# Report Superseded

The landslide mapping in this report has been superseded by the 2017 report:

Revised landslide database for the coastal sector of the Dunedin City district.

Please refer to the 2017 document for the most up to date landslide information.

Landslide maps and associated information are available online through the ORC's Natural Hazard Database:

https://www.orc.govt.nz/managing-our-environment/natural-hazards/otago-natural-hazards-database

# Active landslides in the Dunedin area

**October 2015**

Otago Regional Council
Private Bag 1954, Dunedin 9054
70 Stafford Street, Dunedin 9016
Phone 03 474 0827
Fax 03 479 0015
Freephone 0800 474 082
www.orc.govt.nz



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Report writer: Ben Mackey, Hazards Analyst (Geologic)
Reviewed by: Michael Goldsmith, Manager Natural Hazards

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Cover: Abbotsford landslide, 1979. Photo courtesy of Otago Daily Times.

# Overview

In this report, existing information relating to the most recently active group of known landslides in Dunedin City has been collated to help inform the review of the Dunedin City District Plan. Three sub-categories within this group of landslides have been determined, with reference made to original source reports.

The attributes of approximately 2,100 mapped landslide features in Dunedin City were collated into a database by GNS in 2012 and 2014 (Glassey and Smith Lyttle, 2012; Glassey et al, 2014), hereafter termed the landslide database. A subset of 24 mapped features that meet the following criteria has been selected from that database. These include:

- those that have definitely been formed by landslide movement
- those where movement has been observed within the last 50 years
- those that have a high sensitivity to environmental and/or human-induced modifications.

Another three landslides that were not included in the landslide database, but which are actively monitored by the Dunedin City Council (DCC), have been included in this subset. The full list of 27 landslides is shown in the table below, and the group is termed 'Dunedin high-importance landslides'.

Existing information relating to each of these 27 landslides has been collated and reviewed to separate them into three sub-categories:

a. landslides that are currently moving at a rate of 10 mm/year or more (based on recent high precision surveys), and/or are particularly sensitive to changes in the environment (labelled '*Active*')

b. landslides that have experienced historic movement, but ongoing monitoring suggests that there is little or no current movement (labelled '*Minimal recent activity*')

c. landslides that have experienced historic movement, but there is insufficient information to determine current rates of movement (labelled '*Insufficient information*').

**Table 1** **Dunedin high-importance landslides: The 27 landslides selected using the criteria listed above, separated into three sub-categories, based on additional analysis undertaken for this investigation[1]**

| Active | Minimal recent activity | Insufficient information |
|---|---|---|
| Brighton Road | Albany Street | Black Head |
| Church Hill Road | Cargill Street | Blue Slip – SH1 |
| Dickson St | West Abbotsford | Camp Road |
| District Road | 237 Brockville Road* | Duke St |
| Howard St (secondary) | East Abbotsford / Sun Club | Irvine Road |
| Howard St (primary) | Sidey Street area* | 577 Kaikorai Valley Road |
| Jeffcoates Road | | Koremata St |
| Puketeraki | | Site Office |
| Puketeraki (Embankment earthflow) | | GullySlide |
| Rockview Road | | No. 38 Landslide |
| Greenacres Street earthflow* | | |

This report does not provide a hazard or risk assessment for mapped landslides, but it is noted that the features that are most active and sensitive to modifications are more likely to pose a hazard to existing or proposed new development. Future development on these landslides may be a contributing factor to increased rates of landslide movement, or increase the likelihood of sudden failure. Equally, development commonly results in improved drainage via stormwater systems, and so the reverse may apply. The consequences for stability due to any new development require careful evaluation at the planning/design stage. There is sufficient information for landslides in category 'a' to indicate that they are likely to pose a hazard to existing or new development.

Development on known landslides that appear to have stabilised or which show minimal signs of recent movement (category 'b') should only be undertaken if supported by robust geotechnical evaluation. Further site-specific investigation may reveal whether the landslide has stabilised, or whether there is potential for reactivation under particular circumstances. Further investigation may determine whether suitable and cost-effective engineering options to minimise landslide risk are available. It should be understood that development increases the exposure to the potential hazard and therefore increases risk.

Within the third category of landslides, there is insufficient information to determine whether they are currently active (category 'a') or have minimal recent activity (category 'b'). An appropriate geotechnical evaluation would be needed to determine the suitability or otherwise of any further development on, or near, these features.

[1] The landslide names listed in the database are adopted in this report. In some cases, landslides were not previously named, and an appropriate identifying label has been added for this report. The three landslides that do not meet the selection criteria from the 2014 GNS database, but are actively monitored by the DCC, are marked with an asterisk.

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# 1. Introduction

The Otago Regional Council (ORC) has reviewed information on the most active group of landslides in the Dunedin City urban area to help inform decisions on land-use zonation in the Dunedin City District Plan, which is currently being re-evaluated and updated by the Dunedin City Council (DCC).

This report collates available existing data relating to known landslides within Dunedin City that have moved in historic times. It outlines the state of knowledge relating to the recent activity state of each landslide to guide the determination of the landslide hazard for each site. No site-specific investigations have been undertaken in the course of this review, although information obtained during an assessment of parts of the Dunedin district after a heavy rainfall event in June 2015[2] has been included where appropriate.

Information reviewed includes:

- Dunedin City landslide database collated by GNS Science (the landslide database). Last updated 2014 (Glassey *et al*., 2014)
- reports detailing repeat survey results of active landslides conducted by MWH for the DCC (13 landslides)
- source geotechnical reports and maps (if accessible)
- 2012, 2014, 2015 GNS reports on landslides in Dunedin City for ORC[3]
- LiDAR data and aerial photos
- any other information located relating to individual landslides.

The primary source consulted was the landslide database, a recent GNS compilation (Glassey *et al*., 2014). The landslide database includes attribute data listing available information and interpretations about landslides, and the source of that information (Figure 1). This geodatabase was compiled in part to consolidate and vet a suite of historic landslide inventory maps and site specific investigations. A 2015 GNS study (Barrell and Smith Lyttle, 2015) augments this inventory with an assessment that identifies areas possibly susceptible to future landslide movement, based primarily on slope angles, the presence of past landslide movements, and the presence of particularly sensitive geological strata.

This review is restricted to landslides within the landslide database, or additional slides that are monitored by MWH Ltd[4] for the DCC.

[2] Coastal Otago flood event 3 June 2015, Report 2015/1008 by ORC
[3] Glassey and Smith Lyttle, 2012, Glassey *et al*., 2014, Barrell and Smith Lyttle, 2015
[4] Engineering firm, MWH Ltd, surveys some landslides periodically for the DCC to document any ongoing movement.

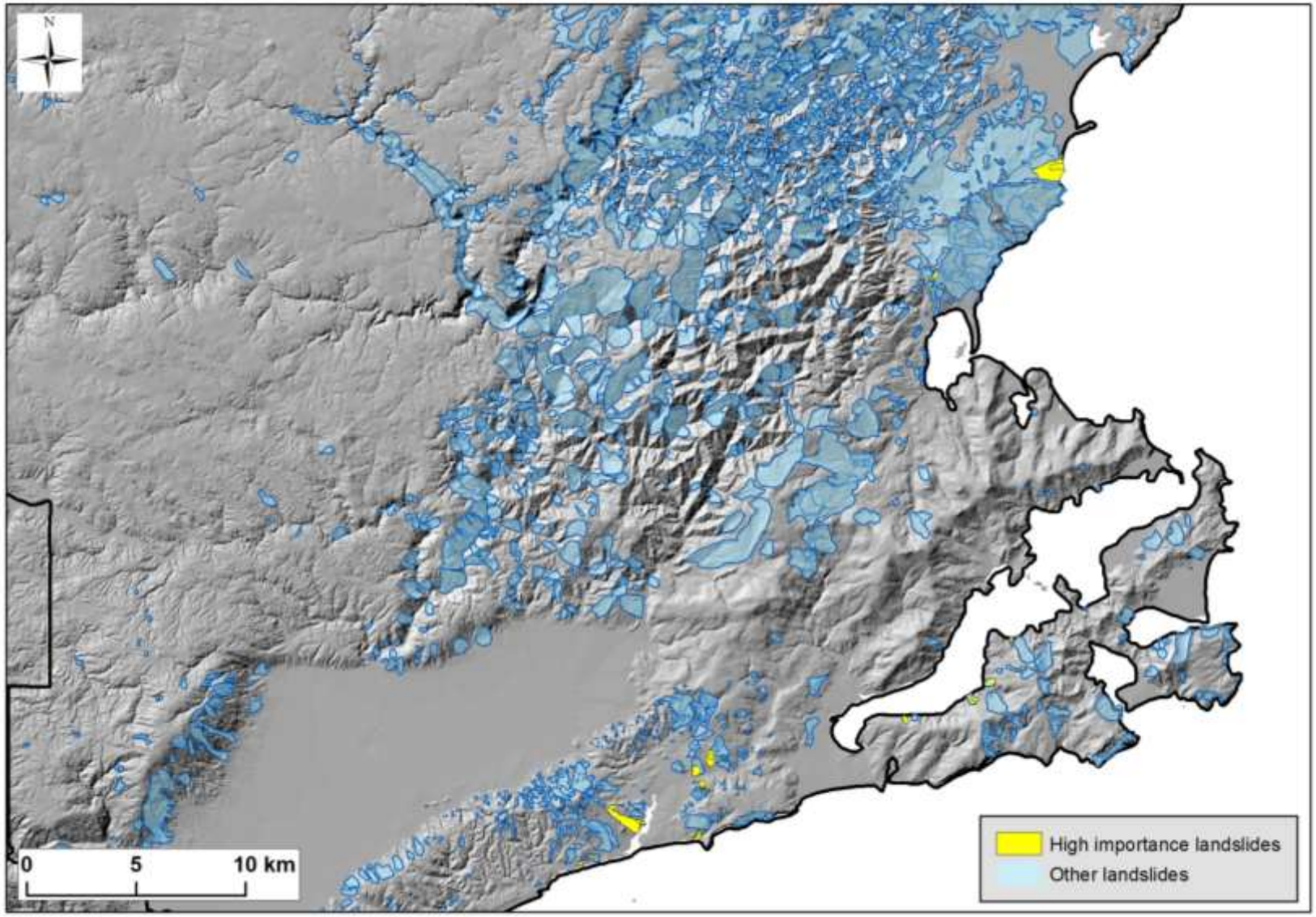


**Figure 1** **Mapped landslides in the Dunedin City district (from Glassey et al., 2014). Slides coloured yellow are the 27 landslides discussed in this report (Dunedin high-importance landslides). Landslides that do not meet the criteria outlined in Table 2 are shaded blue. See Figure 3 for more detailed views of the landslide locations.**

## 1.1. Defining 'active' landslides

The following criteria that were previously applied by GNS in 2014 to individual mapped features within the landslide database were used to select the most active group of landslides. These include:

- those that have definitely been formed by landslide movement
- those where movement has been observed recently (past ~50 years), or is actively occurring (in the past year)
- those that have high sensitivity to environmental and / or human-induced modifications (e.g. a small change in loading or groundwater conditions could cause movement).

Twenty-four individual landslide features in the eastern Dunedin City district were found to meet this threshold. A further three landslides that were not included in the landslide database, but which are currently monitored by MWH for the DCC, were also included. These are the Sidey Street movement area, the 237 Brockville Road landslide, and an earthflow near Greenacres Street, Macandrew Bay.[5] The 27 landslides reviewed for this report, and identified collectively as the Dunedin high-importance landslide dataset, are listed in Table 2, and their general locations are illustrated in Figure 3.

Existing information relating to each of these 27 landslides has been collated and reviewed to further separate them into three sub-categories:

a. Landslides that are moving at a rate of 10 mm/year or more (based on recent surveys), and/or are particularly sensitive to changes in the environment (labelled '*Active*')

b. Landslides that have experienced historic movement, but ongoing monitoring suggests that there is little or no current movement (labelled '*Minimal recent activity*')

c. Landslides that have experienced historic movement, but there is insufficient information to determine current rates of movement (labelled '*Insufficient Information*').

**Table 2 High-importance landslides in the Dunedin district, separated into three sub-categories**

| Active | Minimal recent activity | Insufficient information |
|---|---|---|
| Brighton Road | Albany Street | Black Head |
| Church Hill Road | Cargill Street | Blue Slip – SH1 |
| Dickson St | West Abbotsford | Camp Road |
| District Road | 237 Brockville Road* | Duke St |
| Howard St (secondary) | East Abbotsford / Sun Club | Irvine Road |
| Howard St (primary) | Sidey Street area* | 577 Kaikorai Valley Road |
| Jeffcoates Road | | Koremata St |
| Puketeraki | | Site Office |
| Puketeraki (Embankment earthflow) | | Gully Slide |
| Rockview Road | | No. 38 Landslide |
| Greenacres Street earthflow* | | |

[5] Marked with an asterisk in Table 2

It is likely that there are other features that meet the above criteria, but for which there is little or no existing information. In addition, new landslides that would meet these criteria may occur in the future (e.g. as a result of heavy rainfall or seismic shaking events). For example, ORC and GNS identified a large number of fresh landslides after heavy rainfall on 3 June 2015.[6]

Some landslides were found to be active on the basis of recent surveying, but not listed as active in the landslide database. Where data indicates a landslide is active, the GNS landslide database has been updated with the reclassified activity status. This specifically applies to the Brighton, Howard St (primary) and Dickson St slides.

## 1.2. Accuracy of mapped landslide extent

The accuracy of the mapped extent of the landslides listed in Table 2 varies considerably. Generally speaking, in the Dunedin district and further afield, most landslide features are mapped on the basis of distinctive landform characteristics, many of which persist in the landscape long after movement has occurred. Undoubtedly, many of the landslides represented in the database originated in prehistoric times (e.g. thousands of years ago), irrespective of whether or not specific landsides have experienced more recent activity in all or part of their areas. Many of the large landslides with prehistoric initiation have well-defined upslope extents, marked by a prominent step (head scarp), created by the downslope migration of the landslide body. Commonly, the downslope limit (toe) is less clearly defined, and the middle to lower margins may also be difficult to discern clearly in the landforms. Mapping is often most clear-cut in rural areas under short pasture. Accurate mapping of landslide perimeters is commonly much more difficult in forested or scrub-covered areas, and in urban areas where the land surface form was smoothed and modified as part of the urbanisation. Landslide areas that have experienced recent (e.g. <50 years) or ongoing activity may be accurately defined from offsets of human-constructed features, such as fence lines, roads or kerbs, provided that mapping has been undertaken in detail (e.g. survey precision). Most landslides in the Dunedin district have been mapped from broad-scale interpretation of landforms visible in aerial photographs, and their interpreted outlines plotted on base maps of 1:50,000 scale or poorer. Relatively few have been mapped or surveyed in detail (e.g. scale of 1:15,000 or better).

Consequently, the mapped landslide extents should generally be regarded as an indicative guide to the actual landslide extent. The 2015 GNS report and associated datasets (Barrell and Smith Lyttle, 2015) define perimeters (buffers) around the mapped landslide extents, with the buffers and the mapped extents in unison providing what are termed ‘landslide awareness areas’. These are intended to highlight the inherent imprecision with which most of the landslides in the database have been mapped. The landslide awareness areas are shown in the figures of individual landslides below.

In many cases, the mapped landslide extent presented in this report will not be appropriate for property-specific hazard zonation.

## 1.3. Source data for landslide investigations

The landslide database (Glassey *et al*., 2014) delineates the areas covered by the original source maps showing landslide extents, from which landslide extents were digitised and

[6] GNS, 2015. *Landslides observed following June 2015 rainfall event.* Report in progress

identifies the source report (if any). Most landslides were mapped on broad-scale landslide inventory maps, or in the course of creating generalised geologic maps (e.g. QMAP; McKellar, 1990). These maps provide few, if any, data other than the location of individual landslide features, and give limited information on the age of landslide features (e.g. prehistoric versus historic).

A number of detailed geotechnical or engineering geological reports have been prepared for some of the subset identified here (Dunedin high-importance landslides), particularly where they have affected aspects of the existing or proposed built environment. Information on the areas addressed in these reports is provided in the landslide database, and the most comprehensive reports, and other related documentary records (e.g. movement-monitoring reports), are identified, where appropriate, in the individual landslide descriptions in this report. These are noted in the reference list. ORC is working to collate digital copies of the main reports.

The most reliable and up-to-date source data for assessing rates of current movement comes from ongoing high-precision surveys of individual landslides for the DCC by MWH.

## 1.4. Review of active landslides

The following sections briefly describe the most active group of landslides in the Dunedin City district (as listed in Table 2 and shown in Figure 2 and Figure 3). In the accompanying figures, landslides outlined and shaded red are currently ‘active’, whereas those shaded yellow are designated ‘recently active’ in the landslide database. Where warranted by recent survey evidence, the activity status of some ‘recently active’ landslides has been upgraded to ‘active’ in the landslide database.

Areas shaded blue are other landslides in the database that are not designated as currently or recently active, or are not considered to be highly sensitive to environmental and/or human-induced modifications. The white polygons on some maps indicate the extent of survey networks used to assess landslide movement. The cross-hatch pattern defines the landslide awareness area associated with each landslide (Barrell and Smith Lyttle, 2015).

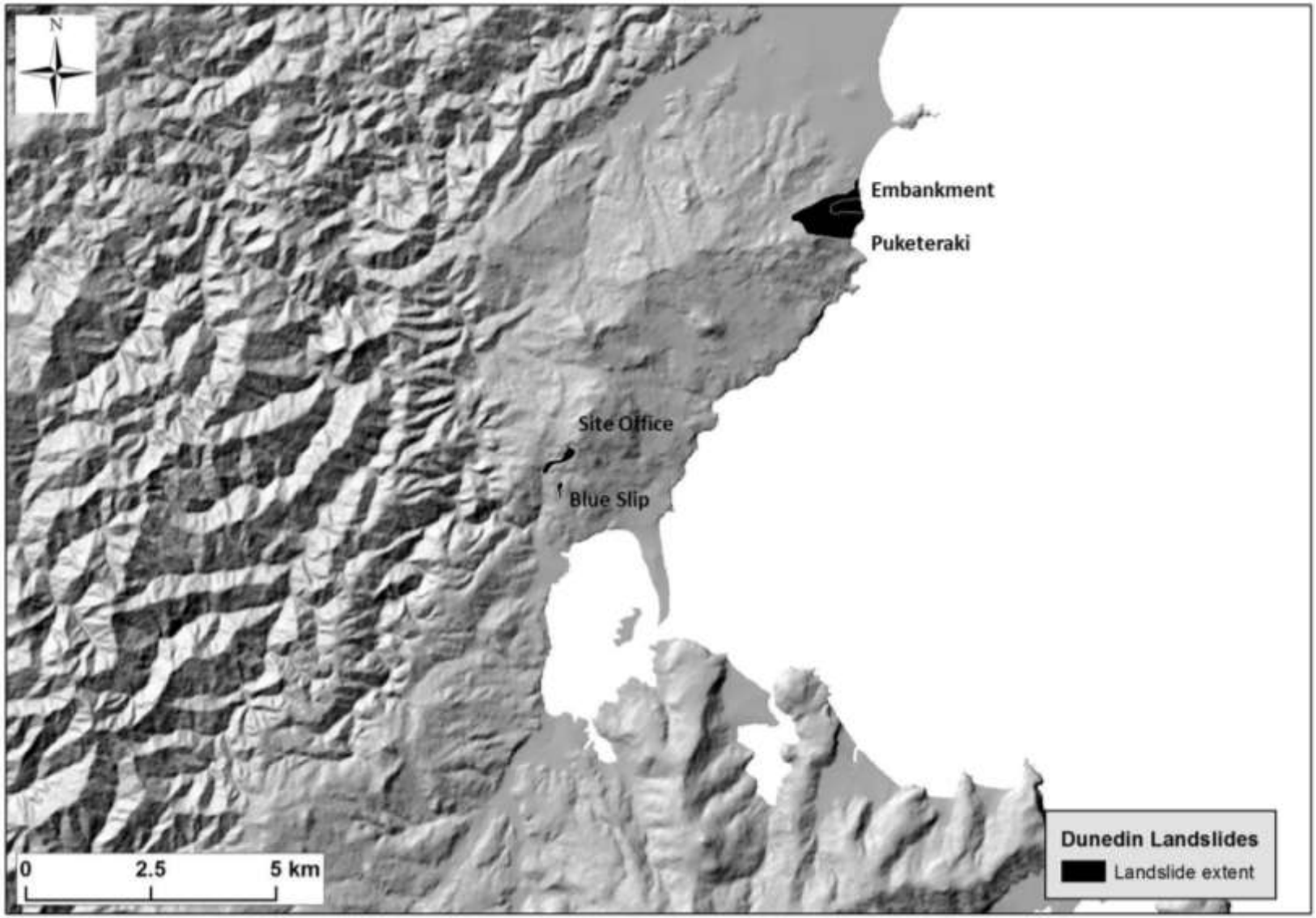


**Figure 2** **Map showing the location of high-importance landslides in the northern part of the Dunedin district**

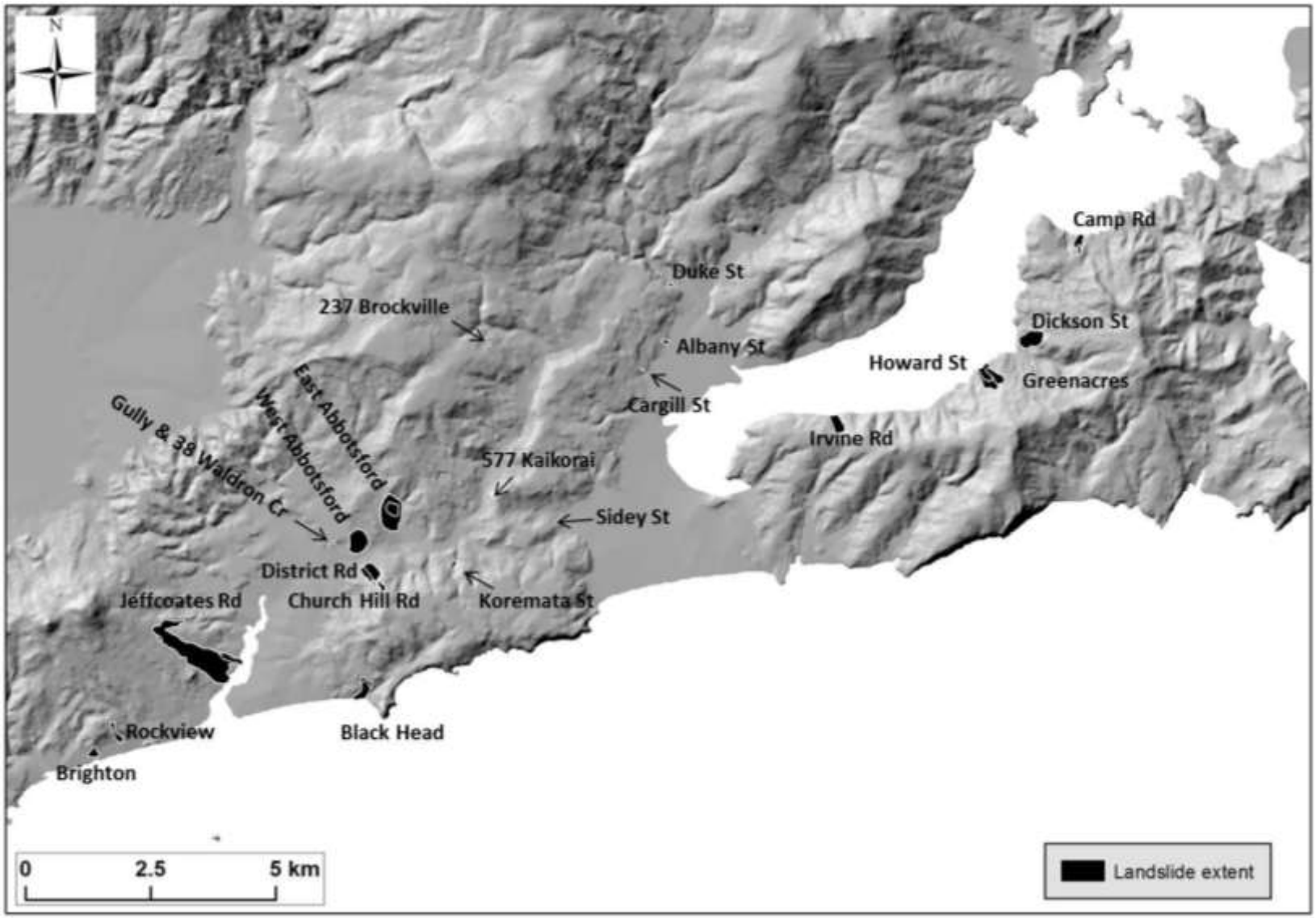


**Figure 3** **Map showing the location of the high-importance landslides in the southern part of the Dunedin district**

# 2. Active landslides

As described in Section 1.1, active landslides are those that have been shown to be moving at a rate of 10 mm/yr or more (based on recent surveys), and/or are considered to be particularly sensitive to changes in the environment. The location of these slides are shown in Figure 3A and 2B.

## 2.1. Brighton Slide

The Brighton Slide is a pre-existing regressive slump complex (Stevens *et al*., 2003). Parts of the landslide reactivated following heavy rains in 2008. The landslide involves part of an abandoned Holocene sea cliff (i.e. less than 6,500 years old), cut by wave action before the accumulation of the recent dune field along the coastline. The earliest known depiction of this landslide is on the geological map of McKellar (1990), from which its mapped extent has been adopted in this report. The upper extent of the landslip is defined morphologically due to the short pasture and lack of development across the slip. The movement is greatest in the upper slope of the landslide, with no confirmed movement lower down the slope near the row of houses next to Brighton Road.

MWH monitors the site for the DCC (1998−present). The eastern flank of the landslide has experienced the greatest movement, with 1250 mm of cumulative movement over that period. During the most recent survey period (2013−2015), up to 116 mm of horizontal movement was recorded, again with the greatest movement on the eastern edge of the landslide. Only the northern or upslope part of the mapped landslide feature indicated in Figure 5 has been shown to be active.

It is possible for smaller slips or mobile earthflows to slough off the face of the main landslide face, as occurred after heavy rains in 2008 (Figure 6) (Woods, 2008). Ongoing surveys indicate the landslide mass is still moving, and it has therefore been reclassified as ‘active’ in the database.


**Figure 4** **Brighton Slide. Brighton Road runs across the map parallel to the beach.**

**Figure 5** **Brighton Slide from the air, looking towards the west, 16 June 2015. The landslide mass in the center of the image is the active part of the slide.**

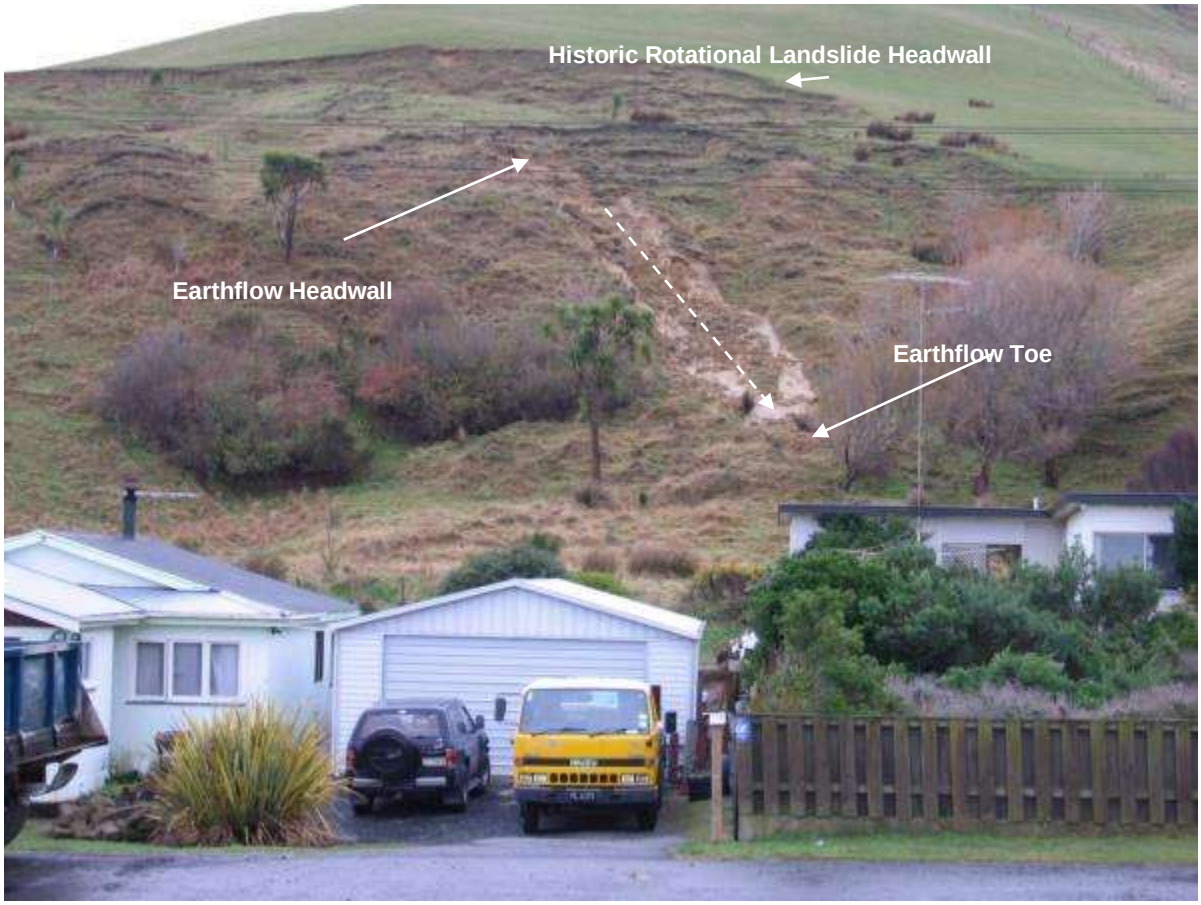


**Figure 6 Evidence of recent movement on the Brighton Slide, 13 August 2008**

## 2.2. Church Hill Road Slide and District Road Slide

The Church Hill Road Slide and District Road Slide are located on the southern slopes of Kaikorai Valley in Green Island. MWH has conducted repeated surveying for the DCC across both landslides since 1997.

The eastern half of the District Road Slide has urban development, while the western area consists of farmland. Surveying indicates parts of the District Road Slide have moved nearly 400 mm over the 17 year monitoring period (1997−2014). Recent surveys have detected an increase in horizontal movement rate (31−57 mm/yr), over the background rate (13−21 mm/yr). This is currently one of the more active monitored landslides in the Dunedin urban area.

The Church Hill Road Slide is upslope of the District Road Slide. Aerial photos indicate that the area was planted in a plantation forest until about 2009, and several structures were built on the site by 2011. The landslide database shows that the slide was active in 1977, although recent observations (summarised below) indicate that parts of the slide are still active. Surveying suggests that the total movement of the Church Hill Road Slide was up to 90 mm between 1997−2014, with 55 mm of this displacement occurring between 2011 and 2014.

Several other landslides have been mapped in the vicinity of the Church Hill Road and District Road Slides (Figure 7). Although these landslides are not thought to be currently active, they show that hillslopes in this area are prone to instability.

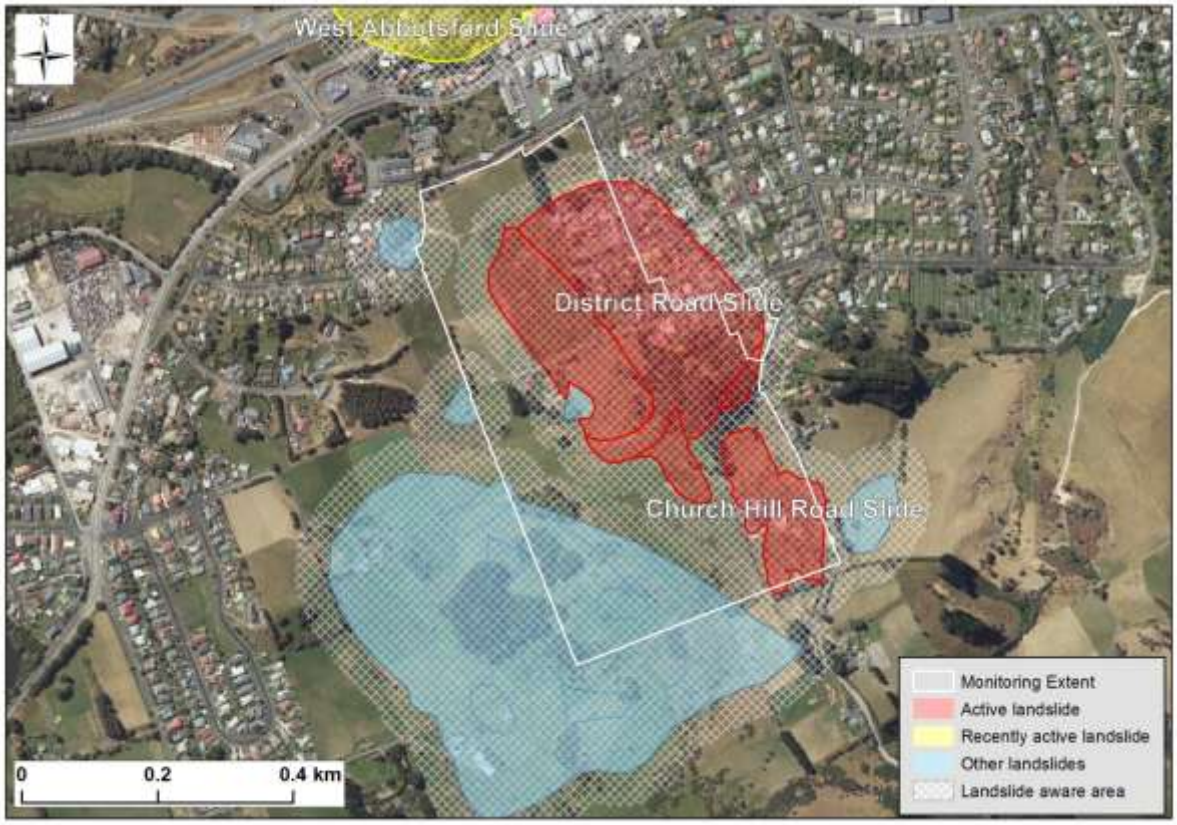


**Figure 7** **The District Road Slide and Church Hill Road Slide, and other nearby landslides**


**Figure 8** **Oblique view east along Kaikorai Valley and Green Island, showing the District Road Slide and Church Hill Road Slide on the southern slopes. Background image from McKellar (1990), original date unknown**

## 2.3. Dickson Street Slide

The Dickson St Slide is a large landslide on the northern slopes of Macandrew Bay. The lower parts of the slide have been developed into residential lots.

Geotechnical reports (Johnson, 1987; Barrell, 1994) have identified landslides on different parts of the slope (Figure 9). For the purposes of this report, the larger Dickson St Slide area (Johnson (1987), shaded red in Figure 9), has been classed as active on the basis of survey data described below. A reassessment of existing data and recent surveying results would help define what parts of the slope are currently moving.

MWH has monitored the slope for the DCC since 1997. Maximum vertical and horizontal displacements over that period are 90 mm and 100 mm, respectively. Horizontal and vertical movement have increased beyond low background levels since about 2010, currently averaging 30−40 mm/yr. Some of the survey markers that have been displaced are outside the mapped landslide area, indicating that the area of movement is more extensive than that currently mapped.

Surveying indicates that the slide is currently active, and it has therefore been reclassified as active within the landslide database. The survey network could be expanded and densified to identify the extent of movement across the slope.


**Figure 9** **The Dickson Street Slide. The internal area of the slide (black outline) was assessed by Barrell et al., 1994. The larger red outline is from Johnson, 1987.**

## 2.4. Greenacres St Earthflow

This feature appeared to reactivate after heavy rains in early June 2015, as is shown on Figure 11. The active area is about 200 m long, and 40 m wide, with two head scarps visible, both about 1 m high. The movement was contained within a previously mapped landslide termed the 'Greenacres Mass Movement Area' (Johnson, 1987) (Figure 10). A pine plantation now exists on the upper section of this wider feature, and this may have helped to stabilise part of the landslide.

The slide overlies Dunedin Volcanic Group strata, although the active portion of the slide appears to comprise earthflow-style movement in a northerly direction, possibly to a depth of several metres. The reactivated earthflow may be overriding a section of the larger inactive landslide.

The landslide database identifies this landslide as having a moderate sensitivity to environmental change. As such, it does not meet the criteria outlined in Section 1.1. However, it has been included in this report as the DCC monitors it occasionally for movement, and ORC observed evidence of recent movement in June 2015. Further assessment and monitoring is required to determine whether the larger landslide feature, or a smaller part of it, should be reclassified as 'active' in the landslide database.

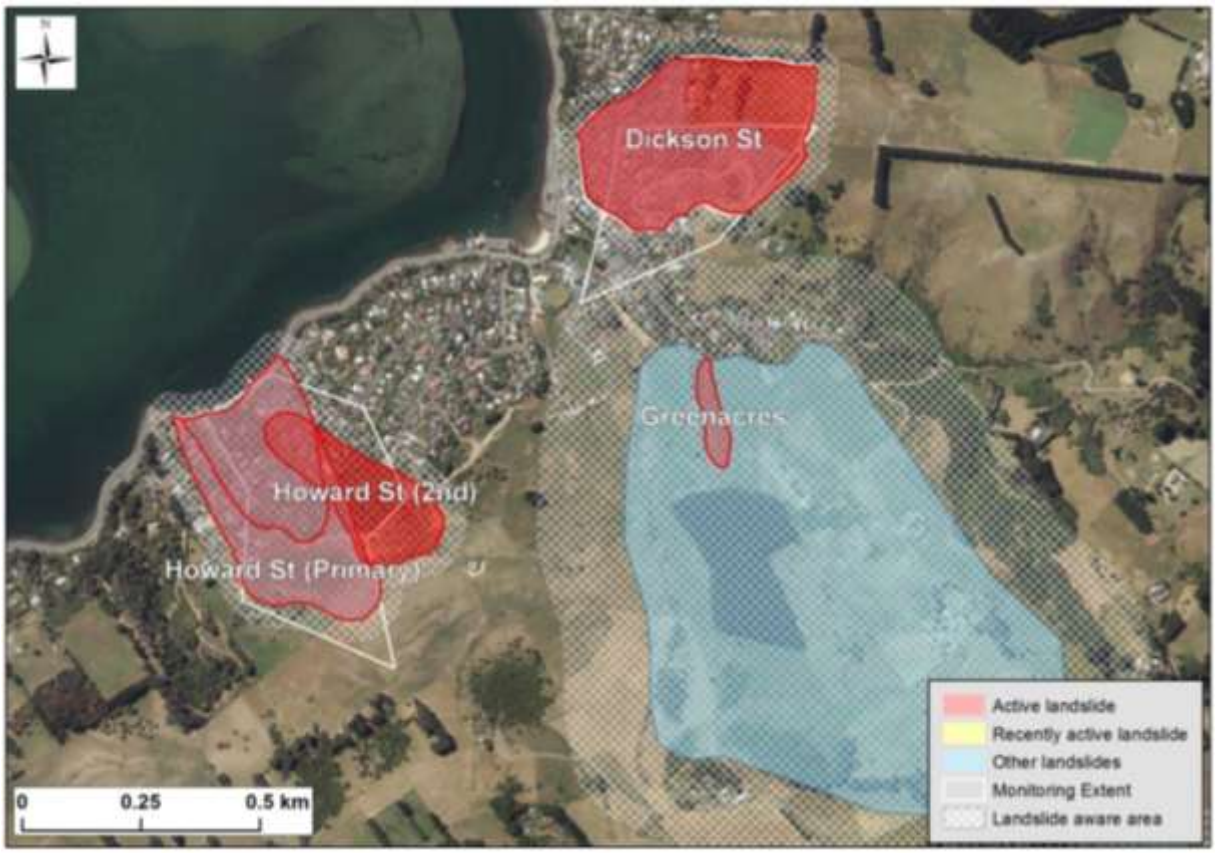


**Figure 10** **An active earthflow within the larger Greenacres Mass Movement Area (shaded blue). Signs of activity on the earthflow were observed in June 2015.**

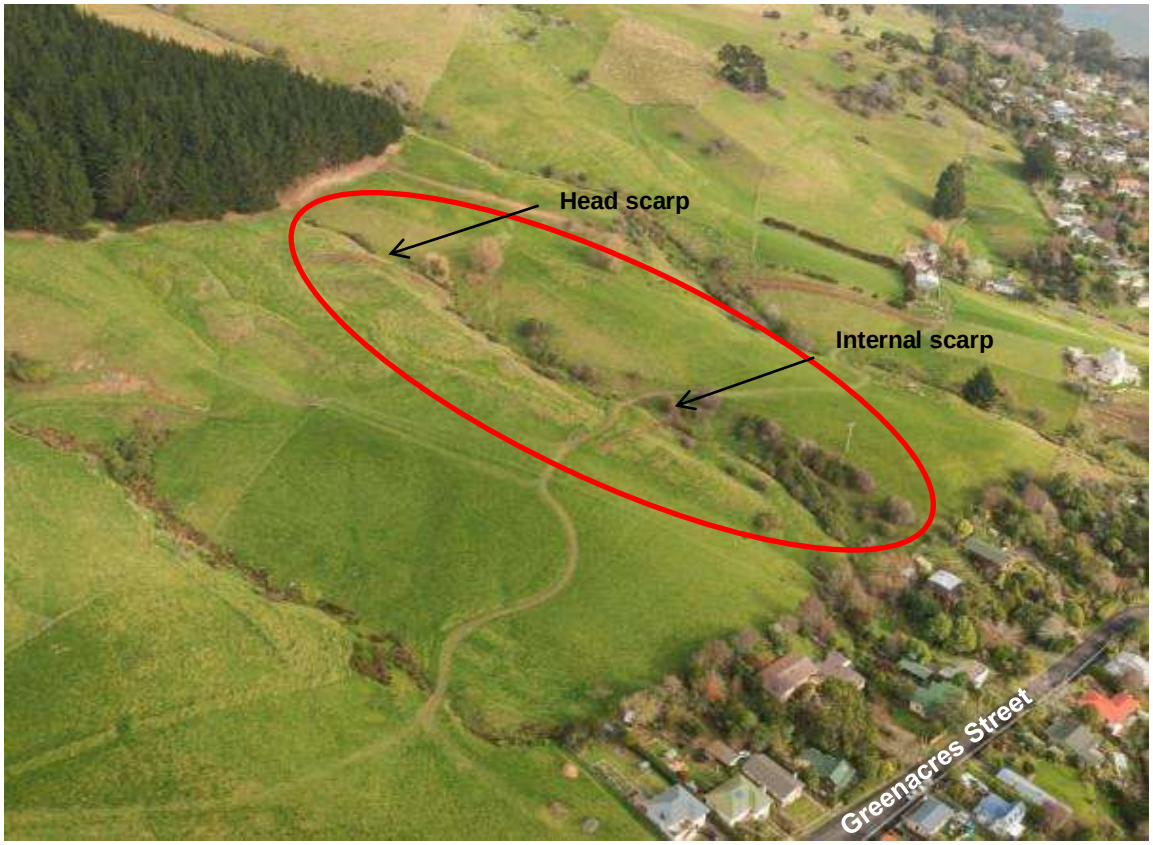


**Figure 11** **Aerial view of the slope above Greenacres St on 16 June 2015. The approximate extent of the most recent movement is circled in red. The view is to the southwest.**

## 2.5. Howard St Slide (primary and secondary)

The Howard Street Slide is located on the southern margin of Macandrew Bay. The slide comprises the larger Howard St Slide ('primary'), which is not currently classified as active or recently active. Geotechnical reports (e.g. Macfarlane, 1990; Glassey, 1995) describe the Howard Street Slide as a multiple rotational slump, with movement initiating in 1968. The secondary slide comprises a lobe of slow-moving debris in a topographic hollow that coalesces with the eastern margin of the primary slide. Recent reviews of movement and landslide interpretations are provided by Tonkin and Taylor (2013) and Glassey (2014).

The DCC has monitored the Howard Street area almost annually since 1998. The monitoring extent is shown in Figure 12. Maximum cumulative horizontal displacement over that period is 180 mm (most of which occurred during 2013). The upper portion of the slide above Howard Street is the most active area of the slide based on the survey data. Following the period of increased activity in 2013, monitoring up until February 2015 indicated that movement across both the primary and secondary areas of the landslide has decreased to background levels of < 30 mm/yr.


**Figure 12** **Howard Street landslides. The approximate location of surficial landslides observed in June 2015 are shown (pink circles), and the uppermost survey point is labelled 'A'.**

The uppermost survey point (marked as 'A' on Figure 12) has experienced the most vertical deformation of 130 mm between 1998 and 2015. The main body of the primary Howard St Slide was not designated as either active or recently active in the landslide database. However, surveying indicates that parts of the primary slide area are still active, and it has therefore been reclassified as such within the database.

Aerial observations of the Howard Street area did not reveal any significant movement on these mapped features after a heavy rainfall event on 3 June 2015. However, movement across much of the landslide may be difficult to detect due to the thick vegetation or residential development that covers much of the slides. Additionally, movement of the slide may be delayed due to complex groundwater behaviour, which takes some time to respond to rainfall events. Additional monitoring by the DCC will help to determine whether the rate of movement has increased as a result of this event.

The aerial inspection did reveal a number of surficial landslides on the slopes above and adjacent to the Howard Street slides, and these are shown in Figure 12 and Figure 13.

**Figure 13** **Aerial view of the slopes above the Howard Street slides on 16 June 2015. The approximate locations of the surficial slides shown in this photograph (red arrows) are shown in Figure 12.**

## 2.6. Jeffcoates Road Slide and Rockview Road Slide

The Jeffcoates Road Slide is a large earthflow on the southeast flank of Saddle Hill (Glassey, 1993). The underlying bedrock is Onekakara Group, and there is evidence of widespread modern and prehistoric instability on the southern slopes of Saddle Hill. The average gradient down the earthflow is 5°.

The landslide has distinctive hummocky terrain common to earthflow-style movement (Figure 15). Jeffcoates Road, which runs up the axis of the landslide, has reportedly been affected by movement in the past. There has been minimal residential development on the earthflow surface, and no dwellings appear to be affected by the present mapped extent of the slide. The last known episode of movement was 1994, although earthflows can creep slowly (<10 mm/yr), making movement difficult to detect without ongoing monitoring.

The Rockview Road Slide (named here), which was last active in 1980, is an elongate earthflow that shares similar characteristics to the Jeffcoates Road slide.

No evidence of large-scale surficial movement of these two landslides was observed during an aerial inspection in June 2015. However, some new surficial landslides were observed further upslope, as shown in Figure 16.

The justification for including these slides in category ‘a’ (‘active’), when there is no ongoing monitoring to confirm current movement, is the earthflow-style nature of these landslides. Earthflow features similar to the Jeffcoates Road Slide or the Rockview Road Slide can remain active for centuries, and commonly show periods of creeping activity interspersed with decades of dormancy. They are highly sensitive to changes in groundwater level.

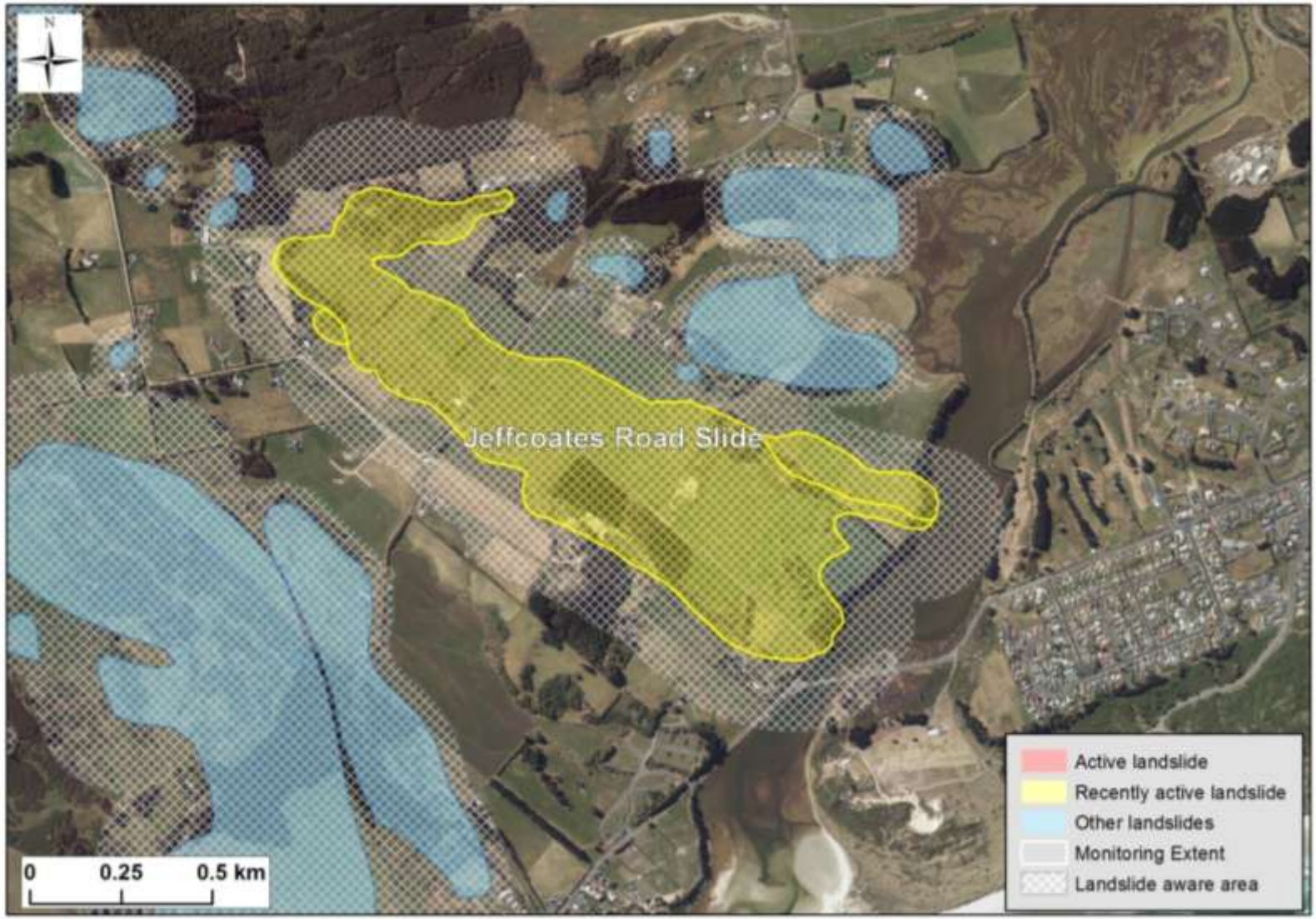


**Figure 14** **Jeffcoates Road Slide**

**Figure 15** **Aerial view of the upper part of the Jeffcoates Road earthflow, August 2014. Saddle Hill is the prominent peak on the skyline. Jeffcoates Road is on the lower left of the image.**

**Figure 16** **Surficial landslides on the southern flank of Saddle Hill, 16 June 2015**

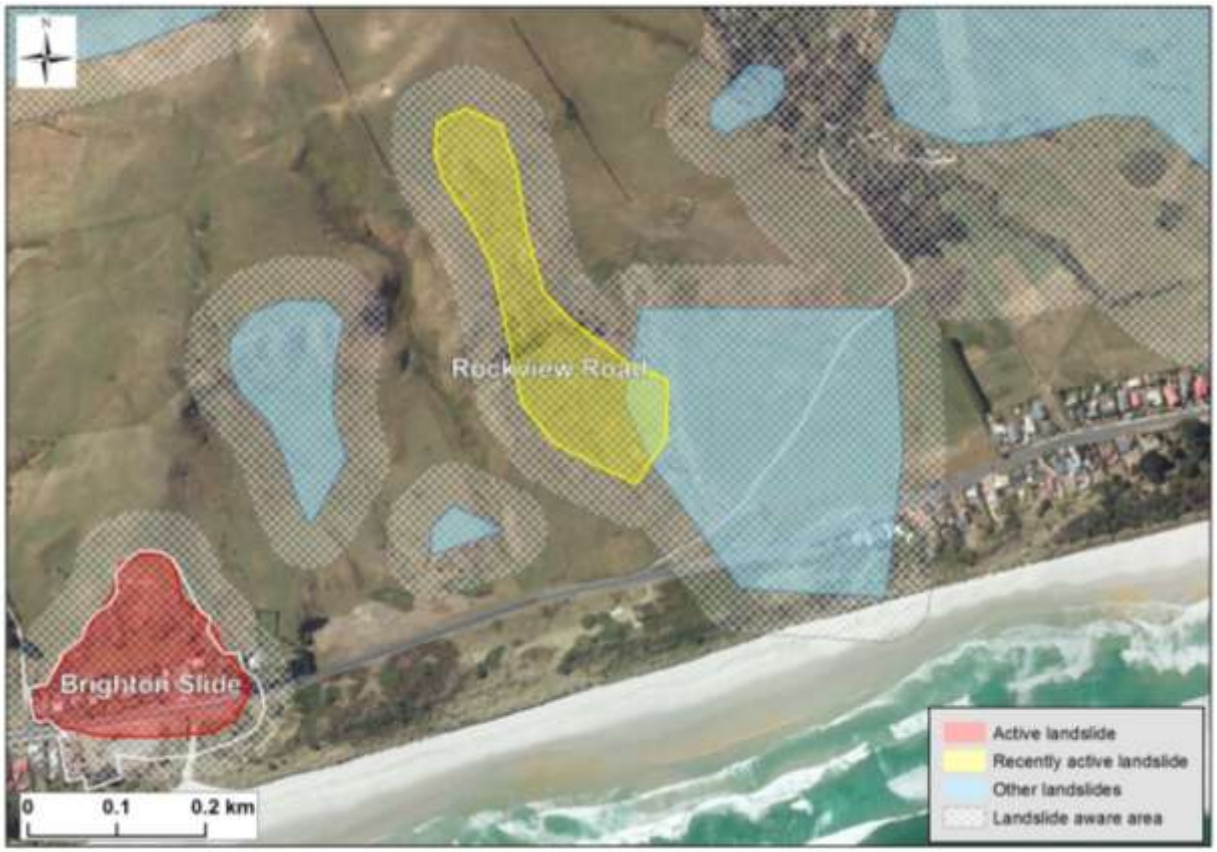


**Figure 17 Rockview Road Slide. The Brighton Slide is approximately 500 m to the west.**

## 2.7. Puketeraki Landslide (and Embankment earthflow)

The Puketeraki Landslide is a large movement on the northern Dunedin coast, near Karitane. The landslide crosses the South Island main trunk line and was studied intensively in the early 1990s (e.g. Glassey, 1994). The Embankment earthflow is a distinct feature within the larger Puketeraki landslide. The underlying geology is the Otakou Group, and the slide mass is assumed to be failing on a weak bedding plane, potentially associated with greensand layers (Glassey, 1994).

Most of the neighbouring slopes have evidence for prehistoric slope instability, indicating that this area is particularly susceptible to landsliding (Figure 18). Studies suggest continual wave erosion of the Puketeraki Landslide toe could be contributing to ongoing instability.

The DCC has surveyed the slide since 1992. Horizontal movement has recently averaged 230 mm/yr, with maximum horizontal displacement of 2,800 mm over the total survey period.

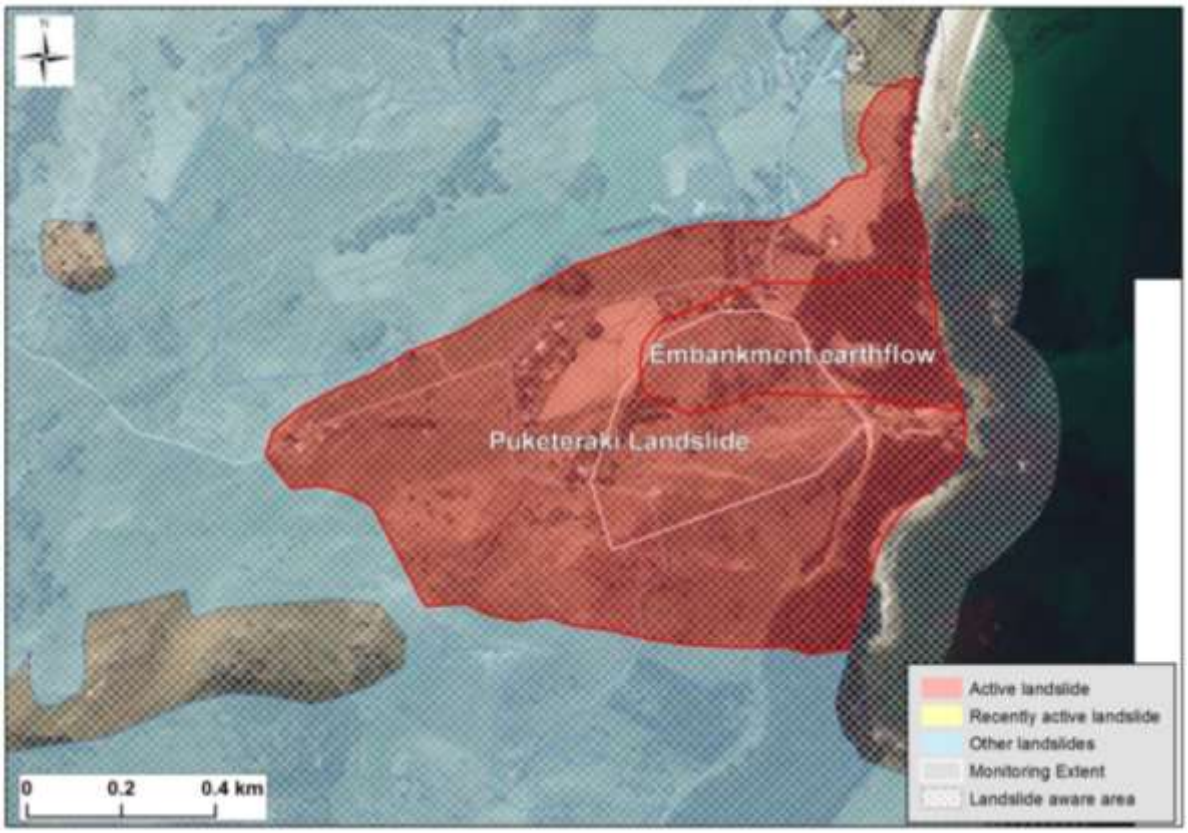


**Figure 18** **The Puketeraki landslide and Embankment earthflow. These active landslides are surrounded by landslides currently assessed as inactive.**

**Figure 19** **Aerial view towards the Puketeraki landslide from Karitane, following a period of heavy rainfall in August 2012. The red oval indicates the approximate location of the slide.**

# 3. Landslides with minimal recent activity

As described in Section 1.1, this group comprises landslides that have experienced historic movement, but ongoing monitoring or observation suggests that there is little or no current movement.

## 3.1. Albany St Slide

The Albany St Slide is mapped as a ~10,000 $m^2$ feature at the intersection of Albany and George streets near central Dunedin, and is located in an intensively developed urban area.

MWH monitors the site for the DCC for signs of ongoing movement. Monitoring has been conducted since 1987, although the current survey network was established in 2010. There was minimal movement detected in the most recent survey (2014), with about 10−12 mm total horizontal movement and 10−14 mm vertical settlement in the four-year survey period since 2010. The greatest amount of surveyed vertical displacement (14 mm between 2010−2014) occurs near the intersection of Albany and Queen Streets.

The Albany St Slide has been the focus of multiple engineering reports (Johnson, 1987; Glassey, 1991).


**Figure 20 Albany Street Slide**

## 3.2. Cargill St Slide

The Cargill St Slide is on the south side of Cargill Street at the intersection of Haddon Place. The slide has a mapped area of ~2000 $m^2$, and an average slope of 15°.

MWH has monitored the slide for the DCC since 2000. A series of pins along the southern margin of Cargill Street form a survey transect that is monitored for vertical and horizontal deformation. Most movement occurs between 74 and 84 Cargill Street, with up to 37 mm horizontal (downslope) and 42 mm of vertical lowering recorded over the 15-year monitoring period. There is little discernible movement during the recent survey intervals.

The Cargill St Slide was previously investigated by Macfarlane (1989).


**Figure 21 The Cargill St Slide**

## 3.3. 237 Brockville Road Landslide

The landslide at 237 Brockville Road was a pre-existing slump before residential development. The landslide experienced episodes of movement after heavy rains in 1968, 1977 and 1980 (MWH, 2015). The site has since been stabilised and drainage measures installed. According to the reports, periodic (currently decadal) visual monitoring by MWH for the DCC, most recently in 2015, has revealed no additional movement of the site.

The landslide database identifies this landslide as having a moderate sensitivity to environmental change. As such, it does not meet the criteria outlined in Section 1.1; however, it has been included in this report as it is still monitored for movement by MWH for the DCC.


**Figure 22 237 Brockville Road Landslide**

## 3.4. West Abbotsford Slide

The West Abbotsford Slide is a large deep-seated failure that extends across a large area of residential Abbotsford (Barrell, 1999). The outline of the landslide is clearly visible in LiDAR-derived digital topography (Figure 24). The southwest lower toe area of the larger slide complex (sometimes referred to as the 'motorway slide') is identified as recently active, and is traversed by the main South Island main trunk line and the Southern Motorway.


**Figure 23 The West Abbotsford Slide**

This slide is reported to have been reactivated during removal of toe support during construction of the motorway, and the last documented movement was in 1968. Sand was placed to re-buttress the toe during road construction, which inadvertently partly contributed to the failure of the East Abbotsford Slide in 1979, as the sand was sourced from the base of the East Abbotsford Slide hillslope (Hancox, 2008).

MWH monitor the slide for the DCC, with most recent monitoring in January 2014, by way of a visual inspection of features (cracks, fissures). Field observations were compared with previous surveys. No new evidence of movement was documented during this 2014 inspection.

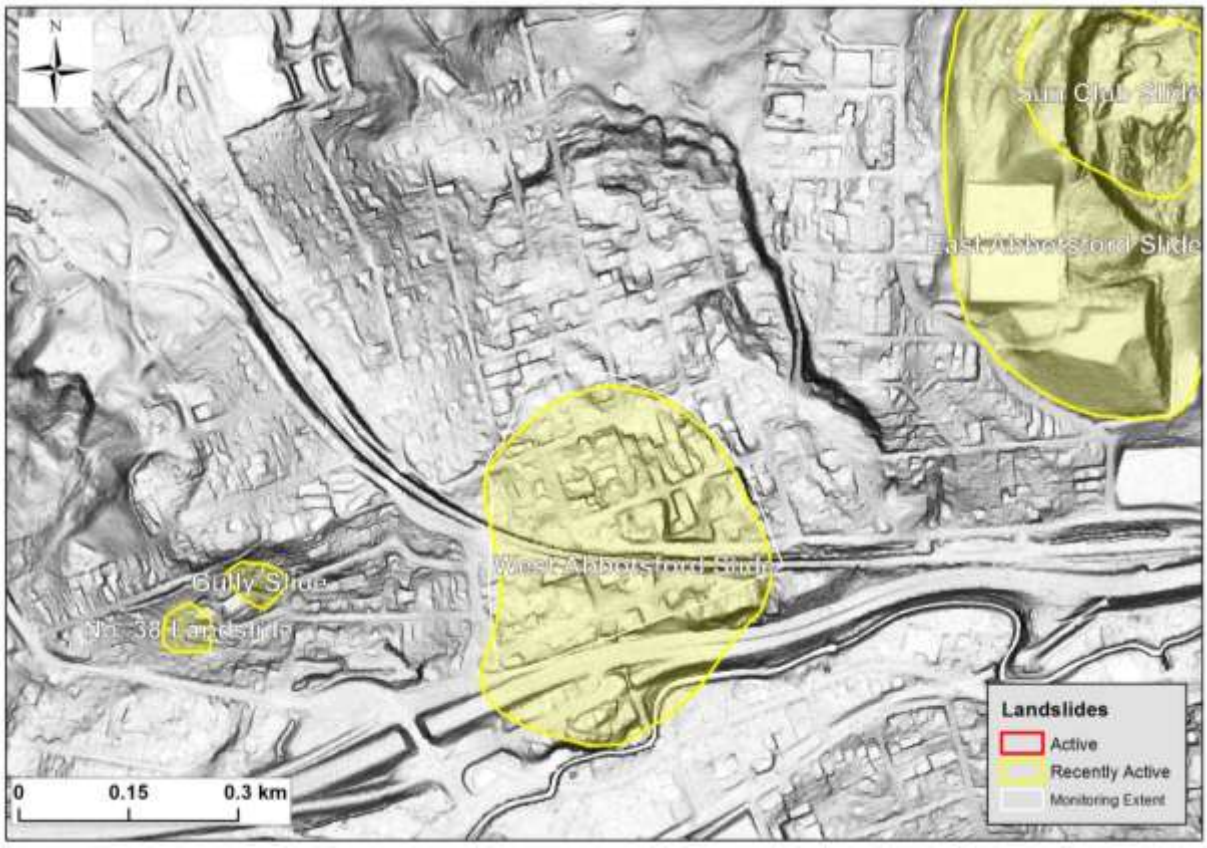


**Figure 24** **Lidar-derived slope map of the West Abbotsford Slide. The scarp of the larger inactive part of the landslide is clearly visible upslope. Mapped inactive slides omitted for clarity.**

## 3.5. East Abbotsford Slide and Sun Club Slide

The East Abbotsford Slide failed catastrophically in 1979 (e.g. Hancox, 2008), and remains the most damaging landslide in an urban New Zealand area. The East Abbotsford Slide incorporated the pre-existing smaller Sun Club Slide, which was rafted down the slope within the East Abbotsford Slide block.

The landslide surface has been re-contoured to form several sports playing fields. The landslide area has been re-zoned rural in the Dunedin City District Plan, although original streets and property boundaries remain on the plan. All residential dwellings that were on the landslide at the time of failure have been removed.

ORC investigated the creek next to the upper part of the landslide in June 2008 when a culvert intended to drain outflow from a pond on the upper part of the landslide became blocked, and piping occurred through the soil above the culvert. As Figure 26 shows, this resulted in a significant increase in pond level, damage to vegetation downstream and sedimentation of the channel (Woods, 2008b).

The East Abbotsford Slide is not part of the DCC's ongoing monitoring programme.

It is unknown whether this site may be deemed suitable for development in the future. Once landslides have failed catastrophically, as at East Abbotsford, they can attain a stable geometry, with minimal risk of further movement. Future development of the site should be approached very cautiously, however, if at all. Full geotechnical consideration would need to

be given to the risks of ongoing movement, land settlement, drainage and whether development of the site could increase the risk of future instability.

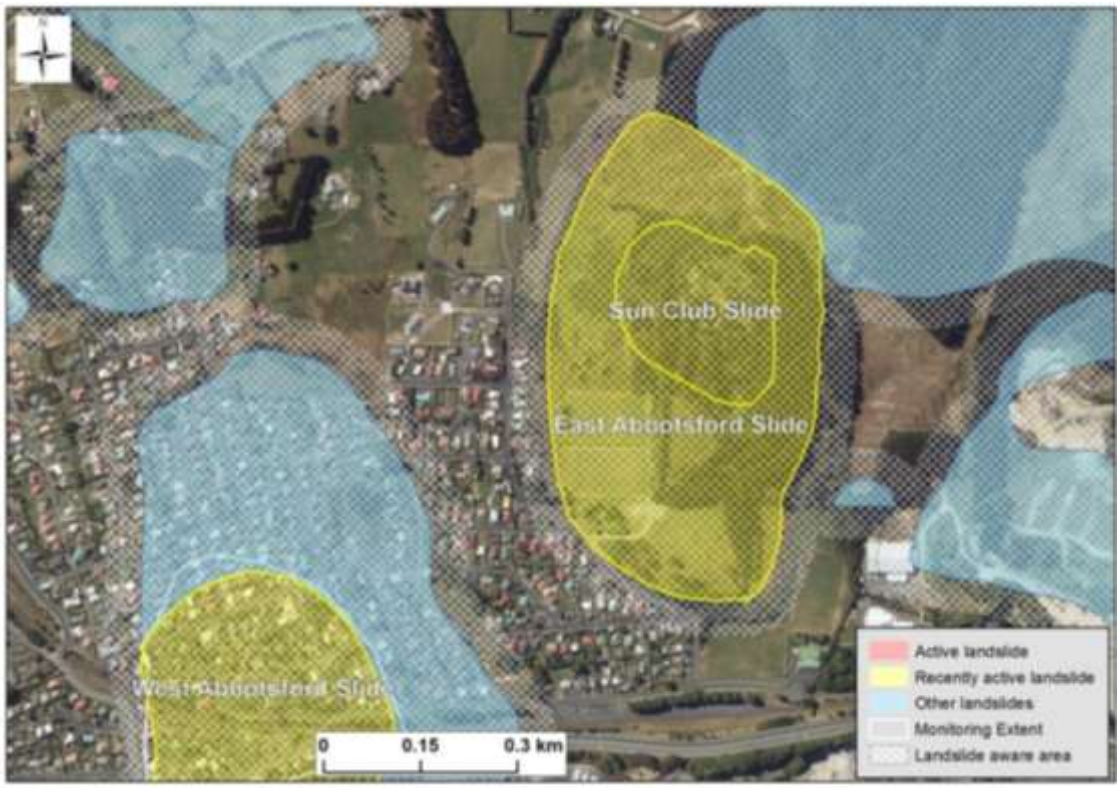


**Figure 25** **The East Abbotsford Slide and Sun Club Slide**

**Figure 26** **A view looking upstream showing the downstream limit of channel erosion in June 2008, caused in part by overlow of the pond. The pond is about 100 metres upstream from where this photograph was taken.**

## 3.6. Sidey Street Slide

A mapped landslide extent for this movement area has not been determined, and the feature was not included in the landslide database. Movement of up to 1 metre or so occurred in 1997. At its head, it displaced part of the Sidey Street carriageway and affected as many as three properties downslope. A deep-piled retaining structure was constructed across the slide at the NE margin of the Sidey Street roadway, and the road was repaired. Little, if any, movement has been noticed subsequently (D. Barrell, pers. comm., July 2015).

MWH has monitored the area since 1997, and a new survey network was installed in 2010. The monitoring extent is shown in Figure 27. The most recent survey (April 2014) indicates there has been no detectible vertical movement at the site since the survey network was reinstated in 2010.


**Figure 27** **Sidey Street Slide area, showing the extent of the monitoring conducted by the DCC**

# 4. Landslides with insufficient information

As described in Section 1.1, this group comprises landslides that have experienced historic movement (past 50 years), but for which there is insufficient information to determine if they are currently stable or moving.

## 4.1. Blue Slip and Site Office Slide

The Blue Slip cuts across State Highway (SH) 1 as it climbs north of Blueskin Bay (Figure 28). The underlying geology is the Onekakara Group strata (Abbotsford Formation). For many years, ongoing movement required frequent repairs to the road. Detailed investigations have been undertaken since the 1980s (e.g. McMillan and Reay, 1983) before extensive remedial work was done in the 1990s, which appears to have largely stemmed the movement (D. Barrell, pers. comm, July 2015).

The Site Office Slide is an elongate slide feature (Johnson, 1987). The lower section of the slide crosses SH1, just north of the Blue Slip.

There is no residential development on the slide mass, although a dwelling is located just back from the southern portion of the headscarp.

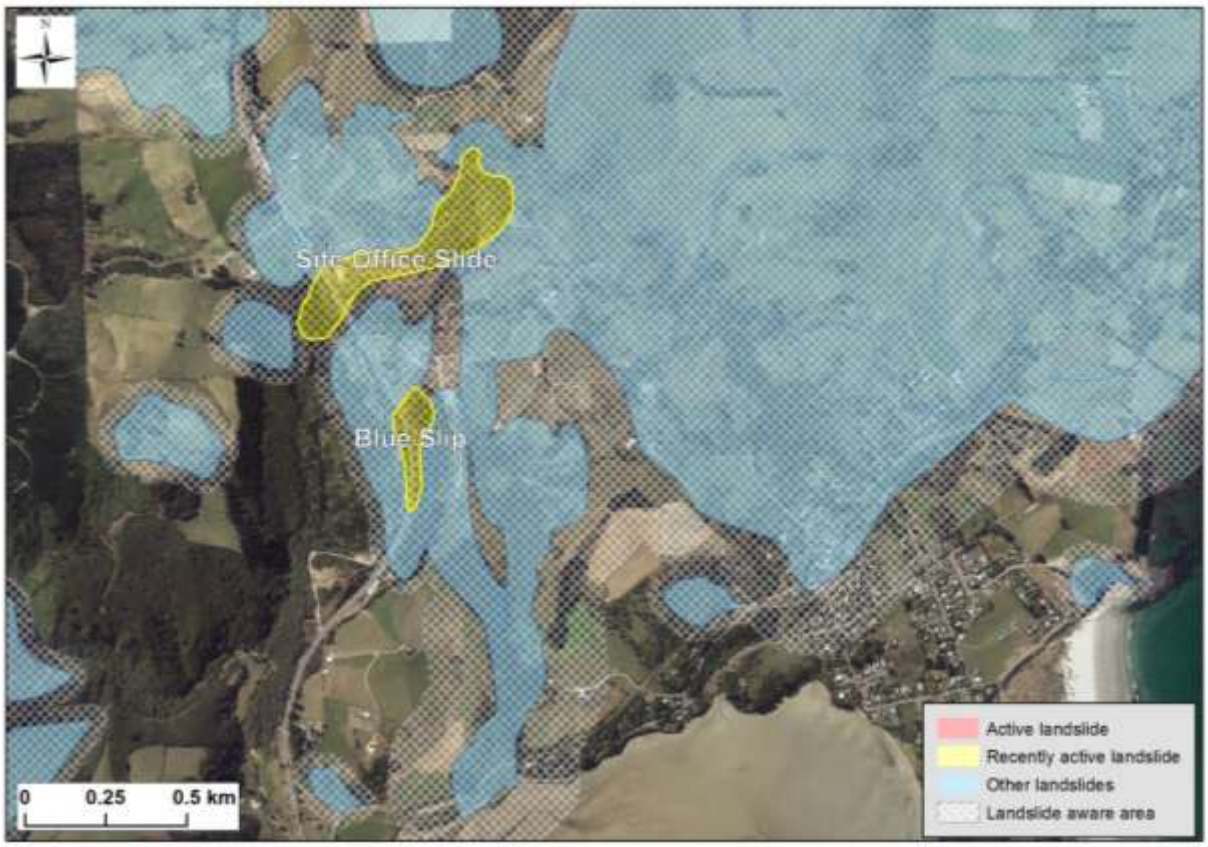


**Figure 28** **Blue Slip and Site Office Slide. SH1 can be seen traversing both landslides.**

## 4.2. Camp Road Slide

The Camp Road Slide is located on the southern side of Otago Harbour at Broad Bay. The toe of the slide extends across Portobello Road to the shoreline. Several structures are located on the left (western) margin of the lower body of the slide.

Movement was reportedly initiated in 1950, with the last known period of movement in 1986 (Johnson, 1986).


**Figure 29** **The Camp Road Slide (lower and upper), shaded yellow**

**Figure 30** **View of the Camp Road Slide towards the west. Portobello Road can be seen on the right (Google Street View).**

## 4.3. Duke St Slide

The Duke St Slide is located to the south of Duke and Malvern Streets, at the base of a steep basalt cliff within the Dunedin Volcanic Group. The toe of the slide area abuts alluvial fan deposits of the Leith River. The slide is within the 'Green Belt' and is some distance from any residential dwellings. A foot trail known as the Bullock Track, leading from Stonelaw Terrace to Duke Street cuts across the top of the landslide.

The landslide database indicates that the slide was last active in 1991 (Glassey, 1991). Following a heavy rainfall event on 3 June 2013, landslide activity was observed to the southeast of this mapped feature (Figure 32), suggesting that the wider area is still prone to shallow failure.


**Figure 31 The Duke St Slide**


**Figure 32** **Aerial view showing a cleanup underway to remove landslide debris at the base of the Bullock Track and on Duke Street. Source: DCC/Fulton Hogan**

## 4.4. Gully Slide and No. 38 Landslide

The Gully Slide and No. 38 Landslide are located in Waldron Crescent in the Sunnyvale suburb, west of Green Island. Barrell and Glassey (1993) found that the No. 38 Landslide was initiated during excavation of a building platform in 1993. The nearby Gully Slide was identified during assessment of the No. 38 Landslide. Both slides occur in clayey colluvium overlying Abbotsford Formation.


**Figure 33** **Gully Slide and No. 38 Landslide**

## 4.5. Irvine Road Landslide

The Irvine Road landslide is in a topographic hollow on the south side of the Otago Peninsula. It extends from the shore up to the crest of the slope. The last known movement was in 1979 (Turnbull, 1979).

There is extensive urban development across much of the mapped landslide area.


**Figure 34 Irvine Road Slide**

## 4.6. 577 Kaikorai Valley Road Slide

This landslide is mapped on the west-facing slope of Kaikorai Valley, near the intersection of Kaikorai Valley Road and Townleys Road. The landslide was originally mapped by McKellar (1990), and the last known movement was 1980 (landslide database).

The land is currently undeveloped (Figure 36).


**Figure 35** **The 577 Kaikorai Valley Road landslide**


**Figure 36** **View of the 577 Kaikorai Valley Road landslide from Kaikorai Valley Road (Google Street View)**

## 4.7. Koremata St Slide

The Koremata Street landslide in Green Island (Brickell Moss & Partners, 1981) was last reported active in 1980 (landslide database). It is on the eastern side of a small gully backing onto Koremata St, and appears to involve a section of slope having collapsed into the gully. There is evidence for pre-historic, deep-seated landsliding to the east of the mapped area.

The DCC does not currently monitor the landslide for movement, and no residential dwellings appear to be directly affected by the extent of the mapped movement as the land is currently undeveloped.


**Figure 37 The Koremata St Slide**

## 4.8. Black Head Slide

The Black Head Slide was depicted from aerial photo mapping in a 2001 compilation (Glassey, 2001). Although the terrain is largely obscured by sand dunes, the landslide became evident in the mid-1990s when slow earthflow movement displaced and deformed the Blackhead Road carriageway. A deep excavation was made, and the road was repaired, with little noticeable movement since. At the time, an exposure at the back of the active beach showed plastic greensand at the foot of the slide area, and it is likely that the movement was at least in part seated on Concord Greensand (D. Barrell, pers. comm., July 2015).

The mapped extent of the slide cuts across Blackhead Road, but is not in the vicinity of any dwellings.

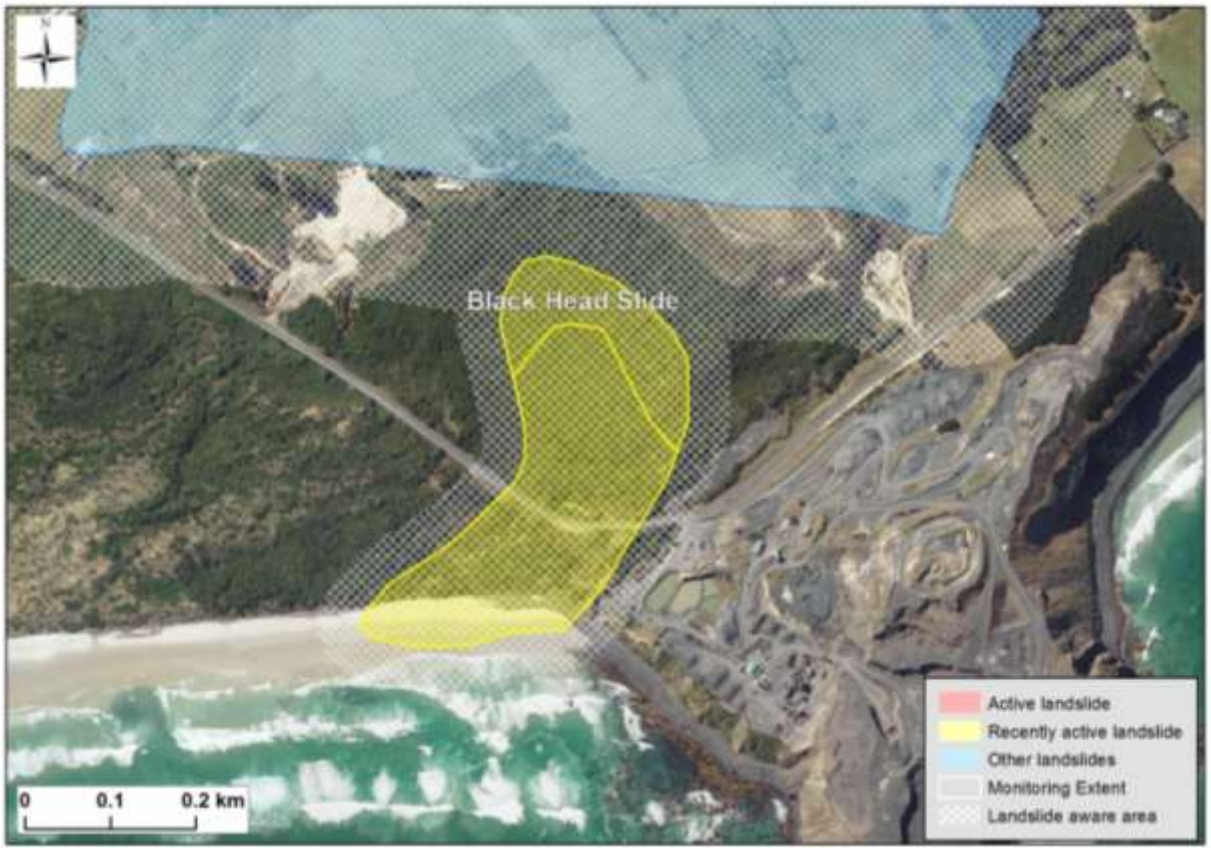


**Figure 38 Black Head Slide**

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NB: A * indicates the reference document was not located during this investigation

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