Detailed map of landslides in the Silverdale area, northern Auckland

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PURPOSE

This report provides Auckland Council with information on the locations of past landslide movements in northern Auckland. Accompanying geographic information system (GIS)-format datasets that identify landslide locations and the types/extents of ground-surface human modifications to the landslides have been supplied separately to Auckland Council, with the landslide GIS data (points and polygons) specifically structured for upload to the New Zealand Open Landslides Database. The report and ancillary data provide Auckland Council with a landslide information resource intended to assist future technical work and the delivery of information to current and future property owners and the general public.

EXECUTIVE SUMMARY

This report documents a map of landslide features within a 30 km by 40 km rectilinear footprint that encompasses the wider Silverdale area in northern Auckland. The landslide information reported here was compiled in conjunction with government-funded geological mapping datasets being produced by GNS Science (now a business unit of Earth Sciences New Zealand as of 1 July 2025). A contract with Auckland Council provided co-funding to aid creation of a digital detailed map of landform interpretations (geomorphology) with emphasis on landslide information. The detailed geomorphological map dataset provides an information base from which Earth Sciences New Zealand will produce generalised geological and geomorphological maps of the wider Silverdale area for publication. The contract helped support the mapping of the landslide component of the geomorphological dataset in a format compatible with the New Zealand Open Landslides Database (NZOLD) overseen by Auckland Council, the delivery of a report documenting the landslide dataset and the transfer of data to Auckland Council and upload to the NZOLD.

The Earth Sciences New Zealand Silverdale detailed landslide map dataset is in a GIS format and provided as polygons and points. The polygon component shows the extent of each landslide. An accompanying point provides information (attributes) for each of these landslides, including interpreted characteristics of the landslide movement.

The detailed geomorphological map, which includes the landslide polygons, is being compiled in a GIS on-screen by drawing expert interpretations over a high-resolution topographical basemap generated from lidar data (airborne laser scanning of the ground) collected in 2016. The mapping has an assigned resolution of 1:10,000 scale. The Earth Sciences New Zealand geomorphological map data structure differs from that of the NZOLD. Selected attribute information from the geomorphological dataset was translated into the NZOLD format and supplemented by information specific to the NZOLD. The project brief required attributes for six specific information categories (fields), noting that data could be added to other NZOLD fields where information was readily available and easily incorporated. As a result, most of the landslide features have attributes in up to 21 fields.

During the project, two amendments were made to the scope of work. The first enabled additional assessment of landslides within built-up areas and preparation of brief descriptions for specific landslides, including the evidence used in landslide recognition and interpretation. The second provided enhanced information on where landslides have had their diagnostic natural terrain modified, and to some extent obscured, by human actions such as earthworks. This information, conveyed via attributes in the landslide point and polygon datasets and as a separate ‘landslide modifications’ polygon dataset, is intended to better quantify the nature and extent of landslide modification.

The Silverdale detailed landslide map dataset is an inventory of landslides identified from evidence of land surface form (geomorphology). The dataset documents the locations and extents of previous landslide movements that have left diagnostic landform features in the landscape. In built-up areas, where possible, the dataset includes original landslide extents where these have subsequently been partially or completely obscured by land modification and development. The dataset does not imply anything about past, present or future land stability in relation to the mapped landslides.

In total, 7310 landslides have been mapped. The smaller landslides are dispersed throughout the map area, but there are concentrations of larger landslides in the north, west and east. Individual landslides range in size from as little as ~700 m^2 to as much as ~767,000 m^2. The Silverdale detailed landslide map dataset represents landslides as mapped, interpreted and provided to Auckland Council in late March 2025. The completion in coming years of the Silverdale geomorphological record map as part of the Earth Sciences New Zealand Urban Geological Mapping Project will include placing the landslide extents into context with other geomorphological and geological components of the mapping. This may result in some refinements to the landslide interpretations presented here.

1.0 Introduction

1.1 Overview

The New Zealand Institute for Earth Science Limited (Earth Sciences New Zealand)[1] has a government-funded project to compile new geological maps and geological data products for selected urban or urban-fringe areas of New Zealand (Urban Geological Mapping Project). One of the targets for urban geological mapping is the wider Silverdale area of northern Auckland within a specified map footprint (Figure 1.1).

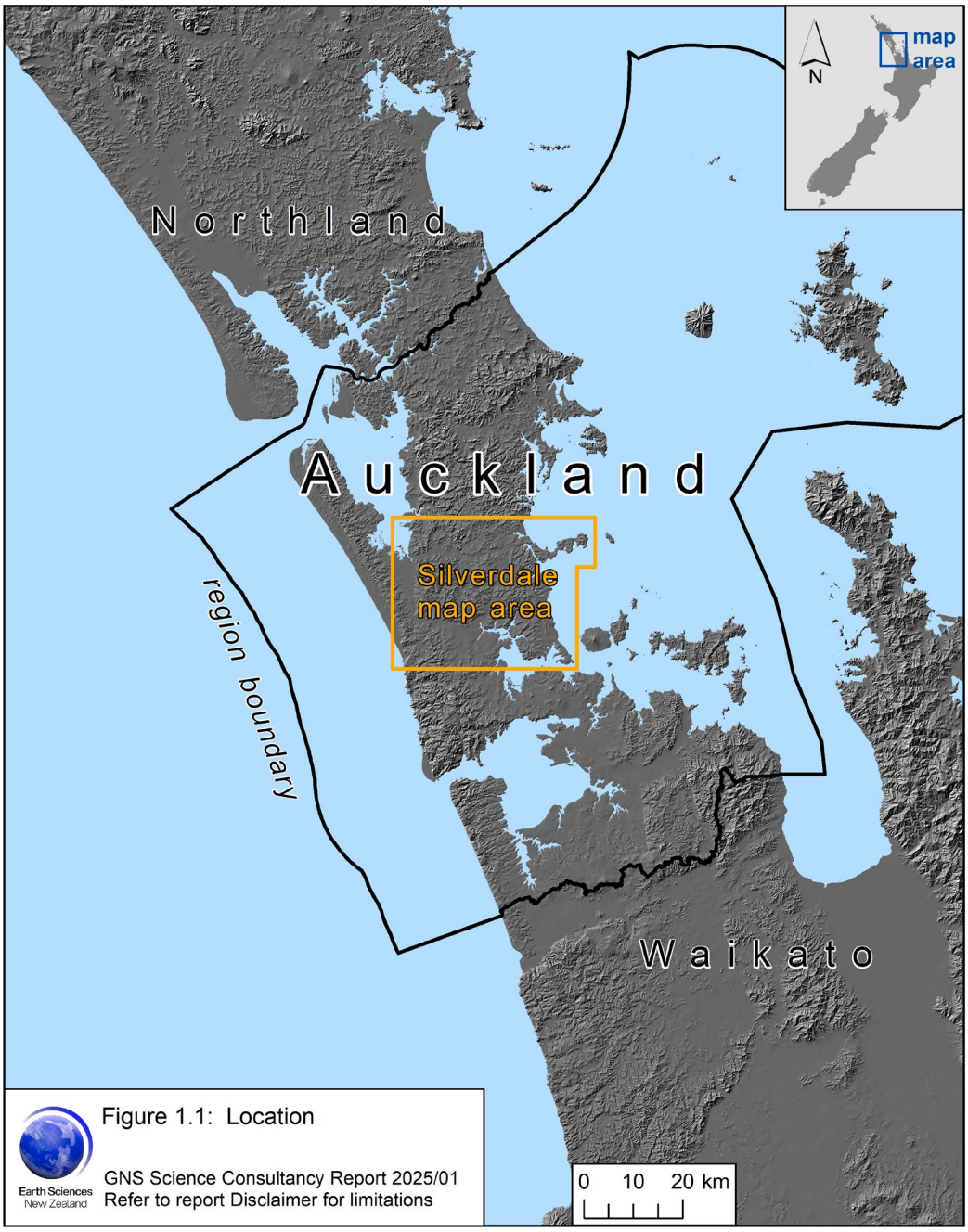

Figure 1.1 Location of the Silverdale map area.

1 GNS Science (Institute of Geological and Nuclear Sciences) merged with NIWA (National Institute of Water & Atmospheric Research) on 1 July 2025 to become Earth Sciences New Zealand.

Geological data products published so far for the Auckland region as part of the Earth Sciences New Zealand Urban Geological Mapping Project focus on the Pukekohe area and include a borehole database, 3D geological model, geological map and geomorphological map (respectively, Hill [2019], Jones et al. [2022], Bland et al. [2023a, 2023b] and Townsend et al. [in prep.]). Companion publications provide a stratigraphic framework for the naming of the geological units (Bland et al. 2020; Barrell et al. 2021). A geological map, geomorphological map and text are planned publications for the Silverdale area (Bland et al., in prep.). A detailed landslide map for the Pukekohe area, analogous to the dataset reported here, is documented by Townsend et al. (2024).

A key component of the methodology of compilation for the forthcoming Silverdale geological and geomorphological maps is to first make a detailed interpretative map of geomorphological features based on high-resolution topographic information from lidar data, which currently exists for the entire Silverdale map area, surveyed in 2016 and issued in 2018. This detailed geomorphological map, prepared at ~1:10,000 scale and including delineation of the extents of landslide terrain, is referred to in this report as a 'geomorphological record map'. The information from the Silverdale geomorphological record map will be used as the basis for drawing two simplified ('generalised') maps, one emphasising the geology and the other highlighting the geomorphology. The detailed landslide information from the geomorphological record map, which comprises the dataset described in this report, will be generalised for each of those map publications. The Silverdale geomorphological record map will be stored by Earth Sciences New Zealand as a digital archive but is not intended to be published.

By mid-2024, the geomorphological record map had been compiled across the southern and south-eastern parts of the Silverdale map area, encompassing about 25% of the onland part of the map. In discussion with Auckland Council, a project was developed to accelerate the production of detailed landslide information for the Silverdale area by providing funding to assist completing the compilation of the landslide component of the geomorphological record map. The work involved mapping the extents of landslide terrain as areas ('polygons'); creating an accompanying point-location dataset ('points') that includes descriptive information ('attributes') aligned with the requirements of the New Zealand Open Landslides Database (NZOLD), overseen by Auckland Council; and uploading of the new landslide dataset to the NZOLD. This report describes the work that was done and documents the information within the Earth Sciences New Zealand Silverdale detailed landslide map dataset (henceforth, 'Silverdale detailed landslide map').

1.2 Work Programme and Deliverables

The following work components are set out in the project brief:

- Completing the compilation of geomorphological record map landslide polygons of the Silverdale geomorphological map area, including data attribution, peer review and quality assurance.
- Extraction of the landslide component from the Silverdale geomorphological dataset and making the landslide data compatible with the NZOLD data structure.
- Delivery of a report on the landslides (this report), including documentation of the Silverdale detailed landslide map digital data, data transfer to Auckland Council and upload to the NZOLD.

Two scope-of-work amendments were made during the project via contract variations. The first related to enhanced assessment and documentation of landslides within built-up areas. The second related to provision of additional information for places where human actions, such as undertaking earthworks, have modified the original landslide terrain.

1.3 Methodology

The geomorphological record map is being compiled using the ArcGIS geographic information system (GIS) by on-screen mapping over topographical basemaps through expert interpretation of landforms. The main resource of topographical information is a high-resolution lidar dataset generated from airborne laser scanning of the ground. The main lidar dataset used for the Silverdale map area was issued in 2018 and made available on a Creative Commons basis by Land Information New Zealand. That dataset was surveyed in 2016 (referred to here as the '2016 lidar') and supplements two previous lidar surveys from ten and three years earlier (2006 lidar, 2013 lidar). In some instances, brief inspection was made of aerial imagery available via the ArcGIS basemap service, particularly the Auckland Region 2017 orthophoto mosaic.

For this Silverdale detailed landslide map project, the new mapping of landslides was done by a subset of the authors of this report (DBT, KJB, KEJ and JML), with each mapper assigned a specific sector of the map area within which they identified and delineated landslides. The overall mapping was overseen and given quality-assurance refinement by DBT. Final review of the mapping was provided by DJAB, and GIS work, including generation of the point dataset, was carried out by LHEC. The report was drafted by DJAB and DBT, with contributions from other co-authors.

As the work progressed, the mappers found evidence for numerous landslides in areas that already have intensive urban development or are in the late stages of development ('built-up areas'). Such areas have almost invariably undergone considerable modification of the ground as part of residential, industrial or commercial development, hindering the assessment of original ground conditions. The scope of work was expanded to improve the resolution and confidence of the landslide dataset in built-up areas via additional desktop assessment of historical aerial photography, especially that which pre-dates the development. The expanded scope includes the preparation of brief descriptions of the evidence used to identify and interpret specific mapped landslides where these underlie approximately 10 or more residential properties, or commercial or industrial precincts, or other major public infrastructure (see Appendix 2).

Outside of the built-up areas, many landslides in the Silverdale mapping area have experienced some modification of the original terrain by human activity. The changes range from very minor, such as the cutting of a farm track across a slope, through to larger-scale earthworks for buildings or other infrastructure. Where modification was noted by the landslide mapper, the landslide data collection included the addition of the qualitative term 'modified' or 'completely modified' to the descriptive comment fields of landslide digital point and polygon datasets. The addition of a modification descriptor, although not part of the contractually required landslide data, was intended as a useful highlighter that a landslide's natural terrain is now obscured to some extent. The noting of modification was not done in a structured or consistent way across the overall map area. While about 700 individual landslides were identified as having some degree of modification, these represent only a subset of many other modified landslides within the map area. In an April 2025 review of an interim draft of this report, Auckland Council identified a desirability of generating more information on landslide modifications. The additional information is intended to better quantify the nature and extent of landslide modification.

A modification methodology was developed in discussion between Auckland Council and Earth Sciences New Zealand. The additional work addresses only the ~700 landslides originally identified in the landslide datasets as having some modification. An overlay polygon dataset (landslide modifications) has been generated to show the extent of modified areas on individual landslides. Although the landslide mapping was done primarily with 2016 lidar, it was agreed to make the modification dataset for the ~700 landslides as up to date as possible, based on the recently released 2024 lidar. The scope of work excluded any mapping from the 2024 lidar of previously unidentified landslides. Also outside of scope for inclusion in the modification dataset are any landslides that were not tagged in the April 2025 draft GIS datasets as having some degree of modification.

Modification overlay polygons are limited to the extent of the mapped landslide (i.e. ground modification that is not on a landslide was not mapped). There is a minimum size threshold of 1000 m^2 for the mapping of a modification polygon to ensure that the dataset resolution accords with the nominal 1:10,000 scale of the landslide polygon map dataset. Landslides identified as modified, but with modification areas below the minimum size, are identified as 'slightly modified ground'. Those landslides do not have modification polygon(s) mapped, but the modification types are listed in the landslide datasets.

The landslide mapping documented here was undertaken in the Earth Sciences New Zealand geomorphological map data structure and then exported to the NZOLD data structure. As the rest of the Silverdale geomorphological record map is compiled as part of future work in the Earth Sciences New Zealand Urban Geological Mapping Project, the landslide extents will be reviewed and, as needed, refined as these are placed into context with other geomorphological components of the map. This may result in some refinements to the landslide interpretations presented here. The Auckland Council landslide dataset for Silverdale described in this report represents the late 2024 version of the landslide interpretations, based mainly on 2016 lidar, with review and refinement in early 2025. Landslides in this dataset are identified as 'GNS Silverdale 2025'. Any future updated Silverdale landslide dataset will be appropriately versioned and consideration given to the best way to accommodate it within the NZOLD or other relevant databases.

2.0 Datasets and Characteristics

The Earth Sciences New Zealand geomorphological map data structure uses an ArcGIS platform and attaches all of the landslide descriptive information as attributes to each polygon. The NZOLD takes a slightly different approach, whereby each landslide is primarily represented by a data point at about the source area of each landslide. The data point contains the attribute information for the landslide and is linked to other geographic features, such as landslide polygons, by a Globally Unique Identifier (GUID) value.

The Silverdale detailed landslide map was made compatible with the NZOLD by supplementing polygons from the source dataset with point data (Table 2.1). The point dataset provides each landslide with attribute information on interpreted characteristics of the landslide movement. Points for each landslide are placed at approximately the centroid of the associated vacated source or landslide area polygon (see below). The accompanying polygon dataset shows the extent of each area interpreted to have been involved in landslide movement.

Table 2.1 Key components of the Silverdale detailed landslide map dataset. The third column indicates the link to the geomorphologic feature type in the Earth Sciences New Zealand geomorphological record map dataset. Italicised text indicates the attribute fields within the two datasets, and terms in inverted commas denote the equivalent attributes.

Data Geometry	This Dataset	Earth Sciences New Zealand Geomorphological Map Dataset
Point	Centroid of 'Source area' or 'Landslide area' polygon	Not part of the Earth Sciences New Zealand geomorphological map dataset structure
Polygon	• *landslide_polygon_type* - 'Source area' - 'Debris area' - 'Landslide area'	• *GeomorphologicFeatureType* - 'Landslide vacated' - 'Landslide terrain' - 'Landslide terrain inferred' or 'landslide area' (without differentiated source and debris areas) or 'landslide terrain' (mapped as debris only). Note that landslides in built-up areas that are 'completely modified' – i.e. no surface feature remains in the landscape – will not be shown in the Earth Sciences New Zealand geomorphological map dataset.

2.1 Landslide Polygon Dataset

The locations of landslides in the Silverdale detailed landslide map are shown in the context of the Silverdale map area at 1:125,000 scale in Figure 2.1, while Figure 2.2 gives a representative close-up illustration of the mapped landslides on the western side of the Orewa population centre at 1:10,000 scale.

The Silverdale geomorphological record map on which the detailed landslide map is based has a data structure developed for the Earth Sciences New Zealand Urban Geological Mapping Project, as will be outlined by Bland et al. (in prep.). For many of the landslides, the geomorphological record map and detailed landslide map differentiate the vacated part of the source area (from which some, or all, of the displaced material was removed during landslide movement) and the debris area (where the displaced material resides and/or has accumulated).[2] Together, these components represent an area affected by landslide movement. The vacated area commonly represents only part of the source, as debris typically rests on mid- to lower parts of the source area. The lidar-based methodology allows delineation of only the vacated part of the source area.

2 'Debris' as used here refers to any material displaced by landslide movement; it includes material that has been translated largely intact through to material that has been highly disrupted and fragmented during movement.

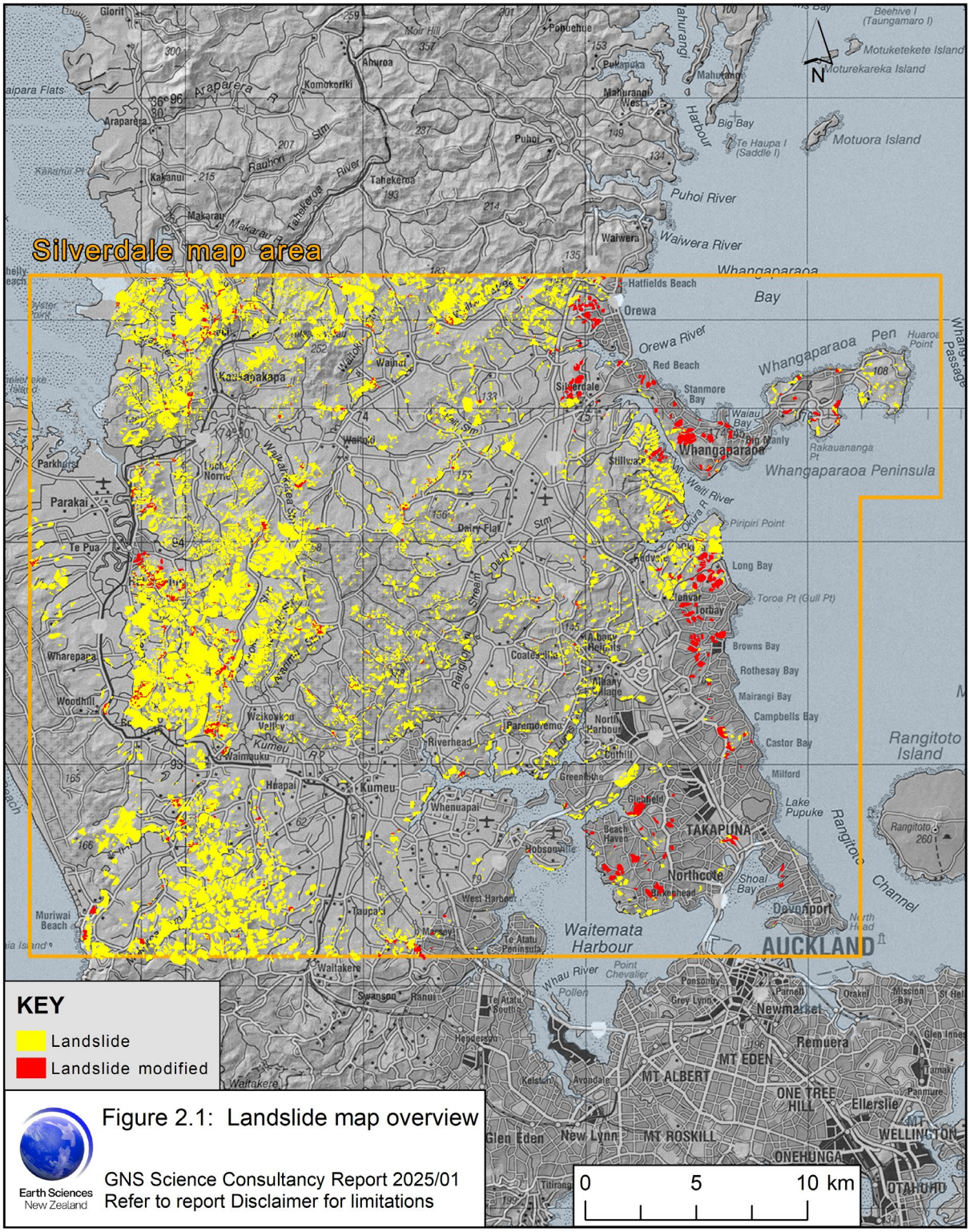

Figure 2.1 Landslide map overview, showing just the landslide polygon dataset, with red denoting landslide-modification polygons that have been mapped for landslides with modified terrain. Smaller landslides are dispersed throughout the map area. Larger landslides are concentrated in a N–S-oriented belt in the west between Kaukapakapa and Muriwai Beach, in the north between Kaukapakapa and Orewa, and in the east between Silverdale and Browns Bay.

Where differentiation of landslide source and deposit has not been made, a single polygon called 'landslide area' has been mapped. 'Landslide area' polygons are of two types, identified in the *landslide_polygon_description* field of the polygon dataset. One type comprises polygons that encompass both source and debris areas. Reasons for non-differentiation include displacement not having been

sufficient to delineate an exposed source area at the 1:10,000 scale of mapping or where satisfactory interpretation could not be made of the relative extents of the source and debris area. The other type is where a source area could not be satisfactorily identified and the polygon encompasses only a debris area characterised by hummocky ground. It thus denotes a minimum extent of that landslide.

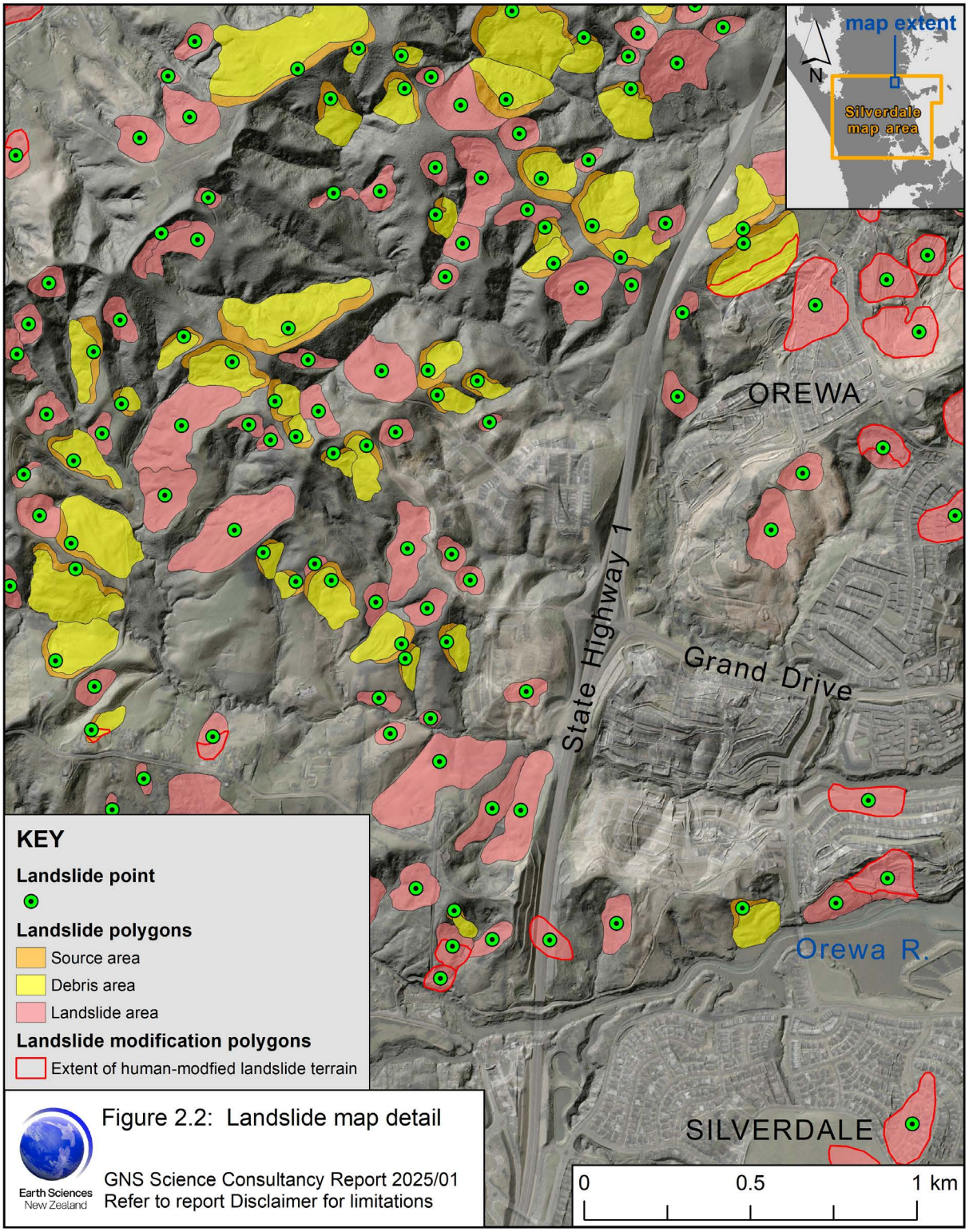

Figure 2.2 Landslide map detail: a sample illustration of the Silverdale detailed landslide map (points and polygons) in the Orewa area (see Figure 2.1). For many landslides, the polygons distinguish the source (vacated) area from the debris area. The remainder are represented by a single landslide area polygon (see text). The background comprises a lidar digital elevation model draped transparently over vertical imagery from the ArcGIS basemap service.

2.2 Landslide Point Dataset

A point dataset was produced for this project to match the NZOLD approach. The NZOLD specifies that the point representing each landslide be positioned in the centre of the zone of depletion of the landslide. The zone of depletion is where there has been net volume loss of ground-forming material downslope due to the movement. Conceptually, it is partnered by a down-slope zone of accumulation where there was net gain of ground-forming material. Determining the centroid of the depleted zone would necessitate topographic-geometric profiling of each landslide. This is difficult to use for prehistoric landslides, which comprise most of the features mapped in this dataset, due to a lack of direct information on the configuration of the slope prior to movement. In contrast, for historically observed landslides, there may be topographical information pre-dating a slope movement. For simplicity and consistency in the dataset described here, a point was generated at the geometric centre (centroid) of each source area polygon or, for undifferentiated landslide areas, the centroid of each landslide area polygon.[3] Pending the upload of the Silverdale detailed landslide map dataset to the NZOLD, a GUID ('gns_GUID') has been created to link each associated entity of the polygon and point components of the dataset.

Due to the pre-established rectilinear shape of the Silverdale map area, some landslides are bisected by the map boundary. In the Pukekohe detailed landslide map dataset, polygons representing truncated landslides within the map area were removed from the dataset, and only a representative point indicating the location and characteristics of that landslide was included (see Townsend et al. [2024]). The Silverdale detailed landslide map used a different approach; the full extent of a landslide crossing the map boundary was delineated, extending it beyond the map-area footprint. Some landslide point locations therefore may lie outside the Silverdale map area. The different approach reflects that the Silverdale work was new mapping, readily allowing capture of the full extent of a landslide, compared to the Pukekohe detailed landslide map that was extracted from an existing map dataset.

2.3 Landslide Characteristics

The NZOLD has many attribute fields, as set out in its operational manual.[4] A subset of these fields, suitable for use in desktop geomorphological mapping work, has been used in the Silverdale detailed landslide map point dataset and populated with attributes as per the manual (Table 2.2).

The field attributes assigned in this dataset were either adapted from the geomorphological record map dataset or generated for the Silverdale detailed landslide map dataset via expert interpretation, or other information, as noted in the digital dataset and Table 2.2. Rather than manual assignment of an *Aspect* attribute for each landslide point location, we used a digital slope map to calculate the azimuthal direction towards which the slope faces ('aspect'). The project brief only required the populating of six specific fields with attributes but acknowledged that entries may be made in any other NZOLD fields where suitable information was readily available (Table 2.2). As a result, for most landslides documented in this dataset, attributes were entered in 21 fields.

A generalised GIS map of land cover (Figure 2.3) was drawn for this project to provide a basis for assigning location accuracy. The default location accuracy in open country is <10 m. A lesser location accuracy (<100 m) has been assigned to landslides in areas where the ground surface is obscured by >50% by area forest cover (forested hill country) or urban-development landscaping/earthworks (built-up areas). The built-up areas shown on this map are where the enhanced landslide assessment and documentation were undertaken (Section 1.2).

3 In relation to geographic information systems, the centroid refers to the geometric centre, or average location, of a spatial feature. In the case of an irregularly shaped polygon, its representative centroid point may lie outside of the polygon; numerous instances of this occur in this dataset.

4 https://landslides.nz/nz-landslides-database-manual/; accessed October 2024.

Table 2.2 Data fields and attributes compatible with the New Zealand Open Landslides Database for the Silverdale detailed landslide map point dataset. Where a field has a restricted list of attributes, we include the list as specified at the time of report preparation. The six fields required to be populated with attributes are shaded. There is further information in Appendix 1.

Field Name (Field Identifier Code)	**Attribute Type**	**Comment**
Identifier (*gns_GUID*)	GUID (Globally Unique Identifier)	Provisional identifier (*gns_GUID*) links the data point and associated polygons for each landslide. It does not have connections with any other dataset.
Landslide name (*crf02_landslide_name*)	Text	A common identifying attribute used for every data point in 'GNS Silverdale 2025'
Has the landslide been active in the last 1000 years? (*crf02_activityrecent*)	Text restricted list [five options: Certainly; No; Probably; Probably Not; Unknown]	'Unknown' is used most commonly in this dataset. This acknowledges that lidar-based mapping rarely provides information on whether there has been recent activity. 'Probably not' is used where ground-surface form suggests that displacement is relatively old. 'Probably' is used where roughness of the ground surface suggests more recent movement. 'Certainly' is used where a landslide appears to have affected/displaced human-made features; the map dataset contains 11 landslides in this category.
Landslide activity (*crf02_activitytype*)	Text restricted list [five options: Active; Inactive; Reactivated; Suspended; Unknown]	'Unknown' is used in all cases because assessment of landslide activity is not possible with the desktop methods used in this project.
Aspect (*crf02_aspect*)	Text restricted list [representative octants: North; North-East; East; South-East; South; South-west; West; North-West; Unknown]	Value generated from digital slope map. 'Unknown' is not used in this dataset.
Source of landslide information (description) (*crf02_landslidesourcetype*)	Text restricted list [three options: Desktop; Detailed; Intermediate]	'Desktop' used for every point in this dataset.
Estimated error in location recording method (*crf02_locationaccuracy*)	Text restricted list [eight options: <1m; <10m; <100m; <500m; <1km; <2.5km; <25km; Unknown]	'<10m' is the default value, signalling that all of the mapping is based mainly on good-quality lidar. Where at least 20% of the landslide terrain margin is obscured by vegetation (Figure 2.3), '<100m' has been used to signify lesser precision.
Complexity of mass movement (*crf02_movementstyle*)	Text restricted list [four options: Multiple Events, Multiple Styles (Composite); Multiple Events, One Style (Multiple/Successive); One Event, Multiple Styles (Complex); One Event, One Style (Single)]	A representative value was assigned based on expert interpretation of lidar information. No entry (i.e. null) is made for about half the landslides in this dataset.
Primary movement type (*crf02_primarymovement*)	Text restricted list [11 options: Erosion; Fall; Flow; Not collected; Other; Retaining Wall Failure; Slide; Slope Deformation; Spread; Topple; Unknown]	A representative value was assigned based on expert interpretation of lidar information.

Field Name (Field Identifier Code)	Attribute Type	Comment
Centre of source (*crf02_XCoordinate*, *crf02_YCoordinate*)	Two integers; NZTM easting and northing	Centroid of each source-area polygon or landslide-area polygon for undifferentiated landslide features.
Comments (*crf02_comments*)	Text	Comments are provided for more than half of the landslide dataset.
Project name / number (*crf02_project_id*)	Text	'GNS Consultancy Report 2025/01' used for every data point.
Date of first movement (*crf02_dateoccurrence*)	Date [dd/mm/yyyy]	Landslides interpreted as prehistoric have a default value of 01/01/1000 applied.
Estimated date of most recent movement (*crf02_recentdateoccurrence*)	Date [dd/mm/yyyy]	Landslides interpreted as prehistoric have a default value of 01/01/1000 applied. Eleven landslides are interpreted to have occurred within historic times; these have been assigned values of 01/01/1950.
Accuracy of dating method (*crf02_datingmethodaccuracy*)	Text restricted list [11 options: Second; Minute; Hour; Day; Month; Year; Decade; Century; Millennia or more; Unknown; Not Recorded]	'Millennia or more' applied to almost all landslide features, as these are interpreted as prehistoric. For the 11 historic landslides, the dating method accuracy is assigned a value of 'Century'.
Is the age of the most recent movement able to be estimated quantitatively? (*crf02_recentagequantifiable*)	Yes/No	'No' was applied to landslides in this dataset, with a few exceptions.
Is the age of the initial movement able to be estimated quantitatively? (*crf02_initialagequantifiable*)	Yes/No	'No' was applied to landslides in this dataset, with a few exceptions.
Estimate the most recent movement age using qualitative descriptors (*crf02_recentagequalitative*)	Text restricted list [five options: Pre-Holocene; Holocene; Old; Recent; Unknown] (see Appendix 1 for definitions)	A default of 'Unknown' has been adopted for all landslides other than those that were determined quantitatively.
Estimate the initial movement age using qualitative descriptors (*crf02_initialagequalitative*)	Text restricted list [five options: Pre-Holocene; Holocene; Old; Recent, Unknown]	As above, defaults of 'Unknown' have been applied.
How confident are you that the mapped feature is a landslide? (*crf02_landslideconfidence*)	Text restricted list [four options; 4 – Very high; 3 – High; 2 – Moderate; 1 – Low] (see Appendix 1 for definitions)	'3 – High' applied to all features where source and debris areas are differentiated; '2 – Moderate' applied to undifferentiated landslide-area polygons (see Table 2.1 and text).
Source of landslide information (description) (*crf02_source_description*)	Text restricted list [six options]	See Table 2.3 for further information

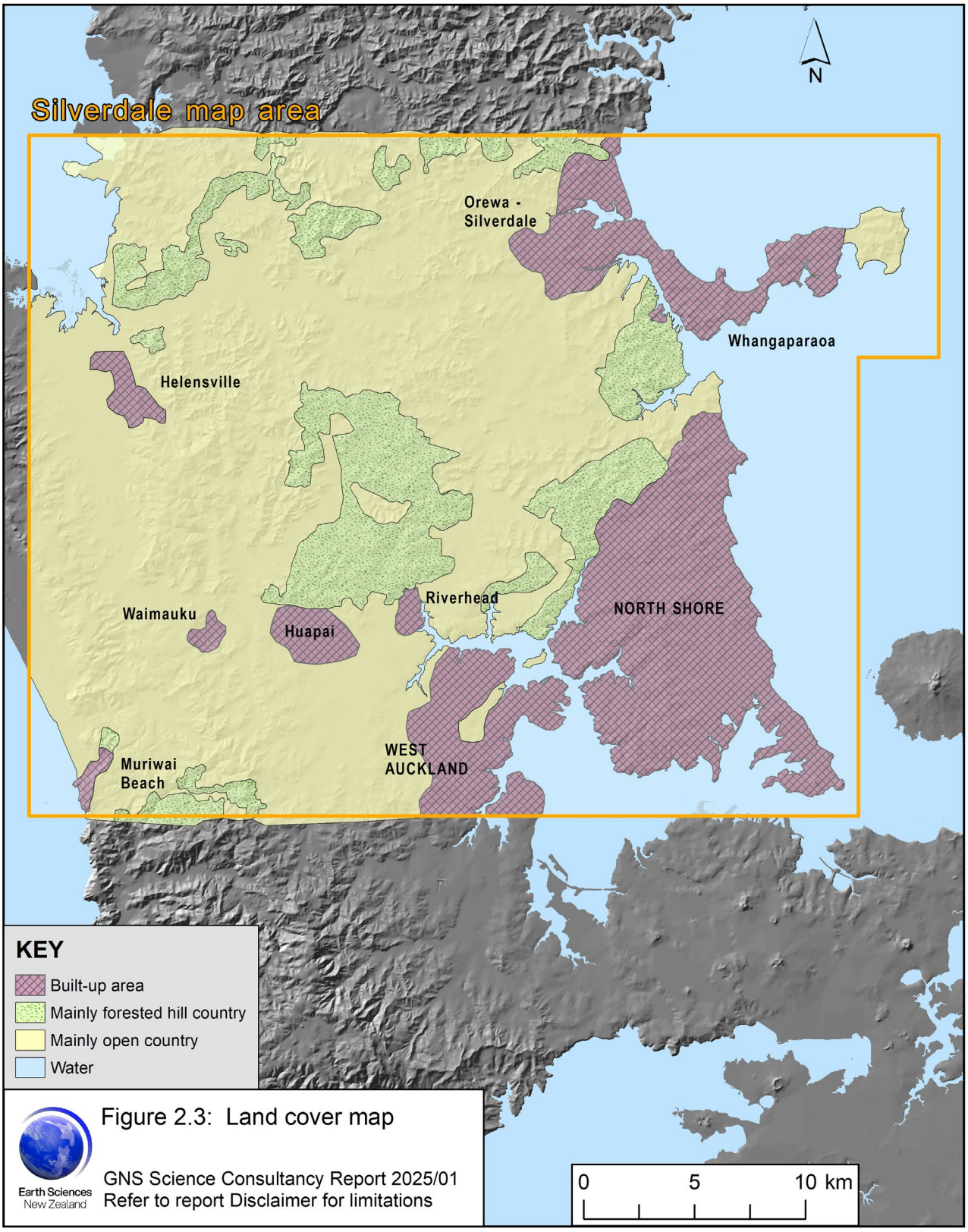

Figure 2.3 Land-cover map. This very generalised map was drawn for the project with reference to the Land Cover Database (LRIS Portal 2019) and vertical imagery from the ArcGIS basemap service, especially the Auckland Region 2017 imagery. The background digital elevation model is the LINZ 8 m resolution hillshade model.

The landslide dataset described here documents the locations and extents of previous landslide movements that have left diagnostic landform features in the landscape. The additional use of historical (typically black and white) aerial photographs in built-up areas has made it possible to recognise areas of landslide terrain that were later obscured by land modification and development (see Section 2.4 and Figure 2.4). The sharp topographic change typically marking the head of a landslide source area is often covered or removed during landscaping associated with urban development, with debris areas greatly smoothed over. However, usually remaining in the overall landform are shallow topographic depressions of source areas, as well as indications of the irregular to lobate terrain of debris areas. Combined use of historical aerial photographs taken before development, and lidar collected before, during or after development, enables mapping of the original landslide extents. Typically, mapping in built-up areas is limited to debris areas, because their characteristic irregular ground can be identified with greater confidence than the original extents of vacated source areas.

The landslide datasets do not imply anything about present or future land stability in relation to the mapped landslides.

Table 2.3 Source of landslide information. The six attributes are generic and comprise a restricted list. The 2016 lidar data are the main basis for landslide interpretation and mapping and are the default assigned to most landslides. For landslides classified as modified ground, modifications were mapped from the 2024 lidar, the most up-to-date topographic information dataset (see Section 2.4). In built-up areas, some landslides have specific descriptions, including source information (see Appendix 2).

Landslide-Source Description Attributes	Comments
Landslide mapped from 2016 lidar	No identified ground modification; no specific description. This is the default for most landslides in the dataset.
Specific description included in Appendix 2	No identified ground modification; has a specific description. Applies to landslides identified during enhanced landslide mapping in built-up areas; modification information (if any) is provided in the description.
Landslide mapped from 2016 lidar; ground modifications related to land-use identified from 2024 lidar but not mapped	Slight ground modification identified but not of sufficient extent to map modification polygons. There is no specific description.
Ground modifications related to land-use identified from 2024 lidar but not mapped; specific description included in Appendix 2	Slight ground modification identified but not of sufficient extent to map modification polygons. The landslide has a specific description.
Landslide mapped from 2016 lidar; ground modifications related to land-use mapped from 2024 lidar	Extent of modified ground mapped as polygon(s). There is no specific description.
Ground modifications related to land-use mapped from 2024 lidar; specific description included in Appendix 2	Extent of modified ground mapped as polygon(s). The landslide has a specific description.

2.4 Landslide Modifications

On hill slopes, building or other human activities involving earth-moving typically involve at least some alteration of the natural terrain. Where a slope has previously undergone landslide movement, these human modifications can partially or completely obscure the characteristic landform features associated with landslide movement. To assist a user of the landslide information with reconciling the landslide interpretation with the current physical appearance of the ground, the initial mapping tagged modified landslides by the addition of the terms ‘modified’ or ‘completely modified’ to the *Comments* field of the landslide point dataset and *landslide_polygon_description* field of the landslide polygon dataset. A scope-of-work variation was made to enable the provision of more information on landslide modifications (Section 1.2).

An enhanced modification classification was developed and definitions provided (Table 2.4). Landslides initially tagged as 'modified' have been differentiated into three classes comprising 'slightly modified ground', 'partly modified ground' and 'largely modified ground', while 'completely modified ground' equates to 'completely modified' as initially applied. The word 'ground' was added to emphasise that the modification relates to ground conditions rather than to any subsequent editorial changes to mapped landslides within the dataset.

Table 2.4 Landslide modification classification. The landslide modification class (*landslideModificationClass*) comprises a field within the landslide-modification polygon dataset and the class is included in the *Comments* field of the landslide points and *landslide_polygon_description* field of landslide polygons.

Modification Class	Definition	Comment
Slightly modified ground	Small part(s) of the landslide terrain have been modified, but the overall original landform characteristics remain evident.	Applied where the modification areas are less than the 1000 m^2 minimum size and modification polygons are not mapped
Partly modified ground	Part(s) of the landslide terrain have been modified sufficiently to obscure some of the original landform characteristics.	Applied where modification areas are mapped over part(s) of the landslide polygon area
Largely modified ground	Only subtle evidence for the landslide remains in the landscape. Typically associated with built-up areas, and landslide mapping is usually based on historic aerial imagery.	Modification polygon typically replicates the landslide polygon extent
Completely modified ground	No evidence for the landslide remains in the landscape. Typically associated with industrial/major road developments but also occurs in some residential areas, especially more-recent subdivisions.	Modification polygon always replicates the landslide polygon extent

A new polygon feature class, 'landslide modification', has been added to the GIS dataset. This polygon feature class acts as an information overlay for the landslide polygon dataset. To maintain direct association between the modification and landslide polygons, each modification polygon matches, or lies within, the location of the landslide polygon. In other words, the modification polygons are confined to the mapped landslide area, even if the modification extends beyond the landslide. There is a minimum size of 1000 m^2 for the mapping of a modification polygon.

Each landslide-modification polygon uses the same GUID as the landslide polygon and point to which it relates. The modification polygons have five main fields: *GUID*, *landslideModificationClass, modificationType*, *modificationDescription* and *interpretationSource*. There are restricted lists of attributes for the *landslideModificationClass*, *modificationType* and *modificationDescription* fields (Tables 2.4 and 2.5). The *informationSource* field is free text, but, with few exceptions, the attribute of '2024 lidar' has been used throughout. The *modificationType* and *modificationDescription* attributes are hard-linked so that, for each modification polygon, the same *modificationDescription* always accompanies the *modificationType* attribute.

It is anticipated that the modification polygon dataset described here will be uploaded to the 'corrective action feature' polygon component of the NZOLD. The corrective action feature dataset represents a convenient repository for modification information, but many of the modifications identified here were likely not done with landslide stability improvement in mind. To avoid implying that a corrective action assessment may have been completed, three additional fields have been incorporated into the landslide modification dataset: *Type*, *Integrity* and *Description*. These fields equate to existing fields in the corrective action feature dataset schema. All landslide-modification polygons have been

assigned a *Type* of 'other' and *Integrity* of 'unknown'. Every *Description* comprises the words "ground modification related to land-use", followed by a concatenation of attributes from the other fields in the order of: *modificationClass*, *modificationType*, *modificationDescription*, *interpretationSource*.

A landslide noted as modified, but with modification area(s) >1000 m^2, is classified as slightly modified ground in the landslide point and polygon datasets. Where modification areas(s) are large enough to be mapped, the landslide is classified as partly, largely or completely modified ground. For those landslides classed as slightly modified, the relevant attribute or attributes from the *modificationType* field (Table 2.5) have been added to the *landslide_polygon_description* field of the landslide polygon dataset and the *Comments* field of the landslide point dataset.

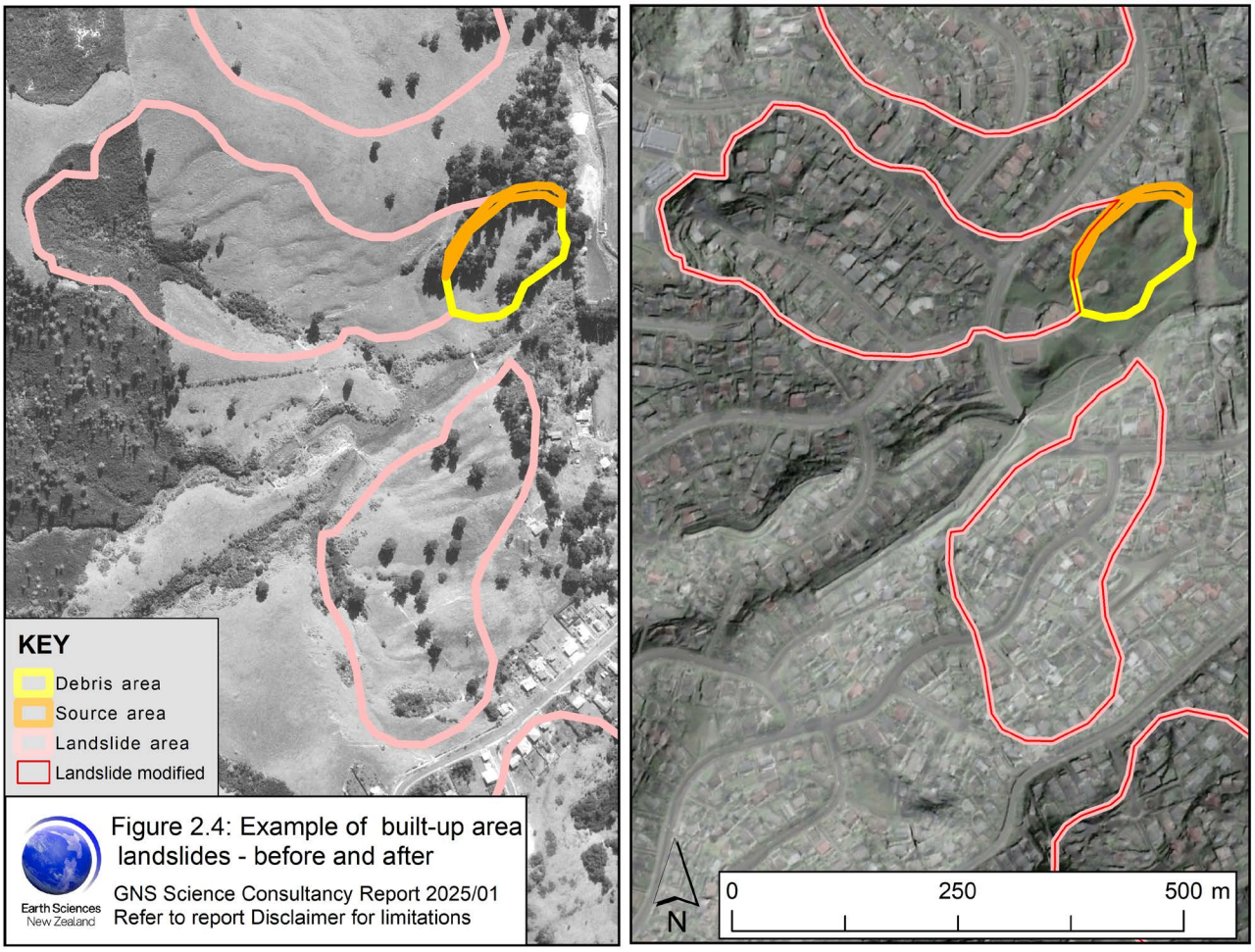

Figure 2.4 Example of built-up area landslides – before and after development. The example comes from the Browns Bay area of the North Shore. The landslide polygon map is the same in both panels. The left panel has a 1963 aerial photograph as its background. The right panel background comprises the 2016 lidar digital elevation model draped transparently over vertical imagery from the ArcGIS basemap service. All landslide-modification polygons (red) in this view are classed as 'largely modified ground'. The ground is extensively altered, but the broad topographic features of the landslides remain evident in the landscape.

Table 2.5 Restricted list of attributes for the *modificationType* and *modificationDescription* data fields in the landslide-modification polygon dataset. The *Type* attribute of 'unspecified modification' is included for completeness in the data structure, but there are no instances of its use in the current dataset.

***modificationType* Attribute List**	**Corresponding *modificationDescription* Attribute List**
Cut and fill	Earthworks involving cutting and filling, such as for large building platforms and water retention
Road formation	Earthworks for formation of roads, tracks or driveways
Filled ground	Placement of fill (ranging from engineered to uncontrolled)
Excavated ground	Removal of natural ground-forming materials
Building-related landscaping	Ground modified during built-environment landscaping
Multiple types	Several different types of ground modification
Unspecified modification	Nature/origin of modification uncertain or not specified

Some landslides are differentiated into a 'vacated area' polygon adjoining a 'debris area' polygon. Together, these represent two parts of one landslide area. Modifications are identified in relation to the overall landslide area, and its modification class is applied to both of its differentiated parts. A modification area that straddles both parts of a differentiated landslide is represented by a single modification polygon.

In detail, modifications commonly have different components, and each modification polygon has had the dominant modification identified via the assigned modification *Type*. For largely and completely modified ground polygons that occupy the entire landslide area, the most representative *Type* is assigned. The *Type* category of 'building-related landscaping' recognises that several modification elements, such as building platforms, retaining wall excavations, driveways and pathways, and garden benching and terracing, commonly occur within one modification area. The 'multiple types' category indicates that an array of modifications is present, such as lines of road formation, areas of cut and fill and building-related landscaping around residences.

Absence of a modification comment or polygon simply means that modification was not noted using the 2016 lidar, but this does not necessarily mean that the landslide has not been modified.

The modification dataset does not imply anything about present or future land stability in relation to any ground modifications or about stability of the landslide on which the modification has occurred.

3.0 Results and Discussion

Mapped types of landslides comprise: 'Unknown' (329), 'Flow' (589), 'Slide' (6270) and 'Slope Deformation' (122). Their aspects are distributed around all of the direction octants, with each direction similarly represented (N = 915, NE = 778, E = 883, SE = 998, S = 979, SW = 873, W = 961, NW = 923).

Quantifying the range of extents of individual landslides is not a simple calculation because most landslides are divided into source-area and debris-area couplets, which would need amalgamating to obtain an overall extent. However, debris-area polygons are typically the considerably larger component of each couplet, so each approximates a minimum extent for each landslide. Data derived from the GIS show that 'Debris area' polygons range from about 1000 m^2 to 754,000 m^2, 'Landslide area' polygons range from about 700 m^2 to 767,000 m^2 and 'Source area' polygons range from about 300 m^2 to 74,000 m^2.

Many landslides in this dataset have morphologies indicating that these are composite features comprising several overlapping or adjoining movement areas. It is difficult, based on desktop evidence alone, to make robust interpretations of whether multiple movements occurred simultaneously, or successively over time. The database field *Complexity of mass movement* provides a provisional interpretation of whether a landslide formed in multiple events or involved multiple movement styles (Table 2.2). No entry (i.e. null) is made for about half the landslides in this dataset. Some polygons in the dataset represent multiple, either adjacent or disjunct, features that have been amalgamated due to mapping scale. These contain the keyword 'multiple' in the *Comments* field. Similarly difficult from desktop methods is determining when a landslide was initiated and how recently it last moved. The approach taken with the Silverdale detailed landslide map is that, unless there is information to support a specific age classification, each landslide's *age of the initial movement* and *age of the most recent movement* are assigned as 'Unknown'. Virtually all landslides represented in this dataset have little known about them, apart from lidar-based interpretation of their extent and surface form.

Despite the default attribute 'Unknown' being used extensively for landslide age in this dataset, the topographic settings and surface form of most of the mapped landslides suggest that their initiation was likely at least several hundred years ago (i.e. 'Holocene' or 'Pre-Holocene' by the definitions in Appendix 1). As their initiation likely preceded human settlement of New Zealand, we use the informal term 'prehistoric' as collective shorthand for discussing landslides with assigned qualitative ages of 'Unknown'. Their formation likely relates to natural evolution of the landscape, linked to the underlying geological substrate and erosive processes operating within valleys or gullies that have increased slope angles and encouraged slope instability.

During the Pukekohe/Silverdale landslide mapping projects, discussions between Earth Sciences New Zealand, Auckland Council and Beca (operators of the NZOLD on behalf of Auckland Council) resulted in refinements to some aspects of the NZOLD database. The main purpose of the refinements is to improve the utility of the database for accommodating prehistoric landslide features. A landslide mapper has a limited basis for reliably estimating details of movement characteristics for prehistoric landslides, in contrast to landslides that have occurred recently, for example, where the movement was observed, or details can be ascertained from damage to built features. In the NZOLD fields for initial movement and most recent movement, apart from the few landslides that can be identified from aerial imagery and the like as having occurred historically, the same date ('01/01/1000') is applied in both existing fields for the Silverdale detailed landslide map dataset.

Notable among the refinements resulting from the Earth Sciences New Zealand / Auckland Council / Beca discussions was the addition of five new fields to the NZOLD to allow improved characterisation of landslides. The new fields (see Table 2.2) are:

- Is the age of the most recent movement able to be estimated quantitatively? (Yes/No)
- Is the age of the initial movement able to be estimated quantitatively? (Yes/No)
- Estimate the most recent movement age using qualitative descriptors: (Restricted list)
- Estimate the initial movement age using qualitative descriptors: (Restricted list)
- How confident are you that the mapped feature is a landslide? (Restricted list)

The restricted lists and definitions are provided in Appendix 1.

The third and fourth of the new fields are conditional fields with content that depends upon how the first two fields are filled in. For example, if the *Is the age of the most recent movement able to be estimated quantitatively?* field has an attribute of 'Yes', then a date value will be entered into the *Estimated date of most recent movement* field. There are only 11 landslides in the Silverdale detailed landslide map dataset for which a representative date has been assigned. A date of '01/01/1950' was applied and a value of 'Century' was used in the *Accuracy of dating method* field. If 'No' is selected, qualitative age descriptors are applied in the third field (see Appendix 1).

The fifth new field (*How confident are you that the mapped feature is a landslide?*) is a useful addition for inventory mapping of prehistoric landslides because it allows a mapper to assign a level of confidence that a feature was formed by slope movement (Appendix 1). Identification confidence (*landslideconfidence*; Table 2.2) is a field specific to the NZOLD point-data structure and is not part of the geomorphological-map-data structure. A default approach was used to assign *landslideconfidence* to each landslide point, based on the *landslide_polygon_type* values in the polygon dataset. Where the type is 'Landslide area', accompanied by a *landslide_polygon_description* entry that includes 'subdued hummocky ground', the corresponding landslide point was assigned a value of '2 – Moderate'. Where the type is 'Landslide area', with a *landslide_polygon_description* entry that includes 'hummocky landslide area', or for all landslides where an adjoining 'Source area' and 'Debris area' have been mapped, a confidence value of '3 – High' was applied. Future re-evaluation of any specific landslides in the dataset would benefit from confirmation or updating of the *landslideconfidence* value.

When the project was set up, it was anticipated that any lidar-delineated landslides in the Silverdale detailed landslide map dataset already represented in the NZOLD would be linked via a common unique identifier (GUID) value. However, comparative inspection of the data shows that the newly mapped landslides are relatively large landscape features, whereas the existing NZOLD entries are generally small historic failures that are different occurrences to the newly mapped, mainly prehistoric, landslides. Even where an existing landslide (point or polygon) in the NZOLD coincides with the location of a newly mapped landslide polygon, it is likely that the two records represent different landslide events. The exception is two newly mapped landslides on Oyster Point Road that have a similar extent to existing entries in the NZOLD. The *Comments* field lists the NZOLD Landslide ID GUIDs for these landslides so that they can be related between this dataset and the NZOLD.

The mapping methodology identifies the areas where past landslide movement is recognisable in the landscape but does not provide any information on the current state of stability or otherwise of those landslides. It is expected that the landslide map datasets may have utility in future work using new techniques such as InSAR ground-deformation surveying, which may be able to determine whether any detectable landslide movement is occurring.

4.0 Acknowledgements

We are grateful to staff from Auckland Council and the Beca Auckland office for discussions in developing the project brief, provision of information on the New Zealand Open Landslide Database and refinement of some aspects of the database. Internal reviews by Brenda Rosser, Dominic Strogen and Sam McColl of Earth Sciences New Zealand provided useful feedback.

The geomorphological dataset, with which the Silverdale detailed landslide map is associated, is being compiled as part of the Earth Sciences New Zealand Urban Geological Mapping Project, supported by the New Zealand Government though public research funding (Strategic Science Investment Fund) from the Nationally Significant Databases and Collections Programme.

5.0 References

Barrell DJA, Bland KJ, Hill MP, Lee JM. 2021. Revised stratigraphic framework for the Pliocene to Holocene sedimentary deposits of the Auckland area. Lower Hutt (NZ): GNS Science. 25 p. (GNS Science report; 2020/05). https://doi.org/10.21420/2KGA-5R12

Bland KJ, Lee JM, Hill MP, Jones KE. 2020. Lithostratigraphic framework summary and geological context of the southern Auckland area. Lower Hutt (NZ): GNS Science. 62 p. (GNS Science report; 2020/04). https://doi.org/10.21420/97ZH-V040

Bland KJ, Townsend DB, Hill MP, Jones KE. 2023a. Geology of the Pukekohe area [map]. Lower Hutt (NZ): GNS Science. 1 map, scale 1:50,000. (GNS Science geological map; 12b). https://doi.org/10.21420/1FED-P349

Bland KJ, Townsend DB, Hill MP, Jones KE. 2023b. Geology of the Pukekohe area [explanatory text]. Lower Hutt (NZ): GNS Science. 24 p. (GNS Science geological map; 12b). https://doi.org/10.21420/EXAN-S218

Bland KJ, Townsend DB, et al. In prep. Geology and geomorphology of the Silverdale area. Lower Hutt (NZ): Earth Sciences New Zealand.

Hill MP. 2019. Borehole database for urban geological mapping, southern Auckland area, New Zealand. Lower Hutt (NZ): GNS Science. 34 p. (GNS Science report; 2019/12). https://doi.org/10.21420/EZ5W-5K59

Jones KE, Strogen DP, Hill MP. 2022. 3D geological model of the Pukekohe area. Lower Hutt (NZ): GNS Science. 1 model + text + digital data. (GNS Science geological map; 12a). https://doi.org/10.21420/KA0P-SW95

LRIS Portal. 2019. LCDB v5.0 – Land Cover Database version 5.0, mainland, New Zealand. Lincoln (NZ): Manaaki Whenua Landcare Research; [updated 2024 Nov 15; accessed 2025 Jan]. https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

Townsend DB, Barrell DJA, Easterbrook-Clarke LH. 2024. Detailed map of landslides in the Pukekohe area, southern Auckland. Lower Hutt (NZ): GNS Science. 16 p. Consultancy Report 2024/101. Prepared for Auckland Council.

Townsend DB, Jones KE, Bland KJ. In prep. Geomorphology of the Pukekohe area. Lower Hutt (NZ): GNS Science. (GNS Science geological map; 12c).

APPENDICES

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APPENDIX 1 Definitions for Attributes of Selected Fields

This appendix provides definitions for the restricted-field attributes given in Table 2.2 where the attribute name is not self-explanatory.

A1.1 Landslide Qualitative Age Descriptors

These definitions were refined in discussion with Auckland Council and used in the Pukekohe landslide dataset (Townsend et al. 2024) to provide improved relative age estimation for the proposed new fields of 'Estimate the most recent movement age using qualitative descriptors' (field identifier code: *crf02_recentagequalitative*) and 'Estimate the initial movement age using qualitative descriptors' (field identifier code: *crf02_initialagequalitative*) (see Table 2.2). Restricted list values (in **bold**) and definitions are:

- **Pre-Holocene**: Geomorphology suggests movement pre-Holocene [5]
- **Holocene**: Geomorphology suggests Holocene movement but no significant movement within a few hundred years.
- **Old**: Geomorphology suggests movement within a few hundred years but not within the last few decades.
- **Recent**: Geomorphology suggests movement within the last few decades.
- **Unknown**. Not known or specified.

A1.2 Landslide Confidence

The 'Qualitative Landslide Confidence' field provides a parameter expressing the degree of confidence that the mapped feature was formed by landslide processes. It applies only to the identification of the landslide and not to other characteristics such as type of movement, whether multiple or single, etc. Restricted list values (in **bold**) and definitions are:

- **4 – Very high**: There is no doubt that the feature was formed by landslide movement. This typically applies where landslide identification and extent mapping are based on detailed field observations and/or expert analysis of high-resolution topographic data or aerial imagery, or where a landslide was observed to have occurred (first-hand or in time sequences of imagery).
- **3 – High**: High confidence is applied where there is a small possibility that the feature may have at least in part been formed by processes other than landsliding (e.g. other types of erosion or human ground modification). This typically applies to mapping using detailed field observations and/or expert analysis of high-resolution topographic data or aerial imagery where the original ground surface is obscured to some extent by vegetation cover or has been affected by human ground modification. This level of confidence may also be applied when the evidence is from good-quality maintenance records or newspaper reports, which sometimes mis-identify other similar hazards as landslides.
- **2 – Moderate**: Moderate confidence is applied where it is reasonably possible that the feature was formed by processes other than landsliding (e.g. other types of erosion or human ground modification). A landslide origin is equally or more likely than not. Typically applied where diagnostic landslide landform characteristics are ambiguous (e.g. subtle or discontinuous) because the ground is largely obscured by tall vegetation; extensively modified by human activity, including intensive urbanisation; or the landslide is very old. It may also apply to where mapping is based on limited information, such as distant or reconnaissance field inspection, lower-resolution imagery or topographic maps.

5 The Holocene is an epoch of geological time, spanning from ~12,000 years ago to the present day.

- **1 – Low**: Low confidence indicates that the feature was possibly formed by landslide movement but more likely to have formed by processes other than landsliding (e.g. other types of erosion or human ground modification). Typically applied where few diagnostic landslide landform characteristics are present or are very subtle in their expression.

APPENDIX 2 Descriptions of the Basis for Mapping Specific Landslides in Built-Up Areas

This appendix provides brief commentary on the technical basis for recognition, interpretation and mapping of individual landslides in the main existing, and in-development, built-up areas within the Silverdale map area. Commentary is provided for individual or groups of closely spaced landslides where these coincide with ~10 or more residential properties; industrial, commercial or infrastructural developments; or public facilities/structures. Elsewhere, on rural or less intensively developed land, characterisation of landslides is confined to general area-wide summary description in the main report.

In contrast to most of the Silverdale map area, where ground-elevation data from airborne lidar surveys (digital elevation models) are the primary information source for landslide recognition and mapping, an enhanced mapping method was applied in built-up areas that included examination of historical aerial photos sourced from the Retrolens historical image resource (https://retrolens.co.nz/), available online and licensed by Land Information New Zealand (LINZ; CC-BY 3.0), as well as time-stamped imagery available in Google Earth. The commentary in this appendix uses approximate locational reference focusing on street/road names. Approximate estimates of when subdivision/development occurred are from the LINZ digital cadastral database. Each landslide description includes a statement of the level of confidence that the mapped feature was in fact formed by landslide movement, rather than being of some other origin (e.g. progressive erosion by rain and gullying). That statement may include a range of confidence levels (e.g. moderate to high) that provide a more comprehensive estimate of the level of confidence than the single value assigned to *landslideconfidence* field in the NZOLD point data structure (Appendix A1.2).

The landslide map information dataset described here (GNS Silverdale 2025) documents the locations and extents of previous landslide movements that have left diagnostic landform features in the landscape. In built-up areas, where possible, the dataset includes original landslide extents where these have subsequently been partially or completely obscured by land modification and development. The dataset does not imply anything about present or future land stability in relation to the mapped landslides.

The commentary below is grouped according to suburbs and/or general localities in a sequential order that is approximately north to south, east to west (Figure A2.1). The locational groupings are listed, with page numbering, in the Table of Contents of the main report.

A2.1 Hatfields Beach

Ocean View Road / Sykes Avenue: Three small east-facing topographic basins evident in lidar are visible in historical aerial photos (photo series SN143, run 82; taken 1941), which show indications of irregular ground within the basins. Subsequent earthworks, landscaping and building has considerably modified and obscured the original ground surface. These basins are interpreted, with moderate confidence, to have been formed by landslide movement.

A2.2 Orewa

Pacific Heights Road, near Ringi Lane: A north-facing topographic basin with irregular ground is evident in 2013 lidar. It is interpreted with moderate confidence to have been formed by landslide movement. It has subsequently been modified extensively by earthworks during subdivision and development. No information is available from historical aerial photography (photo series 1565, run C; taken 1963) because the ground was obscured by thick vegetation.

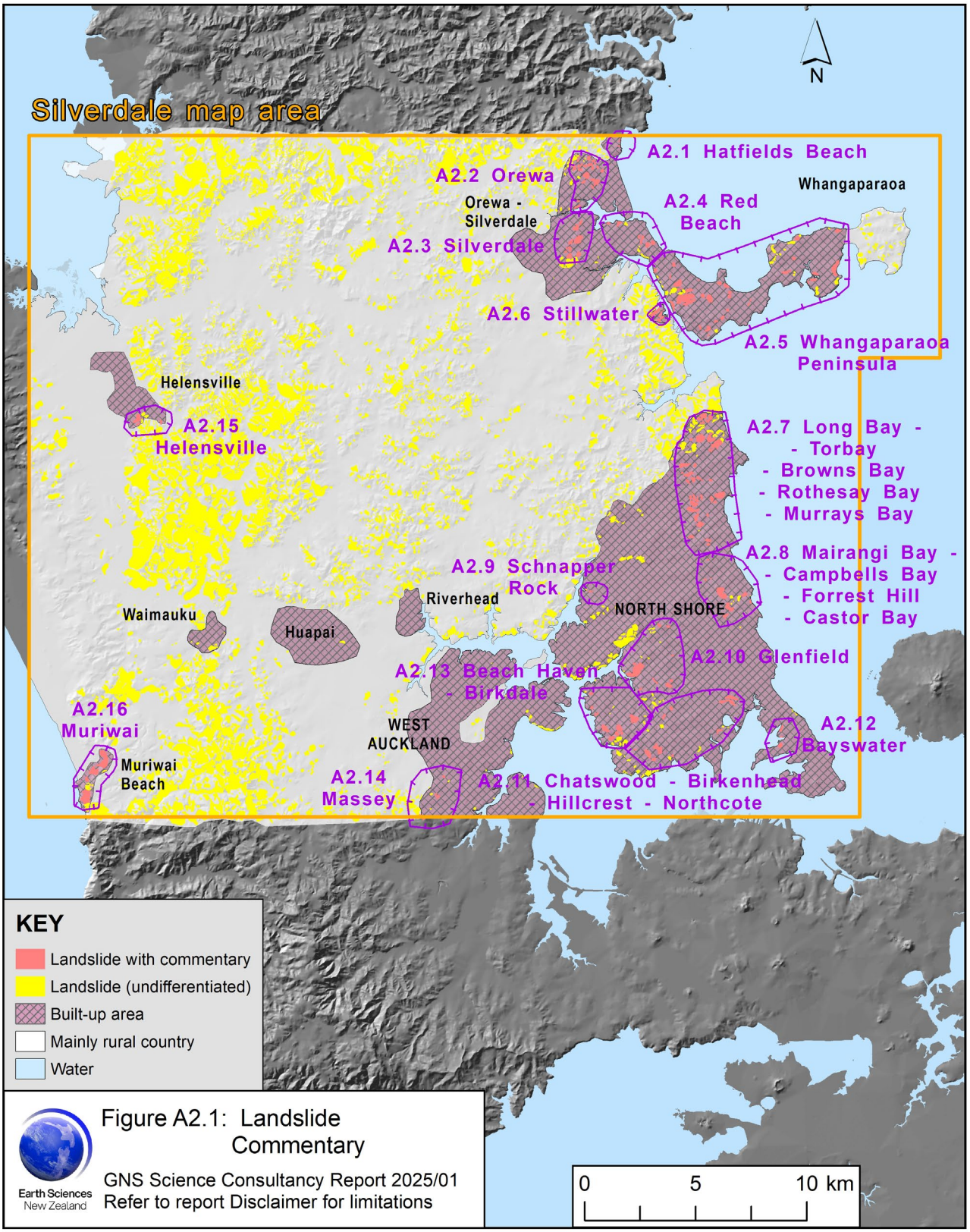

Figure A2.1 Landslide commentary. This diagram provides the subheading numbers and suburb names under which the Appendix 2 landslide descriptions are grouped.

Pacific Heights Road, between Rockpool Road and Waimaru Lane: An east-facing topographic basin with curved steps is evident in historical aerial photography (photo series 1565, run C; taken 1963) and partly visible in 2013 lidar when some development earthworks were underway. The basin is interpreted with moderate confidence to have been formed by landslide movement, but the 2016 lidar shows that it has been completely modified and obscured due to earthworks.

Celestial Crescent / Franheim Crescent / Tautoro Avenue / Sunnyheights Road: This area of west-facing slope has irregular ground evident in historical aerial photography (photo series 1565, run C; taken 1963) and in the 2013 lidar, but the original ground had been completely modified by earthworks by the time of the 2016 lidar survey. This area is interpreted with high confidence to have been previously affected by landslide movement.

East end of Rockpool Road: A small east-facing topographic basin with irregular ground is evident in 2013 lidar and visible in historical aerial photography (photo series 1565, run C; taken 1963). The basin is interpreted with moderate confidence to have been formed by landslide movement, but the 2016 lidar shows that it has been completely modified and obscured due to earthworks.

Matangi View Drive / Makomako Drive: An east-facing topographic basin with curved steps and irregular ground is clearly evident in 2013 lidar and visible in historical aerial photography (photo series 1565, run C; taken 1963). The basin is interpreted with high confidence to have been formed by landslide movement, but the 2016 lidar shows that it has been completely modified and obscured due to earthworks.

Southern Matangi View Drive / Makomako Drive: A north-facing topographic basin with curved steps and irregular ground is clearly evident in 2013 lidar and visible in historical aerial photography (photo series 1565, run C; taken 1963). The basin is interpreted with high confidence to have been formed by landslide movement, but the 2016 lidar shows that it has been considerably modified and obscured due to earthworks.

Eastern Makomako Drive / Sapphire Sea Road: A west-facing topographic basin with curved steps and irregular ground clearly evident in 2013 and 2016 lidar and visible in historical aerial photography (photo series 1565, run C; taken 1963). The basin is interpreted with high confidence to have been formed by landslide movement, but aerial/satellite colour imagery from 2017 onward, seen in Google Earth, shows that the natural ground has now been considerably modified and obscured due to earthworks.

Northern Makomako Drive / Azure Ocean Road: A north-facing topographic basin with curved steps and irregular ground clearly evident in 2013 and 2016 lidar and visible in historical aerial photography (photo series 1565, run C; taken 1963). The basin is interpreted with high confidence to have been formed by landslide movement, but aerial/satellite colour imagery from 2017 onward, seen in Google Earth, shows that the natural ground has now been considerably modified and obscured due to earthworks.

Roberta Crescent / Fern Court / Ngahere Views / Rakau Views: Four small topographic basins have irregular ground clearly evident in historical aerial photography (photo series 1565, run C; taken 1963), prior to subdivision (late 1990s to early 2000s), but the original natural ground is now completely modified and obscured due to earthworks and building. Only the broad outlines of the basin heads are evident in 2013 and 2016 lidar. Mapping of these features is based on interpretation of what can be seen in the historical photos, and there is high confidence that they were formed by landslide movement.

Ngahere Views / Ngahere Jelas Reserve: A small topographic basin has irregular ground clearly visible in historical aerial photography (photo series 1565, run C; taken 1963) prior to development, and elements of the irregular ground are still evident in 2013 and 2016 lidar. There is high confidence that the basin was formed by landslide movement.

Rewa Rewa Lane / Panorama Heights / Landmark Terrace / Plantation Terrace / Orewa Heights Crescent / Millennial Way: What appears to be an area of irregular ground is evident in historical aerial photography (photo series 1565, run C; taken 1963) prior to subdivision (from the mid-2000s), but the original natural ground is now completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos, and there is moderate confidence that it was formed by landslide movement.

Waldorf Crescent: What appears to be an area of irregular ground in a broad basin at the head of a small gully is evident in historical aerial photography (photo series 1565, run C; taken 1963) prior to subdivision (mid-1990s). The original natural ground has now been completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos, and there is moderate confidence that it was formed by landslide movement.

Grovenor Drive / Manhatten Rise: An area of irregular ground on a northeast-facing slope is evident in historical aerial photography (photo series 1565, run C; taken 1963) prior to subdivision (early 2000s). The original natural ground has now been completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos, and there is high confidence that it was formed by landslide movement.

Grovenor Drive / The Ritz / Carlton Way: An area of distinctly irregular ground on an east-facing slope is evident in historical aerial photography (photo series 1565, run C; taken 1963) prior to subdivision (early 2000s). The original natural ground has now been completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos, and there is high confidence that it was formed by landslide movement.

Grovenor Drive / Dorchester Place: What appears to be an area of irregular ground on an east-facing slope is evident in historical aerial photography (photo series 1565, run C; taken 1963) prior to subdivision (early 2000s). The original natural ground has now been completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos, and there is moderate confidence that it was formed by landslide movement.

Ascension Crescent / Tawa Place / Manawanui Way: An area of irregular ground on an east-facing slope is evident in historical aerial photography and in the 2006 lidar data (photo series 1565, run C; taken 1963) prior to subdivision (mid-2010s). Between the 2006 and 2013 lidar surveys, the original natural ground was completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos and the 2006 lidar. There is high confidence that it was formed by landslide movement.

Arran Point Parade / Paige Road: What appears to be an area of irregular ground on a north-facing slope is evident in historical aerial photography (photo series 1565, run C; taken 1963) prior to subdivision (late 2010s to early 2020s). The original natural ground has now been completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos, and there is moderate confidence that it was formed by landslide movement.

Arran Point Parade / Cassidy Drive: What appears to be an area of slightly irregular ground in a topographic basin on a south-facing slope is evident in 2013 lidar prior to subdivision (late 2010s), although this is not clearly expressed in historical aerial photography (photo series 1565, run C; taken 1963). The original natural ground has now been completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in 2013 lidar, and there is moderate confidence that it was formed by landslide movement.

A2.3 Silverdale

Major Henry Greens / Walter Crescent: An area of irregular ground on a northwest-facing slope is evident in historical aerial photography (photo series 1565, run C; taken 1963) and 2006 lidar prior to subdivision (late 2000s to early 2010s). The original natural ground has now been completely modified and obscured due to earthworks and building. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos, and there is moderate confidence that it was formed by landslide movement.

Butler Stoney Crescent / Kawerau / Metro Park West: An area of irregular ground on a north-facing slope in a basin at a catchment head is evident in historical aerial photography (photo series 1565 run C, taken 1963) and 2006 lidar. The original natural ground was modified by landscaping as part of development of this park/green space between the 2006 and 2013 lidar surveys. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos and 2006 lidar, and there is moderate confidence that it was formed by landslide movement.

Pioneer Rise / Miller Rise / Grut Green / Ormonde Drive / Pommes Way / Manuel Road: A northeast-facing slope with irregular ground, including curved steps, is clearly visible in historical aerial photography (photo series 1565, run D; taken 1963) and 2006 lidar prior to subdivision development (mid-2010s). The original natural ground was thoroughly modified by earthworks between the 2006 and 2013 lidar surveys. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos and 2006 lidar, and there is high confidence that it was formed by landslide movement.

Manuel Road / Outlook Terrace: A north-facing slope with irregular ground is evident in historical aerial photography (photo series 1565, run D; taken 1963) and 2006 lidar prior to subdivision development (early to mid-2010s). The original natural ground was thoroughly modified by earthworks prior to capture of the 2013 lidar. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos and 2006 lidar, and there is high confidence that it was formed by landslide movement.

Manuel Road / Ormonde Drive / Croix Greens / Colonial Drive: Two areas of irregular ground on a south-facing slope are evident in 2013 lidar, which was captured just prior to subdivision development (mid-2010s). The ground-surface features are not clearly expressed in historical aerial photography (photo series 1565, run D; taken 1963). The original natural ground was modified by earthworks prior to capture of the 2016 lidar and subsequently further modified by landscaping and building. Mapping of these topographic features is based on interpretation of what can be seen in the 2013 lidar, and there is high confidence that they were formed by landslide movement.

Wainui Road / Ormonde Drive / Vue Terrace: A small area of irregular ground on an east-facing slope is evident in 2013 lidar, which was captured just prior to subdivision development (mid-2010s). The ground-surface features are not clearly expressed in historical aerial photography (photo series 1565, run D; taken 1963). The original natural ground was modified by earthworks prior to capture of the 2016 lidar and subsequently further modified by landscaping and building. Mapping of this topographic feature is based on interpretation of what can be seen in the 2013 lidar, and there is moderate confidence that it was formed by landslide movement.

Wainui Road / Ormonde Drive / Colonial Terrace / Bonair Crescent: A broad north-facing slope with a topographic basin near its crest that has irregular ground visible in 2013 lidar, which is also evident, although not well resolved, in historical aerial photography (photo series 1565, run D; taken 1963). The original natural ground was modified by earthworks prior to capture of the 2016 lidar and subsequently further modified by landscaping and building. Mapping of this topographic feature is based on interpretation of what can be seen in the 2013 lidar, and there is high confidence that it was formed by landslide movement.

Wainui Road / Cilliers Drive / Arriere Lane / Colonial Terrace: A broad north-facing slope with a topographic basin near its crest that has irregular ground evident in historical aerial photography (photo series 1565, run D; taken 1963). The original natural ground was modified by earthworks prior to the 2006 lidar survey and subsequently further modified by landscaping and building at the time the 2016 lidar was captured. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photography and 2013 lidar. There is high confidence that it was formed by landslide movement.

A2.4 Red Beach

Maori Hut Road: A small area on a north-facing slope has what appears to be irregular ground in historical aerial photography (photo series 1565, run C; taken 1963), and a broad topographic step is evident around the upslope margin of this area in 2013/2016 lidar. The original natural ground had been partly modified by roading earthworks and some buildings in the 1963 photo and is much more modified now, as seen in the lidar. Mapping of this area is based on interpretation of what can be seen in historical photography and lidar, and there is moderate confidence that it was formed by landslide movement.

Twin Coast Discovery Highway / River Road / Pohutukawa Avenue: A northeast-facing topographic basin has indications of irregular ground evident in historical aerial photography (photo series 1565 run C, taken 1963) and 2013/2016 lidar. The original natural ground was partly modified by roading earthworks and some buildings in the 1963 photo and is more modified now, as seen in the lidar. Mapping of this basin is based on interpretation of what can be seen in historical photography and lidar, and there is moderate confidence that it was formed by landslide movement.

Gilshennan Valley / Rushden Terrace: Part of the west-facing side of the valley has a broad bench, with a topographic step around its upslope margin, evident in 2013/2016 lidar. The area was in pasture when historical aerial photographs (photo series 1565, run D) were taken in 1963, and ground-surface features are not clearly resolved in those photos. Residential subdivision between the mid-1970s and 1990s resulted in landscaping and building that has considerably modified the ground surface, as registered in lidar imagery. This topographic feature was mapped based on the interpretation of lidar. There is low to moderate confidence that it was formed by landslide movement.

Rushden Terrace / William Bayes Place: This east-facing valley side slope has irregular ground evident in historical aerial photography (photo series 1565, run D; taken 1963), when it was in pasture. Residential subdivision between the mid-1970s and 1990s resulted in landscaping and building that has considerably modified the ground surface, pre-dating the 2013/2016 lidar. This topographic feature was mapped based on the interpretation of historical photography and lidar. There is moderate confidence that it was formed by landslide movement.

Esther Place / Marellen Drive / Durness Place / Chelverton Terrace: Two areas, a northwest-facing slope and northeast-facing topographic basin, have irregular, in places stepped, ground that is clearly visible in historical aerial photography (photo series 1565, run D; taken 1963). Residential subdivision beginning in the late 1960s resulted in landscaping and building that has considerably modified the ground surface, pre-dating the 2013/2016 lidar. These topographic features were mapped based on the interpretation of historical photography and lidar. There is moderate confidence that they were formed by landslide movement.

A2.5 Whangaparaoa Peninsula

Landslides is this area are described in sequential order, approximately west to east.

Poplar Road / Rivervale Grove: This west-facing slope overlooking the Weiti River estuary has stepped topography, evident in historical aerial photography (photo series SN143, run 85; taken 1940) that pre-dates development here, as well as in the 2006 and 2016 lidar. There is moderate confidence that the stepped topography was formed by landslide movement.

Vipond Road / John Road / Brian Crescent / Carento Way: An area of irregular stepped ground on this south-facing slope at the head of a gully is clearly visible in historical aerial photography (photo series SN143, run 85; taken 1940) when the land was farmland in pasture and no urban development had begun. The original natural ground is now considerably modified and obscured due to landscaping and building. Mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the likely positions of this feature's margins. There is moderate confidence that it was formed by landslide movement.

Whangaparaoa Road / Dobell Road / Gledstane Road: What appears to be an area of irregular ground on this east-facing slope is evident in historical aerial photography (photo series SN143 run 85, taken 1940), when it was in pasture. The original natural ground has now been considerably modified and obscured due to landscaping and building prior to the 2006 lidar survey. Mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the likely positions of this feature's margins. There is moderate confidence that it was formed by landslide movement.

Whangaparaoa Road / Elliston Crescent / Brightside Road: What appears to be an area of irregular ground on this north-facing slope is evident in historical aerial photography (photo series SN143 run 85, taken 1940), when it was in patchy scrub prior to development. The original natural ground has now been considerably modified and obscured due to landscaping and building prior to 1963 aerial photography and the 2013/2016 lidar surveys. Mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the likely positions of this feature's margins. There is moderate confidence that it was formed by landslide movement.

South of Whangaparaoa Road near the Brightside Road junction: This south-facing slope has irregular ground evident in historical aerial photography (photo series 1370, run H; taken 1963) and in the 2013 and 2016 lidar imagery, downslope of a steep topographic step. Those information sources provide the basis for mapping this topographic feature. There is moderate to high confidence that it was formed by landslide movement.

Whangaparaoa Road / Brightside Road / Beverley Road / Wiriana Place: This south-facing slope has irregular ground evident in historical aerial photography (photo series SN143, run 85; taken 1940), elements of which can still be discerned in lidar imagery despite considerable modification of the original ground by earthworks, landscaping and building. The historical photography and lidar provide the basis for mapping this topographic feature. There is moderate confidence that it was formed by landslide movement.

Western Cedar Terrace / Riverhaven Drive: This southwest-facing slope overlooking the Weiti River estuary has variably irregular, stepped topography, evident in historical aerial photography (photo series SN143, run 85; taken 1940) that pre-dates development here, as well as in the 2013 and 2016 lidar. There is moderate confidence that the stepped topography was formed by landslide movement.

Central Cedar Terrace: This north-facing slope has irregular ground evident in historical aerial photography (photo series SN143, run 85; taken 1940), elements of which can still be discerned in lidar imagery despite considerable modification of the original ground by earthworks, landscaping and building. The historical photography and lidar provide the basis for mapping this topographic feature. There is moderate confidence that it was formed by landslide movement.

Eastern Cedar Terrace / Norfolk Road / Scott Road / Whangaparaoa Road: This feature occupies a broad north-facing topographic basin. The ground was farmland in pasture at the time of the earliest historical aerial photography (photo series SN143, run 85; taken 1940), and irregular stepped ground is clearly visible, as is a prominent topographic step encircling the western side of the basin which, despite considerable modification of the original ground by earthworks, landscaping and building, remains well expressed in the 2013/2016 lidar imagery. The historical photography and lidar provide the basis for mapping this topographic feature. There is moderate confidence that it was formed by landslide movement.

South side of Scott Road / Pāmu Wēra Drive / Hau Tapu Loop / Whenuateitei Crescent: This feature occupies a south-facing slope, with a prominent topographic step along its upslope margin. Variably irregular or benched terrain is evident on the slope in the 1963 historical aerial photography (photo series 1370, run H). Despite modification of the western and northern parts of the slope by earthworks, landscaping and building prior to 2013, elements of the original terrain remain well expressed in the 2013/2016 lidar imagery, especially an area of benched and locally stepped ground on the mid- to lower eastern slopes. Earthworks beginning in 2021 (Google Earth imagery) have now greatly modified the original ground in that area. Historical photography and lidar provide the basis for mapping this topographic feature. There is moderate to high confidence that it was formed by landslide movement.

Joydon Place: A small north-facing topographic basin, bordered seawards by the coastal cliff, is tentatively interpreted to be a landslide based on the landform setting. The ground surface was mostly obscured by scrub in 1940 (photo series SN143, run 85) and was subdivided and mostly built on by the time of the 1963 aerial photography (photo series 1370, run H). The mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the position of its perimeter. There is moderate confidence that it was formed by landslide movement.

Totara Road / Surf Road: A broad north-facing topographic basin in the head of a gully has indications of stepped terrain in 2013/2016 lidar and is tentatively interpreted to be a landslide based on the landform setting. The land was farmland in pasture and some scrub at the time of the 1940 aerial photography (photo series SN143, run 85), and the stepped terrain is also evident in the photo. The mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the positions of its perimeter. There is moderate confidence that it was formed by landslide movement.

Totara Road / Kauri Road / Rimu Road / Matai Road / Rata Road: A broad east-facing topographic basin has notably irregular ground in historical aerial photography (photo series SN143, run 85; taken 1940), when the area was farmland in pasture. Subdivision and extensive earthworks and building occurred prior to the 1963 aerial photography, and only the broad elements of the topographic basin are evident in the 2013/2016 lidar. The mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the positions of its perimeter. There is moderate confidence that it was formed by landslide movement.

Wade River Road / Ferry Road: What appears to be an area of somewhat irregular and stepped ground on this east-facing slope is evident in historical aerial photography (photo series SN143, run 85; taken 1940, and series 1370, run H; taken 1963). The stepped ground, backed to the west by a steep slope, is visible in the 2013/2016 lidar imagery. Mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the likely perimeter of this feature. There is moderate confidence that it was formed by landslide movement.

Ferry Road / Montpellier Heights: In this area, a broad southeast-facing topographic basin with stepped ground, adjoined to the southwest by a smaller south-facing slope, has irregular ground surfaces visible in historical aerial photography (photo series 1370, run H; taken 1963). Despite considerable modification by earthworks, landscaping and building, elements of the original terrain remain evident in the 2013/2016 lidar imagery. The mapping of these topographic features is based on interpretation of the historical photography, aided by lidar. There is moderate confidence that these were formed by landslide movement.

Kestrel Heights / Mollyhawk Rise / Coralsea Way: A small northwest-facing basin in a gully margin has irregular stepped ground visible in historical aerial photography (photo series 1370, run H; taken 1963). Despite considerable modification by earthworks, landscaping and building, elements of the original terrain remain evident in the 2013/2016 lidar imagery. The mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar. There is moderate confidence that it was formed by landslide movement.

Cochrane Avenue / Wade River Road / McKenzie Avenue: A steep south-facing slope that has had forest cover since at least 1940. Despite localised modification of the natural ground by road formation and building-related landscaping, its topographic features, with a steep crest to the slope and irregular topography on the slope indicated in lidar, suggest, with moderate confidence, that it was formed by landslide movement.

Wade River Road / McKenzie Avenue: A south-facing slope with a steep crest to the slope, broad bench below and indications of irregular ground in historical aerial photography (photo series SN143, run 85; taken 1940, and series 1370, run H; taken 1963) and 2013/2016 lidar. These features suggest that it may be a slumped block of bedrock. There has been considerable modification of the natural ground by road formation and building-related landscaping. There is moderate confidence that it was formed by landslide movement.

Stanmore Bay Road / Ardern Avenue / Melandra Road: What appears to be an area of somewhat irregular and stepped ground on this west-facing slope is evident in historical aerial photography (photo series SN143, run 85; taken 1940). The area was subdivided and largely built up by 1963, and the original landform has been completely modified by earthworks, landscaping and building. Mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the likely position of its perimeter. There is moderate confidence that it was formed by landslide movement.

Melandra Road / Swann Beach Road / Monyash Road / Hurdlow Place: What appears to be an area of somewhat irregular and stepped ground on this northeast-facing slope is evident in historical aerial photography (photo series SN143, run 85; taken 1940). The area was subdivided and largely built up by 1963, and the original landform has been greatly modified by earthworks, landscaping and building. Mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the likely position of its perimeter. There is moderate confidence that it was formed by landslide movement.

Stanmore Bay Road / Shuttleworth Place / Monyash Road: What appear to be two areas of somewhat irregular and stepped ground on this east-facing slope are evident in historical aerial photography (photo series SN143, run 85; taken 1940). Subsequent subdivision has resulted in the original landform being greatly modified by earthworks, landscaping and building. Mapping of these topographic features is based on interpretation of the historical photography, aided by lidar to interpret their likely perimeters. There is moderate confidence that these were formed by landslide movement.

Tower Hill / Kenneth Hopper Place: What appears to be an area of irregular and stepped ground on this northeast-facing slope is evident in historical aerial photography (photo series SN143, run 85; taken 1940). Subsequent subdivision has resulted in the original landform being greatly modified by earthworks, landscaping and building. Mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar to interpret the likely position of its perimeter. There is moderate confidence that it was formed by landslide movement.

Rawhiti Road / Brixton Road: What appear to be two areas of irregular and somewhat stepped ground on this northwest-facing slope are evident in historical aerial photography (photo series 1370, run H; taken 1963). Elements of these features are evident in the 2013/2016 lidar. Mapping of these topographic features is based mainly on interpretation of the lidar. There is moderate confidence that these were formed by landslide movement.

Roberts Road: What appears to be an area of irregular and somewhat stepped ground within a broad, north-facing, topographic basin is visible in historical aerial photography (photo series SN143, run 85; taken 1940). Only the general form of the basin is evident in the 2013/2016 lidar due to obscuring of the original ground surface by earthworks, landscaping and building. Mapping of this topographic feature is based on interpretation of the historical photography, aided by lidar. There is moderate confidence that it was formed by landslide movement.

Clayden Road: What appears to be an area of irregular ground on a south-facing slope is visible in historical aerial photography (photo series SN143, run 85; taken 1940). The original form of the ground has now been completely modified by earthworks, landscaping and building. Mapping of this topographic feature is based on interpretation of the historical photography. There is moderate confidence that it was formed by landslide movement.

Siesta Terrace: A northwest-facing topographic basin with what appears to be a somewhat irregular stepped ground surface in historical aerial photography (photo series SN143, run 85; taken 1940). The original form of the ground has been largely modified by earthworks, landscaping and building. Mapping of this topographic feature is based on interpretation of the historical photography. There is moderate confidence that it was formed by landslide movement.

The Anchorage / Te Kauae Rise: Two areas of irregular and stepped ground, one on a north-facing slope and the other on a west-facing slope, are clearly visible in historical aerial photography (photo series SN143, run 85; taken 1940) and evident in 2006 lidar. Subsequent landscaping as part of roading development and subdivision has largely or completely obscured the original landform. Mapping of these topographic features is based on interpretation of the historical photography, aided by lidar to interpret their likely perimeters. There is high confidence that these were formed by landslide movement.

Voyager Drive: An area of irregular ground on a south-facing slope is characterised by relatively subdued topographic steps defining a series of broad steps, visible in historical aerial photography (photo series SN143, run 85; taken 1940). The shoreline marks the downslope margin of this area. None of these landforms remain evident following landscaping as part of subdivision and development, other than a broad basin within which the features lay. Mapping of this area is based on interpretation of historical photography and lidar, and there is high confidence that it was formed by landslide movement.

Island View Drive: An area of curved topographic steps and irregular ground within an east-facing topographic basin is visible in historical aerial photography (photo series SN143, run 85; taken 1940), particularly towards the northern end of the area. Despite considerable modification of the original ground surface due to earthworks, landscaping and building, the topographic step at the upslope margin of the basin remains evident in 2013/2016 lidar and in Google Street View. Blocky debris is present along the shore platform adjacent to the seaward margin of this area. Mapping of this topographic feature is based on interpretation of historical photography and lidar. There is high confidence that its central and northeastern sector was formed by landslide movement. Its southwestern sector has very subdued hummocky ground and is assigned moderate confidence of being of landslide origin.

Pacific Parade: A north-facing basin landward of the coastal cliff has a prominent topographic step at its head and distinctively irregular ground clearly visible in historical aerial photography (photo series SN143, run 85; taken 1940). The original form of the ground has been greatly modified by earthworks, landscaping and building, but the basin overall remains evident in 2013/2016 lidar and in Google Street View. The basin is interpreted with high confidence to have been formed by landslide movement.

A2.6 Stillwater

Duck Creek Road / Coastal Heights / Stillwater Crescent: This northwest-facing slope within a broad topographic basin has irregular stepped ground evident in historical aerial photography (photo series 1565 E series, taken 1963) that pre-dates most of the subdivision and development. The ground irregularity is also discernible in 1940 aerial photography, despite thick scrub cover. Much of the original ground has been greatly modified by earthworks, landscaping and building, and only the general outline of the broad basin is evident in the 2006/2013/2016 lidar. There is moderate confidence that this basin was formed by landslide movement.

Duck Creek Road / Stillwater Crescent: Two shallow, southeast-facing basins, one large and one small, evident in the lidar are tentatively interpreted to have been produced by landsliding. These areas of slope were thickly scrub-covered at the time of 1940 aerial photography, and development was well underway at the time of 1963 aerial photography, with the ground modified by earthworks, landscaping and building. Mapping is based on the 2006/2013/2016 lidar, and there is moderate confidence that these areas of slope are the result of landslide movement.

Stillwater Crescent / Snapper Road / Donald Place: This shallow north-facing basin revealed in 2013/ 2016 lidar has its clearest expression at the head of the slope. The slope was partly covered in thick scrub at the time of 1940 aerial photography, and development was well underway at the time of 1963 aerial photography, with the ground modified by earthworks, landscaping and building. Mapping is based on the 2006/2013/2016 lidar, and there is moderate confidence that this basin was formed by landslide movement.

Stillwater Crescent / Snapper Road / Flounder Point Road: This northwest-facing slope is in a shallow basin revealed in 2013/2016 lidar. There are indications of irregular ground visible in historical aerial photography (photo series SN143, run 85; taken 1940), when the land was in pasture, but development was well underway at the time of 1963 aerial photography, with the ground modified by earthworks, landscaping and building. Mapping is based on the 2006/2013/2016 lidar, and there is moderate confidence that this area has been involved in landslide movement.

Flounder Point Road / Cockle Place / Duck Creek Road: This small northeast-facing basin has indications of irregular ground visible in historical aerial photography (photo series SN143, run 85; taken 1940), when the land was in pasture, but development was well underway at the time of 1963 aerial photography, with the ground modified by earthworks, landscaping and building. Mapping is based on the 1940 photography and 2006/2013/2016 lidar, and there is moderate confidence that this basin was formed by landslide movement.

A2.7 Long Bay – Torbay – Browns Bay – Rothesay Bay – Murrays Bay

Te Oneroa Way / Headsail Drive / Longshore Drive / Kumukumu Road / Tupa Street / Tawatawa Street / Tikati Rise: Three areas of irregular stepped ground on this generally south-facing slope are well expressed in the 2006 lidar but have subsequently been completely modified by earthworks, landscaping and building, as evident in the 2016 lidar. There is moderate confidence that these three areas were formed by landslide movement.

Glenvar Ridge Road / Koiora Lane / Kukupa Lane: An area of distinctively irregular ground lying downslope of a concentrically curved topographic step is clearly visible in historical aerial photography (photo series 3226, taken 1963) and 2006 lidar but, by the time of the 2016 lidar, had been completely modified by earthworks and landscaping. This area of irregular ground is interpreted with high confidence to have been formed by landslide movement.

Northern Ashley Avenue area: A large area of what appears to be irregular ground is evident in historical aerial photography (photo series 3226, taken 1963). Irregular ground in the northern part of this area is clearly visible in the 2006 lidar but, by the time of the 2016 lidar, had been completely modified by earthworks and landscaping. This area of irregular ground is interpreted with moderate to high confidence to have been formed by landslide movement.

Eastern central Long Bay: Four areas, each displaying closely spaced steps in the ground approximately following the original contour of the land, were originally present in the now intensively built-up area of central Long Bay. These landforms are clearly visible in historical aerial photography (photo series 3226, taken 1963), with most also present in the 2006 lidar and some in the 2013 lidar, but these have now been completely modified and obscured by earthworks, landscaping and building. Examples of similar landform features are preserved nearby in the hill terrain of Long Bay Regional Park. A good example has its upslope end about 100 m east of the gate into the regional park at the Headland Drive carpark. It is about 100 m wide and 175 m long, meeting the valley floor at about 5 m above sea level. The four, now obscured, areas of this landform type are tentatively interpreted, with moderate confidence, to have formed by landslide movement. An alternative is that these are some sort of erosional landform whose character reflects the nature of the underlying bedrock.

Fitzwilliam Drive / Emlyn Place / Portobello Place: This north-facing shallow topographic basin has distinctively stepped and irregular ground clearly visible in historical aerial photography (photo series 3226, taken 1963). Subsequent development has greatly modified the original ground by earthworks, landscaping and building, but the overall form of the topographic basin remains evident in 2006/2013/2016 lidar. Mapping is based on the historical photography aided by lidar, and there is high confidence that this basin was formed by landslide movement.

Stredwick Drive: This small west-facing shallow topographic basin has indications of irregular ground evident in historical aerial photography (photo series 3226, taken 1963). Despite subsequent development that modified the original ground by earthworks, landscaping and building, the topographic basin's overall form remains evident in 2006/2013/2016 lidar. Mapping is based primarily on lidar, with moderate confidence that this basin was produced by landslide movement.

Kate Sheppard Avenue / Devana Court: This small south-facing topographic basin has a concentric topographic step at its head, suggestive of landslide movement in the area downhill of the step. The area is thickly vegetated in historical aerial photography (photo series 3226, taken 1963), and the ground surface is not visible. Mapping is based on lidar, with moderate confidence that this basin was produced by landslide movement.

South end of Caversham Drive / Lingham Crescent / Phoebe Meikle Place / Carnmore Place / Shannon Place: This north-facing shallow topographic basin has distinctively stepped and irregular ground clearly visible in historical aerial photography (photo series 3226, taken 1963). Subsequent development has greatly modified the original ground by earthworks, landscaping and building, but the overall form of the topographic basin remains evident in 2013/2016 lidar. Mapping is based on the historical photography aided by lidar, and there is high confidence that this basin was formed by landslide movement.

Glamorgan Drive / Cranston Street / Cottam Grove / Topliss Drive: This south-facing slope has irregular ground evident in historical aerial photography (photo series 1911, taken 1940). The position and orientation of a topographic step running across the slope suggests that it was formed by slope movement. Development has greatly modified the original ground by earthworks, landscaping and building, but the topographic step within the area remains evident in 2013/2016 lidar. Mapping is based on the historical photography aided by lidar, and there is moderate confidence that this area has previously been affected by landslide movement.

Glamorgan Drive / Cranston Street / Lingham Crescent / Weatherly Road: This south-facing shallow topographic basin has concentric steps near its head evident in historical aerial photography (photo series 1911, taken 1940; and 3226, taken 1963) when the area was in pasture with some trees. Subsequent earthworks, landscaping and building has greatly modified the original ground, but the overall form of the basin remains discernible in 2013/2016 lidar. Mapping is based on the historical photography aided by lidar, and there is moderate confidence that this basin was formed by landslide movement.

Weatherly Road / Glamorgan Drive / Gerontius Glade: This northeast-facing slope has irregular and stepped ground clearly visible in historical aerial photography (photo series 1911, taken 1940). Development has greatly modified the original ground by earthworks, landscaping and building. Mapping is based on the historical photography aided by lidar, and there is high confidence that this area has previously been affected by landslide movement.

Alexander Avenue / Carina Crescent: This very shallow north-facing basin has indications of irregular ground evident in historical aerial photography (photo series 3226, taken 1963). Development has greatly modified the original ground by earthworks, landscaping and building. Mapping is based on lidar aided by the historical photography, and there is moderate confidence that this basin was formed by landslide movement.

Beach Road / Orchard Road / Oban Road / Valley Road: This southeast-facing topographic basin has a broad concentric topographic step up around its upslope margin, which does not appear to relate to a stream and gully drainage network. This basin was subdivided and developed before the earliest historical aerial photography (1940), with the ground greatly modified by earthworks, landscaping and building. Mapping is based on interpretation of the topography seen in the 2013/2016 lidar. There is moderate confidence that this basin was formed by landslide movement.

Beach Road / Carlisle Road: This southwest-facing topographic basin has a broad concentric topographic step up around its upslope margin, which does not appear to relate to a stream and gully drainage network. This basin was subdivided and developed before the earliest historical aerial photography (1940), with the ground greatly modified by earthworks, landscaping and building. Mapping is based on interpretation of the topography seen in the 2013/2016 lidar. There is moderate confidence that this basin was formed by landslide movement.

Bayview Road / Bute Road: This small south-facing topographic basin has a prominent concentric topographic step up around its upslope margin, which does not appear to relate to a stream and gully drainage network. The earliest historical aerial photography (photo series 1911, taken 1940) precedes subdivision and development, but the ground is completely obscured by trees. With the original ground now greatly modified by earthworks, landscaping and building, mapping is based on interpretation of the topography seen in the 2016 lidar. There is moderate confidence that this basin was formed by landslide movement.

Carlisle Road / Branston Avenue / Wilkinson Way / Oldham Place: This south-facing basin has indications of irregular ground evident in historical aerial photography (photo series SN143, taken 1940; and 3226, taken 1963). Earthworks, landscaping and building have now greatly modified the original ground. Mapping is based on historical photography aided by lidar, and there is moderate confidence that this basin was formed by landslide movement.

Barker Rise / Newstead Avenue / Stapleford Crescent: This southeast-facing slope has indications of irregular ground visible in historical aerial photography (photo series SN143, taken 1940; and 3226, taken 1963), although development and ground modification were in progress in 1963. Earthworks, landscaping and building have now greatly modified the original ground. Mapping is based on historical photography aided by lidar, and there is moderate confidence that this area has previously been involved in landslide movement.

Stapleford Crescent / Newstead Avenue / Carlisle Road / Kegworth Place / Sandiacre Way: These generally south-facing slopes wrap around the front of a ridge, with irregular ground clearly visible in historical aerial photography (photo series SN143, taken 1940; and 3226, taken 1963), although development and ground modification were in progress in 1963. Earthworks, landscaping and building have now greatly modified the original ground. Mapping is based on historical photography aided by lidar, and there is high confidence that this area has previously been involved in landslide movement.

Robin Lane / Stapleford Crescent / Sandiacre Way: This northeast-facing slope has distinctly irregular stepped ground clearly visible in historical aerial photography (3226, taken 1963; scrub completely obscured the ground at the time of 1940 photography). Subsequent earthworks, landscaping and building have now greatly modified the original ground. Mapping is based on historical photography aided by lidar, and there is moderate to high confidence that this slope has previously been involved in landslide movement. The southern part of this landslide is included in Figure 2.4 of this report.

King Richard Place / Sartors Avenue / John Downs Drive / Stapleford Crescent: Both sides of this east-draining gully have irregular stepped ground clearly visible in historical aerial photography (3226, taken 1963; scrub completely obscured the ground at the time of 1940 photography). Subsequent earthworks, landscaping and building have now greatly modified the original ground. Mapping is based on historical photography aided by lidar, and there is moderate to high confidence that these slopes have previously been involved in landslide movement. At the eastern end of this landslide is a topographic basin on the lower slope that is interpreted with high confidence as a landslide and mapped separately from the larger landslide. These landslides are included in the northern part of Figure 2.4 of this report.

Glencoe Road / Walnut Lane / Oaktree Avenue / Hollyhock Place / Arran Road: This north-facing slope has distinctly irregular stepped ground clearly visible in historical aerial photography (3227, taken 1963). During subsequent development, earthworks, landscaping and building have greatly modified the original ground. Mapping is based on historical photography aided by lidar, and there is high confidence that this slope has previously been involved in landslide movement. This landslide is included in the eastern part of Figure 2.4 of this report.

Nigel Road / Beach Road: A small basin on an east-facing slope that has what appears to be irregular ground evident in historical aerial photography (photo series 1911, taken 1940). The area has now been greatly modified by earthworks, landscaping and building, although overall elements of the basin and possibly stepped ground remain expressed in the 2013/2016 lidar. Mapping is based on historical photography aided by lidar, and there is moderate confidence that this basin was formed by landslide movement.

Arran Road / Phillipa Place / Nigel Road: This southeast-facing slope has irregular and, in places, stepped ground clearly visible in historical aerial photography (photo series 1911, taken 1940; and 3227, taken 1963). Subsequent earthworks, landscaping and building have now greatly modified the original ground. Mapping is based on historical photography aided by lidar, and there is high confidence that this area has previously been involved in landslide movement. The northwestern part of this landslide is included in the southern part of Figure 2.4 of this report.

Arran Road / Helvetia Drive: This southeast-facing slope has distinctly irregular and stepped ground clearly visible in historical aerial photography (photo series 1911, taken 1940), although the ground surface was hidden by scrub cover at the time of 1963 photography. Modification by subsequent earthworks, landscaping and building has obscured the original landform features. Mapping is based on historical photography aided by lidar, and there is high confidence that this area has been previously affected by landslide movement.

Calypso Place / Knights Road / Wyoming Avenue: This shallow southeast-facing topographic basin shows indications of irregular and stepped ground in historical aerial photography (photo series 1911, taken 1940; and 3228, taken 1963). Subsequent earthworks, landscaping and building mean that only the broad elements of the basin are discernible in the 2016 lidar. Mapping is based on historical photography aided by lidar, and there is moderate confidence that this basin was formed by landslide movement.

Calypso Place / Seaford Place / Macnay Way: This south-facing slope has irregular ground clearly visible in historical aerial photography (photo series 3228, taken 1963), although the ground surface is not well resolved in the 1940 photography. Modification by subsequent earthworks, landscaping and building has obscured the original landform features. Mapping is based on historical photography aided by lidar, and there is moderate to high confidence that this slope has previously been involved in landslide movement.

A2.8 Mairangi Bay – Campbells Bay – Forrest Hill – Castor Bay

Honeysuckle Lane / Tudor Place: This north-facing slope has indications of irregular ground evident in historical aerial photography (photo series 3228, taken 1963), although the ground surface is not well resolved in the 1940 photography. Subsequent modification by earthworks, landscaping and building has obscured the original landform features. Mapping is based on historical photography aided by lidar, and there is moderate confidence that this slope was formed by landslide movement.

Elizabeth Place / Kiri Place / Surville Place: This north-facing slope has irregular ground clearly visible in historical aerial photography (photo series 143, run 90, taken 1940), although development was underway, and the ground partly obscured by earthworks, at the time of 1963 photography. Subsequent modification by earthworks, landscaping and building has further obscured the original landform features. Mapping is based on historical photography aided by lidar, and there is moderate to high confidence that this slope was formed by landslide movement.

Nereus Place: This north-facing slope has what appears to be irregular ground evident in historical aerial photography (photo series 143, run 90, taken 1940), although development was underway, and the ground obscured by earthworks, at the time of 1963 photography. Subsequent modification by earthworks, landscaping and building has further obscured the original landform features. Mapping of this area is based on historical photography aided by lidar, and there is moderate confidence that this slope was formed by landslide movement.

Pupuke Golf Course: Within Pupuke Golf Course, three large areas of irregular stepped ground are evident in historical aerial photography (SN143/90/33 and SN143/91/30, taken 1940). The overall original topographic character remains visible in lidar data. All three have been modified by earthworks for the golf course, and residential housing along Aberdeen Road has encroached onto the south-eastern one. Mapping of these topographic features is based on available historical aerial photographs and lidar data and there is moderate confidence that these were formed by landslide movement.

Campbells Bay Tennis Club / Morton Way: Slightly irregular ground is evident from historical aerial photography (SN143/90/35, taken 1940). The area was modified prior to 2006 but the overall original topographic character remains evident in the lidar data. Mapping of this topographic feature is based on interpretation of what can be seen in the historical photos, and there is moderate confidence that it was formed by landslide movement.

Ravenwood Drive: A north-facing basin with irregular, stepped ground is evident in historical aerial photography (SN143/91/30, taken 1940) and the overall original topographic character is still visible in lidar data. The upper part of this area comprises Greville Reserve, but there are several houses, accessed via Ravenwood Drive, built on its lower slopes. Mapping of this topographic feature is based on available historical aerial photographs and lidar data, and there is moderate confidence that this basin was formed by landslide movement.

Beach Road southeast of the Aberdeen Road intersection: An east-facing basin with irregular stepped ground between Beach Road and the coastline is evident in historical aerial photography (SN143/91/30, taken 1940). The area was modified prior to 2006, but the overall original topographic character is still visible in lidar data. Mapping of this topographic basin is based on available historical aerial photographs and lidar data. There is moderate confidence that it was formed by landslide movement.

A2.9 Schnapper Rock

Lucas Creek View Way: A south-facing topographic basin below a curved scarp appears to have slightly irregular ground on historical aerial photography (SN143/90/29, taken 1940). The area was developed between 2013 and 2016, although the broad topographic features are evident in the older lidar data. Mapping of this basin is based on available historical aerial photographs and 2013 lidar data, and there is moderate to high confidence that it was formed by landslide movement.

A2.10 Glenfield

Powrie Street: Two separate areas of irregular ground are evident along a northeast-facing slope to the west of Powrie Street. The area appears as a series of stepped blocks on historical aerial photography (SN143/91/30 and SN143/92/29, taken 1940), and the overall original topographic character is still evident in the lidar data. The south-eastern end of this area is within the undeveloped Powrie Reserve. Mapping of these topographic features is based on available historical aerial photographs and lidar data, with moderate confidence that these were formed by landslide movement.

High Street / Woodcote Drive / Greendale Spur: A southeast-facing topographic basin with irregular stepped ground is evident on historical aerial photography (SN143/91/30, taken 1940). Residential housing development prior to 2006 has removed almost all topographic evidence of this feature. Its mapping is based on available historical aerial photographs, with moderate confidence that it was formed by landslide movement

Agincourt Street / Sovereign Place: An east-facing topographic basin with irregular stepped ground is evident in historical aerial photography (SN143/91/30, taken 1940). Residential housing development prior to 2013 has removed almost all topographic evidence of this feature. Mapping of this basin is based on available historical aerial photographs. There is moderate confidence that it was formed by landslide movement.

Manuka Road / Witheford Drive / Pemberton Drive / Fernlea Rise / Heathglen Place / Valecrest Place: Three adjoining basins on a south-facing slope are evident in the lidar data. This area is partly vegetated in historical aerial photography (SN143/91/30, taken 1940), but there appears to be irregular ground consisting of several arcuate blocks below a curved scarp. Mapping of these topographic features is based on available historical aerial photographs and lidar data, with high confidence that these were formed by landslide movement.

Manuka Road / Emery Grove: A north-facing basin with irregular ground is evident in historical aerial photography (SN143/91/30, taken 1940), and the overall original topographic character is still visible in lidar data. Mapping of this basin is based on available historical aerial photographs and lidar data, and there is moderate confidence that it was formed by landslide movement.

Chivalry Road / Ondine Place / Weldene Avenue / Hatherlow Street: A north-facing slope appears to have irregular ground on historical aerial photography (SN143/91/30, taken 1940). Residential housing development prior to 2006 has removed almost all topographic evidence of this feature. It is mapped from available historical aerial photographs, with moderate confidence that it was formed by landslide movement.

Albany Highway / Jacanas Place / Tenbless Court: A northeast-facing slope appears to have irregular stepped ground on historical aerial photography (SN143/91/30, taken 1940). Residential housing development prior to 2006 has removed almost all topographic evidence of this feature. It is mapped from available historical aerial photographs, with moderate confidence that it was formed by landslide movement.

Sunset Road / Odette Road: An east-facing basin with irregular stepped ground is evident in historical aerial photography (SN143/91/30, taken 1940), and the overall original topographic character is still visible in lidar data. Mapping of this topographic feature is based on available historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

Tree View Reserve / Seaview Road / Valley View Road: A southwest-facing basin near the head of a gully shows, despite scrub cover, several areas of irregular stepped ground in historical aerial photography (SN143/92/29, taken 1940). The general topographic features are also evident in lidar data. Subdivision and building have subsequently occurred on the southern and eastern parts of this area. The basin was mapped using available historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

A2.11 Chatswood – Birkenhead – Hillcrest – Northcote

Park Hill Road: A south-facing topographic basin is evident in lidar data spanning the eastern part of Park Hill Road. Historical aerial photography (SN143/92/29, taken 1940) appears to show slightly irregular ground, but most of the debris may have been vacated by natural processes or human action. This basin was mapped from available historical aerial photographs and lidar data, and there is moderate confidence that it was formed by landslide movement.

Glenfield Road / Speedy Crescent / Gretel Place / Ensign Place: The head of a southeast-facing gully has irregular stepped ground evident in historical aerial photography (SN143/92/29, taken 1940). Residential housing development prior to 2006 has removed almost all evidence of this topographic feature. It is mapped from available historical aerial photography, with moderate confidence that it was formed by landslide movement.

Akoranga Drive / Kitewao Street / Puriri Street: Three areas of irregular, hummocky or blocky ground in the broad floor of the Hillcrest Creek valley, each backed by a well-defined topographic step, are clearly visible in the 2016 lidar and in historical aerial photography (SN143/92/31, taken 1940). There is moderate to high confidence that these were formed by landslide movement. The smaller, more northwestern, landslide lies north of Hillcrest Creek and has not been built on, other than being crossed by the Akoranga Drive road formation. It abuts a larger elongate landslide to the south of the creek that is also crossed by Akoranga Drive, and part of it has been built over by a shopping complex and several houses. On the north side of Hillcrest Creek, the more northeastern landslide is traversed by State Highway 1, and part of it is built over by several houses and a retirement village.

Balmain Road: A north-facing basin has irregular ground evident in historical aerial photography (SN143/92/28, taken 1940). Residential subdivision and building since the 1950s has largely obscured the original landform. This feature was mapped from available historical aerial photographs and lidar data, and there is high confidence that it was formed by landslide movement.

Heaton Grove / Mappin Place / Langstone Place / Porritt Avenue: On a southwest-facing slope in the Duck Creek valley, what appears to be an area of slightly irregular ground in a topographic basin lies below a distinct curved topographic step evident in lidar surveys. The ground was obscured by vegetation in at time of 1940 aerial photography and by houses since subdivision in the early 1970s. Mapping of this basin is based on the topographic characteristics evident in the lidar data, with moderate confidence that it was formed by landslide movement.

Porritt Avenue / Blundell Place: A southwest-facing basin on the northern side of the Duck Creek valley has a curved form and irregular ground evident in lidar data. The ground was obscured by vegetation in historical aerial photography (SN143/92/28, taken 1940). This feature was mapped from lidar data, with moderate confidence that it was formed by landslide movement.

Chatswood Grove / Calman Place / Porritt Avenue / Holyoake Place / Colonial Road: A southwest-facing topographic basin with arcuately-stepped irregular ground is evident in 2006 and 2016 lidar. The ground was obscured by scrubby vegetation at the time of aerial photography in 1940 and by houses since subdivision in the early 1970s. Mapping of this basin is based on the topographic characteristics evident in the lidar data, with moderate confidence that it was formed by landslide movement.

Rawene Road / Inkster Street: An east-facing topographic basin with arcuately-stepped irregular ground is evident in 2006 and 2016 lidar. The ground was already obscured by houses at the time of aerial photography in 1940. This basin was mapped based on the topographic characteristics evident in the lidar data, with moderate confidence that it was formed by landslide movement.

Porritt Avenue / Blundell Place: A southwest-facing basin on the northern side of the Duck Creek valley has a curved form and irregular ground evident in lidar data. The ground was obscured by vegetation at the time of 1940s aerial photography (SN143/92/28, taken 1940). This feature was mapped from lidar data, with moderate confidence that it was formed by landslide movement.

Exmouth Road / Howard Road: A southeast-facing area of irregular ground on the northwestern margin of the Onepoto volcanic crater is evident in in historical aerial photography (SN143/92/32, taken 1940) and in lidar data. This feature was mapped from lidar data, with moderate confidence that it was formed by landslide movement.

A2.12 Bayswater

Bayswater Avenue / Beresford Street: A northwest-facing topographic basin below an arcuate topographic step is visible in the lidar. It is partly occupied by O'Neills Point Cemetery, with housing on its western part. Historical aerial photography (SN143/92/33, taken 1940) shows that the eastern part of the basin was already partly modified by the cemetery in 1940, but there is irregular ground to the west of this. Mapping of this feature is based on available historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

Eversleigh Road / Keys Street: A south-facing area of irregular stepped ground is evident in historical aerial photography (SN143/92/33, taken 1940) between the southern end of Eversleigh Road and Keys Street. This area was already built up in 2006, but both the 2006 and 2016 lidar survey show that the broad topographic elements are still evident. This feature is mapped based on available historical aerial photographs and lidar data, with moderate confidence it was formed by landslide movement.

Hillary Crescent / Lowe Street: Two adjoining northwest-facing topographic basins on the northwest side of Eversleigh Road are evident in the lidar data. The first underlies an area that has been subdivided for housing but, other than the formation of Hillary Crescent, has not been built on (Google Earth imagery, February 2024). The second basin is just to the northeast and underlies Northboro Reserve. Although scrubby, both areas show up on historical aerial photography (SN143/92/33, taken 1940) as irregular stepped ground. Mapping of these features is based on available historical aerial photographs and lidar data, with moderate confidence that these were formed by landslide movement.

A2.13 Beach Haven – Birkdale

Kauri Park School: An area of slightly irregular ground in a topographic basin on an east-facing slope below a distinct curved scarp is evident in historical aerial photography (photo series 143, run 92 number 27; taken 1940) prior to development of the school. The scarp and what remains of the irregular ground near the base of the slope are evident in 2016 lidar. Mapping of this feature is based on the interpretation of what can be seen in the historical photos, and there is moderate confidence that it was formed by landslide movement.

Bishopgate Street / Canongate Street / Abbeygate Street / Erewhon Place / Salisbury Road / Verbena Road: Two topographic basins face each other and merge along the headwaters of an unnamed stream near Birkdale. These areas are both visible as slightly irregular ground in historical aerial photography (photo series 143, run 92 number 27 and 29; taken 1940). The basins and their irregular topography are still evident in the lidar data. Mapping of these features is based on interpretation of what can be seen in the historical photos, with moderate confidence that these were formed by landslide movement.

Island Bay Road / Odin Place: Two adjoining topographic basins on a north-facing slope are evident in the lidar data and have what appears to be irregular ground in historical aerial photography (photo series 143, run 92 number 28; taken 1940). The area was already developed by 2006, but the basins are still visible in the lidar data. Mapping of these features is based on interpretation of what can be seen in the historical photos, with moderate confidence that these were formed by landslide movement.

Mariners View Road: A southwest-facing topographic basin with arcuately-stepped irregular ground is evident in 2006 and 2016 lidar. Historical aerial photography (photo series 143, run 92 number 27; taken 1940) appears to show slightly irregular ground in this area, although there was partial scrub cover at that time. Mapping of this feature is based on historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

Hadfield Street / Sea Vista Avenue / Anchor Place / Rangatira Road: A southwest-facing topographic basin is evident in 2006 and 2016 lidar. Historical aerial photography (photo series 143, run 92 number 27; taken 1940) appears to show slightly irregular ground in this area, although there was partial scrub cover at that time. Mapping of this feature is based on what can be seen in historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

Rangatira Road / Island Bay Road / Pluto Place: A broad west-facing topographic basin at the head of a gully has stepped ground evident in the lidar data and in historical aerial photography (photo series 143, run 92 number 28; taken 1940). The area was already developed by 2006. Mapping of this feature is based on interpretation of what can be seen in the historical photos, with moderate confidence that it was formed by landslide movement.

Rangatira Road north of Island Bay Road intersection: A small, northeast-facing topographic basin with arcuately-stepped irregular ground is evident in 2006 and 2016 lidar just north of Rangatira Road. Historical aerial photography (photo series 143, run 92 number 24; taken 1940) appears to show slightly irregular ground in this area, although there was partial vegetation cover at that time. Mapping of this feature is based on available historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

Neptune Avenue / Sispara Place: What appears to be an area of irregular ground on a south-facing slope is evident in historical aerial photography (photo series 143, run 92 number 27; taken 1940), although the area was partly vegetated at that time. Irregular topography is evident in the 2006 and 2016 lidar surveys. Mapping of this feature is based on available historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

Rosecamp Road / Mayall Avenue / Teal Crescent: Two adjoining elongate southwest-facing basins are evident in lidar data. In historical aerial photography (photo series 143, run 92 number 27; taken 1940) these appear to have slightly irregular ground below an arcuate topographic step. Most of the debris appears to have vacated the area or been smoothed over by natural processes or human action. Mapping of these features is based on available historical aerial photographs and lidar data, with moderate confidence that these were formed by landslide movement.

Beach Haven Road / Sunnyhaven Avenue: A southwest-facing topographic basin with arcuately stepped irregular ground is evident in 2006 and 2016 lidar. Historical aerial photography (photo series 143, run 92 number 27; taken 1940) appears to show slightly irregular ground, but most of the debris may have been vacated or smoothed over by natural processes or human action. Mapping of this feature is based on available historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

A2.14 Massey

Don Buck Road / Massey High School: Irregular ground below a curved topographic step in a southwest-facing hillslope basin is evident on historical aerial photography (SN147/94/16, taken 1940). This area was already built up in 2006, mainly for Massey High School. Much of the basin was filled in and levelled for playing fields, whereas some of the upper part was excavated and now underlies the school's buildings. A small portion of the original landform is preserved in the west. Mapping of this feature is based on available historical aerial photographs, with high confidence that it was formed by landslide movement.

McClintock Road / Carillon Place: Two northeast-facing topographic basins with slightly irregular ground are evident in historical aerial photography (SN147/94/16, taken 1940). The area was already built up in 2006, but the general topographic characteristics remain evident in the lidar data. Mapping of these features is based on available historical aerial photographs, with moderate confidence that these were formed by landslide movement.

Carnelian Court / Richfield Crescent: An area of irregular ground on a northwest-facing slope is evident on historical aerial photography (SN143/93/17, taken 1940). The area was already built up in 2006, and the natural ground features have been completely removed or obscured by residential housing and part of a sports field. Mapping of this feature is based on available historical aerial photographs, with moderate confidence that it was formed by landslide movement.

A2.15 Helensville

Urumaraki Avenue / Awa Avenue / Turehu Road / Minerva Avenue: An area of irregular, stepped ground on an east-facing slope is evident on historical aerial photography (SN143/87/13, taken 1940), and a subtle area of raised ground is evident in the 2006 lidar data. Subsequent residential development has removed or obscured all of the natural landform. Mapping of this feature is based on available historical aerial photographs and 2006 lidar, with moderate confidence that it was formed by landslide movement.

Hand Road / Wishart Road: An area of irregular ground on a west-facing slope below a curved topographic step is evident on historical aerial photography (SN143/87/13, taken 1940), and the overall original topographic character is evident in the 2016 lidar data. Mapping of this feature is based on available historical aerial photographs and lidar data, with low to moderate confidence that it was formed by landslide movement.

St James Avenue / Makiri Street / Mangakura Road / St Julia Court: An area of irregular ground on a northwest-facing slope is evident on historical aerial photography (SN143/87/13, taken 1940), and the overall original topographic character is evident in the 2016 lidar data. Mapping of this feature is based on available historical aerial photographs and lidar data, with low to moderate confidence that it was formed by landslide movement.

St James Avenue / Garfield Road / Kaipara Crescent / Downer Street / Makiri Street / Puriri Street: A west-facing slope below an irregular curved topographic step appears to have slightly irregular ground in historical aerial photography (SN143/87/13, taken 1940), and the overall original topographic character is evident in the 2016 lidar data. Mapping of this feature is based on available historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.

A2.16 Muriwai

Motutara Road / Oaia Road: A large west-facing basin with irregular ground below a curved topographic step is evident in historical aerial photography (SN143/93/2-4, taken 1940) and lidar data. Although partly forested in 1940, the irregular texture of the ground was still apparent. It is now partly smoothed by Motutara Road and residential modifications. The large topographic step (up to 80 m high in places), interpreted as the headscarp of a large landslide that has formed the basin, was the source of several shallow landslides in 2023 (the Auckland Anniversary and Cyclone Gabrielle storms) that resulted in fatalities. The lower part of the basin has been invaded by sand dunes blown in from the nearby coast. Mapping of this feature is based on available historical aerial photographs and lidar data, with high confidence of a landslide origin.

Domain Crescent / Motutara Road / Oaia Road: Two adjoining areas of irregular terrain are identified from lidar data and historical aerial photography (SN143/93/2-4, taken 1940), as follows:

- The eastern (upslope) area comprises somewhat subdued irregular ground below a steep topographic step. It is tentatively interpreted to have formed from debris falls from the topographic step that has filled in pre-existing gullies eroded into the bedrock. Mapping of this feature is based on available historical aerial photographs and lidar data, with moderate confidence that it was formed by landslide movement.
- The western (downslope) area has better expressed ground irregularity and is interpreted to represent re-mobilisation of debris that was formerly contiguous with the upslope area. Although partly forested in 1940 and partly built up by 2006, the irregular texture of the ground is still apparent in the photos and lidar data. This area is mapped from the photography and lidar, with high confidence that it was formed by landslide movement.

Domain Crescent / Motutara Road / Waitea Road: An area of irregular ground below a curved topographic step on a northwest-facing slope is evident in historical aerial photography (SN147/93/2, taken 1940) and lidar data. Although partly forested in 1940, the irregular texture of the ground was still apparent in the photos. The feature is mapped based on historical aerial photographs and lidar data, with high confidence that it was formed by landslide movement.

Waitea Road / Edwin Mitchelson Road / Berridge Road / Ngatira Road: Several areas of conspicuously irregular terrain are apparent in historical aerial photography (SN147/94/1, taken 1940), some parts of which remain evident in the lidar data. The ground is predominantly hummocky, with many curved blocks stepping down in different directions, consistent with having been broken up by different episodes of landslide movement. One area along Berridge Road is smoother and may represent an older landslide that is partly eroded or covered by sand. Mapping of these features is based on available historical aerial photographs and lidar data, with high confidence that these were formed by landslide movement.

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