

# Braidplain delineation methodology

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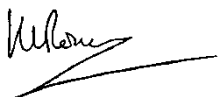
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## Contents

<b>Executive summary .....</b>	<b>5</b>
<b>1     Introduction .....</b>	<b>6</b>
1.1   Aim .....	7
1.2   A note on definitions and geomorphic context .....	8
<b>2     Methodology .....</b>	<b>10</b>
2.1   Overarching approaches .....	10
2.2   Data availability .....	10
2.3   Delineating the historical braidplain .....	12
2.4   Delineating the contemporary braidplain .....	21
<b>3     Results .....</b>	<b>25</b>
3.1   Shapefiles provided .....	25
3.2   Areas of uncertainty and geomorphic context .....	29
3.3   Comments on the software and time taken to apply this methodology .....	29
<b>4     Summary and recommendations .....</b>	<b>32</b>
<b>5     Acknowledgements .....</b>	<b>33</b>
<b>6     References .....</b>	<b>34</b>
<b>Appendix A             Ashley floodplain geomorphology map .....</b>	<b>35</b>

## Tables

Table 2-1:	Available GIS data layers used to delineate the braidplains of the Waiau and Ashley Rivers.	11
Table 2-2:	Quality control notes on the delineation of boundaries from the maps and aerial photographs.	19

## Figures

Figure 1-1:	Schematic diagram showing the adjustment of active channels over time within the braidplain.	7
Figure 1-2:	Map showing the location of the Waiau and Ashley River catchments.	8
Figure 1-3:	Schematic showing how braidplain margins vary depending on the landscape context.	9
Figure 2-1:	Spatial coverage of data for the Waiau catchment.	11
Figure 2-2:	Spatial coverage of data for the Ashley catchment.	12
Figure 2-3:	Changes in map detail and style over time for the Waiau River.	14
Figure 2-4:	Changes in map detail and style over time for the Ashley River.	15
Figure 2-5:	Examples of how the recently mobile bed was delineated on three historical maps of the Ashley River.	16
Figure 2-6:	Black Maps of the Ashley River.	17
Figure 2-7:	Examples of delineation of the recently mobile bed on the historical aerial photographs for a reach of the Ashley River.	18
Figure 2-8:	Example of historical braidplain definition for a reach of the Ashley River where there is a trend of agricultural encroachment.	20
Figure 2-9:	Example of historical braidplain definition for a reach of the Ashley River where there has been recent channel adjustment altering the maximum extent.	21
Figure 2-10:	Example of contemporary braidplain delineation for a reach of the Ashley River based on LiDAR DEM step-elevation (bath tub) analysis.	23
Figure 2-11:	Refinement of contemporary braidplain delineation for an example reach of the Ashley River.	24
Figure 3-1:	Screen print of the expanded ArcGIS map package for the Ashley River.	26
Figure 3-2:	Screen print of the expanded ArcGIS map package for the Waiau River.	27
Figure 3-3:	The 2015 aerial photograph of the Waiau catchment with the braidplain boundaries overlaid.	28
Figure 3-4:	The 2015 aerial photograph of the Ashley catchment with the braidplain boundaries overlaid.	28
Figure 3-5:	The reach in the Waiau catchment where the contemporary braidplain boundary cannot be determined from LiDAR.	30
Figure 3-6:	Hillshade DEM of the lower reaches of the Ashley catchment where the river crosses the unconfined lowland plains.	31
Figure 3-7:	Late Holocene geomorphic units associated with the lower Ashley River braidplain.	31
Figure A-1:	Map 4.3 of the Ashley River Floodplain Management Plan: Floodplain Geomorphology.	35

## Executive summary

Braided rivers are an iconic and highly valued feature of the Canterbury landscape. In order to protect the rivers of the Canterbury region, Environment Canterbury has policies in place which outline permitted activities within the river bed. However, the definition of 'river bed' in the Resource Management Act and referred to in current Environment Canterbury policy documents is unclear with respect to braided rivers. The river bed of braided rivers comprises multiple channels which frequently adjust across a braidplain. The aim of this project was to develop a methodology and rules to objectively delineate the braidplain of a given braided river (under current geomorphic controls), setting aside the presence of any engineered flood control, such as stop banks or willow belts. However, identification of these engineered controls to define the 'restricted' or 'managed' braidplain could be easily incorporated at a later stage (e.g., simply by overlaying stop bank positions and/or willow-belt boundaries). The methodology was developed using two test catchments, the Ashley River/Rakahuri and the Waiau River.

The methodology we have developed delineates the braidplain using two approaches. The first approach involves digitising a boundary around where we know the active channels of our rivers have been since European arrival, based on historical imagery and maps. We refer to this as the **historical braidplain**. The second approach involves analysing the LiDAR-derived digital elevation models (DEMs) and assessing the area that the river channels could adjust within, based on elevation and topography, such as existing river terraces which show earlier (early Holocene age or older) river extents. We refer to this area as the **contemporary braidplain**. Each of these approaches has advantages and disadvantages, and we recommend using a combination of these approaches where possible.

The methodology we have presented for delineating the contemporary braidplain best represents the area the active channels could adjust within under current geomorphic controls (ignoring engineering controls). However, in areas where there is no LiDAR data available the methodology cannot be applied. Also, in some areas the braidplain boundaries are highly uncertain due to geomorphic context (e.g., where the river crosses lowland plains or where there are tributary alluvial fans). In these areas, the methodology presented for delineating the historical braidplain provides an alternative approach. However, this approach may underestimate the area of the braidplain and digitising the boundary is more time consuming than the LiDAR based approach, which is partly automated.

The historical braidplain and contemporary braidplain boundaries for the Waiau and Ashley Rivers, determined while developing this methodology, and the various shapefiles used to determine these boundaries have been supplied to Environment Canterbury as ArcGIS map package files named Ashley\_All\_Results.mpk and Waiau\_All\_Results.mpk. An outline of each of the layers included in these packages is listed in this report.

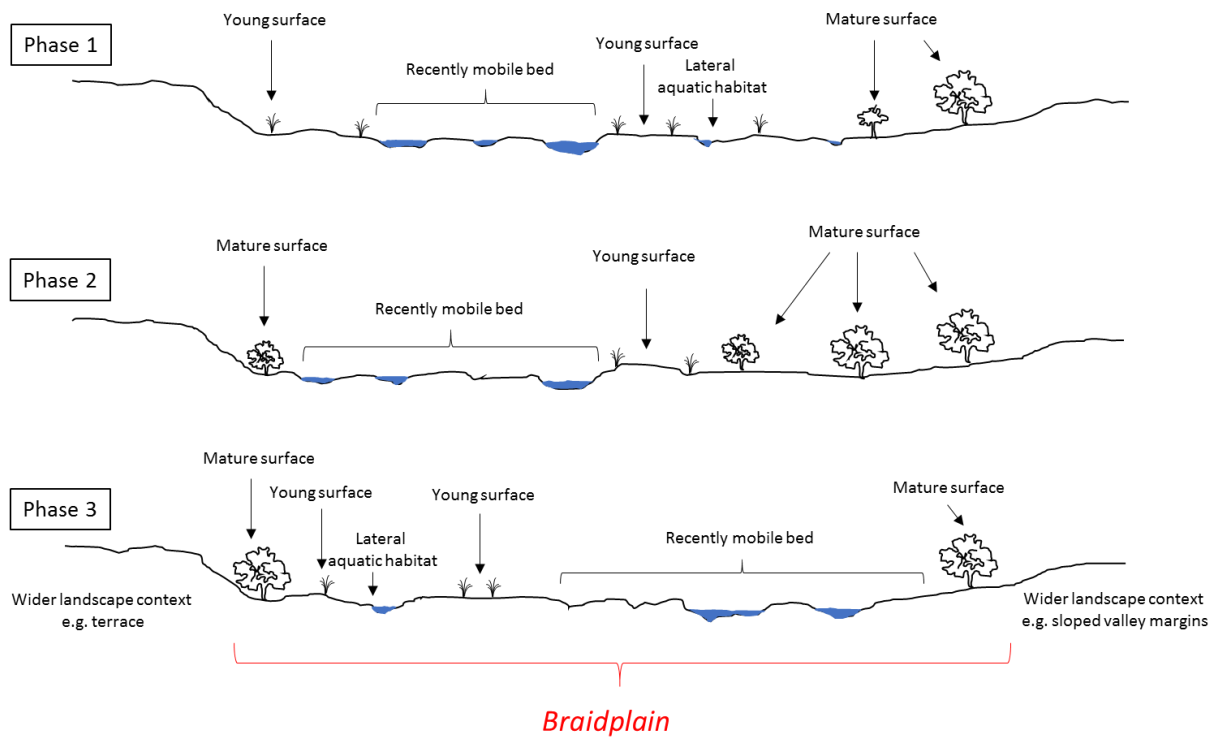
This was a desktop study only and the shapefiles produced for the test case catchments using either approach may not perfectly match boundaries on the ground. For example, this historical braidplain approach relies on the accuracy of early maps (which may be questionable) and the contemporary braidplain approach requires a degree of interpretation in some areas. For any areas of the Ashley or Waiau catchments where braidplain boundaries are of particular interest, we recommend that the boundaries are verified on the ground with a site visit. This would also be our recommendation when applying this methodology to other catchments.

# 1 Introduction

Braided rivers are an iconic feature of the Canterbury landscape and their complex and dynamic nature provides a range of valuable aquatic, wetland and terrestrial habitat. As such, braided rivers are very highly valued for natural character and biodiversity. Many Canterbury braided rivers are necessarily constrained by flood defence works. However further encroachment by agricultural development, both within and outside of existing flood defence areas, is impacting on natural character and ecosystem values (Grove et al. 2015). The natural character and ecological values of braided rivers can also be impacted by changes in flow regime (e.g., due to water abstraction or hydropower dams) or sediment supply (e.g., due to gravel extraction) and the encroachment of exotic vegetation.

In order to sustainably manage the rivers of the Canterbury region, Environment Canterbury has policies in place which outline permitted activities within the river bed. However, the definition of 'river bed' in the Resource Management Act (1991) and in current Environment Canterbury policy (e.g., Environment Canterbury 2017) are unclear with respect to braided rivers, and may not adequately incorporate the area required to protect the natural character of braided rivers.

The Resource Management Act (1991) defines river bed as "*the space of land which the waters of the river cover at its fullest flow without overtopping its banks*". This definition is based on the geomorphic concept of 'bank full', where increasing flow covers the river bed, fills up the channel and then spills over the banks onto a floodplain. The application of this bank full approach relies on the presence of static and well-defined river channels and banks, which do not exist in braided rivers. Braided rivers have multiple channels, with increasing flow often spilling to additional channels, and these channels also move frequently (from flood event to flood event), sometimes adjusting over large areas. The braided river bed is the area that the various channels adjust within. This area is also referred to as the 'braidplain' (Figure 1-1). Introduction, definition and spatial delineation of this term to planning documents would remove uncertainty for land owners and resource managers. However, this change would require clear definition of the parcel of land classified as braidplain for each braided river.

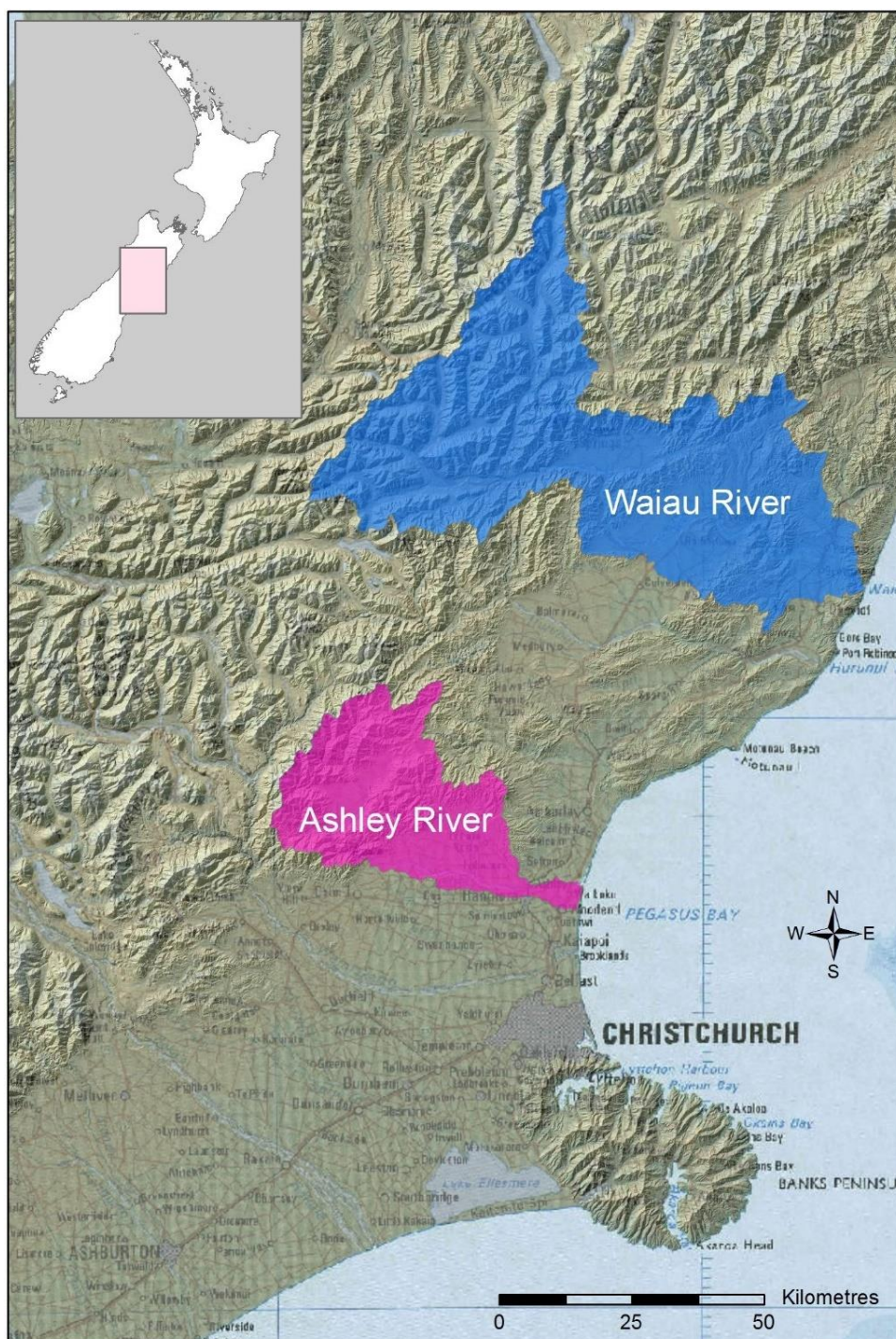


**Figure 1-1:** Schematic diagram showing the adjustment of active channels over time within the braidplain.

## 1.1 Aim

The aim of this project was to undertake a desktop study to develop a methodology and rules to objectively delineate the braidplain of a given braided river (i.e., the area the active channels have adjusted within, and could adjust within in future, under current geomorphic controls).

The methodology was developed using two test catchments, the Ashley River and the Waiau River (Figure 1-2). These rivers were chosen because, respectively, they provide good examples of “foothills-source” and “alpine-source” braided rivers with their associated geomorphic characteristics.



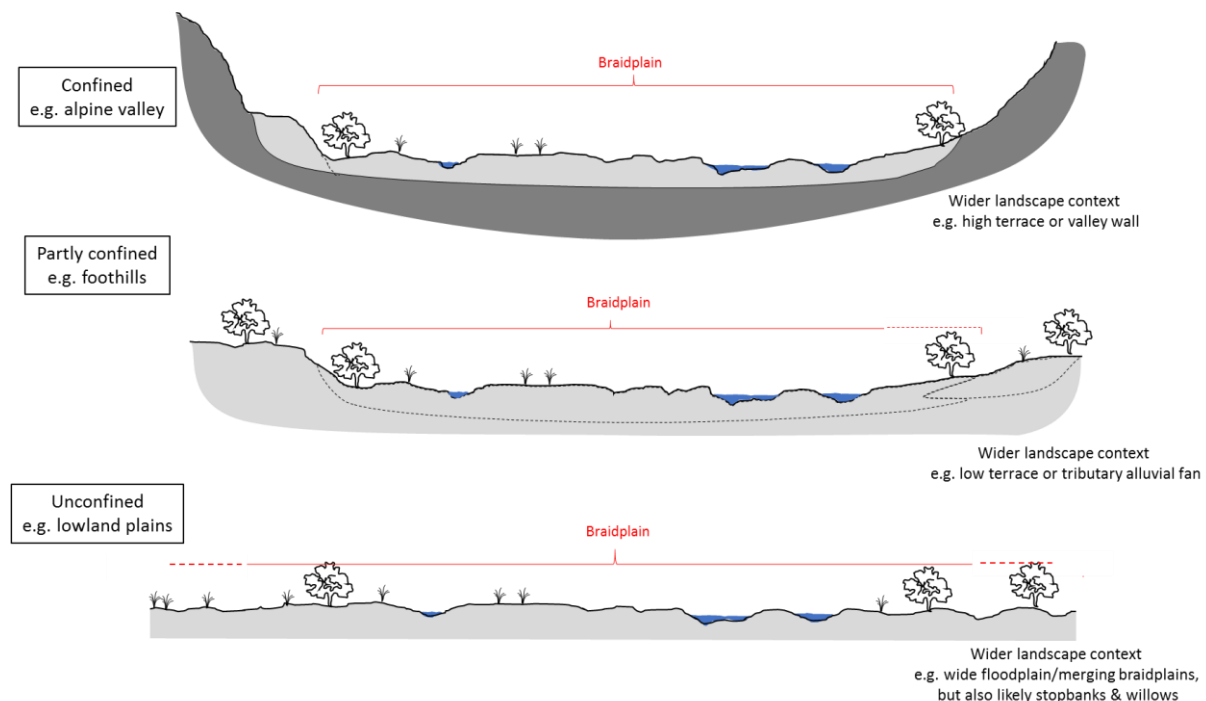
**Figure 1-2: Map showing the location of the Waiau and Ashley River catchments.**

## 1.2 A note on definitions and geomorphic context

Delineation of the braidplain of a braided river presents several challenges. Due to the complex and dynamic nature of braided rivers, parts of the braidplain of a given braided river may not have been occupied by active channels for some time (i.e. several decades or more, Figure 1-1). This may be due to natural river migration, and may be temporary, or may be the result of longer-term river adjustment in response to geomorphic controls such as: changes in flow regime or sediment supply, river management controls such as willow planting and stop banks, or invasion of exotic vegetation.

For the purposes of this project the braidplain is defined as the area that might be occupied by the active channels of the river under the contemporary flow and sediment supply regime. Also, in delineating the braidplain, the influence of willows and stop banks are set aside. However, identification of these controls to delineate the 'restricted' or 'managed' braidplain could be easily incorporated at a later stage (e.g., simply by overlaying stop bank positions and/or willow-belt boundaries).

The ease with which the margins of a braidplain can be defined often depends on the geomorphic setting or wider landscape context (Figure 1-3). A braidplain may occupy the full width of an alpine valley, pinned only by valley walls or old terraces. Valley walls and large terraces provide relatively clear braidplain boundaries. While adjacent terraces may represent old braidplain surfaces with evidence of old channels, their elevation is typically such that the river can no longer occupy those surfaces under current flow and sediment supply regimes. However, terrace elevations will vary and some may be only slightly elevated above the braidplain making them more difficult to distinguish. Also, a braidplain may have gently sloping valley margins, such as from a tributary alluvial fan, providing 'fuzzy' braidplain margins that are difficult to distinguish. On the lowland plains, the braidplain margins may be very wide and may be impossible to define from variations in elevation. Also, the braidplains of various braided rivers may merge across large, old alluvial fans. In these areas, braidplain delineation is particularly challenging and it may be more useful to consider the braidplain as the area that has been occupied by the active channel within a given historical time period rather than trying to identify where the active channels could adjust to. Having said this, the lowland plains are also typically the parts of the catchment where the braidplain is confined between stop banks and/or willow belts, and, therefore, braidplain delineation may be less of a concern.



**Figure 1-3: Schematic showing how braidplain margins vary depending on the landscape context.** Note: the dark grey underlying the upper cross section indicates bedrock, and the light grey substrate in all cross sections indicates alluvial gravels. Dashed black lines indicate the indistinct boundaries between recently mobile alluvial gravels, alluvial gravels from tributary alluvial fans (right side of partly confined cross section), underlying older alluvial gravels and those comprising terraces. Dashed red lines indicate where braidplain boundaries are uncertain.

## 2 Methodology

### 2.1 Overarching approaches

During this study, we delineated the braidplain of our test case rivers using two approaches.

The first approach was to draw a boundary around where we know the active channels of our rivers have been since European arrival, based on historical imagery and maps. We refer to this as the **historical braidplain**. This approach is easy to apply (albeit time-consuming, due to the amount of manual digitising required) and is robust and objective as there is unmistakable evidence from given points in time. However, this approach will likely underestimate the true braidplain of the river, as maps and aerial photographs are only snap-shots in time and, from a geomorphic perspective, are only available for a relatively short period (e.g., photographs post 1940's). It is important to recognise that the historical braidplain is a subset of the contemporary braidplain; just because active river channels have not been captured in a given area on a map or photo does not mean that they haven't been there in the past (under current geomorphic conditions) or that they couldn't adjust there in the future.

The second approach was to analyse Light Detection and Ranging (LiDAR) derived digital elevation models (DEMs) and assess the area that the river channels could possibly adjust within, based on elevation and topography that captures geomorphic features such as river terraces. This area is a truer representation of the braidplain, so we refer to this as the **contemporary braidplain** to avoid confusion with the historical braidplain. This approach also follows an objective methodology but requires a greater degree of geomorphic interpretation, and the complexity of interpretation in braidplain delineation depends on the landscape context (Figure 1-3). It is also not possible to apply this methodology where no LiDAR data are available, as the geomorphic interpretation required needs robust underpinning topographic information.

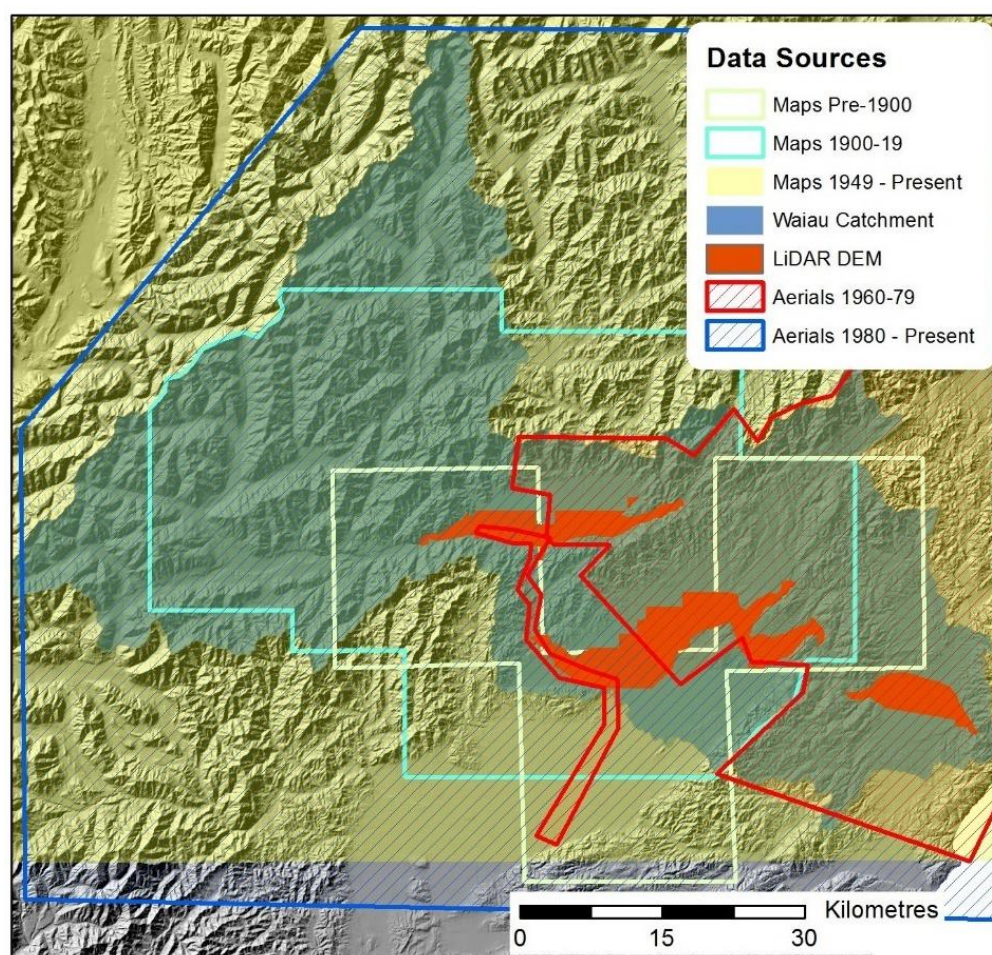
### 2.2 Data availability

The data used for the delineation of the Waiau and Ashley braidplains are listed in Table 2-1. The historical maps were downloaded from the Maps Past website (<http://www.mapspast.org.nz/>). The aerial photographs were accessed through the Environment Canterbury mapserver (<https://canterburymaps.govt.nz/>). The Black Maps and the LiDAR DEMs were provided directly by Environment Canterbury. The soil maps were the Fundamental Soil Layer available from the Landcare Research website (<https://soils.landcareresearch.co.nz/soil-data/fundamental-soil-layers/>).

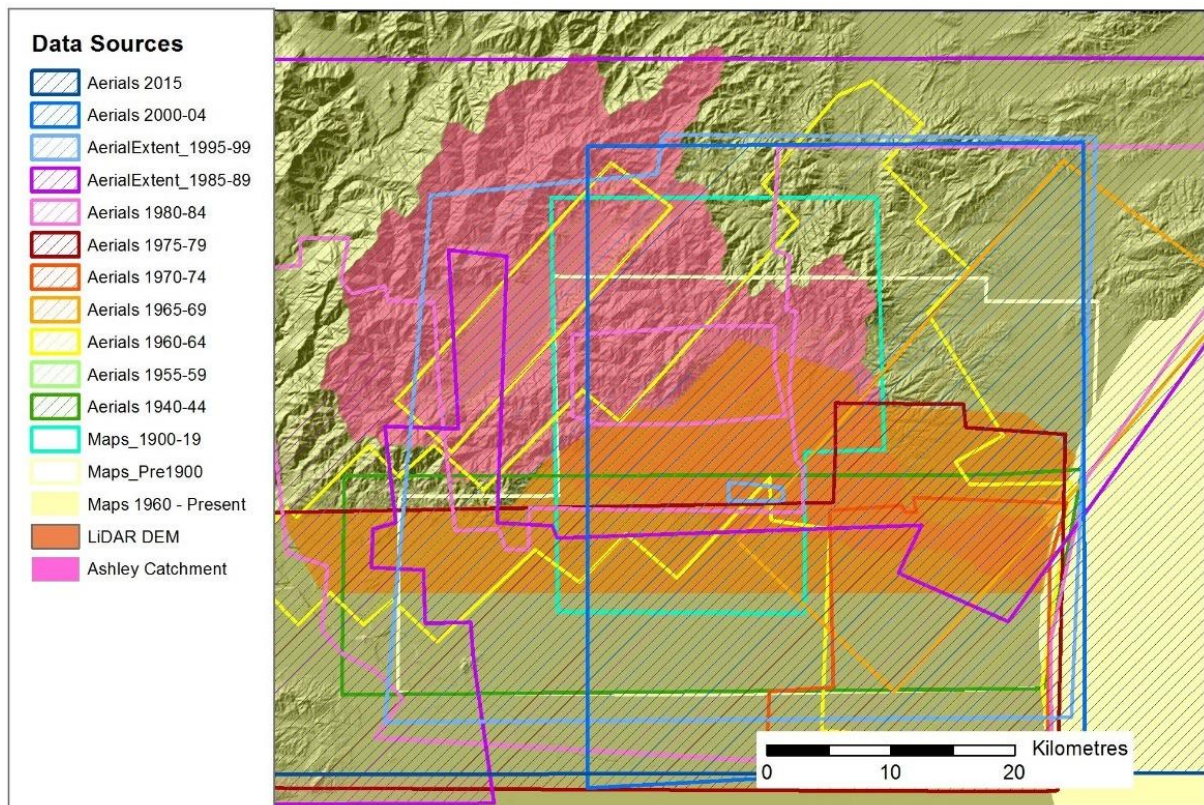
Many of these data layers have limited spatial coverage and are only available for part of the catchment. The spatial coverage of the data layers is presented in Figure 2-1 and Figure 2-2.

**Table 2-1: Available GIS data layers used to delineate the braidplains of the Waiau and Ashley Rivers.**

Data layer	Waiau River	Ashley River
Historical topographic survey maps	1879, 1919, 1949, 1959, 1969, 1979, 1989, 1999, 2009	1899, 1909, 1959, 1969, 1979, 1989, 1999, 2009
Other maps	Soil maps	Soil maps Black Maps 1850
Aerial photographs	1960-64, 1965-69, 1984, 1989, 2004, 2015	1940-44, 1955-59, 1960-64, 1970-74, 1975-79, 1980-85, 1985-89, 1995-99, 2000-04, 2015
LiDAR DEMs	Subset of the North Canterbury Rivers 2013 LiDAR survey	Subset of the Waimakariri 2005 LiDAR survey



**Figure 2-1: Spatial coverage of data for the Waiau catchment.**



**Figure 2-2: Spatial coverage of data for the Ashley catchment.**

## 2.3 Delineating the historical braidplain

We define the historical braidplain as the area where we know the active channels of our test case rivers have been since European arrival, based on historical imagery and maps.

There were three steps to delineating the historical braidplain:

1. Drawing a boundary around the recently mobile river bed on each historical map and aerial photo, with the recently mobile area defined as the area of bare gravel and connected wetted channels.
2. Compiling each of these boundary shapefiles, and carrying out quality control on each layer (adjusting reaches where georeferencing could be improved and/or discarding shapefiles, or parts of shapefiles, where accuracy was unreliable).
3. Delineate the maximum extent of the combined shapefiles, i.e., the furthest extent to the right and left of the river that has been occupied by active channels historically.

Note that the area of river defined on each of the maps and photos individually does not represent the braidplain, each of these boundaries only represents the area of the braidplain that was recently mobile at the time of the map or photo. The historical braidplain is only delineated once all the mobile bed boundaries are compiled.

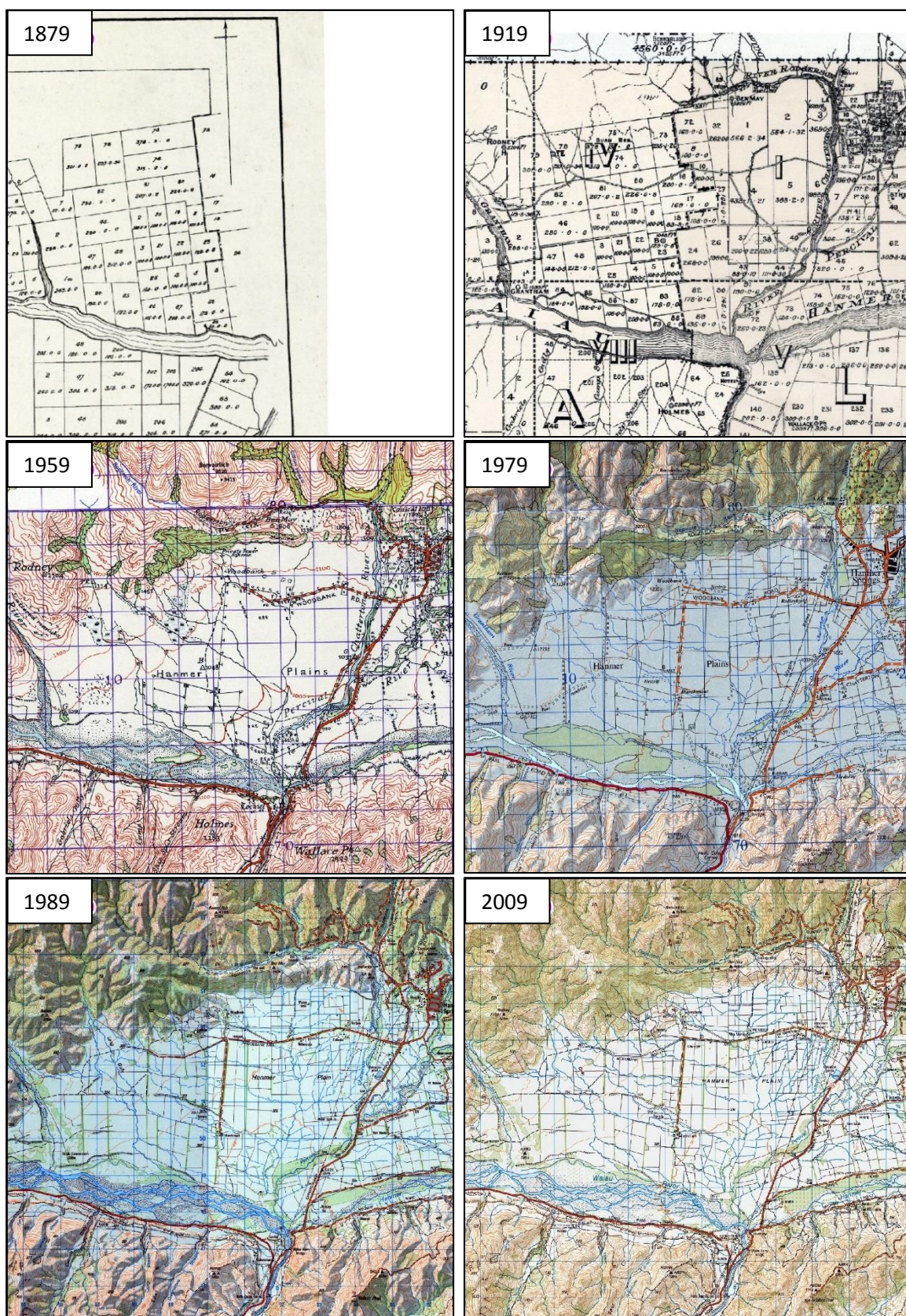
Further details and examples of these steps are provided in the following sections.

### 2.3.1 Analysis of historical topographic maps

The historical topographic maps vary in spatial coverage, detail and accuracy over time. The spatial coverage of data for the Waiau and Ashley rivers is shown in Figure 2-1 and Figure 2-2 respectively.

The change in detail and the symbology of how the rivers are mapped can be seen in Figure 2-3 and Figure 2-4 for the Waiau and Ashley respectively. The maps available on the Maps Past website are assigned to a given decade, such that the river in any decade may be represented by a range of different maps (particularly the earlier decades). The actual dates of each map are generally unknown. The early maps will have been surveyed, whereas the later maps will likely have been digitised off aerial photographs. Having said this, no given map appeared to directly match a given aerial photograph.

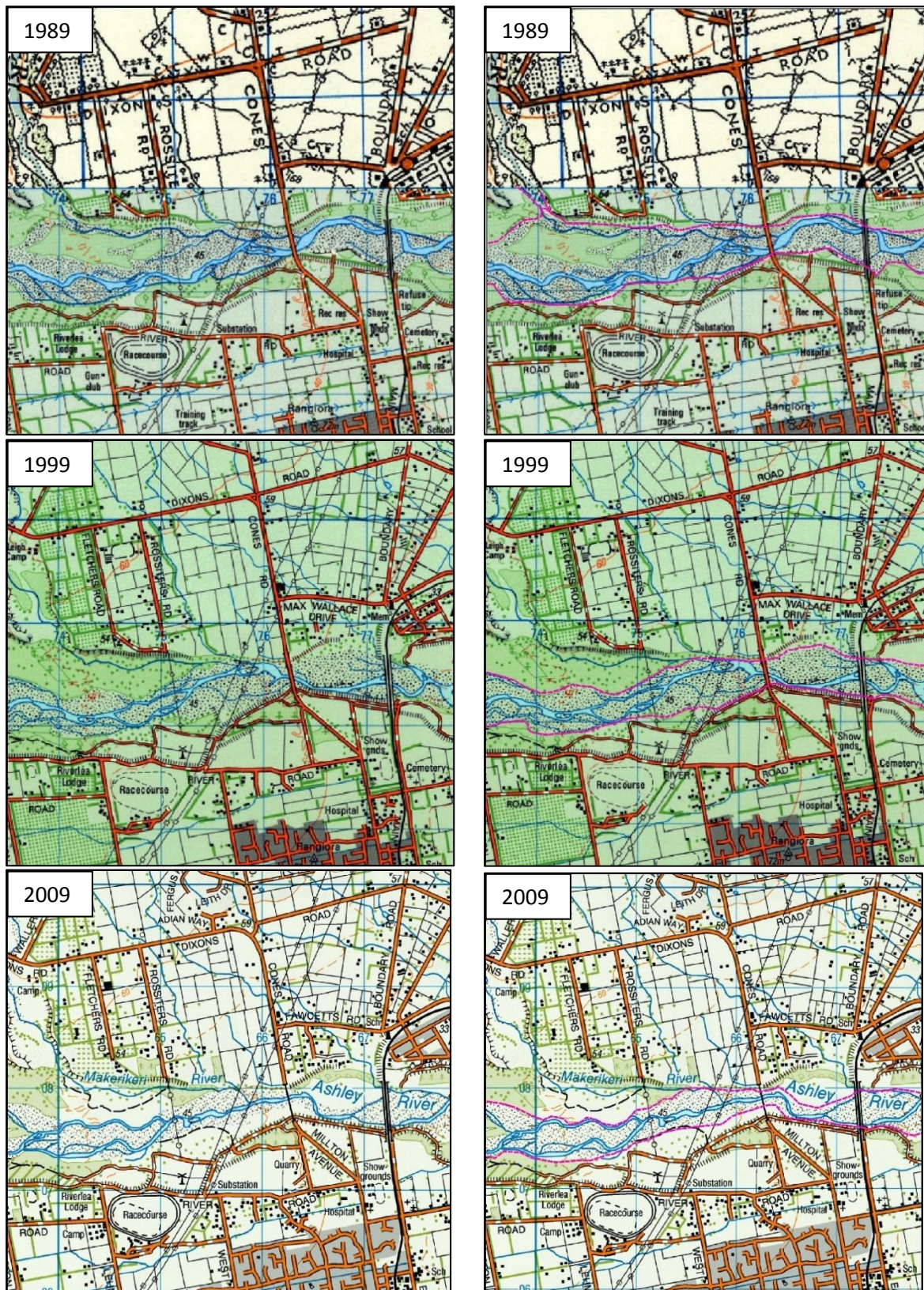
Digitising the boundary of the recently mobile river bed was relatively simple for the maps prior to the 1980's, as these maps all have river boundaries already delineated (in black for the 1879, 1899, 1919, 1959 maps, and in blue for the 1969 and 1979). For the later maps, the boundary of the recently mobile river bed was digitised based on the outer boundary of connected river channels, indicated in blue, or bare gravel, indicated by stippling. An example of how this area was defined for an example reach of the Ashley River is shown in Figure 2-5 for the 1989, 1999 and 2009 maps.



**Figure 2-3: Changes in map detail and style over time for the Waiau River.** Note: The date is shown top left of each map, and each map shows the same reach of the Waiau River, near Hanmer Springs.



**Figure 2-4: Changes in map detail and style over time for the Ashley River.** Note: The date is shown top left of each map, and each map shows the same reach of the Ashley River, near Rangiora. The 1979 map has not been included in this figure because the river in this reach was the same as on the 1959 map.



**Figure 2-5: Examples of how the recently mobile bed was delineated on three historical maps of the Ashley River.** The maps to the left are the base maps (1989, 1999 and 2009) and those to the right are the same maps with the delineated boundaries overlaid in pink.

### 2.3.2 Analysis of other maps

Having digitised the historical topographic maps, we compared the river boundaries with those indicated on the available Black Maps and Landcare Research's Fundamental Soil Layer maps, to see if these provided additional information on braidplain area.

The Black Maps are a very valuable data layer, as they provide the earliest available documentation of river position. The Black Maps provided to NIWA by Environment Canterbury only covered the lower reaches of the Ashley River and only covered the true right side of the river (Figure 2-6). We digitised the river boundary shown on the Black Maps for the Ashley River and found that it corresponded very closely with the river boundary digitised on the 1899 maps of the Ashley River. No Black Maps were provided for the Waiau River.

The Fundamental Soil Layer maps showed differing boundaries to the topographic maps but the river extent remained within the topographic map boundaries, and therefore didn't provide any additional information. Also, the river boundaries indicated by the soil maps appeared to be similar, capturing less detail than the topographic maps.

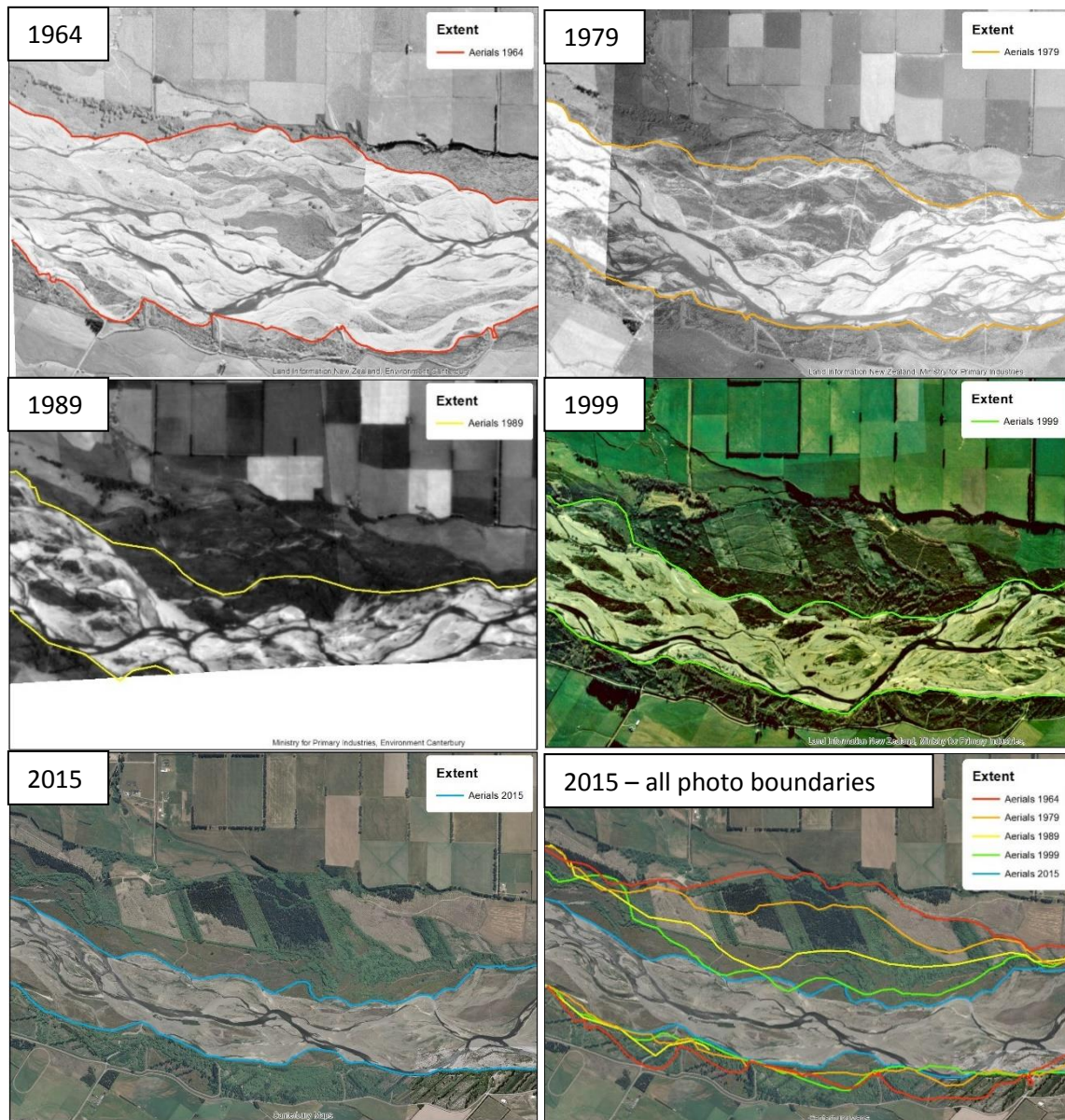
In summary, in terms of identifying river boundaries, neither the soil maps nor the Black Maps provided additional information on past channel locations to that obtained from the topographic maps. However, this may not be the case for other catchments, and we would recommend that the Black Maps (where available) continue to be considered in future if this method of delineating braidplains is to be applied to other catchments.



**Figure 2-6: Black Maps of the Ashley River.** The red line is the river boundary digitised off the Black Maps. This line corresponds very closely with the river boundary delineated on the 1899 survey map. The underlying photograph is the 2015 aerial photograph.

### 2.3.3 Analysis of historical aerial photographs

The boundaries of the recently mobile bed were delineated on the historical aerial photographs using the same approach as on the historical maps, defining the recently mobile bed as the area of connected wetted channel and bare gravel (generally lighter grey). An example for a reach of the Ashley River is shown in Figure 2-7.



**Figure 2-7: Examples of delineation of the recently mobile bed on the historical aerial photographs for a reach of the Ashley River.** Note the bottom left image shows the 2015 photograph will all the boundaries from historical aerial photographs overlaid. This reach shows a clear example of agricultural encroachment over time.

### 2.3.4 Quality control for the historical data layers

When checking the quality of georeferencing for the maps and aerial photographs, the most recent layers were taken as the 'source of truth' (2015 aerial photographs or 2009 maps). If there were obvious offsets in channel alignment between years (visible most clearly along the narrow gorges), the digitized boundary shapefile segments were shifted into an approximately correct position and

the shifted lines were noted in a column in the shapefile attribute table. Further close inspection of each line was only undertaken if the boundary for a given year described the maximum extent line. The accuracy of the boundaries delineated on the aerial photographs can be limited by both the accuracy of the georeferencing and the quality of the photographs themselves. Most aerial photographs were well georeferenced and of good quality, which meant that delineation of the boundaries could be carried out with high detail by zooming in on the photographs. Quality control notes, identifying maps and photographs with specific issues are provided in Table 2-2.

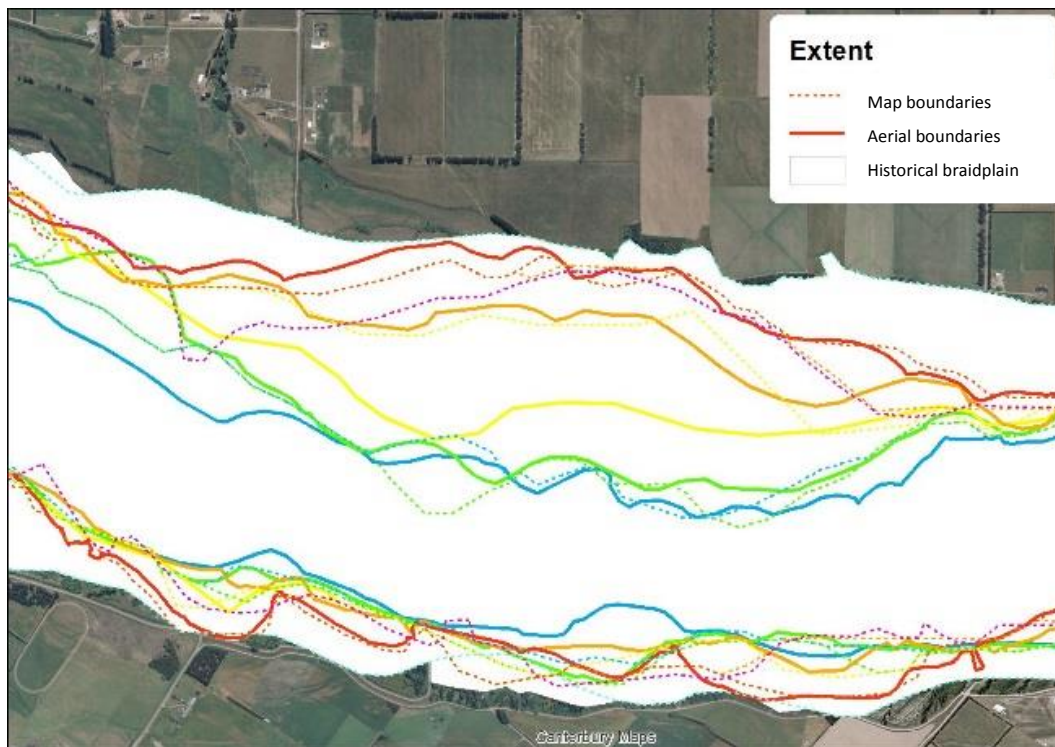
**Table 2-2: Quality control notes on the delineation of boundaries from the maps and aerial photographs.**  
Note: data layers where quality and georeferencing were reasonable, and no specific adjustment was required are not listed.

Catchment	Map quality notes	Photo quality notes
Waiau	1879 – very poor georeferencing, excluded from maximum extent analysis	1984 - black and white, poor quality, some segments realigned
	1919 – reasonable georeferencing, adjustment near Rotherham	1989 - black and white, poor quality, some segments realigned
	1949 – mostly good georeferencing, adjustment of right bank near Rotherham	
	1959 – poor georeferencing, whole shapefile shifted and then local tributary adjustment	
Ashley	1959 – poor georeferencing, adjustments made where possible, Makerikeri tributary excluded from maximum extent analysis	1940-44 – at upstream extent of coverage photos show dense vegetation with some evidence of channels within the vegetation. However, these were difficult to delineate so were excluded from the delineation. However, we note that the area defined as recently mobile bed is an underestimate
	1979 - mostly good georeferencing, adjustment made to Makerikeri tributary alignment	1960-64 - poor quality and the Makerikeri was heavily vegetated making delineation difficult
		1980-85 - black and white, very poor quality, segments realignment throughout catchment
		1985-89 - black and white, poor quality, some tributary segments realigned
		2015 – colour, good quality. However, tributaries have substantial gravel extraction, so extra lines added to delineate these with a new attribute column

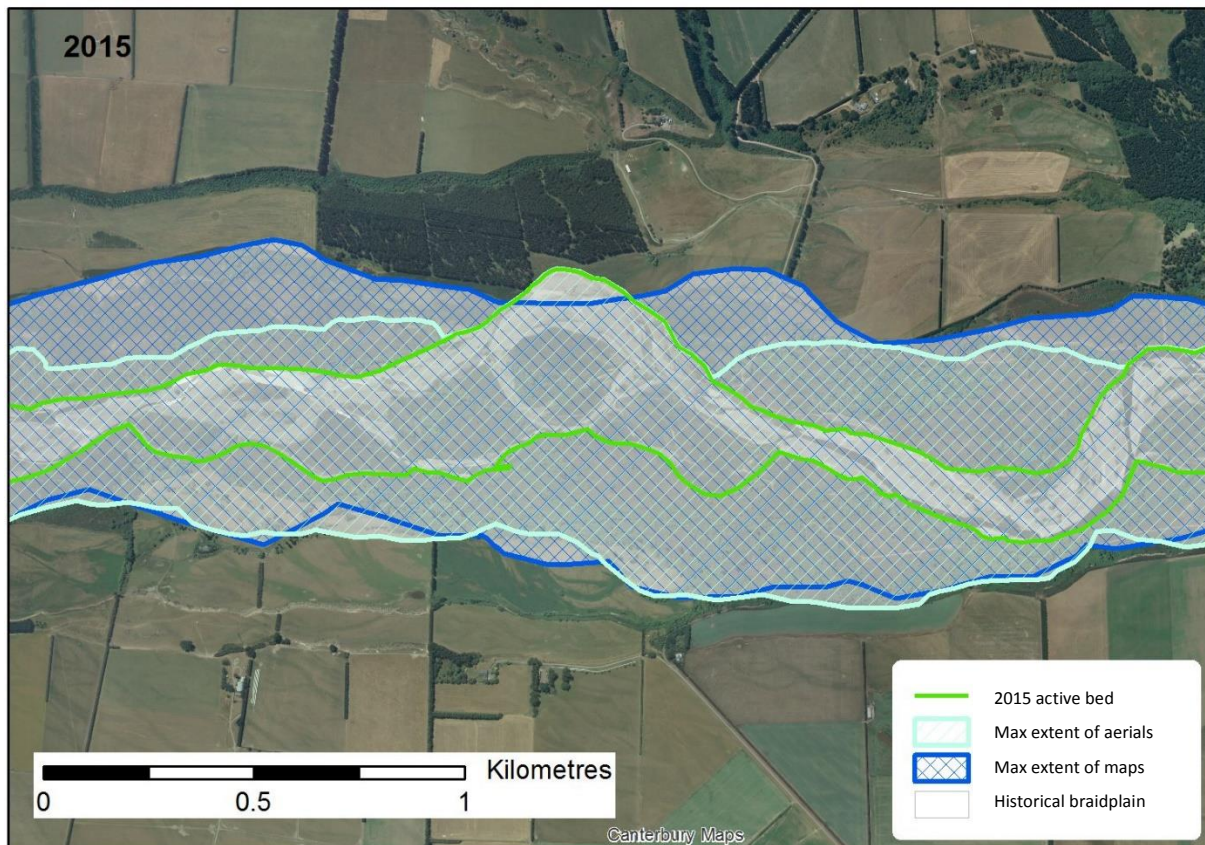
### 2.3.5 Delineating maximum extent

Once the recently mobile bed boundaries had been digitised for all maps and aerial photographs, these boundary polygons were overlaid and merged into one polygon, eliminating all contained polygons, thereby creating one new line which describes the outermost extent of all of them. We did this in two steps: first defining the maximum extent from the maps and the maximum extent from the aerials separately, and then combining the results to give the maximum extent overall. Separating out the maps and aerial photos is not strictly necessary, but the separate results may be of interest.

In some reaches the maximum extent may be largely defined by a shapefile boundary from one point in time. For example, where there have been trends of agricultural encroachment into the braidplain, the older boundaries may describe the maximum extent (e.g., Figure 2-8). This is not always the case, however. In some reaches the maximum extent can be defined by recent channel adjustment (e.g., Figure 2-9).



**Figure 2-8: Example of historical braidplain definition for a reach of the Ashley River where there is a trend of agricultural encroachment.** The image shows the 2015 aerial photograph with the recently mobile bed boundaries from each of the aerial photographs (solid coloured lines) and maps (dashed coloured lines) overlaid and the maximum extent of these combined boundary shapefiles (white area), which is largely defined by one of the oldest maps.



**Figure 2-9: Example of historical braidplain definition for a reach of the Ashley River where there has been recent channel adjustment altering the maximum extent.** This figure shows the maximum extent from maps (dark blue outline) and the maximum extent from aerials (light blue outline) separately, as well as the combined maximum historical extent (shaded white). The green outline shows the recently mobile bed boundary from the 2015 aerial photograph. This highlights that the river has increased its maximum extent between 2009 (the most recent map) and 2015 (the most recent aerial).

## 2.4 Delineating the contemporary braidplain

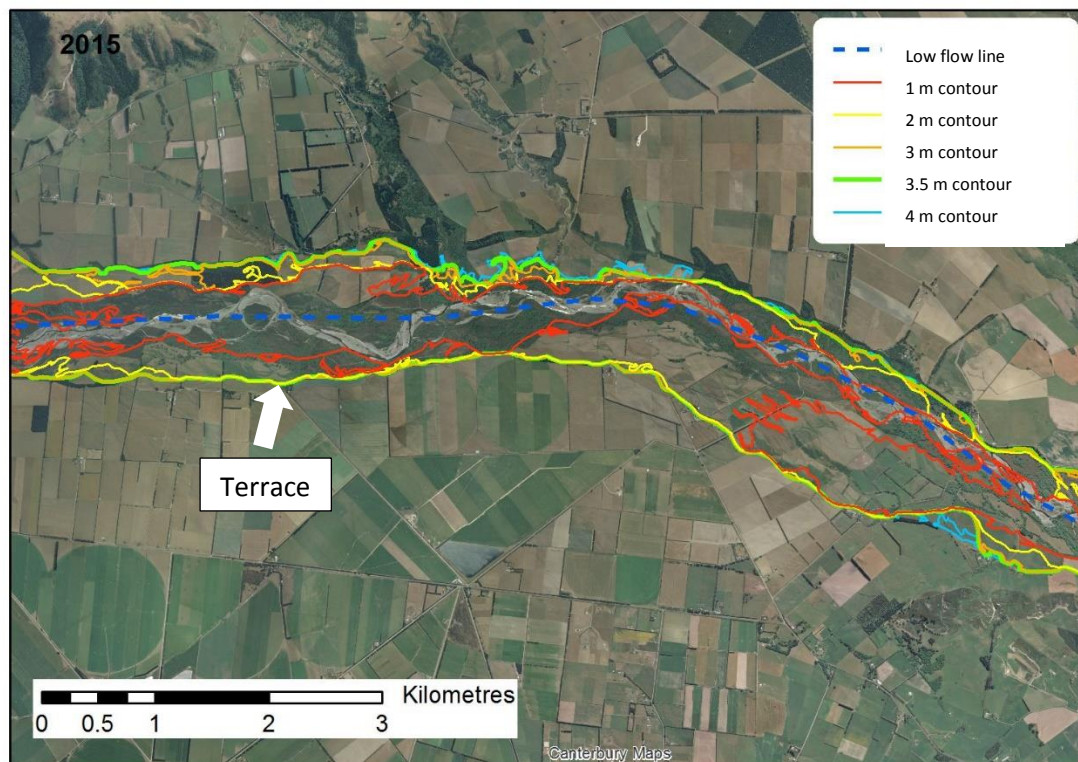
### 2.4.1 LiDAR Analysis

The extent of the contemporary braidplain was derived by analysing the LiDAR derived DEM to detect small geomorphic features such as terraces that would confine the extent of the river. This was a three step process:

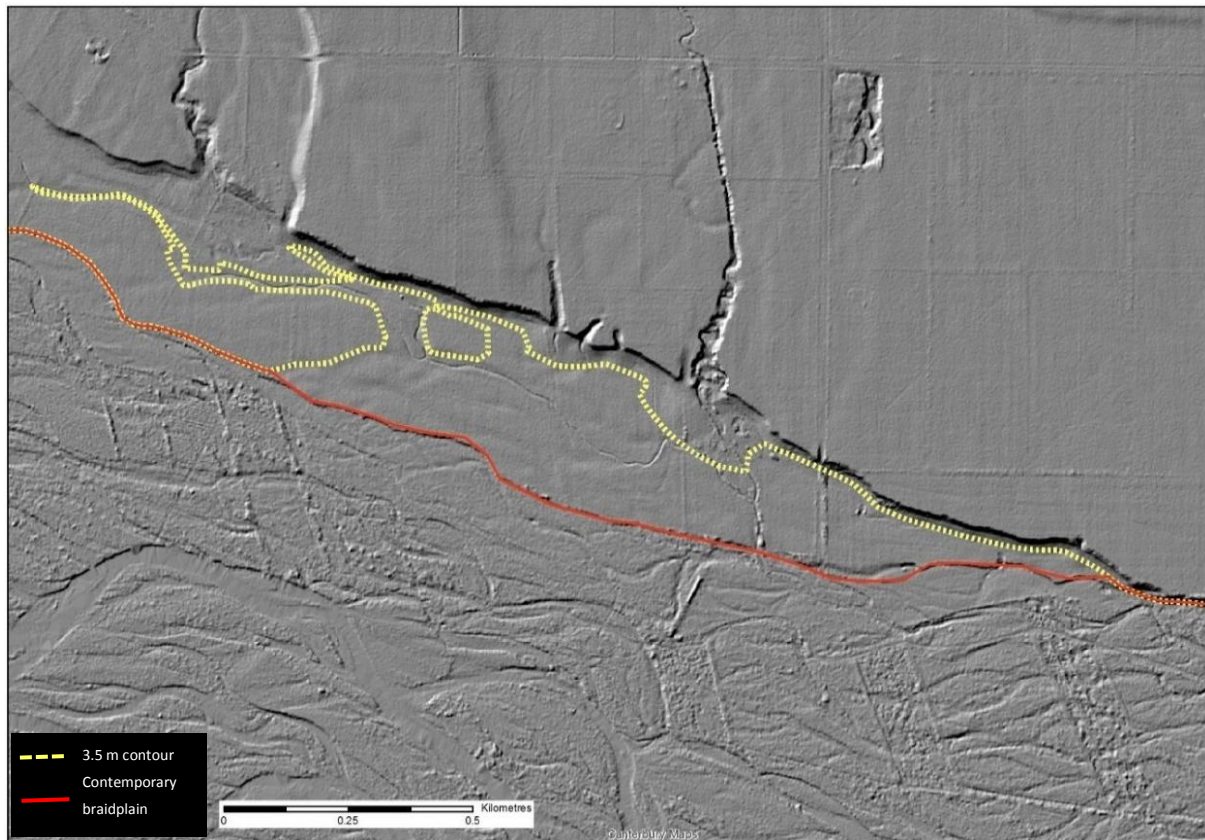
1. **Mapping contours relative to low flow water surface:** An “At-LiDAR-Capture” water level was extracted at points along the dominant channel at regular intervals. These points were then copied 2000 m to each side perpendicular to the direction of the channel, creating three points of equal height along a 'cross-section'. These points were then used to create a Triangular Irregular Network (TIN) of the water surface elevation along the entire reach. The height of this surface was then increased by steps of 0.5 m and the intersection with the DEM was mapped. The range of analysed elevations above the water level was 2-4.5 m for the Ashley River and 1–6 m for the Waiau River (a larger range for the Waiau was necessary to get a better understanding of the water extent behaviour due to the lack of terraces in some areas). An example of these step-elevation water level lines is shown for a reach of the Ashley in Figure 2-10.

2. **Identifying appropriate contour for terrace definition:** Next, we identified the contour line that showed the least amount of complexity, i.e., the one that showed the straightest or most compact shape. This usually indicates that the DEM has a sharp rise at this location. We then looked at a hillshade model of the DEM to see whether this contour aligned with a terrace. Generally, there was one contour that intersected with most of the major terraces. This contour was then used as a basis for defining the contemporary braidplain boundary. For the Ashley River, the 3.5 m contour best described the braidplain boundary (e.g., Figure 2-10). For the Waiau River, the DEM was available in three parts, each covering a floodplain pocket (Figure 2-1). The braidplain in the middle floodplain pocket was best described by the 4 m contour, and in the other two floodplain pockets the braidplain as best described by the 3.5 m contour. In some areas terraces could not be defined. These are discussed further in Section 3.2.
3. **Refining boundaries in areas of ambiguity:** Finally, these best fit contour lines were overlaid on the hillshade DEM and were modified by expert judgement in areas that remained ambiguous, i.e., the lines were not delineating a terrace. Terraces were generally reasonably clear on the hillshade DEM, and where multiple terraces existed or terraces were only of low elevation, differences in texture between lower and higher elevation surfaces were used to interpret terrace edges. An example of this type of modification is shown for a reach of the Ashley River in Figure 2-11.

Note that this approach ignores the presence of stopbanks or willow belts. The DEM is a bare earth model (i.e. the LiDAR detects vegetation but laser returns from the top of vegetation were removed in the development of the DEM, prior to NIWA obtaining the DEM) so the vegetation does not feature on the DEM. The stopbanks do feature on the DEM but our process manually excludes them. The methodology of laterally projecting a defined elevation above water surface (step 1 above) may define a boundary beyond the stopbank, and if the elevation of the stopbank is higher than the projected elevation then the stopbank will protrude (as may other features). The protruding features are then manually excluded if they provide no barrier to adjustment or are engineered stopbanks.



**Figure 2-10: Example of contemporary braidplain delineation for a reach of the Ashley River based on LiDAR DEM step-elevation (bath tub) analysis.** Terraces are clearly defined where an increase in elevation above the low flow channel causes little change in extent (e.g., 2 m to 4 m elevations above low flow all align at a terrace indicated by the arrow).



**Figure 2-11: Refinement of contemporary braidplain delineation for an example reach of the Ashley River.** Background image shows hillshade DEM, yellow dashed line shows initial delineation based on a contour 3.5 m above the low flow water level, and red line shows final delineation. The yellow dashed line shows an area where the 3.5 m above low flow polygon does not clearly define a terrace edge. However, closer inspection of the hillshade DEM shows two terraces, a lower terrace delineated in red, and a higher terrace beyond (above) the dashed yellow line. Textural differences either side of the red line helped to define this as a terrace/braidplain boundary.

## 3 Results

The aim of this project was to develop a methodology for delineating braidplain boundaries. The key results from this study are the methodology itself (described in the previous section) and the shapefiles developed for the test catchments using the methodology. The shapefiles have been provided to Environment Canterbury as ArcGIS map packages. The contents of these map packages are presented and described below. We also highlight key areas of uncertainty and geomorphic context for the test catchments.

### 3.1 Shapefiles provided

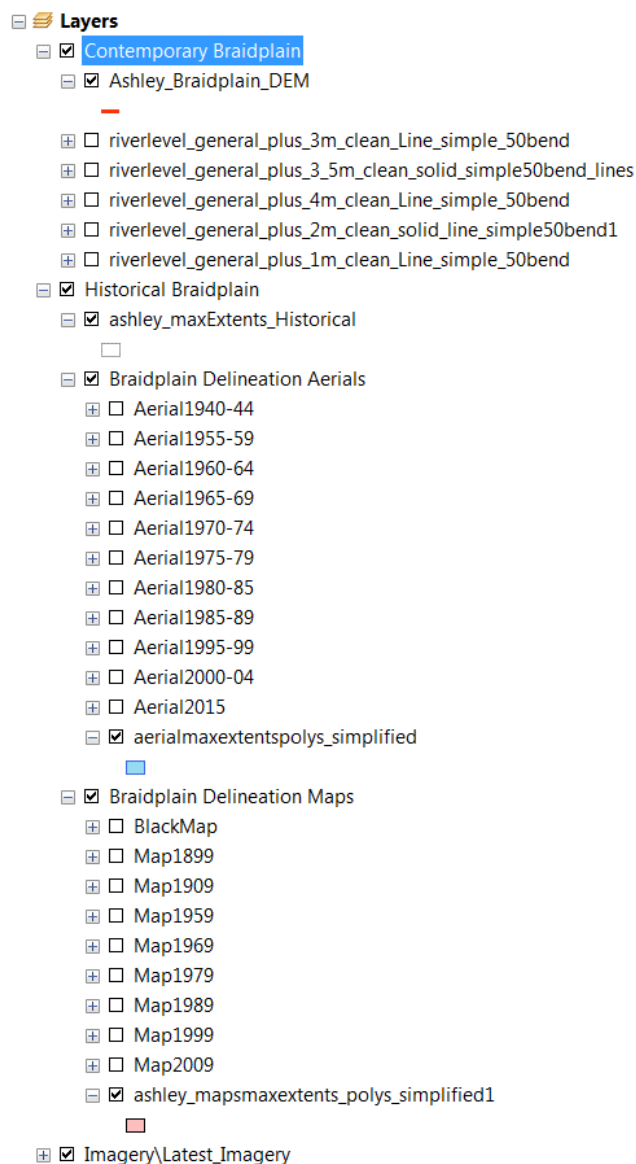
The ArcGIS map package files provided to Environment Canterbury are named Ashley\_All\_Results.mpk and Waiau\_All\_Results.mpk. Screen prints of the layers included in the ArcGIS map packages for the Ashley and Waiau Rivers are presented in Figure 3-1 and Figure 3-2 respectively. There are three groupings of layers provided; Contemporary Braidplain, Historical Braidplain and Imagery/Latest Imagery.

Within the Contemporary Braidplain grouping we have provided the final contemporary braidplain delineation (named Ashley\_Braidplain\_DEM and LiDAR\_Braidplain for the Ashley and Waiau respectively), as well as the various step-elevation polylines used to generate this final outline. For the Ashley, the 1–4 m lines are provided. For the Waiau, the 1–6 m lines are provided and these are grouped under the headings DEM1, DEM2 and DEM3, which correspond to the three areas of LiDAR coverage numbered from downstream to upstream.

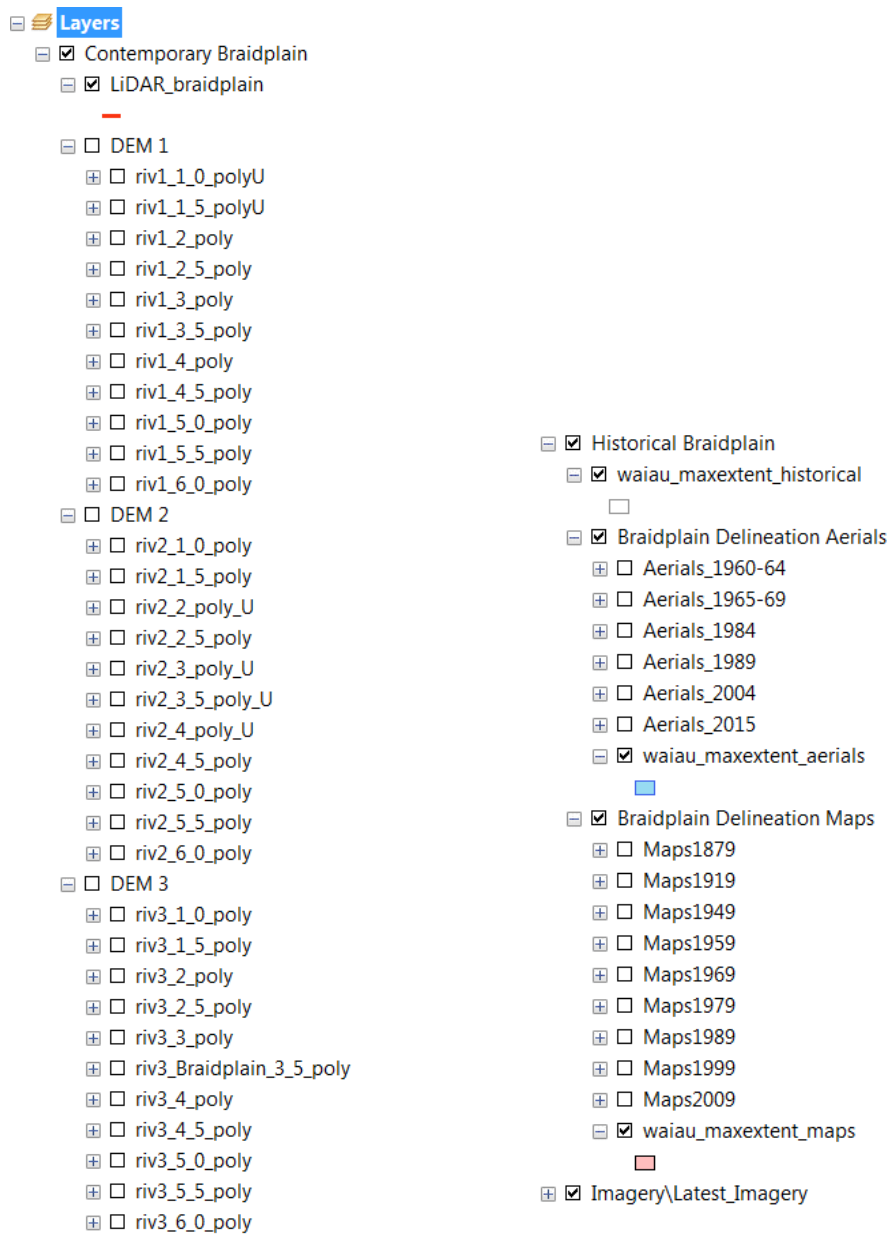
Within the Historical Braidplain grouping we have provided the final historical braidplain polygon (named the ashley\_maxExtents\_Historical and waiau\_maxextent\_historical), as well as the shapefiles outlining the recently active bed for each set of aerials (grouped under Braidplain Delineation Aerials) and each set of maps (grouped under Braidplain Delineation Maps). The maximum extents polygons for the maps and for the aerial that were generated individually before being combined to produce the historical braidplain polygon are also provided under their respective grouping.

The Imagery/Latest Imagery layer provides the 2015 aerial photographs.

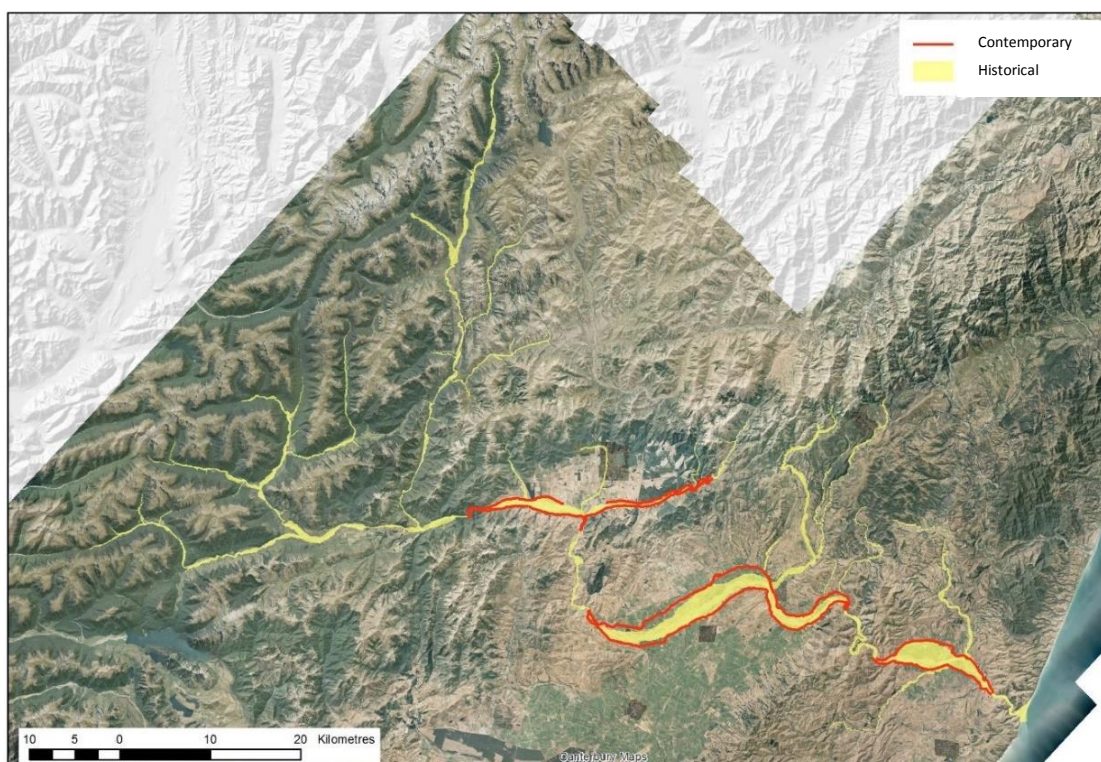
The final contemporary braidplain boundary and historical braidplain polygon are presented over the 2015 aerial for the Waiau and Ashley catchments in Figure 3-3 and Figure 3-4 respectively.



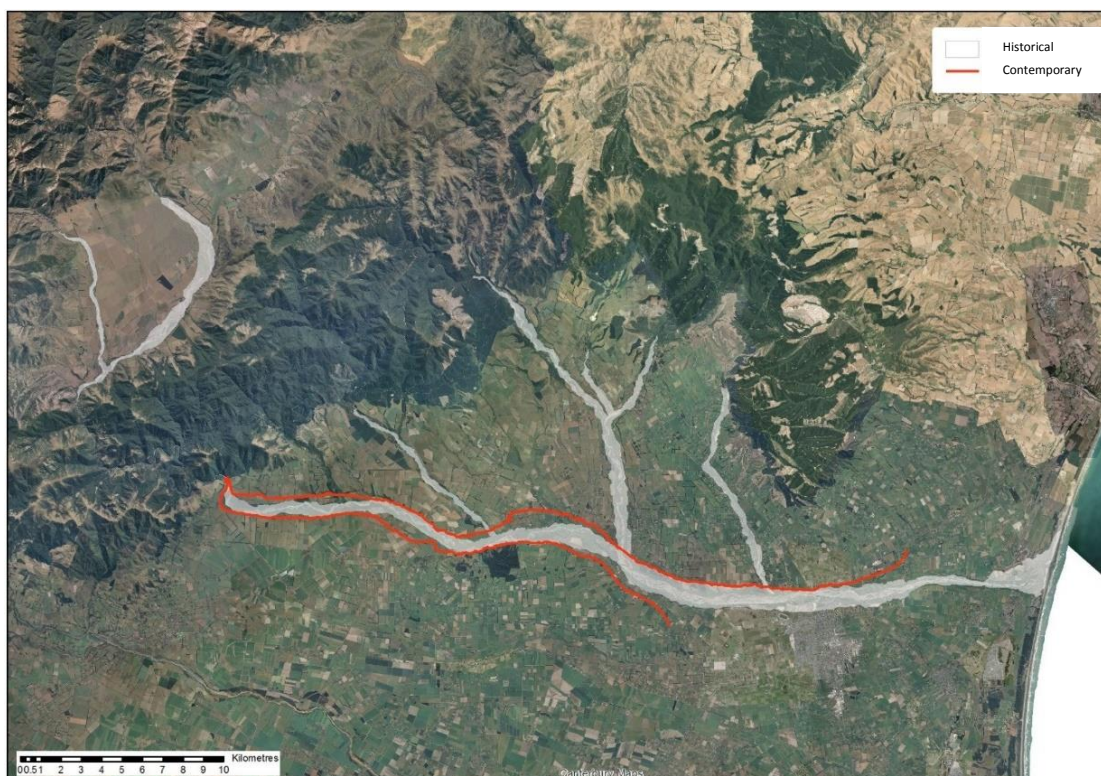
**Figure 3-1: Screen print of the expanded ArcGIS map package for the Ashley River.**



**Figure 3-2: Screen print of the expanded ArcGIS map package for the Waiau River.**



**Figure 3-3: The 2015 aerial photograph of the Waiau catchment with the braidplain boundaries overlaid.** The historical braidplain is shaded in yellow and the contemporary braidplain boundary is indicated with a red line (note the red line doesn't cover the whole catchment due to LiDAR availability and boundary uncertainty).



**Figure 3-4: The 2015 aerial photograph of the Ashley catchment with the braidplain boundaries overlaid.** The historical braidplain is shaded in white and the contemporary braidplain boundary is indicated with a red line (note the red line doesn't cover the whole catchment due to LiDAR availability and boundary uncertainty).

### 3.2 Areas of uncertainty and geomorphic context

As discussed in the introduction, the degree of certainty with which braidplain boundaries can be defined varies depending on the geomorphic context (Figure 1-3). The contemporary braidplain delineation approach is based on defining the location of terraces from LiDAR. In areas where there aren't terraces (or there isn't LiDAR), braidplain boundaries are highly uncertain.

In the upper floodplain pocket of the Waiau catchment (near Hanmer Springs) there is a reach where the contemporary braidplain boundary on the left bank cannot be defined using our approach (Figure 3-5). In this reach the Percival and Hanmer Rivers join the Waiau River and there are no clear terraces where the braidplains merge. Tectonic activity in the region will also be altering ground elevations in this area (with likely changes following the LiDAR acquisition) and this may impact river behaviour.

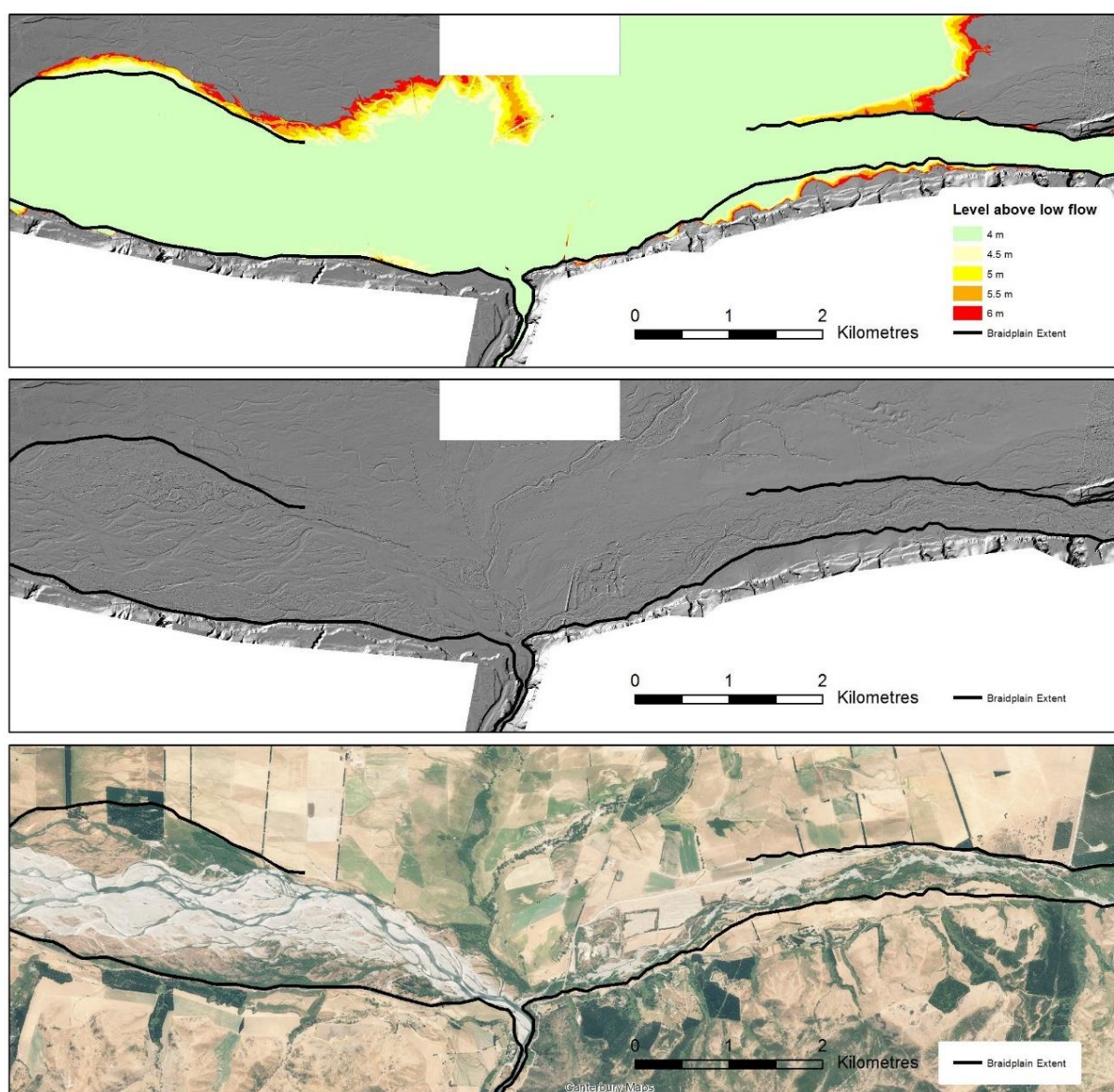
In the Ashley catchment, as there are no LiDAR data in the Lees Valley, the contemporary braidplain could not be established in the upper catchment. In the lower catchment, the Ashley River crosses the unconfined lowland plains (e.g., Figure 1-3) and the absence of terraces in this region makes the contemporary braidplain highly uncertain (Figure 3-6). We note, however, that overlaying our contemporary braidplain boundaries on the floodplain geomorphic units identified on Map 4.3 of the Ashley River Floodplain Management Plan (Figure A-1) shows that they align well with the end of identified river terraces (on the left bank) and older aggradation surfaces on the right bank (Mairaki unit). Hence the contemporary braidplain could perhaps be considered to follow the boundaries of the Rangiora and Ashley Major Alluvial Fans (Figure 3-7), which are both late Holocene aged material that has been deposited by the Ashley River.

### 3.3 Comments on the software and time taken to apply this methodology

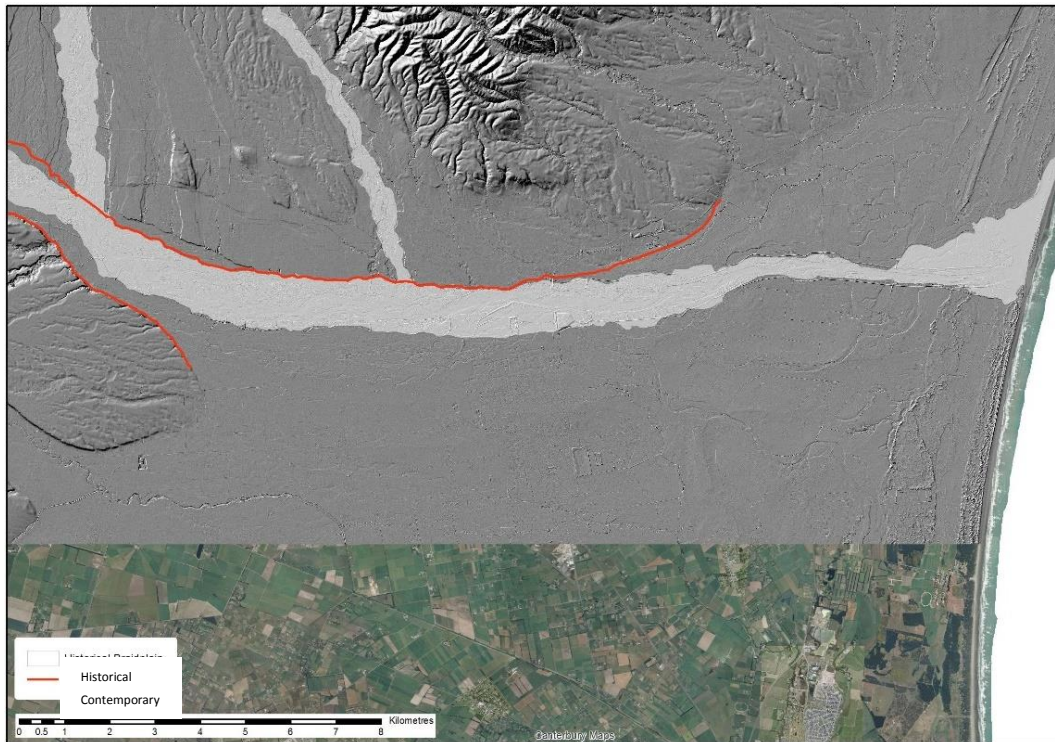
The various data layers (see Section 2.2) were overlaid and analysed in ArcGIS.

The manual digitising required for the historical braidplain approach took approximately 50 hours for the Ashley catchment and approximately 100 hours for the Waiau catchment (which is much bigger). This work could be undertaken by NIWA, ECan staff, or be a student project. Whoever does the work needs a basic knowledge of ArcGIS. The critical steps are ensuring that the maps and photographs are appropriately georeferenced and that an objective and consistent approach is taken to defining the active river boundaries on each layer (e.g., see Section 2.3.1). NIWA could provide guidance on this if required.

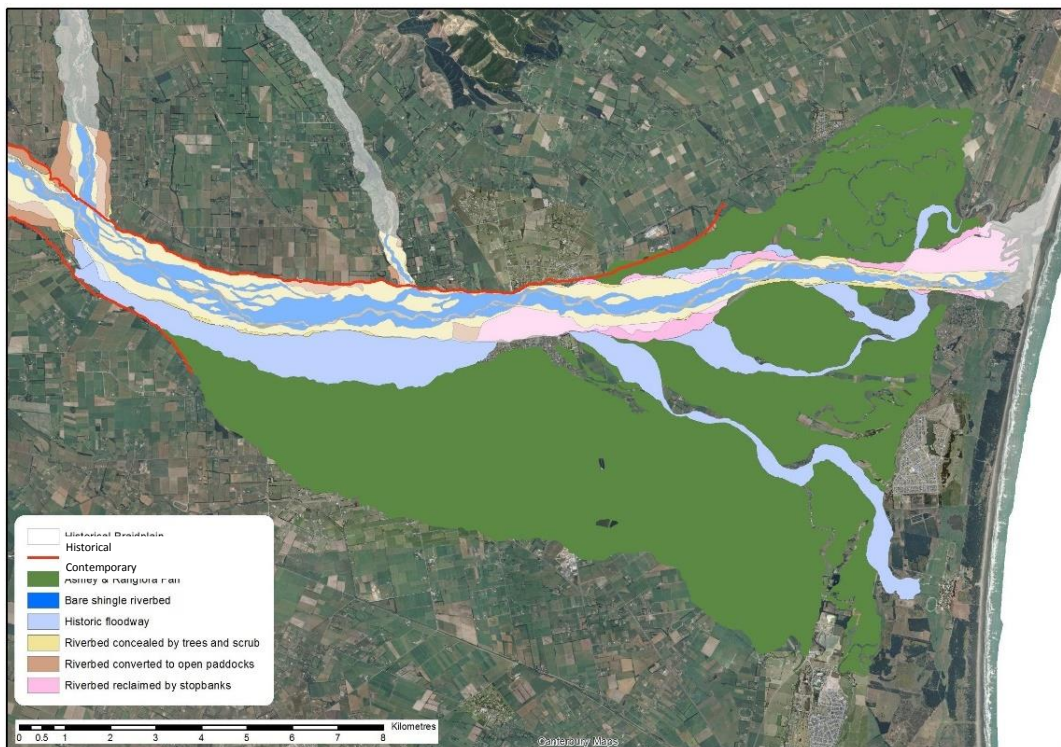
The LiDAR analysis required for the contemporary braidplain approach took approximately 30 hours for the Ashley catchment and approximately 50 hours for the Waiau catchment. This analysis takes less time but requires a greater degree of geomorphic interpretation. This would best be undertaken by someone with a geomorphic background who is used to analysing LiDAR data and interpreting landscapes (i.e. best suited to NIWA geomorphologists and not a suitable student project).



**Figure 3-5: The reach in the Waiau catchment where the contemporary braidplain boundary cannot be determined from LiDAR.** The upper figure shows how water at given elevations above the low flow would ‘spill’ into the Hanmer and Percival tributaries, i.e., no terrace is present. The middle figure shows the hillshade DEM in this region and the lower figure shows the 2015 aerial photograph. In all three figures, the black line shows the identified contemporary braidplain boundary.



**Figure 3-6:** Hillshade DEM of the lower reaches of the Ashley catchment where the river crosses the unconfined lowland plains. Light grey shows historical braidplain and red line shows contemporary braidplain.



**Figure 3-7:** Late Holocene geomorphic units associated with the lower Ashley River braidplain. This figure shows selected units from Map 4.3 of the Ashley River Floodplain Management Plan (Environment Canterbury 2002). Note that the historical braidplain polygon covers the four riverbed units and the contemporary braidplain boundary stops at the end of the terraces but aligns well with the Ashley and Rangiora major alluvial fan units.

## 4 Summary and recommendations

The aim of this project was to use a desktop study to develop a methodology to objectively delineate the braidplain of a given braided river. The methodology was developed using two test catchments, the Ashley River/Rakahuri and the Waiau River.

This report outlines two approaches for delineating the braidplain; the contemporary braidplain approach and the historical braidplain approach. Each of these has advantages and disadvantages, and we recommend using a combination of these approaches where possible.

The methodology we have presented for delineating the contemporary braidplain best represents the area the active channels could adjust within under current geomorphic controls. However, in areas where there are no LiDAR data available the methodology cannot be applied. Also, in some areas the contemporary braidplain boundaries are highly uncertain due to geomorphic context (e.g., lowland plains or around tributary alluvial fans). In these areas, the methodology presented for delineating the historical braidplain provides an alternative approach. However, this approach may underestimate the area of the braidplain and digitising the boundary is more time consuming than the LiDAR based approach, which is partly automated. Note that both of these braidplain boundaries ignore the presence of any engineered flood control, such as stop banks or willow belts, which are currently controlling the area of river bed that can be occupied by the active channels. However, identification of these controls to define the 'restricted' or 'managed' braidplain could be easily incorporated at a later stage (e.g., simply by overlaying stop bank positions and/or willow-belt boundaries).

This was a desktop study only and that the shapefiles produced for the test case catchments will not perfectly match boundaries on the ground. For any areas of the Ashley or Waiau catchments where braidplain boundaries are of particular interest, we recommend that the data provided is verified on the ground with a site visit. This would also be our recommendation when applying this methodology to other catchments.

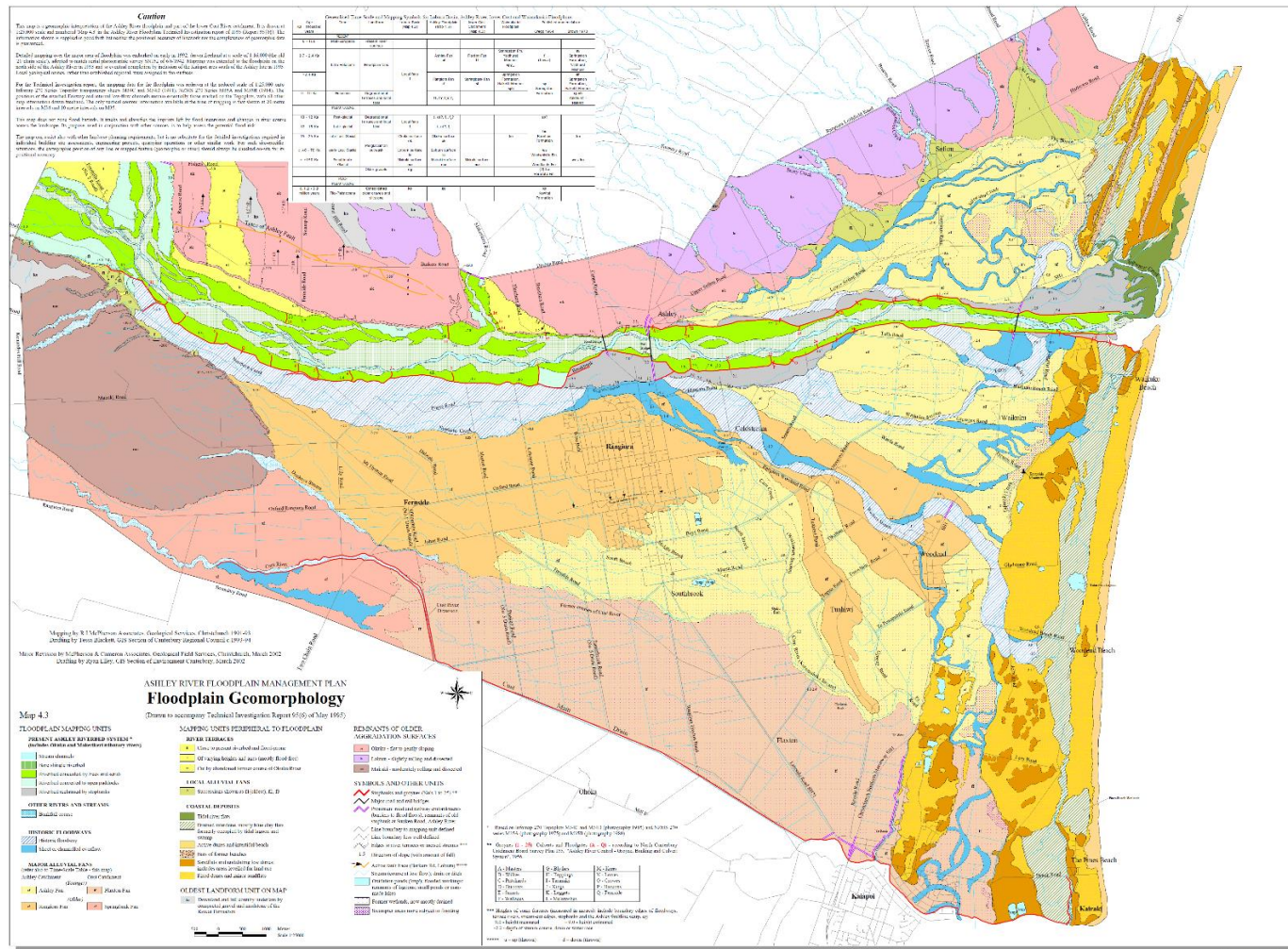
## 5 Acknowledgements

We would like to thank Duncan Gray and Ryan Elley for providing data to support this study, and Murray Hicks for advice on methods to define braidplain boundaries.

## 6 References

- Environment Canterbury (2002) *Map 4.3 Ashley River Floodplain Management Plan: Floodplain Geomorphology*. Major Revision by McPherson & Cameron Associates, Geological Field Services, Christchurch, March 2002. Drafting by Ryan Elley, GIS Section of Environment Canterbury, March 2002.
- Environment Canterbury (2017) *Canterbury Regional Policy Statement 2013, Revised 2017*. 358p.
- Grove P, Parker M, Gray D, Behrens F. 2015. Land use change on the margins of lowland Canterbury braided rivers 1990-2012. Environment Canterbury.
- New Zealand Government (1991) *Resource Management Act*. Part 1 Interpretation and Application.

## Appendix A Ashley floodplain geomorphology map



**Figure A-1: Map 4.3 of the Ashley River Floodplain Management Plan: Floodplain Geomorphology.** Environment Canterbury (2002).