ATTACHMENT E4

Taroona Landslide Area

Kingborough draft Local Provisions Schedule

This page intentionally left blank

Mineral Resources Tasmania
Department of Infrastructure, Energy and Resources

Tasmania
Explore the possibilities

Kingborough Council

Taroona Landslide Area

"The History, Current Understanding of Risks and Proposed Management of the School Creek Landslide and Surrounds"

September 2014

Table of contents

Figure index

Appendices

1. Introduction

1.1 Purpose of this Report

The purpose of this report is to provide a general overview of the history, potential risks imposed by, and proposed ongoing management of the landslides at Taroona, and in particular the School Creek Landslide (Figure 1). This summary is based on recent investigations undertaken by GHD with supplementary information supplied by Mineral Resources Tasmania (MRT).

The report is intended to provide general information on the landslide feature without going into specific details in terms of the technical aspects of the landslide. Much of the technical details are contained in three recent reports published by GHD for Kingborough Council as well as those from MRT and other sources.

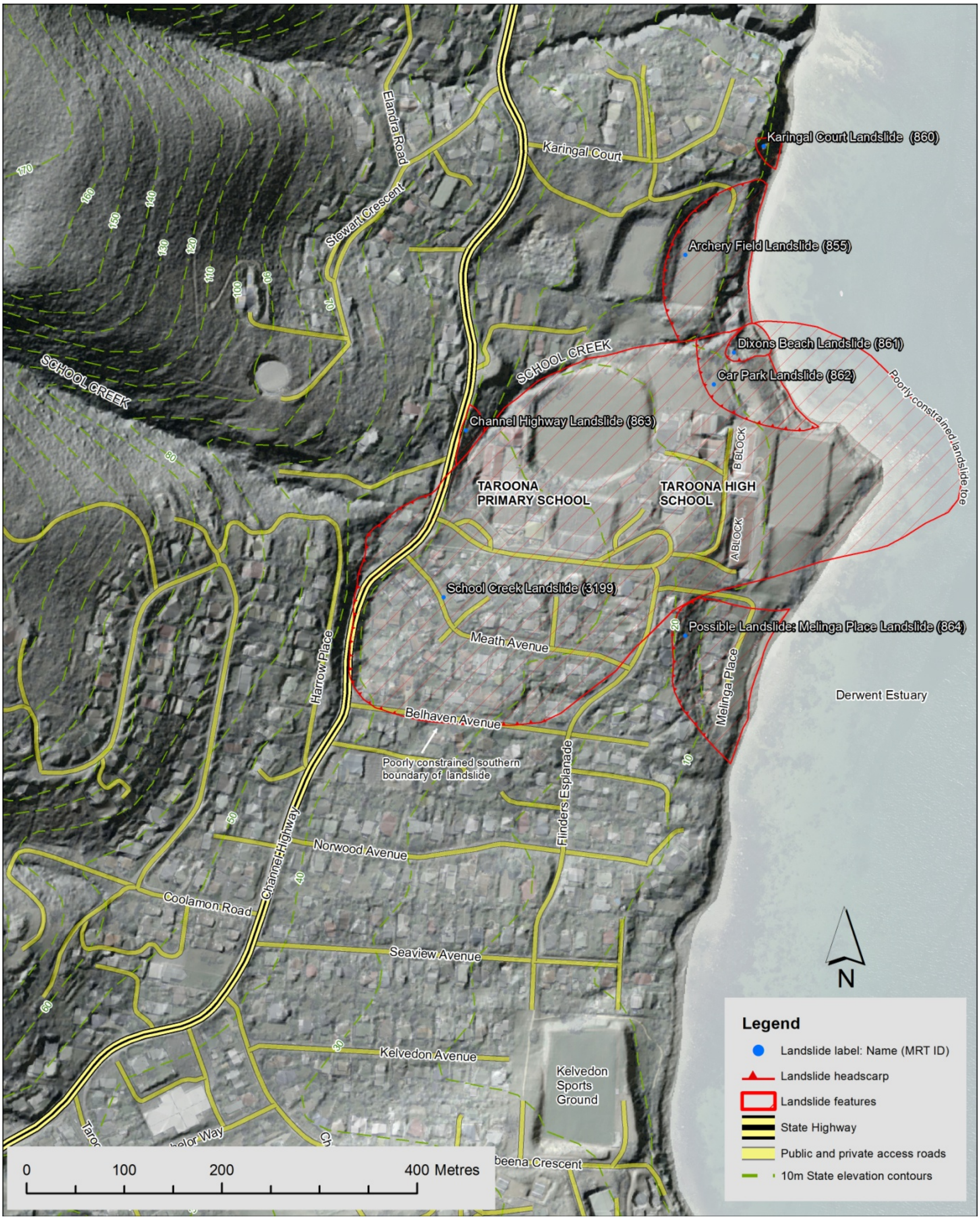


Figure 1 General plan of the landslides at Taroona

1.2 Scope and Limitations

This report: has been prepared by GHD and Mineral Resources Tasmania (MRT) for Kingborough Council and may only be used and relied on by Kingborough Council for the purpose agreed between GHD and the Kingborough Council as set out in section 1.1 of this report.

GHD and MRT otherwise disclaim responsibility to any person other than Kingborough Council arising in connection with this report. GHD and MRT also exclude implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD and MRT in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD and MRT have no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD and MRT described in this report (refer section(s) 1, 2 and 3). GHD and MRT disclaim liability arising from any of the assumptions being incorrect.

GHD and MRT have prepared this report on the basis of information provided by Kingborough Council and others who provided information to GHD and MRT (including Government authorities), which GHD and MRT have not independently verified or checked beyond the agreed scope of work. The authors do not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2. History of Landslides at Taroona

The evidence for active land-sliding at Taroona has been gradually compiled from various episodic observations and investigations over a period of nearly 40 years. Unfortunately the understanding of the landslides was developed well after housing and schools were developed. A brief introduction to the landslides is provided below.

There are several relatively small active coastal landslides that have been known since the 1970’s (namely the **Archery Field, Car Park and Dixons Beach Landslides**) that have a relatively clear expression on the landscape Figure 1. There are currently no buildings on these features.

Subsidence and damage along the Channel Highway, centred about 100m north of the intersection of the school driveway has been ongoing for several decades. This feature, here named the **Channel Highway Landslide** (Figure 1), is considered to be a small landslide and is probably related to failure of the embankment fill.

There is a much larger feature - the **School Creek Landslide**, in the vicinity of the two schools and south to Belhaven Avenue (Figure 1) which is an active landslide. This feature is not obvious on the landscape. It had been known for many years that buildings in the general area have required periodic structural repairs, much of it attributable to poor foundation construction on highly reactive soil. However, the continuing program of repairs to a section of the Channel Highway adjacent to the Taroona Primary School appear to have prompted more critical investigation of land instability in the mid 1970’s by the then Department of Main Roads. This resulted in a large landslide hypothesis (Moon and McDowell 2002) that has been subsequently refined by various parties. In hindsight direct evidence of contemporary movement of the School Creek Landslide dates back to the beginning of aerial photography in the State (mid 1940’s).

An even bigger feature, the **Taroona Landslide Complex**, was proposed by Moon and McDowell (2002) to contain the School Creek Landslide in the north and extend south to the vicinity of the Kelvedon Sports Ground. However, the evidence for the landslide complex is not definitive and is not clearly expressed in the landscape. Subsequent monitoring has not provided evidence of active movement south of Belhaven Avenue.

A further landslide has been mapped in the vicinity of Melinga Place (the **Melinga Place Landslide**), based entirely on the arcuate form of the landscape. This feature is classified by MRT as a **possible** landslide as there could be other explanations for the landscape form and there is no evidence of recent movement.

2.1 Previous Studies

Since the identification of significant ground movement in the 1970’s, the Taroona area has been the subject of a significant range of published and unpublished studies, many of which are available from the websites of MRT and Kingborough Council. These reports include a geological investigation by Latinovic et. al. (2001) and a landslide risk assessment report by Coffey Geosciences (Moon and McDowell 2002).

Landslide monitoring equipment (viz. inclinometers) was installed by the Department of Main Roads along the Channel Highway in early 1990’s. The monitoring activity was subsequently taken over by Mineral Resources Tasmania and expanded in area. The information arising from this monitoring has progressively improved the understanding of landslide distribution and nature of movement. The position of instrumentation and survey monitoring points are shown in Appendix C.

In 2009 MRT and the State Emergency Service organised a risk assessment workshop to which key stakeholders were invited. Preparation for the workshop included a technical review of existing information that substantially improved the understanding of the landslides. One of the principal outcomes of the workshop was recognition of the need to undertake further investigations to address key questions facing the stakeholders, especially how to manage their risks. This led Kingborough Council and partnering organisations to apply for federal grants from the Natural Disaster Resilience Programme. The outputs from the successful applications were awarding of contracts to GHD, beginning in 2011 to undertake these investigations that forms the basis of this report. The technical reports produced by GHD are summarised below.

2.2 Recent GHD Studies

The recent and ongoing GHD study, with contributions from Mineral Resources Tasmania (MRT), has been undertaken for Kingborough Council and commenced in 2011. This study has been undertaken using a staged approach with the aim of assisting the key stakeholders in managing the risk due to landslide activity in the Taroona area.

2.2.1 Stage 1

This stage of the study commenced in 2011 and was reported in March 2012.

Major elements included:

- A validation study, including collation and review of the available geotechnical and infrastructure information.
- Revision of the geological model considering information subsequent to the Latinovic et al. (2001) report.
- Development of a GIS based data repository of landslide related information.
- Development of 3D digital models to allow visualisation of landslide activity.
- Re-survey of the previous Channel Highway road survey to estimate net movement since the original surveys in the 1980s.
- A technical review to refine the geological setting and behaviour of the landslide(s). The information included in this technical review included historic information, physiographic evidence, infrastructure damage, inSAR (Interferometric synthetic aperture radar) survey results and borehole inclinometer monitoring results.
- Preparation of a series of images to allow technical and non-technical conceptualisation of the geometry and location of the landslide and related features.
- Preparation of recommendations for additional investigation and monitoring.
- Preparation of interim planning advice.

The results of this stage of the study were reported in March 2012 in GHD Report 32/15950/55683, ‘Report for Technical Review for Taroona Landslide – Risk Assessment & Mitigation Stage 1’, with planning advice provided in April 2012 in GHD Report 32/15950/56097, ‘Taroona landslide risk assessment and mitigation plan. Interim planning advice’.

2.2.2 Stage 2A

Stage 2 of the study was commenced in February 2013 and comprised the following activities:

- Collation and analysis of InSAR survey data (a satellite based remote sensing method for measuring land movement) to improve the delineation of the extent of landsliding in the School Creek area.
- A CCTV (Closed Circuit TeleVision) survey of the stormwater drain network at the site to identify any damage to the stormwater pipes that may be attributed to landslide movement.
- A visual structural inspection of buildings in the School Creek area to determine the extent and type of damage which may be attributed to landslide movement.

InSAR

The results of the InSAR survey provided positive confirmation of mass ground movements within the School Creek Landslide area. Unfortunately, the data did not provide sufficiently precise spatial or temporal information to accurately define the extent, type and movement characteristics of the landslide.

CCTV Survey of Stormwater

A total of 1.6 km of stormwater drains was surveyed with a CCTV system during April 2013, and a large number of pipe displacements were identified. Although the majority of these were not considered to be indicative of significant soil displacement, a limited number of angular and longitudinal displacements have occurred at various locations in the storm water pipe system and may be attributed to landslide movement.

These observations may identify longer term movements and when combined with other data may show the direction of movements and recent activity.

Visual Damage Survey

A total of 81 property visual assessments were completed during February to May 2013. These assessments identified the most probable cause of distress in all buildings to be attributable to reactive foundations. Some distress in footpaths in Meath Avenue and the road pavement in Channel Highway (from 40 m north of the school driveway intersection to Belhaven Ave intersection) are attributable to landslide movement; however parts of the Channel Highway distress, particularly opposite the primary school, are also consistent with instability of local fill embankments below the roadway (the Channel Highway Landslide).

It was therefore recommended that no further assessment of the distress in the inspected buildings is required to assist with the study of the landslide(s) at Taroona.

The results of this stage of the study were reported in August 2013 in GHD Report 32/16698/59062, “Taroona Landslide Risk Assessment & Mitigation Stages 2 & 3- Report for Stage 2A’, prepared for Kingborough Council.

2.3 Stage 2B

Stage 2B comprised improvements to the ground survey network and installation of additional underground instruments to monitor landslide movement and pore water pressure from groundwater fluctuations; the data from which would be useful in correlating observed moments from the inclinometers with rainfall records.

2.3.1 Survey Network Upgrade

An analysis of existing permanent survey monuments was undertaken to help define the movement and extent of the active landslides. Unfortunately, given that these survey features were installed for a different purpose and survey accuracy they mostly provided only limited information regarding landslide movement.

In order to establish a more robust and useful survey control, a total of 17 additional permanent survey monuments were installed. The locations of these were chosen mainly to allow better monitoring of the School Creek Landslide (including constraining the margins of the slide), but also to detect possible movement on the Taroona Landslide Complex and the Melinga Place, Car Park and Archery Field landslides. The new survey monuments were built to a very high standard and will allow long term monitoring capability, conceivably into the 22nd Century. Appendix C shows the current monitoring network including new survey monuments.

2.3.2 Additional underground instruments for landslide monitoring

Systematic landslide monitoring at Taroona (since 1991) has mainly been through the use of inclinometers. Inclinometers consist of plastic tubes permanently installed in boreholes, down-which a probe is lowered to measure any deformation that may have occurred between measurements from which movement vector and geometry can be potentially derived. Each year MRT commission a geotechnical engineer with specific landslide expertise to undertake this task.

In 2008, a more sophisticated monitoring system was installed near the Primary School that measures rainfall, groundwater pressure (using an instrument called a piezometer) and landslide movement (using permanently installed inclinometer probes) on an hourly basis (giving “near real time” data). While this system is presently working very well, these types of instruments have a finite life-span and will eventually fail, possibly within this decade.

In order to address this life-span issue, and to further our understanding of the landslide, two new boreholes were drilled near the intersection of Flinders Esplanade and Melinga Place in which an inclinometer casing and two peizometers have been placed. These are shown on Appendix C.

The results of this stage of the study were reported in January 2014 in GHD Report 32/16698/60230, “Taroona Landslide Risk Assessment & Mitigation Stages 2 & 3- Report for Stage 2B – Geological Drilling Factual Report & Installation of New Permanent Survey Monitoring Points’, prepared for Kingborough Council.

3. Current State of Knowledge of Earth Movements at Taroona

3.1 Type and Extent of Earth Movement

- Taroona Landslide Complex

The Taroona Landslide Complex concept, as proposed by Coffey Geosciences (Moon and McDowell 2002), was based on recognition of an area of slightly hummocky ground south of the School Creek Landslide. Coffey Geosciences considered this to be a large deep-seated landslide in which smaller parasitic landslide features occur, all of which (except for the Melinga Place Landslide) are active. However, the evidence for the landslide complex existence is weak and while it cannot be definitively discounted there is certainly no evidence of recent landslide movement. For this reason it has not been included in the risk assessment component of this report. However, as previously discussed, the new monitoring network has been expanded to detect any movement within this area should it occur.

- School Creek Landslide

The School Creek Landslide (SCL) is currently regarded as the largest of the active landslides at Taroona, and for which there is a large amount of evidence to prove its existence and define its extent and kinematic (movement) style. The SCL is a deep-seated translational feature controlled by bedrock structure and contains two smaller parasitic landslides on the coast, the Car Park and Dixons Beach landslides. These parasitic features have behaved in a different manner to the parent feature and therefore need to be considered separately in terms of the risk assessment. The margins of the landslide have been adjusted more than once by MRT to fit improved topographic information and other emerging evidence. For instance the Archery Field Landslide has been removed from the SCL by MRT to simplify the geometry. The School Creek Landslide is the principal focus of the risk assessment given that it contains the two schools and a substantial number of residences.

- Car Park and Dixons Beach landslides

These two landslides are situated on the High School grounds adjoining the foreshore. They were documented in 1988 when active movement was recorded by the Department of Main Roads. The Car Park Landslide is a rotational landslide of uncertain depth but may be deep-seated (> 5m below the ground surface). The Dixons Beach Landslide is a shallow and largely translational feature, parasitic to the Car Park Landslide. The two features are set in an area of active coastal retreat but two reports of movement in 1988 and 1989 (involving 2-3m of movement) may have been exacerbated by placement of fill onto the area.

A sewer line is present in proximity to the Car Park Landslide headscarp and water testing was undertaken in 1989 to determine whether there was a possible leak in the pipe. The results were negative. However, in February 2014 leakage in the pipe was discovered by TasWater and there is an unconfirmed report that this was due to landslide movement. While the two landslides do not have buildings constructed on them, the risks they present to adjacent buildings and motorists needs to be assessed separately from the SCL.

- Melinga Place Landslide

The Melinga Place Landslide is classified by MRT as a possible deep-seated landslide feature on which no definitive active movement has been reported. Given the uncertainty of the feature, it is not considered in the risk assessment. A ground survey monument has been recently installed to record future movement should it occur (refer Appendix C).

- Archery Field Landslide

The Archery Field Landslide is a deep-seated rotational landslide on which recent activity (up to 0.3m) was recognised in the 1970's (Donaldson 1977). However, the boundaries of the feature are not well constrained and the landscape has been heavily modified disguising the landslide margins. The setting of the landslide is similar to that of the Dixons and Carpark landslides, being closely related to contemporary coastal processes. The toe of the landslide is in the form of a coastal cliff, over steepened by marine erosion and retreating through rock fall and shallow landslide processes. Moon and McDowell (2002) mapped a small landslide on the cliff here which they named the Foreshore Landslide, although for reasons of scale MRT have chosen not to show it on Figure 1. While there are no current developments on this area, any proposal to develop the land should be strongly discouraged. A ground survey monument has been recently installed to record future movement (refer Appendix C)

- Channel Highway Landslide

This landslide has records of highway damage dating back several decades and continues to the present. The extent of the feature is approximate as margins of the feature are not precisely known. It is possible that the deformation is caused by shallow failure of the embankment fill triggered by local groundwater accumulation associated with rainfall events. Treatment options to stabilise the road have been applied at several instances although this is not well documented. A gabion wall was constructed in 2008 that has showed progressive deformation since it was built. Tension cracks have been noted by MRT at the base of the gabion wall after rainfall events. When inspected, these cracks were filled with water along with evidence of piping structures (tunnels formed by groundwater movement, exiting on the slope). Based on concerns regarding the stability of the bank adjacent to the Taroona Primary School playground, additional stabilisation measures were added in 2013 through the insertion of timber piles into the ground at the base of the gabion wall.

3.2 School Creek Landslide

The School Creek Landslide is believed to be a feature that formed long before urbanisation of the area, possibly hundreds of years or more ago. The evidence for this is in the unusual arcuate trace of School Creek below the Channel Highway. Normally streams in this setting would follow roughly straight paths but this shape appears to be a natural feature as it existed in nineteenth century plans of the area (Anon 1988). The creek would appear to be intimately related to the landslide, the latter creating a depression along which the creek follows rather than maintaining a straight course to the sea. There is also evidence that the landslide has moved episodically over time. Since the 1940's when regional aerial photography commenced, each of the subsequent surveys show damage to the road pavement in the vicinity of the headscarp.

It was only after the schools and adjacent subdivisions were constructed that the annual movement of the landslide become observable.

This prolonged period of uncertainty in recognising the landslide is a result of the following factors:

- The landslide movements are very gradual, and annual movements are generally small and spatially and temporally variable.
- Evidence of past landslide movements has largely been masked by construction activities.
- The soils in the area are generally highly reactive and it is difficult to assign the cause of observed deformation effects on buildings and other infrastructure to landslide movement or to reactive soil movement.

- Much of the base data available for defining the extent, and type, of landslide activity is highly variable in frequency and precision.

Since the work of Moon and McDowell (2002), more recent information and analysis have confirmed the broad areal extent of the landslide complex, the rate of movement and correlation of movement with rainfall and groundwater observations (Figure 2 and Figure 3). Inclinometer monitoring (including two instruments installed since 2002) has revealed that the landslide is moving in similar directions, although slightly different rates. Minor adjustments to the landslide outline have been made by MRT, the most significant being the adjustment to the northern boundary to exclude the Archery Field Landslide and therefore simplify the landslide geometry. The other adjustment being the shifting of the southern boundary away from the High School A-Block given there is no noticeable distortion of the large rigid structure. Previous reports of damage to A-Block are attributed to causes other than landslide movement (Gandy 1988).

However, despite advances in our knowledge, there remain a number of aspects of the landslide that are still not clear. Of the most important aspects is the poorly constrained position of the southern boundary, given that there is no obvious landscape expression and despite parts of it apparently intersecting houses and infrastructure. Moon and McDowell (2002) proposed that the boundary may occur in localised zones of distortion, tension or shear which may help to explain this phenomenon. 3D modelling by MRT suggests that this boundary may be steep (~40 degrees), similar to bedrock dip, and therefore form a broad zone of deformation in the near surface soils. To address this question, a new inclinometer has been installed that should with time shed light on the problem. Furthermore, the establishment of a ground monitoring network will also help to constrain the landslide boundaries.

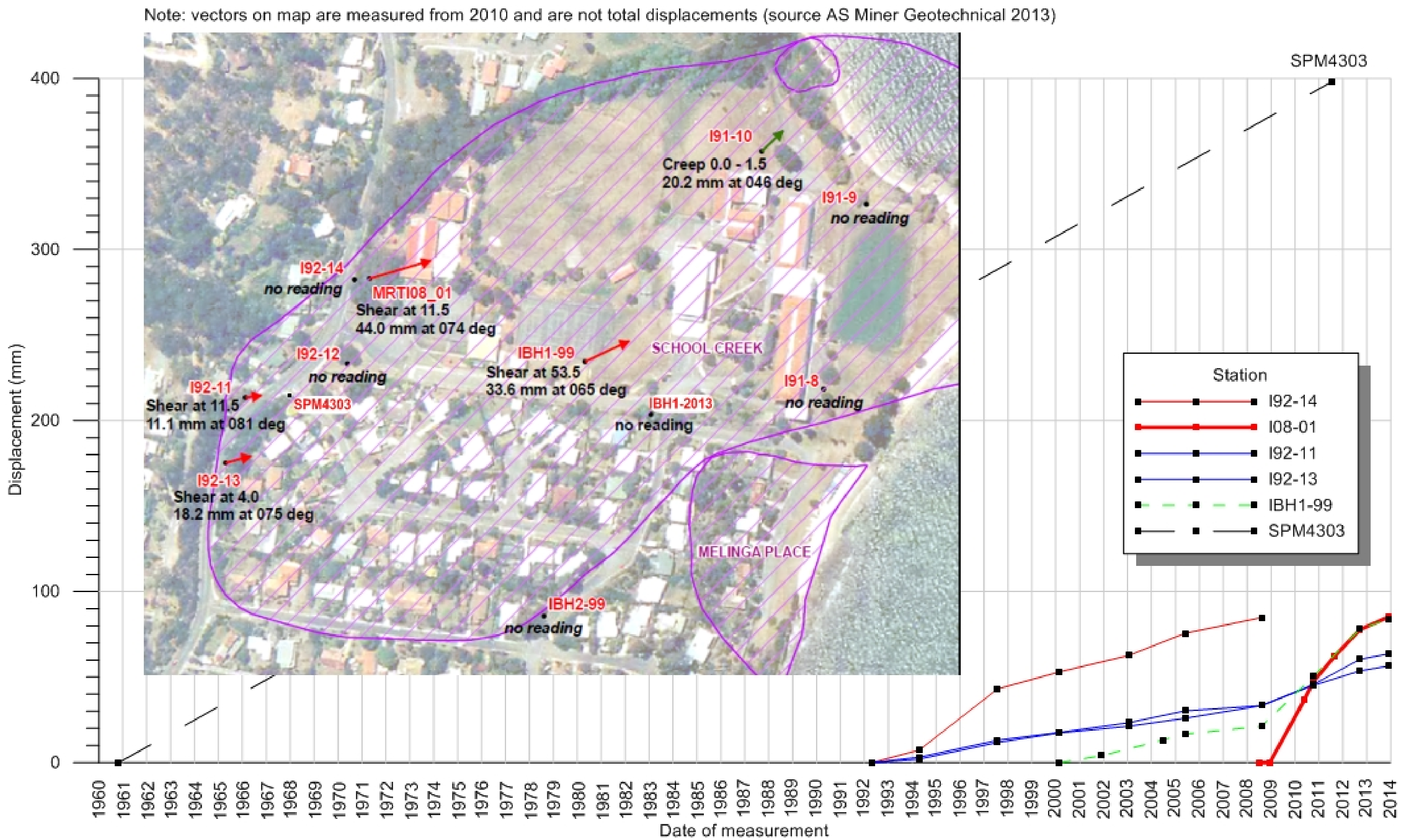


Figure 2 Displacement versus time plot of inclinometers and a single survey mark within the School Creek Landslide. The inset plan shows the location of the instruments and movement vectors since 2010.

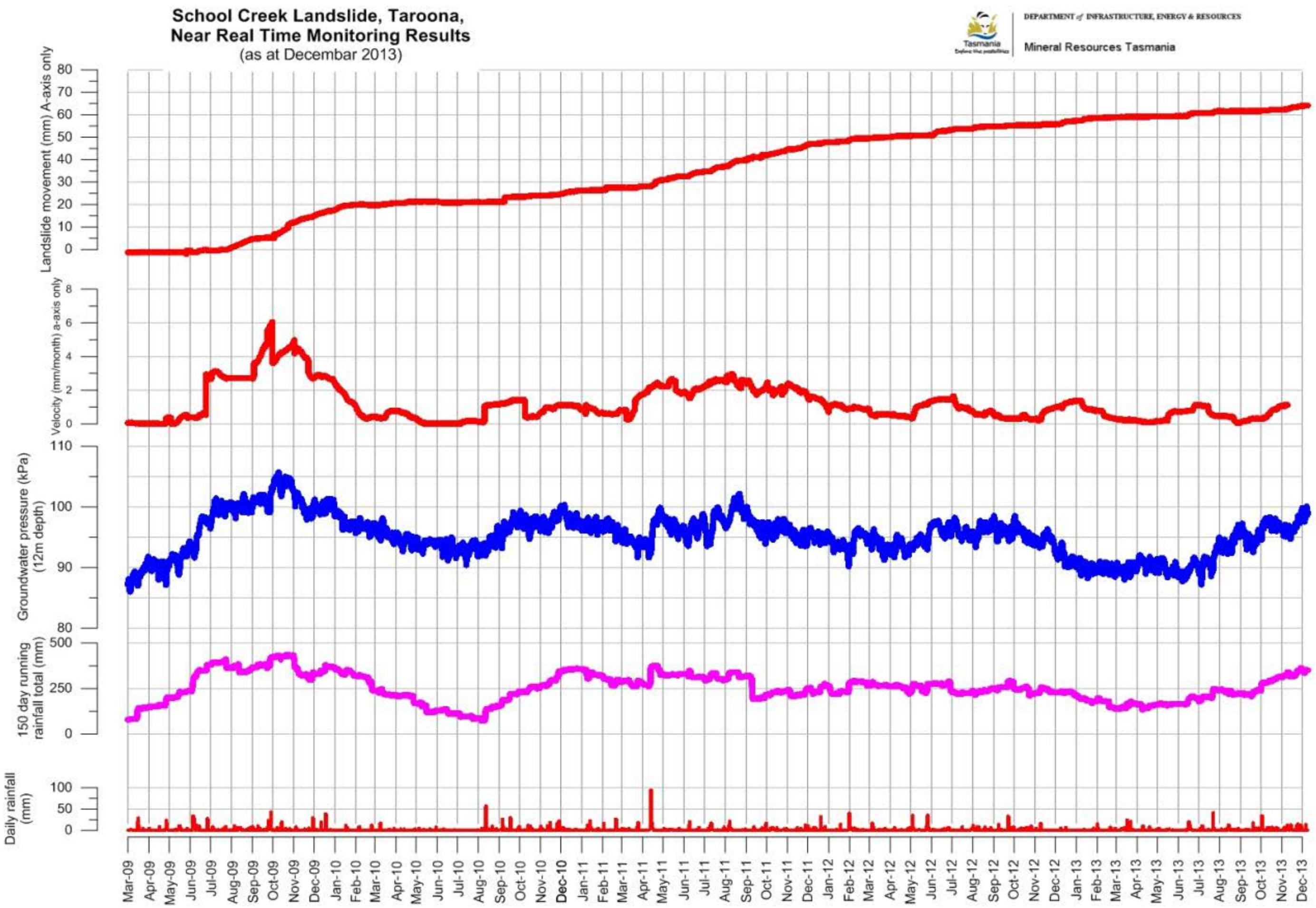


Figure 3 Time series plot of rainfall/groundwater pressure & near real time inclinometer displacement. Note that groundwater pressure and landslide movement is strongly correlated to long term rainfall

3.3 Role of Geology and Groundwater

Despite the previous investigation work at this site there remain a number of significant uncertainties in the geological and hydrogeological characteristics of the area. These uncertainties contribute to difficulties in accurately defining the nature and extent of the landslide activity, in the ability to predict the likely scale and rate of movement, and the consequences of future deformations.

Previous reports (particularly Latinovic et. al. 2001 and Moon and McDowell 2002) have outlined the geology and the geological and geomorphological history at this site. More recently MRT have revised the geology to assist the GHD investigation based on subsequent evidence, particularly borehole information collated from various sources by Mineral Resources Tasmania. This has led to some minor refinement of the understanding of the geology of the site (Appendix B). Reinterpretation of the major structural elements at Taroona following the more recent geological mapping has suggested that the position of the major Taroona Fault located near the base of the dolerite escarpment to the west of the site requires adjustment. This reinterpretation has also indicated that the trace of this fault may have been offset in the vicinity of the Taroona Primary School by other fault structures. It has been noted that there is an apparent coincidence of the largest movement zones within the landslide with the major fault intersections. The exact nature of this relationship is not clear but may involve deeper groundwater discharge zones beneath the Paleogene age sediments. Although several bores (inclinometer bores) have piezometer installations that allow groundwater measurements to be collected, the nature of the more general groundwater regime at the site is poorly understood. The groundwater regime is likely to be complex with potentially several confined and unconfined aquifers separated by aquitards. The groundwater recharge and surface drainage model is not fully understood.

3.4 The Influence of Previous Land Use

Although vegetation clearing, excavation of minor road cuttings and other landscape modifications have been undertaken in the Taroona area over the last 200 years, the commencement of significant modification of the landscape can be traced back to the 1950's when residential development began in a previously rural area.

Aerial photographs from the 1940's reveal that prior to this development; several streams crossed the coastal plain below the steeper escarpment slope. In the vicinity of School Creek, these streams originated in the base of the steep gully that descends the escarpment slope immediately west of the point where School Creek crosses beneath the Channel Highway. The aerial photographic record shows that in developing the Taroona residential area some of these natural stream courses were filled in and residential streets and buildings constructed over the filled stream courses. The recent visual damage survey of buildings in the landslide area (see section 2.2.2 of this report) has assessed the damage of these buildings under five rating classes, from no damage through to severe damage. When the traces of the existing and former natural stream courses are superimposed on the plan of buildings examined, there is a strong correlation of former stream courses with buildings exhibiting severe and moderate damage. This correlation suggests that the observed building damage may in some part be due to ongoing long term settlement of poorly compacted fill within the former stream courses. Confirmation of this causal relationship would require more detailed investigation including sub-surface insitu material testing.

Figure 4 shows the location of the old stream paths overlaid onto the structural damage map.

Figure 4 Plan showing overlay of building damage survey results and infilled stream locations

3.5 Potential Impacts of Climate Change

It is currently predicted that Climate Change will most likely be manifest as an increase in mean, minimum, and maximum air temperatures, changes in precipitation patterns (most likely including more intense rainstorms) and sea-level rise. A study of rainfall patterns is particularly relevant to understanding the expected behaviour of the landslide into the future given the established relationship discussed previously. The Climate Futures of Tasmania climate modelling technical report (Corney et. al. 2010), which models the State in ~10km cells, forecasts that, in a high emissions scenario, the mean annual rainfall for the Taroona area will increase by up to 20 to 40 mm (up to 6% change) by the end of the current century. However, the cell in which Taroona lies has a high degree of rainfall variability as a result of orographic effects of the landscape. MRT have analysed the nearest Bureau of Meteorology station (94111 Taroona) whose records extend back to 1961. This work suggests that the local rainfall conditions that correspond to landslide movement (Figure 3) are actually decreasing, and therefore reduce groundwater pressure and possibly movement with time.

Given this apparently contradictory information and the stated uncertainties of the Climate Futures predictions we are not confident that rainfall alone will result in a significant change to landslide behaviour. However, the effect of ongoing coastal recession, perhaps exacerbated by predicted sea-level rise, could realistically trigger reactivation of the smaller landslides within and to the north of the School Creek Landslide (SCL). Whether this removal of mass could accelerate the much larger SCL is not clear.

To conclude, so far global changes in landslide activity can hardly be detected in observational records. As climate change is predicted to be a gradual process, it is not anticipated that this large scale and incremental change to climate patterns will have a marked effect on the behaviour of the SCL in the foreseeable future.

3.6 Likely Future Movement Scenario

The School Creek Landslide is a large mass movement and monitoring to date indicates that the overall movement pattern has not been uniform. Although there is a generally consistent direction of movement, different parts of the landslide show differing rates of movement, and probably move at different times.

The reason for these differences is not currently known but, they suggest that the landslide may be in part composed of separate sections that respond to a range of localised factors.

It is hoped that surface movement monitoring via the improved surface survey network will provide insight into the landslide mechanisms within the larger School Creek Landslide mass.

The level of knowledge of the landslide and its causal factors does not allow accurate prediction of the scale and nature of future movements. Preliminary assessment of potential long term movement trends is based on previous monitoring results, and analysis of these results in long term average rates of movement varying from 14.4 to less than 3mm/year near the landslide headscarp at the Channel Highway, to 6 mm/year near the centre of the landslide mass. It is likely that the general pattern of landslide movement is episodic over the larger time scale (> 100 years), with the movement usually being extremely slow (i.e. <15mm/year) but accelerating to 30 or 40 mm/year in wetter years. Given that this feature probably pre-dated building on the site, and could be much older than 100 years, it is therefore possible that it could easily continue to move for centuries.

Further refinement of prediction of future movements will require assessment of ongoing monitoring data.

4. Assessment of Risk

In 2002 a comprehensive landslide risk assessment of the Taroona area was completed by Coffey Geosciences (Moon and McDowell 2002). Although this assessment is still largely relevant, some of the conclusions can be modified with the acquisition of more recent information.

The previous risk assessment considered, in addition to the School Creek Landslide, the other landslides in the area. These features pose potential dangers that need to be addressed and the findings of the Coffey report are still relevant today. However, this discussion will largely focus on the School Creek Landslide.

As with the previous work, it is to be emphasised that it is based mainly on professional judgement, and that the available data to inform the judgements remains insufficient to allow definite conclusions. Much of the data available for defining the previous landslide activity has been highly variable in frequency and precision. It is anticipated that the risk assessment will be reviewed following further developments and when additional information becomes available.

4.1 Defining the Hazard - What Might Happen

The identified hazard zone encompasses the area of the School Creek Landslide and is shown in Appendix A It is noted that the definition of the area of the School Creek Landslide is based on sometimes widely spaced information and that some aspects of the extent of the landslide are poorly defined (e.g. the southern boundary of the landslide is not well understood).

In general, the higher hazard zones, where differential movements are most noticeable, encompass the boundary zones of the landslide, in particular the headscarp area. The headscarp area (whose boundary with the side scarps is poorly defined and conjectural) is regarded as the most hazardous, as differential movements recorded in this area are regarded as having the highest hazard. The correlation of movement in this area with rainfall, and the significant vertical component of the displacement vectors are typical of a headscarp regression of a landslide. These headscarp displacements are evidenced by the continued deformation of the Channel Highway at this location, and can be expected to continue as long term displacements accumulate.

The main body of the landslide is regarded as a medium level hazard zone where movement of the body of the landslide mass may occur, but differential movements will be less noticeable. The areas outside the main body of the landslide are regarded as forming a lower hazard area where differential movement is less likely.

4.2 Likelihood

The likelihood of landslide displacement is assessed as variable depending on the part of the landslide in question and the expected scale of movement. It is regarded that the main body of the landslide and the headscarp area are **almost certain** to undergo annual movements in the range of up to 10 mm. Annual movements between 10mm and 100mm are **likely** whereas movements in excess of 100 mm are regarded as **possible**. Movements of a greater scale than 100 mm per year are considered **unlikely**.

The area most likely to show the most noticeable surface effects within the range of annual movement is the headscarp zone. Records of movement indicate that total movements in some areas are likely to be less. Investigations to date indicate that the southern boundary zone of the landslide may experience less movement. However, the reasons for this variability are not well understood.

4.3 Consequences – Risk to Property

4.3.1 Buildings

The structures at risk include private houses and buildings included in both the Taroona Primary and Secondary Schools. With annual movements in the order of 10 mm or less, the structural damage is expected to be **minor to insignificant**. If the annual movements exceed 10 mm the damage to most buildings affected could be major. For larger displacements the rate of movement will also affect the scale of damage, particularly as strains accumulate over many years.

The buildings adjacent to the headscarp area are judged to potentially experience the greatest amount of displacement, and therefore the greater scale of damage.

4.3.2 Infrastructure

The major infrastructure most at risk of experiencing significant damage due to landslide activity include roads, water mains and drainage services, but most notably sewers.

Roads

The Channel Highway has a history of deformations requiring relatively regular maintenance including regulation and resealing of the road surface. It is estimated that this section of the highway has experienced accumulated roadway regulation exceeding 600 mm (based on 1988 observations). As the highway is situated across the projected headscarp zone it is anticipated that significant damage to the roadway is likely to occur with further movement of the landslide.

Minor roads within the Taroona area are also expected to show significant deformation with ongoing landslide movement, in particular where roads cross the boundaries of the landslide mass.

Drainage

The main drainage asset at risk in the landslide area at Taroona appears to be the sewer pipe network.

Recent CCTV surveys of the stormwater drains have identified a large number of pipe displacements. Although not considered to be generally indicative of significant soil displacements, a limited number of angular and longitudinal displacements have occurred at various locations in the storm water pipe system that may be attributed to landslide movement.

If this observed displacement result is imposed on the sewer pipe network, significant damage requiring major repair work can be anticipated with ongoing landslide movement. The damage is expected to be most severe where the sewer network crosses the boundaries of the landslide mass.

Water Services

A network of water mains traverses sections of the School Creek Landslide. As with the sewer pipe network, moderate to severe displacements of the water main pipelines can be expected to result in significant damage. Also in common with the drainage pipelines, the damage is expected to be most severe where the network crosses the boundaries of the landslide mass.

4.4 Risk to Life

Most injuries and deaths associated with landslides in Australia occur where landslides are rapidly moving and where there is insufficient warning to take evasive action.

The landslide movement characteristics observed on the School Creek Landslide Taroona are exclusively slow (less than 40 mm per year in wettest years) and rapid movement of the landslide mass is considered highly unlikely.

With the current level of knowledge of the likely movement scenario of the School Creek Landslide the qualitative assessment of risk of loss of life is considered **low**.

However, it is considered that the greatest risk of loss of life or injury is associated with the Channel Highway Landslide situated on a steep embankment relatively close to the Taroona Primary School. In an intense and prolonged rainfall event, it is possible that the highway embankment at this location may fail rapidly and it is important that data be collected in this area to allow a sensible stability model and rainfall/movement thresholds to be established. The recent addition of further stabilisation measures will have reduced the risks. However, given the difficulty of stabilising this section of highway in the past, the effectiveness of these measures needs to be regularly monitored.

5. Management of Landslide Risk at Taroona

5.1 Existing Controls

In recent years Kingborough Council, with the guidance of MRT, have led the management of the landslide risk at Taroona. In 2011 the council commissioned a long term study titled - 'Taroona Landslide Risk Assessment & Mitigation Plan'. This study builds on previous investigation work, and is ongoing.

Currently there are no substantive controls in place, although the landslide is routinely monitored through:

- A series of borehole inclinometers and associated instruments that measures sub-surface displacements.
- A ground control survey network of survey monuments that was installed in 2013.

5.2 Ongoing Movement Monitoring

It is an important element of landslide movement monitoring that the landslides be regularly monitored and accumulated results reviewed. A formalised data collection and analysis methodology should be formulated and reviewed annually.

Consideration should be given to extending the monitoring to include the gabion wall which supports the Channel Highway embankment above the Taroona Primary School.

5.2.1 Importance of Frequency

An important element of a landslide monitoring program is that an appropriate data collection frequency be maintained. The episodic collection and collation of data will often prevent an accurate characterisation of the landslide extent, movement characteristics and causal factors. Correlation of movement information with other data (e.g. rainfall records) requires a rigorous control on both the spatial and temporal reference of data.

It is recognised that the regular collection of monitoring data carries a financial penalty, however to be effective a regular monitoring regime is required.

It is recommended that manual inclinometer readings be carried out annually.

It is recommended that the near-real-time monitoring facility be supported for the length of its useful life and that additional sensors recently installed be integrated with this facility.

The ground control network should also be monitored regularly, the frequency partly determined by the survey accuracy limitations. The current level of funding is such that this survey may only be possible every 2 years.

5.2.2 Annual Review

Possibly the most important element of a landslide monitoring regime is the need to periodically review results to enhance knowledge of the landslide extent and movement characteristics, to gain a timely warning of changed movement rates, and to determine adjustments to the monitoring regime.

An annual review should be undertaken by a geotechnical professional experienced in landslide monitoring, and the review should be formalised as a document for consideration in subsequent reviews.

5.3 Who is Managing the Landslide Risk?

The School Creek Landslide is currently being monitored through a joint initiative which includes Kingborough Council, Mineral Resources Tasmania, Department of Education and Transport and Infrastructure Service of the Department of State Growth.

5.3.1 Clarification of Stakeholder Roles

There are a number of stakeholders associated with the landslide area including:

- TasWater – responsible for sewer and reticulated water services.
- Kingborough Council – responsible for Council road network and stormwater system.
- Aurora Energy – responsible for overhead power supply.
- Telstra – responsible for telecommunications equipment.
- The Department of State Growth– responsible for Channel Highway.
- The Department of Education – responsible for Taroona Primary and High Schools.
- The Local Residential Community – responsible for individual properties.

In order to ensure long term monitoring of the landslide it is important that all stakeholders are active participants in this process not only through funding but, also by providing advice in relation to potential impact of the landslide on infrastructure.

In regards to the statutory agencies, it is recommended in the planned workshop that discussion be undertaken with the view of the agencies entering into a memorandum of understanding to provide a long term commitment to the monitoring and management of the landslide.

At this time Kingborough Council will act as the coordinating authority for the management of the landslide.

5.4 Residential Community Information

Residents are advised to contact Kingborough Council if they have any concerns or would like to report any evidence of landslide activity.

Kingborough Council and MRT also maintain information on the landslide and residents can access this information from their respective websites.

5.5 Emergency Management

In accordance with the Tasmanian Emergency Management Plan, Mineral Resources Tasmania (MRT) has the primary responsibility for management of landslides from a state research and policy development perspective. However, Kingborough Council will be the coordinating authority in regards to landslide preparedness and response. Council's role will be to receive technical advice from MRT and appropriate consultants and consider this in preparing risk management and long term recovery strategies.

5.6 Land Use Planning

GHD reviewed the land use planning issues for the Taroona Landslide Area in Stage 1 of the Project (Interim land use planning advice, GHD 2012). This report identified current land use planning approaches to landslide risk areas in Tasmania and the Taroona Landslide area, and the proposed measures under the Southern Regional Planning Scheme Template. Relevantly the report identified that Landslide hazard areas outside of declared landslips, such as the Taroona Landslide Area, are predominately the responsibility of planning and building authorities.

Kingborough Council is the responsible planning and building authority for the Taroona Landslide Area.

Council assesses any planning application within this area against the requirements of the Kingborough Planning Scheme 2000 and in particular the Environmental Management Schedule which provides for landslide issues for slopes in excess of 1:5.

Kingborough Council has since endorsed, at its meeting on 24 February 2014, the final draft version of the Kingborough Interim Planning Scheme 2014. The Interim Planning Scheme will replace the Kingborough Planning Scheme 2000 and will come into force following ministerial endorsement.

The Interim Planning Scheme provides for a Landslide Code which applies a risk management approach to use and development within a Landslide Hazard Area.

A Landslide Hazard Area is identified on the planning scheme maps, and divided into the following bands:

- Low Landslide Hazard Area,
- Medium Landslide Hazard Area,
- Medium Active Landslide Hazard Area,
- High Landslide Hazard Area.

The Taroona Landslide Area is identified as being within the Medium Active Landslide Hazard Area on the planning scheme maps. Building and works within this area will generally require a landslide risk management report prepared by an suitably qualified person to demonstrate that the landslide risk associated with the buildings and works is either:

- acceptable risk; or
- capable of feasible and effective treatment through hazard management measures, so as to be tolerable risk.

Stages 2 and 3 of this Project further recommended that the best approach to mitigate the landslide hazard risk through the land use planning process is to introduce local provisions to provide for a specific area plan. Such controls would require an amendment to the Interim Planning Scheme, and would introduce site specific controls that implement the technical recommendations of this Report. Council would be responsible for the implementation of this recommendation.

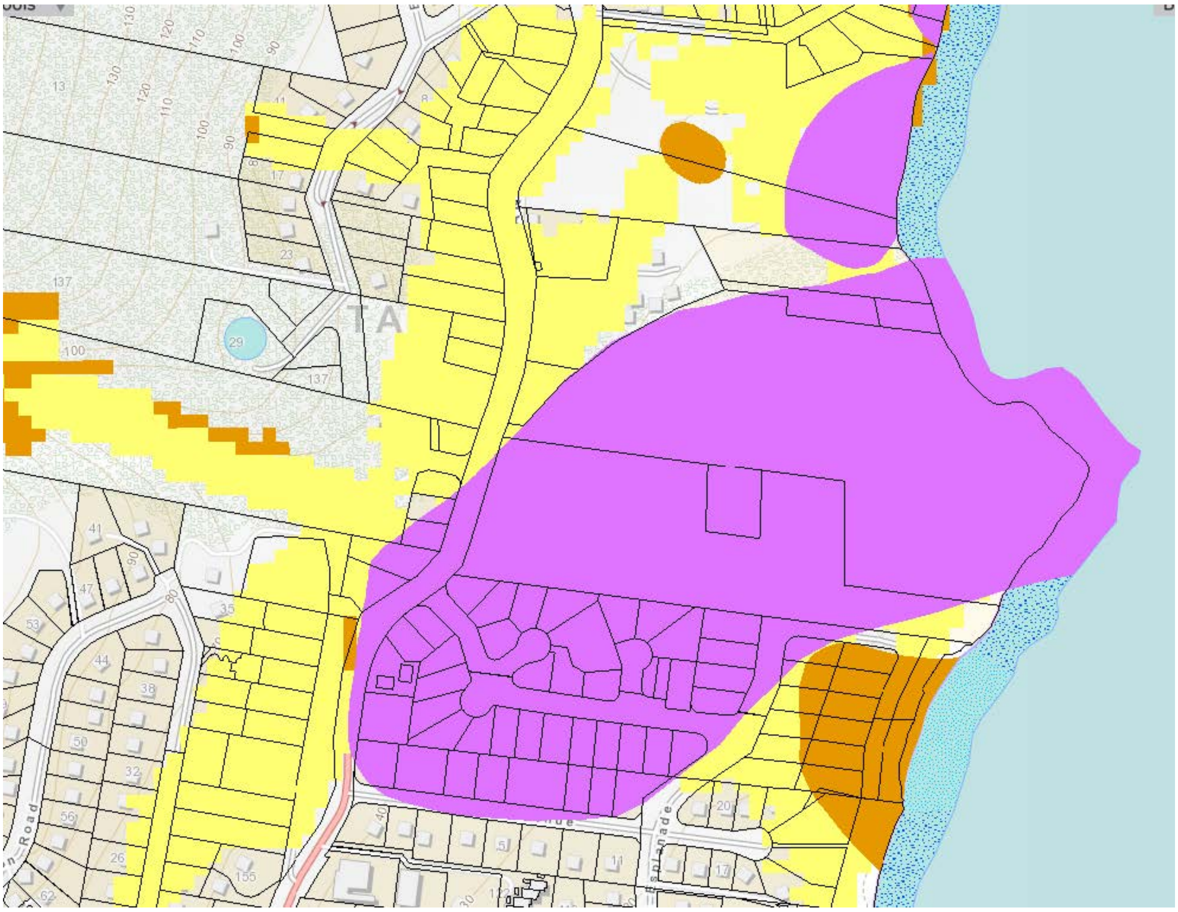


Figure 5 Landslide Hazard Bands, Kingborough Interim Planning Scheme 2014 (Source: The LIST)

5.7 Future Projects

In order to manage risks from active landslides in the built environment, it is normal practice to undertake a monitoring programme of some form. The sort of information collected will be displacement, velocity (or rate) and direction along with environmental information such as rainfall and groundwater data. While a new ground survey network has been developed that will meet much of this information requirement, the question to consider is what to do when the inclinometer network, and especially the near-real-time monitoring facility, eventually fail. Such instruments will require a considerable financial investment to replace.

One solution is to take advantage of a continuous GPS (Global Positioning Station) that is to be installed at the High School as part of a federally funded GPS in Schools Programme. From this instrument daily landslide movement can be derived as long as the GPS programme is supported. This data stream, along with the other new monitoring network needs to be integrated with the existing datasets and data management facilities to allow efficient and reliable analysis and reporting and thus is a project in itself that requires the endorsement of the stakeholders.

6. References

Anon. 1988. Taroona 1808 -1986: farm lands to a garden suburb. Taroona Historical Group: Hobart. 360p.

CORNEY, S.P.; KATZFEY, J.J.; MCGREGOR, J.L.; GROSE, M.R.; BENNETT, J.C.; WHITE, C.J.; HOLZ, G.K.; GAYNOR, S.M.; BINDOFF, N.L. 2010. Climate Futures for Tasmania: climate modelling technical report. Antarctic Climate & Ecosystems CRC: Hobart, Tasmania.

DONALDSON, R.C. 1977. Foreshore instability near Taroona High School. Department of Mines, Tasmania, Unpublished Report 1977/41. 7p.

GANDY, J.R. 1998. Re: Taroona High School. Report to Department of Education, Tasmania, by Gandy and Roberts.

GHD 2012. Report for technical review for Taroona Landslide. Risk assessment and mitigation Stage 1. Unpublished consultants report to Kingborough Council, by GHD: Hobart. Report No: 32/15950/55683.

GHD 2012. Taroona landslide risk assessment and mitigation plan. Interim planning advice. Unpublished consultants report to Kingborough Council, by GHD: Hobart. Report No: 32/15950/56097.

GHD 2013. Taroona Landslide Risk Assessment & Mitigation Stages 2 & 3. Report for Stage 2A. Unpublished consultants report to Kingborough Council, by GHD: Hobart. Report No: 32/16698.

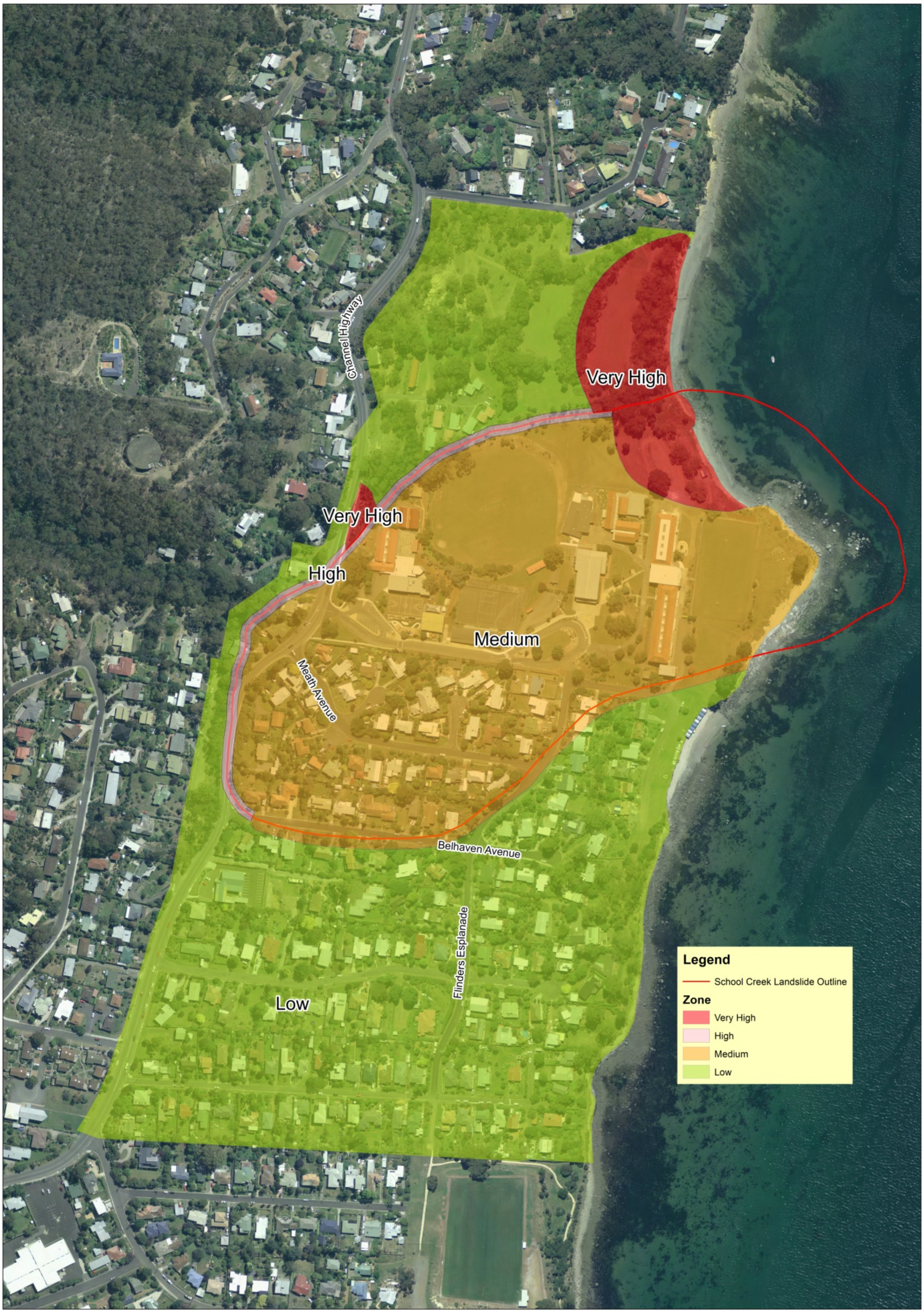
GHD 2014. Taroona Landslide Risk Assessment & Mitigation Stages 2 & 3- Report for Stage 2B – Geological Drilling Factual Report & Installation of New Permanent Survey Monitoring Points. Unpublished consultants report to Kingborough Council, by GHD: Hobart. Report No: 32/16698/60230.

LATINOVIC, M.; WAITE, A.; CALVER, C.R.; FORSYTH, S.M. 2001. An investigation of land stability in the Taroona area. Tasmanian Geological Survey Record 2001/01. Mineral Resources Tasmania. 50p. [available online: www.mrt.tas.gov.au].

MOON, A.T.; MCDOWELL, B. 2002. Landslide risk assessment and management in Taroona. Report to Mineral Resources Tasmania, by Coffey Geosciences Pty Ltd: Hobart. Report No: HO104/3-AC

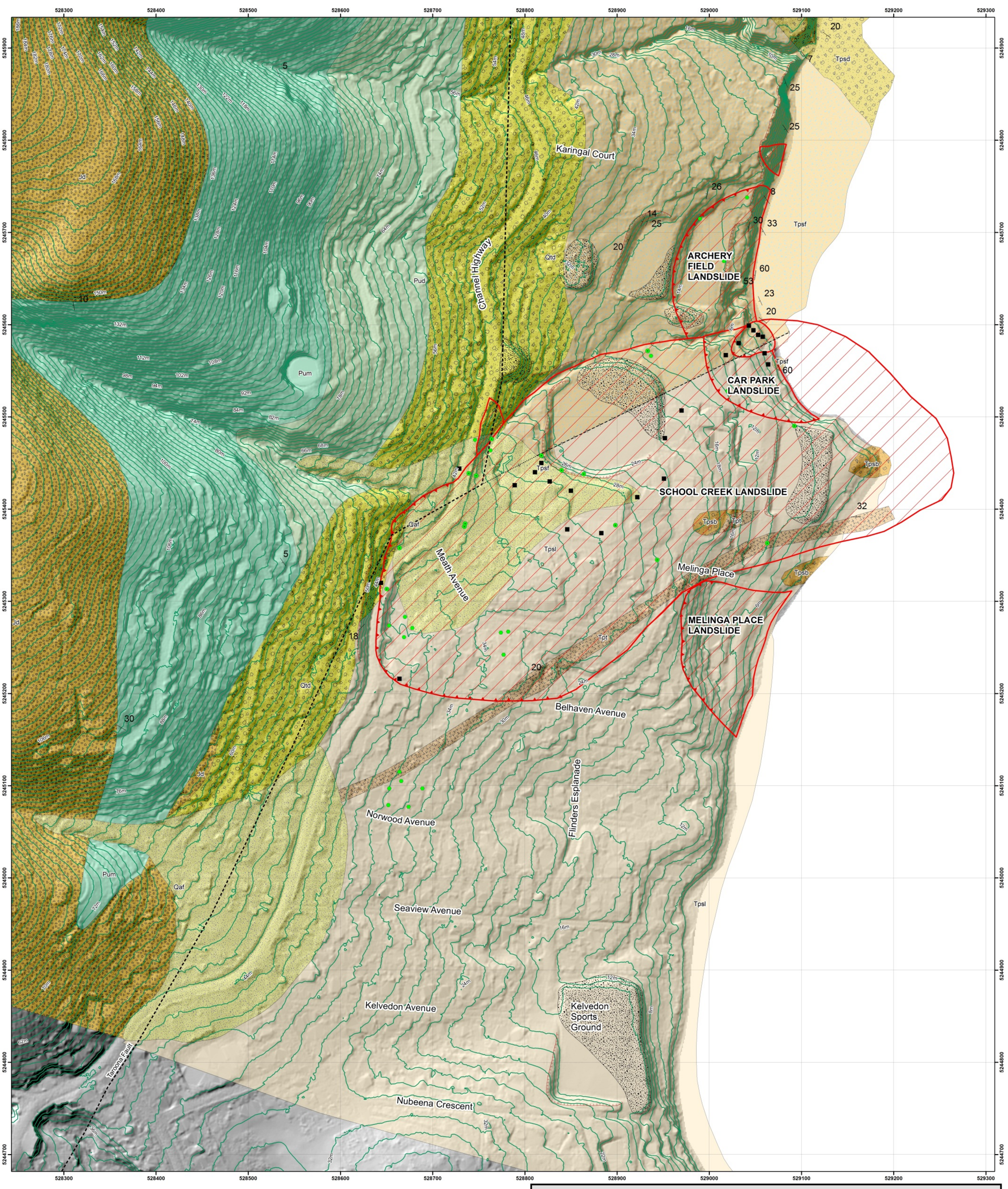
Appendices

Appendix A - Site Plan showing Hazard areas



Channel Highway
Very High
Very High
High
Medium
Meath Avenue
Belhaven Avenue
Flinders Esplanade
Low
Legend
School Creek Landslide Outline
Zone
Very High
High
Medium
Low

Appendix B - Revised Geology of the Taroona Area



Revised geology of Taroona

Preliminary revision by Colin Mazengarb for the purposes of the Taroona Landslide Project and 3D model construction,
May 2014

Map grid: GDA94 Zone 55 MGA

1:2,000

Legend

Drill holes

- Auger
- Diamond
- Test Pit

Topographic contours from LiDAR

24m

Convex break-in-slope

Faults

Fault type and qualifier

- Normal fault, approximately located, concealed
- Fault inferred, approximately located
- Fault inferred, approximately located, concealed

Landslide

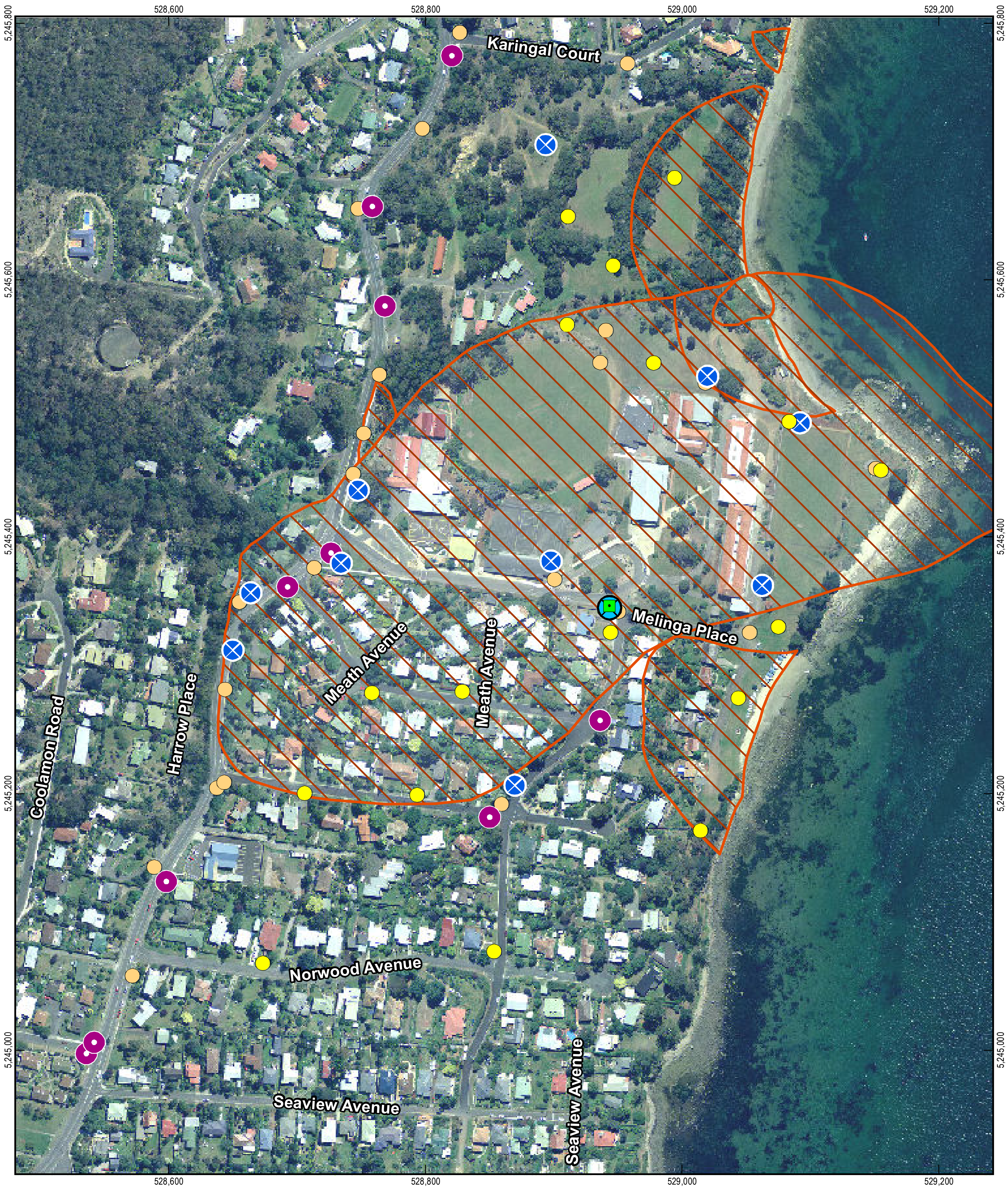
Landslide headscarp

Artificial fill

Revised geology

- Qaf Alluvial fan
- Qtd Pleistocene dolerite talus
- Tpsf Paleogene fluvial sands, conglomerate
- Tpsd Paleogene boulder beds in fluvial sequence
- Tpsl Undifferentiated Paleogene lacustrine sediments
- Tpt Paleogene tuff
- Tpsb Paleogene dolerite boulder beds in clay
- Jd Jurassic dolerite
- Pum Permian sandstone
- Pud Permian siltstone

Appendix C – Site Plan - Instrumentation & Additional Survey Monitoring Points



LEGEND

- New Ground Control Points (Stage 2B)
- Inclinometer IBH-2013
- Vibrating Wire Piezometer VWP-2013
- Existing Ground Control Points
- Existing Inclinometer
- State Permanent Mark
- School Creek Landslide - approximate extent

Paper Size A4

0 10 20 40 60 80 100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Kingborough Council
Taroona Landslide Risk Assessment Stages 2 & 3

Site Plan - instrumentation and additional survey monitoring points

Job Number	32-16698
Revision	2
Date	12 Jun 2014

Appendix C

G:\32\16698\GIS\Maps\3216698_09_SurveyMarks_Rev2.mxd

2 Salamanca Square Hobart TAS 7000 Australia **T** 61 3 6210 0600 **F** 61 3 6210 0601 **E** hbamail@ghd.com **W** www.ghd.com

Data source: MRT aerial imagery 2013; Peacock Darcey and Anderson Pty Ltd survey control & inclinometer locations 2014, KCC roads 2011, GHD landslide outline 2011. Created by: jtoregan, updated by jtoregan

GHD

2 Salamanca Square Hobart 7000
GPO Box 667 Hobart 7001
T: 03 6210 0600 F: 03 6210 0601 E: hbamail@ghd.com

G:\32\16698\WP\Laymans Report\June 2014 laymans Report\60724 Colins Edits.docx

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	G. Granger	K.McIntosh		K.McIntosh		20.02.2014
1	G.Granger	C.Mazengarb		K.McIntosh		03.09.2014

www.ghd.com