LANDSLIDE STABILISATION AT THE CLYDE POWER PROJECT: A MAJOR GEOTECHNICAL UNDERTAKING

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Construction work on one of the world's largest landslide stabilisation projects is drawing to a close in Central Otago. Begun in mid 1990, major stabilisation work has been carried out on seven large rockslides which will be partly inundated when the Clyde dam reservoir (Lake Dunstan) is filled. The work has required the construction of 14.5 km of tunnel, 60 km of surface drilling, 78 km of drilled drainage holes and 5 million cubic metres of earthworks. The stabilisation programme has been carried out by the Electricity Corporation of NZ as part of the Clyde Power Project, a hydro-electric development on the Clutha river.

BACKGROUND

The landslide stabilisation work described has delayed electricity generation from the Clyde power station. Review of the reservoir slope stability in 1987, utilising information from the major reconstruction of SH8 in the Cromwell gorge, led to the identification of complex groundwater conditions. These conditions were quite unlike those previously encountered in the Cromwell Gorge and were considered unfavourable for the stability of the reservoir slopes. Intensive investigations followed and identified other similar areas. Lake filling, planned for September 1989, was delayed while investigations and a reassessment of slope stability continued.

The Cromwell Gorge landslides are subtle features, lacking prominent scarps or markedly hummocky topography. They developed at least 50 - 150,000 years ago and are either dormant or creeping translational rock and chaotic debris slides. The landslides show no evidence of large scale rapid movement. They range in size from 3 million to over 1 billion cubic metres.

At the time of dam site selection in the early 1970's the presence of the Cromwell Gorge landslides was recognised. Stabilisation works were recommended for the Cromwell and Clyde slides because of their location adjacent to the Cromwell township and the Clyde dam respectively. Based on the

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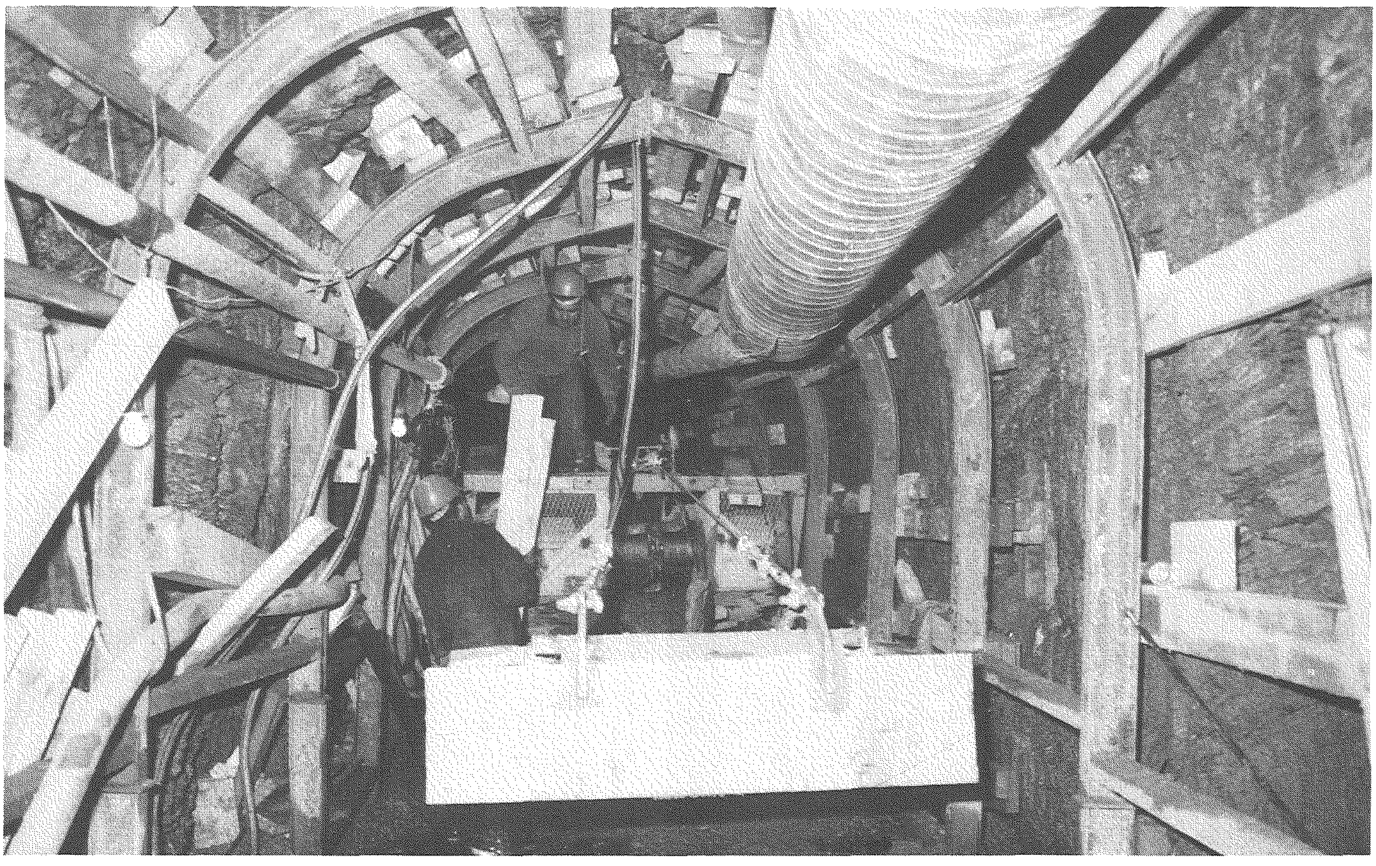

Figure 1. Drainage drive construction at Jackson Creek Slide

general appreciation of other similar landslides within the region at that time, it was not considered that the other landslides required treatment.

These elements of uncertainty were recognised and accommodated in the reassessment of the reservoir slopes by:

STABILITY, HAZARD AND RISK ASSESSMENT

The assessment of rock slide stability, hazard and risk is a challenging assignment for the geotechnical practitioner. The complexity of landslides is often such that observational data can be interpreted in a number of ways. Judgements are necessary at many stages in the assessment of stability, hazard and risk.

- aiming for good quality observational data, recognising that this was the basis on which later judgements would be made
- ensuring observations were separated from interpretation
- integrating the detailed observations to develop summary descriptions of the landslides and their groundwater systems so that sound general conclusions could be drawn
- providing appropriate organisational structures and utilising suitably qualified and experienced staff
- appreciating that the primary role of numerical analysis is in understanding the main factors influencing stability and in determining the relative changes in stability
- accepting that there are no reliable established methods of predicting landslide movements (velocity, acceleration and displacement) in relation to changes in stability
- evaluating the effect of judgements at key decision steps
- providing technical review by both independent specialist consultants and an independent Review Panel with interntional experience in similar work
- providing, where necessary, robust engineering solutions which could accommodate uncertainty.

Stability assessments prepared in mid 1990 described the nature and extent of each landslide, together with the effect of reservoir inundation on their stability so that the level of hazard and risk could be determined. It was found that the level of hazard and risk associated with the larger slides was such that stabilising measures were required to reduce risk to an acceptable level.

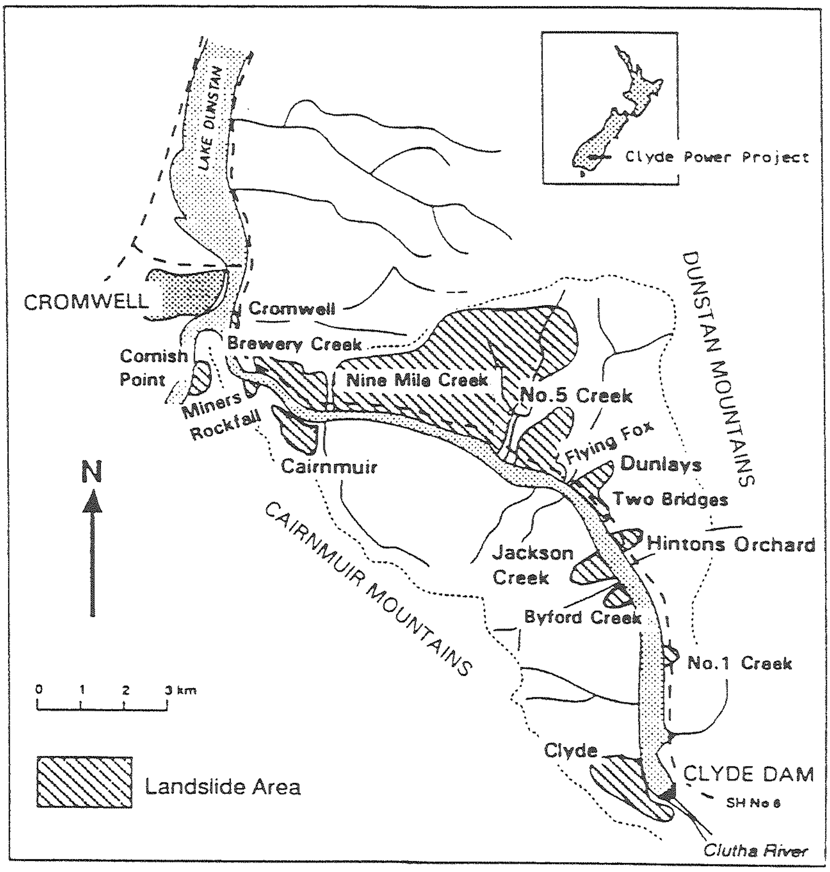

Figure 2. Project location

ENGINEERING WORKS

Drainage measures are widely recognised as the single most effective and economical stabilisation measure for large rock slides. The stabilisation programme developed in mid 1990 was based on tunnel layouts having dual objectives of providing definitive information on the landslides and stabilisation by drainage. The tunnels provided high quality geological observations on the nature of the landslides. Groundwater drawdown due to tunnel excavation also provided valuable information for the planning of underground drainhole patterns.

The concurrent investigation - design - construction activities inherent in this approach required information gained from tunnelling, drainhole drilling and groundwater monitoring to be quickly assimilated and alterations to engineering works promptly actioned. Extensive use was made of computer databases to manage technical information.

In addition to gravity drainage measures, the stabilisation works have also included the construction of toe buttresses in several situations. In the case of the Brewery Creek slide, the combination of a comparatively dry slide mass and a narrow river channel precluded a gravity drainage/toe buttress solution. A low level pumped drainage system was adopted combined with a grouted cutoff and zoned earthfill blanket to limit seepage.

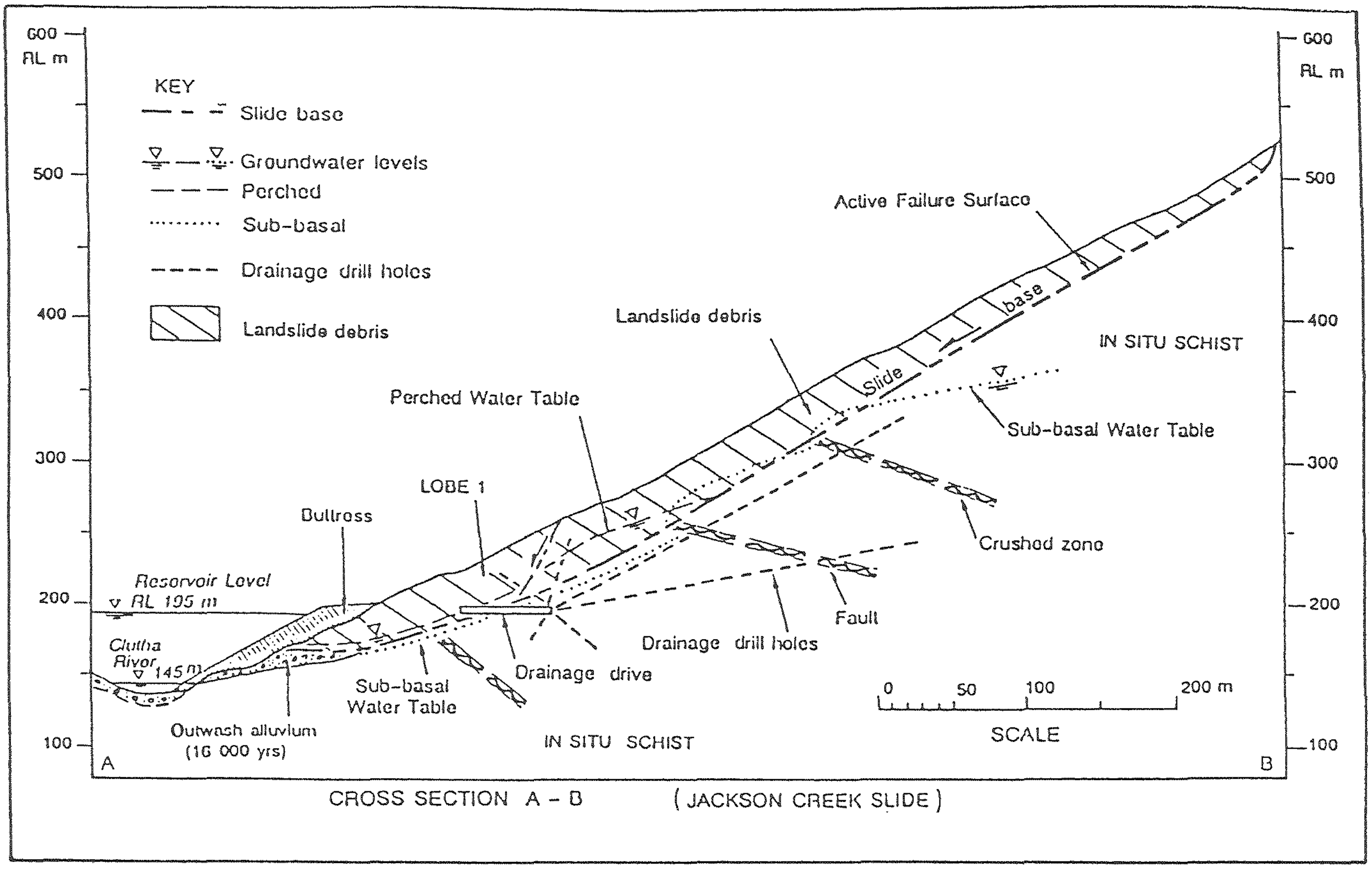

Figure 3. Stabilisation by gravity drainage and butressing works at Jackson Creek Slide

Stabilisation works carried out to date have halted movement at the Jackson Creek, Number Five Creek and Nine Mile Creek landslides.

Contracts for the various engineering works were initially cost reimbursable plus fixed fee so that alterations to the works could be made quickly for maximum overall time and cost benefits. In later stages, when the work was more clearly defined, target cost contracts were negotiated.

INSTRUMENTATION AND MONITORING

Central to the investigation, stabilisation and future management of the landslides are the network of instruments which have been developed for monitoring landslide deformations, groundwater pressures and drainage flows. There are approximately 3500 points being monitored on the Clyde dam and the reservoir landslides during lake filling.

The network includes instruments installed in boreholes, on the ground surface and in tunnels. A range of methods is used for collecting data, including manual recording, logging by electronic datalogger and transmission by telemetry.

Instrument readings are recorded in a computer database which has facilities for raising an alarm if the actual results are outside forecast ranges. The computer system also monitors the actual reading of instruments against the reading frequencies which have been requested so that the planned coverage of readings can be tracked and maintained.

LAKE FILLING

Lake filling will be a closely monitored and managed activity. It will be controlled by the response of the Clyde dam and landslides to inundation and the associated monitoring and evaluation activities. It is expected to start in April-May 1992.

The lake will be filled in a number of stages extending over a 1-2 year period. A high degree of control is available at each stage from the low level sluices and spillway in the dam. Electricity generation will be available from the first stage onwards.

During lake filling the behaviour of the dam and reservoir shoreline will be monitored by both instruments and regular visual inspection. Results will be assessed by experienced staff and reported regularly. Information obtained during lake filling will be used to confirm the geological and geohydrological models of the landslides. These will form the basis of the future management strategy for each landslide.

Following lake filling, monitoring and evaluation of landslide behaviour and the performance of the engineering works will continue throughout the life of the reservoir.

PROJECT ORGANISATION

The stabilisation works described result from the effects of a large, well integrated team working together to meet demanding project deadlines and objectives. The team was assembled by the Electricity Corporation of NZ and included members of their own organisations, staff from Works Consultancy Services Ltd, DSIR Geology and Geophysics, and specialist subconsultants.

The work has been subject to regular review by both specialist subconsultants and an International Review Panel. In their seventh report dated February 1992 the International Review Panel stated *"... that the geological and engineering work has been well done and equals or exceeds current international practice"*.

The project team look forward to the final stage of the Clyde Power Project - lake filling and generation.

As a postscript to the above, the following update was provided by Murray Gillon in June on progress at that time on the filling of the Clyde dam reservoir:

The reservoir has been filled to El 177 m, 17 metres below normal operating level and 39 metres above the former river level. Filling started on 22 April and was completed to El 177m on 14 May.

All the lower level slides in the Cromwell gorge have been inundated to varying degrees. No shear movements have been detected in the major landslides. There has been minor surface cracking in some of the major road fills and landslide buttresses due to differential settlement following toe inundation.

The instrument network has been further developed and currently there are 5200 instrumented locations. The computer database and data management facilities have performed extremely well and have enabled the design team to confidentially and quickly evaluate the monitoring results.

It is anticipated that performance evaluation of the dam and landslides will be completed to allow the lake level to be raised to El 185 m in August.

Murray Gillon 17 June 1992