Flood Hazard on the Taieri Plain and Strath Taieri

Review of Dunedin City District Plan:

Natural hazards

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Cover Photo: Mosgiel and the East Taieri Plain (source: NZ Stock Library)

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1. Introduction

1.1. Overview

As part of its current review of its District Plan, the Dunedin City Council (DCC) is reviewing the way it manages the use of land, so that the effects of natural hazards (including the effects of climate change) can be avoided, or adequately mitigated. The Otago Regional Council (ORC) is supporting the DCC by collating and presenting information on natural hazards to help inform this review. This present report describes the characteristics of flood hazard on the Taieri Plain and the Strath Taieri. As well as helping to inform the management of land use through the review of the District Plan, the report will assist with other activities such as the development of local emergency management response plans, building consents and infrastructure planning, renewal and maintenance.

This report identifies areas on the Taieri Plain and the Strath Taieri where flood hazard may affect public safety, buildings and the infrastructure that supports communities. It is part of the following series of reports that have been prepared to inform the review of Dunedin City District Plan:

1. Project Overview (ORC, 2014a)
2. Coastal hazards of the Dunedin City District (ORC, 2014b)
3. **Flood hazard on the Taieri Plain and Strath Taieri**
4. Flood hazard of Dunedin's urban streams (ORC, 2014c)
5. The hazard significance of landslides in and around Dunedin City (GNS, 2014a)
6. Assessment of liquefaction hazards in the Dunedin City District (GNS, 2014b

Although the focus of this present report is on flooding, the effects of other hazards, climate change and sea-level rise are also described where these are considered to be significant. Ideally, the reader should view the description of natural hazards contained in this report alongside the information contained in the other reports, particularly the project overview and the assessment of liquefaction hazard (1 and 6). Additional information relating to the natural hazards of the Taieri Plain can be found in ORC (2013).

1.2. Scope

The geographical scope of this report is the Taieri Plain and the Strath Taieri. The Taieri Plain is a low-lying, relatively flat expanse of land located to the west of Dunedin city (Figure 1), covering an area of 21,000 hectares. Used for rural, residential, commercial and industrial activities, the Taieri Plain is home to about 15,000 people, mostly clustered in and around the urban area of Mosgiel. The main land use is agriculture, an activity that was established with the arrival of the first European settlers in the mid-1800s. The land is highly productive, with fertile soils providing ideal conditions for crop and pasture growth. Dunedin International Airport is situated at the centre of the plain.

The Strath Taieri area is located in a 5-6km-wide, 20km-long basin of the Taieri River, confined within steeper gorge areas upstream near Hyde and downstream from Sutton. The steep Rock and Pillar Range lies to the west, while the more gently rolling Taieri Ridge is to the east (Figure 38). Strath Taieri is situated in the western part of the Dunedin district, 64km north of Mosgiel on State Highway (SH) 87. In 2013, the small town of Middlemarch had a population of 156, and the surrounding rural area (including Hyde and Sutton) had a population of approximately 500 (Statistics NZ, 2013). The predominant industry in the area is mainly sheep farming, although there has been a move in recent years to deer farming and dairy grazing.

2. Flood hazard characteristics of the Taieri Plain

The nature and severity of flood hazard varies across the Taieri Plain due to topography, proximity to watercourses, the characteristics of those watercourses, and the influence of the Lower Taieri Flood Protection Scheme. The plain was divided into geographical areas, based on flood hazard characteristics by ORC (2013). Further analysis has been undertaken for this project to refine the mapping of flood hazard in ORC (2013) in two areas:

- Area 1 (West Taieri Plain), which has been further refined into land below or above the current high tide level (areas 1A and 1B, respectively)
- Areas 14 to 16 (North Taieri), which have been combined into one area (Area 14), and then restructured into areas that are critical for the conveyance or storage of floodwater (areas 14A and 14B), and the residual floodplain (Area 14C). As a result of this change, areas 15 and 16 are not shown on Figure 2.

The revised flood hazard areas, as described in this report, are shown in Figure 2. It is noted that flood hazard within each area is not necessarily uniform, as it is influenced by localised topographical features and flood-management structures.

It is also noted that while the flood hazard areas described in this report are used to inform the District Plan review, they are not ‘zones’ as defined in the District Plan. The delineation of the areas is based on flood-hazard characteristics and not on the activities considered appropriate (such as rural, residential, commercial, etc.).

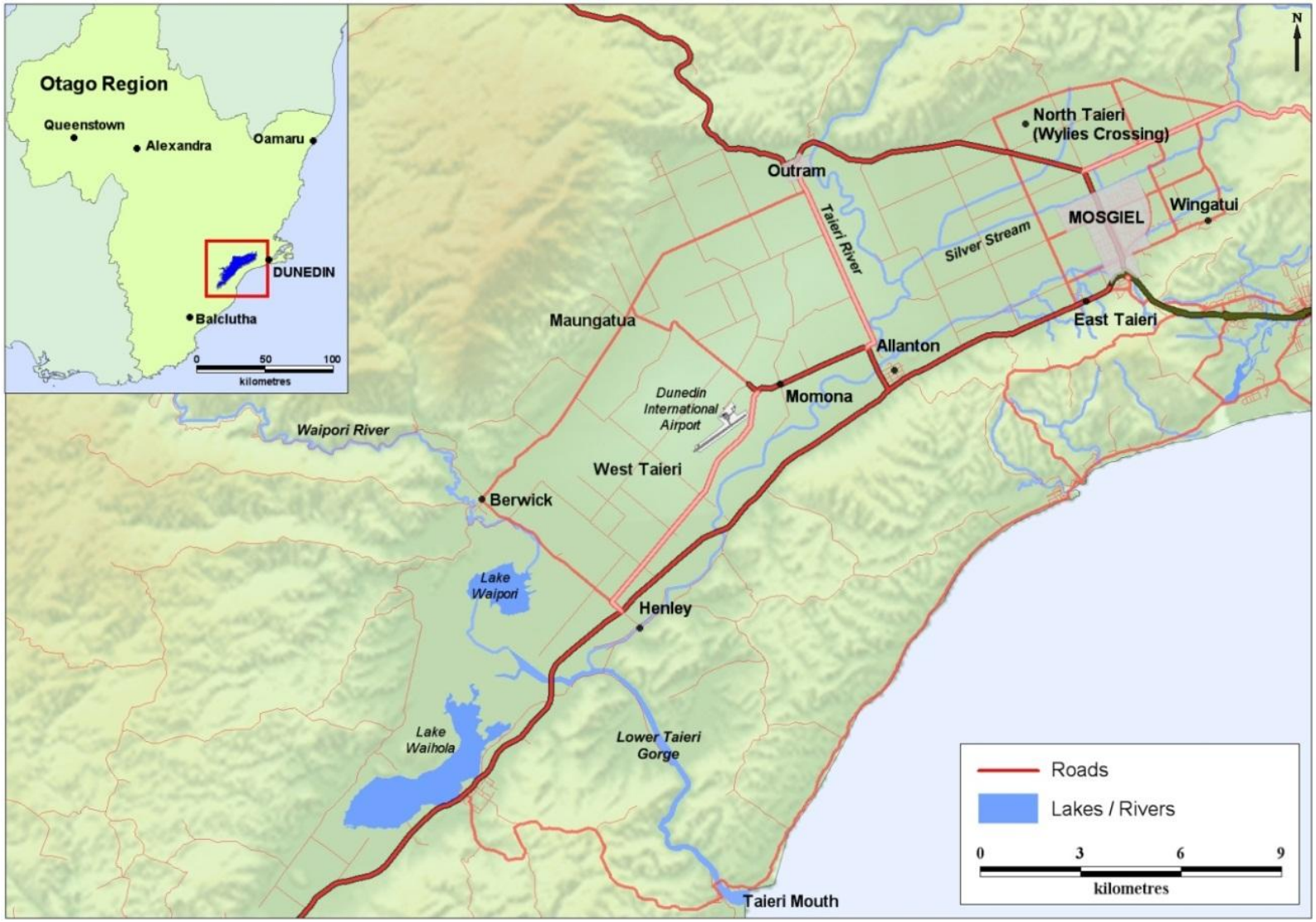

Figure 1 **Location map showing the topography and communities located on the Taieri Plain**

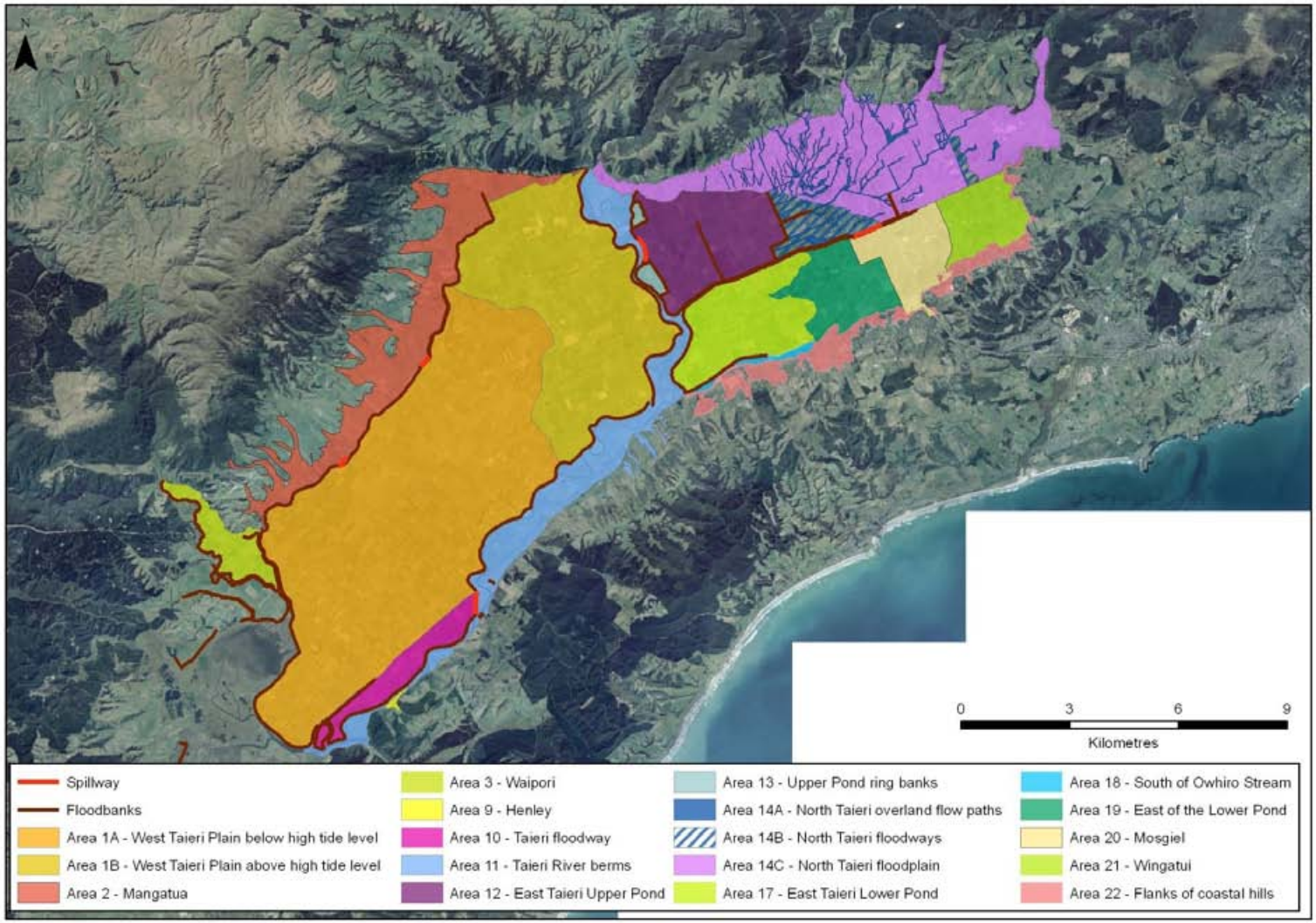

Figure 2 **Flood hazard areas on the Taieri Plain. Area 1 and areas 14-16 (as defined by ORC, 2013) have been further refined, as described above**

2.1. Area 1A – West Taieri Plain (below high-tide level)

Setting: As all of Area 1A is at or below the current high-tide level,[1] it relies on Lower Taieri Flood Protection Scheme floodbanks to prevent it from being inundated on a day-to-day basis[2] and during flood events. The contour channel (to the north) intercepts and diverts runoff from the Maungatua Range to Lake Waipori. Flow from the Taieri River, Waipori River and runoff from the Maungatua Range would naturally flood Area 1A. This occurred not only during the February 1868 and May 1923 flood events, when the level of flood protection was more limited, but also during the June 1980 flood due to numerous floodbank failures (ORC, 2013).

As gravity drainage is very limited, the area relies on two West Taieri Drainage Scheme pump stations and a network of drains to remove runoff and floodwater. Following flood events, it may take a considerable length of time to drain water ponding in Area 1A, due to the large volume of water that could pond in this area.

Flood hazard characteristics and effects: Extensive ponding is the main type of hazard in this area, to depths of more than 3m in some places (Figure 3). Sources of flooding include the Taieri River to the south, Waipori River to the west, Maungatua Range to the north and internal runoff from areas 1A and 1B. The flood hazard associated with these waterways can be significant (ORC, 2013). The natural tendency of waterways to inundate Area 1A is mitigated to some extent by flood protection and drainage schemes. As a result, flood hazard in this area is generally limited to ponding of a moderate depth and duration and low-velocity flows (see Scenario 1 and Figure 4 below).

However, the effects of flooding would be considerably greater if the flood protection and drainage schemes were to fail (i.e. they could no longer provide the intended level of protection), or if they were overwhelmed by a flood event larger than their intended design (see Scenario 2 and Figure 5 photo below). In these situations, significant damage to buildings and other assets could occur, and, in some circumstances, the velocity, depth and unpredictable nature of flood flows could be life-threatening (particularly in a floodbank breach situation).

The likely attributes of floodwater (depth, velocity and duration) during each of these two scenarios are listed on the next page.

[1] Normal tidal variation along the east coast of Otago is approximately 1m above or below mean sea level (msl) (NIWA, 2005).
[2] i.e. by the normal range of tidally influenced water levels experienced in the lower Taieri and Waipori rivers

Scenario 1 **flood protection and drainage schemes remain operational, and events smaller than design**	Scenario 2 **flood protection and/or drainage schemes fail, or events larger than design**
Depth of water: 0.9 to 1m, but up to 3m in places if rainfall was exceptional Duration of flooding: Few days to a few weeks Generally low velocity, apart from defined floodways and drains (Figure 3)	Depth of water: Generally 1m, but up to 3m in places Duration of flooding: Several weeks Velocity: Low in ponding areas to very high in close proximity to where failure or overtopping of floodbanks occurs

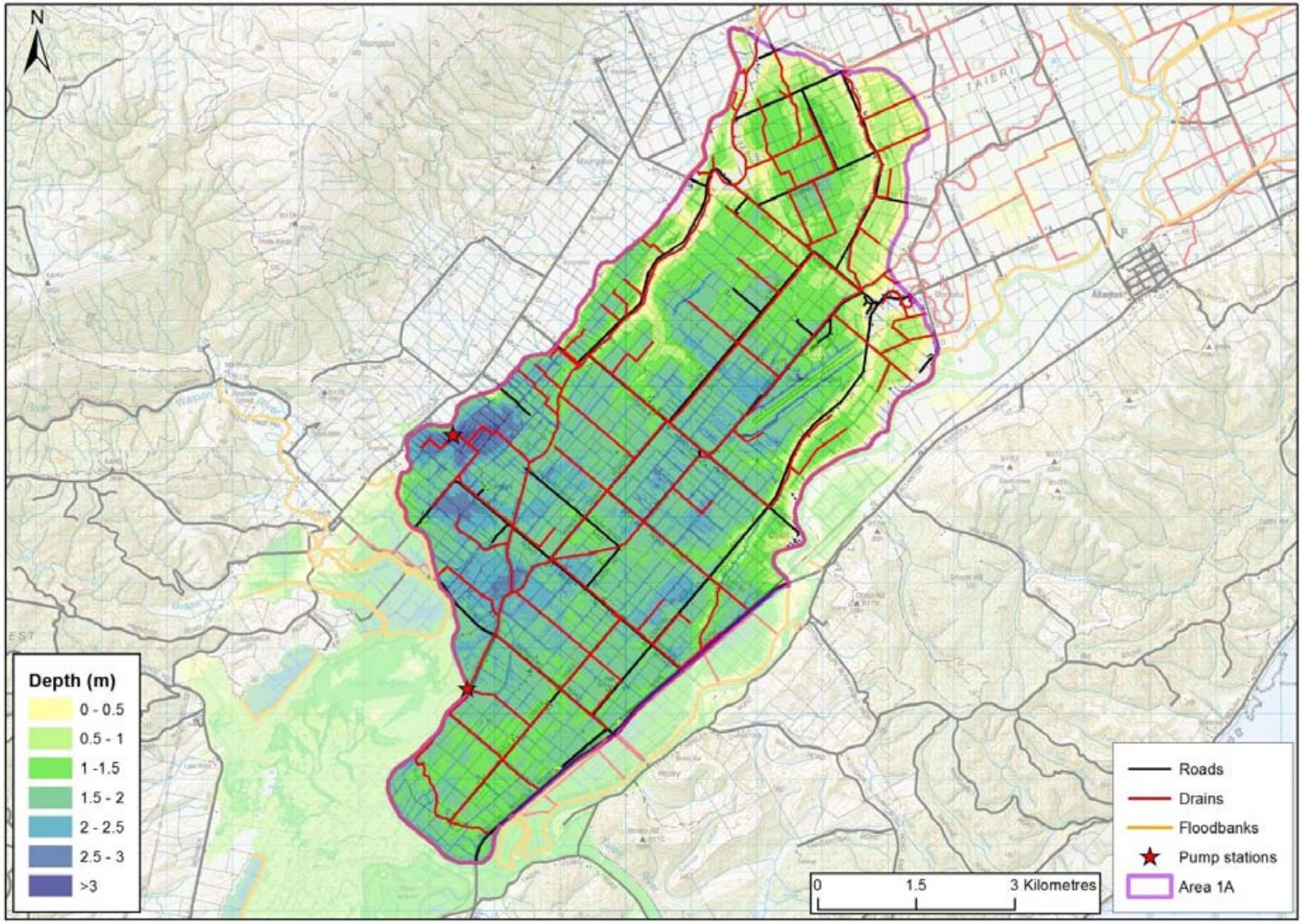

Figure 3 **Depth of inundation on the lower West Taieri Plain (Area 1A) at a water level of 1.5m above msl (the estimated level of the June 1980 flood)**

Figure 4 **Aerial view of ponding on the West Taieri Plain, resulting from internal runoff from areas 1A and 1B during heavy rainfall in June 2013 (195mm over eight days at the Riccarton Road rain gauge). Lakes Waipori and Waihola can be seen in the distance.**

Figure 5 **Aerial view (looking south) of flooding on the West Taieri following the June 1980 flood event. Area 1A is to the right (west) of the 'flood-free' highway.**

2.2. Area 1B – West Taieri Plain (above high-tide level)

Setting: Area 1B is elevated sufficiently to be above the current tidal range (as observed in the lower reaches of the Taieri and Waipori rivers). However, it is still a natural flood plain, and historical records show that it was inundated in February 1868, May 1923 and June 1980 (ORC, 2013). Parts of Area 1B were also affected by internal runoff in June 2013 (Figure 7). The area relies on Lower Taieri Flood Protection Scheme floodbanks and the contour channel to prevent it from being inundated during higher flows. It also relies on a network of drains to remove runoff. These scheduled drains, and other natural overland flow paths, provide an important function by conveying floodwater downslope to Area 1A, and to the two West Taieri Drainage Scheme pump stations. Structures and earthworks can impede or redirect this flow of water.

Flood hazard characteristics and effects: Sources of flooding include the Taieri River to the east and the streams that drain the Maungatua Range to the north (ORC, 2013). The effects of flooding could be significant if Lower Taieri Flood Protection Scheme floodbanks were to fail (breach), or were overtopped by a flood event larger than their intended design. In such a situation, the velocity and depth of flood flows could damage buildings and other assets, move vehicles and make walking difficult or unsafe, and therefore present a possible risk to life. The risk associated with a floodbank breach near Outram is particularly high, due to the potential impacts on this community. The likely attributes of flood flows (depth, velocity and duration) during such a scenario, and also in the case of smaller (less than design) events, are:

Scenario 1 **flood protection and drainage schemes remain operational, and events smaller than design**	**Scenario 2** **flood protection and/or drainage schemes fail, or events larger than design**
Depth of water: 0.5m to 2.0m in runoff areas; up to 2.5m in the natural ponding area labelled X in Figure 6 Duration of flooding: few hours (runoff) to few days (ponding) Low to medium velocity (higher in drains and swales)	The depth, duration and velocity on the downslope side of the contour channel and Taieri River floodbanks would vary, depending on the amount of water overtopping the bank, or the nature of floodbank failure. Likely attributes for a failure of the Taieri River floodbanks are: • Depth of water: 0.5m to 2.0m in runoff areas; up to 2.5m in the natural ponding area labelled X in Figure 6 • Duration of flooding: few hours (runoff) to several days (ponding) • Medium to very high velocity (highest near point of failure or overtopping).

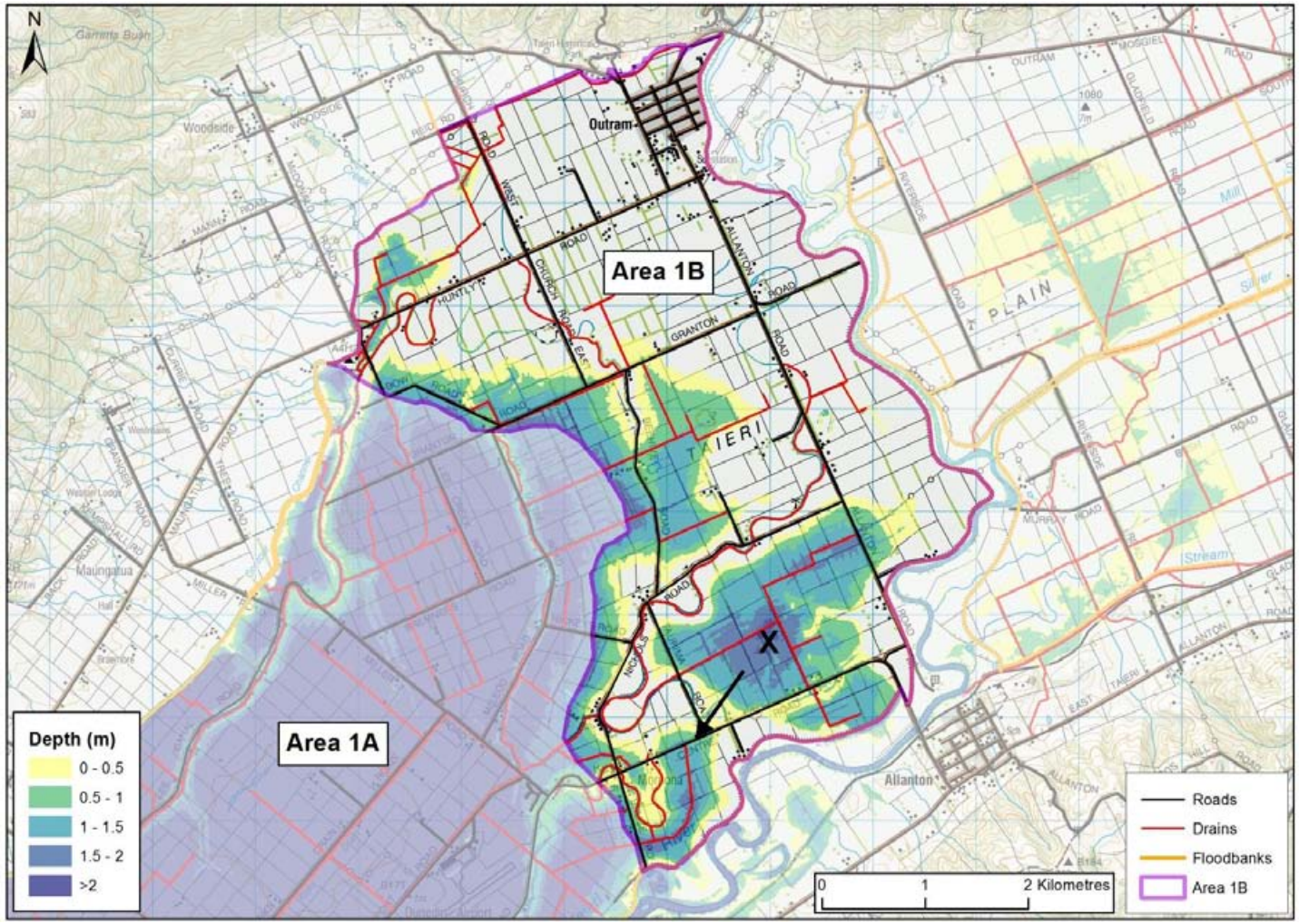

Figure 6 **Depth of inundation in the lowest-lying part of Area 1B if water was at a level where it began to overtop the ponding area labelled X (3.1m above msl). The black arrow shows the approximate location where water would initially overtop from 'X' and flow downslope to the southwest.**

Figure 7 **Aerial view of ponding on the West Taieri Plain (looking south), resulting from internal runoff from Area 1B during heavy rainfall in June 2013 (195mm over eight days at the Riccarton Road rain gauge)**

2.3. Area 2 Maungatuas

Setting: This gently sloping area (Figure 8) is located between the steeper slopes of the Maungatua Range, and the flat, low-lying West Taieri Plain. Runoff from the streams that drain the Maungatua Range is collected by the contour channel and diverted into Lake Waipori. High-sediment loads in these streams have built alluvial fan features (ORC, 2013), and can reduce the capacity of the contour channel during high-flow events. During peak flow, excess floodwater from the contour channel overflows into areas 1A and 1B at numerous locations, including at two defined spillways (near Otokia Road and Miller Road).

Flood hazard characteristics and effects: Flood hazard in this area is derived from the contour channel itself, overland flow due to overtopping of the streams that drain the Maungatua Range and the floodwater-dominant alluvial fans that have formed on the margins of these streams. Although sometimes ephemeral, these streams can carry deep (up to 1m) and medium to fast flows during heavy rainfall events, with large amounts of sand and gravel adding to their volume (Figure 9). Structures and earthworks can impede or redirect this flow of water. Flows of this nature are sufficient to damage buildings or other assets.

Alluvial fans can be inactive for long periods of time, and their streams are often dry or inconspicuous, creating the impression that little or no hazard exists. Channels are often very mobile, quickly and easily changing position during high-flow events. This, combined with their steep gradient and limited warning of flood events, means they can be very destructive and unpredictable.

Figure 8 View downslope across Area 2, from Kempshall Road

Figure 9 Deposition of gravel in the contour channel from a tributary hill stream

2.4. Area 3 Waipori

Setting: A significant part of this area (which includes the settlement of Berwick) lies at, or below, the current high-tide level,[3] and it was extensively inundated in the floods of 1868, 1923 and 1980 (ORC, 2013). Floodbanks that are part of the Lower Taieri Flood Protection Scheme provide a low level of protection during flood events. The ability of floodwater to drain from this area is affected by the level of Lake Waipori, which in turn can be affected by conditions at the mouth of the Taieri River.

Flood hazard characteristics and effects: Extensive ponding is the predominant type of flood hazard in this area, although surface runoff and peak river flows can also create a hazard (Figure 10). Inundation depths of up to 2m are possible, with velocities ranging from slow (in ponding areas) to fast where surface runoff occurs. It is exposed to flood hazard from the Waipori River, the streams along the Maungatua Range (via the contour channel)[4] and Lake Waipori. Flood-hazard effects are likely to be exacerbated by changes in climate or sea level.

[3] Normal tidal variation along the east coast of Otago is approximately 1m above or below msl (NIWA, 2005).
[4] The contour channel intercepts runoff from the Maungatua Range and discharges these flows into Lake Waipori.

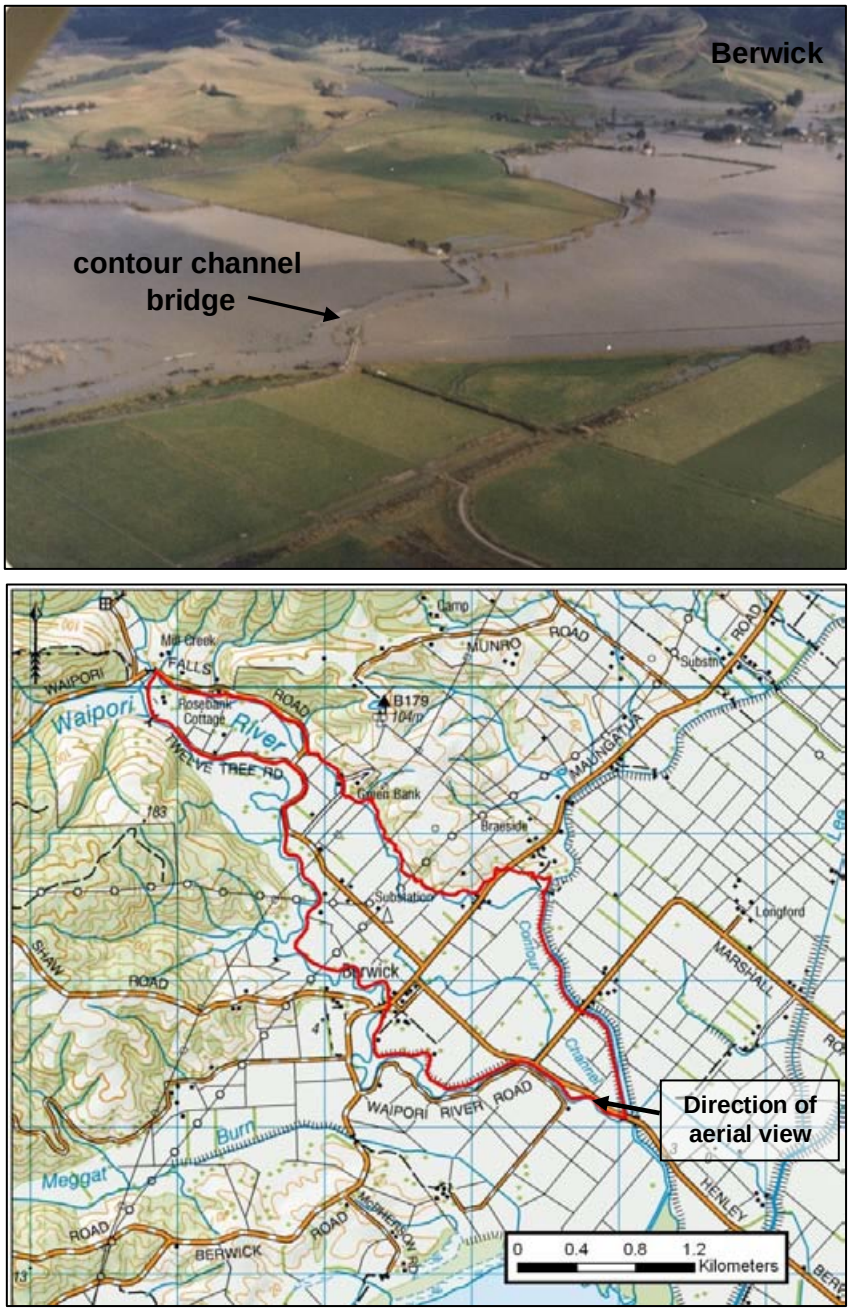

Figure 10 **Top: Aerial view of Waipori River No. 1 contour channel bridge, looking towards Berwick (May 1977). Bottom: Map of the same area (with Area 3 outlined in red)**

2.5. Areas 4 & 5 South of Waipori & South of Meggatburn (Clutha District)

The characteristics of flood hazard in these two areas are similar to those in Area 3. See ORC (2013) for more detail.

2.6. Areas 6, 7 & 8 Lakes Waipori & Waihola (Clutha District)

These areas are below current msl and are exposed to flood hazard from surrounding hill catchments and lakes Waipori and Waihola. (See ORC (2013) for more detail.)

2.7. Area 9 Henley

Setting: Henley is a low-lying area, with much of the land being less than 0.5m above current msl. The area has been flooded on numerous occasions (ORC, 2013). A low floodbank constructed on the true left bank of the Taieri River near the Henley settlement in the 1990s is part of the Lower Taieri Flood Protection Scheme and provides protection from small flood events in the Taieri River. Despite the floodbank, flooding of parts of this area typically occurs every few years. This part of the Taieri River is subject to tidal influences.

Runoff from the coastal hills to the south flows into this area during rainfall events (Figure 14). The runoff is generated mainly by one catchment (approximately 138ha), whose outlet is located at the southern end of the Henley township. A basic drainage network composed of short ditches and flap-gated culverts (located under the road and the low-lying floodbank) convey the runoff from the coastal hill catchments to the Taieri River.

Flood hazard characteristics and effects: Sources of flooding include the Taieri River and runoff from the hills to the south. During and after significant rainfall events, high-water levels in the Taieri River prevent the runoff from the hill catchments from discharging into the Taieri River. The outlet culverts of the drainage network collecting the runoff from the coastal hill catchments are equipped with flap gates that shut when the Taieri River is high, resulting in ponding on the landward side of the floodbank. Depending on the extent and depth of ponding, houses with low floor levels can be flooded. Additionally, if these flap gates cannot close properly, water from the Taieri River can flow back up in the drainage network and flood the area located on the landward side of the low-lying floodbank.

Runoff from two smaller catchments behind Henley (3ha and 8ha, as shown in Figure 14), and from rainfall accumulation within Area 9, also contribute on a smaller scale to the ponding on the landward side of the floodbank when the Taieri River is high.

The maximum depth of inundation during the June 1980 flood in the Taieri River was approximately 1.5m (Figure 12), lasting for a few days to a few weeks. Velocity of floodwater is generally slow.

This area can also be affected by sedimentation in the form of debris and/or floodwater flows from the coastal hills to the south, during extreme rainfall events. The effects of flooding will be exacerbated by changes in climate or sea level. The Henley community is regularly isolated during flood events, and the threat of heavy rainfall / high-flow events can cause anxiety for local residents.

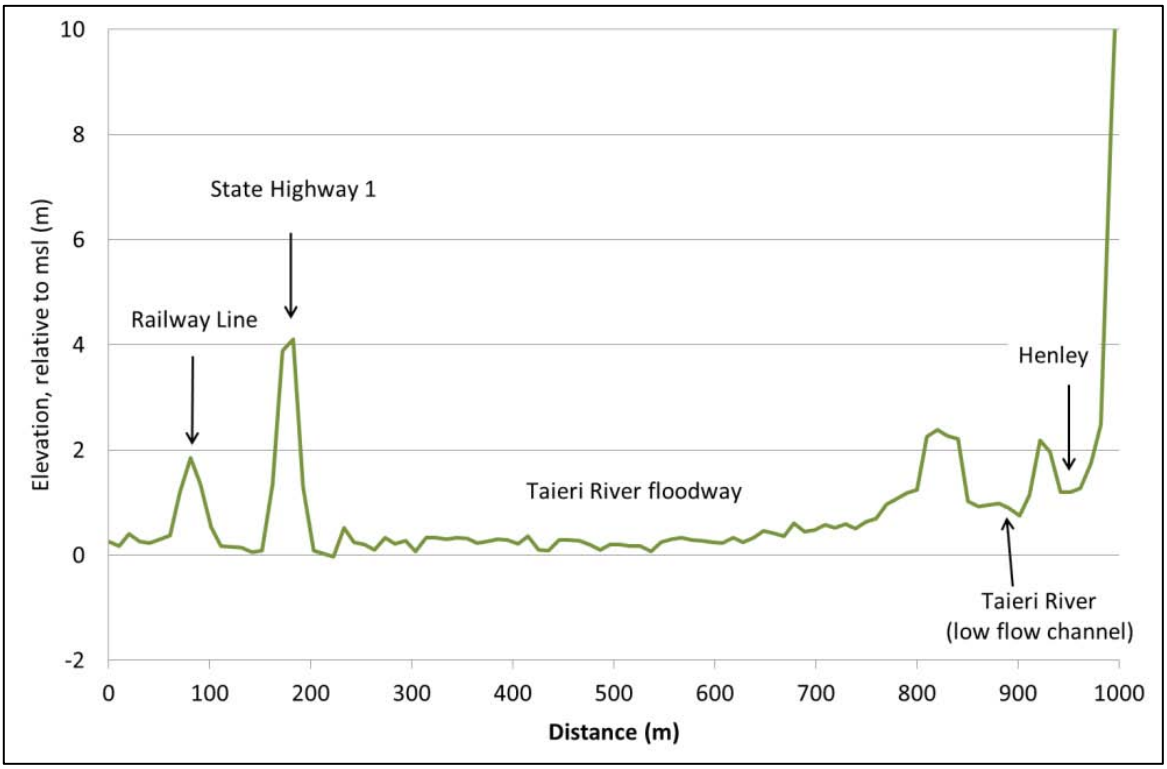

Figure 11 **Cross section from the West Taieri Plain to Henley, just upstream of Henley-Berwick Road**

Figure 12 **Henley, 29 May 2010 (source: ODT)**

Figure 13 **Henley, 5 June 1980 (source: ODT)**

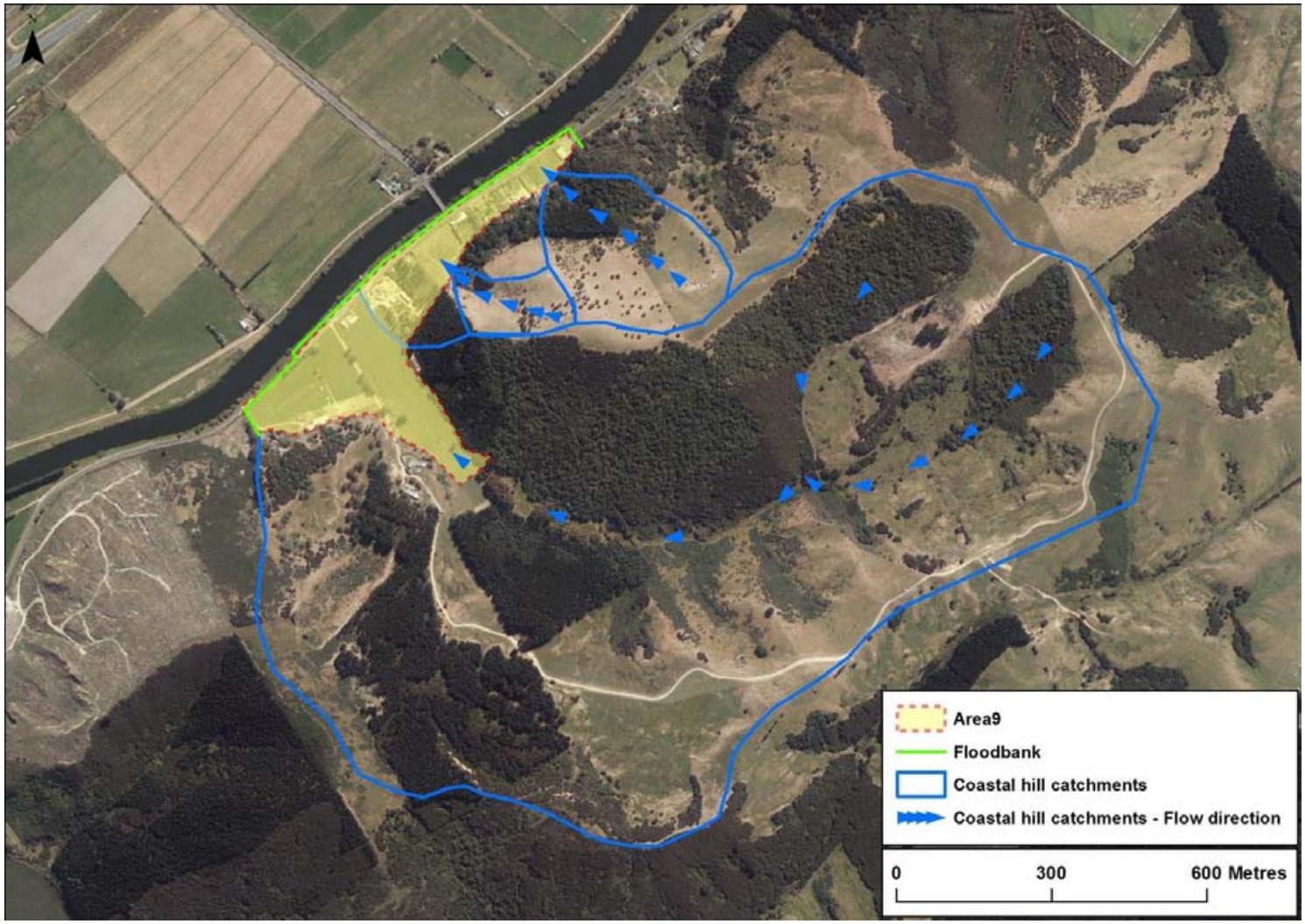

Figure 14 **Coastal hill catchments behind Henley and general flow direction**

2.8. Areas 10 and 11 Lower Taieri Floodway & Taieri River Berms

Setting: These areas consist of the berms that lie between the Taieri River floodbanks, or, downstream of Allanton, between the foothills on the true left bank and the Taieri River floodbank on the true right bank. They are exposed to flooding from the Taieri River, and to a lesser degree, the Silver Stream and Owhiro Stream. They play a crucial role in the conveyance and temporary storage of floodwater and hence the mitigation of flood hazard for other parts of the Taieri Plain. Area 10 is generally lower lying than Area 11, and therefore has less ability to drain by gravity. Tidal effects are observed as far upstream as Allanton, although these are largely drowned out and have little effect on river levels during floods. Low-lying parts of Allanton are situated within Area 11, and were flooded in June 1980 (ORC, 2013), although there are few residential dwellings in this area.

Flood hazard characteristics and effects: These areas are typically flooded annually. The maximum depth during a major Taieri River flood event is 2.5 to 4.5m, with velocities of over 1m/s in some places. Any buildings or other assets located in these two areas would be significantly damaged or destroyed during major flood events, and in many circumstances the velocity, depth and unpredictable nature of flood flows would be life threatening. The effects of flooding will be exacerbated by changes in climate or sea level.

Figure 15 **Lower Taieri Floodway, looking downstream to Henley, 31 July 2007. Several rows of trees and balage lie perpendicular to the direction of flow.**

2.9. Areas 12 & 13 East Taieri Upper Pond & Upper Pond Ring Banks

Setting: Historically, these areas flooded frequently for long periods because they are naturally low lying. The perimeter of Area 12 is the possible extent of ponding within the East Taieri Upper Pond. The eastern boundary of the area is defined by the Upper Pond cut-off bank. Without the cut-off bank, the pond would extend further east. The area is separated from the Taieri River to the west by floodbanks, which are part of the Lower Taieri Flood Protection Scheme. Water from the Taieri River enters this area over the Riverside spillway at a flow (in the Taieri River at Outram), which has an assessed return period of approximately ten years (Figure 16). The Riverside spillway was destroyed by a flood event in December 1993 (ORC, 2013), and improvements were made to the integrity of the spillway in 2013 to reduce the likelihood of it failing while in operation and causing rapid uncontrolled release of water from the Taieri River into the Upper Pond.

Land that has been isolated from Area 12 by the construction of ring banks in the 1990s, and therefore provided with a higher standard of protection, is included within Area 13. The ring banks around these two areas supplement rather than replace the primary floodbanks on the Taieri River and Silver Stream. This area was flooded in the 1868, 1923 and 1980 events.

Flood hazard characteristics and effects: Flood hazard relates mainly to the Taieri River, but also to the Silver Stream, Mill Creek, the hill catchments to the north and internal runoff. Flooding can occur from any one of these sources, or in combination. Ponding can reach depths of up to 4m or more if water were to reach the crest of the cut-off bank or the Silver Stream floodbank (Figure 18), and can last for several weeks. If the Taieri River floodbanks, Area 13 ring banks, Silver Stream floodbank or the Riverside spillway were to fail, or if they were overwhelmed by a flood event larger than their intended design, then the effects of flooding may also include water travelling at medium to high velocities, particularly in close proximity to that failure.

Figure 16 **Taieri River flows spilling into Area 12 on 29 May 2010 (source: ODT)**

Figure 17 **Water ponding in Area 12 on 31 May 2010. The upper pond cut-off bank is at the bottom of the image.**

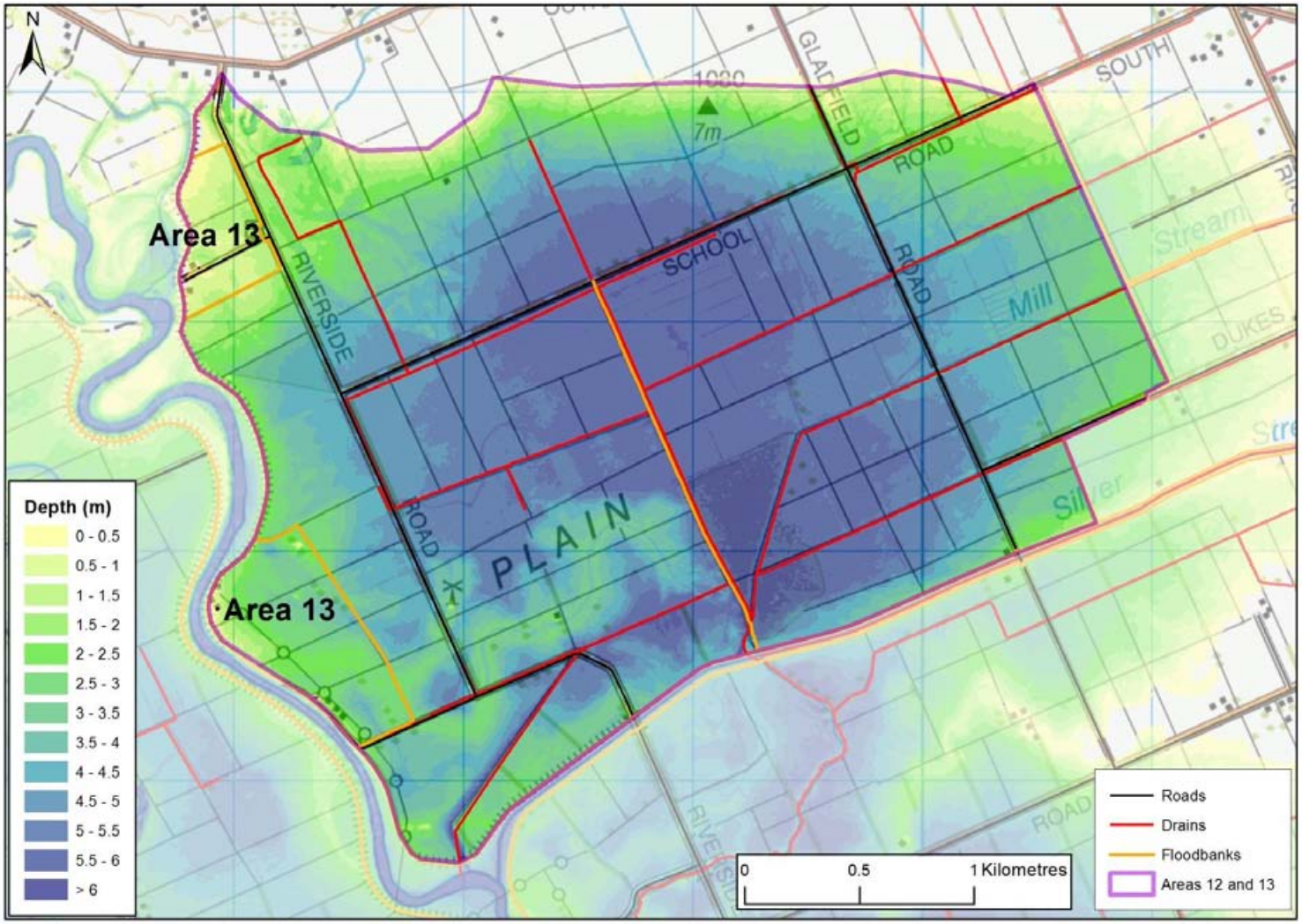

Figure 18 **Depth of inundation in areas 12 and 13 if water were to reach the crest of the upper pond cut-off bank or the Silver Stream floodbank**

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2.10. Area 14 North Taieri

Setting: The North Taieri area is bounded by a range of 300 to 500m high hills to the north, the Silver Stream to the south, the East Taieri Upper Pond Cut-off Bank to the west and Milners Road to the east. Other features within this area include SH87 which links Mosgiel and Outram, the Taieri Aerodrome, and the Five Roads and Wyllies Crossing intersections (Figure 20). Area 14 comprises the three areas identified in ORC (2013) as areas 14, 15 and 16.

North Taieri is the highest-elevated part of the Taieri Plain, with the land gradually sloping downslope to the south and west. A series of active floodwater-dominated alluvial fans emerge from the hill catchments in the north. These fans grade into an extensive alluvial plain in the south, with a corresponding change in elevation from about 40m down to less than 10m (ORC, 2013). High flows and surface runoff, resulting from heavy rainfall, can occur in this area with little warning, due to the short, steep and relatively high (500m+) upstream catchments that discharge onto this northern part of the Taieri Plain. The area is crossed by a number of ephemeral swales (overland flow paths) that can carry significant overland flow during heavy rainfall events (Figure 20). Along with a number of smaller catchments, the area is exposed to flood hazard from Mill Creek and the Silver Stream. Water from the Taieri River is generally prevented from entering this area by the Upper Pond Cut-off Bank.

Because of the generally subtle topography of Area 14, the depth and extent of flooding is also influenced by local features such as embankments, fences, shelterbelts and buildings, which can impede natural downslope drainage.

The characteristics of flood hazard in this area are described below, firstly for the areas that are critical for the conveyance or storage of water during flood events (areas 14A and 14B), and secondly for the residual areas where flooding occurs when floodwaters spill out across the wider floodplain or alluvial fan surface (Area 14C).

Figure 19 **Flooding at Wyllies Crossing in April 2006 (top), and July 2007 (bottom)**

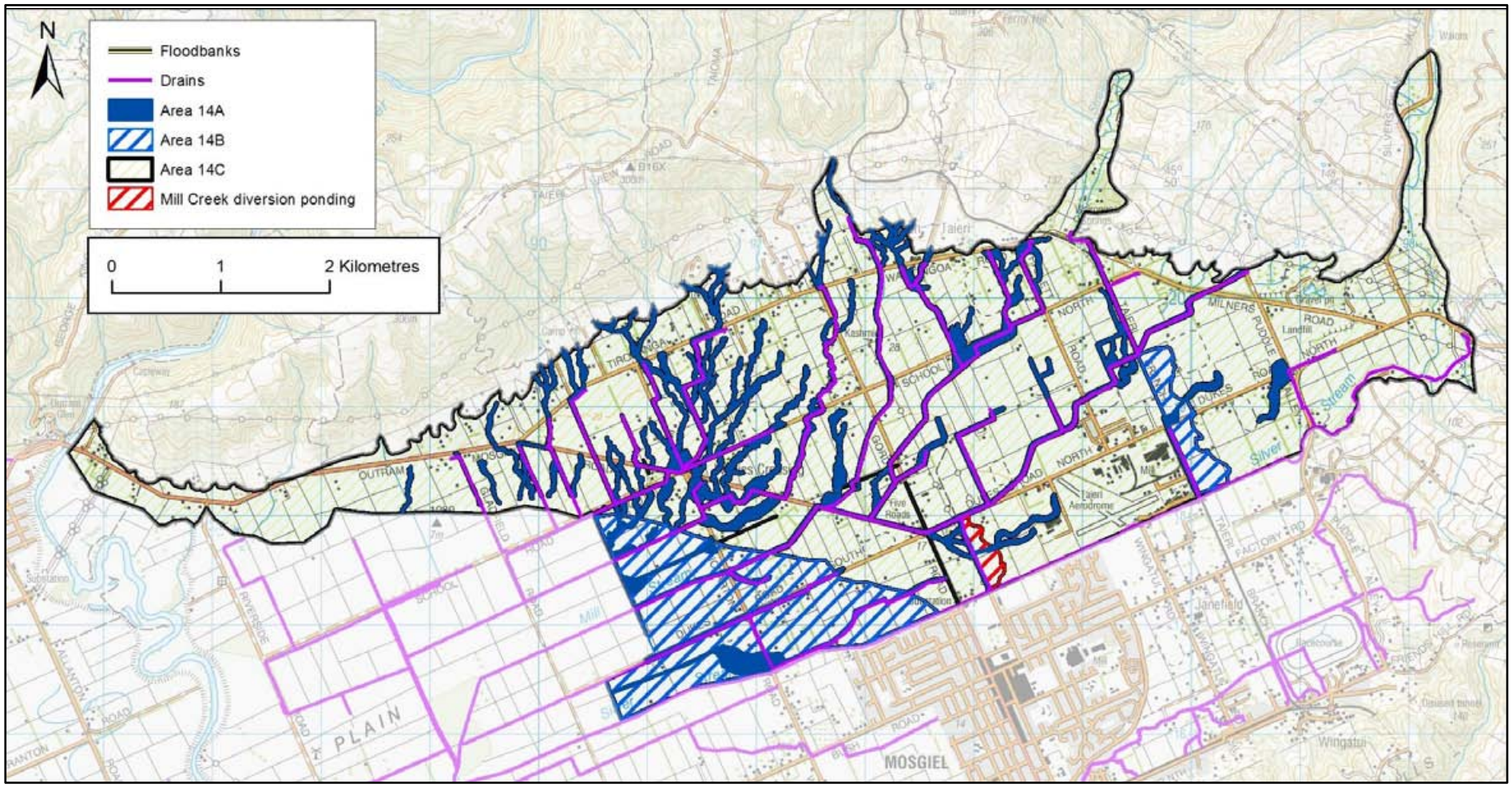

Figure 20 **Map of North Taieri (areas 14A, B and C)**

Flood hazard characteristics and effects (Area 14A – North Taieri overland flow paths): The overland flow paths that comprise this area are exposed to floodwater runoff and extensive ponding (Figure 19).

Figure 20 shows the network of ephemeral swales that convey runoff downslope towards the Upper Pond. The depth of water in these features ranges from 0.5m in the wider or smaller features, to 2m in the larger and more defined drains.[5] Similarly, the velocity of floodwater varies from relatively slow in the wider flow paths, to very fast (more than 1m/s) in the major drains. The duration of flooding is generally limited to a few hours, during the time of peak rainfall intensity. Note that these areas can only be defined approximately, as the characteristics of each flood event (including the relative contributions of each catchment) will differ.

Flood hazard characteristics and effects (Area 14B – North Taieri floodways): Area 14B consists of two areas where overland flow and ponding are deeper, faster and more extensive than in Area 14A: below the Gordon Road Bridge on the true right of the Silver Stream, and along the north-eastern side of the Taieri Gorge Railway between Puddle Alley and Hazlett Road. The areas are shown in Figure 20. As noted above, flooding can start to affect these areas with minimal warning (<3 hours).

Large flows and significant ponding occurs when the Silver Stream overtops the true right bank below the Gordon Road bridge. This occurs when flow in the Silver Stream exceeds 150-170m^3/s at the Gordon Road spillway (ORC, 2013). This occurred in April 2006 (Figure 21), June 2007 and was imminent in May 2010 and April 2014. Due to the lack of any defined path, these flows tend to spread out over a wide area en route to the upper pond cut-off bank, combining with flows from Mill Creek and the hill catchments to the north. The depth of water ranges from 0.5 to 1m, with velocities of up to 1m/s, and therefore poses a high hazard for people, stock, buildings and other structures.

The deepest and swiftest flows in this area would be associated with a failure of the upper pond cut-off bank, which could produce flows 2.5-3m deep, with a high velocity, as water drained rapidly from the Upper Pond (Area 12). The ability of this bank to contain water for a prolonged period and to a depth of up to 3m has not been tested in a flood event since it was built in the 1990s. The lower part of Area 14B can also be affected by water ponding behind the upper pond cut-off bank to a depth of 3m, over a period of several hours to days (Figure 23). The rate at which ponded water can drain away depends on the rate at which area 12 (Upper Pond) drains.

The second part of Area 14B is the land behind the Taieri Gorge Railway embankment between Puddle Alley and Hazlett Road. This area can be inundated to a depth of 1.5m due to surface runoff and excess flow from Mill Creek, as occurred in April 2006 (Figure 22).

[5] Maps of scheduled drains and overland flow paths owned or under the control of the Otago Regional Council are contained in ORC (2012)

Figure 21 **Silver Stream flows spilling over the Gordon Road spillway (April 2006)**

Figure 22 **Water ponding behind the Taieri Gorge Railway, 26 April 2006**

Figure 23 **Flooding behind the Upper Pond cut-off bank, April 2006. A flood mark is visible on the house in the upper image (source: TVNZ).**

Flood hazard characteristics and effects (Area 14C – North Taieri floodplain): Flood hazard in this area is derived from the Silver Stream, Mill Creek, hill tributaries to the north, when floodwaters spill out across the wider floodplain or alluvial fan surface and from internal runoff.[6] The predominant type of flood hazard is overland flow, although localised ponding can occur in places where vegetation, topography or man-made structures block the conveyance of water. There is also some potential for sedimentation to occur in conjunction with floodwater-dominated alluvial fans.

The velocity of runoff is generally slow to medium, and it tends to not last more than a few hours, during the period of peak rainfall intensity. As this area excludes the major drains and

[6] This area is sufficiently elevated not to be affected by the Taieri River.

overland flow paths (as defined by areas 14A and B), the depth of flooding is generally limited to 1m or less (Figure 24). However, this combination of depth and velocity is sufficient to create a 'moderate' flood hazard, where wading becomes unsafe, and damage to structures may occur due to inundation and floating debris.

Figure 24 **East Taieri flooding, looking down Hazlett Road to Dukes Road north (April 2006)**

2.11. Area 17 East Taieri Lower Pond

Setting: The perimeter of this area is the likely extent of ponding because of flows from the Taieri River. Historically, the area flooded frequently and for long periods because it is naturally low lying (ORC, 2013). The floodbanks located next to the Taieri River, Silver Stream and Owhiro Stream have reduced the frequency of flooding.

Flood hazard characteristics and effects: Flood hazard relates to the Taieri River, Silver Stream, Owhiro Stream (Figure 25) and to the hill catchments to the south. Ponding can reach depths of over 5m if water were to reach the minimum crest level of the Taieri River true left floodbank (Figure 26), and it can last for several weeks. The extent, depth and duration of ponding during each flood event depends on the flood's duration and size. If any of the surrounding floodbanks were to fail, then the effects of flooding may also include water travelling at medium to high velocities, particularly in close proximity to that failure. A significant volume of water could pond in Area 17 (particularly if there were inflows from the Taieri River), and land could therefore be flooded for a prolonged period.

Figure 25 Overtopping of the Owhiro Stream into Area 17 (August 2012)

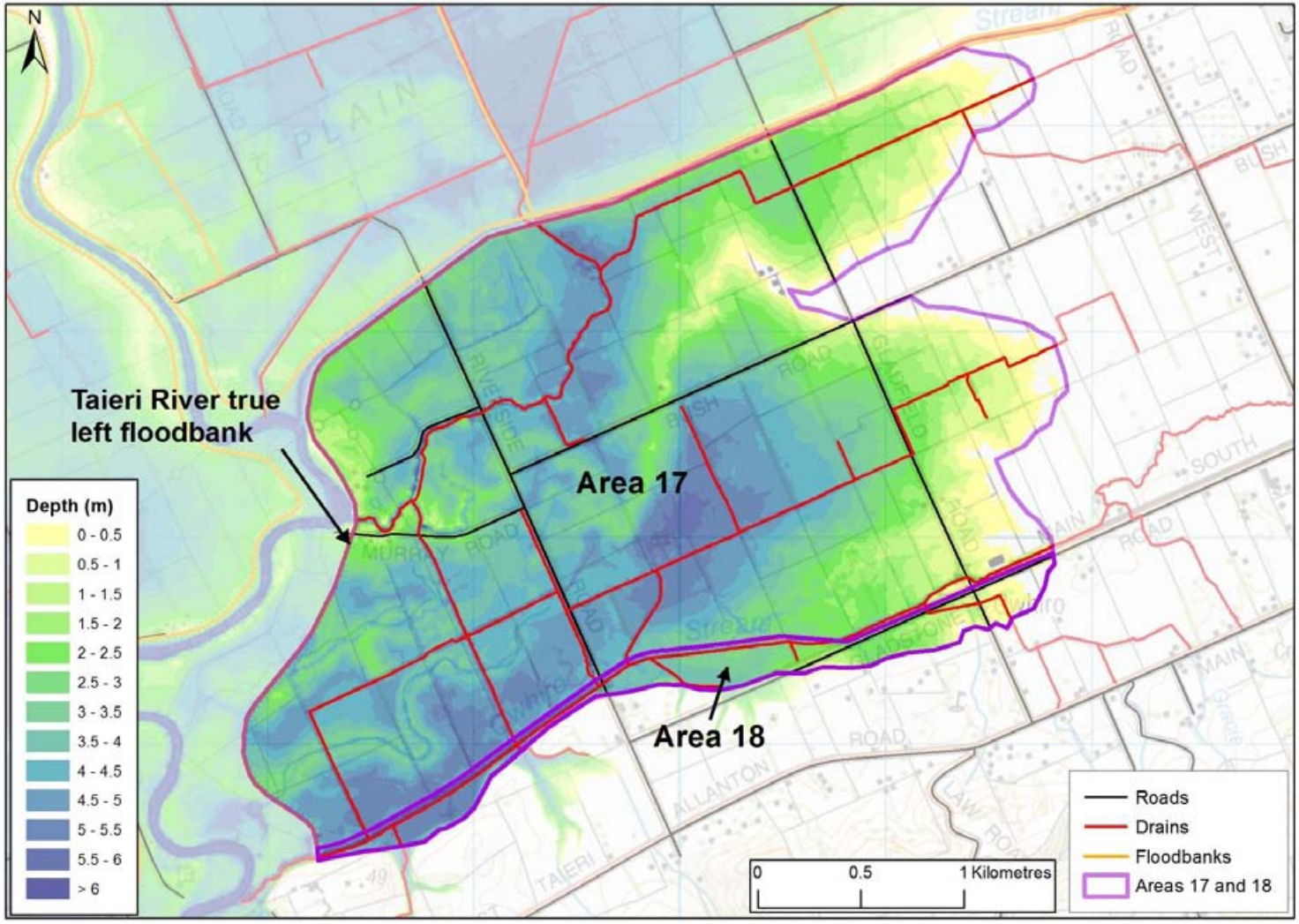

Figure 26 **Depth of inundation in areas 17 and 18 if water were to reach the crest of the Taieri River true left floodbank**

2.12. Area 18 South of Owhiro Stream

Setting: This area can be affected by flooding in the Owhiro Stream, as well as the Taieri River and runoff (which may include sedimentation) from the hill tributaries to the south. The Owhiro Stream gated outfall structure (OSGOS) is designed to prevent flow from the Taieri River entering this area, while providing the capability for the Owhiro Stream to discharge by gravity into the Taieri River whenever water levels in the river are lower than those in the Owhiro Stream. Ponding occurs behind (to the east of) the flood gate during high-flow events. There is some connectivity between Area 17 (East Taieri Lower Pond) and Area 18, via culverts in the railway embankment that continues in an easterly direction along the edge of the Lower Pond.

Ponding can reach depths of 5m if water were to reach the minimum crest level of the Taieri River true left floodbank (Figure 26), and can last for several days. The extent, depth and duration of ponding during each flood event depends on the flood's duration and size.

2.13. Area 19 East of the Lower Pond

Setting: Internal runoff is the predominant source of flooding in this area, although it is also exposed to flooding from the Silver Stream[7] and Owhiro Stream (ORC, 2013) (Figure 27). The southern part of this area was affected by flood flows in the Owhiro Stream in April 2006, making Gladstone Road south impassable to vehicles and pedestrians. Scheduled drains and other overland flow paths provide an important function by conveying floodwater downslope to Area 17 (Figure 27). Structures and earthworks can impede or redirect this flow of water.

The depth of water can range from 0.25m in smaller and wider overland flow paths, through to 2m in some drains. Velocity of runoff is generally relatively slow, although higher speeds can occur, due to water overtopping adjacent floodbanks, and in the larger drains.

[7] The floodbanks along the southern side of the Silver Stream are designed to contain flows of 260m^3/s or more.

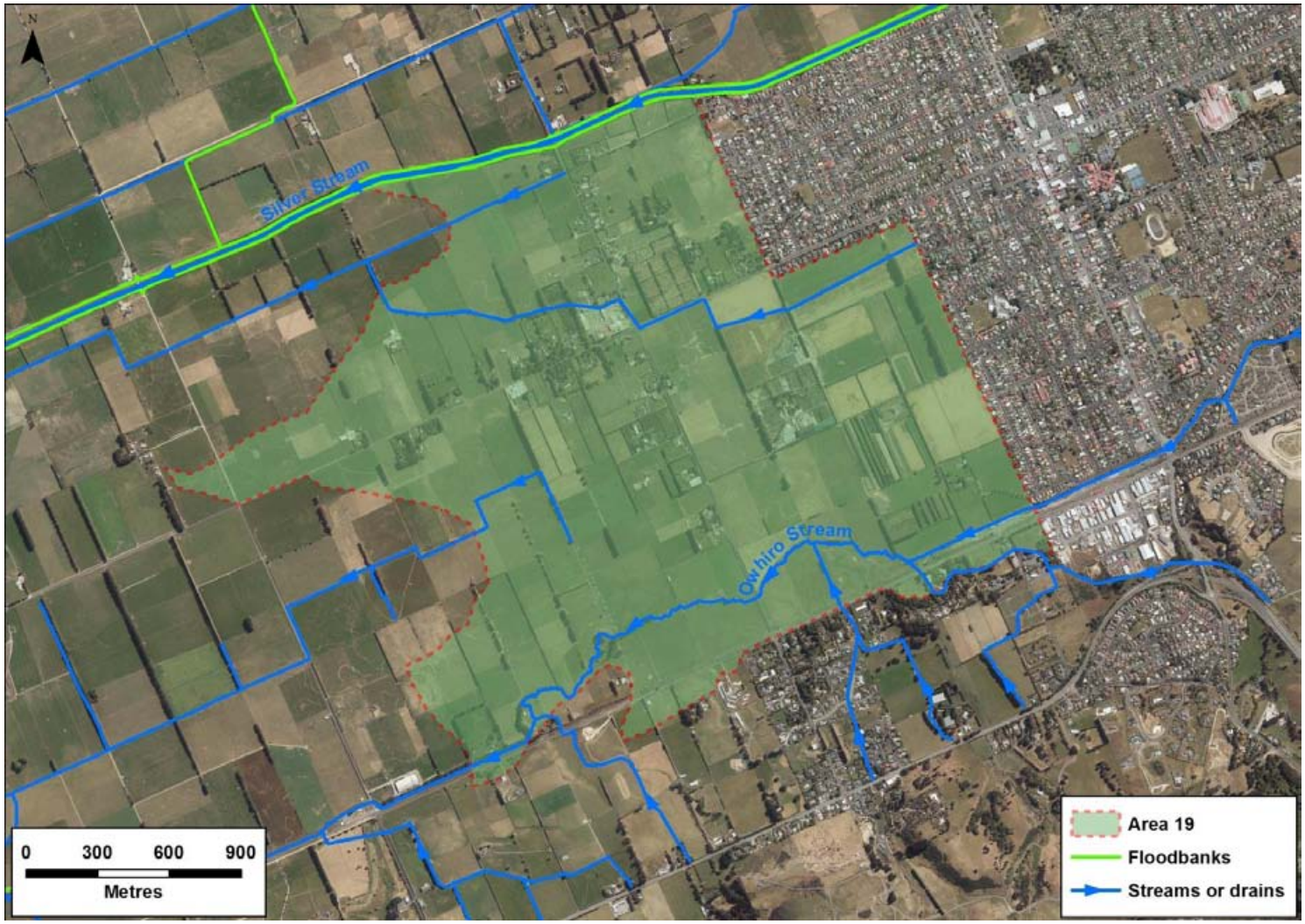

Figure 27 **Area 19 – Streams and drains and general direction of flows in Area 19**

2.14. Area 20 Mosgiel

Setting: Most of the Mosgiel urban area is elevated slightly above the land on the northern side of the Silver Stream (Figure 28) and the land to the south alongside the Owhiro Stream. Therefore, it has limited exposure to flood hazard from the Silver Stream, Owhiro Stream, Quarry Creek, internal runoff from within Area 20, and downslope runoff from Area 21 (Figure 34). The floodbanks along the southern (true left) side of the Silver Stream are designed to contain flows that have an assessed return period of approximately 100 years.

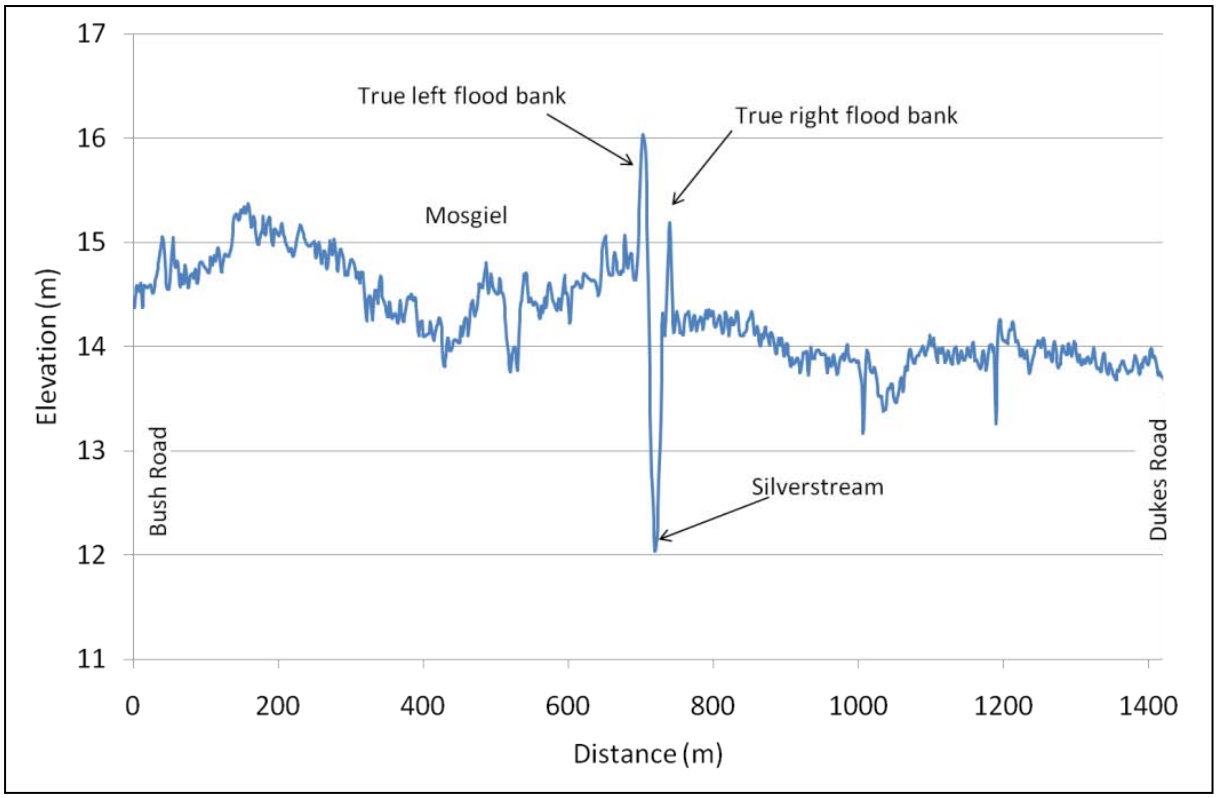

Figure 28 **Cross section through the Silver Stream (from Bush Road in Mosgiel to Dukes Road in Area 14), looking downstream**

The characteristics of flood hazard (including depth, duration and velocity) within urban Mosgiel are determined in part by the capacity of the drainage network, and most of Area 20 is serviced by an urban standard stormwater network. Heavy rainfall events that exceed the design capability of this network can result in internal runoff and ponding of floodwater (Figure 29).

During periods of heavy rainfall, surface flooding and runoff from the eastern hills can cause localised ponding, especially in the industrial, southern part of the urban area, near Quarry Creek (ORC, 2013) (Figure 30). The flooding in the industrial area is not directly caused by Quarry Creek overtopping its true right bank but is the result of an undersized stormwater network (Figure 31). The flooding is exacerbated by the location of the stormwater network outlets discharging into Quarry Creek: when the water level in the creek is high flood water can impede the stormwater discharge, and water can back up through the stormwater network causing flooding in the industrial area.

Figure 29 **Surface flooding on Gordon Road, November 2012 (source: Otago Daily Times)**

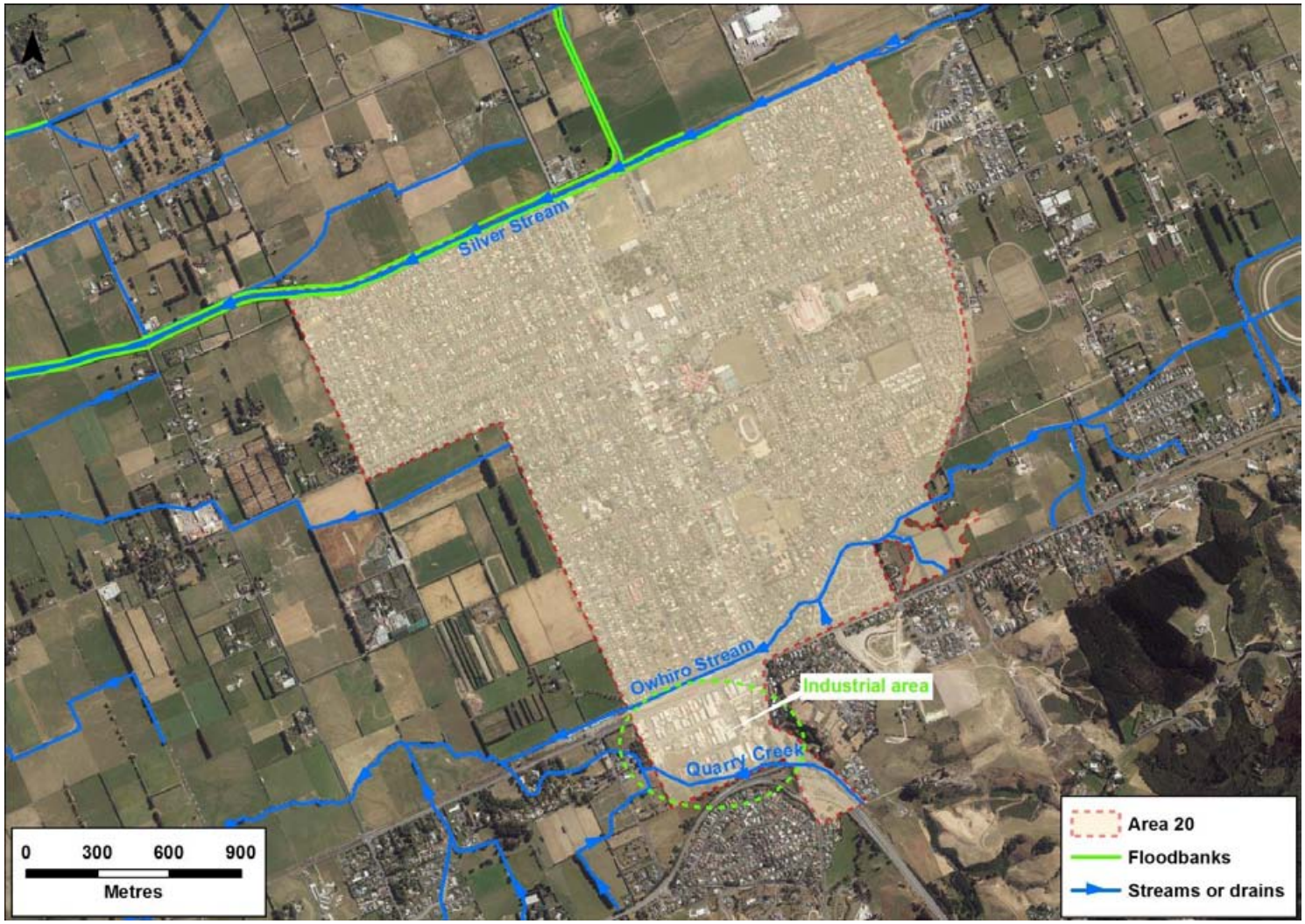

Figure 30 **Area 20 – Streams and drains, and the location of the industrial area at the southern end of Area 20**

Figure 31 **Area 20 – Industrial area and location of the stormwater network and outlets**

2.15. Area 21 Wingatui

Setting: The Wingatui area is exposed to flood hazard from internal runoff, the hill catchments to the east and south, the Owhiro Stream, and, to a lesser extent, the Silver Stream[8] (ORC, 2013). A series of active floodwater-dominated alluvial fans emerge from the adjacent hill catchments (Abbotts Hill (360m) to the east; and the Chain Hills (approximately 150m) to the south (GNS, 2014c). These fans grade into an extensive alluvial plain, with a corresponding change in elevation from about 40m down to 25m near Mosgiel. Surface runoff and ponding resulting from heavy rainfall can occur in this area with little warning, due to the short, steep upstream catchments that discharge onto this eastern part of the Taieri Plain (Figure 32).

There are a limited number of formal drains that cross Area 21, and the location of these is shown in Figure 33. These drains carry much of the overland flow that flows towards the southwest during heavy rainfall events. Because of the generally subtle topography (as shown in Figure 34), the depth and extent of flooding can also be influenced by local features such as embankments, fences, shelterbelts and buildings, which can impede natural downslope drainage. The area lies within the East Taieri Drainage Scheme, which provides land drainage to a rural standard, and Figure 33 shows the location of scheduled drains (as defined in ORC, 2012).

Figure 32 **Overland flow that has drained from the adjacent hill catchment, ponding near Puddle Alley, at the northern end of Area 21 (June 2013)**

[8] The length of the Silver Stream adjacent to Area 21 is deeply incised.

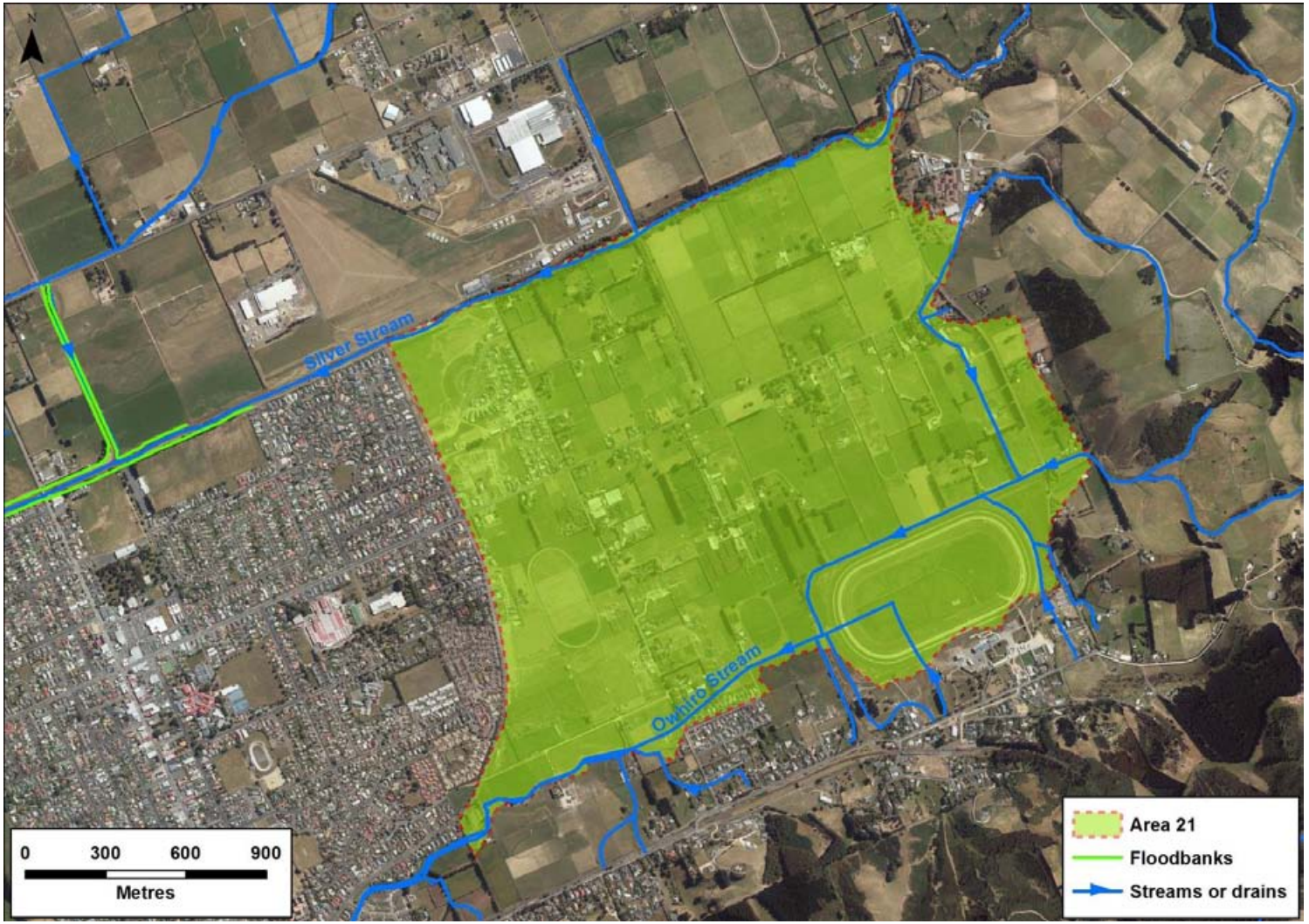

Figure 33 **Area 21 – Streams and drains and general direction of flows in Area 21**

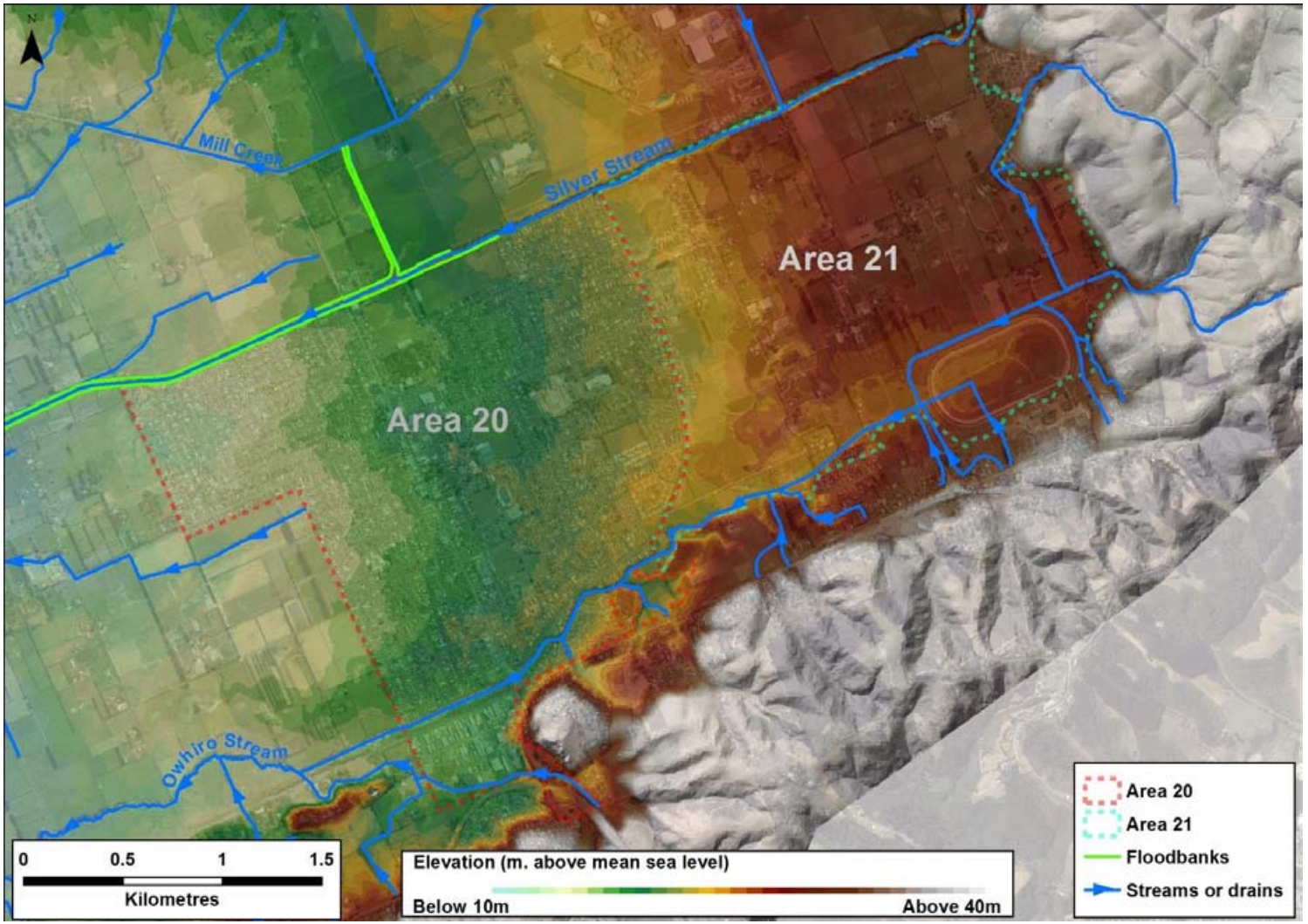

Figure 34 **Topography of areas 20 and 21 (Mosgiel and Wingatui)**

2.16. Area 22 Flanks of coastal ranges

Setting: This area is sufficiently elevated not to be affected by the Taieri River or the Silver Stream. Flood hazard is derived from Quarry Creek (Figure 35), Owhiro Stream and the hill tributaries to the south and east (Figure 36). Flood hazard is mainly associated with overland flow and, in some places, the presence of floodwater-dominant alluvial fans (Opus, 2009). High stream flows, surface runoff and ponding resulting from heavy rainfall can occur in this area with little warning, due to the short, steep upstream catchments that discharge onto the Taieri Plain. The depth of flooding can range from less than 0.25m through to about 2m in the deeper drains. The velocity of runoff is generally slow to medium, and runoff generally does not last more than a few hours, during the period of peak rainfall intensity.

Quarry Creek is a short watercourse (approx. 3.5km) that drains the north-facing slopes of Saddle Hill. It has a catchment area of approximately 3.5km^2. The creek passes through a culvert under SH 1 adjacent to Kinmont Park and flows through Area 20 (see Area 20 description and Figure 31) and the East Taieri School grounds before joining the Owhiro Stream about 400m below Cemetery Road (Figure 37). The area adjacent to the creek between the culvert under SH 1 and Cemetery Road bridge is low lying (Figure 37). During periods of heavy or extended rainfall, the creek can cause flooding of these low-lying areas, in particular the car park of the East Taieri School and parts of the school grounds. The school car park area and part of the East Taieri School grounds are located at a relatively low level adjacent to a breakout point (Figure 37). Given the topography of the area (flat and low lying), the flood hazard is significantly influenced by the backwater effect from the Owhiro Stream. High water levels in Quarry Creek can also cause the bridge on Cemetery Road to flood.

Figure 35 **Quarry Creek at Cemetery Rd Bridge, April 2006. Photo was not necessarily taken at the time of peak flow.**

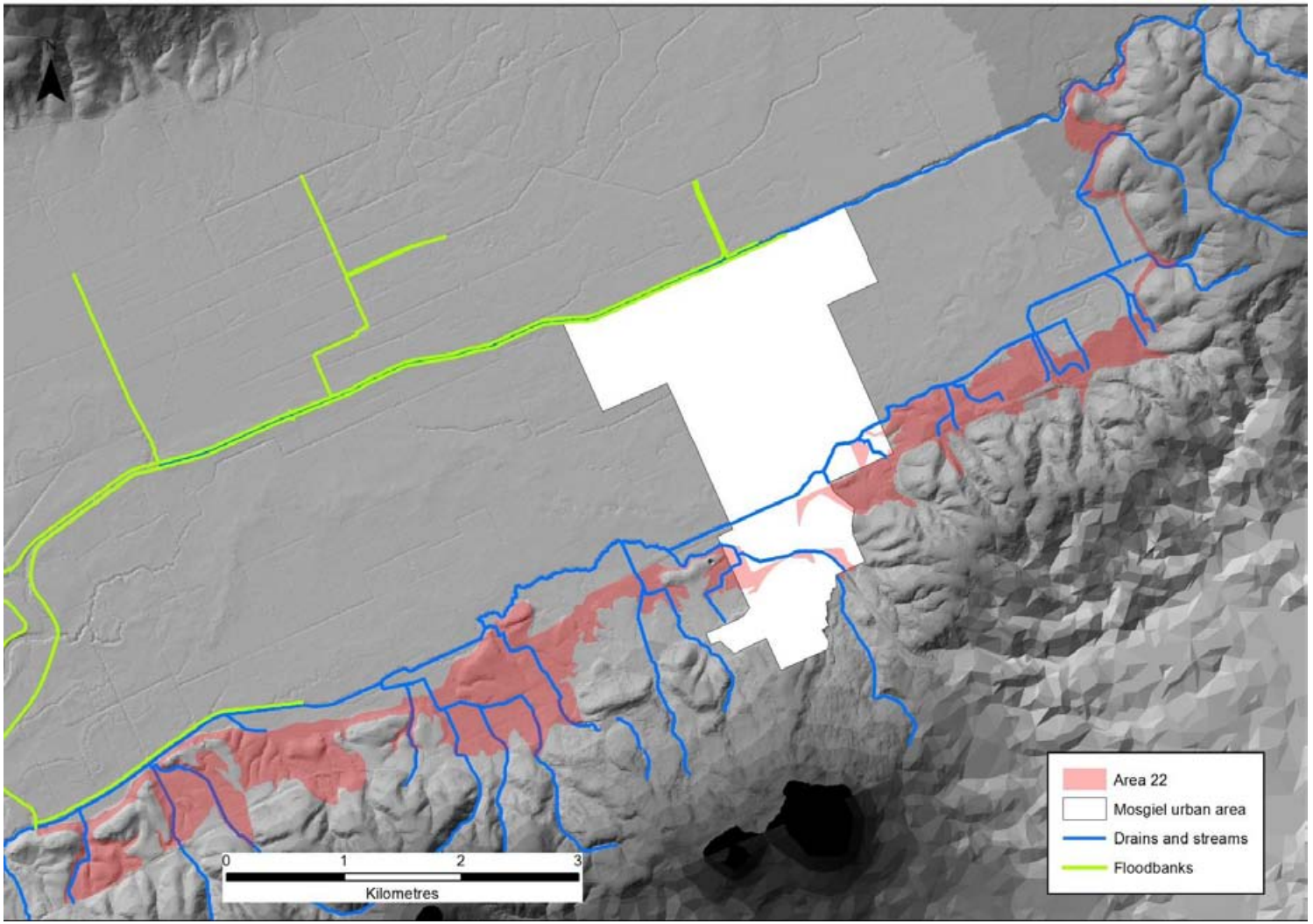

Figure 36 **Coastal hill catchments that traverse Area 22**

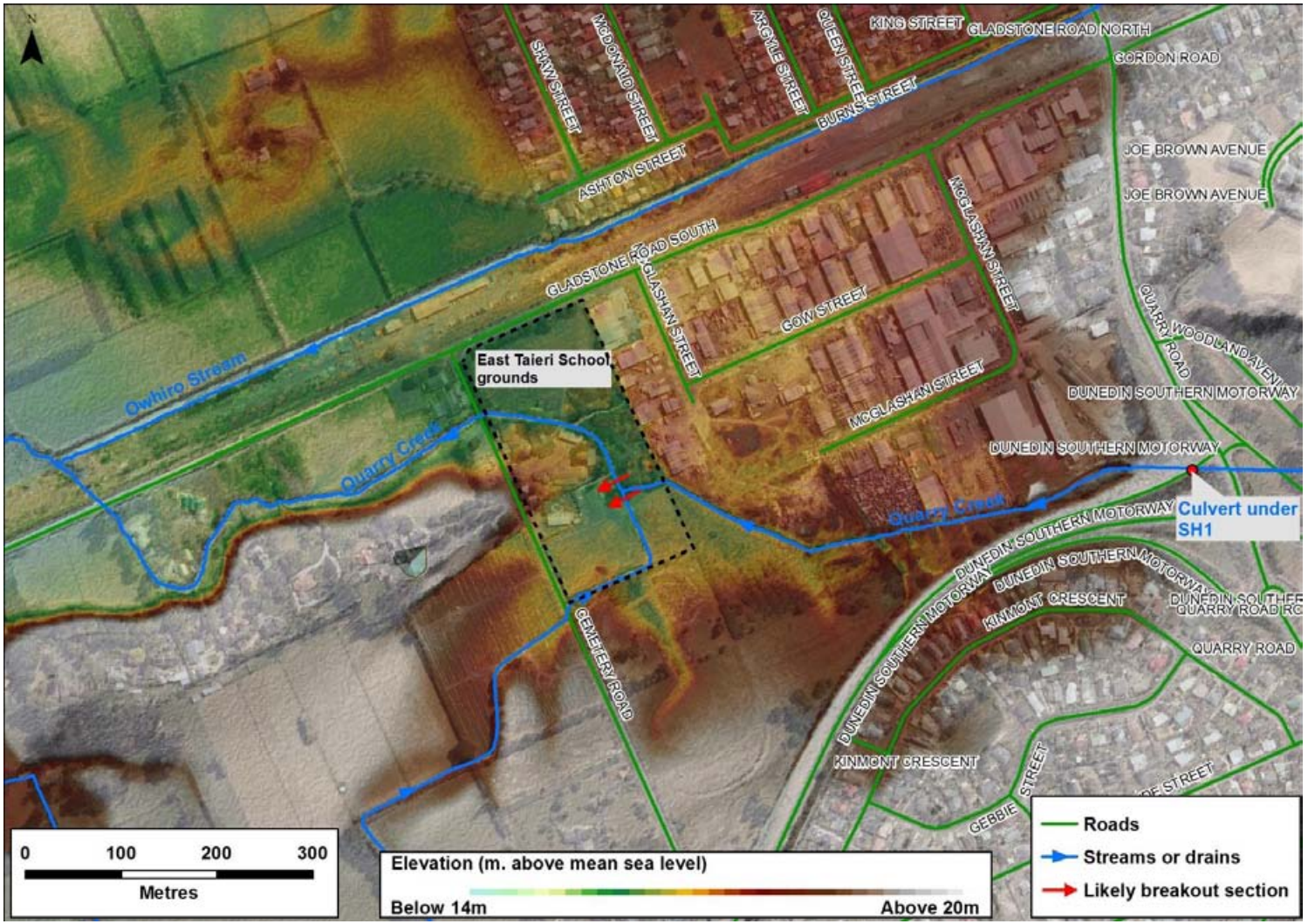

Figure 37 **Topography of the vicinity of the East Taieri School grounds and Quarry Creek**

3. Flood hazard characteristics of the Strath Taieri

The Strath Taieri area is located in a basin of the Taieri River, which is bounded by steeper gorge areas upstream near Hyde, and downstream below Sutton (Figure 38). The flood hazard in this area is derived from both the Taieri River and the tributaries that drain the ranges to the east and west. Some minor control works and channel maintenance has historically been undertaken on both the Taieri River and some tributaries, although there is no formal flood protection scheme.

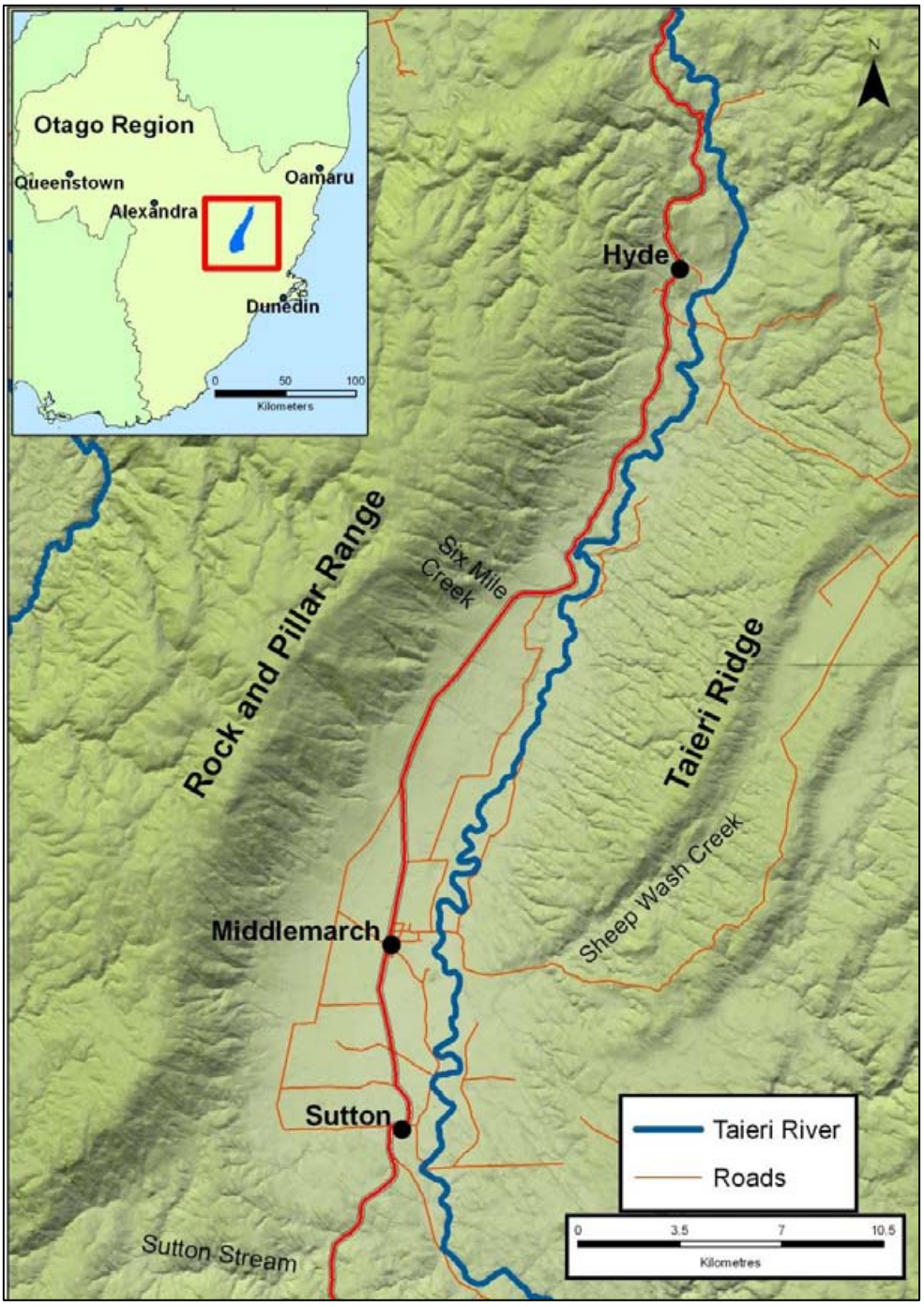

Figure 38 **Location map showing the topography and communities located on the Strath Taieri**

3.1. Taieri River flood hazard

The Taieri River upstream of Sutton has an extensive catchment area of more than 6,000 km^2, which extends to the Kakanui Mountains and Ida Range in the north, Rough Ridge in the west, and the Lammerlaw Range in the south. Prolonged heavy rain in the headwaters of the Taieri catchment will eventually result in high flows further downstream, although flood peaks can take several days to reach the Strath Taieri, due to the moderating influence of the Taieri scroll plain wetlands.

The Taieri River flood-hazard area (as shown on Figure 43) has been mapped primarily using information from flood events in June 1980 and December 1993. These are the two largest floods since records began in 1960. The flood-hazard area extends 20km from the confluence of Last Creek with the Taieri River in the north, to Sutton in the south. It covers an area of 85km2 and is almost 2km across at its widest point. There have been relatively few large flood events since the mid-1990s, and the peak flow at Sutton during the June 2013 flood was considerably smaller than during previous events. Recent experience of flood events may therefore not represent the full spectrum of risk associated with flood hazard. However, Figure 39 shows that there have been occasions when several large floods have occurred within 12 months or less (March 1986 to March 1987, and December 1993 to July 1994).

Characteristics of flood hazard, such as depth, velocity and duration for this area have not been specifically calculated by ORC. However, anecdotal evidence of previous flood events show that inundation of 1m or more can occur (Figure 40 and Figure 41), and that the area can be affected for up to one week following major flood events (ORC, 1993).

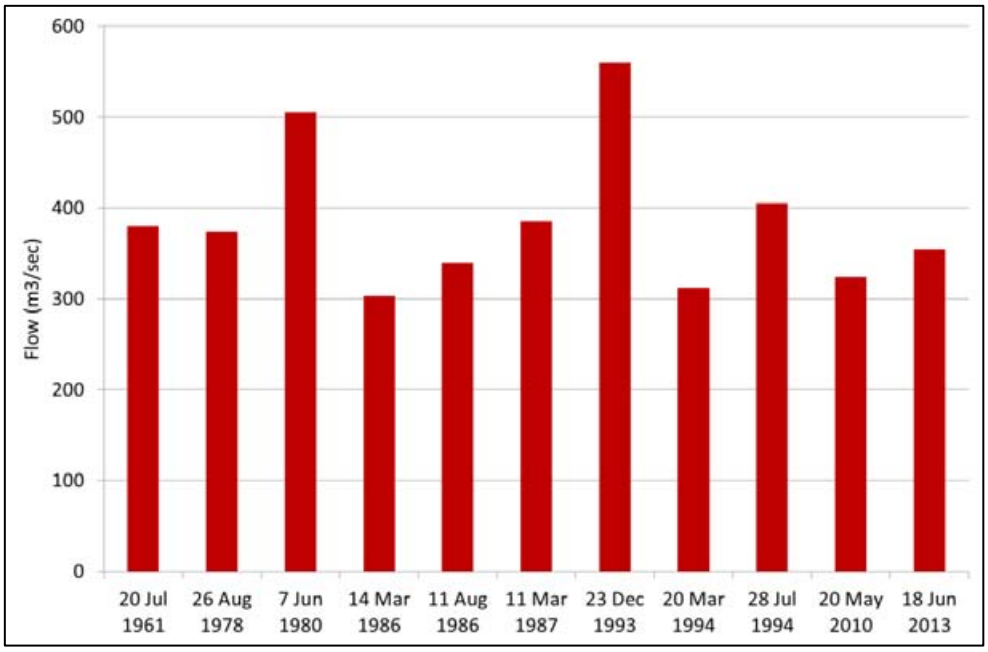

Figure 39 **The ten highest flows in the Taieri River at Sutton since records began in August 1960**

Figure 40 **Inundation of rural land near Creamery Creek (Middlemarch) following the May 1957 flood. Note the lines of fence posts just visible above the water level.**

Figure 41 **Inundation of rural land on the margins of the Taieri River on 18 June 2013, following a prolonged period of heavy rainfall. This photo was taken six hours after the flood peak, when flow in the Taieri River at Sutton had dropped from 354m3/s to 326m3/sec. The ORC natural hazards database (www.orc.govt.nz) contains other photos of the Strath Taieri taken on this day.**

3.2. Tributary / alluvial-fan flood hazard

The largest tributary streams in the Strath Taieri include Sheepwash Creek on the eastern side of the valley, and Six Mile Creek, Sutton Stream and several other short, steep tributary streams that have their source high on the slopes of the Rock and Pillar Range to the west. ORC (1993), Opus (2009) and GNS (2009) all describe the alluvial fan-building processes that occur at the base of these western tributaries. Some streams have a tendency to break out of their existing channels at times of higher flows, and ORC (1993) lists several events where flooding has occurred on higher river terraces (including in Middlemarch) due to high flows in adjacent creeks. GNS (2009) found that flooding is the dominant process associated with alluvial fans in this area, with fan-building activity and sedimentation limited to areas close to the present stream channels. However, GNS did consider that larger debris flows were a prominent feature of some alluvial fans at some stage in the past, judging by the large boulders on parts of the lower fan surfaces.

The extent of 'active' alluvial fan surfaces, as mapped by Opus (2009) and GNS (2009), is also shown in Figure 43. The Opus maps were produced at a scale of 1:50,000 and are derived from pre-existing geologic and landform maps. The GNS maps were produced at a scale of 1:10,000 and were created using both existing information and field checks.[9] The alluvial fan features shown on Figure 43 include the more detailed GNS information where it is available and the 1:50,000 mapping elsewhere. The features shown include:

- 'active' fan areas, which may be prone to surface flooding, or channel floods carrying sediment within the next 100 years or so (from Opus, 2009)
- 'fan recently active' areas, where sedimentation has occurred within the last 300 years, or where the stream is more likely to break out of its channel during periods of high flow (from GNS, 2009).

Recently active landslides and areas of gully erosion in upper catchment areas are also shown (as mapped by GNS, 2009). As well as indicating areas of land instability, landslides and erosion can provide a source of sediment for downstream alluvial fan features.

Figure 42 Taieri River at Sutton Bridge, during the June 1980 flood

[9] The Opus (2009) mapping has an estimated accuracy +/-100m, while the accuracy of the GNS (2009) data is +/-20m.

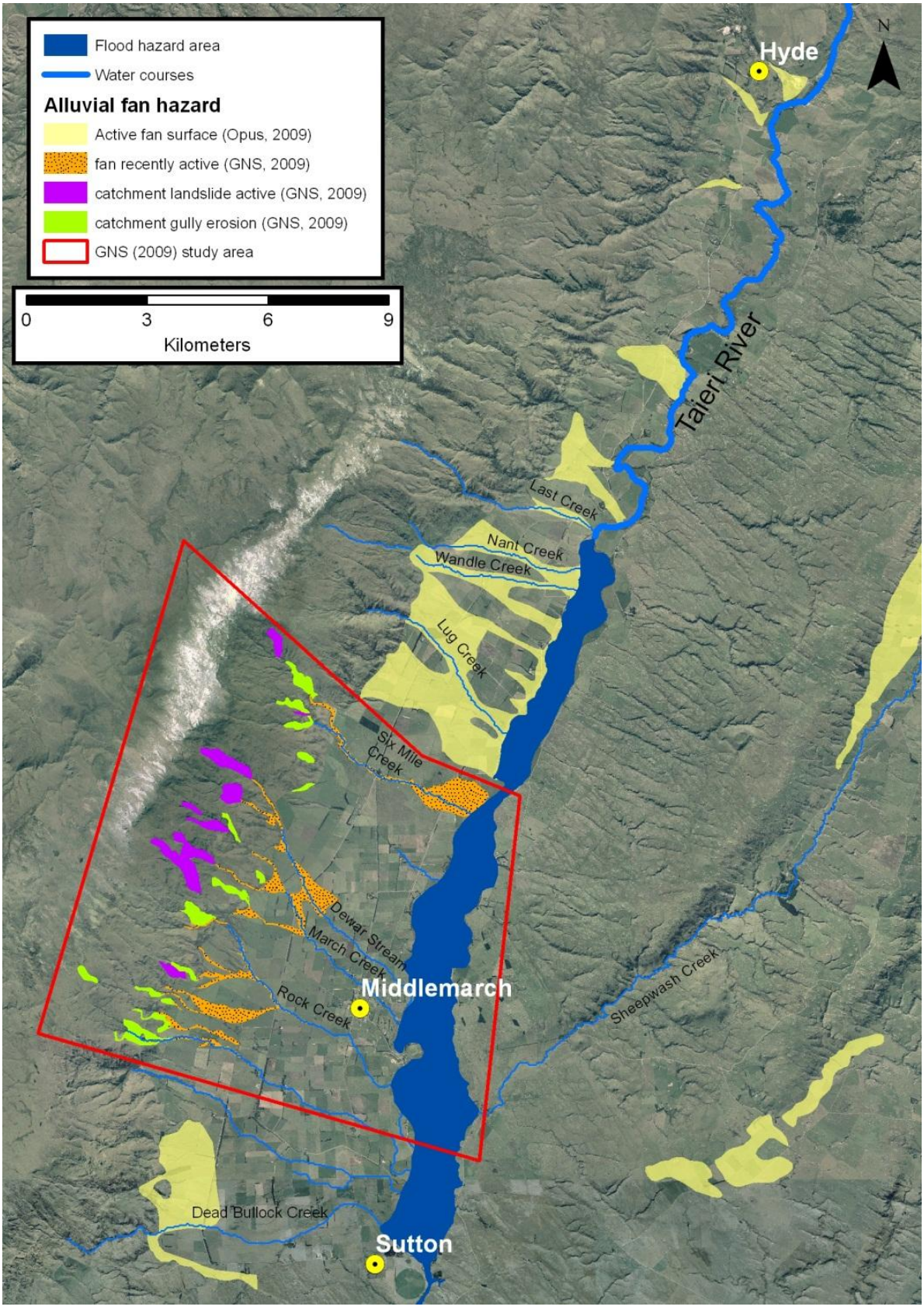

Figure 43 **Strath Taieri flood-hazard area (ORC, 1993), and active alluvial-fan surfaces (GNS, 2009 and Opus, 2009)**

3.3. Strath Taieri flood hazard: Summary

The largest floods in the Strath Taieri occur when slow moving fronts pass from west to east over the catchment, and the flood peak from the upper catchment coincides with the maximum local runoff in tributary streams (ORC, 1993). Figure 43 shows valley floor areas that may be subject to river flooding, as well as alluvial-fan areas that may be subject to debris and/or flood flows in the tributaries that drain from the Rock and Pillar Range.

Flooding can be compounded by the effect of the gorge below Sutton, which can restrict the drainage of floodwater. Damage from previous flood events has included inundation of buildings, houses and roads, scouring of river banks and road embankments, and substantial damage to bridges and fences (Figure 40 and Figure 42). Localised heavy rainfall events, or ‘cloudburst’, can occur with little warning, and result in surface flooding and sedimentation when tributary streams break out of their channels. Much of the area can become isolated due to high flows in the Taieri River or its tributaries.

References

GNS Science, 2014a. *The hazard significance of landslides in and around Dunedin City.* Report prepared for the Otago Regional Council, Dunedin.

GNS Science, 2014b. Assessment of liquefaction hazards in the Dunedin City district.

GNS Science, 2014c. Extent and characteristics of alluvial fans in the north-eastern sector of the Taieri Plain, Otago. Report prepared for the Otago Regional Council.

GNS Science, 2009. Otago Alluvial Fans Project: Supplementary maps and information on fans in selected areas of Otago, Prepared for the Otago Regional Council, Dunedin.

GNS Science, 2001. Geology of the Waitaki Area.

GNS Science, 2006. Geology of the Dunedin Area.

Ministry for the Environment, 2008. *Climate Change effects and impacts assessment,* A Guidance Manual for Local Government.

Otago Regional Council, 2014b. Coastal Hazards of the Dunedin City District.

Otago Regional Council, 2014c. Flood Hazard of Dunedin's urban streams.

Otago Regional Council, 1993. Floodplain Management Report: Dunedin District – Rural Areas, Dunedin.

Otago Regional Council, 2012. *Flood Protection Management Bylaw 2012,* Dunedin.

Otago Regional Council, 2013. Natural Hazards of the Taieri Plains, Otago, Dunedin.

Otago Regional Council, 2014a. Review of the Dunedin City District Plan – Natural Hazards: Project Overview.

Opus International Consultants and GNS Science, 2009. *Otago Alluvial Fans Project,* Prepared for the Otago Regional Council, Dunedin.

Opus International Consultants, 2005. *Seismic Risk of the Otago Region*, Prepared for the Otago Regional Council, Dunedin.