The advent of post European Erosion in a Valley Swamp

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ABSTRACT: *Incision of Scrubby Creek was initiated when human intervention exposed subsoils with an erosive cocktail of high sodium (Na^+) concentrations, alkaline pH and humic material associated with buried swamp deposits to streamflow. Such conditions coupled with clay cracking generated by wetting and drying cycles within the drain itself were critical for subsequent rapid erosion, rather than catchment wide changes. Although subsoils were potentially dispersive, actual losses from the cliffs were governed by the imposed hydrological setting, with the greatest erosion evident during the period of greatest change shortly after the original swamp was drained.*

1. INTRODUCTION

Since the arrival of European settlement, Scrubby Creek has transported some 175,000 m^3 of sediment. Consequently, the original valley swamp 40 km north of Melbourne, fed by a 2,500 ha catchment, has degraded into a 10 m deep incised watercourse. This paper outlines research into the development of gullies along drains originally cut in 1903 and mechanisms contributing to the ongoing instability (Fisher, 1993). Although an emphasis is placed on quantifying the erosion processes within a small study area, a thorough understanding of the important mechanisms potentially has broader applications including rehabilitation strategies for the 17,000 km of degraded streams in Victoria (Mitchell, 1990)

2. THE ADVENT OF INCISION

The arrival of European settlement within the Scrubby Creek valley heralded major changes for the watercourse. The creek flats were cleared to make way for horticultural crops such as apples; and drains were installed to alleviate the waterlogging identified by the original government inspectors. The intensive settlement between 1893 and 1910 laid the framework for subsequent gully formation along the cleared and burnt drainage lines.

Incision along the newly created drains was rapid, especially through Mr. Gilchrist's swampy flats (Lots 12 and 13: Figure 1). The stream erosion progressively destroyed bridge crossings and eventually threatened the safety of pupils at the Humevale Primary School. The magnitude of this erosion is depicted in Figure 2. Erosion along the lower reaches was less severe with no incision evident beneath an aqueduct bridge constructed in 1886.

The period of down cutting between 1900 and 1940 was not linked to unseasonally wet years or widespread catchment clearing. Rainfall and flood records fail to indicate any significant changes in rainfall intensity and flooding frequency during this period. Indeed the largest recorded floods within the catchment occurred in 1878 and 1974, outside the period of greatest stream instability. Similarly, an increase in total discharge during the same period is unlikely as much of the catchment remained forested, initially set aside as a possible water catchment for Melbourne.

3. THE ROLE OF DISPERSION

The soils adjoining Scrubby Creek developed on an alluvial fan produced by hill wash deposits from the weathering of lower Devonian sedimentary rocks. Successive swamps were buried by erosion cycles, incorporating grey organic sands, muds and humic material within the soil profiles. Finely ground muscovite and illite were the dominant clay minerals.

Weathering produced sodic yellow duplex soils with typically alkaline or neutral subsoils (Northcote and Skene, 1972). These subsoils were highly dispersive when immersed in natural creek water, a process aided by the mechanical energy supplied by running water. In contrast, subsoils saturated with natural groundwater failed to disperse when inundated by creek flows.

Buried humics associated with previous swamp deposits also aided the dispersion process. Organic coatings on the clay particles increased the pH range over which the clays were potentially dispersive. However, difficulties in accurately isolating the organic groups precluded the establishment of any unequivocal relationships between buried humic material and subsequent erosion.

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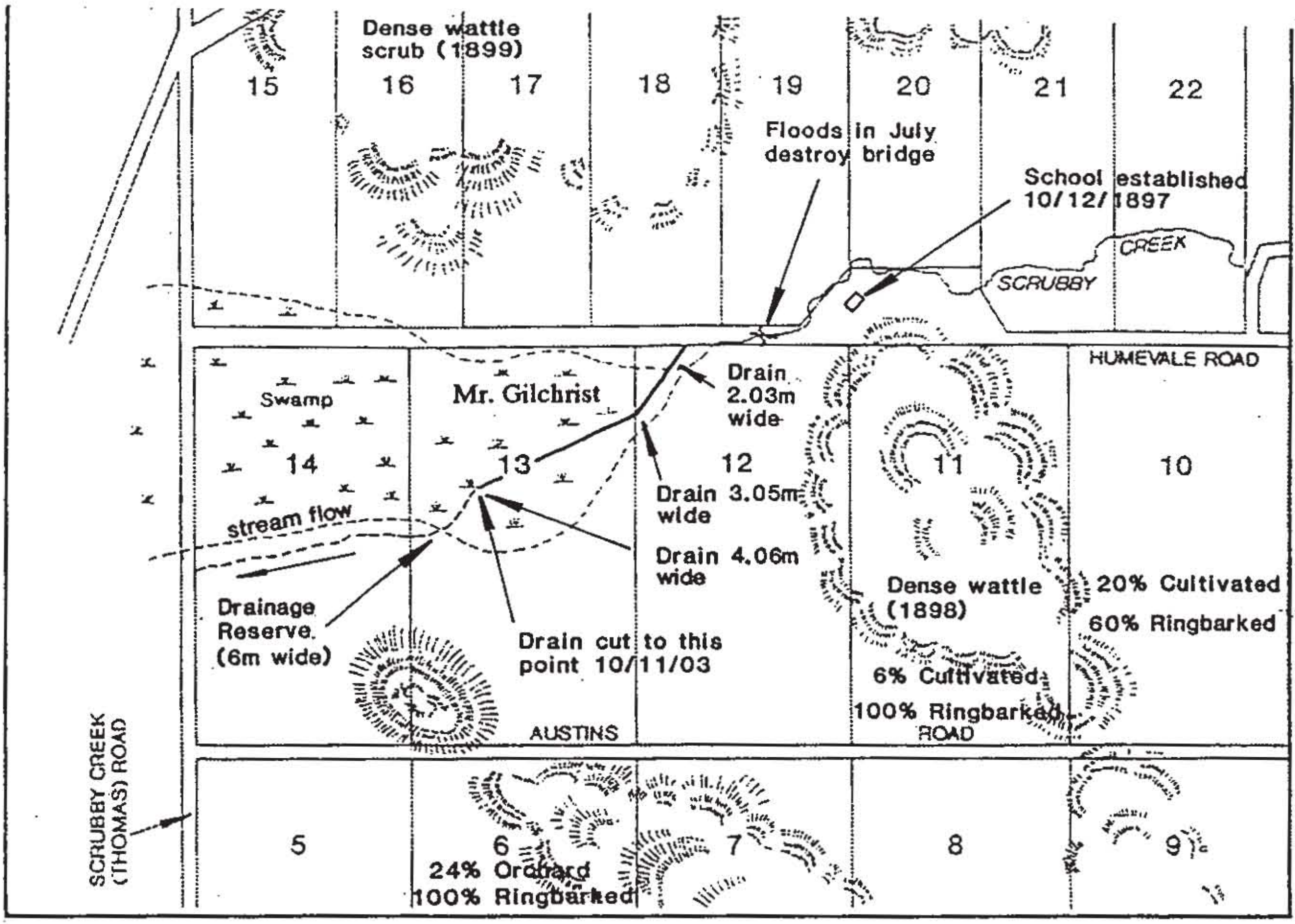

Above: 1904, Drainage works initiated

(Source: field notes, closer settlement files)

Below: 1920, Orchards and Vineyards

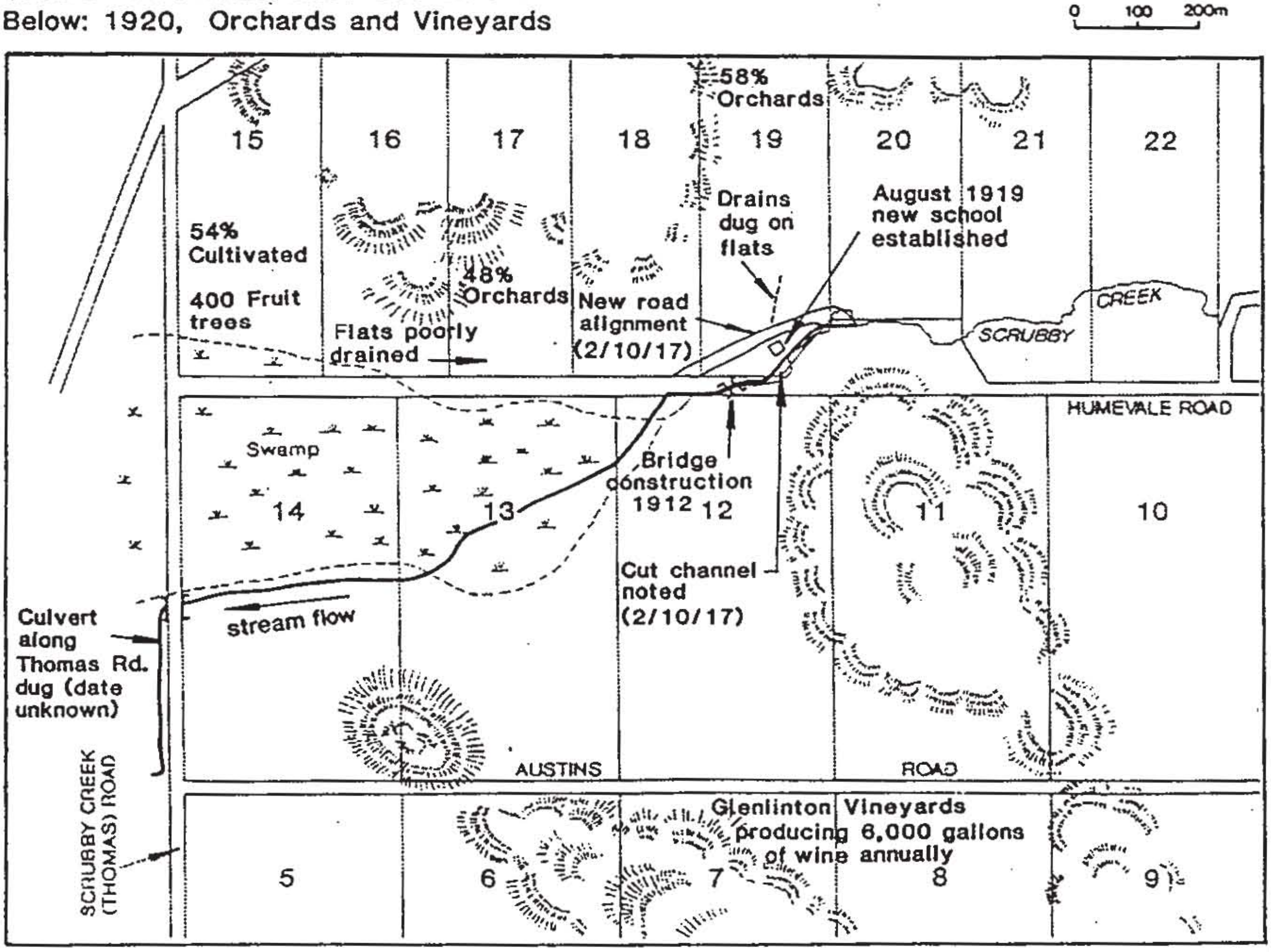

Figure 1. Initial Development of Incision

Above: Primary School site in 1906 looking North. Limited incision is already evident and vegetation has been removed. Note, stock access track.

Right: The same site in 1991 looking west. Note the creek now follows the road alignment depicted above. The fence provides a common reference point. Concrete footings from the school toilet block cling to the edge.

Figure 2. Comparison of the Humevale Primary School Site in 1906 and 1991

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4. CONTEMPORARY EROSION LOSSES

Although potentially dispersive in a test tube, the response of subsoils to the imposed hydrological setting must be assessed in the field. The very act of preparing soils for examination in a laboratory radically changes any natural resistance to erosion.

Erosion losses from the Scrubby Creek gully were directly assessed using terrestrial photogrammetry. This technique was adopted as hazardous site access and complex surface shapes precluded traditional tacheometry. Continuous monitoring of sediment discharge was also precluded by sampling difficulties especially fluctuations in sediment generated even within a particular storm (Olive and Rieger, 1986).

Monitoring over two years identified significant differences in erosion rates both down a given cliff profile and between sites along the creek. The greatest erosion on individual cliffs was evident where moisture fluctuation produced cracking. This typically occurred in a zone between maximum and minimum groundwater levels or where banks were regularly inundated. The bulk of the cliff profile which remained either dry or saturated by saline groundwater throughout the season failed to exhibit any significant losses. Significant erosion was confined to a small number of actively eroding sites, less than 11% of the total channel length.

The sodic nature of cracked subsoils aided subsequent fluvial removal. The high Na^+ concentrations ensured that both the clays within the cracked material readily dispersed in running water, and binding vegetation failed to establish in an otherwise suitable seedbed.

Once the cracked material was removed the underlying fresh subsoil was largely impermeable to streamflow, due to the dense structure produced by a combination of overburden pressure and sodic groundwater conditions (Shainberg and Letey, 1984). Consequently, frequent sediment exhaustion was noted as the potentially erodible material became progressively more difficult to detach as the season or individual storms progressed.

The timing of streamflow rather than discharges or length of inundation *per se* was critical for subsequent erosion. Erosion was greatest when drying and wetting cycles occurred in quick succession with frequent flows to remove loose material. Consequently, small Autumn flows removed greater quantities of material than prolonged inundation of already wet profiles such as occurred in July 1990.

Preferential erosion in the zone of moisture fluctuation at the base of the cliff produced a characteristic undercut (Figure 2). Greater undercuts were evident where drying cycles and subsequent fluvial removal were most severe, such as outside meander bends devoid of stabilising vegetation. Undercuts eventually caused the overlying material to collapse either as small fretting failures or as cantilever collapses where the rate of removal was greatest. The former process where small blocks or slabs 'flaked' from the surface and were subsequently removed was the dominant erosion process.

Although visually dramatic, the cantilever failure of large slabs was a minor contributor to overall sediment loads. Such cantilever failures only occurred when the undercuts exceeded approximately 0.60 m or up to 2.0 m when the banks were reinforced with tree roots. Groundwater levels or structurally weak soil horizons did not directly contribute to such failure.

Although trees increased the interval between cliff collapses and reduced subsoil moisture variation, treed banks were eventually undercut by fluvial processes.

Failed slabs also protected the cliff base from subsequent fluvial action for at least six months. The predominately dry material deposited within the channel was not readily removed by fluvial action until subjected to a number of cycles of wetting and drying.

5 . LESSONS FROM THE PAST

Erosion rates during the period of active incision were significantly higher than the 7 $m^3 km^{-2} y^{-1}$ rates currently evident within the incised channel. The Scrubby Creek gully would require approximately 3,000 years to form based on such losses.

Rapid lowering of the groundwater table and headwards erosion within the channel itself doubtlessly accelerated the initial losses. Poor vegetation re-establishment associated with dry, salty subsoils, fluctuating moisture conditions and over grazing, further aided rapid incision.

The role of subsoil cracking in the erosion process was particularly important during the initial incision process. Draining rapidly lowered the water-tables beneath the original swamps introducing major fluctuations in subsoil moisture regimes. In contrast, moisture fluctuations today are linked to seasonal variations in groundwater levels associated with catchment rainfall. Consequently, desiccation cracking was deeper and more extensive immediately after the drains were cut, despite similar rainfall patterns during the 1900-1940 and 1940-1992 periods. A feedback mechanism exists whereby drain incision lowers the water-table which subsequently controls the depth to which the drain can erode (Bird, 1987).

The vulnerability of the cut drain to subsequent erosion was critical for incision within the Scrubby Creek valley rather than either catchment wide landuse change or a significant increase in channel grade. Similarly, the upstream migration of nick points generated by changes in the lower catchment was not implicated in the development of incision. Falling water-tables and the removal of dense suckering swamp vegetation from the drain environs were major factors in subsequent erosion.

Once mobilised by streamflow, less than 0.1% of transported sediment was retained within the gully system. This once again reflects the dispersive characteristics of exposed, dry and cracked subsoils. An additional contributing factor in minimal sediment retention was the overgrazed and denuded floodplain evident during the period of active stream incision.

Draining also potentially altered the anaerobic (reducing), alkaline and sodic conditions under the original swamp and hence the dominant chemistry at the clay surface. Drying and oxidation changed the nature of the humics and potentially increased humic adsorption onto the clay surface (Greenland, 1971). Such adsorption would increase the vulnerability of exposed subsoils to disturbance (cf. section 3, above).

6. CONCLUSION

Although the incised watercourse generated by Scrubby Creek is visually dramatic, the 10 m cliffs have largely stabilised with ongoing collapses expected from less than 11% of the total channel length. Within such actively eroding profiles, losses were often further confined to the zone between maximum and minimum groundwater levels or where banks were regularly inundated. Such moisture fluctuations produced cracked material which is readily removed by subsequent streamflow. Further drying is required before the freshly exposed subsoils are readily entrained. Consequently a focus on the variations in moisture regimes, rather than increases in total discharge is pertinent for erosion studies within comparable watercourses.

Despite contemporary erosion rates being less than intuitively expected and rehabilitation difficult to justify economically, initial incision within the valley was rapid and significantly degraded downstream water quality. Consequently, it is along watercourses starting to incise, or within undeveloped valleys with similar yellow duplex soils, illitic clays, buried humics and high Na^+ concentrations that the preceeding findings have the greatest potential application. Any predictive model for stream incision on similar soil types must consider subsoil chemical charcteristics and focus on disturbances within the channel, especially changes in the hydrological setting. A watercourse best remembered as 'Gilchrist's Gully' has important implications for proponents of major landuse change, especially 'improvements' to natural drainage lines.

7. REFERENCES

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