# GEOPHYSICS

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## 13. Summary of methods and ideas in landslip geophysics.

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There has been an increase in interest and activity in the problem of landslips in Tasmania in recent years. With the passing of legislation relating to landslips much greater emphasis on recognition, appraisal and corrective recommendation has been required. Until a slip actually occurs, geological recognition remains largely an intuitive process based on certain surface features which may not be pertinent to a correct conclusion. Appraisal of a failed area is also difficult especially if the heel and toe are not physically obvious such as in a very recent failure. Corrective recommendations are largely based on inferences deduced from certain types of observations such as ground cracking, wetness, relief shape or slope, or material class. Very little quantitative measurement is currently undertaken and in order to gain some extra information on material properties, water content, potential failure sites, size of failed areas, indication of past failures and physical dimensions of recent failures, geophysical work has been suggested. This report presents a brief summary of methods which might be applied, the type of results to be expected and a discussion of the problems to be faced.

*Form of landslip*

There are two main types of landslip:

(1) a slide, slump or creep which is essentially a linear feature with the failure surface at shallow depth and roughly parallel to the surface, and

(2) a rotated block which is more equidimensional and may involve quite massive material.

By their very nature, the study of landslips is a difficult problem to approach since the range of properties tends to be minimal and crucial features, such as the failure surface, are restricted and narrow areas. Many determinant features may be present, none of which occurring alone might be serious.

### GEOPHYSICAL METHODS AND THEIR APPLICATION

*Seismic methods*

*Refraction.* Conventional and fanspread layouts can be used to determine slide thickness (presumes slump type). In such cases there is a thickening of the upper low velocity layers although it must be noted that an increased thickness may be due either to localised weathering or a previous and perhaps not obvious failure. In the case of failures, the failed earth which is, or has been, waterlogged or is fractured has a distinctly lower seismic velocity and in the dry condition determination of the slump surface is possible. When saturated such determination will probably not be possible due to the hidden layer condition because the failed wet soil may be denser or as dense as unfailed wet soil.

Where rotational slides involve soil and weathered material a similar situation applies. Where relatively unweathered rock is involved, no simple determination of slip scale will be possible as the narrow low velocity slip zone will be hidden. Various applications based on fan methods may be successful if shot downslope of the failure.

It is also possible to measure *in situ* the bulk modulus, Poisson's ratio and rigidity modulus using three component geophones. Whether measurement of such properties is useful remains to be proved. There would be an obvious relationship between these characters and soil, slip material and rock.

*Vibration dynamics*. In this method two types of measurement are feasible. It is possible to determine the natural frequencies of a slab of earth, or the attenuation properties of the material. This method can be applied to very small areas (a problem with other methods) and can thus detect localised zones which are vibration sensitive. Normally the more unconsolidated the material the lower the critical resonance frequency. Therefore it is possible to locate areas where there are accumulations of soil or dislocated rock. Natural frequencies are determined from examination of records from pulse sources. Enhancement seismographs with display are ideal for this purpose. Having determined the set of frequencies induced in the material, the critical resonance can be isolated using standard seismic equipment and a vibratory source adjusted across the required range. Critical resonance is recognised by a large amplitude increase.

*Electrical methods*

*Resistivity*. Conventional traversing could be used to locate failed zones or zones which are water saturated that might fail in the future. Failed areas, in part at least, have a variation in texture, structure and fracturing and consequently a different resistivity. Old failures which may be present as a depression in soil would probably be detected by water content. The resistivity of any contained water contrasted with the soil resistivity is crucial to the success of the method and as a result the method may not be precise.

The use of sounding methods is limited due to the broad summation of effects. Although it might be possible to make estimates of slide thickness, presuming a resistivity contrast between slide and base, it is unlikely to be sufficiently accurate in view of the scale of near surface errors. Rotation failures involving any large amount of earth could not be approached with this method.

*Potential methods*. Landslips in most materials are related to water content, water paths or leakage.

Small self potentials can be present in addition to piezo and electrokinetic potentials. The latter properties are probably dwarfed by the self potential and are included in any such measurement.

In a clay-water situation, induced potentials would probably yield the most reliable information on water content since the chargeability will be related to the water content. Self potentials offer a very useful method which needs some development in this field.

*Magnetic methods*

Where magnetic rocks are involved it is possible to determine rotation movements by comparing the magnetic orientation of the slip fragments with *in situ* material.

## SUMMARY


The problem of geophysical identification of landslips reduces to two parts:

(1) identification of potential failure areas; and
(2) description of slip and slip material properties.

The first part requires location of thick accumulations with high water content in appropriate relief situations. In certain cases resistivity surveys can indicate such zones but the vibration methods and possibly the IP methods are more reliable.

The second part requires description of physical scale and properties, which only seismic methods could be sufficiently reliable, but even then only in some circumstances could the depth and shape of the failure zones be determined.


## EXAMPLES OF INITIAL RESULTS

The results are expressed as periods rather than frequencies indicating the means of determination.

| | |
|---|---|
| Batman Bridge: | Seismic velocity, material in slip 335 m/s<br>sub-slip 750 m/s<br>Tertiary units 1500 m/s<br>On slip: vibration - natural periods 24-26, 32-36, 42-44, 52-56, 60-62, 64-70 significant dispersion only of 42-44 group to 44-48. All periods ms.<br>Resonance at 25 Hz, 55 Hz.<br>Off slip: periods 24-26, 30-32, 34-36, 40. No long periods.<br>Maximum thickness of slip: 2.75 m. |
| Rhyndaston: | Pulse off slip: natural periods 18, 24, 28, 32, 38 ms. |
| St Helens: | Soil velocity: 300 m/s.<br>Tertiary unit velocity: 1300 m/s (indicates high sand proportion since Tertiary clays are usually 1500-1650 m/s).<br>There were very obvious changes in wave form as the margins of the slip area were crossed with the pulse source.<br>Most recorded periods in the range 20-40 ms with some dispersion.<br>Not all results have been examined to date. |

*Comparative results*

| | | *ms* | | *ms* |
|---|---|---|---|---|
| Undisturbed | Tertiary clay | 10-40 | Recent Fill | |
| | Tertiary sand | 12-40 | Cornelian Bay | 16-54 |
| | Sand | 10-24 | Dolerite | |
| | Mathinna rocks | 3-4.9 | Domain | 8-32 |
| | Basalt | | Basalt talus | |
| | Kelso | 6-18 | Hillwood | 14-40 |
| | | | Windermere | 19-45 |

Resonant period: 24 ms

*Conclusions*

(1) The lower the natural periods (or higher frequencies) the more stable, compact and solid is the material. The presence of even one major joint makes a 33% variation.

(2) Solid rocks have narrow ranges of low periods (see basalt).

(3) Critical resonance is at low period (high frequency) in solid rocks, normally >50-100 Hz.

(4) Unconsolidated or poorly consolidated materials have a wide spectrum which normally terminates at 45-50 ms. The presence of ground cracking or water extends this range.

(5) The form of the transmitted vibration changes drastically with crossing of ground fractures. Longitudinal vibrations are reduced in favour of shear vibrations.

(6) Slips can be detected if enough is known about the surrounding materials.

(7) In Tertiary rocks a wide band, low resonance frequency and low velocity may well indicate a slip, either recent or potential.