3. LANDSLIDE TYPES AND OCCURRENCE

3.1 *Classification of Landslides*

The main categories of mass movement along slopes are creep, slide, flow and fall. The term “landslide” is generally applied only to slope movements involving sliding, flowing or falling, occurring either individually, or in combination. More specific classification is achieved by describing the following features:

* Type of movement in more detail
* Type of material
* Dimensions
* Other characteristics such as moisture content, age, type location and geological type

Figure 3.1 is a general classification system based on the landslide features described above. It is modified from Varnes (1958) and include ideas from Hutchinson (1968) and Nemcok at al (1972).

Figure 3.1 – Landslide classification system

TYPE OF MOVEMENT		**TYPE OF MATERIAL**	
		BEDROCK	Highly weathered to fresh rock
		DEBRIS	Rocks fragments ± soil matrix
		SOIL	Sand, silt and clay. Soil in the engineering sense
		EXAMPLES	
FALLS	Material suddenly detached from slope with little or no shear displacement	Rock fall, debris fall, soil fall	
SLIDES	**ROTATIONAL**	Shear displacement of partly coherent material along concave surfaces	Earth slump, debris slump, rock slump, terracettes
	TRANSITIONAL	Shear displacement along planar sliding surfaces	Debris slides, earth slides, rock slides.
FLOWS Slow or rapid, wet or dry flows along planar sliding surfaces		Debris flow, earth flow, quick clay flow, solifluction, soil creep, dry sand flow.	
COMPLEX TYPES Combination of one or more of the above types		Slump, earth flow	

After Varnes 1958, Hutchinson 1968, and Nemcok 1972

3.2 *Recognition of Landslides*

Recent landslides are easily recognised by the presence of diagnostic features such as those shown on Figure 3.2. With time, the features become less prominent due to natural weathering processes and cultivation of the land, until identification can become quite difficult. However, with the aid of aerial photography and careful observation on the ground, aged landslides can be identified with a high degree of certainty. The following features are indicators of past landslide activity in the study area:

* Anomalous changes in slope, often highlighted by irregular shadow patterns. Arcuate depressions and the steep main scarps are the dominant geomorphological features of old landslides. However, hummocky ground and lobate earth flows also remain as distinctive features for many years.

* Zones of impeded drainage and seepage, usually indicated by variation in vegetation type and vigor.

  These features are more pronounced in recent landslides, but colour infrared photography can assist in delineating moist zones in old landslides as shown in Figure 3.3. Included in this category are the small basins of internal drainage which often contain pools of water as shown in Figure 2.5.

* Accumulation of landslide material in valleys and erosion of this material by streams.

*		Disturbed, displaced or covered: trees, roads, fences etc.

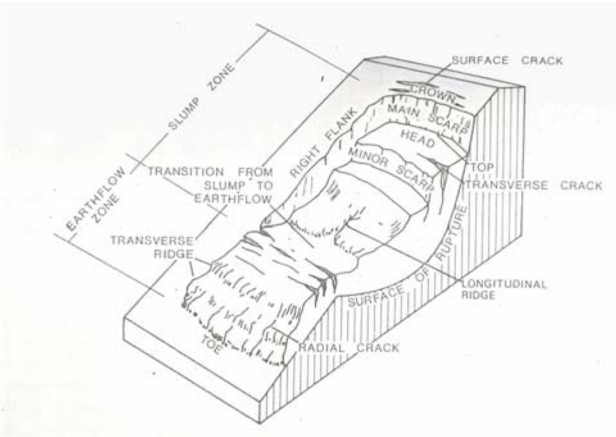


Figure 3.2 – Diagrammatic representation of a typical slump – earth flow (After Varnes, 1958).

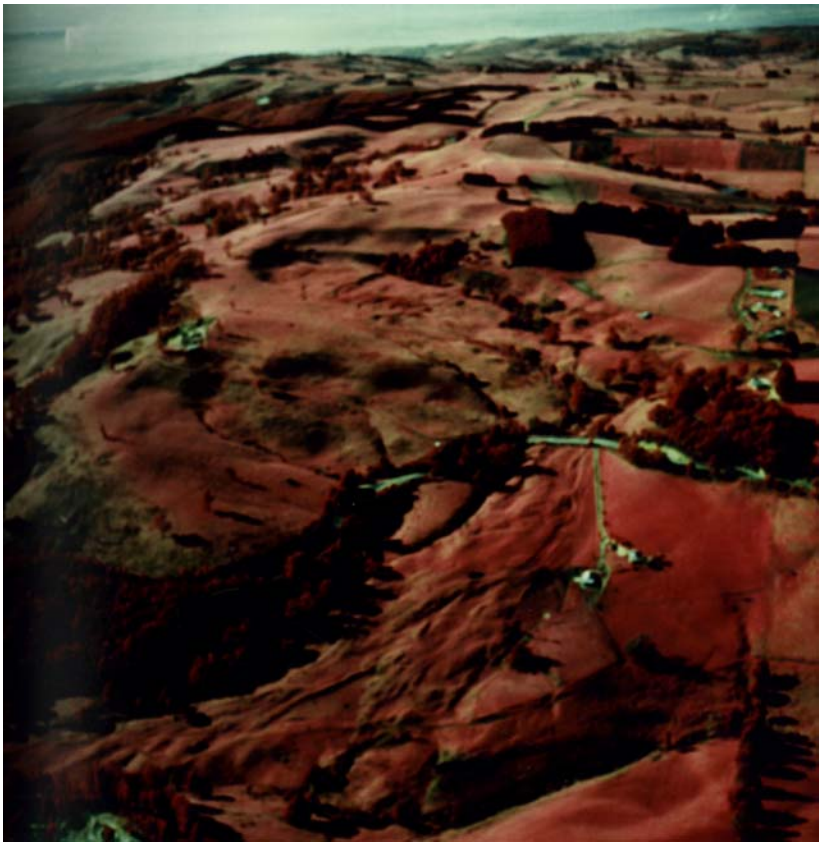


Figure 3.3 – Oblique aerial infrared photograph of landslide No. 10 on the Trafalgar-Thorpdale Road, near Ryans Road.

Moist zones in the recent slump-earth flow are shown in green shadings. Features of the fossil and dormant landslides to the left and in the background are more subdued. Unfortunately, the photograph is slightly out of focus.

The following types of aerial photography were used in the study as an aid to landslide recognition:

*		Black and white, vertical photography at 1:25 000 with stereoscopic cover
*		Oblique and vertical, large scale colour photography, sometimes with stereoscopic cover
*		Oblique, large scale colour infrared photography, with some stereoscopic cover

The colour and infrared aerial photography was carried out by Mr B Sawyer of the Country Roads Board, Victoria. The use of detailed and varied aerial photography proved to be an extremely valuable means of studying landslide development and morphology, and of recognizing old landslides. Details of the photographic equipment and techniques used are given in Appendix 3.1.

3.3 Landslides in the Study Area

3.3.1 Landslide Distribution

The distribution of old and recent landslides was determined mainly by interpretation of 1:25 000 black and white vertical aerial photographs combined with careful field observation. The distribution was plotted on a 1:25 000 base map then transferred to the 1:126 720 road base map for correlation with the geology, terrain and road maps in Section 6. The landslide distribution map is included as Figure 3.4.

3.3.2 Roadside Landslides

The locations of roadside landslides listed by the Shire in 1975 are shown in Figure 3.5 in Appendix 1.2. In Section 4, the nature of each roadside landslide and the damage caused is described together with details of the field work carried out. From this list, several typical landslides are now selected to illustrate the nature of landslides in the study area.

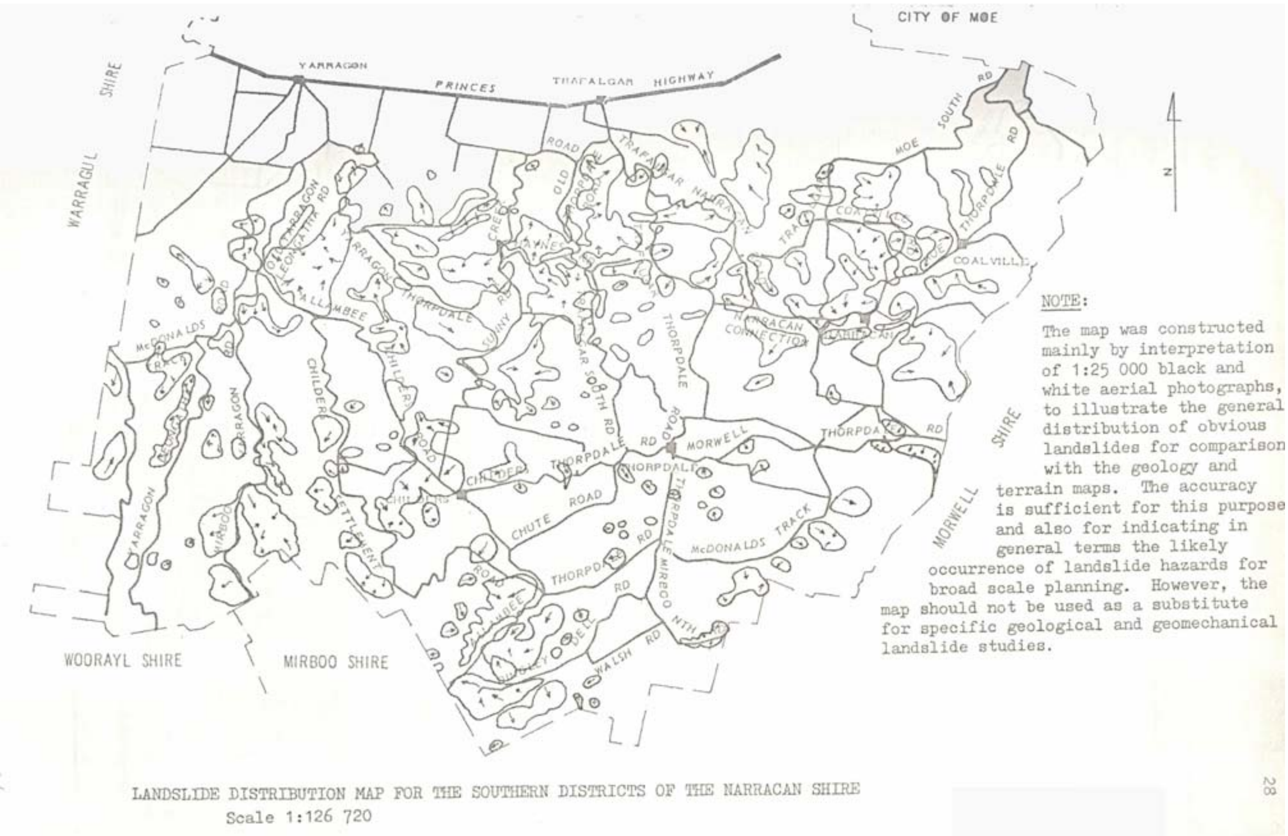
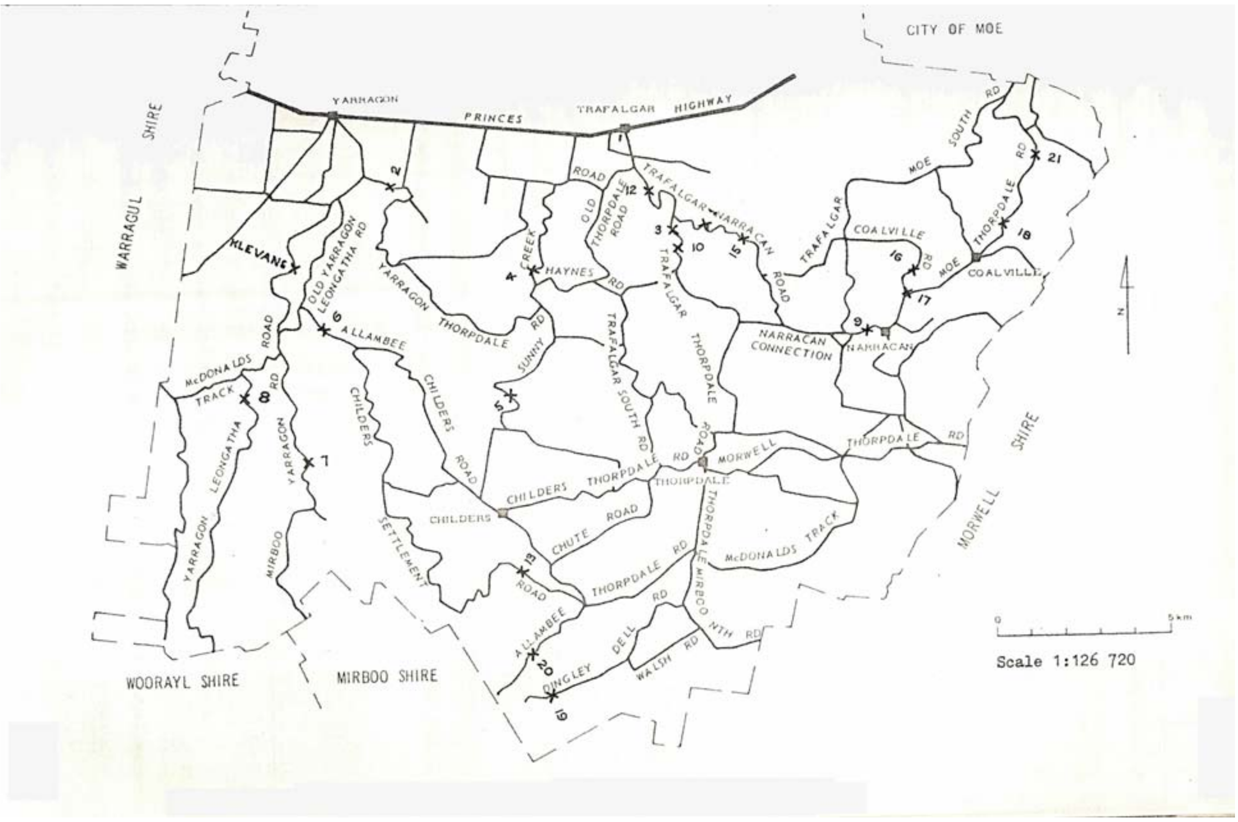


Figure 3.4 – Landslide distribution for the Southern Districts of the Narracan Shire Location of Roadside Landslides listed by the Shire in 1975



3.3.3 Landslide Types

The most common landslides are complex ones of the slump – earth flow type as shown in Figure 3.2, 3.6, 3.7 and 3.8. These landslides disturb many hectares of land and cause serious damage to the Shire roads each winter. The roads are narrowed by slumping, covered by earth flows and displaced laterally by creeping landslide material. Figure 3.8 is a photograph of a typical large slump-earth flow which crosses the main Trafalgar to Thorpdale Road (Landslide No. 10).

The slump-earth flows combine several types of movements. In the slump zone, where material is removed from the slope, the movement is dominantly rotational, but translational shear displacement can also occur. A typical slump zone is shown in Figure 3.6. The slumped material proceeds to break into smaller components and flow downslope as a wet viscous mass of earth as shown in Figure 3.7. The rate of flow is a function of the viscosity of the slope. Flow rates for fresh earth flows at the time of failure have been reported by local people to be in the order of 1 metre per minute, but accurate measurements have not been made. Following the initial period of relatively rapid flow, slow creep in the order of 1 metre per year or less can continue for many years,

When landslides originate within the road pavement (e.g. Figure 1.2), the material often consists predominantly of sand and gravel used in the construction of the road – especially when the road has been repetitively filled after previous small landslides. These landslides are also of the slump-flow type, but the term slump – debris flow should be used rather than slump-earth flow, because "earth" refers to sand silt and clay soils, while debris consists of rock fragments usually in a soil matrix. "Klevans" landslide on the Yarragon to Leongatha Road is also a typical slump-debris flow, but in this case the landslide occurs within the natural slope debris which consists of angular fragments of weathered mudstone in a clay and silt matrix.

On grassed slopes, relatively shallow landslides are common in which the movement is basically translational with shear displacement along approximately planar sliding surfaces. The movement usually terminates in an earth flow. Complex landslide types occur between the translational landslides and the slump-earth flows, but the two types dominant over the variations in-between. The translational landslides are typically small features in contrast to the relatively large and damaging slump-earth flows. A diagrammatic representation of a typical translational landslide is shown in Figure 3.9. Shallow translational landslides are also referred to as "sheet slides" (Zàruba and Mencl, 1969) or "slip-off slop landslides" (Jones, 1961).

Other slope movements operating in the study area include soil creep, rock falls, and possibly small terracettes. Soil creep is a long term process in which the velocity does not increase. Rock falls are rare, and are confined to the steep road cuttings in the Lower Cretaceous sandstones and mudstones. Small ridges contouring the hillslopes are common and most probably are due to contour ploughing and/or cow tracks, but it is possible that in some cases they are small stepped rotational landslides called terracettes.

Figure 3.6 – Slump zone of active slump-earth flow, Dingley Dell. July 1978.

Figure 3.7 – Toe of earth flow zone of recent landslide, Dingley Dell. July 1978.

Figure 3.8 – Slump-earth flow cutting across Trafalgar-Thorpdale Road. Slump zone above the road, earth flow zone below road. Winter 1978.

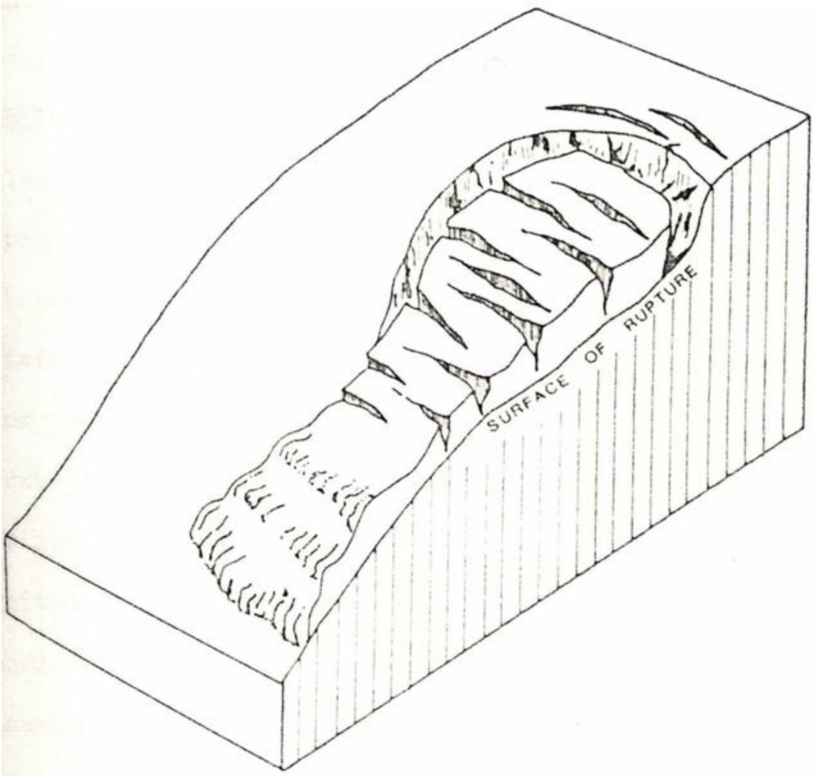


Figure 3.9 – Diagrammatic representation of a typical translational landslide.

3.3.4 The Age of Landslides

Zàruba and Mencl (1969), distinguish the following 3 classes of landslides according to age:

1. Contemporary or recent landslides which are usually active and easily recognized by the sharp topographic expression of the landslide features.
2. Dormant landslides in which the topographic expression is obscure and recognition may be difficult; though the cause of the movement may be renewed.
3. Fossil landslides generally developed in the Pleistocene or earlier periods, under different morphological and climatic conditions. Movement cannot be repeated under present conditions.

Evans and Joyce (1974) point out that the landslides were observed in Victoria before any land clearing and farming took place. For example, Major Mitchell commented on landslides in the Glenelg River Valley near Coleraine, Victoria in 1839. Similar historical accounts of pre-settlement landslides are not known for the Strzelecki Ranges, probably because the dense forest made observation difficult. It is certain though, that landslides did exist in the Strzelecki Ranges prior to settlement. Much of the landscape has been shaped into large arcuata depressions on a scale that would certainly have raised considerable comment among the early settler if landslides of such magnitude had followed the clearing of the forest. Early newspapers record details of other natural hazards such as floods and fires, but no mention is made of large landslides. These landslides are more than a kilometre across in places and represent the natural maturing of the landscape as stored energy is released during weathering and unloading. They probably occurred during the Pleistocene when different climatic conditions existed, and as such, would be classified as fossil landslides.

A dominant characteristic of the landslides is the tendency for progressively smaller landslides to develop on larger pre-existing ones. In the Dingley Dell landslide complex, at least 3 generations of landsliding can be observed. Fossil, dormant and recent landslides are all present as shown in Figure 3.10. The recent landslides affect less than 10% of the fossil landslide area, nevertheless they have caused considerable damage to farm land and have closed the Dingley Dell Road.

Figure 3.10 – Dingley Dell landslide complex, consisting of at least 3 generations of multiple slump-earth flows.

The entire foreground is a fossil landslide, clearly defined by the large arcuata depression at the head of the slump zone. Numerous grassed dormant landslides are superimposed on the fossil landslide. The active landslides are obvious from fresh earth scars and earth flows. The Dingley Dell Road traverses the area. At point A, the road is entirely removed by a slump and at point B it is covered by an earth flow. Following heavy rain, further landsliding occurred below a dam (point C) a few week after this photograph was taken in winter 1978.