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Soil Health Strategy - A Component of Catchment Management

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EXECUTIVE SUMMARY

Water quality in streams and lakes has received much interest from the community and the Government in the last two decades with the setting up of the Victorian Water Quality Monitoring Network (WQMN). Water quality is being monitored at some 280 stations around the State. Water quality in streams and lakes is affected by what happens on land in the catchments draining to these streams or lakes. The Catchment Management Authorities (CMA) in Victoria were set up to promote sound land management in order to promote healthy rivers and streams. Promoting the health of the soil therefore is an essential task. What needs to be done is to develop an understanding of the hydrological, geochemical and biological functions of soils in catchments, and what constitutes a healthy soil from this perspective. We also need to develop better predictive models to link the flow regimes and water quality of streams to soil and land management because there are constant changes of land use in many catchments with unknown impacts at present. These tasks seem not within the scope of WQMN and appear not well integrated with the Departments of Primary Industry and the Department of Sustainability and Environment.

This paper is limited to a cursory investigation of the link between soil health status of lands within the Glenelg-Hopkins CMA region, land use and land use changes, and water quality in the streams and lakes in these catchments.

INTRODUCTION

The Glenelg-Hopkins CMA region contains three drainage basins: Hopkins River (Basin 236 incorporating 5 monitoring stations including 1 lake), Portland Coast (Basin 237 incorporating 2 stations) and Glenelg River (Basin 238, incorporating 11 stations and 2 lakes) as shown in Figure 1. All monitoring stations measure pH, turbidity (Tb) and electrical conductivity (EC), but only 9 stations measure Total Nitrogen (TN) and Total Phosphorus (TP). A report commissioned by the then Department of Natural Resources and Environment (DNRE) and produced by Sinclair Knight Merz (undated, apparently 1999) using data from 33 stations concluded that in the majority of stations over the last 10-20 years the water quality changes were negligible, except for EC.

With respect to EC, it was possible to detect a “loose regional trend with predominantly increasing trends in the southern and eastern areas of the region and predominantly decreasing trends in the north-western region”. The data were analysed by a parametric method called General Additive Model (GAM) to estimate time trends in hydrologic time series data. GAM was considered to be particularly suited for investigating water quality trends as, according to the authors, it accounted for the effects of exogenous influences such as stream flow. This report also shows that, as well as quality data, monthly discharge data were available for 33 monitoring stations going back to 1977 in most cases.

Beyond observing a loose regional trend of increasing EC in the southern and eastern parts of the catchment, there appears to be no possible way in which we can interpret this in terms of a causal dynamic in the land.

A later report commissioned by the Department of Sustainability and Environment (DSE) and produced by Water Ecoscience Pty Ltd (2002) rated water quality in terms of attainment results using SEPP objectives and ANZECC guidelines, noting that:

- all bar 3 stations achieved low attainment for EC in terms of ANZECC guidelines,
- all bar 1 station achieved low attainment for TN,
- all bar 6 stations had low attainment for TP,
- all bar 3 stations achieved low attainment for oxidised forms of nitrogen (NOx), and
- all stations achieved high attainment for suspended solids (SS) and turbidity by both SEPP and ANZECC criteria

Again, this diagnosis stops at mere water quality data and fails to address the link with land use. Why is the water quality what it is? And can we do anything about it? What happens if we change land use? What is the relationship with the lands and soils and their use in the catchment? The soil hydrological function varies with the condition in which the soil exists, and will change if that condition is changed by management. That condition at any time represents the health of the soil.

SOIL HEALTH DEFINED

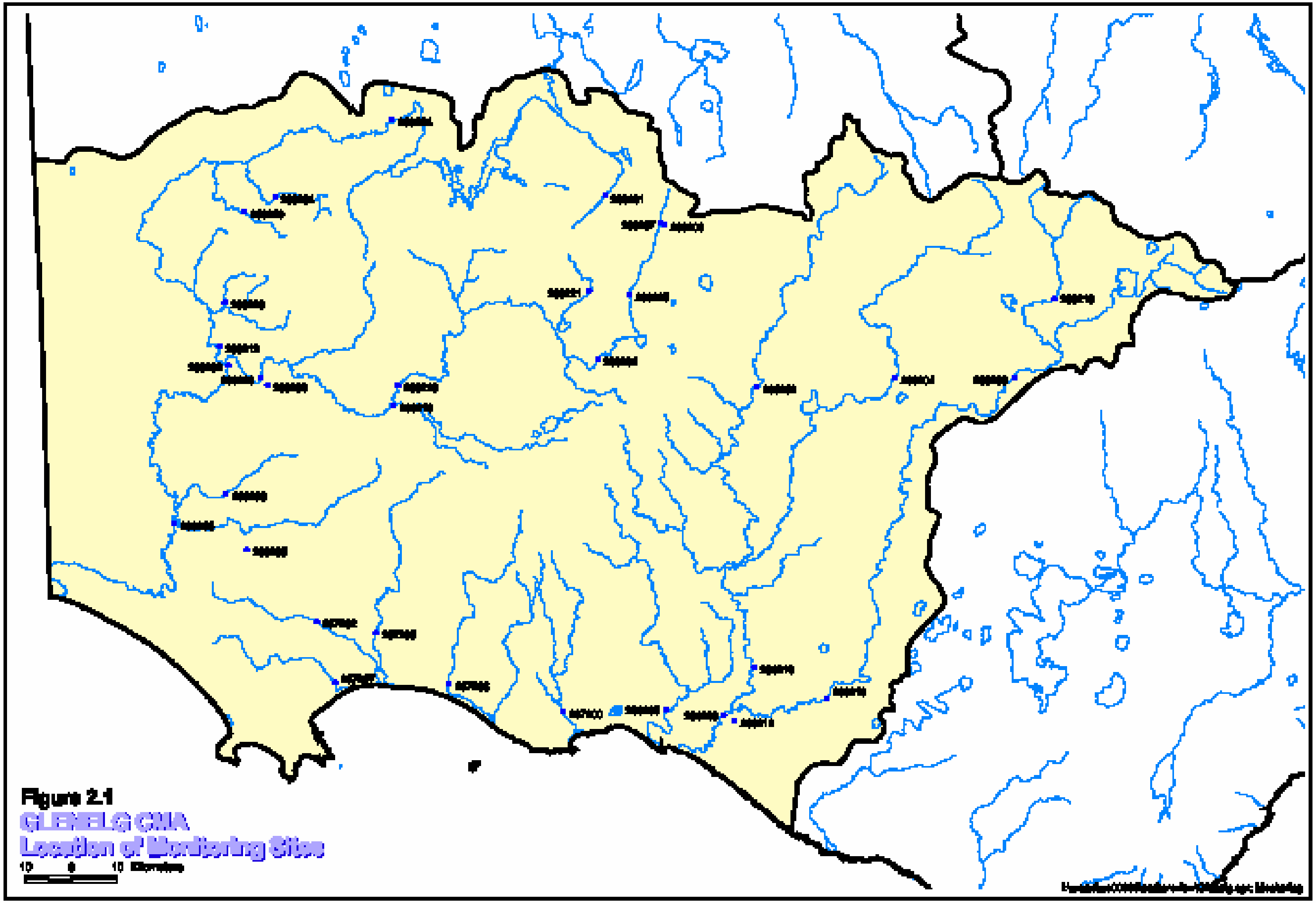
Soil health is defined as the state in which the soil currently exists compared to a condition in which it can support the highest potential biological productivity combined with the lowest environmental impact. This potential is limited by the soil's properties like structure, texture, natural fertility and biological qualities which are different for different soils. Therefore two soils having the same state of health do not necessarily have the same productivity from an agricultural or biological point of view.

It is not correct to view the virgin condition of the soil as its greatest state of health, even though often the exploitation of the soil causes a decline of its biological productivity and its hydrological and environmental functioning. It is possible to manage a soil in a manner that increases its biological richness and diversity, as well as its other environmental functions.

LAND USE, LAND DEGRADATION AND SOIL HEALTH

The Glenelg Hopkins catchment occupies 12% of Victoria and has contrasting geology, topography and climate, and consequently contains different agricultural industries and natural areas. Human activities on the land generally result in changing the rate at which natural processes take place; they may slow them down or accelerate them. How the soil reacts depends on its unalterable properties, for example its texture. The use made of the land by humans can activate or accelerate the degradation, for example by clearing a sand dune; it becomes more likely to suffer wind erosion than it was with its vegetation intact. Clearing of a wooded area will increase the deep recharge to the groundwater table and hence increase the risk of dry land salinity in low lying parts of the landscape. Elsewhere it can cause prolonged waterlogging. Regular cultivation tends to reduce its soil organic matter content, which in turn reduces water holding capacity and can increase surface runoff. In all three examples, the land's biological productivity may be impaired.

Figure 1 The Glenelg-Hopkins Catchment Area



All agriculturally used lands are in fact like managed ecosystems, agro-ecosystems. To conserve these on a sustainable basis so they provide food and environmental benefits for successive generations we need to understand how they operate. Brouwer (2001) summarised the development of such understanding in a paper dealing with conserving biological diversity, with a checklist, SYSTANAL.

In Brouwer's view, and that of most agricultural and environmental scientists, ecosystems are complex with many interacting processes, biological, physical and chemical. But Brouwer specifically states that human use of the land, along with its economic and cultural elements, only increases the complexity of these processes. Any strategy therefore is unworkable unless it takes account of the human factors, but neither can it ignore the natural feed back loops resulting from a change of land management. Any strategy to preserve such ecosystems or to exploit them in a sustainable manner must be based on a detailed and systematic analysis of how they function.

The human factors can be engaged by communication and participatory involvement of the land users and other stakeholders. The natural feed back loops arise from changing a current type of land management to another, which may result, for example, in less water running off and streams being depleted and becoming more saline. The ultimate outcome of the change may be more harmful than not changing the land use. It is often difficult or impossible to predict such effects quantitatively. The aims and interests of the landholders and producers and the five aspects of sustainability of the ecosystems they exploit, (a) productivity, (b) protection of the environment, (c) acceptability, (d) security and dependability, and (e) economic viability, which concern them intimately, must be considered.

In the GHCMA area there is no detailed inventory of the extent and severity of actual land degradation or soil health problems that covers the entire area. Information on actual land degradation and soil health problems is only available in a general fashion from the land system mapping done by Gibbons and Downes (1964) and Sibley (1967) and to a more limited extent from the mapping by PIRVic. A survey of the community attitude found the following concerns with regard to soil health. These are:

a) Soil acidification and nutrient decline;
b) Soil compaction, soil structure decline and water logging;
c) Sodicity is a minor regional problem but potentially a major problem in certain locations, i.e. areas consistently treated with dairy effluent;
d) Organic solutions to soil health problems.

HYDROLOGICAL AND WATER QUALITY IMPACTS OF LAND USE CHANGES

A main limitation for agricultural use of the land on the Dundas Tablelands is prolonged waterlogging in winter and spring, which prevents cropping for cereals, causes lucerne pastures to drown and die, and increases groundwater recharge and hence the extension of dryland salting (Brouwer and van de Graaff, 1988). Prior to clearing, the native parkland vegetation of red gums, shrubs and perennial herbs used up most of the rainfall, although waterlogging in winter did occur. Inherent waterlogging was due to a restrictive very dense subsoil layer between 0.3 to 0.6 m (bulk density 1.7-1.9 t/m^3) and a winter rainfall maximum. Later it was found that the main throttle to flow occurred between 0.6 and 1.1 m with bulk density 2.5 t/m^3. Removal of most of the trees and replacement with shallow-rooted annual pastures made waterlogging much more severe and prolonged. It is considered a deterioration of soil health.

Deep ripping and planting perennial pastures (Phalaris and lucerne) at Gatum in order to increase the depth of the rooting zone and evapotranspiration simultaneously to combat dryland salting caused two effects. It did increase the water use and the yield of the crop with Phalaris yield going up from 4.5 t/ha to 7.0 t/ha, and lucerne from 2.7 t/ha to 3.5 t/ha. At the same time deep ripping changed the mean horizontal hydraulic conductivity in the ripped zone – 0 to 0.55 m – and further down as follows:

Soil horizon	Depth (m)	Ksat in natural soil (m/day)	Ksat in deep ripped soil (m/day)
A	0.12 – 0.27	5.27 (1 test)	3.2 (3 tests)
B2	0.47 – 0.61	0.15 (3 tests)	1.5 (4 tests)
BC	0.65 – 1.02	0.14 (4 tests)	0.23 (4 tests)

Where the unripped soil normally was fully saturated in the top 30 to 40 cm for extended periods in winter, so that additional rains just sheeted off, the deep ripped land was no longer saturated but also produced no runoff. The experiment did not succeed in reducing deep groundwater recharge, but did increase transpiration and air humidity above the crop. It was believed that deficient phosphorus and aluminium toxicity due to low pH limited growth of the lucerne (and possibly the phalaris) and reduced evapotranspiration to well below potential. These deficiencies are easily overcome by liming and fertiliser. However, widespread adoption could result in much reduced spring runoff to streams.

During the same years, a Department of Agriculture scientist introduced a combination of mole drainage and subsurface tile drainage. This work succeeded in eliminating waterlogging also, enabling the land to be cropped, but we believe the water balance as such was not an issue. In recent years, this idea has been adopted by a landholder on a large scale. Here, the water discharging from the tile system flows into dams and is retained there. The result on pasture productivity has been great, and, presumably due to the fact that the soil no longer suffers from prolonged waterlogging, the root systems survive over winter and are able to be active at depth in summer, providing water to the pasture, where pastures on surrounding farms brown off and are unproductive. As the waterlogging was made much more severe by the land use (grazing) established by European settlers, drying up the soil may qualify as improving its health. However, large scale adoption could see much winter and spring water being released into the natural drainage system. This could lower the proportion of inflowing saline groundwater compared to fresh surface water, and flush out the saline stream water.

A highly emotive issue in the GHCMA region is the rapid expansion of blue gum plantations on former grazing land. Land preparation frequently involves deep ripping and creating low raised bunds along the contour to retain surface water. Within the plantation, such soil management may be seen as improving soil health, yet the impact on stream flows is only beginning to be analysed (Sinclair Knight Merz, 2005).

Economic imperatives drive the dairying industry to increasingly intensive operations. This means very high fertiliser application rates and very high stocking rates. In winter, the soils in the dairying areas often are also waterlogged, so that cattle create muddy pastures and highly sediment and nutrient-laden runoff. The recommended solution being adopted by some is to move the cattle to concreted surfaces during winter. Furthermore, research work being carried out by the DPI Ellinbank Research Station for Dairying (Barlow et al., 2004; Nash et al. 2005), suggests that, as soluble P is difficult to remove from drainage water, a farm runoff re-use pond will be the most effective way to keep P out of streams. Soil health improvement in terms of improving structure, increasing infiltration rate, improved grass cover, etc., apparently do not offer much scope to reduce P export. Thus, large scale adoption to protect stream water quality by impounding runoff will reduce stream flow.

A serious sleeping threat to soil health is the slow, but inexorable increase in acidity due to improved fertility, especially the use of superphosphate. This stimulates the growth of legumes (clovers), and in turn increases the fixing of atmospheric nitrogen that, initially via proteins, ultimately becomes re-mineralised to nitrate. As the NO_3^- ions are leached out of the soil profile by rainwater, they take cations such as Ca^{+2}, Mg^{+2}, etc., with them. These are not replaced by calcium and magnesium at equivalent rate from fertilisers and hence they are replaced by H^+ ions, the supply of which in rain water is inexhaustible. Slowly the cation exchange complex of the soil becomes enriched in exchangeable H^+ and the soil acidifies. Once the soil pH passes a low 4.5-5.0 the original clovers fail to grow and Al^{+3} ions are being released from dissolving clay mineral crystal edges. Aluminium toxicity can develop. Pastures and crops grow less vigorously and transpire less water. The cost of liming to correct the problem may become too high on land that has always been of only low productivity. The hydrologic impact is very difficult to predict.

A CATCHMENT-WIDE INVENTORY FOR SETTING PRIORITIES

The available data base for the Soil Health Strategy for the GHCMA consists of the only detailed land studies of two areas with the region: Land Systems of South Western Victoria (Gibbons and Downes, 1964) and Land Systems of the Grampians Area (Sibley, 1965), a rapid reconnaissance soil inventory (1:250,000) of south western Victoria (Maher and Martin, 1987), and Baxter and Robinson’s (2001) Land Resource Assessment in the Glenelg Hopkins Region.

The Land System studies mentioned provide detailed descriptions of the land forms, soils and native vegetation, as well the agricultural uses of the land, but they are out of date with regard to the latter. They have much soil chemical information. Maher & Martin covered an area extending from Queenscliff and Ballarat to the border with South Australia and dealt exclusively with the chief soil types in their mapping units, but present no laboratory data or information on soil problems Their mapping units are based on the boundaries of the geological maps at the same scale. Baxter & Robinson seem to have largely ignored the work of Gibbons & Downes and of Sibley, and used up-to-date geological maps in combination with radiometrics and a digital elevation model. However, they did not have the opportunity to do more ground-truthing and as such their mapping is incomplete.

In view of these facts, van de Graaff & Associates used geological maps as a base for transposing the Gibbons & Downes and Sibley mapping, and their wealth of descriptive material to describe the mapping units to the maximum extent, including their assessments of soil-related environmental problems. This was in order to map the catchment as part of the GHCMA soil health strategy. As part of the strategy, all the soil classificatory terminology used in the older works has been updated to what is in use in Australia today. All the appendices with soil profile descriptions and soil laboratory data were scanned, more effectively arranged and re-published, as, without this, the information will be lost because the original publications are out-of-print.

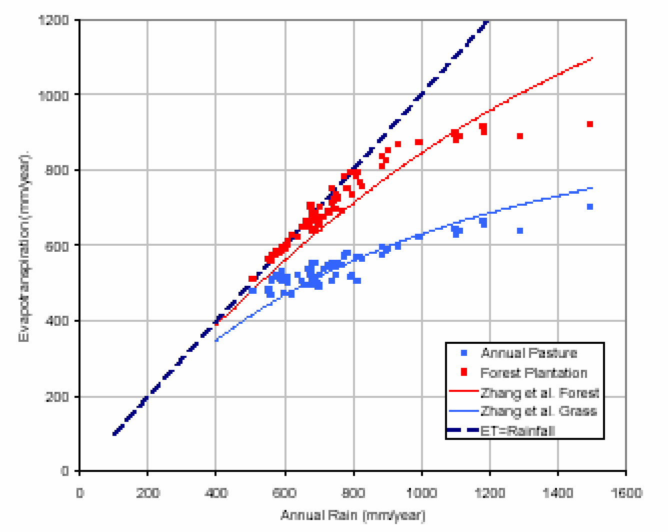
This information was then compiled with as much categorical information on agricultural land uses, including yield data and information on profitability as was obtainable. From the economic data and by assessing the environmental consequences of significant soil health problems, a system for prioritising these soil health issues could be developed.

The Soil Health Strategy Report (van de Graaff et al. 2006) recommends a number of soil health management strategies by which the overall state of soil health can be improved. Further, the report suggests priorities for these strategies, and evaluates the costs and benefits of improved health to land holders. Priority areas are identified at the scale of sub-catchments and explicit recommendations on soil management activities are made. The costs and likely financial benefit that will follow of each proposed soil management practice are estimated. Practices that are likely to be profitable are therefore able to be identified. Areas that are identified as high priority, but are uneconomic for landholders to treat are also identified and an estimate made of the inputs required to implement the practices that would restore soil health. All information is provided as hard copy, in electronic form, and has been given a GIS format that can be interrogated.

What is lacking in this exercise is a better link with water quality and stream flow regimes. There is a need for more profound study of what land use changes, which are mandated by a changing economic environment, will mean for the Catchment in terms of its hydrology. Without that, we are likely to discover that we have allowed yet another environmental problem to creep up on us. With the GIS base that is now available, it may be possible to develop catchment-wide modelling of these hydrological impacts.

Figure 2

WatLUC modelled values of evapotranspiration (ET) for annual pasture and forest plantations plotted against the Zhang* curves for grass and forest and the line for ET=rainfall. The graph helps to confirm the reliability of WatLUC modelling.



A beginning has been made in the Water and Land Use Change Study (WatLUC) carried out by SKM Pty Ltd (2005) with support from several organisations, including the Glenelg Hopkins CMA. The WatLUC study covered more than the Glenelg Hopkins Rivers catchments and considered the hydrological impacts on a sub-catchment basis. It based its modelling on the water use characteristics of each land use, running a soil water and salt balance model (SoilFlux) for each land use, soil type and depth to water table, and predicting deep aquifer discharge and surface drainage (Figure 2). However, it contains as yet no explicit connection to soil health in the Glenelg Hopkins CMA area.

CONCLUSION

This paper, based on a study of the condition of the soils in the Glenelg-Hopkins Catchment Region, argues that one cannot understand, and therefore manage, water quality in streams and lakes without reference to the land that produces the water, both as runoff and seepage, and hence the use of the land and the health of the soil. This is a task for joint work by soil scientists, hydrologists and geographic information experts. It should be continued with great vigour.

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