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THE SUSTAINABILITY OF LAND USES IN THE STRZELECKI RANGES IN VICTORIA, AUSTRALIA

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ABSTRACT

Integrated catchment management and the preservation of water and soil resources are essential in developing more sustainable land and water management initiatives. The implementation of catchment management methodologies faces a variety of social and technical obstacles. Social obstacles may include the willingness of landowners to participate in catchment management initiatives; however, these can usually be overcome by effective community engagement and economic incentives. Technical obstacles include reliable water quality monitoring and data collection. These are essential to ensure that research across catchments is meaningful, comparable, and reproducible. Data collection remains a major issue in water quality monitoring and analysis of catchment health. A simple and reliable methodology is required to enable the general community to monitor and develop an understanding of the issues related to their local environments.

The landscape of the Strzelecki Ranges features a mixture of land uses including agriculture and forestry. The Strzeleckis form the headwaters of major streams and rivers flowing east to the Gippsland Lakes and south to Bass Strait. The intensive nature of land uses in catchments of the Gippsland Lakes has generated significant environmental impacts. To protect the values of the lakes, pollutant sources need to be identified and appropriate mitigation measures implemented. A comprehensive catchment management strategy in the Strzeleckis will lead to improved environmental health both inland and in the coastal / estuarine areas receiving their flows. A strategy incorporating careful management of landscape values and proper land management approaches would ensure that forestry and agriculture become sustainable land uses in this sensitive environment.

The definition of sources and assessment of land management practices requires accurate estimates of pollutant load levels. The suspended sediment load in streams is strongly dependent on supply factors and is rarely transport limited. The analysis of water quality within a stream, over a period of time, may be helpful in isolating possible water quality trends in the catchment; thereby, identifying how land use change may impact the catchment.

This paper outlines research conducted for the development and implementation of a straightforward methodology based on the use of reliable and readily measurable water quality indicators to monitor the variations in water quality associated with land uses in the Strzeleckis. A paired catchment methodology was adopted using turbidity, stream temperature and electrical conductivity as the primary indicators. Adoption of this methodology will enable agencies, community groups and / or land managers to determine which land management practices are generating the greatest impact in any given catchment.

These water quality indicators were demonstrated to be good indicators of land use impacts in the catchments. The differences found between forestry, agriculture, and the control catchment linked the degradation of water quality with the intensity of land management.

Agriculture is generating the greatest impact on the local water quality. Results demonstrated that turbidity was increased by more than three times the natural rate or more than twice the maximum *Default Target for Upland Rivers* as published by the Australian Department of Environment and Heritage (2003). A key in reducing impacts associated with grazing is the establishment and protection of healthy riparian zones. This can only be achieved by controlling livestock access to the riparian zone and stream channels. These basic measures would help to improve catchment health, provide habitat connectivity, and lead to a more sustainable industry.

Forestry also created water quality impacts. These impacts were more of an indirect nature resulting from increased streamflows and concentration of fauna along the moist stream channel zones. Indicators of these impacts included extensive baring of soils through bioturbation and enhanced streambank erosion in more vulnerable stream reaches. Bioturbation dramatically increases the potential for suspended sediment generation especially during the low flow conditions encountered during the summer period. These enhanced natural processes were not as evident in the control catchment.

INTRODUCTION

The study was based in the Strzelecki Ranges in Gippsland, Southeast Victoria. It targeted the headwaters of the Morwell River. The Morwell River is a tributary to the Latrobe River, the catchment of which is outlined in Figure 1.

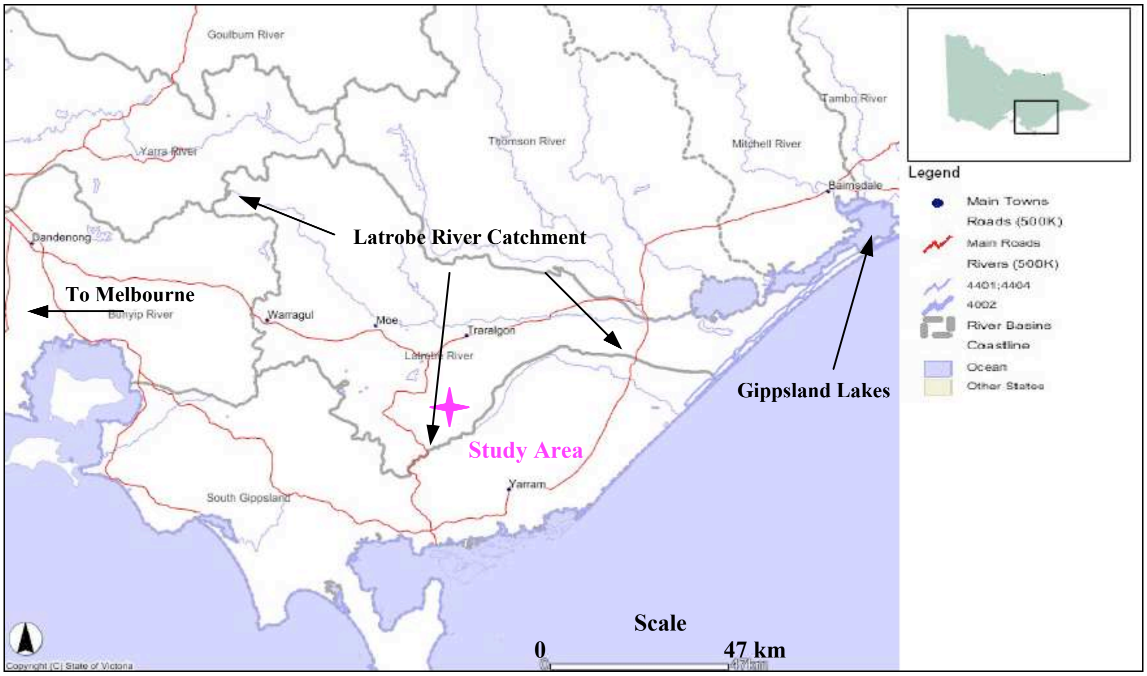

Figure 1 Locality Plan (Department of Sustainability and Environment 2004)

Prior to European settlement, the Strzeleckis were densely vegetated by wet forest and cool temperate rainforest-type vegetation similar to remnant communities still found at Tarra and Bulga National Parks. In the time period from 1870 to 1900, settlers largely destroyed the stands of high quality mountain ash (*Eucalyptus regnans*) forests. Today, the landscape of the Strzeleckis consists of a mosaic of land uses ranging from protected forests to plantation forests to agriculture with small settlements and hobby farms interspersed throughout the area.

Current agricultural practices in the Strzeleckis are based on traditional practices, including unabated livestock access to drainage lines and streams, which enhances stream bank erosion processes. The lack of protected riparian vegetation heightens sediment and nutrient delivery to the local waterways. Colman et al.(1991) highlight that approximately 60% of the State of Victoria's surface area is utilised for agriculture. The impacts of agricultural practices have a very high potential to affect water quality through the delivery of sediment and other pollutants to the local waterways.

The forests of Victoria are rich, renewable resources that play an important role in providing for sustainable economic development through the production of timber, water and other products. They provide for the conservation of water, soils, flora and fauna, and catchment and landscape values (Department of Natural Resources and Environment 1996). Forests make up approximately 30% of Victoria's total surface area, with most of the forests located in the steep humid headwaters of the State's major rivers. Colman et al.(1991) emphasise that the timber industry poses a large potential for impacts on the aquatic environment, second only to agriculture. However, forest streams are perceived as being in a more natural state than streams flowing through agricultural areas; therefore, the public is likely to consider them as more sensitive and more deserving of conservation.

The majority of the plantation areas in the Strzeleckis are currently owned and managed by Grand Ridge Plantations (GRP). Forestry operations primarily consist of clearing mature stands of Mountain Ash or Radiata Pine for sawlogs and pulpwood. However, timber production and timber harvesting activities on public land and private land are governed by the Code of Forest Practices. Department of Natural Resources and Environment (1996) developed the Code to ensure that forestry operations are carried out in such a way that:

- they promote an internationally competitive forest industry;
- they are compatible with the conservation of the wide range of environmental values associated with forest; and
- they promote the ecologically sustainable management of native forests proposed for continuous timber production.

METHODOLOGY

A paired catchment approach was adopted to measure the relative impacts of each land use. Jayasuriya and O'Shaughnessy (1988) reported that paired catchment studies provide a quick and reliable means of establishing, quantifying and comparing trends within catchments. The three catchments that were selected all lie within the same geographical area with similar landform and soil types.

Identical automated data loggers fitted with turbidity probes and level sensors were installed at the outlet of each catchment. Remote turbidity and flow data was collected on a 5-minute interval for a period of approximately 18 months. This data was supplemented with weekly manual turbidity observations using a simple turbidity tube.

In addition to the weekly turbidity readings, manual electrical conductivity and stream temperature observations were recorded using a hand-held probe. This ensured that the accuracy and operation of the automated equipment was not only being verified for quality control purposes but also to determine which indicators best reflected the impacts of land management practices resulting in environmental degradation.

Simple statistics and trending were used for the data analysis to identify changes in water quality resulting from forestry and agriculture in the catchment of the Morwell River. These results were compared to the data collected from a control catchment. The results are also considered in the context of the *Default Target Values for Upland Rivers* as published by the Commonwealth Department of the Environment and Heritage (2003),

- 2 – 25 Nephelometric Turbidity Units (NTU) for turbidity, and
- 30 – 350 microSiemens per cm (µS/cm) for electrical conductivity (EC) (at 25^{o}Celsius).

Each catchment was visually surveyed to determine the main mechanisms for sediment generation and delivery to the waterways. The visual survey concentrated on the "saturated' zone adjacent to the streams. Erosion and sediment source indicators that were being sought included:

- the extent of leaf litter and presence of bare earth along the stream channel and embankments,
- areas exhibiting clear indications of lateral corrasion,
- tree fall,
- bioturbation such as the evidence of foraging and crayfish burrows,
- newly incised drainage channels, and
- landslips.

The project methodology and data analysis was kept simple to encourage its use as a tool to carry out catchment studies resulting in comprehensive and successful catchment management strategies. The key to sustainable land management is the availability and use of affordable, low tech, and reliable water quality monitoring equipment such as the turbidity tube and electrical conductivity / temperature probes. This equipment combined with a simple and adaptable paired catchment methodology, such as the one used in this study, can cater for detailed large scale catchment studies whilst still being within reach of the individual land owner or stakeholder. It generates readily reproducible and comparable results, providing a good indication of catchment health and enabling targeted mitigation programs.

CATCHMENT FEATURES

Features of the control area included:

- steep slopes;
- established Mountain Ash plantation reafforested in 1972 and 1973;
- remnants of Wet Forest (Ecological Vegetation Class - EVC 30) riparian vegetation;
- natural surface track 1850 meters long, running up the southern ridge of the catchment (Grey Gum Track);
- small unkept fire access track 2650 metres long along the north ridge;
- extensive damage to tracks caused by recreational use by 4WD vehicles and dirt bikes; and
- healthy continuously flowing stream supporting a variety of flora and fauna.

Features of the plantation area included:

- combination of forested and cleared steep slopes;
- established hardwood plantation forest with remnants of Central Highlands Cool Temperate Rainforest (EVC 31-01, a threatened ecological community) as riparian vegetation;
- approximately 3550 metres of unsealed roads and tracks; and
- healthy continuously flowing stream supporting a variety of flora and fauna with evidence of extensive biological activity along the moist zones of the catchment.

Features of the agricultural area included:

- fully cleared slopes;

- main gravel road, maintained by the local Shire, approximately 3900 metres long running alongside the stream and crossing it in two locations by means of culverts;
- numerous privately owned natural surface tracks for access to the paddocks and trafficking livestock;
- 8 homes with outbuildings, all with gravel driveway access (one home's access runs through the stream channel);
- continuous grazing with unrestricted access to the steam and drainage lines;
- visible damage to the streambanks resulting in accelerated erosion;
- no riparian vegetation or buffer strips; and
- continuously flowing stream intercepted by a total of seven farm dams constructed directly in the stream channel.

RESULTS AND DISCUSSIONS

The data collected made it possible to establish an indicative baseline water quality for each sub-catchment. These findings should be considered in the context of having been collected over a relatively short period of time. Other catchment studies cited in literature have spanned a much longer time period (ie. some as long as 30+ years) resulting in findings which could be considered more representative of the longer term mechanisms occurring in their respective catchments. Mechanisms affecting catchment dynamics are dependent of a number of factors including climate change, changes in land management practices, catchment-scale land use change, large scale events such as fires or large landslides, economics, plus a number of other natural and anthropogenic factors.

The averaged baseline water quality results for each sub-catchment summarised in Table 1 are based on the data collected during low flow conditions.

Table 1 Summary of Water Quality Indicators at Baseflow Flow Conditions

Catchment	Turbidity (NTU)	EC (µS/cm)	Temperature (^{o}C)
Plantation	28	112	10.2
Agriculture	52	168	12.6
Control	9	101	10.3

Baseflow refers to the steady-state flow of watercourses in the absence of precipitation or rain events typically during summer or dry periods. It provides a strong indication of instream mechanisms affecting water quality. Gippel (1989) states that most streams transport the bulk of their suspended sediment load during relatively infrequent storm events. However, Grayson et al.(1997) emphasise that from a point of view of water quality and ecological health, the low flow period is generally the most critical time for the system.

The water quality at steady-state flow in the control catchment was typically high. The turbidity was normally below 10 NTU with instances where the turbidity tube tests returned a 0 reading. As expected, higher sediment flows were observed during rain events of high intensity and short duration. Sediment sources generally being the stream channel itself.

As highlighted in Table 1, the baseline water quality in the plantation area exhibited a higher NTU reading. If compared to the control catchment, the turbidity value was three times that observed in the control area. However, if taken in the context of the *Default Target Values for Upland Rivers* (Department of the Environment and Heritage 2003) the turbidity value is only slightly above the maximum value of 25 NTU. The site survey revealed extensive bioturbation along the saturated zone of the stream and within the stream channel. This high degree of disturbance may be responsible for the majority of baseflow turbidity. This suggests that the riparian zone of this stream is providing habitat for a large concentration of burrowing and foraging fauna. The higher turbidity values may not be a direct result of timber harvesting but a product of natural processes. However, increased streamflows and loss of habitat resulting from the timber harvesting can potentially enhance the natural processes of bioturbation and streambank erosion.

Baseflow water quality in the agricultural catchment was consistently poorer than that observed in the other two catchments. Turbidity was generally twice the maximum default target value for upland streams and more than five times that observed in the control catchment. The obvious effects of unabated livestock access to the stream combined with the absence of riparian vegetation for the majority of the stream length are the major contributors to the lower water quality, especially during baseflow conditions. In addition, higher light levels reaching the stream and resultant higher water temperatures changes the instream characteristics by promoting the growth of aquatic organisms. The presence of a number of farm dams directly in the stream channel also provides for ideal conditions for enhanced growth of these organisms affecting turbidity.

The importance of EC during baseflow conditions is based on the fact that at low flow conditions the dissolved solids concentration will be at its highest since the stream water has been in storage in the catchment for sufficient time to come into chemical equilibrium with the surrounding environment (Tchobanoglous & Schroeder 1987). Although a slight difference in the electrical conductivities for each catchment has been observed, EC values fall within the recommended *Default Target Values for Upland Rivers* (Department of the Environment and Heritage 2003). However, if EC is used as a means of measuring land use impacts; the higher EC values observed in the agricultural catchment suggests a slight degradation in water quality based on current land use. Herricks & Milne (1998) suggest that EC is the most reliable indicator of changing water quality in a catchment. Variations in stream water EC is related to a number of parameters such as soil type, geology, groundwater, land use, vegetation cover, and precipitation regime (Fletcher 1995). Spatial variations in EC are primarily related to geology; however, within individual geological formations variations in EC have been attributed to differing land uses (Finlayson 1979). Condina (1990) reported values in the upper Morwell River between 80 and 160 µS/cm. Grayson et al. (1997) state that since the upper Morwell River catchment is predominantly underlain by Cretaceous sediments, runoff should produce natural EC values in the range of 150 to 200 µS/cm. However, the lower EC values measured in this and other studies, even in the agricultural catchment is a result of the high rainfall regime in the Strzeleckis (Nicholson 1978).

These results highlight that intensively managed landscapes contribute to the degradation of water quality and overall environmental health. It is quickly being recognised that the preservation and enhancement of healthy riparian zones in combination with changes to management approaches can dramatically increase water quality, ecological viability, and improve the sustainability of land uses. Adherence of the forest industry to the prescriptions of the Code of Forest Practices (Department of Natural Resources and Environment 1996) will improve the general management of timber production area and harvesting coupes. However, as highlighted by the Review of the Code of Forest Practices for Timber Production (CSIRO Forestry and Forest Products 1996) and by O'Shaughnessy (1995) there are a number of areas where the Code can be improved. These include:

- mechanisms for the protection of habitat and water quality;
- definition and protection of rainforest;
- silvicultural practices for native forests;
- guidelines operations on steep slopes and proximity to streams; and
- wet weather operations.

CONCLUSIONS AND RECOMMENDATIONS

Sustainable land use in the Strzeleckis can only be achieved through considered and honest approaches to the management of local resources, understanding the nature of the environment, and by respecting its limitations. It is clear that it takes commitment and foresight to properly manage the landscape in an environment as sensitive as the Strzeleckis. A proactive approach in implementing proper management procedures and tending to the trouble areas will lead to improved environmental quality and sustainability.

Changes to agricultural practices are key to maintaining and improving the health of the landscape. Key measures include:

- restricting livestock access to the stream channels;
- use of bridges over streams rather than crossing within the stream channel;
- establishing healthy riparian zones where streams flow throughout the year and establishing filter strips in drainage lines;
- upgrading of access tracks;
- more appropriate siting of drainage structures;
- extensive use of sediment trapping measures;
- upgrading, resurfacing and/or sealing of roads or tracks to prevent the generation of sediment;
- restrict wet weather operations;
- rapid and effective rehabilitation of redundant tracks;

- effective rehabilitation of livestock tracks including fencing off of degraded areas to allow for re-establishment of vegetation; and
- the development and implementation of a Code of Practices for Agriculture similar to the Code of Forest Practices.

The forest industry has taken significant steps in the right direction to reduce and mitigate the effects cause by its activities. Improved practices and continued responsible stewardship of the land will ensure that the forest industry also becomes sustainable in the Strzeleckis. The project has shown that elements of the Code of Forest Practices are very relevant to the conditions found in the Strzeleckis. However, recommendations for continued work and advances on the following points in the Code of Forest Practices will ensure that the forest industry will be more sustainable in the Strzeleckis:

- proper resurfacing and maintenance of haul roads and tracks,
- effective closure and rehabilitation of unused tracks,
- better drainage works including extensive use of sediment trapping measures,
- redirection of surface runoff away from steep coupes, streams and drainage lines,
- maintenance and protection of healthy riparian zones of appropriate width designed for the specific harvest areas,
- better control of wet weather operations,
- smaller coupes in steeper areas or during wet weather, and
- rapid rehabilitation and reafforestation of harvested areas.

It is also critical to minimise and mitigate the impacts of recreational use. The popularity of 4WD and dirt bike ridding is quickly increasing. If the trend towards irresponsible recreational use of the area continues, this will increase the risk of wide scale erosion and degradation of water quality. Gullying and erosion of tracks not only reduces the amenity of the area but also restricts access to other vehicles in case of fire or other emergencies. Proper surfacing and maintenance of these tracks is required, including closure and effective rehabilitation of some tracks. A Code of Practice for Recreational Use and Wet Weather Trafficking may lead to a more responsible approach. The promotion of a "FRIENDS OF" group or other similar community organisation charged with community engagement and maintenance of tracks could result in well-maintained and safer tracks.

Conclusion of the study will result in recommendations guiding the development of a strategic framework for forestry and agricultural practices. This framework will provide management directions leading to the sustainability of these land uses in priority areas.

Further work is required in the areas of:

- Catchment surveys and water quality monitoring to determine the extent and magnitude of bioturbation in the Strzeleckis and its impact on the local water quality.
- Quantify the extent and magnitude of damage caused by recreational use of the catchment and its effects on local water quality.
- Detailed streamflow and turbidity monitoring to generate site specific and catchment wide suspended sediment load models.
- Further research in the use of electrical conductivity and temperature as cost effective and reliable indicators of land use impacts on water quality.

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