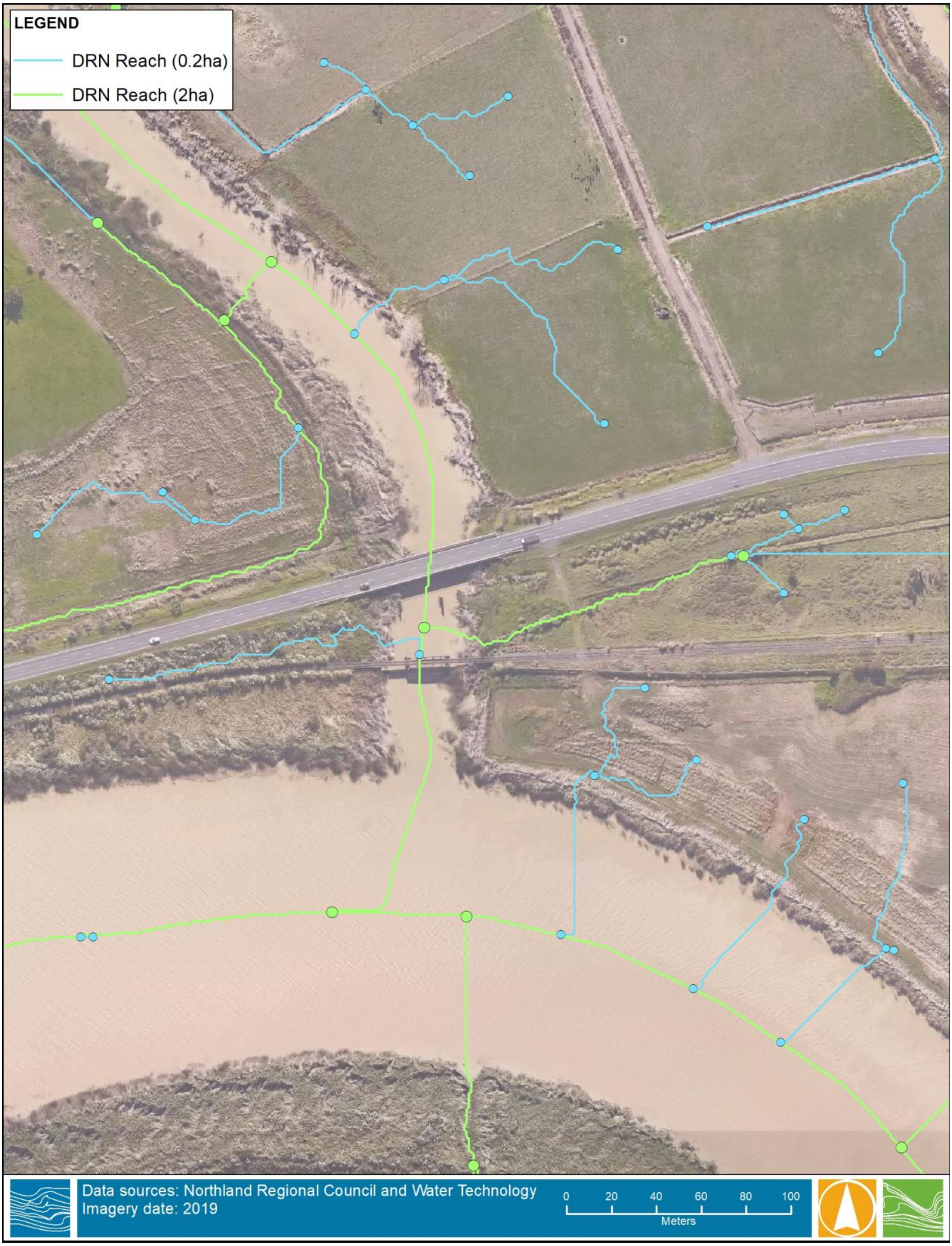


Figure 2-4 River centreline delineation

3 DELINATION OF FMU BOUNDARIES

NRC provided Water Technology with a GIS layer of FMUs to be used for splitting and delivering the DRN data. The thirteen FMUs are shown in Figure 3-1.

Initial testing of ArcHydro tools showed that it would not have been possible to process the DRN as a single regional file, due to the extremely large number of reaches and drainage lines to be produced, and large size of files generated during the geoprocessing. Water Technology thus split the HE-DEM up into thirteen separate files using FMU boundaries, to process the DRN for each FMU separately. Northern Wairoa FMU was delivered first by Water Technology, with a draft DRN for Northern Wairoa produced by 30th May 2022.

Figure 3-1 Freshwater Management Units (FMUs) Provided by NRC

3.1 Issues with first iteration due to coarse FMU boundary

Once the draft DRN for Northern Wairoa and other FMUs were processed and delivered, a problem at the FMU boundaries was identified. The Northland FMU boundaries layer had been produced by merging REC watersheds, which are derived from a coarser DEM dataset (30x30m satellite DEM data), and thus when compared closely to the new 1x1m LiDAR DEM at very high level of detail, the FMU boundaries did not align perfectly with the actual drainage divide.

A result of using Northland FMU boundaries layer to clip the LiDAR before processing the DRN data individually for each FMU was that there were areas near the drainage divide which had not been processed as well as they could be. These areas were located between the FMU boundary (GIS layer) and the actual drainage divide (e.g., black hatched areas on Figure 3-2). These areas of discrepancies between NRC FMU boundaries and LiDAR derived catchment boundaries were up to 100-200m wide in some places. The original Northland FMU boundaries (GIS layer) are represented by the thick black line on Figure 3-2.

This FMU boundary issue was resolved by delineating a more accurate drainage divide between FMUs using some additional catchment analysis of the 1m LiDAR DEM. The green line on Figure 3-2 shows the more accurate catchment delineation between FMUs representing an improved version (GIS layer) of Northland FMU boundaries by using high resolution LiDAR DEM.

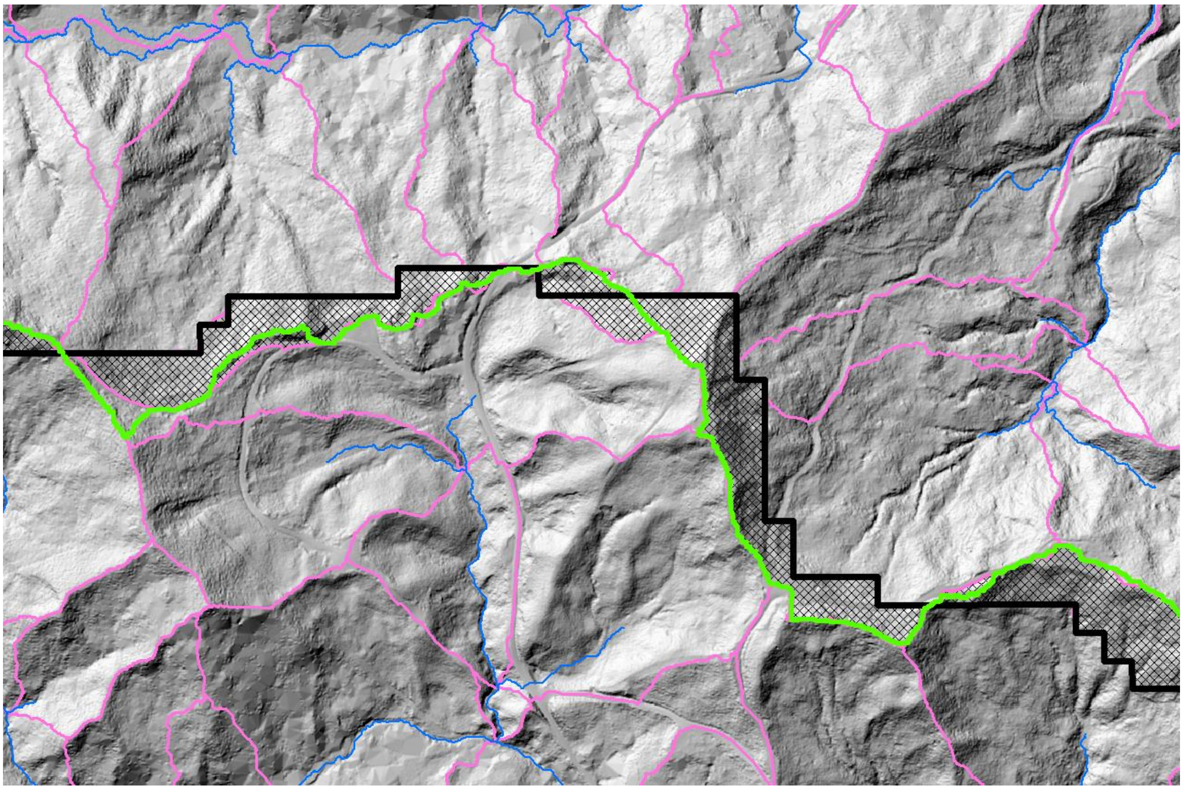


Figure 3-2 The discrepancy of catchment areas (black hatched areas) between the NRC FMU boundary (thick black line) and the improved FMU boundaries (green line) using NRC LiDAR.

This new and more accurate version of Northland FMU boundaries (GIS layer) based on LiDAR was subsequently used to split the HE-DEM by FMUs and re-process the DRN spatial dataset for final submission to NRC.

3.2 Coastal boundary

A GIS file representing the Northland coastline, defined by the current Mean High Water Springs (MHWS) level, plus a 10% AEP (Annual Exceedance Probability) sea level increment, was provided to Water Technology by NRC to use for defining the seaward limit of the DRN.

This step was required because the LiDAR DEM data is provided as 1km x 1km tiles, and along the coastline the data generally extends offshore into the water, to the edge of the 1km x 1km tile.

Given the DRN processing is based on the LiDAR data, if this step is not completed the DRN datasets would also extend into those offshore areas. This situation is demonstrated in Figure 3-3, where the LiDAR DEM (grey shading) can be seen to extend some distance offshore, but the DRN data stops at the coastline (MHWS), represented by the yellow line.

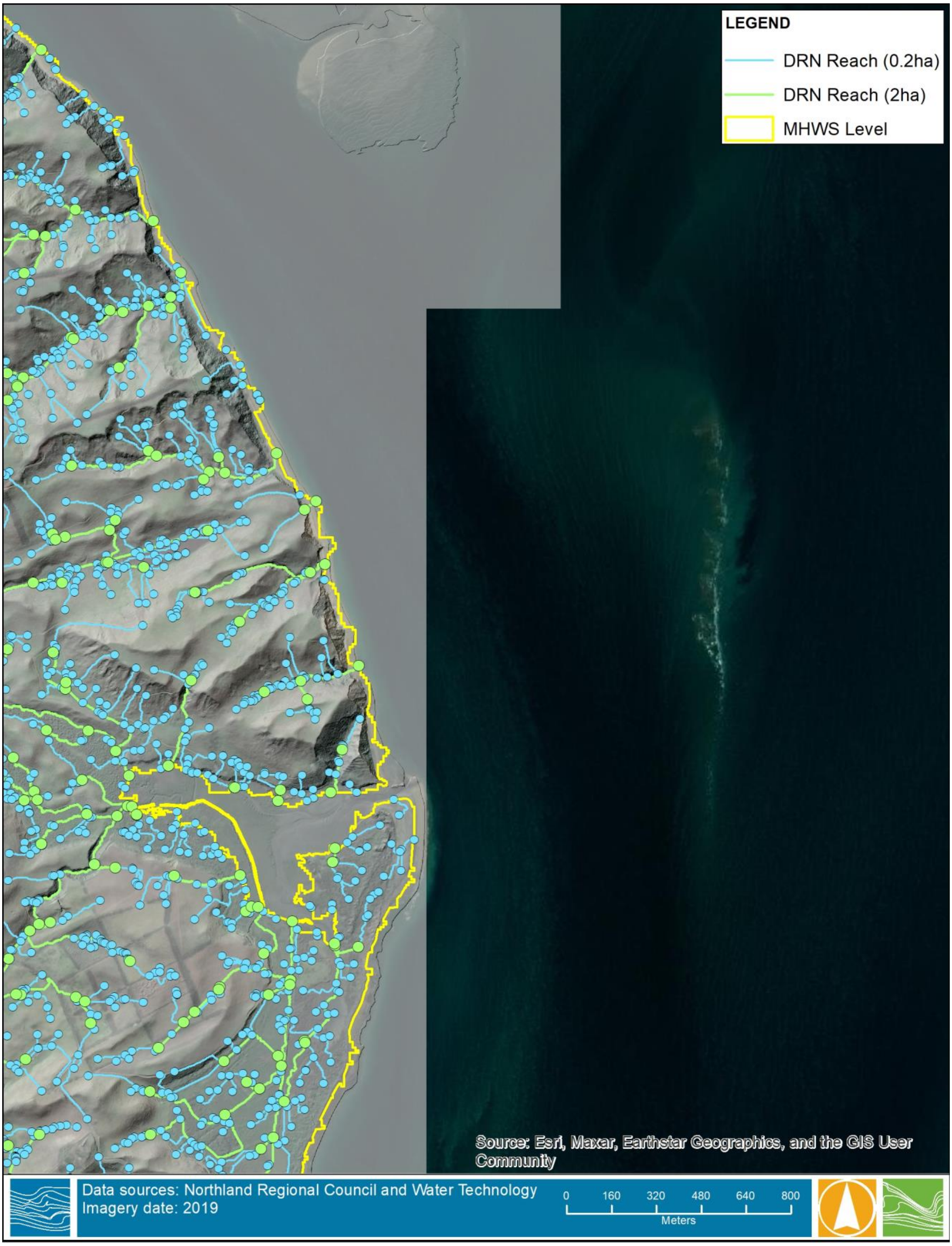


Figure 3-3 Mean High Water Springs **(**MHWS) level used to limit DRN data at the coastline.

3.3 Splitting by FMU for data processing

The revised, more accurate FMU boundaries produced by Water Technology, and the coastline delineation provided by NRC, were then used to clip the hydrologically-enforced (burnt) LiDAR DEM into separate HE-DEM files for each FMU, so that processing of the DRN layers could be completed for each FMU.

The separate HE-DEM file for the Northern Wairoa FMU is demonstrated in Figure 3-4.

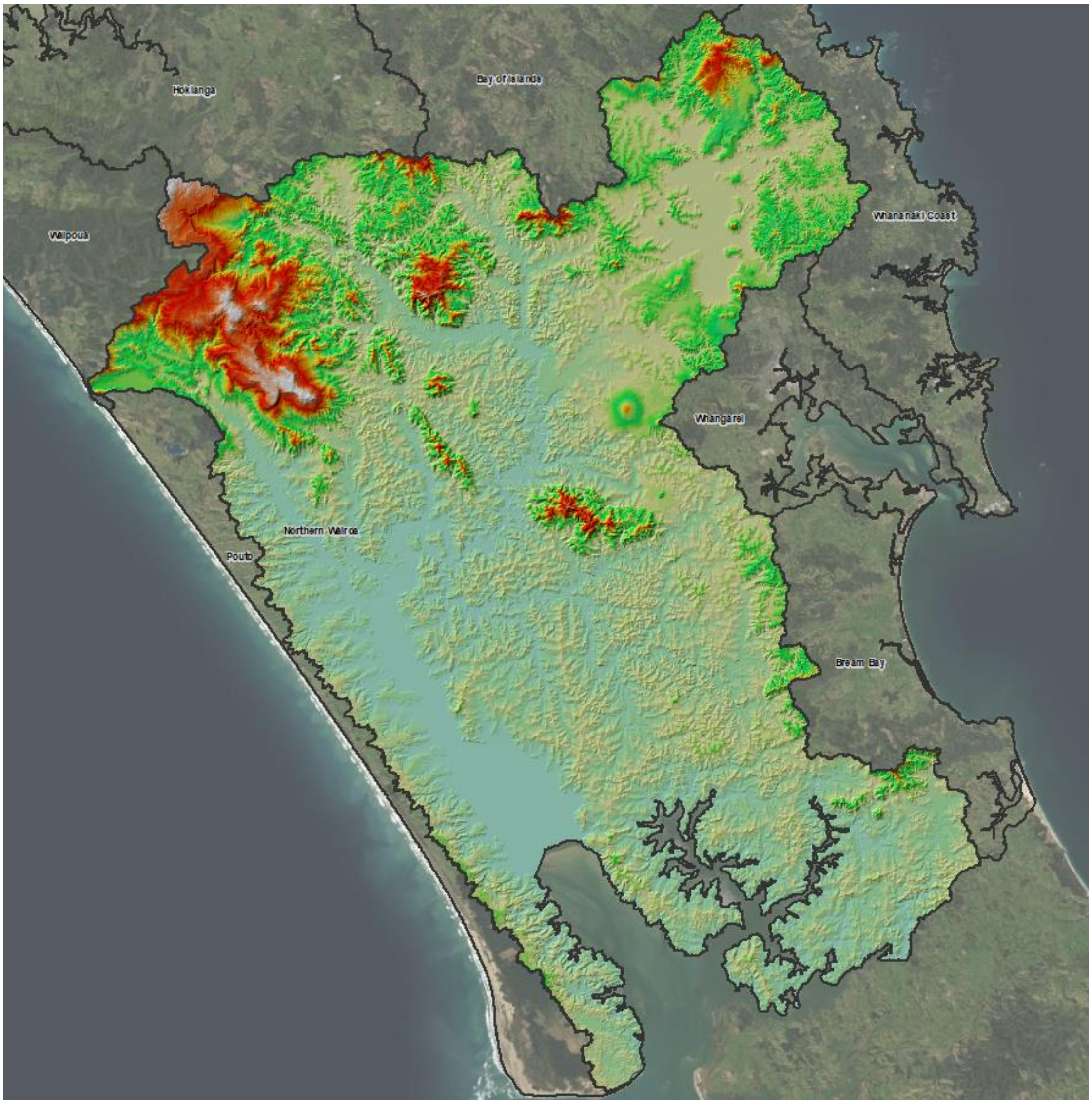


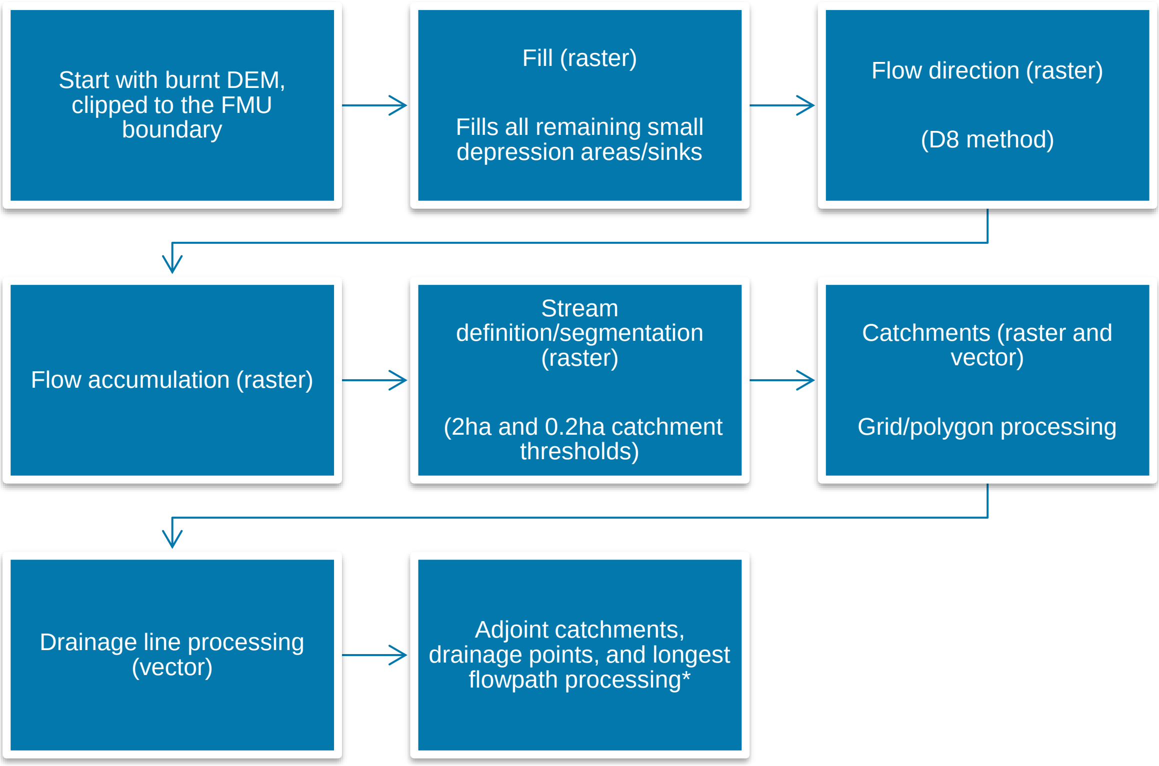
Figure 3-4 Hydro-Enforced Digital Elevation Model (HE-DEM) for Northern Wairoa FMU.

4 DEVELOPMENT OF DRN SPATIAL DATASETS

The ArcHydro package in ArcGIS was used to produce the DRN spatial datasets. The starting point for DRN processing is the HE-DEM file for each FMU.

4.1 ArcHydro processing steps

The general process steps undertaken with the ArcHydro package to produce catchments and drainage lines is demonstrated below. The process produces both raster and vector data outputs:



- The starting point is the 'burnt' HE-DEM raster file, clipped to a particular FMU boundary (as defined by the improved, more accurate LiDAR-derived FMU boundaries).
- Fill: a hydro-flattened elevation raster in which all depressions (or sinks) are filled up to the level of their lowest outlet point, to ensure that flow direction and a continuous flow accumulation can be produced.
- Flow direction: a raster where cell values represent the flow direction from each cell in a DEM to its steepest downslope neighbour. The output of the flow direction tool run with the 'D8' flow direction type is an integer raster whose values range from 1 to 128, as specified in Figure 4-1.

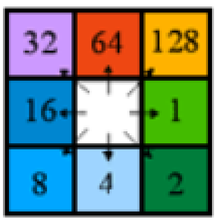


Figure 4-1 D8 flow direction raster values

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- Flow accumulation: a raster where each cell value represents the number of contributing cells flowing into the target cell, determined using the flow direction raster.
- Stream definition: a raster representing a stream network, produced by querying a flow accumulation raster to find cells with high contributing flow, based on a user-defined threshold.
- Stream segmentation: a raster representing individual streams with unique IDs, produced by splitting the stream definition raster at each stream intersection.
- Catchment (raster): a raster which represents individual catchments, whereby each cell contains the value of the corresponding stream segment that drains that area, thus linking the catchment to the individual stream segment.
- Catchment (polygon): a vector version of the catchment rasters, which includes the source catchment raster ID, its own unique ID and the unique ID of the next downstream catchment.
- Drainage lines: a vector version of the stream segmentation raster, which includes the source stream segment raster ID, its own unique ID and the unique ID of the next downstream drainage line.

*Adjoint catchments, drainage points and longest flowpaths are also produced as part of the ArcHydro process. These layers are not included in the final DRN database, but they are required for calculating certain attributes belonging to the DRN drainage lines and catchments.

A description of these three datasets is given below:

- Adjoint catchments: these are aggregated upstream catchments. For each catchment that is not a headwater catchment, a polygon representing the entire upstream area draining to its outlet point is constructed and added into the adjoint catchment layer. These are used to calculate upstream contributing area, slope, and longest flowpath.
- Drainage points: these are the outflow location for each catchment (i.e., the location with the largest flow accumulation for that catchment). These are used to relate catchments to adjoint catchments (by way of shared unique ID).
- Longest flowpaths: these are the longest possible flowpaths within each catchment and adjoint catchment, from the drainage point upstream to the furthest point, following the flow direction raster upstream. These are used to calculate hydraulic parameters such as time of concentration.

4.1.1 Determining 2ha and 0.2ha catchments

The stream definition step is used to control the density of the delineated catchments and drainage lines, and it requires some user-input to specify the required flow accumulation threshold. For a 1m-resolution flow accumulation raster, a threshold of 20,000 cells was used to produce 2ha stream segments and catchments, and a threshold of 2,000 cells was used to produce 0.2ha stream segments and catchments.

This means the upstream starting point (or headwater point) of a stream segment is located where there is an upstream contributing area of 2ha or 0.2ha.

It should be clearly noted that this does not mean the resulting catchments are 2ha and 0.2ha in size, rather it means that 2ha and 0.2ha is the *minimum* size a headwater catchment can be when using those thresholds. The actual size of each catchment depends on the nature of the stream network, specifically the distance downstream until the next junction point. Mid-stream (non-headwater) catchments do not follow the flow accumulation threshold; their size and shape depend on the nature of the stream network and the location of the next downstream junction point.

The key outputs from the ArcHydro process that form the DRN include the catchments (vector polygons) and drainage lines (vector lines). Because the 2ha and 0.2ha catchments are produced from the same flow accumulation raster they have parent-child relationship, which means that there will be multiple 'child' 0.2ha catchments fitting neatly inside one 'parent' 2ha catchment. Again, it should be noted that this does not mean there will be exactly ten 0.2ha catchments inside one 2ha catchment. The number of 0.2ha catchments will depend on the nature of the stream network.

4.2 Junction points and crossing layers

4.2.1 Junction points

Headwater (start nodes) and midstream junction points, representing the start and end point of each individual stream reach, were also produced for both the 0.2ha and 2ha waterway reaches. Each junction point has the unique ID of its upstream (multiple) and downstream (single) waterway reaches within the attributes, although headwater junction points only have the downstream ID.

It should be noted that there are no 'duplicate' junction points, meaning a single midstream junction point represents the 'end point' for all upstream reaches flowing to that location. It is important to derive the hydro-junction points layer with no duplicates, as this will aid in catchment delineation process (e.g., by running the Trace Network tools in ArcGIS Pro) upstream or downstream of any stream junction point. This means the hydro-junction points layer (together with DRN watersheds) will help in delineating capture zones or cumulative catchment areas upstream of any monitoring location.

4.2.2 Final DRN datasets

These ArcHydro products (catchments, drainage lines, and junction points) represent the 'key' datasets making up the Digital River Network.

The layers have been compiled into a separate ESRI File Geodatabase for each FMU, with consistent layer naming conventions as demonstrated in Figure 4-2, where '2ha' refers to 2 hectares, and '2k' refers to 0.2 hectares (or 2,000m²).

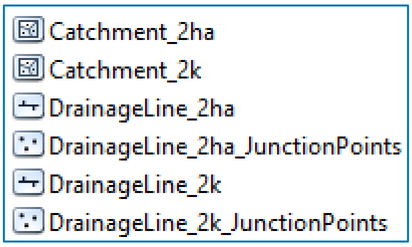

Figure 4-2 Key DRN vector datasets

An example of the final DRN network is presented in Figure 4-3, which focussed on a specific 2ha catchment (with watershed ID number 118). The waterway reach with matching ID number (118) is also shown, as are the contributing or 'child' 0.2ha catchments, and their linked reaches, all with shared IDs. There are eleven 0.2ha catchments within this larger 2ha catchment. The junction points for the 0.2ha and 2ha waterway reaches are also shown.

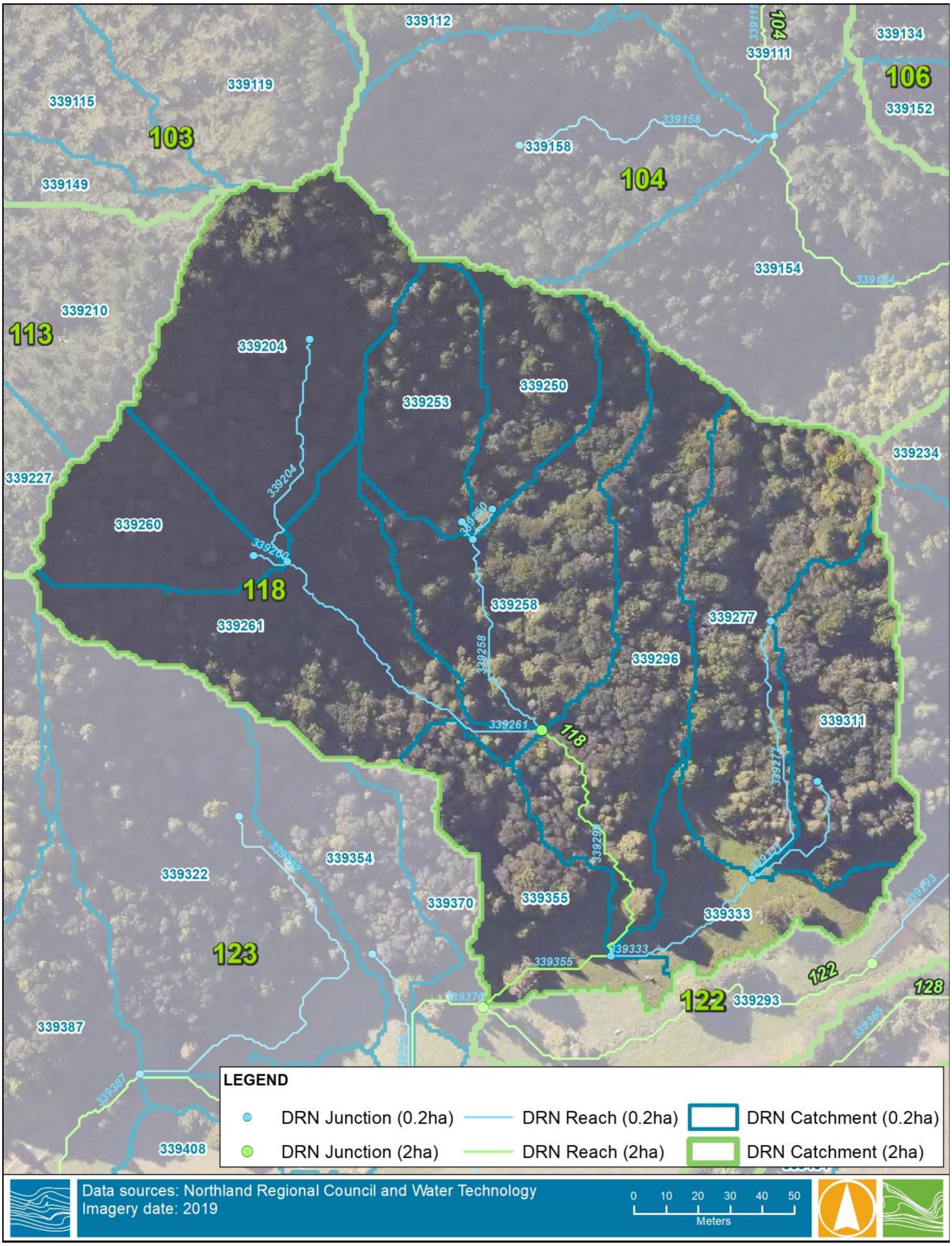

Figure 4-3 Example of the final spatial outputs (vector dataset) for the Northland DRN model.

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4.2.3 Additional DRN datasets

In addition to the key vector datasets which make up the DRN network, other associated spatial datasets were provided in the Geodatabase including:

- Stream crossing points (potential fish passage barriers)
- HE-DEM rasters
- HE-DEM 1m elevation contours
- Flow direction arrows

4.2.3.1 Stream crossing points

In addition to the key DRN spatial datasets, a set of GIS files was produced to represent potential fish passage barriers. These layers were produced by finding the intersection points of DRN 0.2 ha waterways, and district and regional roads layers. The intersection points thus indicate locations where there is likely to be a bridge or culvert.

It should be noted that not all the waterways in the DRN network would be large enough to warrant a bridge or culvert, and not all the waterways cross the road in the truly correct location. Major waterways with depression areas on the upstream side of the road would likely have had a burn line created and they should generally intersect the road at the correct location.

The stream crossing points layer contain the attributes of both the DRN 0.2ha waterways layer and the NRC roads layer, so the attributes could be used to help filter or classify the potential fish barriers (for example, the layer could be filtered to only show crossings which belong to a ‘perennial’ waterway).

The DRN attributes are discussed in Chapter 5 of this report, and an example stream crossing point on State Highway 14 is shown in Figure 4-4.

Figure 4-4 Example stream crossing point representing potential fish passage barrier.

4.2.3.2 HE-DEM and contours

A copy of the final HE-DEM (i.e., the 'burnt' version of the LiDAR DEM) has been provided for each FMU.

A 'hillshade' version of the HE-DEM is also provided, along with vector elevation contours at 1m interval. These datasets are provided as reference layers to the DRN and can be viewed/used in a desktop GIS application (e.g., ArcGIS Pro). An example of the hillshade and 1m contours is shown in Figure 4-5.

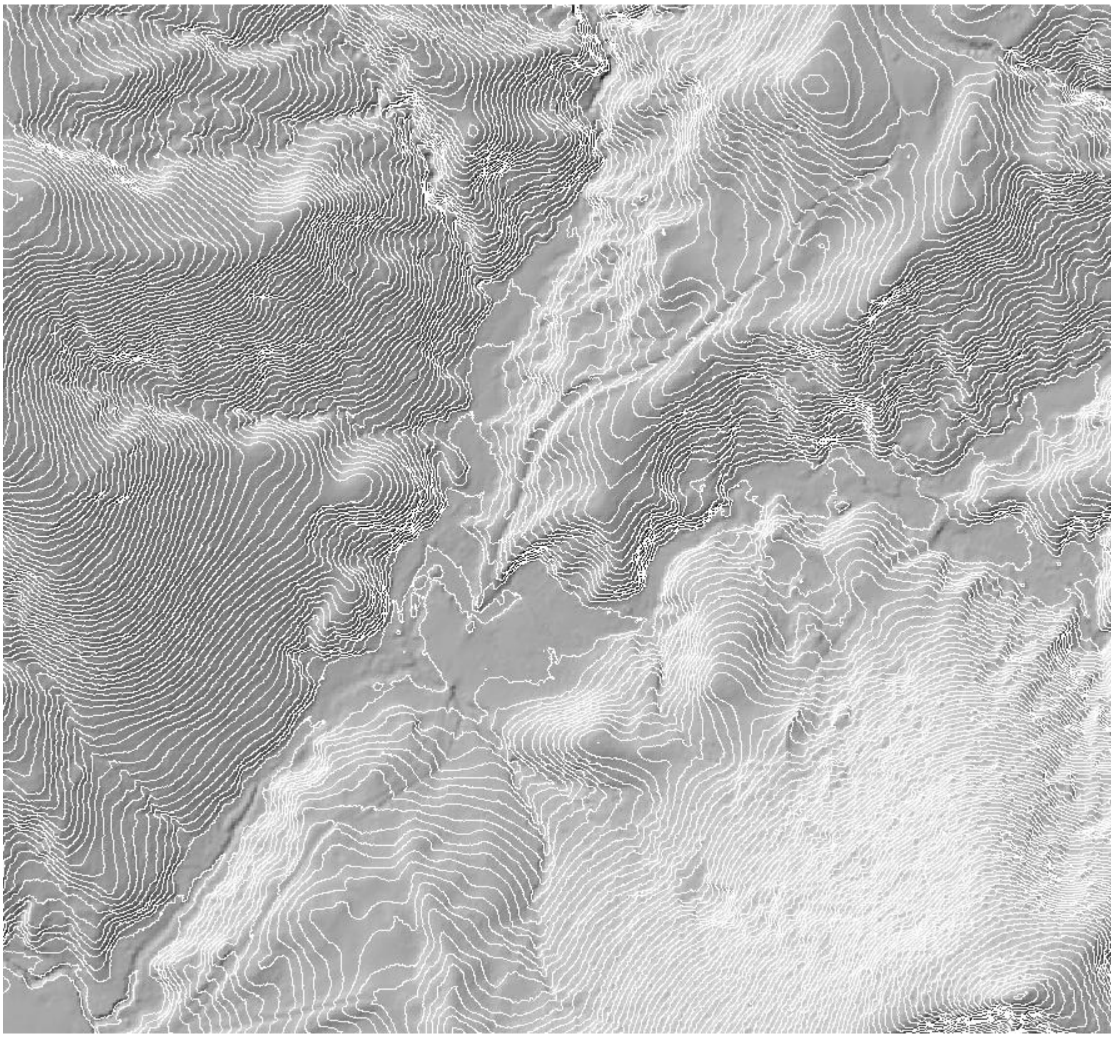

Figure 4-5 An example of 'hillshade' version of the HE-DEM and 1m contours

4.2.3.3 Flow direction arrows

A raster dataset representing flow direction has also been included in the Geodatabase for each FMU.

This product is derived from the flow direction output generated as part of the ArcHydro process, however the data has been reclassified so that the values in the raster represent the *geographic* flow direction, rather than the *D8* flow direction; where 0 degrees is North, and 180 degrees is South.

The flow direction raster can be used in a desktop GIS application (e.g., ArcGIS Pro) and symbolised to display scalable flow direction arrows for the entire FMU. An example of the flow direction arrows at both large (or zoomed in) map scale (1:100), and a smaller (zoomed out) map scale (1:4,000) is shown in Figure 4-6 and Figure 4-7 respectively.

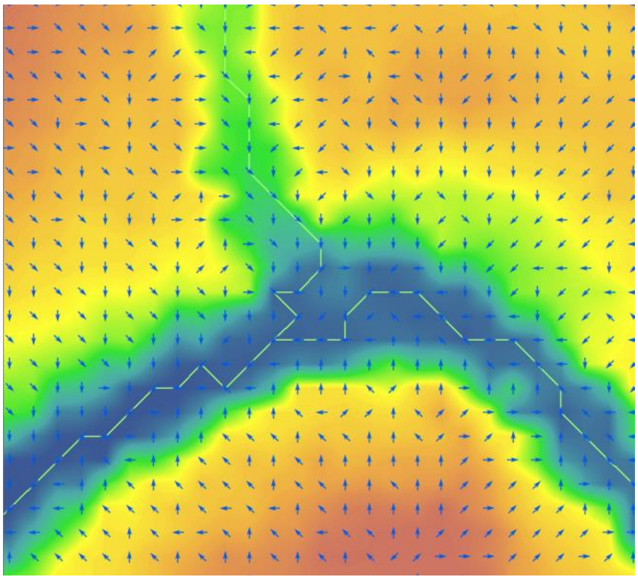

Figure 4-6 Flow direction arrows (large map scale – zoomed in)

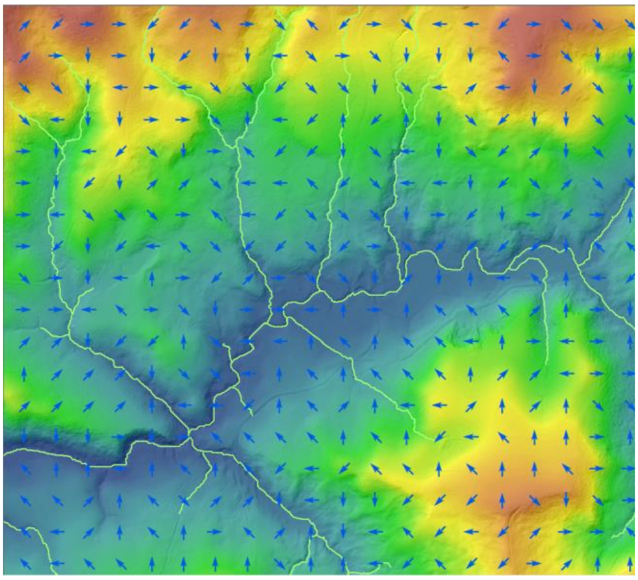

Figure 4-7 Flow direction arrows (small map scale – zoomed out)

These additional DRN datasets have been added to the key datasets to make up the final suite of DRN layers in an ESRI Geodatabase for each FMU, with consistent naming conventions as demonstrated in Figure 4-8, where ‘Xing’ refers to the crossing points.

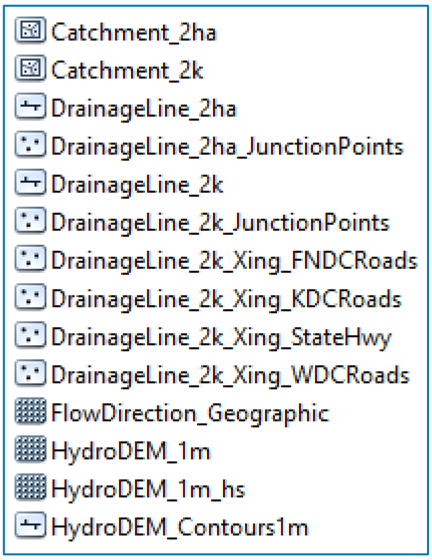

Figure 4-8 Full suite of DRN datasets

It should be noted that there are four possible stream crossing layers, representing waterway crossings on Northland State Highways, and roads administered by each of the three district councils (Far North DC, Kaipara DC and Whangarei DC). Most of the FMUs cover only one or two district councils, and some do not contain any State Highways, so the Geodatabase for each FMU only contains the relevant stream crossing layers.

5 DEVELOPMENT OF ATTRIBUTES FOR STREAM NETWORK AND WATERSHEDS

Northland Regional Council provided Water Technology with a list of attributes required to be added to the DRN stream network and catchments layers, as detailed in Table 5-1.

Table 5-1 Attributes required for stream network and catchment layers

B. Attributes for stream network layer	i) Reach-ID (UID), Watershed ID, stream order, reach length, reach elevation (max and mean), reach slope (max and mean), distance to sea (stream length downstream), REC2 Segment ID
	ii) Reaches classified by: Broad landcover type (e.g., indigenous forest/habitat, scrub, exotic forest, pasture, urban) at reach scale and upstream, Geology type (aggregated LRI rock types), and Stream habitat type – i.e., ephemeral, intermittent, and perennial.
	iii) Reaches identified with riparian vegetation width (could be categorical such as 5m, 10m, 20m)
C. Attributes for watershed layer	i) Watershed ID, catchment area, catchment slope (max and mean), catchment elevation (max, mean), cumulative upstream catchment area, upstream catchment slope (mean), upstream catchment elevation (mean), REC2 Segment ID, hydrological river catchment name
	ii) Hydraulic data including: Time of concentration, mean curve number, land use (majority), manning's roughness value

Some of these attributes are automatically produced while running the ArcHydro processing, whilst others require additional analysis steps, and the use of reference GIS layers to calculate the final attribute values.

The full list of attributes and a metadata description for each DRN dataset is detailed in Appendix A.

5.1 Stream network attributes

Reach ID, Watershed (catchment) ID, stream order and reach length are automatically produced as part of the ArcHydro process. An example of the Strahler stream order methodology is shown in Figure 5-1, where headwater stream reaches are classified as stream order 1, and Figure 5-2 shows the stream order mapping for the Northern Wairoa FMU.

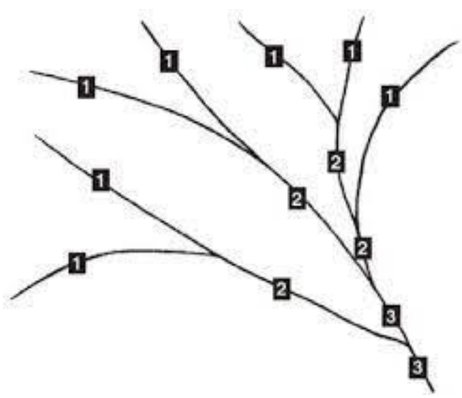

Figure 5-1 Strahler stream order methodology

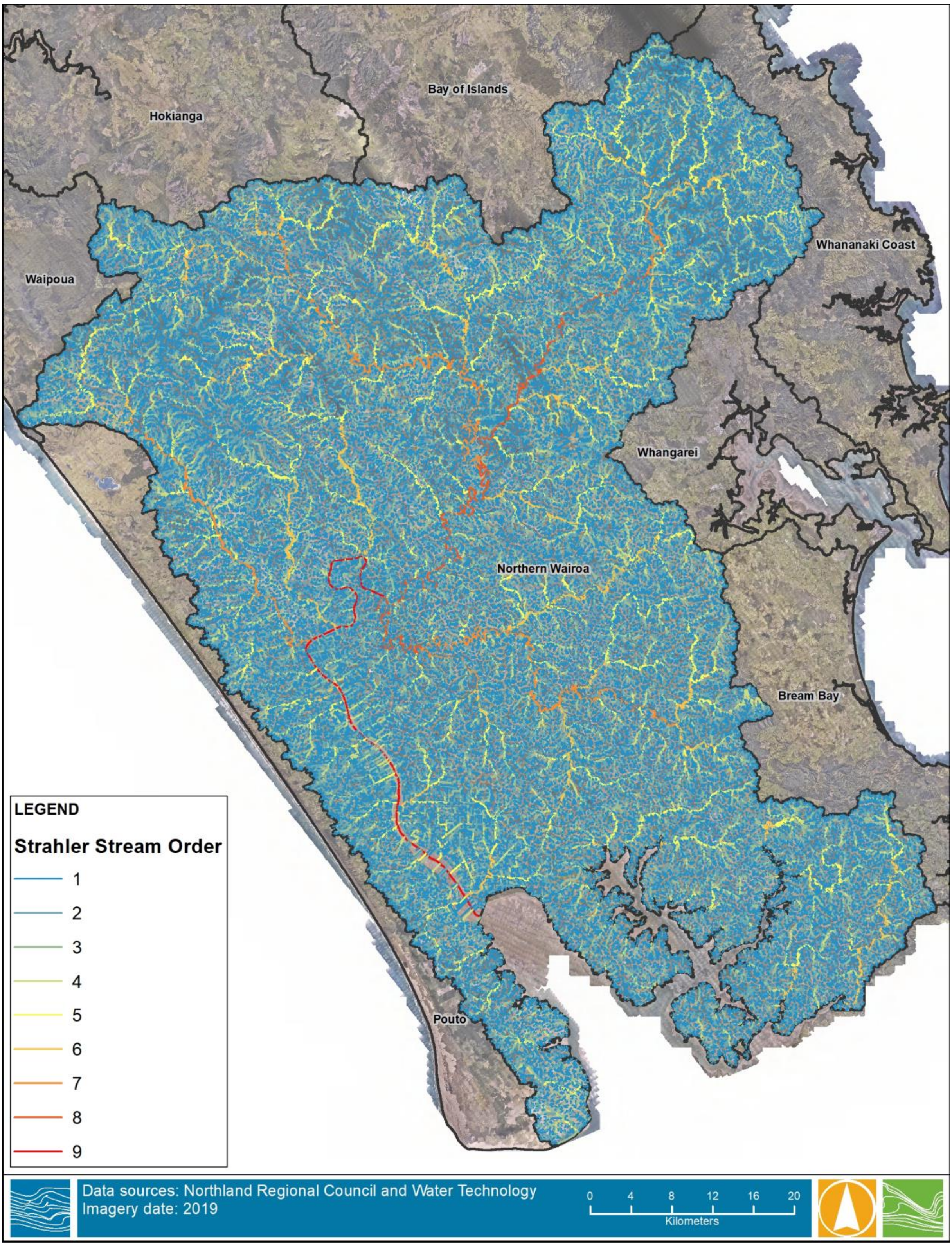

Figure 5-2 Stream order: Northern Wairoa FMU

Mean and maximum reach elevation and slope were calculated in the GIS by using the LiDAR elevation and derived slope (percent) DEMs.

REC2 segment ID (nzsegment) was assigned to each waterway reach by spatial overlay with the REC2 catchments. It should be noted that some unavoidable discrepancies arose where DRN reaches extend into the neighbouring REC2 catchment, where the REC2 catchments do not accurately define the catchment divide to the same level of detail as the DRN data. This is demonstrated in Figure 5-3.This means that some upper reaches have a different REC2 segment ID to their downstream reaches.

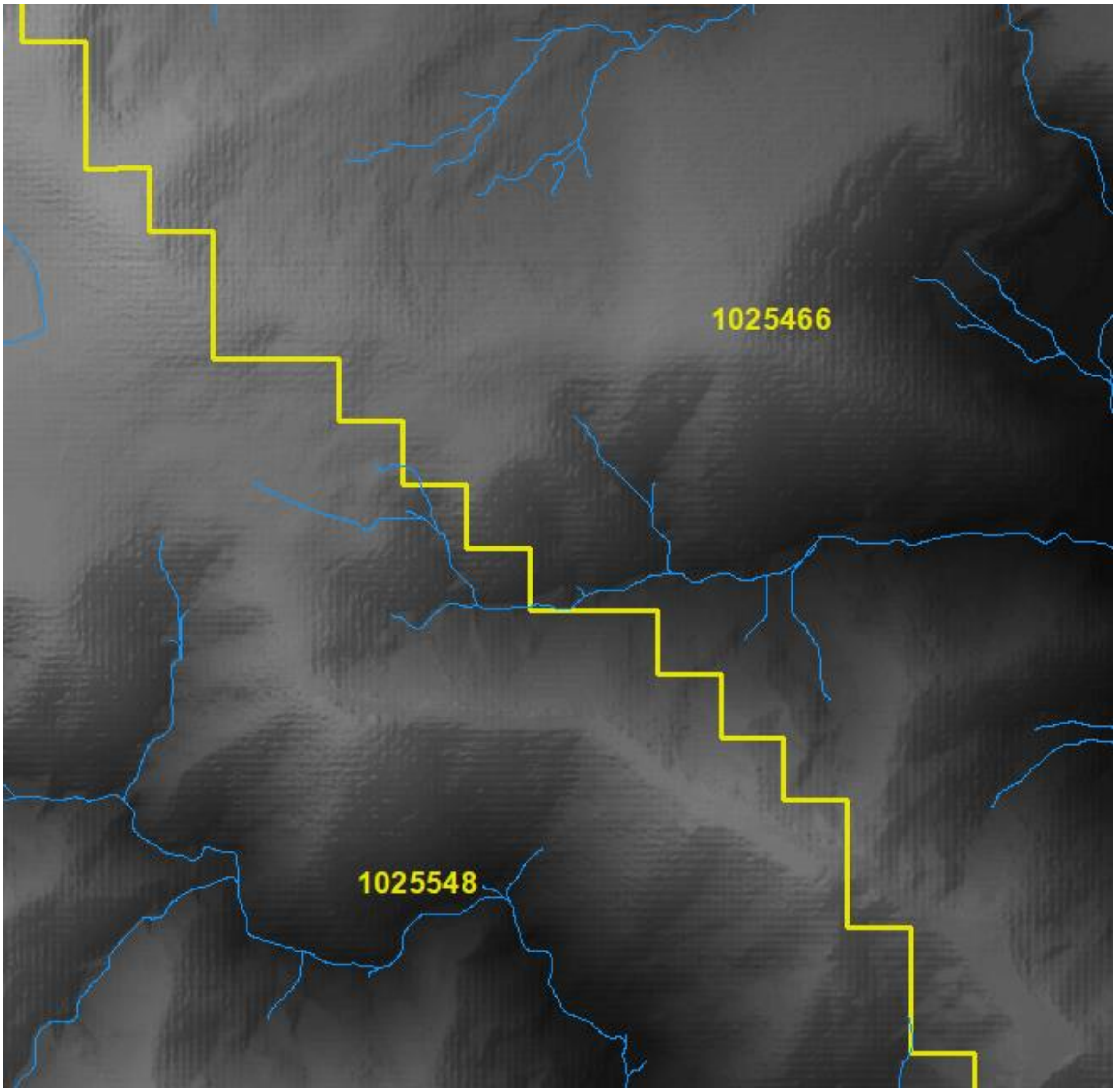

Figure 5-3 Example of a discrepancy between DRN reaches and REC2 catchment boundaries

The length downstream attribute (i.e., river distance to sea) was also calculated for the 2ha drainage lines dataset using ArcHydro tools. To demonstrate how this attribute can be used, a categorised map of 'length downstream' for the Northern Wairoa waterway reaches is shown in Figure 5-4. The colours represent the length downstream (in kilometres) along the DRN stream network, from each individual waterway reach to its eventual outflow point on the coast.

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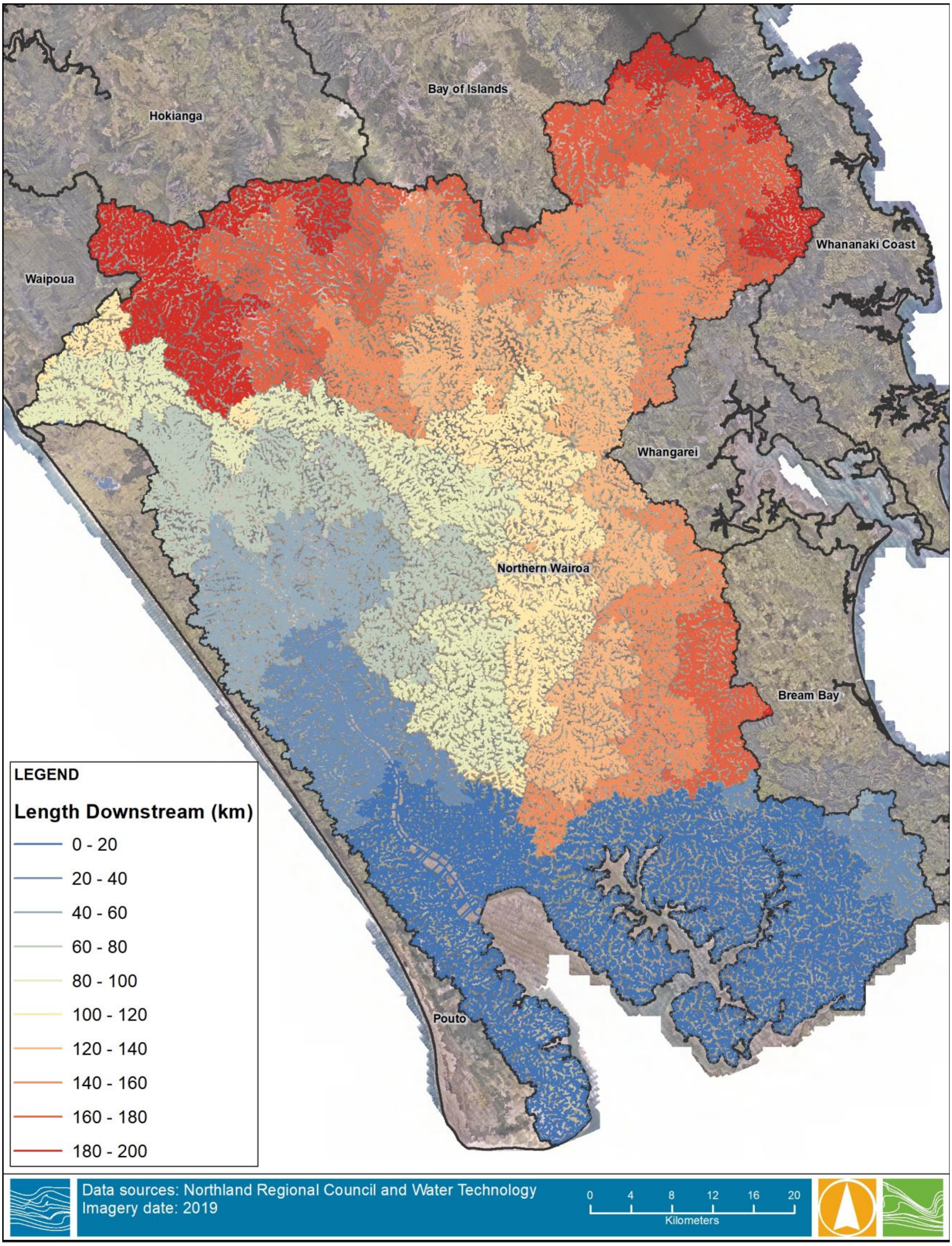

Figure 5-4 Length downstream: Northern Wairoa FMU

5.1.1 Broad land cover and geology type

These attributes were calculated for the 0.2ha drainage lines by spatial overlay using the following reference layers and attributes provided by NRC:

- Broad land cover type:
  - calculated using the New Zealand Land Cover Database version 5.0 or **LCDB v5.0** dataset [1]
  - 'Name_2018' attribute field.
- Geology type:
  - calculated using the New Zealand **Land Resource Inventory** dataset[2]
  - 'ROCK' attribute field.

5.1.2 Stream habitat type

A stream habitat type classification has been applied to the 0.2ha drainage lines. This is based on the Strahler stream order associated with the 0.2ha drainage lines and uses the following classification:

- Perennial: where stream order is > 5
- Intermittent: where stream order is 4 – 5
- Ephemeral: where stream order is 1 – 3

This classification was determined by comparison of a large number of DRN reaches of all stream order types with the LiDAR DEM, high-resolution aerial photography, 10% and 1% AEP rainfall-on-grid flood mapping outputs, and other reference datasets including the NZ 1:50,000K waterways. The accuracy of the classification has also been checked and reported on as part of the QA/QC process undertaken on the DRN (see Performance Measurement).

An **ephemeral** stream can be defined as a waterway that:

- Does not have an active bed,
- Has a bed which is predominantly vegetated,
- Only conveys water during and immediately following heavy rainfall events, and
- Does not convey or retain surface water at other times.

An **intermittently** flowing stream can be defined as a waterway that:

- Has a well-defined channel, such that beds and banks can be distinguished,
- Is naturally dry at certain times of the year,
- Retains and conveys surface water longer than an ephemeral stream following heavy rainfall events which results into river flow and creates natural pools, and
- Does not have established terrestrial vegetation across the entire width of the channel.

A **perennial** or permanently flowing stream can be defined as a waterway that:

- Does not meet the criteria for an ephemeral or an intermittent stream, and

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[1] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/
[2] https://lris.scinfo.org.nz/layer/48076-nzlri-land-use-capability-2021/

- Retains and conveys water throughout the year irrespective of the rainfall event.

5.1.3 Riparian vegetation width

The riparian vegetation width has been estimated for each individual 0.2ha drainage line reach, across all FMUs.

Due to the extremely large number of waterway reaches produced for the DRN (there are over 1 million 0.2ha reaches in the Northern Wairoa FMU alone), it would of course not be possible to visually or manually measure the riparian vegetation width for all reaches. Thus, Water Technology developed a semi-automated solution for estimating riparian vegetation width using GIS processing tools. The method involved two general steps:

1. Developing a current woody vegetation coverage map for the entire Northland Region
2. Use the vegetation coverage map to estimate riparian vegetation width for each reach by spatial overlay

5.1.3.1 Developing a current vegetation coverage dataset

Water Technology considered the existing LINZ 1:50k topographic mapping of vegetation polygons (native/exotic/scrub/scattered scrub) for use in calculating riparian vegetation width, however it is understood this data was produced in 2012 or earlier, and a comparison with 2019 NRC aerial photography revealed many locations where logging or other clearing has occurred, and the 1:50k vegetation polygons were seemingly out of date.

Further checking of the 2019 NRC aerial photography, compared to freely available Sentinel-2 imagery[3] captured in 2022 revealed that more logging/clearing had occurred since 2019.

For these reasons, it was decided that a new vegetation coverage dataset should be developed using a supervised classification of 2022 Sentinel-2 imagery, to create a more current dataset.

Three cloud-free Sentinel-2 10m-resolution images were obtained (freely available via open data licence), captured at the following dates:

- 11/05/2022
- 13/04/2022
- 24/12/2021

Three capture dates were needed because each downloaded tile does not fully cover the Northland region.

A supervised classification[4] of the imagery was undertaken in ArcGIS Pro to attempt mapping the woody vegetation cover. A large number of 'training sites' were created to improve the classification output. The training sites were aimed to distinguish between woody vegetation cover (forest), and urban, bare earth, waterbody or grassy land cover. Figure 5-5 shows an example of the training samples made to assist in the classification, and Figure 5-6 shows the final woody vegetation coverage output.

[3] Sentinel-2 is an Earth observation mission developed and run by the European Space Agency, consisting of two satellites acquiring optical imagery at 10 – 60m resolution over all land areas of the globe at 10-day intervals.
[4] Satellite image classification is a process of grouping the image pixels into a number of 'classes' based on their spectral/colour properties. A supervised classification requires representative samples for each 'class' (e.g., each different land cover type) created by the user, and the software uses these training sites to help classify the entire image.

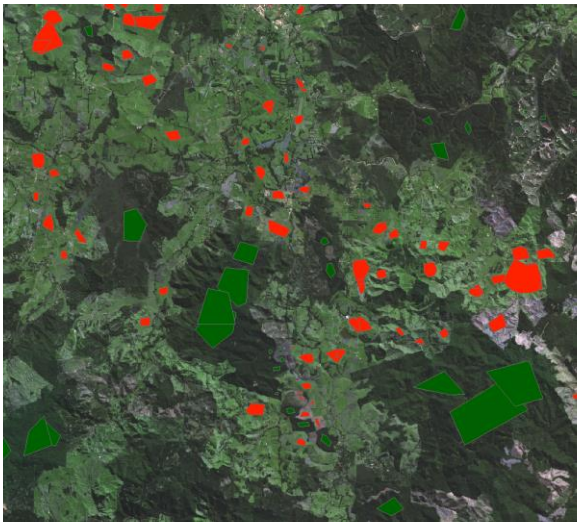

Figure 5-5 Training samples for Sentinel-2 classification

Figure 5-6 Resulting woody vegetation coverage map

The initial classification output underwent some refinement steps in order to prepare the final woody vegetation coverage dataset. These steps included:

- Removing the 'other' classes from the output (bare earth, urban etc)
- Removing small, disconnected portions/pixels from the wooded vegetation class
- Smoothing and generalising the final polygons to produce a more user-friendly dataset

The parameters for the smoothing and removing of disconnected portions of the final output were tested, and it was decided that some smaller areas of riparian vegetation should be included in the final output, for the purposes of estimating stream riparian vegetation width. This output thus provides more coverage of smaller patches compared to the existing LINZ vegetation polygons. This is demonstrated in Figure 5-7, where the LINZ polygons are shown in orange outlines, compared to the masked/wooded areas identified in the new map. It is clear the new map provides more coverage of smaller vegetation patches.

The newly created wooded vegetation coverage dataset has been provided to NRC.

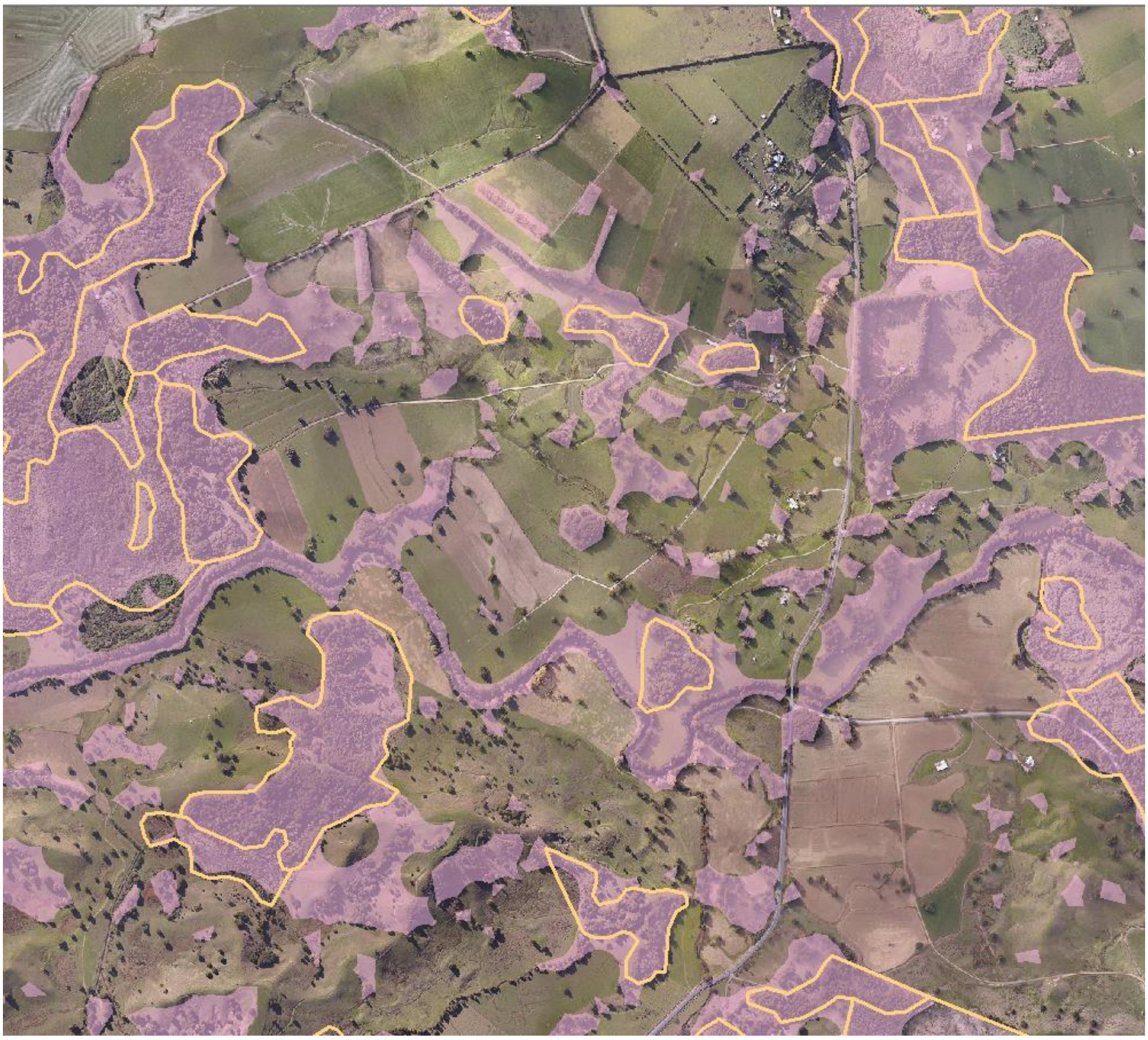

Figure 5-7 New woody vegetation map based on Sentinel-2 (10m spatial resolution) satellite image classification compared to LINZ vegetation polygons (polygons in orange outlines).

5.1.3.2 Methodology to determine riparian vegetation width for reaches

An estimated riparian vegetation width has been calculated for every 0.2ha waterway reach for all FMUs, where the width has been classed as: 0m, 0-5m, 5-10m, 10-25m, > 25m.

To estimate the riparian vegetation width for every individual 0.2ha waterway reach, the following GIS methodology was used:

1. Create a 'middle point' for every reach
2. Buffer the middle points by 5, 10, and 25m with a multi-ring buffer
3. Intersect the buffer layer with the new woody vegetation coverage dataset.
4. Use simple spatial overlay techniques to apply the following rules for classifying the riparian vegetation width:
    a. If the middle point is *outside* the vegetation coverage: 0m
    b. If the middle point is *inside* the vegetation coverage, and the *5m* buffer is *partly* covered by the vegetation coverage: 0-5m

c. If the middle point is *inside* the vegetation coverage, and the *5m* buffer is *fully* covered by the vegetation coverage, but the *10m* buffer is *partly* covered: 5-10m

d. If the middle point is *inside* the vegetation coverage, and the *10m* buffer is *fully* covered by the vegetation coverage, but the *25m* buffer is *partly* covered: 10-25m

e. If the middle point is *inside* the vegetation coverage, and the *25m* buffer is *fully* covered by the vegetation coverage: > 25m

Figure 5-8 demonstrates the methodology used, and the resulting classification of riparian vegetation width for a small area. It is evident that the methodology used has some limitations. These limitations are discussed in 7.2.2.

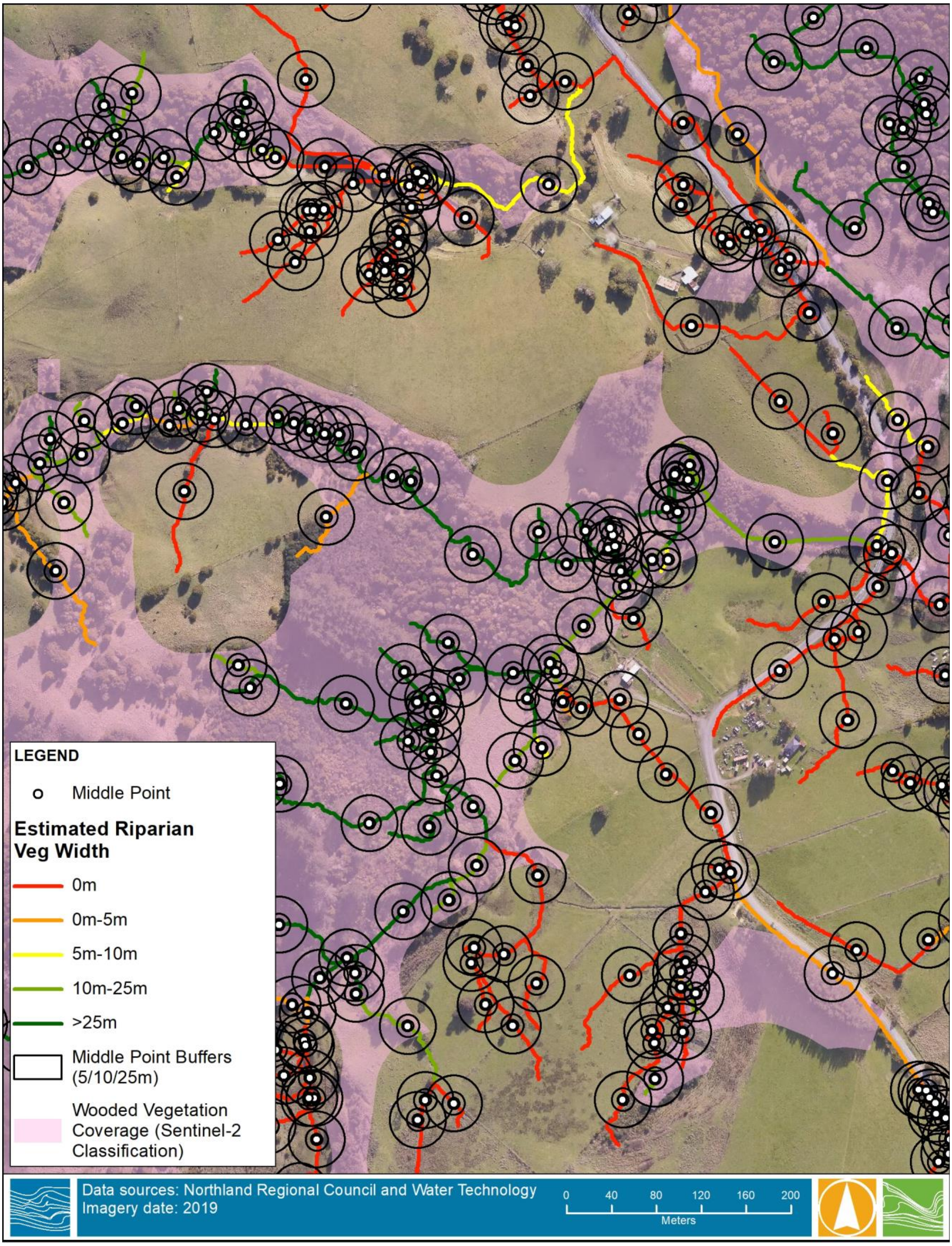

Figure 5-8 Demonstration of the methodology used for estimating riparian vegetation width.

5.2 Watershed attributes

Watershed ID and catchment areas are calculated automatically during the ArcHydro process.

Mean and maximum elevation and slope were calculated in the GIS by using the LiDAR elevation and derived slope (percent) DEMs. REC2 segment ID (nzsegment) and hydrological river catchment name were assigned to each catchment by undertaking a spatial overlay with the necessary layers.

Upstream area, mean slope and elevation, and the longest upstream flow path were calculated for each 2ha catchment using the additional ArcHydro outputs of adjoint catchment and longest flowpath. Each catchment is linked to its adjoint catchment by way of a shared drainage point. These attributes were also required to calculate additional hydraulic data parameters for each catchment.

5.2.1 Hydraulic attributes

Hydraulic attributes were added to the 2ha catchments layer, including time of concentration (2 methods), curve number, land use type and Manning's roughness value.

5.2.1.1 Time of concentration

Two methods were used to calculate time of concentration for each 2ha catchment:

1. [5]Adams (Australian) method: $t = 0.76A^{0.38}$

Where t_c is time of concentration in hours, and A is catchment area in km^2.

2. [6]NZ method: $t = 100.n.L^{0.33}/s^{0.2}$

   Where t is the travel time in minutes, n is the Manning's roughness coefficient, L is the up-slope length of contributing catchment, and s is the catchment slope in %.

For time of concentration calculations, the entire contributing catchment area (adjoint catchment) is used to complete the calculations, so the time of concentration refers to the time taken for water to flow from the furthest upstream point to the outflow point of each 2ha catchment.

5.2.1.2 Curve number, land use and Manning's

For the NZ time of concentration method, the Manning's roughness coefficient is determined by finding the majority land use[7] for the upstream (adjoint) catchment area, and then applying the appropriate Manning's value for that land use type. The land use was found by using the LUCAS New Zealand Land Use Map 2016, and the Manning's coefficient for each land use type is listed below:

Land use	Material class	Manning's coefficient
Natural Forest	71	0.1
Planted Forest - Pre 1990	72	0.1
Post 1989 Forest	73	0.1
Grassland - With woody biomass	74	0.06
Grassland - High producing	75	0.06
Grassland - Low producing	76	0.06

[5] McDermott, G. E. and D. H. Pilgrim (1982). Design flood estimation for small catchments in New South Wales, Department of National Development and Energy and Australian Water Resources Council. Research project No. 778/104. Technical paper No. 73. Australian Government Publishing Service.

[6]Maidment, David R. (1993). Handbook of Hydrology. McGraw-Hill

[7] https://environment.govt.nz/facts-and-science/science-and-data/new-zealand-land-use-map/

Cropland - Orchards and vineyards (perennial)	77	0.04
Cropland - Annual	78	0.04
Wetland - Open water	79	0.04
Wetland - Vegetated non forest	80	0.05
Settlements or built-up area	81	0.1
Other	82	0.06

The mean precinct curve number (CN) across each 2ha catchment has been added by using a CN raster product previously calculated by Water Technology for region-wide flood mapping program for NRC. CN is a measure for predicting runoff or infiltration from rainfall, and is derived from soil type, cover and condition.

An example of the time of concentration output (Adam's method) for 2ha catchments is mapped in Figure 5-9. In this figure each 2ha catchment is symbolised (coloured) based on the time of concentration from the upstream headwater location to the outlet point.

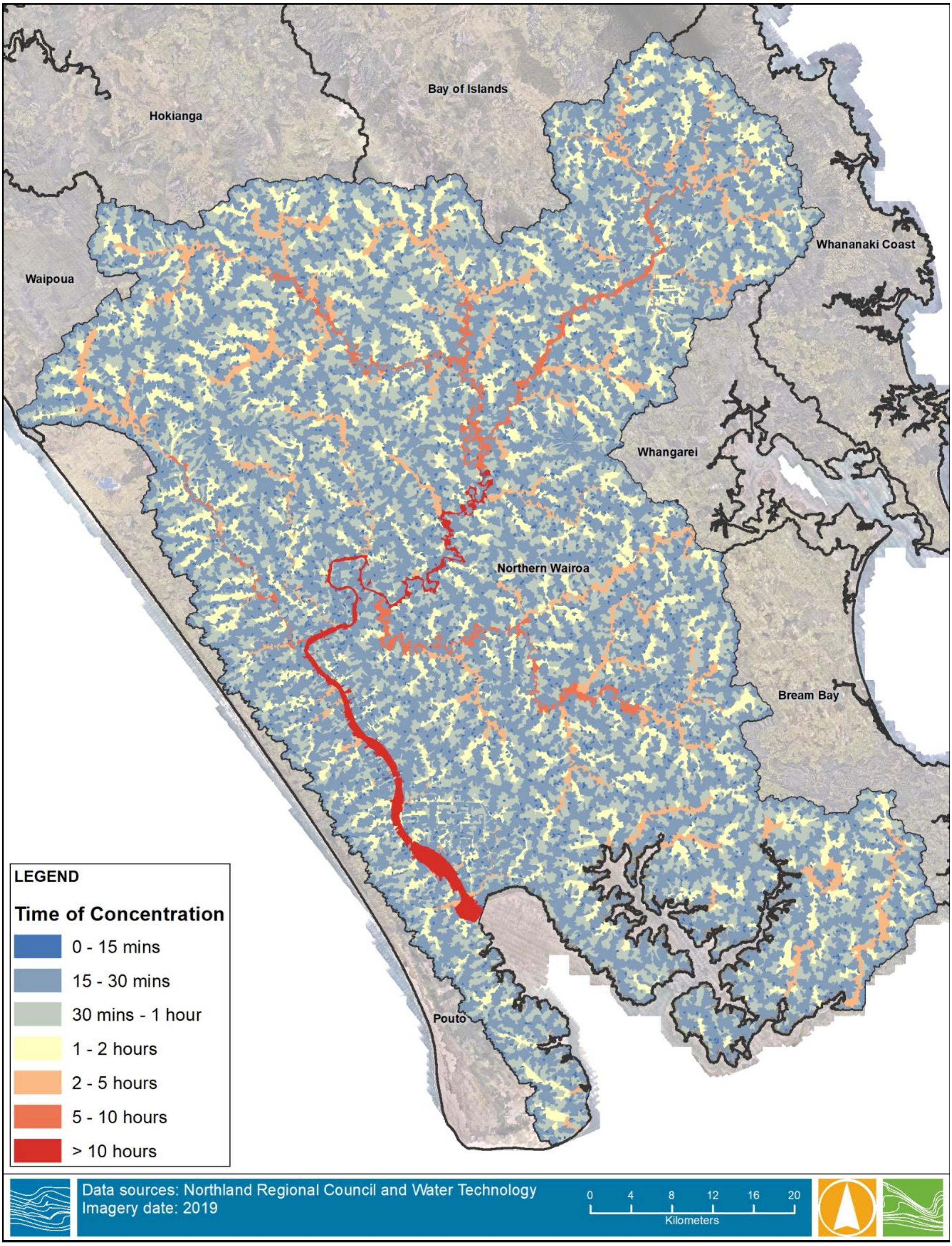

Figure 5-9 Time of concentration: Northern Wairoa FMU

6 PERFORMANCE MEASUREMENT

An NRC requirement for the DRN was that a tolerance of not more than 10% error in terms of deviation from the actual centreline or flow path of a waterway, so that Council staff can be confident enough to use the final product as a true representation of regional river extent at farm scale.

Given the nature of the DRN (being produced based on 1m LiDAR, it will be the most accurate representation of waterways in the Northland Region (much more detailed than the previous REC network), so this means that other river datasets would not be overly useful for checking accuracy.

For that reason, the most suitable data for verifying the accuracy of the DRN was high-resolution aerial photos, and the LiDAR DEM itself.

To that end, a quality checking (QA/QC) process for verifying and recording the accuracy of the DRN was developed.

6.1 QA/QC Methodology

1. Select a small subset of the DRN data, from a range of landscape types (coastal / flatlands, mid-catchment / moderate slope, wooded upper catchment / high slope):
    a. The subset of data to be taken from a number of 1km x 1km zones located in the above landscape types.
    b. A slope analysis of the LiDAR DEM was used to help identify landscape types and position the 1km x 1km zones.
2. Measure the percentage of every 0.2ha stream reach within the zone that deviates off the true centreline, when compared to LiDAR / aerial photos.
3. Use this deviation percentage to find the overall portion of total stream length which deviates from the centreline.
4. The 'stream habitat type' was also verified during this process, by comparing the assigned habitat type of each 0.2ha stream reach within the zone to the habitat type as inferred from aerial photo interpretation. The number of incorrect reaches within the subset of DRN data was used to extrapolate the expected number across the entire network.

It was agreed between Water Technology and NRC that the 2ha stream reaches did not need to be checked for accuracy, given they share the same line network as the 0.2ha streams.

The spread of 1km x 1km locations where a subset of DRN data was selected in Northern Wairoa FMU is demonstrated in Figure 6-1, and the inset map shows the subset of 0.2ha reaches which are within one of the 1km x 1km zones.

Figure 6-2 shows a worked example of how the length of steam deviation is calculated.

The reach in the centre of the figure has a total length of 215m, however it clearly deviates from the correct flow path at approx. halfway downstream along the reach (the deviation is caused by a small blockage in the LiDAR DEM, which is visible in the inset map. Thus, a deviation percent of 50% was applied to that stream reach, resulting in a deviation length of 108m.

Other 0.2ha stream reaches with no discernible deviation are coloured blue, and thus have a deviation percentage of 0%, and a deviation length of 0m.

The total length of deviation across all reaches within the QA/QC subset of data can then be compared to the overall total stream lengths within the subset, to come up with an estimate of the overall percentage of deviation for the DRN 0.2ha stream network.

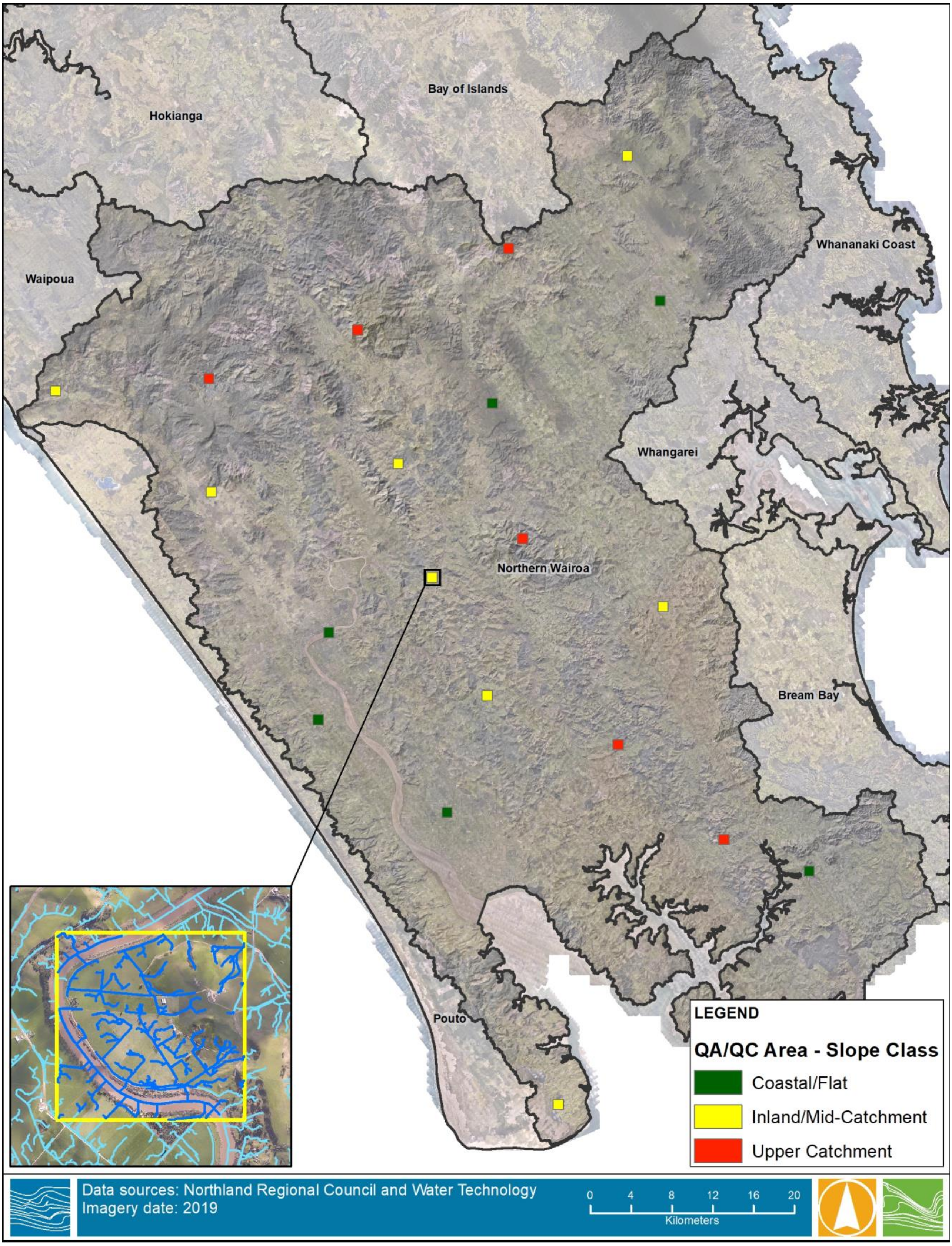

Figure 6-1 Locations for QA/QC of DRN – Northern Wairoa FMU

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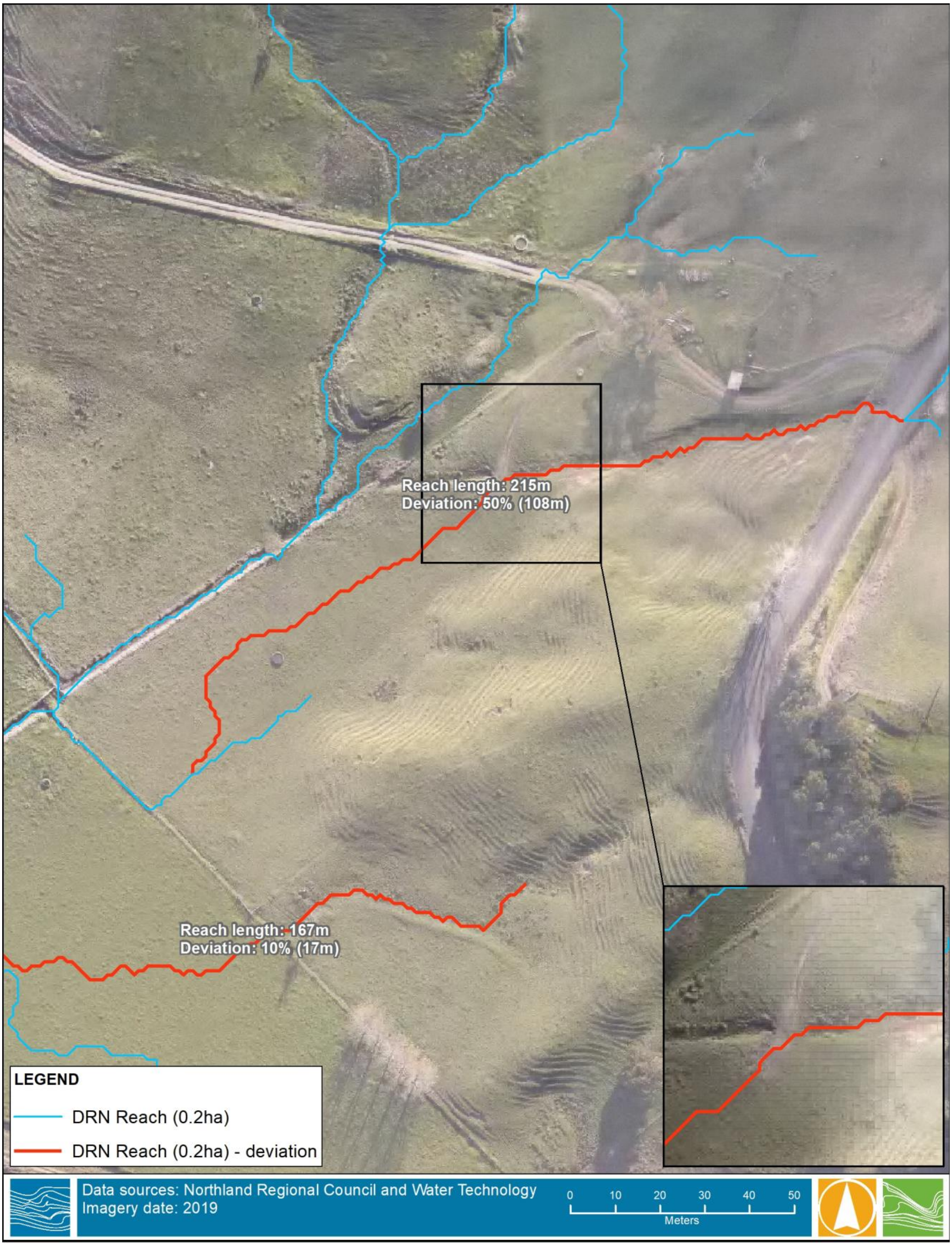

Figure 6-2 Methodology for measuring deviation of stream reaches

6.2 QA/QC Results

The results of the QA/QC performance testing for Northern Wairoa FMU are presented in Table 6-1 (stream deviation), and Table 6-2 (stream habitat type).

Table 6-1 QA/QC Results – stream deviation

Landscape type	Stream deviation (m)	Total length (m)	Percent of deviation
Coastal / flat	6,398	92,260	7%
Inland / mid-catchment	16,124	117,851	14%
Upper catchment	3,672	95,150	4%
Overall	**26,164**	**305,260**	**8.5%**

Table 6-2 QA/QC Results – stream habitat type

Landscape type	No of reaches incorrect	Total no of reaches	Percent incorrect
Coastal / flat	84	1,542	5%
Inland / mid-catchment	75	2,043	4%
Upper catchment	52	1,532	3%
Overall	**211**	**5,117**	**4%**

The overall errors of 8.5% for stream deviation, and 4% for incorrect stream habitat type were within the 10% error tolerance, as required by NRC.

An interesting outlier within the results is the 14% of stream deviation observed in Inland / mid-catchment zones. The reason for this is that one of the zones is located in an area of the Poutō Peninsula where there are many lakes and undulating dune/wetland systems, and the DRN network is not as well defined as other areas.

This is illustrated in Figure 6-3, where many DRN stream network lines, including those in the QA/QC zone, are incorrect because they have not benefited from burning of hydraulic blockages (in this case the correct location for burning could not be identified in this part of the peninsula, as there are no clearly visible waterways).

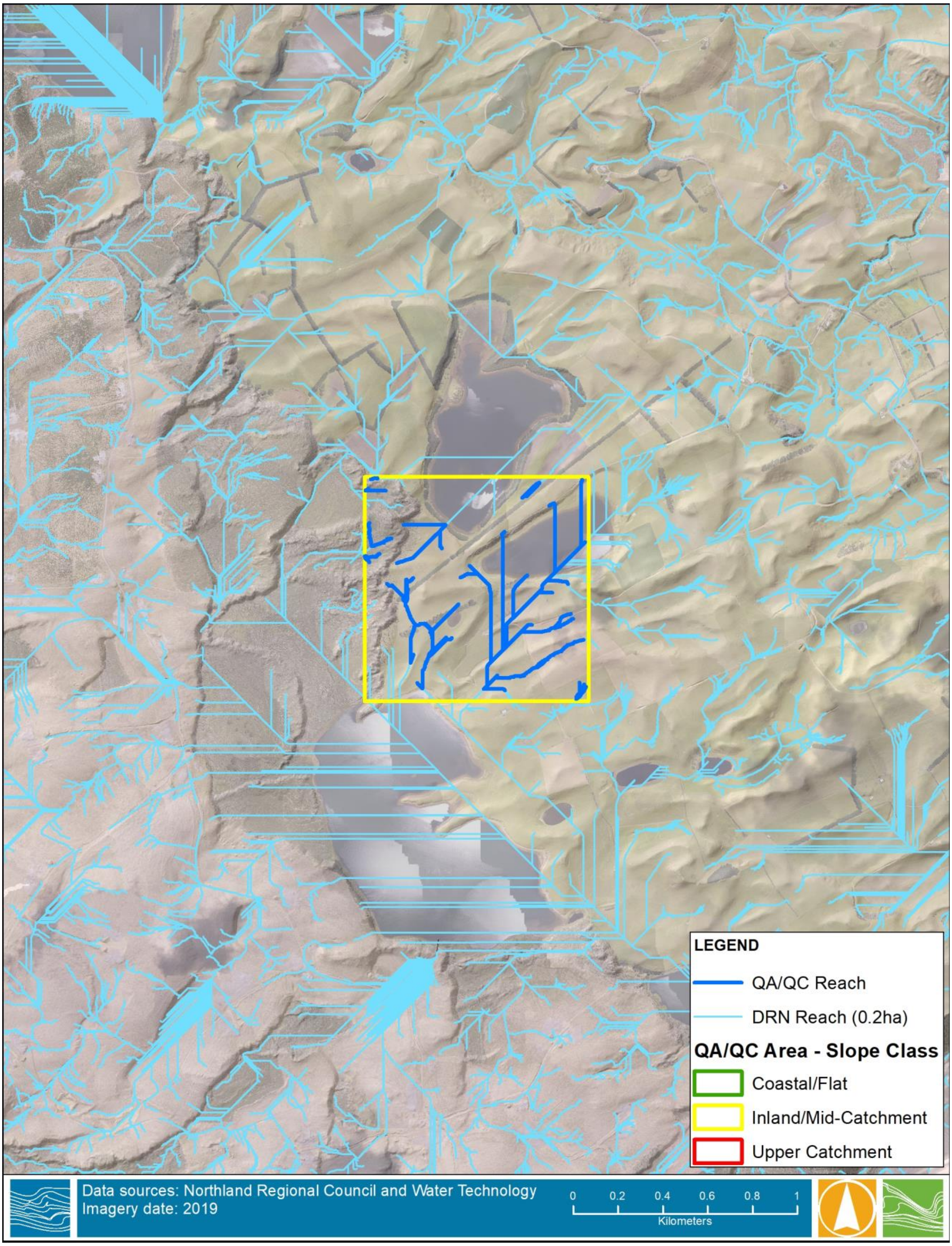

Figure 6-3 Degraded stream definition in the Poutō Peninsula

7 SUMMARY

A new digital river network (DRN) has been produced for the thirteen Freshwater Management Units (FMU) within the Northland Region of New Zealand. The DRN has been produced by conducting catchment and drainage line analysis on a 1m LiDAR DEM, at both 2ha and 0.2ha catchment threshold scales.

Prior to the catchment analysis, the LiDAR DEM was modified with ‘burning’ of hydraulic blockages to produce a hydrologically-enforced DEM (HE-DEM), ensuring that the delineated drainage lines follow their correct path as often as possible.

A number of reference spatial data layers were produced, and spatial data processing steps were undertaken on these reference layers, to help with adding a suite of data attributes into the key DRN layers.

A QA/QC process was developed and undertaken to assess the accuracy and suitability of the DRN, with the NRC desire being that the DRN level of error does not exceed 10%.

7.1 Data Deliverables

The DRN data has been provided to NRC in ESRI Geodatabase format, consisting of one geodatabase for each FMU, and each include the same suite of layers with standard naming convention. The contents of the Northern Wairoa Geodatabase are seen in Figure 7-1.

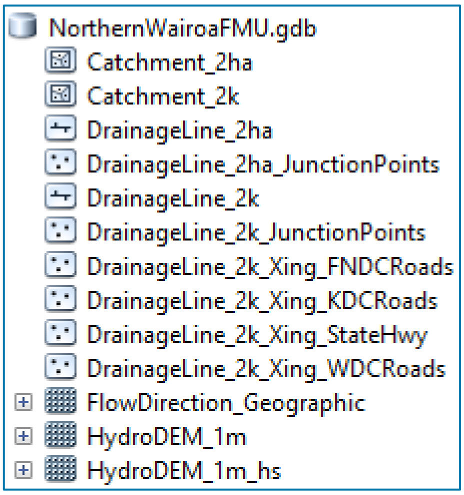

Figure 7-1 The final suite of DRN Spatial Datasets

HydroDEM 1m contours lines have been provided in a separate Geodatabase for each FMU due to file size.

The spatial projection of the DRN data is **NZGD_2000_New_Zealand_Transverse_Mercator**.

7.2 Limitations of the DRN

The DRN should now be considered to be the most accurate representation of waterways and drainage lines in the Northland Region, however there are still some key limitations of the DRN which need to be mentioned.

7.2.1 HE-DEM

Over 28,000 burn lines were used for producing the hydrologically-enforced version of the LiDAR DEM, however there are still thousands of small and medium sized depression areas and other blockages across Northland which did not have a burn line created for them, and thus potentially affect (degrade) the spatial accuracy of the DRN. The primary reason burn lines were not created for more locations is the time and budgetary constraints of the agreed scope of works between Northland Regional Council and Water Technology. Other reasons include:

1. The correct location for creating a 'burn' line could not be identified on the aerial photography and/or LiDAR DEM for certain depression areas.
2. The depression area or blockage was not expected to have a major impact on the accuracy or suitability of the output DRN.

An example of where additional burning could potentially make an improvement to the DRN is in the Poutō Peninsula area, as shown in Figure 6-3. The Aupouri Peninsula area also has similar landscapes and could benefit from additional burn lines being created.

It should be noted that small farm dams, and waterbodies including lakes and reservoirs were generally not considered for burn lines. Small farm dams are too numerous and do not make a significant enough deviation in the drainage line delineation to warrant the effort of creating burn lines, as demonstrated in Figure 7-2.

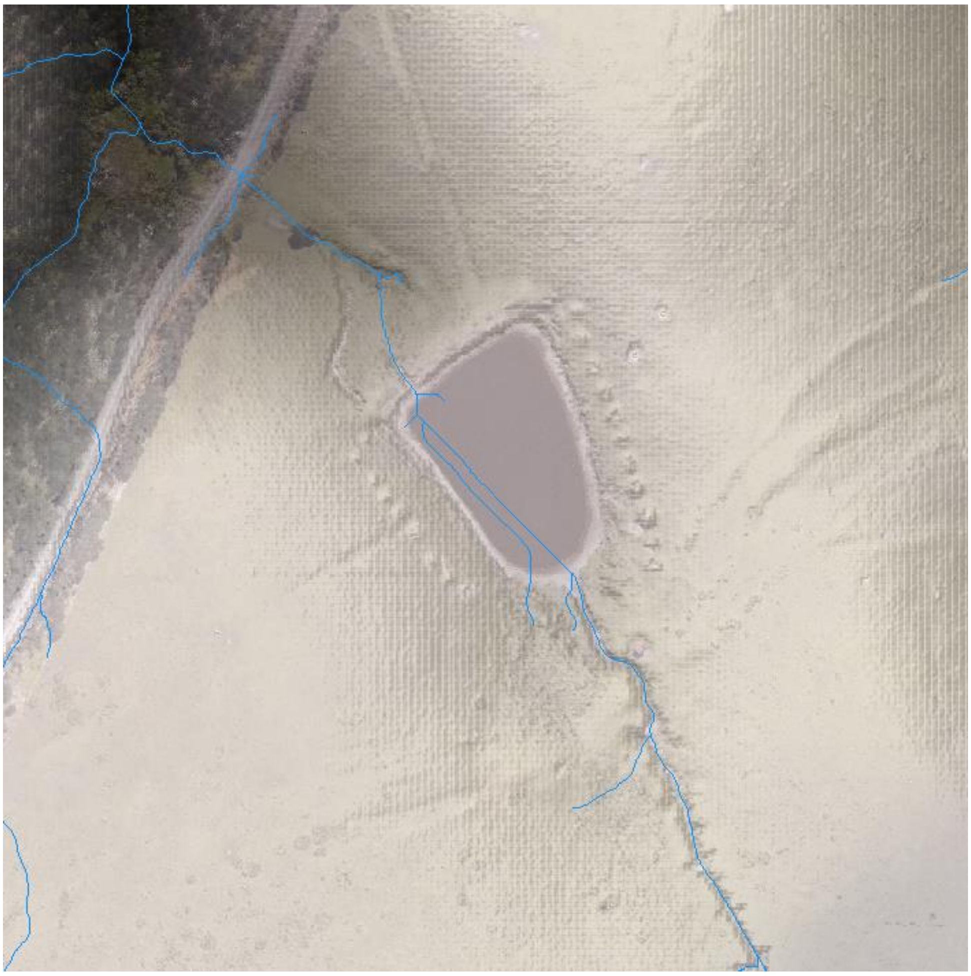

Figure 7-2 Example of a drainage line through an 'un-burnt' farm dam, with minimal deviation in the overall drainage line on the upstream or downstream side of the dam

Lakes and reservoirs were given a burn line only if the outlet point was easily identifiable. Priority for burn lines was given to culverts and other structures which it was anticipated would have the greatest effect on the accuracy of the DRN. An example of a lake where no burn line was created in shown in Figure 7-3. The lack of a burn line does not affect the overall accuracy of the DRN drainage lines flowing into or out of the lake

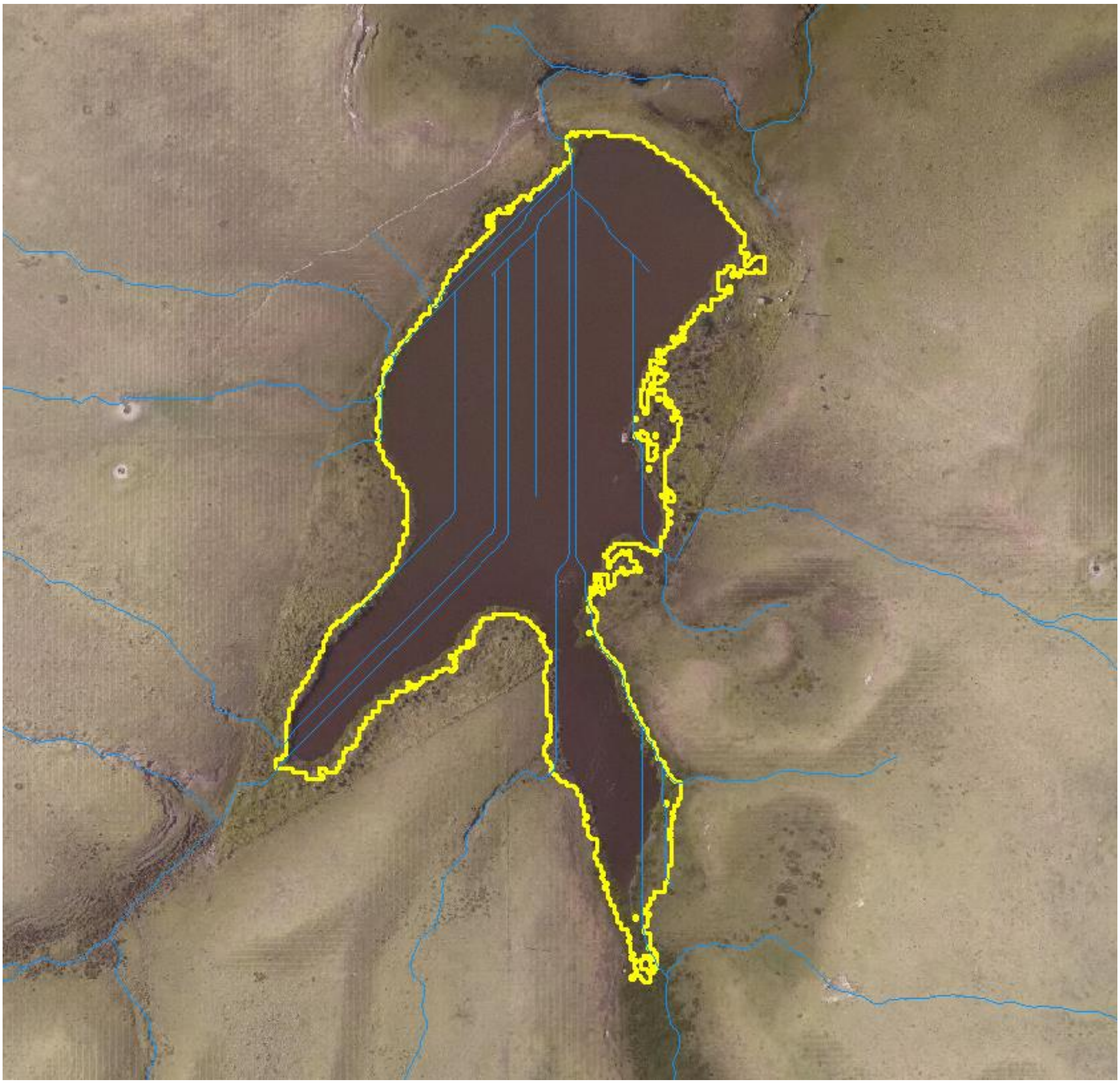

Figure 7-3 Example of a lake with no burn line created – the drainage lines within the lake are not accurate, but the inflow and outflow drainage lines remain accurate

7.2.2 Attribute accuracy

Some of the stream reach and watershed attributes have been calculated by using assumptions or generalised information. The key assumptions and limitations include;

- Stream habitat type: this has been calculated by applying a categorisation of Strahler stream order values, rather than by any detailed in-situ field observations or assessments, which would be well outside the scope of the project, and not possible over the entire Northland Region to such a fine level of detail.

- Time of concentration: this calculation requires upstream slope and manning's coefficient information – the slope and manning's information has been generalised/aggregated for the upstream area to come up with a single value for each.
- Riparian vegetation width: this has been estimated using a semi-automated GIS process which firstly uses a classification of satellite imagery data to estimate and map vegetation cover, and then uses a buffer of the middle-point of each waterway reach to categorise the vegetation width for the reach.
  - The imagery classification process has a number of limitations which affect the accuracy of the resulting vegetation coverage map, including;
    - Spatial and temporal resolution of the satellite image
    - Limitations with the classification process including training samples
    - Smoothing of the output to produce a useable dataset
  - The use of a buffer of the middle point to check the vegetation width of a reach has some clear limitations, primarily that reaches for which the middle point is outside the vegetation coverage are classified as having 0m vegetation width.
  - Considering the above limitations the riparian vegetation width attribute should be considered as indicative in nature.
- Land cover and geology: these have been assigned to each drainage line based on a majority rule (i.e., for those drainage lines that are within more than one land cover or geology category, the predominant land use value has been adopted.
  - The land cover and geology datasets were provided by NRC and the specific spatial and attribute limitations of those datasets would also need to be considered.

7.3 Recommendations

A comparison of the DRN datasets when compared to the previous REC data clearly shows that the DRN should now be used as the authoritative stream network dataset for Northland.

Additionally, the crossings datasets that have been produced should be able to be used by fish experts to identify potential barriers to fish migration. The attributes can be used to filter or classify crossings to assist with identifying crossings of a certain criteria.

7.3.1 Possible improvements or updates

Some of the key reference datasets used to produce the DRN would be expected to be replaced, reproduced or improved in the future, including the digital elevation model (either by LiDAR or other technology), vegetation coverage mapping, and land cover and geology maps. The use of new data would be expected to improve the accuracy and usefulness of the DRN.

7.3.1.1 Possible future attribute updates

Due to ongoing changes such as logging, plantations, land clearing and natural growth, the vegetation coverage in Northland would be expected to be constantly changing. Therefore, it could be useful to reconduct the riparian vegetation width assessment at a certain period in the future, either by using a new round of Sentinel-2 satellite classification (or other equivalent remotely sensed data), or any other improved vegetation coverage dataset that becomes available for the Northland Region.

Geology type and land cover datasets may also change and improve over time, and could be used to update the DRN data. The creation date and ongoing suitability of those datasets should be considered before determining when updates to the DRN might be required.

Ground truthing or field-survey programs could be used to help verify and validate the DRN attributes and spatial accuracy. For example, the stream habitat classification could be checked during targeted field surveys, and the classification could be updated if a consistent error was identified.

7.3.1.2 Possible future spatial updates

Localised editing of the HE-DEM, for example, the creation of additional burn lines to fix an erroneous portion of the DRN, is something that could be considered. This could be undertaken to fix small areas of the DRN, however it should be noted that some re-processing in ArcHydro would need to be undertaken to complete such a task, either at FMU scale or a smaller catchment scale. Additionally, this would result in the improved area not necessarily matching the surrounding DRN features, in terms of linked attributes and spatial alignment.

Looking further afield, longer-term geomorphological changes such as river meandering, and changes to the terrain such as land development or other activities will eventually occur and may mean that the DRN is no longer as accurate as it currently is. It is expected that LiDAR for Northland Region will again be flown in the future, which could be used to reproduce the DRN using the same or similar processing methods. An appropriate timeline for re-processing of the DRN might be in the range of 10 -15 years. It should be noted that the existing burn lines could potentially be used on new LiDAR capture to update the HE-DEM.

The use of sinks as part of the ArcHydro data processing could potentially be considered to help produce more accurate drainage lines where true sinks exist. True sinks are internal basins or smaller depressions (sinkholes) where there is no outflow or discharge point. However, most lakes are not true sinks, meaning they eventually have an outflow point when full, so the drainage network needs to continue on downstream from the lake, as demonstrated in Figure 7-3.

7.4 Acknowledgements

Water Technology would like to acknowledge Northland Regional Council (NRC) Freshwater Scientist Manas Chakraborty for initiating such an ambitious project, and for providing guidance and technical advice.

It has been a challenging project, primarily due to the large amounts of spatial data required to be processed to a high precision, but it's also been extremely rewarding for Water Technology staff to have overcome these challenges with the technical help and confidence of NRC Science and River Management staff, and to have successfully delivered the required datasets.

APPENDIX A
DRN ATTRIBUTE METADATA

A-1 NRC Digital River Network - Key Attributes

Coloured field names indicate linked fields between feature classes

Catchment_2ha

OBJECTID	
Shape	
WatershedID	Unique Catchment_2ha watershed ID
HydroID	Unique ID
NextDownID	HydroID of downstream catchment
CatType	Catchment Type (Null or Coastal)
Slope_Mean	Mean slope of watershed (percent)
Slope_Max	Maximum slope of watershed (percent)
Elevation_Mean	Mean elevation of watershed
Elevation_Max	Max elevation of watershed
Rec2_SegmentID	Unique segment ID from parent REC dataset
Rec2_ReachID	Unique reach ID from parent REC dataset
Upstream_Slope_Mean	Mean slope of upstream contributing catchment area (percent)
Upstream_Elevation_Mean	Mean elevation of upstream contributing catchment area
Upstream_Area	Total upstream contributing catchment area (m^2)
ToC_AUS	Time of concentration – Australian method (hours)[8]
ToC_NZ	Time of concentration – New Zealand method (hours)[9]
CurveNo_Mean	Mean precinct curve number of watershed
LU_Majority	Majority land use value across watershed
Mannings	Manning's coefficient[10] of majority land use type

[8] **$t_c = 0.76A^{0.38}$**

Where t_c is time of concentration in hours, and A is catchment area in km².
(McDermott, G. E. and D. H. Pilgrim (1982). Design flood estimation for small catchments in New South Wales, Department of National Development and Energy and Australian Water Resources Council. Research project No. 778/104. Technical paper No. 73. Australian Government Publishing Service.)

[9] **$t = 100.n.L^{0.33}/s^{0.2}$**

Where t is the travel time in minutes, n is the Manning's roughness coefficient, L is the up-slope length of contributing catchment, and s is the catchment slope in %.
(Maidment, David R. (1993). Handbook of Hydrology. McGraw-Hill)

[10] Based on LUCAS New Zealand Land Use Map 2016:

Land use	Material class	Manning's coefficient
Natural Forest	71	0.1
Planted Forest - Pre 1990	72	0.1
Post 1989 Forest	73	0.1
Grassland - With woody biomass	74	0.06
Grassland - High producing	75	0.06
Grassland - Low producing	76	0.06
Cropland - Orchards and vineyards (perennial)	77	0.04
Cropland - Annual	78	0.04
Wetland - Open water	79	0.04
Wetland - Vegetated non forest	80	0.05
Settlements or built-up area	81	0.1
Other	82	0.06

Shape_Length	
Shape_Area	

Catchment 2k

OBJECTID	
Shape	
GridID	Unique Catchment_2k (0.2ha) watershed ID
HydroID	Unique ID
CatType	Catchment Type (Null or Coastal)
NextDownID	HydroID of downstream catchment
HydroCat	Name of associated hydrological catchment
Shape_Length	
Shape_Area	

DrainageLine_2ha

OBJECTID	
Shape	
arcid	
WatershedID	Unique ID of associated **Catchment 2ha** watershed
from_node	
to_node	
HydroID	Unique waterway ID
NextDownID	HydroID of downstream reach
DrainID	HydroID of associated **Catchment 2ha** watershed
StreamOrder	Strahler stream order of reach
Rec2_SegmentID	Unique segment ID from parent REC dataset
Rec2_ReachID	Unique reach ID from parent REC dataset
Slope_Mean	Mean slope along reach (percent)
Slope_Max	Maximum slope along reach (percent)
Elevation_Max	Maximum elevation along reach
Elevation_Mean	Mean elevation along reach
LengthDown	Downstream length to coast/outflow point (metres)
Shape_Length	

DrainageLine_2ha_JunctionPoints

OBJECTID	
Shape	
Type	Junction point type (Head Water; Regular Junction Points)
Valency	Number of associated reaches (upstream and downstream)
PL_LINK1	HydroID of downstream **DrainageLine 2ha** reach
PL_LINK2	HydroID of upstream **DrainageLine 2ha** reach

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PL_LINK3	HydroID of additional upstream **DrainageLine 2ha** reach
PL_LINK4	HydroID of additional upstream **DrainageLine 2ha** reach
PL_LINK5	HydroID of additional upstream **DrainageLine 2ha** reach

DrainageLine_2k

OBJECTID	
Shape	
WatershedID	Unique ID of parent **Catchment 2ha** watershed
arcid	Unique ID
GridID	Unique ID of associated **Catchment 2k** (0.2ha) watershed
from_node	
to_node	
HydroID	Unique waterway ID
NextDownID	HydroID of downstream reach
DrainID	HydroID of associated **Catchment 2k** (0.2ha) watershed
StreamOrder	Strahler stream order of reach
Rec2_SegmentID	Unique segment ID from parent REC dataset
Rec2_ReachID	Unique reach ID from parent REC dataset
Slope_Mean	Mean slope along reach (percent)
Slope_Max	Maximum slope along reach (percent)
Elevation_Mean	Mean elevation along reach
Elevation_Max	Maximum elevation along reach
Stream_Habitat	Stream habitat type (Ephemeral, Intermittent, Perennial)[11]
RipVeg_Width	Riparian vegetation width (0m, 0-5m, 5-10m, 10-25m, >25m)[12]
Land_cover	Majority landcover type across reach[13]
Geology_type	Majority geology type across reach[14]
Shape_Length	

DrainageLine_2k_JunctionPoints

OBJECTID	
Shape	
Type	Junction point type (Head Water; Regular Junction Points)
Valency	Number of associated reaches (upstream and downstream)
PL_LINK1	HydroID of downstream DrainageLine_2k reach
PL_LINK2	HydroID of upstream **DrainageLine 2k** reach
PL_LINK3	HydroID of additional upstream **DrainageLine 2k** reach
PL_LINK4	HydroID of additional upstream **DrainageLine 2k** reach
PL_LINK5	HydroID of additional upstream **DrainageLine 2k** reach
PL_LINK6	HydroID of additional upstream **DrainageLine 2k** reach

DrainageLine_2k_QAQC

OBJECTID	
Shape	
Join_Count	
TARGET_FID	

[11] Stream habitat type based on Strahler stream order classification; 1 - 3 ephemeral, 4 - 5 intermittent, > 6 perennial.
[12] Based on vegetation coverage map derived by Water Technology by classification of 2022 Sentinel2 satellite imagery
[13] Based on LCDB5 Land Cover Name 2018
[14] Based on NZLRI Rock type

arcid	Unique ID
GridID	Unique ID of associated **Catchment 2k** (0.2ha) watershed
from_node	
to_node	
HydroID	Unique waterway ID
NextDownID	HydroID of downstream reach
DrainID	HydroID of associated **Catchment 2k** (0.2ha) watershed
StreamOrder	Strahler stream order of reach
Rec2_SegmentID	Unique segment ID from parent REC dataset
Rec2_ReachID	Unique reach ID from parent REC dataset
Slope_Mean	Mean slope along reach (percent)
Slope_Max	Maximum slope along reach (percent)
Stream_Habitat	Stream habitat type (Ephemeral, Intermittent, Perennial)
Landcover_Type	Majority landcover type across reach
Elevation_Mean	Mean elevation along reach
Elevation_Max	Maximum elevation along reach
RipVeg_Width	Riparian vegetation width (0m, 0-5m, 5-10m, 10-25m, >25m)
Geology_type	Majority geology type across reach
WatershedID	Unique ID of parent **Catchment 2ha** watershed
QA_ID	Unique ID of QAQC area
QA_SlopeClass	Classification of QAQC area according to its slope (Coastal/flat, Inland/Mid-Catchment, Upper Catchment)
QA_DeviationPct	Percentage of the reach which is not in the correct position
QA_Class	Accuracy check of stream habitat type for the reach (1 - Reach has right stream habitat type; 0 - Reach has wrong stream habitat type)
QA_DeviationLength	Length of the reach which is not in the correct position
Shape_Length	

DrainageLine_2k_Xing_FNDCRoads

OBJECTID	
Shape	
WatershedID	Unique ID of parent **Catchment 2ha** watershed
arcid	Unique ID
GridID	Unique ID of associated **Catchment 2k** (0.2ha) watershed
from_node	
to_node	
HydroID	Unique waterway ID
NextDownID	HydroID of downstream reach
DrainID	HydroID of associated **Catchment 2k** (0.2ha) watershed
StreamOrder	Strahler stream order of reach
Rec2_SegmentID	Unique segment ID from parent REC dataset
Rec2_ReachID	Unique reach ID from parent REC dataset
Slope_Mean	Mean slope along reach (percent)
Slope_Max	Maximum slope along reach (percent)
Elevation_Mean	Mean elevation along reach
Elevation_Max	Maximum elevation along reach
Stream_Habitat	Stream habitat type (Ephemeral, Intermittent, Perennial)
RipVeg_Width	Riparian vegetation width (0m, 0-5m, 5-10m, 10-25m, >25m)
Land_cover	Majority landcover type across reach
Geology_type	Majority geology type across reach
Shape_Length	
carr_way_no	Road segment carriageway number
carrway_end_m	Road segment end measure (m)
carrway_start_m	Road segment start measure (m)
cway_area	
cway_hierarchy	Road use/hierarchy
cway_sub_area	Sub area name
cway_width	Road segment width (m)

end_name	Name of adjoining road at end point
id	
is_converted	
length_m	Road segment length (m)
owner_type	Controlling authority type
pavement_type	Road pavement type
pavement_use	
road_id	Road name
start_name	Name of adjoining road at start point
total_area	
urban_rural	Urban or rural classification

DrainageLine_2k_Xing_KDCRoads

OBJECTID	
Shape	
WatershedID	Unique ID of parent **Catchment 2ha** watershed
arcid	Unique ID
GridID	Unique ID of associated **Catchment 2k** (0.2ha) watershed
from_node	
to_node	
HydroID	Unique waterway ID
NextDownID	HydroID of downstream reach
DrainID	HydroID of associated **Catchment 2k** (0.2ha) watershed
StreamOrder	Strahler stream order of reach
Rec2_SegmentID	Unique segment ID from parent REC dataset
Rec2_ReachID	Unique reach ID from parent REC dataset
Slope_Mean	Mean slope along reach (percent)
Slope_Max	Maximum slope along reach (percent)
Elevation_Mean	Mean elevation along reach
Elevation_Max	Maximum elevation along reach
Stream_Habitat	Stream habitat type (Ephemeral, Intermittent, Perennial)
RipVeg_Width	Riparian vegetation width (0m, 0-5m, 5-10m, 10-25m, >25m)
Land_cover	Majority landcover type across reach
Geology_type	Majority geology type across reach
Shape_Length	
carr_way_no	Road segment carriageway number
carrway_end_m	Road segment end measure (m)
carrway_start_m	Road segment start measure (m)
cway_area	
cway_hierarchy	Road use/hierarchy
cway_sub_area	Sub area name
cway_width	Road segment width (m)
end_name	Name of adjoining road at end point
id	
is_converted	
length_m	Road segment length (m)
owner_type	Controlling authority type
pavement_type	Road pavement type
pavement_use	
road_id	Road name
start_name	Name of adjoining road at start point
total_area	
urban_rural	Urban or rural classification

DrainageLine_2k_Xing_StateHwy

OBJECTID	
Shape	
WatershedID	Unique ID of parent **Catchment 2ha** watershed
arcid	Unique ID
GridID	Unique ID of associated **Catchment 2k** (0.2ha) watershed
from_node	
to_node	
HydroID	Unique waterway ID
NextDownID	HydroID of downstream reach
DrainID	HydroID of associated **Catchment 2k** (0.2ha) watershed
StreamOrder	Strahler stream order of reach
Rec2_SegmentID	Unique segment ID from parent REC dataset
Rec2_ReachID	Unique reach ID from parent REC dataset
Slope_Mean	Mean slope along reach (percent)
Slope_Max	Maximum slope along reach (percent)
Elevation_Mean	Mean elevation along reach
Elevation_Max	Maximum elevation along reach
Stream_Habitat	Stream habitat type (Ephemeral, Intermittent, Perennial)
RipVeg_Width	Riparian vegetation width (0m, 0-5m, 5-10m, 10-25m, >25m)
Land_cover	Majority landcover type across reach
Geology_type	Majority geology type across reach
Shape_Length	
Id	Unique ID
Road ID	Unique ID
State Highway	State highway number
Reference Station	Reference station ID
Direction	Direction category
Offset (m)	

DrainageLine_2k_Xing_WDCRoads

OBJECTID	
Shape	
WatershedID	Unique ID of parent **Catchment 2ha** watershed
arcid	Unique ID
GridID	Unique ID of associated **Catchment 2k** (0.2ha) watershed
from_node	
to_node	
HydroID	Unique waterway ID
NextDownID	HydroID of downstream reach
DrainID	HydroID of associated **Catchment 2k** (0.2ha) watershed
StreamOrder	Strahler stream order of reach
Rec2_SegmentID	Unique segment ID from parent REC dataset
Rec2_ReachID	Unique reach ID from parent REC dataset
Slope_Mean	Mean slope along reach (percent)
Slope_Max	Maximum slope along reach (percent)
Elevation_Mean	Mean elevation along reach
Elevation_Max	Maximum elevation along reach
Stream_Habitat	Stream habitat type (Ephemeral, Intermittent, Perennial)
RipVeg_Width	Riparian vegetation width (0m, 0-5m, 5-10m, 10-25m, >25m)
Land_cover	Majority landcover type across reach
Geology_type	Majority geology type across reach
Shape_Length	
road_id	Road name
carrway_st	Road segment start measure (m)
carrway_en	Road segment end measure (m)
start_name	Name of adjoining road at start point
end_name	Name of adjoining road at end point
cway_area	Sub area name
cway_sub_a	

pavement_t	Road pavement type
pavement_u	
urban_rura	Urban or rural classification
cway_hiera	Road use/hierarchy
length_m	Road segment length (m)
cway_width	Road segment width (m)
total_area	
owner_type	Controlling authority type
managed_by	Managing authority
carr_way_n	Road segment carriageway number
cway_area_	
estimate_l	
cway_use_c	Road use description
asset_owne	Asset owner description
id	
is_convert	

FlowDirection_Geographic

Raster representing geographic flow direction, which has been reclassified from a D8[15] flow direction raster produced by GIS analysis in ArcGIS.
Raster values represent flow direction in degrees (where 0 or 360 degrees means North, 180 degrees means South, etc)

HydroDEM_1m

Hydro-enforced digital elevation model representing elevation in metres. This raster was produced by undertaking 'hydro-enforcing, or burning' of raw 1m LiDAR DEM to unblock structures such as culverts, and ensure correct hydrological flow.

HydroDEM_1m_hs

Hillshade representation raster of the HydroDEM_1m

HydroDEM_Contour1m

OBJECTID	
Shape	
Id	Unique ID
Contour	Elevation of the contour line (in metres)
Shape_Length	

[15] The D8 flow direction method models flow direction from each cell in a DTM to its steepest downslope neighbour. The output of the Flow Direction tool run with the D8 flow direction type is an integer raster whose values range from 1 to 128

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