



Ground movements and house monitoring — Channel Highway, Tarooma

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Abstract

Man-made structures in the vicinity of the Channel Highway entrance to the Tarooma High School complex have a history of distortion. Tertiary-age materials at this location contain clays which are reactive, and some of the distortion is due to these reactive clays. The Tertiary-age clays are also fissured and contain slickensided defects, indicating that they have qualities which make for easy earth movement.

Sections of the Channel Highway have undergone earth movement which may also be affecting a small portion of land west of the highway. Inclinerometers have been installed in boreholes in order that, with time, a trend may be revealed to indicate whether the earth movement is due to landslide movement or to reactive clays.

Introduction

The Channel Highway in the vicinity of the entrance to the Tarooma High School complex (528610 mE, 5245240 mN) (fig. 1) has a history of subsidence. This area has previously been examined by Stevenson (1975) and Donaldson (1977), and the Department of Mines has maintained a watching brief over the area. In addition to investigations associated with distortion in the road surface, several homes have been routinely surveyed to monitor any earth movement.

Geological setting

The oldest rocks in the area are Permian-age mudstone and siltstone. These rocks occur on the lower parts of the steep slopes west of the Channel Highway. Jurassic dolerite also occurs west of the Channel Highway upslope from the older Permian rocks, with the contact between the dolerite and the Permian sedimentary rocks being faulted. Dolerite also occurs along the alignment of the Channel Highway. In places this is *in situ* dolerite, also with a faulted contact with the Permian sedimentary rocks. Elsewhere, the dolerite occurs as large blocks which may have been transported to their present position by slope mass wasting processes.

The next youngest rocks in the area are of Tertiary age. These are usually sediments consisting mainly of plastic clay, but silt, sand, volcanic tuff, boulder beds and peaty soil are also present. These materials vary rapidly both horizontally and vertically, indicating a sedimentary environment where there were periods of active channel erosion followed by infilling. The distribution of a volcanic tuff horizon suggests that a volcanic centre existed offshore to the southeast of the Tarooma High School.

The youngest materials present are Quaternary age gravel and colluvium which occur along drainage lines. Soil has developed on all rock units.

Four diamond-drill holes have been drilled east of the Channel Highway; one in 1988 and three in 1992. These have encountered in excess of 20 m of the Tertiary sediments. Fissures and slickensided defects are visible in the core. Slickensided defects are planes of weakness within a material where friction, arising from movement of particles relative to one another, has caused clay particles to become aligned. This may have occurred during consolidation or compaction of the sediments or at some later stage. Striations have been observed on slickensided surfaces at Tarooma. Whilst the slickensided defects indicate that movement has occurred, it is not possible to date when the movement happened.

Compressible, spongy, black organic clays are present in the Tertiary materials. If loaded, for example by the weight of a house or road works, the organic clay would compress and contribute significantly to settlement.

Background

Stevenson (1975) noted longitudinal cracks in the highway between Meath Avenue and Belhaven Avenue, indicating a total horizontal deformation of about 30 mm across the width of the road. He also noted vertical movement but, because the original camber of the roadway was unknown, was unable to estimate the magnitude of these. Stevenson noted that the house at the northern corner of Belhaven Avenue and the Channel Highway had a history of cracking

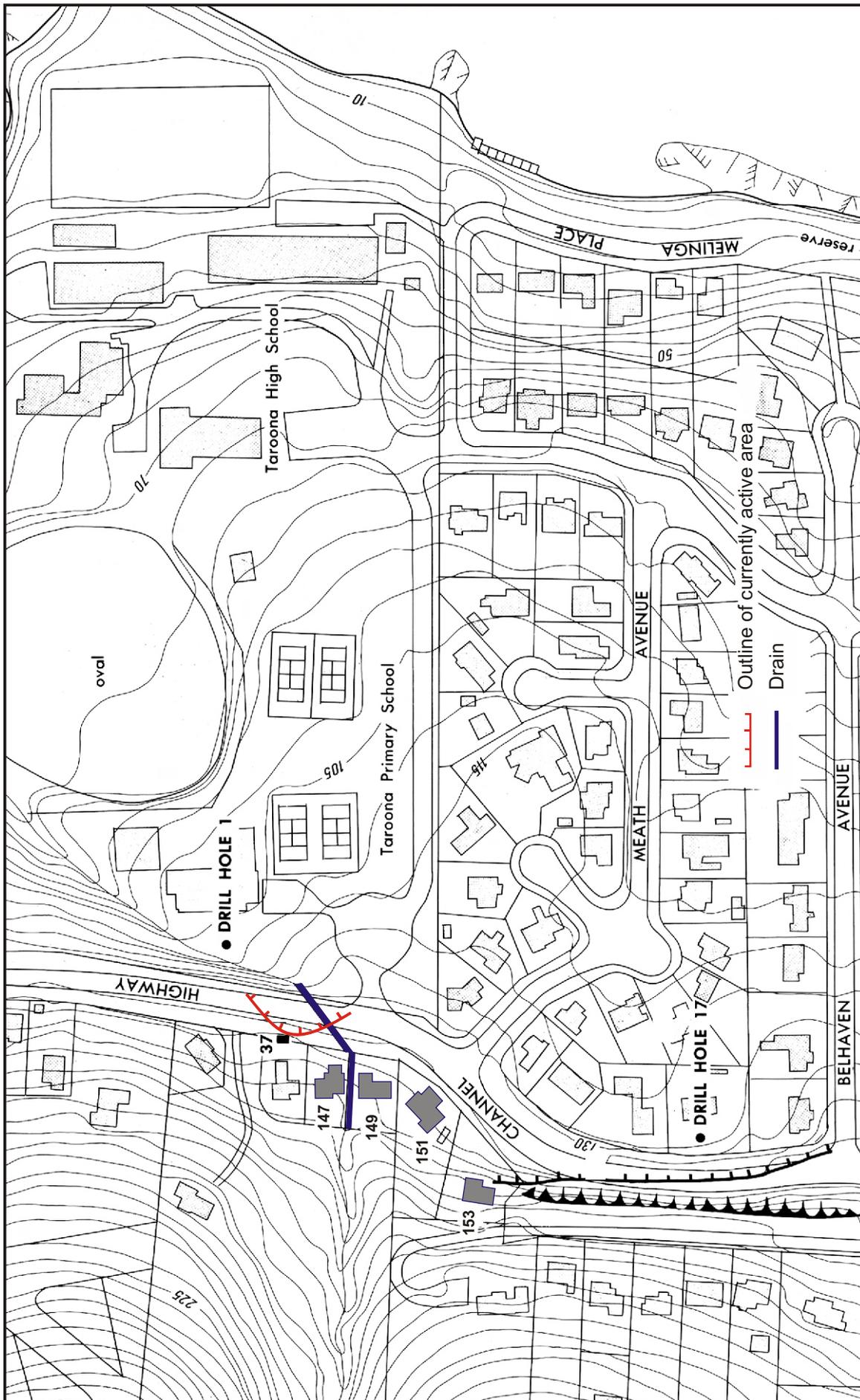


Figure 1
 Location of active areas and monitored houses

but stated that “there is no clear evidence of major ground movement”.

Stevenson (1975) concluded that:

1. No horizontal translatory mass movement was taking place, but there was potential for landslip.
2. Some minor movement in the road surface may be related to consolidation in road fill or underlying soft materials.
3. The same origin was likely for the damage to the house.
4. Any movement would be facilitated by high and active groundwater.

Knights (1977) examined the causes of reported house damage in the Taroom area between Flinders Esplanade and the Channel Highway, including Norwood, Belhaven and Meath avenues. Of the houses in this study area, 46 showed no structural damage, 22 exhibited light structural damage and 15 had major damage requiring extensive and expensive repair work. Knights considered mechanisms for the house damage and concluded that “... the major cause of house damage is the alternate expansion and shrinkage of the clay subsoil due to wetting and drying”.

Knights considered that localised damage was caused by three minor mechanisms:

1. Dispersion of clay particles may cause localised subsidence.
2. Compression of peaty layers in the black soil may cause settlement under load.
3. Clay failure could occur under concentrated loads, or where the subsoil is particularly wet.

Donaldson (1977) examined a section of the Channel Highway between the Taroom High School and Belhaven Avenue at the request of the Kingborough Council. He considered that two separate earth movements had occurred which he called *the Bus Stop 37 road failure* and *the Belhaven/Meath Avenue road failure*. Donaldson considered that the Bus Stop 37 road failure was “...due largely to a decrease in soil strength associated with an increase in moisture beneath the pavement”.

A major contributing factor was the drainage system. In respect to the dwelling at 147 Channel Highway, Donaldson commented that this same drainage system was

“...instrumental in bringing about extensive structural damage to this residence.

This house has a long history of movement, resulting in considerable cost to the owner for the remedial works carried out. The most extensively damaged section is along the southern side and in particular towards the south-west corner. Several years ago, pier foundations were used to support this side of the house, presumably in an attempt to isolate the building and substructure from differential seasonal movements associated with moisture changes in the expansive clay subsoil. This programme proved unsuccessful.

More recently (June 1977) two additional piers were added, involving excavation by pick and shovel to between 4.0 and 5.0 m in depth. This revealed 1.0–1.5 m of expansive brown/black clay overlying a light green/brown clay containing dolerite boulders in various stages of weathering. These clays are derived from the dolerite and Permian rocks which crop out upslope. Excavation, especially at lower depths, was hampered by the excessive inflow of water into the partially dug holes; a pump was necessary to keep water down to a satisfactory level for working. Water was entering through fissures at a rate of 3–4 l/min. The source for this water was found to be associated with the concrete drain carrying water from the creek which flows down from the steep slopes behind the block (fig. 1). This water subsequently crosses the highway at Bus Stop 37. The section of drain running across the block and the foundations of the dwelling on the southern side virtually coincide (plate 2). The drain has been constructed at a relatively shallow depth and has cracked extensively as a result of seasonal soil movements (plate 3). This has allowed water to penetrate under the house foundations which has subsequently lead to failure.

It is pertinent to note that the inflow of water into the excavation ceased within minutes of temporarily plugging the major cracks in the drain with clay. This suggests a well developed deep fissure system. The ground is in a state of tension, having the potential to create a landslip situation”.

With regard to the Belhaven/Meath Avenue road failure, Donaldson noted a series of longitudinal cracks in the road surface, amounting to a total lateral movement of between 35–40 mm across the width of the road. These were probably the same set measured in 1975 by Stevenson who reported a total movement of about 30 mm. Donaldson also noted that significant vertical movement was indicated by the downward curvature of the road in the Kingston-bound lane and reported that on projection of survey data collected over a three-month period, the annual rate of vertical movement indicated by differences in reduced levels was 12–48 mm. The mechanism of this failure could not be determined by Donaldson who wrote:

“A series of tension cracks has developed in the cutting and ground above the highway, extending northwards from the roadway through to the driveway of the dwelling at 153 Channel Highway (plate 5). This house shows signs of structural damage. It is therefore necessary to consider the road failure as part of a landslip complex having the potential for further development if corrective measures are not taken”.

Donaldson concluded that the following were applicable to both road failures:

1. A totally inadequate and poorly designed road drainage system which had accelerated ground movement.

2. The ground above the highway was in a general state of tension and there existed potential for increased landslip activity.
3. There was risk of severance of underground services located along the highway.

By 1988 subsidence of the road surface near the entrance to Taroona High School became of concern with respect to the safety of road users. Prior to remedial works being undertaken by the Department of Main Roads two test pits were opened in June 1988 and logged by the Department of Mines. The first, below Harrow Place, revealed steeply dipping, highly fissured and slickensided surfaces within a predominantly clay material. The other, opposite 147 Channel Highway (the area of maximum surface distortion in the roadway), revealed a subvertical plane of disruption. On one side of this plane there was up to 550 mm of bituminous material but on the other (upslope) side there was only 50 mm of bituminous materials. High plasticity, firm to stiff, dark grey to brown moist clay occurred beneath imported road building materials. A total of at least 500 mm of vertical movement had occurred.

Investigations undertaken at the same time by the Department of Main Roads involved:

- restoration of location and level monitoring pegs installed in 1977 and re-survey of these;
- road defect mapping;
- establishment of the thickness level of correction road pavement courses;
- internal examination of stormwater drains between 147 and 149 Channel Highway, and below the highway.

The re-survey, despite deficiencies and consequent uncertainties arising from them, suggested that there had been eastward movement of over 100 mm.

Maximum vertical movement of 75 mm was indicated along the 1977 survey line. It is noted that these movements are relative between survey points and not absolute readings. It is also noted that the Lands Department level control points (State Permanent Marks) had also moved.

Visual inspection of the stormwater pipes by the Department of Main Roads indicated that:

- the pipe downslope of the roadway and a 3-5 m embankment that supports the roadway was intact;
- the pipe under the roadway had a 50 mm internal (all round) gap at one join and that movement had probably occurred at a number of joins;
- the pipe located between 147 and 149 Channel Highway exhibited signs of very significant movement, with a 120 mm gap with a small cavity at the top of one join and a 50-75 mm wide all round fracture of the pipe in the vicinity of a reconstructed section with a timber roof.

The owner of 147 Channel Highway drew the author's attention to a crack in the concrete slab of the ground floor front room of his residence. A vertical displacement of about 12 mm was observed with a

smaller lateral movement. A crack in the concrete retaining wall on the boundary line with 149 Channel Highway was observed, as was skewing of the palings on top of the concrete retaining wall. A strong concave change in slope occurs in the rear yards of 149 and 151 Channel Highway. The roofline at 153 Channel Highway is bowed and the foundations of this property have previously been damaged and repaired. Parts of the chimney on this property have also been removed.

This information, in conjunction with observations from the test pits and the investigations undertaken by the Department of Main Roads, indicate that the two separate road failures previously reported by Donaldson (1977) could now be seriously considered as part of the one land movement.

Survey monitoring

The Department of Mines commenced routine survey monitoring of houses between 147 and 153 Channel Highway in April 1988. Several reference rods were driven into the ground or concreted into shallow boreholes to assist the survey monitoring and a data logger was installed across the crack in the concrete retaining wall on the boundary between 147 and 149 Channel Highway in order to detect any earth movement.

The results of surveys are reproduced in Figures 2 to 7. Interpretation of the results is not simple. All figures indicate that the surveyed objects are subject to vertical movement. This movement is considered to primarily reflect changes in the moisture condition of the reactive clays which are known to exist in the area. These clays swell upon the uptake of moisture and shrink with loss of moisture.

Peaks in the movement are generally associated with the wetter months and troughs are associated with the drier months. This pattern is best indicated at 151 Channel Highway (refer fig. 6) where the scatter of values at a particular point in time is restricted to a relatively narrow envelope. This suggests that the house is riding relatively uniformly up and down in response to changes in the volume of the underlying clay.

Initial readings at 147, 149 and 153 Channel Highway were also within a relatively narrow envelope, but as time has progressed, this envelope has broadened. This is interpreted to indicate that some other and unknown factor has come into effect. Some possibilities for the unknown factor are:

- a change in the amount of solar radiation reaching the ground at different survey points (e.g. the removal or planting of trees, provision or removal of 'hard-tops' such as concrete, pavers, bitumen);
- a change in maintenance practices with respect to private stormwater drains (e.g. less or more attention to blocked drains);
- a change in the groundwater regime (e.g. undetected broken service pipes contributing more water to groundwater);

- land movement superimposed on the general pattern of changes in volume of the underlying clays, i.e. landslide movement.

The latter cannot be discounted because 147, 149 and 153 Channel Highway sit astride an arcuate-shaped line representing distortions, cracks and other defects detected in the surrounding man-made structures.

Data logger monitoring

An automatic data logger was connected to a strain gauge located across the crack in the concrete retaining wall between 147 and 149 Channel Highway. The monitoring program has not been as successful as was hoped. The strain gauge amplifiers were connected to a 240 v AC power supply from 147 Channel Highway, and there were no problems with this power supply. However due to extended periods between servicing the data logger, batteries contained within the data logger itself lost charge. These batteries maintain the logger's memory and their failure has resulted in loss of data.

The most reliable data (fig. 8) was recorded in 1988/1989. The results show a constant extension of the gap between May 1988 and March 1989 with total displacement of about 0.65 mm. From March 1989 to January 1990, the data is broken but a general closing of the gap with total displacement of about 1.1 mm is indicated. Recordings from January 1990 onwards have shown either no displacement or have exceeded maximum displacement of the instrument and cannot be interpreted. At the request of the owner of 149 Channel Highway, the installation was removed in August 1992.

Where the data is considered reliable, the magnitude of the movement is small but insufficient to draw conclusive results. Movement can equally be explained by landslide movement or changes in the volume of the soil underlying the foundations of the concrete retaining wall.

Expansive soils vs landslide activity

Knights (1977) established that expansive soils exist in the Taroom area. Survey monitoring of supposedly fixed points about 147-153 Channel Highway, including State Permanent Marks, has revealed movements of a cyclical nature which indicate that these properties are affected by expansive clays. The survey results at 147, 149 and 153 Channel Highway may also indicate the presence of another factor. A line of defects in these homes and/or associated man-made structures indicates an arcuate-shaped feature. Observations of materials beneath the road surface and re-survey of the roadway suggest that translational (i.e. landslide type) movements have occurred.

In an attempt to resolve this matter, the Department of Roads and Transport has recently installed a series of inclinometers within boreholes near the entrance to the

school complex. The inclination of special casing installed in these boreholes is accurately measured on a regular basis. Insufficient time (and therefore measurements) has elapsed since the installations were made in order to draw conclusions. In time, it is expected that a trend will be revealed to indicate whether the damage is due to landslide movement or to expansive clays. It is not possible to predict what this timeframe may be.

Conclusions

Tertiary materials underlying the Taroom area have the following characteristics:

- Contain reactive clays which expand and contract with increasing and decreasing moisture content.
- Contain compressible clays which would contribute significantly to settlement if loaded, for example, by housing or road works.
- Vary rapidly in their spatial distribution, thereby increasing the possibility that parts of footings of a dwelling are located on materials with different physical properties.
- Contain fissures and slickensided defects which indicate that prior movement has occurred and which could make for easy earth movement under certain circumstances.

Structures between the Channel Highway and the foreshore from Karingal Court to Norwood Avenue have experienced distortions which have been attributed to differential settlement caused by reactive clays (Knights, 1977).

Earth movement has affected the Channel Highway between the entrance to the Taroom school complex and Belhaven Avenue. In this area, distortion of structures upslope of the highway indicates an arcuate shaped feature suggesting that the earth movement may involve land west of the highway. The situation here is complicated, not only by the probable presence of reactive clays, but also by an underground drainage service between 147 and 149 Channel Highway. Collapse of this service trench or settlement of the backfill could cause some of the observed distortions.

A series of inclinometers has been installed and with time it is probable that a trend will be revealed to indicate whether the pattern of distortions can be attributed to landslide movement or not. It is not possible to predict what timeframe is required to reveal any trend.

References

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- KNIGHTS, C. J. 1977. House damage in the Taroom area. *Unpublished Report Department of Mines Tasmania 1977/35.*
- STEVENSON, P. C. 1975. Ground movement at Taroom. *Unpublished Report Department of Mines Tasmania 1975/69.*

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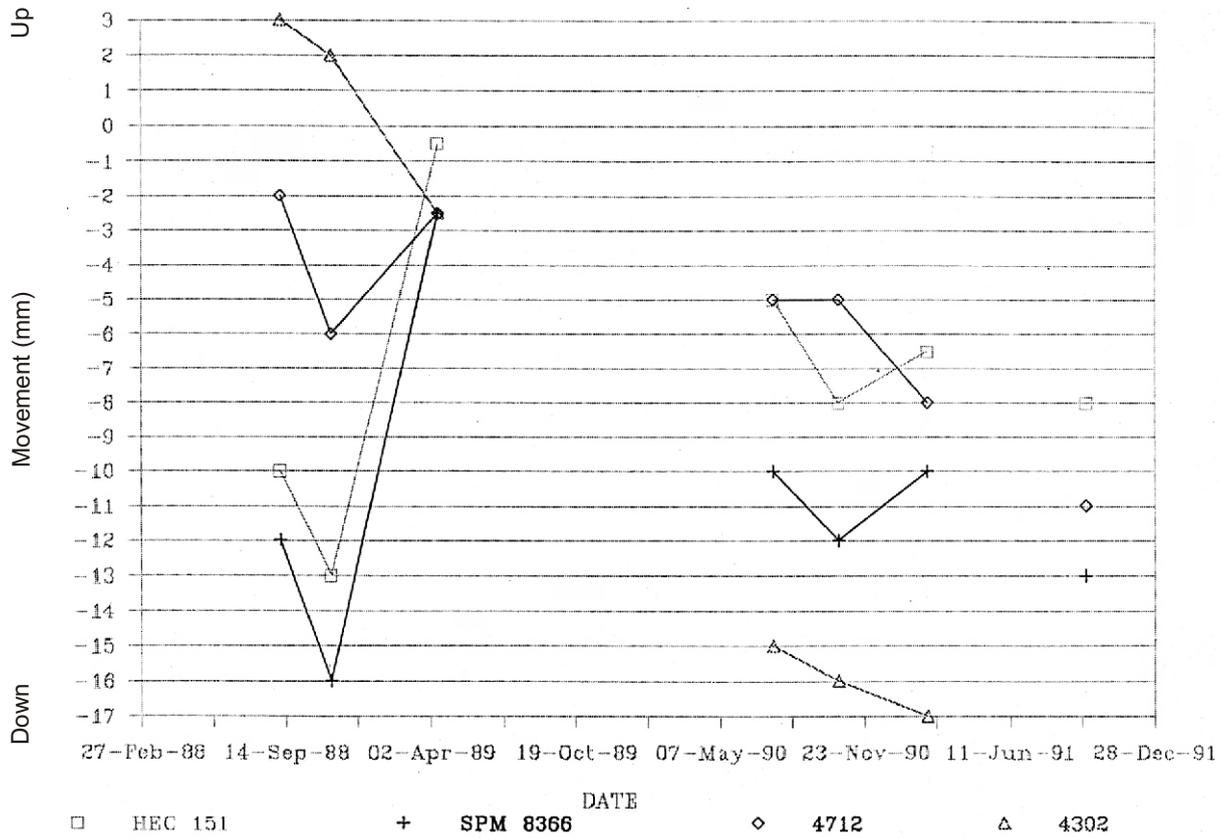


Figure 2
Survey monitoring, SPMs, Channel Highway, Taroom

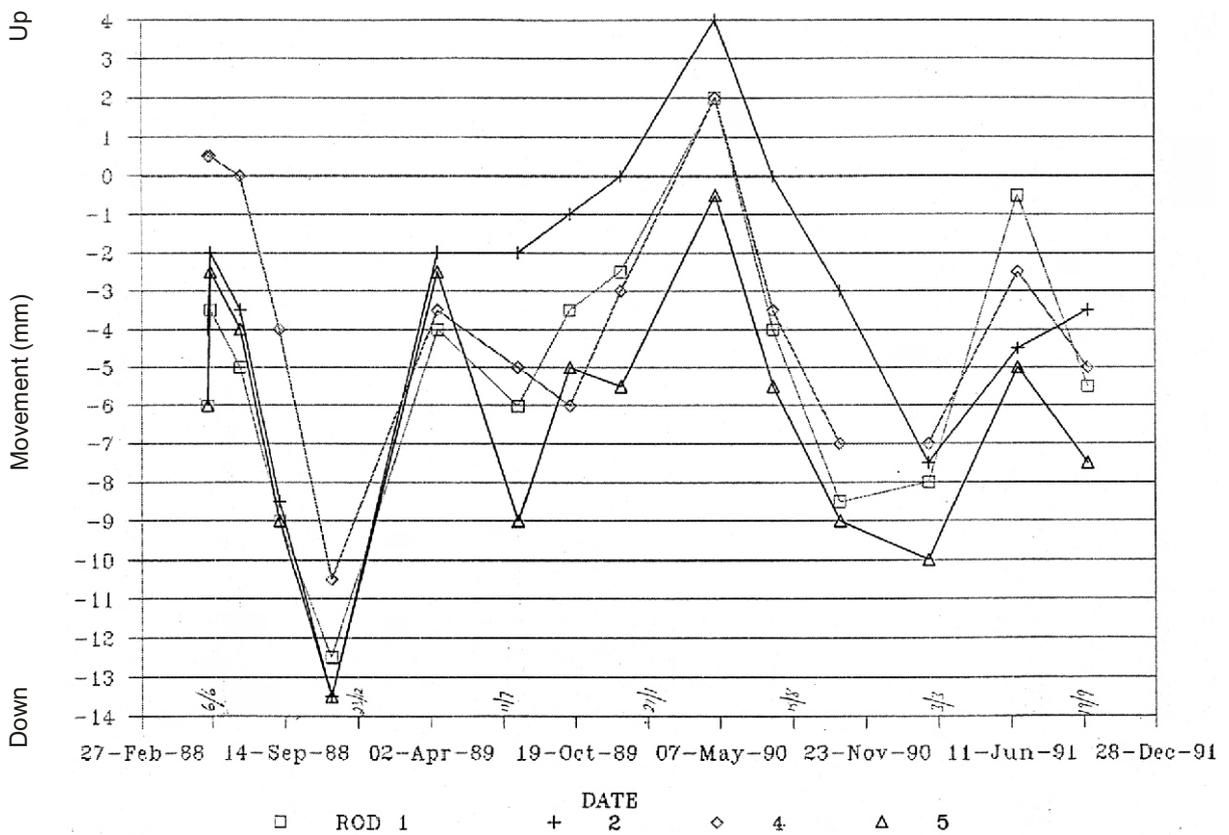


Figure 3
Survey monitoring, rods, Channel Highway, Taroom

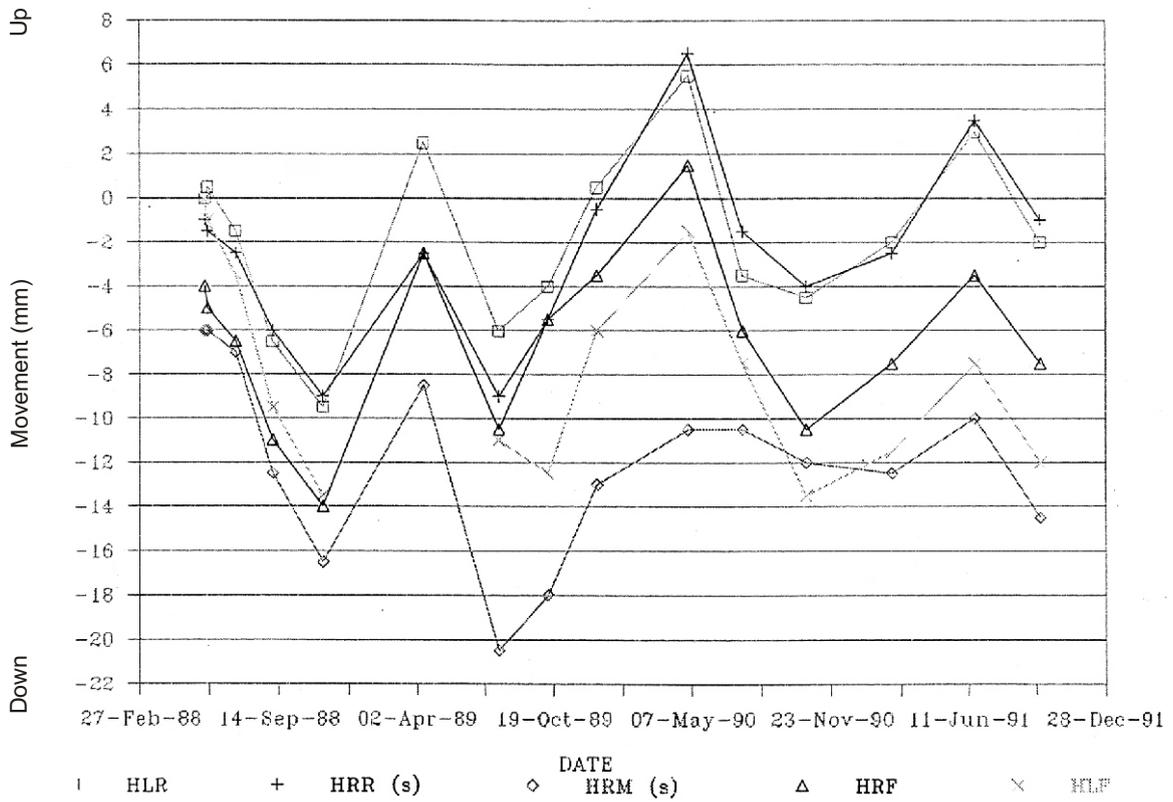


Figure 4
Survey monitoring, 147 Channel Highway, Tarooona

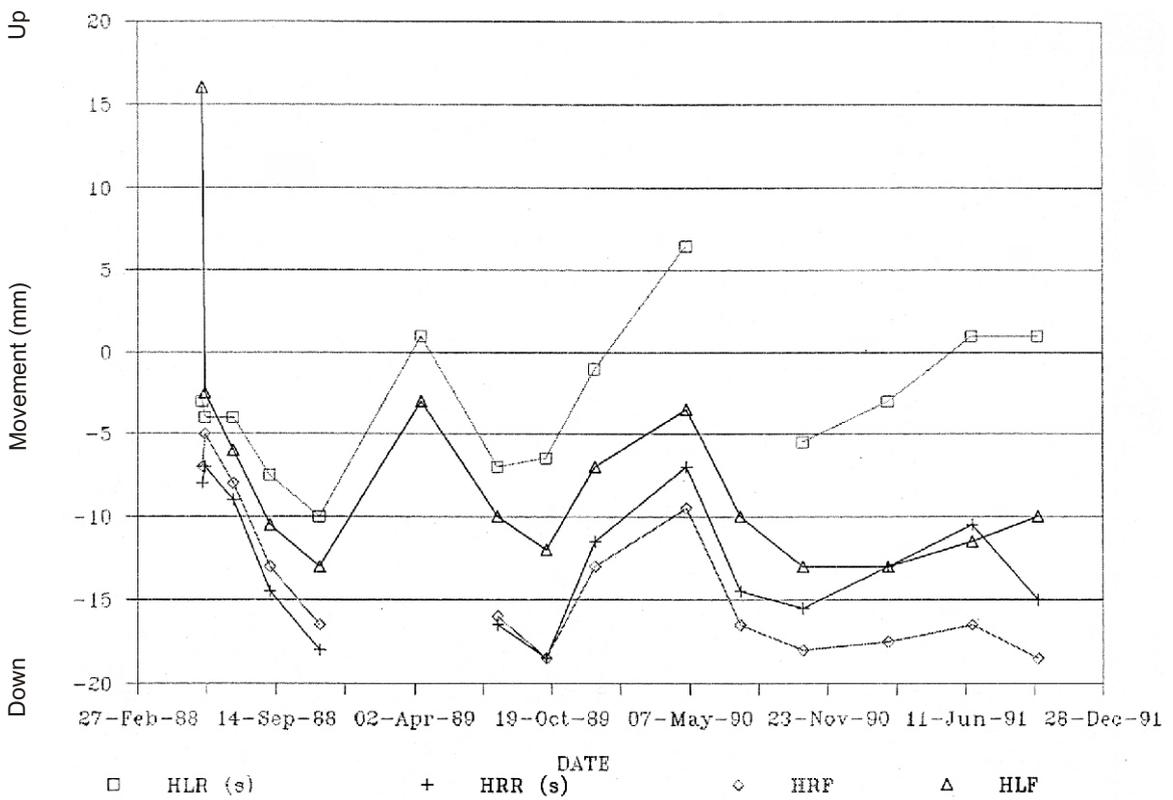


Figure 5
Survey monitoring, 149 Channel Highway, Tarooona

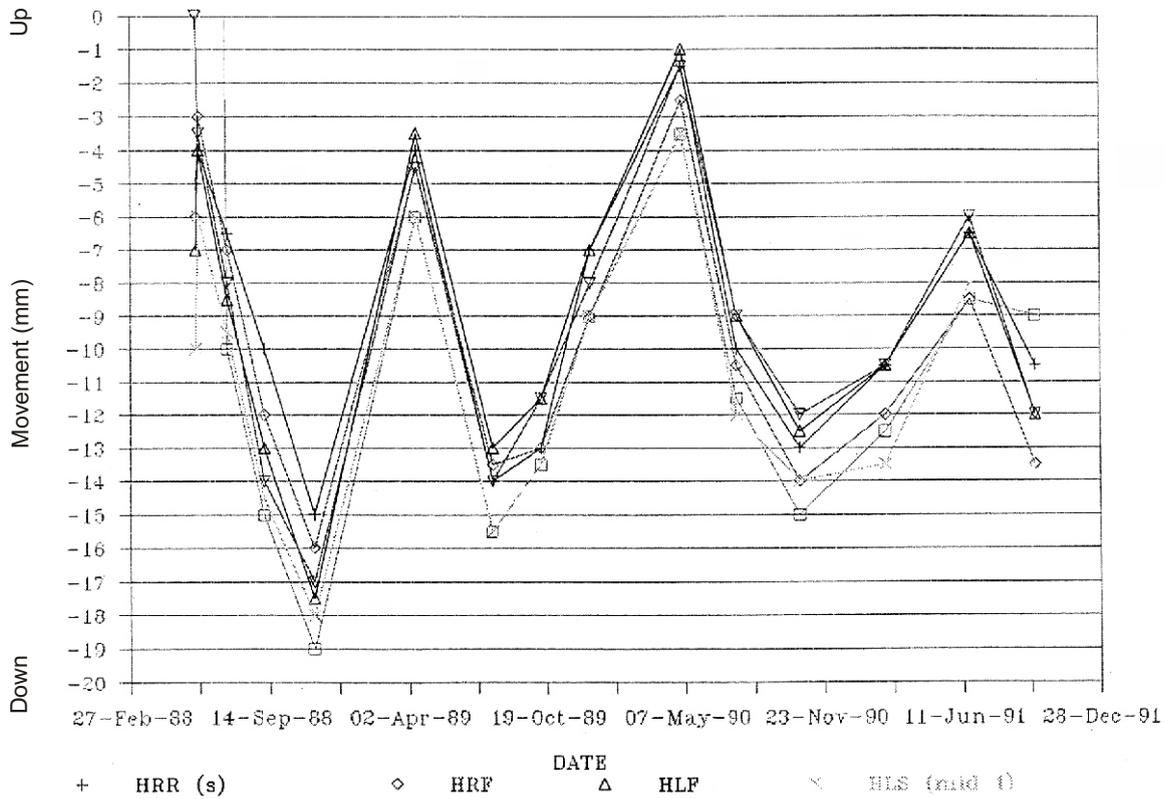


Figure 6
Survey monitoring, 151 Channel Highway, Tarooona

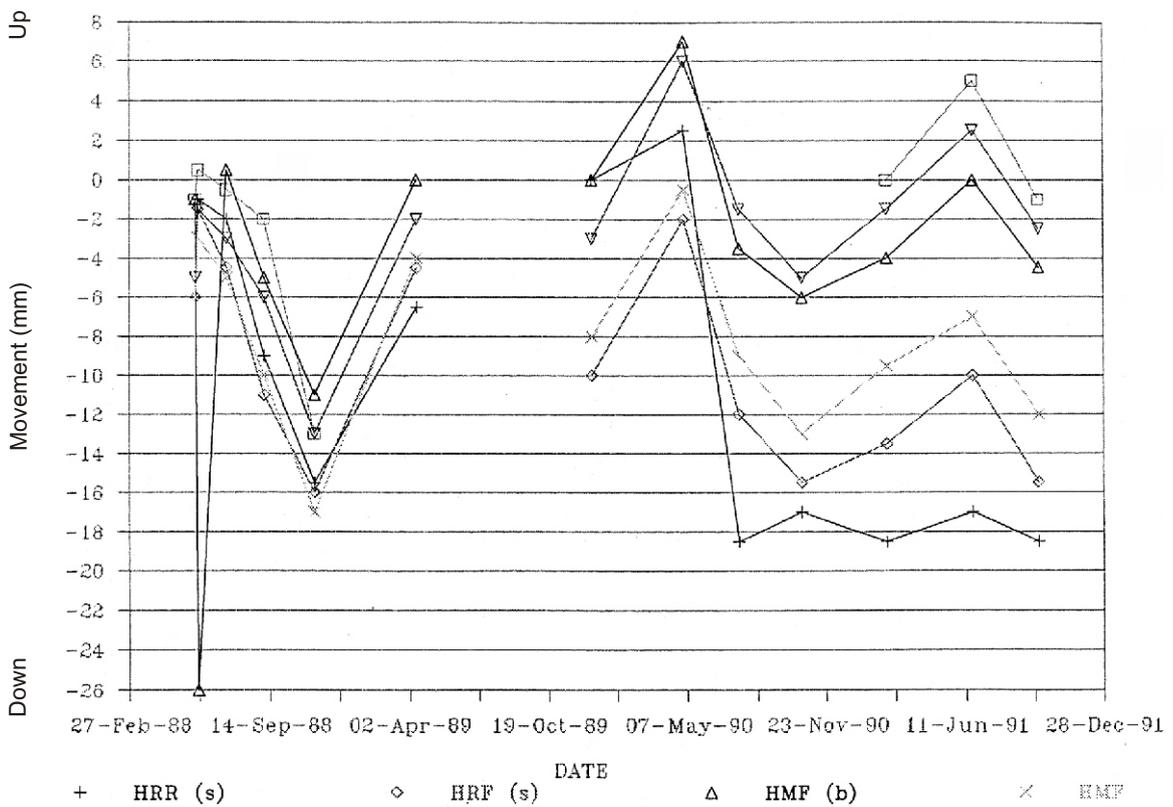


Figure 7
Survey monitoring, 153 Channel Highway, Tarooona

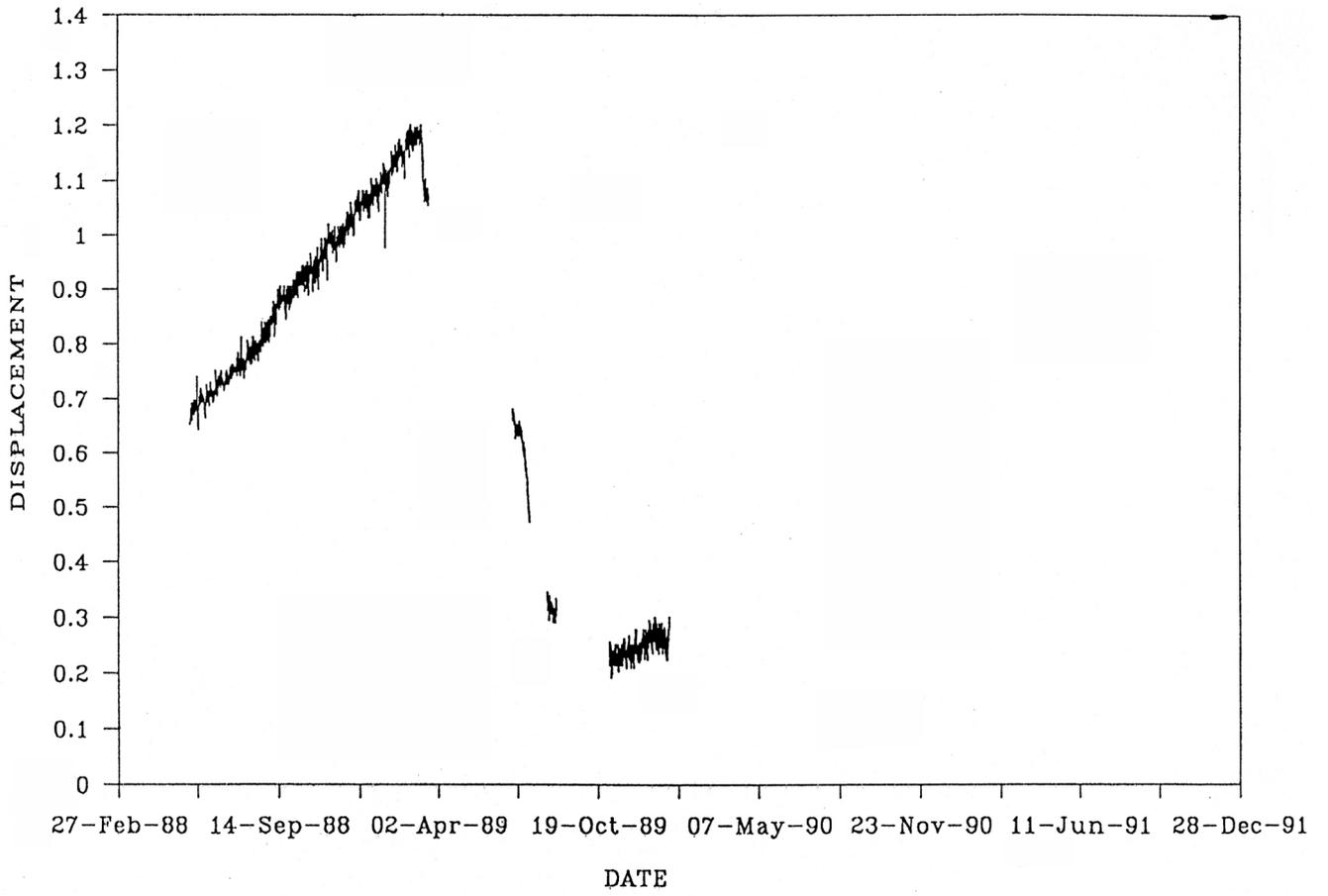


Figure 8
Taroona monitoring station
27 May 1988 to 6 December 1991