Goulburn Broken

Soil Health Strategy

GOULBURN
BROKEN
CATCHMENT
MANAGEMENT
AUTHORITY

Draft

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Foreword

In 2002, the Goulburn Broken Soil Health Working Group (SHWG) was formed to develop a draft Soil Health Action Plan (SHAP) for the Goulburn Broken Catchment Management Authority (GBCMA).

The Goulburn Broken catchment was identified as one of three highest priority catchments targeted by the Murray Darling Basin Ministerial Council's xxxxxx.

The SHAP has been now been implemented for xxxxxx, and endorsement will be sought from the State Government, as well as accreditation of the strategy for the National Action Plan for Salinity and Water Quality.

Reference to funding levels in the strategy, are only indicative. The specific level of government investment is contingent on budgets and government priorities.

The Soil Health Strategy focuses initially on managing soil salinity (EC) and sodicity in irrigated regions, and acidity (pH), soil structure and erosion in dryland regions. Developing more resilient soils through improved protection of soil biodiversity will be promoted later on.

Bill Slattery, Bob Wildes
Chairman, Soil Health Action Plan Coordinating Committee

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Acronyms

BMO	Best management options
CMA	Catchment Management Authority
DSMP	Dryland Salinity Management Plan
EA	Environment Australia
EPA	Environment Protection Authority
GB	Goulburn Broken
GBCLPB	Goulburn Broken Catchment and Land Protection Board
G-MW	Goulburn Murray Rural Water Authority
GVW	Goulburn Valley Urban Water Authority
IC	Implementation Committee (formerly the Irrigation Committee)
MDBC	Murray Darling Basin Commission
ML	Megalitre
NAP	National Action Plan (for Salinity and Water Quality)
NLP	National Landcare Program
NRE	Natural Resources and Environment
NRMS	Natural Resource Management Strategy (of MDBC)
O&M	Operations and Maintenance
OCE	Office of the Commissioner for the Environment
SEPP	State Environment Protection Policy
SIR	Shepparton Irrigation Region
SIRLWSMP	Shepparton Irrigation Region Land and Water Salinity Management Plan

Summary

Purpose and scope of the strategy, magnitude of the problems and are the problems getting worse.

Explanation of Terminology – to be updated

What is meant when these terms are used in this document.

Acidification

Spatial trends

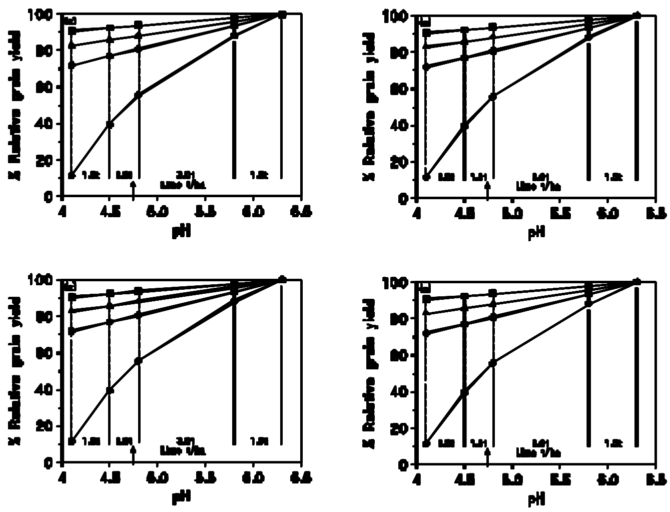
Increasing acidification with increased rainfall, generally a decline in surface soil pH as you move from West to East. Subsurface soil acidity in high rainfall, upper slopes of the Region.

Temporal trends

Acidification increasing at a rate of between 0.01 - 0.37 t/ha/yr of $CaCO_3$ equivalent, depending upon farming practice.

Response curves

see Slattery and Coventry (1993), Response of Wheat, Triticale, Barley and Rapeseed to lime on Four Soil Types in North-Eastern Victoria. *Australian Journal of Experimental Agriculture* **33,** 609-618. Response curves from this paper given below.



Hydrological consequences

In areas where soil pH has dropped to below a pH of 4.5 (pH as measured in $CaCl_2$) vegetation cover will be drastically reduced and the option to establish deep-rooted perennials such as lucerne will be limited. Thus leading to an increase in potential leakage of these systems and potential loss of water use efficiency, if in high recharge areas then potential increased risk of salinisation.

Biological consequences

Declining soil pH will reduce the ability for beneficial microorganisms such as Rhizobium to survive. Therefore reduced N-fixation by leguminous plants and reduced yield.

Impacts

Increased salinity risk if soils in high recharge areas unable to support plant growth due to strongly acid soils. Increased nutrient mobility especially Al which is toxic to plant root growth.

Responses see response curves

Levels of response required to breakeven.

This will vary according to the enterprise and gross returns form produce eg. Cash crops like Canola can pay for lime application in the first year whereas livestock enterprises on permanent pastures may take 10 years or longer.

Attribute Soil Erosion

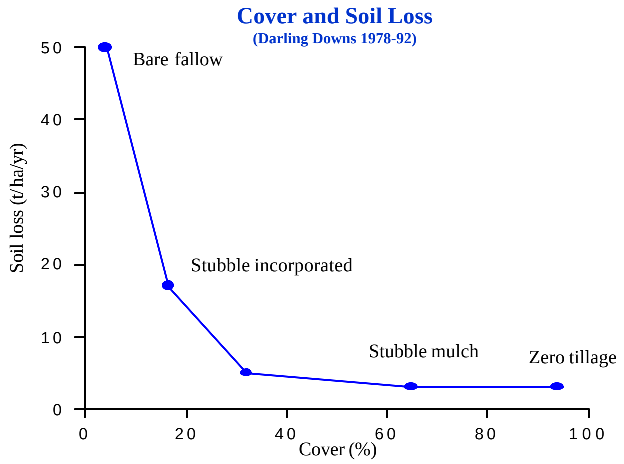
Spatial trends

Soils in the north of the region are generally dispersive and subject to high losses due to water and wind erosion, whereas soils to the south of the region are generally less dispersive and less likely to have soil loss based upon this criteria. However, soils in the south of the region are at higher elevation and receive more annual rainfall than in the north and would be subject to more water erosion loss based upon these criteria.

Temporal trends

Soil loss estimates differ according to land utilisation, for example the following Table indicates soil loss values for different crop management practices.

Management practice	Acidification Rate	Carbon loss	Soil loss (t/ha/yr)
Conservation cropping (stubble retained)	Low	low	4
Stubble shredded (on the surface)	Low	low	6
Stubble burnt	Low	medium	18
Cultivation (excluding sowing operations)	Low	high	50



Response curves as above

Hydrological consequences

Hydrophobicity will reduce water penetration, increased dispersion will lead to reduced water infiltration and therefore reduced water use efficiency and potential increases in salinisation.

Biological consequences

Loss of soil will also equate to a loss in soil C as shown above thus a decline in energy for microbial growth.

Impacts Reduced plant growth, thus yields. Loss of nutrients.

Responses see response curves

Levels of response required to breakeven.

No idea. Will be dependent upon landuse (eg. pasture, cropping, intensity of animal grazing), form of erosion (eg. gully, surface) and will be influenced by other soil constraints such as acidity and salinity.

Other General Terms

A **goal** is a **general** statement of the desired condition or direction of preference for the object *eg* improve and maintain water quality and habitat conditions in the Goulburn Broken Catchment's rivers, wetlands and water storages.

An **objective** is a **specific** statement about something one desires to achieve that includes

- an object (*eg* water quality)
- a decision context (*eg* Goulburn Broken Catchment and
- a direction of preference (*eg* improve and maintain water quality) or a desired state (target) (*eg* Reduce total phosphorus dryland diffuse sources by 20% of 1995 levels by 2016.

An objective is typically derived from the goal and should be sufficiently specific to allow scientists to develop targets. Objectives define what is at stake; they do not prejudge decisions.

A **means objective** is an objective that is used to accomplish another objective, rather than representing the desired state or direction of preference of the entity to be protected. An example is: *Reduce total phosphorus outfalling from irrigation drains to 50% of 1995 loads by 2016.* (Compare to "ends objective".)

An **ends (or fundamental) objective** is a "bottom-line" management objective for something that is valued in its own right (not just as a way to accomplish something else). For example, an ends objective is the overarching objective of the Goulburn Broken Water Quality Strategy: *Improve and maintain water quality in the Goulburn Broken Catchment.* (Compare to "means objective".)

It is critical for decision-making that the hierarchy of goals and objectives is clearly sorted. **Means and ends objectives should not appear in the same level of the planning hierarchy.**

Assumptions are necessary to enable progress to be made towards goals and objectives. They inform the decision-making process and need to be checked and refined regularly to ensure the validity of decisions. (See also "outcome".)

A **target** is the desired state (expressed quantitatively and temporally) of either the asset *eg* Protect 3,000 Ha of riparian vegetation by managing grazing according to best practice by 2006; or the threat to the asset *eg* Reduce total phosphorus dryland diffuse sources by 20% of 1995 levels by 2016. In both cases, the target indicates resource condition.

A target can also be the desired extent of action that will be achieved or maintained following management (*eg* 50% of farms will have whole farm plans developed by 2004).

A **target** is what is intended. (Compare to "measure".)

An **aspirational target** is the desired state of either the asset or threat that is considered desirable and achievable over the long-term (over 10 years) *eg reduce phosphorus levels leaving the catchment by 65% of 1995 levels by 2016*. "Achievable" attempts to factor in anticipated changes in social, economic and environmental conditions which is difficult, but essential, to do.

An **accountable target** is the desired state of the asset or threat or extent of works or action that an individual or organisation is held to account for (usually as the result of receiving funding). For example*, reduce phosphorus levels from irrigation drains by 10% of 1995 levels by 2007* or *have reuse systems in place on 90% of irrigation farms by 2007*. It is the "quantity to be achieved" that is negotiated between strategy investors (usually government) and implementers (such as the GBCMA's Implementation Committees). Accountable targets are short-term, perhaps annual or three-yearly, and are set and reported against during the business planning process. Accountable targets might represent a relatively small overall portion of overall progress expected because contributions are likely from many other sources also. (This is often the essence of any successful change in how natural resources are managed because third parties are ultimately relied on.)

A **best management practice (bmp)** is the most appropriate practice given current knowledge. If the practice is "works" it, will directly contribute to goals and objectives *eg* fencing off remnant, installing reuse dam, diverting drainage water for reuse, controlling weeds. Sometimes objectives for best management practices for different issues conflict, especially if they have not been through an holistic process to establish what they are specifically for the intent of the use of the piece of land. If they are well-defined for specific objectives, then judgments can be readily made to define what the holistic best maangement practice is.

An **action** is a general task (either works, extension, or research and investigation) that needs to be funded so that bmps can be developed and implemented. (Compare to "output".) When accompanied by a target they can be either **aspirational actions** (what is desired to be done) or **accountable actions** (what one is held to account for, usually due to agreed levels of funding provided).

Enabling actions are what will be done. They are capacity building actions that necessarily precede changes in on-ground management. Examples include development of whole farm plans, extension programs, research and investigation programs and prioritisation processes.

A **works action** is also what will be done. It is the physical change that will result from human intervention *eg* construction of a fishway, fencing off remnants.

An **output** is what has been achieved. They are effectively a recording of the actions that have been completed *eg* length of fence constructed; number of whole farm plans done; number of field days conducted.

An **outcome** is what has been achieved, intended or otherwise. It is the same as "goal" or "objective" except it used when the plan has been implemented (the results phase) rather than before. An outcome is measured by multiplying the output by an assumption factor *ie* outcome = output x assumptions.

A **measure** is used to define quantitatively what has been achieved. It is the same as "target", only the term is used once the plan has been implemented.

From NHT doc

Outcomes

High level and preferably measurable and within a specified timeframe, for example 24 EC reduction at Morgan by 2020

Objectives

Same definition as Outcomes above eg high level and measurable

Goals

Same definition as Objectives above eg high level and measurable

Activities

Actions leading to outputs

Outputs

Shorter-term measurable results expected from carrying out specific activities, usually over a 12-month period. *Net Outputs* are those that have no double counting across all projects that are subject to this bid. *Gross Outputs* may include some double counting where two projects could be contributing to similar outputs.

Targets

For the purpose of this document, targets mean the same as outputs.

High Priority Issue

eg Salinity, Water Quality etc

Regional Priorities Document

Developed by each of the ICs and the Community each year to identify where the highest priority issues are, and the works and outputs that will address the issues.

Plan

A (usually) government endorsed document that outlines a long term plan of action for addressing a high priority issue that is in accord with any existing higher level (eg state or commonwealth) that has outcomes, activities and outputs, over specified time frames. The document is developed with significant community and technical input.

Strategy

See Plan above

Catchment

Area that provides water run-off for a major river, in this case the Goulburn, Broken river systems, up to and including sources

Regional

Same as catchment above

Community

The people who live in the catchment.

Agency

Government departments, authorities and corporations (eg DNRE, Goulburn Murray Water)

Ecosystems Services

Ecosystem services flow from natural assets (soil, water, plants, animals etc) to provide the community with financial, ecological and cultural benefits.

Triple Bottom line

The social, economic and environmental benefits that are obtained from an action, project or strategy

Introduction
Soil Health

Soil health *or quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Karlen* et al*. 1996). Implicit, in this definition of soil health, is the concept of* resilience *or the ability to "bounce back" from setbacks in soil function (Kay 1990). These setbacks, or pertubations, are due either to natural processes or human-induced processes. Here, waterlogging in clay soils after heavy rainfall, and soil salinization, resulting from irrigation with pumped, saline-groundwater, are respectively, examples of natural and human-induced processes.*
Care is often needed in the use of the word "health" for soils as it refers to both measured soil properties, reflecting a certain soil function, and judgements about what constitutes a healthy soil (Walker and Reuter 1996). Thus, the measurement of saturated soil hydraulic conductivity is often used to assess the permeability of soil to water, nutrients and air against the judgement that "a healthy soil regulates and partitions water and solute flow".

About the Catchment

Situated in northern Victoria and part of the Murray Darling Basin, the Goulburn Broken catchment comprises the catchments of the Goulburn and Broken Rivers and a small part of the Murray Valley, downstream of Bundalong. (Map 1). The catchment covering 2,391, 544 ha, or 10.5% of the State. Land use is shown in Table 1 and Map 2.
Although it covers only 2% of the Murray Darling BasinGoulburn Broken provides 11% of its stream flow. Usage is as follows:

- Use within the catchment 803,000 Ml plus
- Murray Valley, from River Murray 200,000 Ml
- Exported to adjoining catchment 565,000 Ml (for irrigation, stock and domestic)
- Average flows to River Murray 1,760,000 Ml

Some 185,000 people live in the catchment providing an employment pool of 65,000. Of these, 17,000 are employed in agriculture and associated industries.

Catchment Description

Goulburn Catchment

The Goulburn River catchment is Victoria's largest, covering 1, 619,158 ha or 7.1 % of the state's total area. The catchment has a mean annual water discharge of 3, 040, 000 ML, which is 13.7% of the total state discharge. It produces on average, 1.8 ML/ha.A number of the Goulburn's major tributaries rise on the northern slopes of the Great Dividing Range. These include the Big, Delatite, Howqua and Jamieson rivers.

Terrain varies significantly from the high ranges and mountains in the sourth to the flat country of the Murray Plain to the north.

Rainfall varies substantially. The high country in the south east experiences cold winters with persistent snow and an average annual rainfall greater than 1600 mm. Rainfall decreases northward, and in the far north of the catchment is less than 450 mm per year, only one third of the annual evaporation in that area.

The catchment was once forested over its entire area. N**ative vegetation** has been retained in the mountainous far south, where slopes are steepest, but clearing for agriculture has been extensive in the valleys and plains.

Streamflow along the Goulburn River has been modified by two major features, Lake Eildon and the Goulburn Weir.

Operation of Eildon Reservoir has reduced the July to September flows passing Eildon to 33% of the total annual flow, allowing an increase of the January to March flows to 23% of the annual flow.

The Goulburn Weir near Nagambie and associated diversion channels to the east and west, have reduced the average annual down river flow there to 1 340 000 ML, less than half the pre-regulated flow. Lake Eildon has a capacity of 3 390 000 ML and supplies more than half of the water used in the Shepparton Irrigation Region.

There are several major rural towns and cities in the Goulburn Catchment including Shepparton, Mooroopna, Benalla, Seymour and Kyabram, and a further eight communities with populations greater than 1500.

Map 1 Catchment Map

Broken Catchment

The Broken River is a tributary of the Goulburn River that joins the Goulburn at Shepparton. The basin also includes the catchment of the Broken Creek that diverges from the Broken River west of Lake Mokoan and flows north west to the Murray RiverSmall areas of the Murray catchment, south of the River Murray are also in the catchment of 772 386 ha (3.4% of Victoria's total area).

Again, climate varies considerably. In the south average annual **rainfall** is about 1270 mm. This decreases to about 700 mm near Benalla, 550 mm at Dookie and 470 mm at Cobram. Across the northern section rainfall generally decreases to the west

Streamflow is extremely variable between seasons and between years. The three months July to September generally account for over half the annual stream flow. . The catchment has a mean annual flow of 325 000 ML (0.42 ML/ha), however annual flow has varied from a minimum of 5000 ML in the drought year of 1943 to maxima of more than 1 000 000 ML in the flood years of 1917 and 1956.

Most of the Broken catchment has been **cleared** for agriculture comprising mainly grazing in the south and mixed cereal and dryland grazing in the central region. A large part of the northern section is within the Murray Valley irrigation district where intensive horticultural, dairy and livestock production occurs.

Two major and two smaller storages have been constructed within the catchment. Lake Nillahcootie was builtin 1967 with a a capacity of 40 000 ML and Lake Mokoan, constructed in 1971, has a capacity of 365 000 ML. These reservoirs provide water for stock, domestic and irrigation supplies. On Ryans Creek two small reservoirs, provide water to the town of Benalla.

The city of Benalla is the largest urban community. There are also a number of major towns including Cobram, Nathalia, Yarrawonga and Numurkah. Part of the city of Greater Shepparton lies within the catchment.

Table 1: Land Use in the Goulburn Broken Catchment (after OCE 1991).

Land use type (ha)	Goulburn	Broken	Total
Native Vegetation (forested)	544,000	111,650	655,650
General agriculture (dryland)	916,800	532,070	1,448,870
Intensive agriculture (irrigation)	110,400	99,330	209,730
Plantation (pines)	6,400	16,940	23,340
Urban	1,600	770	2,370
Total (ha)	1,579,200	760,760	2,339,960

National Importance of the Catchment

The Goulburn Broken catchment is widely regarded as the "foodbowl" of Australia with production from the irrigation region (covering 270,000 irrigated hectares) supporting a very large food processing industry that contributes to 25% of Victoria's export earnings. The Dryland area covers 1.4 million ha and generates $1.9 billion each year. Total catchment production value is approximately $7.8 billion per annum (Michael Young and Associates 2001). Over the last 5 years capital investment in food processing has been $630 Million.

Primary industries include horticulture, dairy, cropping, wine grapes, wool, forestry and grazing (sheep and beef). The region supports a large fruit and vegetable food processing industry centred around Shepparton with value adding in other commodities such as milk products, wineries and meats.

Irrigation areas to the west also rely on water supplied from the Goulburn Broken catchment. Infrastructure investment by Goulburn Murray Water alone totals $2.6 billion. This relies heavily on the water resources in the Goulburn Broken catchment.

Tourism is increasingly important to the catchment, particularly in the southern areas where easy access from Melbourne provides numerous options for tourism and recreational activities. Such activities need to be managed with care as inappropriate use can damage waterways and water quality for downstream users. Main tourism activities include wineries, snow and water skiing, camping, 4 wheel driving and fishing.

Goulburn Broken Catchment Assets

Natural Assets

In the following section, soils of the catchment are emphasised. Other natural resources are also described following the format of a recent inventory in the catchment (Ecosystem Services Project 2001). This format not only identifies important natural resources in the catchment but also describes trends in their condition. Where applicable, these trends are also related to their natural soil base.

Risks to these assets are discussed in terms of social, environmental and economic threats in ***the Risk Management Section.***

Soil

Soils are primarily described in this document according to the *Australian Soil Classification* scheme (Isbell, 1996; Isbell *et al*. 1997), which has been widely endorsed by scientists, soil surveyors, and conservation authorities (Table 2).

Table 2 Schematic summary of Soil Orders in the *Australian Classification* (Isbell, 1996)

Human-made soils	ANTHROPOSOLS
Dominated by organic materials	ORGANOSOLS
Negligible evidence of soil forming processes	RUDOSOLS
Minimal evidence of soil forming processes	TENOSOLS
B horizons with accumulated iron /aluminium /organic matter	PODOSOLS
Clay = 35% in all horizons; cracks or slickensides	VERTOSOLS
Prolonged seasonal saturation	HYDROSOLS
Strong texture-contrast between A and B horizons	
Sodic B horizon	SODOSOLS
Non-sodic B horizon with pH < 5.5	KUROSOLS
Non-sodic B horizon with pH = 5.5	CHROMOSOLS
Lacking strong texture-contrast between A and B horizons	
Calcareous throughout profile	CALCAROSOLS
High content of free iron in B horizon	FERROSOLS
Structured B horizon	DERMOSOLS
Massive B horizon	KANDOSOLS

Brief references are also given to older classification schemes, such as the *Factual Key* (Northcote 1979) and the *Handbook of Australian Soils* (Stace *et al.* 1968), together with references to soil types described in local survey reports

Soils and Asset Trends

Calculations of land area for a dominant Soil Order are tabulated below (Table 3). Maps showing the distribution of these Soil Orders within the catchment are attached to this document as Appendix A**.**

Table 3 Area of land within the catchment consisting of a dominant Soil Order.

Dominant Soil Orders	Land Area (ha)	(%)
Calcarosols	1,407	0.1
Chromosols	352,545	14.8
Dermosols	510,732	21.5
Ferrosols	30,840	1.3
Hydrosols	7,904	0.3
Kandosols	211,000	8.9
Kurosols	97,671	4.1
Rudosols	18,054	0.8
Sodosols	983,808	40.8
Tenosols	72,120	3.0
Vertosols	105,463	4.4
Totals	2,391,544	100.0

Sodosols constitute the greatest proportion (41%) of all dominant Soil Orders in the catchment, followed by Dermosols (22%) and Chromosols (15%), with the remaining Orders individually contributing less than 10% to the total mapped area. The Sodosols and Chromosols defined for the catchment are typically duplex in nature - with clay subsoils overlain by finer textured topsoils, while the Dermosols have uniform or gradational texture changes down the profile (see Northcote 1979 for fuller descriptions). General characteristics of each of the Soil Orders listed above and which are relevant to specific soil health issues discussed later are shown in table 4.

Table 4 General characteristics of the Soil Orders of Australia

Order	Sub-order	PAW (mm)	Drainage Status	Aeration Status	Root Restrictions	Erosion Hazard	Nutrient Availability	Toxic Elements	Soil Workability
Calcarosols	Supracalcic	50	good	good	calcrete fragments	low-mod	low	B, Na	good
	Calcic	30	good	good	stone/boulder calcrete	low	low	B	variable
Chromosols	Red	100-200	poor	adequate	crusts & dense subsoil	low-mod	low	B, Al	poor
	Brown	50-150	poor	moderate	clay subsoils	moderate	moderate	low pH, Al	good
Dermosols	Red	100-200	good	good	none	moderate	variable	low pH, Al	variable
Ferrosols	Red	> 250	good	variable	none	high	low-mod	low pH, Al	poor
Kandosols	Red	150-350	good	good	few	high	low	none	moderate
	Yellow	150-350	variable	variable	ironstone nodules	after tillage	low	low pH, Al	good
	Brown	150-350	moderate	variable	ironstone nodules	mod-high	low	low pH, Al	poor-mod
Kurosols	Red	150-200	moderate	variable	tough clay subsoil	mod-high	low	low pH	good
	Brown	150-200	poor	poor	dense clay subsoil	low-mod	low	Al	good
Podosols	Semi-aquic	50-350	good	good	subsoil pans	moderate	very low	none	good
Sodosols	Red	30-200	poor	poor	dense clay subsoil	high	low	B, Na, salinity	variable
	Grey	< 50	poor	poor	dense clay subsoil	high	low	low pH	good
	Black	< 50	poor	poor	dense clay subsoil	high	low	low pH, Al	poor
Tenosols	Orthic	150-350	good	good	few	moderate	low	low pH, Al	good
Vertosols	Black	150-200	moderate	variable	plough pans	high	low-mod	salinity	variable
	Grey	75-150	moderate	poor	plough pans	high	low	salinity	variable
	Brown	100-150	moderate	poor	subsoil pH, ESP	high	moderate	salinity	variable

PAW plant available water **(Adapted from N McKenzie *et. al*., 1999)**

Within the catchment, losses in soil assets have occurred with erosion, salinization and sodification, acidification, soil structural decline, reduced soil biodiversity and lowered soil resilience. Erosion, rising water tables, and subsequent soil salinization followed from extensive periods of tree clearing in the late 1800's. Erosion was exacerbated by the explosion of rabbit populations in the catchment prior to the myxamatosis and calici virus counter-measures. Salinization and naturally occurring soil sodicity are being exacerbated by irrigation with pumped saline-sodic groundwater, and more recently with pumped municipal wastewater. Acidification has developed with the increased use of nitrogenous fertilizers and legume-based crops and pastures, both of which tend to increase pH in soils. Soil structural decline has followed from increased natural slumping under irrigation practices, increased tillage under certain crops, loss of organic soil binding agents under cropping and the increased amount of traffic (both animal and tractor) under increasingly intensive agricultural practices. The alteration of soil structure and thereby the soil moisture regime, together with soil salinization,

sodification or acidification, restricts the range of possible environments in which soil biota can exist, hence leading to losses in soil biodiversity.

Soil Mapping

Soil mapping is most reliable in the irrigated regions of the catchment, where extensive grid surveys were conducted, principally in the period 1940-1965, but extending from the 1930's through to the 1980's. Most of these surveys resulted in detailed maps of soil types, at approximately 1:35,000 scale, and proposed land capability for irrigated crop and pasture species, or identified regions where soil health problems, such as salinity, existed. Subsequent and more recent mapping, at scales of 1:100,000 to 1:2,000,000, has allocated soil types to broader soil associations (eg Great Soil Groups, or Soil Orders) based on landform patterns (eg Northcote, 1962). Information regarding detailed soil surveys within the catchment is presented in Appendix B**.**

Recent soil mapping (David Rees, personal communication) has made use of digital elevation models, surface radiometric surveys, and to a lesser extent, aerial photography, for assessment of land patterns to which soil classes are eventually allocated. Field sampling is used to aid and validate the classifications of regions to a dominant Soil Order. Mapping units of soils in the lower catchment have been extrapolated from existing soil survey data and supplementary soil sampling. Mapping units of soils in the upper catchment have been extrapolated from digital elevation models and existing geological maps, together with supplementary soil sampling. Soil mapping, particularly in the upper catchment, has generally been non-systematic and has tended to exclude surveying of public lands.

Maps generated for specific soil health issues are based on criteria that differ throughout the catchment. Dryland - salinity mapping in the catchment, for example, is based on the distribution of interpolated land-management units, derived mainly from near-surface geological features. Salinity mapping within irrigated regions of the catchment is based on electromagnetic (EM38) surveys, soil surveying, and data interpolation. This lack of consistent mapping criteria across the catchment means that correlations between soils and specific soil health issues are not always readily available.

Biota

The ecosystem services provided by biota depend on there being a diversity of life forms performing a range of functions. Diverse species underpin processes that help prevent erosion and control salinity, filter and purify water and assimilate wastes, provide protection from floods and control of pests and diseases, maintain fertile soils that are the basis for agriculture, attract tourists, and provide cultural, spiritual and intellectual fulfilment in different ways to all people. Science is not able at this time to predict the impact of losing species on delivery of ecosystem services, so we have to conclude that there are risks and species loss should be minimised. In the Goulburn Broken, the suites of species that make up ecosystems have undergone considerable change since European settlement through development of primary industries, including agriculture, mining and forestry.

The Goulburn Broken Native Vegetation Strategy reports that several vegetation types have been reduced to a small proportion (2-9%) of their former abundance and range in the mid and lower catchment. These pressures in the catchment are ongoing. Ninety-five species of plants and 85 animal species are considered threatened. Overall, only around 7% of the native vegetation cover of the region at European settlement remains. Although much of this clearing occurred in the 19th Century, it has continued throughout the 20th Century. There is still gradual degradation of roadside and stream vegetation in the mid-lower Catchment and fragmentation of habitat, which affects the viability of species. Another threat to the natural asset of biota is the wide array of pests and weeds expanding in the catchment and threatening the viability of farms. There are 70 species of noxious weeds. Exotic animals considered pests in the catchment include rabbits, wild dogs, horses, pigs, foxes, feral cats, and goats. In waterways, carp are a major problem, stirring up sediment and causing decline of native species. Some native animals are also considered pests when their numbers increase to levels that threaten agricultural enterprises, these include kangaroos, wallabies, cockatoos, galahs and wombats.

Surface Waters

Pollution of waterways by nutrients flowing from irrigation drainage, sewerage, sediment mobilisation, and intensive animal industries has become a major issue in the catchment. One major consequence is the blooms of blue-green algae that occur frequently in the catchment and downstream, threatening health of people and stock and industries such as tourism. The increased use of streams and rivers in the Catchment by people since settlement has led to problems like stream instability, bank erosion, flooding, and associated threats to public and private assets and habitat. River flows vary greatly due to irrigation needs. Operation of Eildon and the Goulburn Weir has allowed regulation of flows for industrial purposes. These flows differ in pattern across the year from the pre-regulation pattern, which will have implications for river ecosystems.

Ground Waters

An intricate net-work of aquifers older than 36,000 years underly the Goulburn Broken catchment. These aquifers are not fully confined and are often cross-linked with each other resulting in highly variable water quality when pumped. Differences in groundwater salinity, for example, are explained in part by variable salt stores (500 – 15000 mg/L) within different geological formations. Pollution of groundwaters by nutrients, pesticides, heavy metals, radioactive material or microbes has not been widely researched in the catchment. However, recent reports indicate that at some sites groundwater pollution is occurring (Watkins 1999?, Stork 2001).

Atmosphere

Like the rest of the world, the Goulburn Broken catchment is only beginning to grapple with the question of how its industries and other land-uses affect the composition and function of the atmosphere. The Goulburn Broken catchment has a lot at stake in relation to climate change and stability. The region 's primary industries —agriculture, fruit growing and dairy —would suffer negative impacts from climate change. The region is both a positive and negative contributor to climate stability. Contributions to greenhouse gas emissions are made through intensive dairy, cattle and sheep farming, while carbon sinks are provided in the catchment through existing vegetation and revegetation efforts.

Economic Assets

- Primary industry assets (eg irrigation and drainage infrastructure)
- Secondary industry assets (eg food processing)
- Tertiary industry assets (eg transport and storage)
- Quaternary industry assets (eg retail and services)
- Quintenary industry assets (eg tourism, recreation)

The existing assets are being added to at an investment rate of about $100 million each year (or $ 1 billion over 10 years).

All capital assists in the catchment contribute to the gross regional production of about $7.8 billion each year which is the most significant contribution of any non-metro catchment in Victoria.

Social Assets

The social assets of the Goulburn Broken catchment are harder to quantify but include:

- Strong regional centres of Benalla, Seymour and Shepparton.
- A close network of social organisations (eg sporting clubs, community arts groups, environmental groups, welfare groups and family support groups.
- Strong community representation through a wide range of organisations (eg councils, businesses, government agencies, social clubs)
- Good cross section of educational facilities (primary schools, secondary schools and colleges, universities such as University of Melbourne through their Rural Health and Dookie College and TAFES.)
- Some public transport services.
- Resource centres such as libraries and internet access.

Legislative and Policy Background for Soil Health

Legislation

State Legislation, incorporating amendments up to 2001 that are relevant to the SHS include:

- *Environment Protection Act 1970* with regard to soil disposal
- *Litter Act 1987* with regard to soil disposal
- *Land Conservation (Vehicle Control) Act 1972* with regard to traffic control for control of soil erosion
- *Catchment and Land Protection Act 1994* with regard to the conservation of all natural resources in catchments and on farms
- *National Environment Protection Council (Victoria) Act 1995* with regard to Federal-State government relationships and pollution of soils, water and air.
- *Livestock Disease Control Act 1994* with regard to removal of soil from quarantine areas
- *Fisheries Act 1995* with regard to research into soil contamination of aquatic habitats
- *Wildlife Act 1975* with regard to soil removal or depositing in Wildlife and Nature Reserves
- *Land Act 1958* with regard to land drainage
- *Forests Act 1958* with regard to government acquisition of land for soil erosion control
- *Flora and Fauna Guarantee Act 1988* with regard to soil erosion, sedimentation and soil borne diseases

- *Project Development and Construction Management Act 1994* with regard to land transactions
- *Plant Health and Plant Products Act 1995* with regard to disease control, monitoring and treatment
- *Valuation of Land Act 1960* with regard to land value criteria (topography, soil quality, aspect)
- *Conservation, Forests and Lands Act 1987* with regard to land management, soil erosion and codes of practice
- *Land Acquisition and Compensation Act 1986* with regard to temporary occupation by government officers and removal or deposition of soil
- *Agricultural and Veterinary Chemicals (Control of Use) Act 1992* with regard to environmental contamination and soil contaminant sampling
- *Extractive Industries Development Act 1995* with regard to licensing and royalties for soil extraction

Policy and Strategies

The Draft Goulburn Broken Soil Health Strategy compliments and is aligned with a number of federal, State and regional strategies and plans which protect and enhance soil quality.

Catchment

CMA Policy

The Government's primary goal of catchment management is "to ensure the sustainable development of natural resource-based industries, the protection of land and water resources and the conservation of Victoria's natural and cultural heritage".

In developing the Policy on Future Arrangements for Catchment Management, the Government aims: to establish catchment management arrangements that will most effectively and efficiently implement the Regional Catchment Strategies.

The most effective way of implementing the Regional catchment Strategies is to establish management arrangements which:

- Ensure that all resources are targeted to the key priorities of the RCS and which can deliver on-ground outcomes
- Properly integrate service delivery on interrelated issues
- Strengthen links between strategic planning and implementation of on-ground works
- Have clearly defined roles and responsibilities and accountability

Goulburn Broken Catchment Management Authority Regional Catchment Strategy, 1997

The Goulburn Broken Regional Catchment Strategy (RCS) was prepared by the Goulburn Broken Catchment and Land Protection Board, in consultation with and on behalf of the community. The RCS identified ten priority issues for each geomorphic region of the catchment (irrigation, dryland plains, dryland uplands, rivers and public lands). Soil health issues received priority rankings in every region.

Soil health issues raised in this strategy include: waterlogging (irrigation regions); soil acidity, salinity, water erosion, soil structural decline (dryland plains); soil acidity, salinity, water erosion, soil structure decline, soil nutrient decline (dryland uplands); water erosion, salinity (in association with rivers); and water erosion (public lands).

The RCS and its sub-plans and strategies are all integrated. This means that soil health issues will be considered automatically as part of any environmental works that address other priority catchment issues. The RCS is being reviewed and it is anticipated that there will be new RCS by September 2002.

Shepparton Irrigation Region Land and Water Salinity Management Plan (SIRLWSMP)

This plan aims to "manage the salinity of land and water resources and the quality of water in the Shepparton Irrigation Region in order to maintain and, where feasible, improve the social well-being, environmental quality and productive capacity of the Region". The plan has a strong focus on reducing high watertables and on salinity control activities.

The six programs within the (SIRLWSMP)

- Farm program
- Surface drainage program
- Environmental program
- Sub-surface drainage program
- Monitoring program
- Program support

Goulburn-Broken Dryland Salinity Management Plan (1990, 1995)

The Goulburn Dryland Salinity Management Plan (1990) and a subsequent review (1995) identified measures to control the spread of dryland salinity in the Goulburn Broken catchment. Proposed measures focussed on reducing rainfall accessions to groundwater and controlling soil salinization and erosion at discharge sites.

Goulburn-Broken Regional Landcare Plan June 1993

Objectives of the plan for the Goulburn-Broken Region were:

- Long term sustainability of natural resource based industries
- Maintaining vegetation cover
- Protecting water quality and quantity

- Integration of productivity, profitability and conservation
- Improving communication between and across government agencies, community groups and individuals
- Encouraging nature conservation on public and private land

Other Catchments

North East Soil Health Action Plan (2001)

This action plan identified erosion, acidity, declining soil structural stability, salinity, soil chemical residues and potential decline in number and diversity of soil biota as important issues to be addressed by the North East Regional Catchment.

Ballarat Region Conservation Strategy 1999-2004.

This strategy highlights conservation of water, land, vegetation, native fauna, air, energy, minerals, and local heritage items. Under the land program, priority soil health issues include soil structure decline, acidification, declining soil nutrient levels, salinity and erosion.

State

Acid Soil Strategy for Victoria 2001

This commissioned report identified priority areas for the control of soil acidification, particularly in areas of higher rainfall.

Victoria's Biodiversity – Directions in Management 1997

This strategy aimed to develop awareness of partnerships and strategic mechanisms for actions that address flora and fauna objectives, with an emphasis on threatened or depleted types such as Box-Ironbark forests, grasslands and riparian environments which are related to the distribution of soil types.

Victorian State Environment Protection Policy - Waters of Victoria (SEPP WoV)

This policy, declared under the *Environment Protection Act 1970*, has the policy goal: "to attain and maintain levels of water quality, which are sufficient to protect the specified beneficial uses of the surface waters of the policy area". The SEPP WoV is currently being reviewed.

This policy applies to private individuals and government agencies conducting activities on public and private land and differs from other strategies by expressing in law the community's expectations, needs and priorities for using and protecting the environment. This policy will have importance for areas of land that are point sources for nutrients or toxic elements entering waterways.

Victorian Nutrient Management Strategy for Inland Waters, 1995

The objective is:

"to provide a policy and planning framework to assist local communities and the state government manage nutrient levels in water bodies to minimise the potential for the development of algal blooms, particularly blue green algae."

The strategy consists broadly of two components:

- a range of initiatives across the state which reduce or have the potential to reduce nutrient levels and provide net benefits to the community. Developing and implementing these initiatives will involve both the state government and local communities; and
- specific nutrient management options to deal with particular local nutrient problems. These actions will need to be undertaken by local communities, in consultation with the state government.

This second component has implications for management of soil fertility on farms adjacent to waterways, particularly in irrigation regions.

National

National Strategy for the Conservation of Australia's Biological Diversity
(Department of the Environment, Sport and Territories, 1996)

This strategy seeks the development of integrated policies for major uses of biological resource
objectives and principles of the National Strategy for Ecologically Sustainable Development.

National Environment Protection Council (NEPC)

Schedule B (5) Guideline on Ecological Risk Assessment, National Environment Protection (Assessment of Site Contamination) Measure 1999 **and**
Schedule B (1) Guideline on the Investigation Levels for Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure 1999

These documents have been produced to provide a nationally uniform and scientifically defensible protocol for conducting ecological risk assessments of chemically contaminated soils and groundwater. They provide generic and site-specific ecological impact levels for contaminants in Australian soil and groundwater.

The guideline will allow the assessor to:

- Identify
- Evaluate
- Determine the risk that soil or groundwater contaminants may pose to biota that are of ecological value and
- Support informed risk management decisions relating to site contamination

MDBC Water Quality Policy, 1990

The Murray Darling Basin Commission (MDBC) has a water quality policy which aims: "to maintain and, where necessary, improve existing water quality in the rivers of the Murray Darling Basin for all beneficial uses - agricultural, environmental, urban, industrial and recreational.

In the case of those parameters such as salinity and nutrients which are already recognised as causing problems, the policy is to improve water quality..." This was formally adopted as a policy by the Murray Darling Ministerial Council in August 1990.

MDBC Salinity and Drainage Strategy (1989, 1999)

This strategy set out specific salinity reduction targets to reduce average salinity in the River Murray at Morgan, South Australia by 80 EC units. Further it aimed to control existing land degradation and to rehabilitate (where possible) land resources along the Murray and Murrumbidgee valleys.

Since adoption of the strategy, a net reduction of salinity of 57 EC units has occurred, mainly through the construction of salt interception schemes. The implementation of the SIR salinity management plan has resulted in an allocation of 3.4 salinity credits to the catchment, which exceeds credits given to any other regional plan in NSW, Victoria or South Australia.

Increases in salinity from dryland regions and from drainage schemes (constructed before the Strategy) are likely to reverse achievements in salinity control along the Murray and Murrumbidgee valleys in the absence of extra management measures.

International

Several examples of nationally developing soil strategies are provided from England and the European continent.

The draft soil strategy for England

"The English government's overall aim is to ensure that people use and protect soils in a way that is not only sustainable in its own right, but also contributes to the wider aim of achieving sustainable development."

Objectives of the soil strategy are:

- To manage the extent of our soil resource in ways which ensure we can meet our present and future land use needs
- To manage diversity of soils, concentrating particularly on our most valued soils, so that the right balance of soil types is available to meet current and future needs for soil to support our ecosystems, landscape, agriculture and cultural functions
- To maintain and improve the quality of soils at a level where soil function is not impaired, to ensure we can meet our current and future social, environmental and economic needs

To meet these objectives the following action needs to be taken:

- Providing best guidance
- Maintaining regulatory controls where appropriate
- Introducing new controls where they are needed
- Ensuring individual decision-makers take soil into account and
- Providing funding and using economic incentives
-

Strategic action plans include:

- Ensure that all policies and programs which affect soil take into account the strategy's aims and objectives
- Develop a national set of key soil indicators to help provide assessments such as the extent of soil lost to development
- Review current monitoring and develop a national framework for soil monitoring
- Examine existing and recommend ways to improve co-ordination of soil research
- Set a five year goal for evaluating the success of the soil strategy

Soil and Land Alliance of European Cities and Towns

The Soil and Land Alliance of European Cities and Towns is an association whose objective is to promote and work actively for the sustainable use of soil protection and land management on a European level.

ICLEI Soils Network

The objective of the ICLEI (The International Council of Local Environmental Initiatives) Soils Network is to ensure precautionary soil protection and sustainable land use through local actions in order to reach tangible improvements of the global quality of soil and its ability to support life by:

- Taking action and promoting changes that lead to a sustainable land-use and to improvements in the quality of soil
- Bringing soil and land use issues into discussion at local, national and international levels

- Getting soil and land use issues represented in policy at all levels of government
- Enabling exchange and co-operation between local authorities, with stakeholder groups and experts

GBCMA Board
9 community members

8 Community Members

Mid Goulburn Broken Implementation Committee

8 Community Members

Upper Goulburn Implementation Committee
8 Community Members

Municipal Strategic Statements

Local Governments are in the process of reviewing their Planning schemes. Salinity, sodicity, and waterlogging issues are increasingly becoming issues of concern to municipal authorities, due to their associated damage to infrastructure.

Implementation Framework

Goulburn Broken Catchment Management Authority (GBCMA) was established by the State Government in 1997 under the Catchment and Land Protection Act 1994 to manage land and water resources in the Goulburn Broken catchment. The GBCMA is working to ensure land and water resources are protected and enhanced as well as improving the region's social wellbeing, environmental quality and productive capacity in a sustainable manner.

Support from CEO & Staff

Shepparton Irrigation Region Implementation Committee

Figure 1 Institutional arrangements highlighting direct input into community decision making

The Goulburn Broken CMA is a statutory Authority under the Water Act 1989 and the Catchment and Land Protection Act 1994, and is required to operate according to specified protocols. The GBCMA publishes an Annual Report each year which is audited by the Auditor General and tab 99/2000 report. The GBCMA also has c

Biodiversity Coordination Committee and Goulburn Broken River Health and Water Quality Coordination
oversees works in the entire catchment and report to each IC.
(25 community representatives)

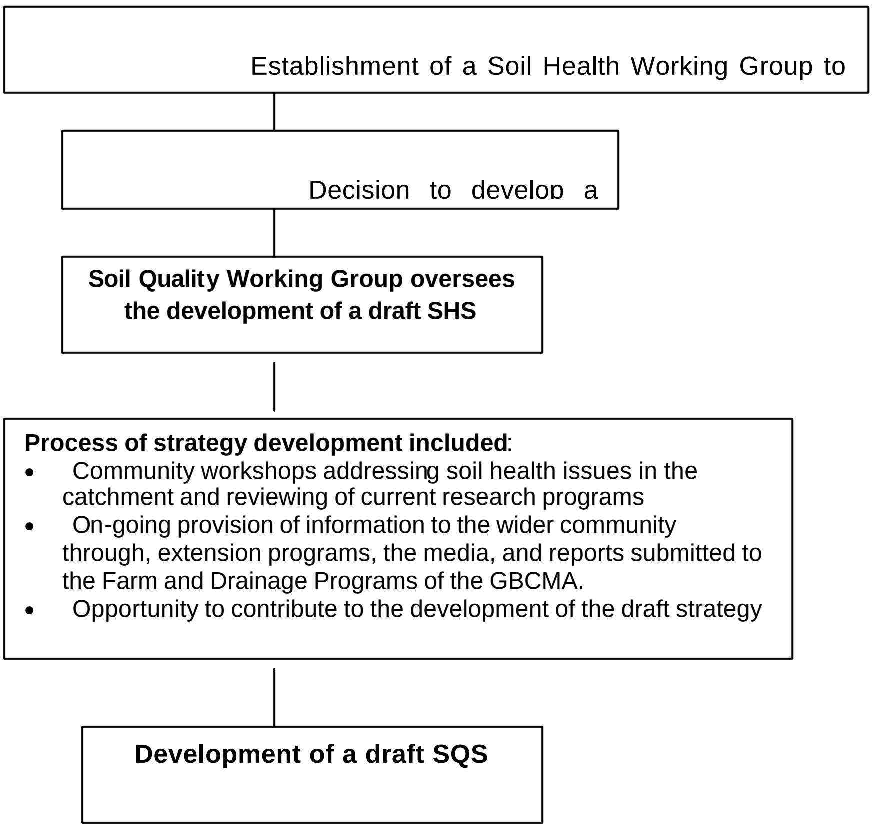
To ensure activities of the authority reflect community views the GBCMA Board has set up three geographically and community based **Implementation Committees** (Figure 1 and Map 2). These committees have the responsibility of developing and putting in place on ground works under the regional Catchment Strategy and associated Action Plans and Strategies as well as acting as a valuable link between the GBCMA Board and the community. Two **Coordinating Committees** also exist to ensure a consistent region-wide approach to issues such as biodiversity and river health and water quality.

Each of the IC's have responsibility for implementing the RCS (and relevant sub-strategies). Implementation is carried out according to a 3 year business plan (also called the Regional Management Plan and associated IC Implementation Schedules). This effectively forms the works plan for the ICs, ie overall objectives, activities, funding and outputs. Works that are catchment wide are funded through the RMP alone.

Community Consultation and Involvement

The flow of the development of the draft SHS (2002) can be described as in the diagram below.

Process for the development of the 2002 Draft SHS



Development of the draft SHS involved a range of key stakeholders, which was overseen by executive officers of the Goulburn Broken Catchment Management Authority. Preparation of the strategy has involved:

- establishment of a Soil Health Working Group
- audit of existing soil health information
- identification of best management options

- economic analysis of proposed action plans

The Draft Goulburn Broken Catchment Soil Health Strategy will involve the community through the three Implementation Committees. The current SHS is also expected to meet NAP accreditation guidelines.

The Programs

Sodicity

Soil Structure

Acidity

Implementation

Several key activities have been identified for the Goulburn-Broken region, which are described below.

1. Develop a focused education program to increase the awareness of landholders and the general public about the causes of soil acidification, the extent of the problem and the impacts on the environment.

2. Initiate and conduct a regional monitoring program to understand the extent of the acidification problem within the catchment. This will identify priority areas for immediate action. The collected data will assist in the planning of cost-effective actions to protect the most valuable assets within the region and reduce the potential impacts on the environment.

3. Classify and prioritise land-use on the basis of the biophysical potential, together with the productive capacity, social and economic viability of the region and link this to the current threat from soil acidification.

4. Develop best practice guidelines for a range of industries in order to control the current rate of acidification.

5. Identify targetted programs for high risk soils under a productivity enhancement program to decrease the offsite impacts and maintain the condition of the catchments water and soil resources.

6. Investigate and develop specific R&D programs to identify alternative strategies for increasing or maintaining soil pH other than applying lime, to reduce the offsite impacts from the acidifying processes and maintain or improve productivity without further soil pH decline.

Soil Biodiversity

Erosion

Implementations

Several key activities have been identified for the Goulburn-Broken region these are described below.

1. Classify and prioritise landuse on the basis of the biophysical potential together with the productive capacity, social and economic viability of the region and link this to current threat from soil erosion.

2. Develop best practice guidelines for soil types and slope of the landscape in order to control the current rate of soil loss.

3. Identify targeted programs for high-risk soils to decrease the offsite impacts and maintain water quality and the soil resource.

4. Investigate and develop specific R,D&E programs to identify alternative strategies for soil erosion control whilst maintaining productivity without further environmental decline.

5. Contour sowing of broadacre agricultural crops in high rainfall regions (upper Goulburn-Broken) and low rainfall susceptible soils such as the Sodosols in the mid and lower Goulburn-Broken.

6. Promote agricultural practices that retain groundcover such as minimum tillage and stubble retention, reduce stubble burning.

7. Increase the amount of grassed waterways in the region by reducing stock movement near streams and rehabilitation of riparian vegetation.

8. Increase the level of treed groudcover in the mid and lower Goulburn-Broken to increase windbreaks and reduce the degree of wind erosion.

Building Capacity and Catchment Standards

SIRCS goals will only be achieved if the community has the capacity to do so. The GBCMA has adopted a set of "Catchment Standards" with "Standard Practices" for *managing* all issues. These Standards direct the actions to build and maintain capacity. The Standards group the essential components for ease of management. The Standards and objectives are not mutually exclusive, which is typical with attempts to isolate components when holistically managing very complex systems.

Catchment Standard	Standard Practice	Capacity Building Action
With Objectives.	*How all RCS issues are addressed to meet Standard.*	*How Standard Practice is implemented for specific issue, eg water quality.*

These Standards and objectives include all "Best Practice Standards" listed in the National Action Plan Agreement (2001).

Building and maintaining capacity comes at a cost. The actions are costed in Section 7 – Support Program. The SIR Implementation Committee (SIRIC) is responsible for implementing all Capacity Building Actions.

The following summarises the Catchment Standards and further details of the standard practice and how the SIRCS will achieve these can be found in the appendix 1.

1 Partnerships fostered (strongly linked to 6 Accountabilities)
- Communication will be optimised.
- Roles will be defined.
- Our diverse communities and agencies will be actively engaged.

2 Priorities rigorous
- Priorities will be based on the best available scientific, economic and sociological information.
- Causes of problems will be targeted in geographic areas that maximise community return on investment.
- Priorities for works will consider risks and multiple benefits.

3 Costs shared fairly
- Costs and benefits will be shared transparently and equitably.
- Triple bottom line accountability.
- Link with supporting legislation will be clear.

4 Large scale focused on
- Land use will change so that it better matches land capability across broad areas.

5 Cultural heritage included
- Aboriginal and non-Aboriginal cultural values will be factored into all decisions.

6 Accountabilities clear (strongly linked to 1 Partnerships)
- Project proposals will align with the priorities of the RCS.
- Progress reports will clearly link to regional, state and national targets and needs.

7 Adaptive Management Systems at all scales

- Management systems will be in place for individuals, sub-catchments, whole of catchment and industries.
- Databases will be optimised.
- Monitoring & evaluation programs will regularly review assumptions underpinning RCS

Partnerships

Communications

Roles and Responsibilities

- IC – documentation of roles – Charter?
- Operating Agreements
- Service Agreements
- Responsibilities detailed in section 7 in the programs and by action

Community Consultation and Involvement

- Surface Water Management
- Sub-surface Water Management
- Farm Program
- Environment Program
- Waterways
- Overall – foresighting workshops

Priorities

There are numerous priority setting processes that occur both at the strategic and annual levels. As part of the SIRCS review process, all programs were required to undertake a prioritisation process for identified activities. Towards the end of the review process, the overall priorities were also identified including works priorities and information gap (or R&D) priorities.

Strategic Priority Setting

Surface Water Management Program

The Surface Water Management Program has a detailed and comprehensive priority setting process for the primary drains and other public infrastructure which includes looking at three weighted parameters as follows:

- Economic Factor 55 %
- Environmental Factor 25 %
- Community Response Factor 20 %

The prioritisation process was undertaken in 2000 with an increase of the environment factor from 10 % in the 1995 Review, to 25 % noted above. This reflects the increased importance that the community is now placing on environmental considerations.

Further details of this process can be found in appendix xx

Sub-surface Water Management

The Sub-surface Water Management Program favours private works where feasible rather than public works and also favours working with recognised landholder groups to maximise regional benefits. In recent years, added priority has been given to private works to meet demand brought about by prevailing dry conditions and limited surface water allocations.

Private Works
Private works are further prioritised by confirming that the property is subject to high groundwater levels (August 1996) and, if needed, giving priority to:

- properties with known salinity problems;
- properties which have potential to provide salinity control to adjoining properties with known salinity problems; and
- properties where some lowering of the generally high watertable level can be achieved.

The reference watertable map for prioritisation is reviewed and adjusted accordingly every 5 years (base year August 1993). The August 1998 map was not considered to be representative due to prevailing dry conditions since 1997. Consequently, the 1996 map was adopted as representative under normal conditions.

Public Works
Where private works are not feasible due to high groundwater salinities and limited reuse potential, site investigations for public pumps are scheduled on the basis of order in which the application is received and accepted. Further prioritisation has not been required to date, as extension activities have been managed to achieve the target of four public pumpsites per year on average.

An informal prioritisation process for extension activities was undertaken in the past on completion of FEDS investigations. A more structured and focussed prioritisation process based on a number of parameters was adopted in August 1998 on a preliminary assessment of:

- salinity problems;
- disposal options;
- key landholder support;
- hydrogeological conditions;
- land use;
- surrounding landholder support; and
- environmental benefits.

The information is collected during the FEDS investigation and ranked in order to focus resources.

Farm Program

Environment Program

Waterways

Overall Strategy

Annual Priority Setting Process

Each year, the SIRIC reviews the priorities for activities and outcomes for each of the high priority issues (from section 2) and produces a SIR Priority document. This document then provides a guide to both community groups and organisations as to the priority activities for the coming year's investment process.

The priorities are updated using the best technical and scientific information available, usually based on the relevant plan or sub-strategy. Obviously, the Priorities Document for the 2003/04 year developed at the end of 2002 will be closely based on the recently reviewed SIRCS. Input from the community is through the various plan Working Groups as well as the Implementation Commmittee.

It should be noted that not all of the SIR priorities are funded in any one year, because of changing and new investment criteria of various funding sources.

Cost Sharing

Economic Analysis

Benefits – Social, Environmental and Economic

Incentive Programs

Five Year Works Budget

Large Scale Land Use

Whole program is driving at large scale land use change particularly through WFP, surface and sub-surface, Lower Goulburn rehab etc.

Cultural Heritage

Accountability

Reporting processes

Adaptive Management Systems

Risk Management Framework

Background
The activities underpinning the Goulburn Broken Regional Catchment Strategy must not only be directed to achieving its aims and objectives in an efficient and effective manner, but also to identifying and managing those risks that prevent it from achieving these aims and objectives.

It is recommended that the Goulburn Broken CMA utilise NRE's Risk Management Strategic Framework and Process in implementing its Regional Catchment Strategy. This has been adapted from the Australian/New Zealand Standard for Risk Management (AS/NZS 4360:1995) and is based on a 6-step approach being applied to the objectives of the Regional Catchment Strategy. These steps are illustrated below;

Identify Risks
↓
Assess Likelihood and Consequence
↓
Identify and Assess Controls
↓
Rank Risks
↓
Treat Risks
↓
Monitor and Review
↓

Approach

Using the above framework, it is recommended that a dedicated session at a future CMA Management Meeting (involving all the key partners) brainstorm the key risks and document their likelihood and consequence. Follow-up work will result in the development of a risk management plan. This document could then be the basis for discussions with the Implementation Committees and the CMA Board.

This approach will take participants through the following activities;

Identifying Risks

A comprehensive list will be generated of events and issues will be generated that may put at risk the CMA achieving the objectives of the Regional Catchment Strategy (see example in Attachment I).

The types of risk categories could include;

- asset management (buildings and equipment etc.)
- change management
- compliance
- environment management (incl. biophysical assets)
- financial
- liability
- personnel/staff
- delivery of services and products
- technology/IT

Assessing Likelihood and Consequences

By reviewing the likelihood and consequence of these events occurring, we can determine the level of risk.

The broad categories used for determining likelihood are;

Rare - event may only occur in exceptional circumstances
Unlikely - event may occur at some time, say once in 10 years
Moderate - event should occur at some time, say once in 3 years
Likely - event will probably occur in most circumstances, say once a year

Almost Certain - event is expected to occur in most circumstances, say many times a month.

Consequence can be measured around the following dimensions;

- Financial
- Human
- Business Interruption
- Environmental

Monitoring

We must monitor our strategy implementation performance. We need to know what's happening and if we are achieving results; we need to report to stakeholders and to those who are paying for strategy implementation. The success of strategy implementation is determined by assessing progress against targets for individual actions.

Evaluation Framework

Evaluation is making a judgement about the value or worth of something. In the case of the GB RCS, there are a range of scales and timeframes over which this must be done. This framework is set out to allow evaluation to occur on three fronts

- accountability (are things achieved that were set out to be achieved?)
- improvement (how can the process be improved to achieve the outcomes sooner, more quickly, more cheaply or achieve greater outcomes?)
- condition (are there changes in catchment conditions that alert us to a new threat?).

Issues

There are a number of issues that were considered in the development of the evaluation framework and these include:

- Assumptions
- Logic
- Time
- Questions
- Related Processes

Further details can be found in appendix xx (Evaluation).

Evaluation Framework

A prerequisite for the evaluation is that the pathway between the outcomes of the RCS, the sub-strategies and actions under the RCS are documented with the basis/assumptions for the connecting logic. From there, the sequence of steps to complete the evaluation matrix is as follows

- identify who the key stakeholders are for each part of the strategy, sub-strategy and a plan being evaluated
- establish their key questions
- determine what success would look like in answering their questions
- select appropriate measures that can demonstrate success or otherwise
- set targets for each measure/indicator/indices

- define the methodology for data capture (spatial and temporal collection, data sources, capture processes)
- identify who will collect, collate and analyse data
- determine how the evaluation is conducted, by whom and how it is fed back into the planning process to allow changes (if needed) to be made to the strategy or plan (which is relevant).

Annual Evaluation Review

An annual review of the evaluation process should be conducted to ensure:

- the evaluation is doing justice to stakeholders views/values
- the program learns from what it is doing
- the evaluation is useful to those involved
- it is persisting through implementation
- it remains relatively simple and effective.

Audits

Research and Development and Information Gaps

- Surface Water Management
- Sub-surface Water Management
- Farm Program
- Environment Program
- Waterways
- Overall

The Issues
Acidity

Nature of the problem

Soil acidification is a major land degradation issue threatening the sustainability and productivity of agricultural soils in Victoria's Goulburn-Broken Catchment. While soil acidification is a natural process, as illustrated by the strongly acidic subsoils in the high rainfall areas of the region, agricultural practices have greatly accelerated the rate of acidification on all soil types.

The rate of pH decline is also related to the amount of organic matter and clay present in the soil (Aitken and Moody 1994) as these components of the soil matrix help to slow the rate of pH decline. It is worth noting that soil carbon levels in the surface of most agricultural soils in Australia are now about half that of what they were before they were first cultivated (Baldock and Skjemstad 1999, Slattery and Surapaneni 2002). Thus our agricultural soils are now less able to resist a decline in soil pH and will acidify much more rapidly than when first farmed.

Clearly the rate of acidification will vary according to the type of rotation, soil type and the climatic region in which plants are grown. This means that varying rates of acidification will exist across different soil types and farming enterprises within the catchment.

Causes of acidity

The major causes of the acidification process are listed below and explained in detail.

- Nitrate leaching
  - Legumes in rotation
  - Dry summer ecosystems
  - Extent of perennial pastures
  - Application of phosphorus fertiliser
- Product removal
- Soil texture

Nitrate leaching

In more recent times, farming systems have relied upon the addition of nitrogen (N) fertiliser to crops to maintain yields, particularly where continuous cropping is practised and high value crops like canola are grown. Some forms of N fertiliser are more acidifying than other forms. Ammonium sulphate for example acidifies the soil as the ammonium is biologically transformed to nitrate. If any excess nitrate is not utilised by the plants, it then can be leached (Helyar 1990); (nitrate fertiliser applied directly and not used by plants also faces this same fate). The leaching of nitrate below the surface soil layers leads to a redistribution of cations in the soil profile. The end result is that more acidic hydrogen is left in the surface layer and nutrient cations are leached to lower soil layers, or into waterways via the lateral flow between the surface and subsurface layers.

Legumes in rotations
The use of leguminous plants capable of making their own nitrogen through their symbiotic relationship with Rhizobia bacteria in the soil has markedly improved the nitrogen status of Australian soils, and therefore greatly increased the potential for nitrate leaching (Helyar 1990, Coventry and Slattery 1991).

Dry summer ecosystems

In Mediterranean environments where the summer months are hot and dry and plant growth is minimal due to the lack of water, there is a build up of nitrate nitrogen due to the breakdown of plant matter. When the season breaks in the autumn months, the roots of germinating annual plants are too young and too small to take up all the nitrate in the soil before it leaches below the maximum depths of annual plant roots, thus leading to increased acidification (Helyar 1990).

Extent of annual pastures
The vegetation in Australian landscapes has changed from perennial to annual plants with settlement and clearing. Perennial root systems are capable of gathering more water and nutrients before they leach below the root zone (Helyar 1990, Ridley et al. 1990a), therefore farm systems that contain fewer perennial pastures will acidify more quickly. In recent times this trend has begun to change with the introduction of incentive schemes to promote the wider use of lucerne.

Application of phosphorus fertiliser
The major indirect effect on acidification from the addition of phosphorus fertiliser is through the improved growth of pasture legumes, which increase the soil levels of nitrate and result in increased nitrate leaching, relative to that of unfertilised pastures. In addition, these highly productive pastures have carried much higher animal stocking rates, which often lead to higher grazing pressures and shorter plant heights over the winter months. When the pasture is kept short for long durations, there is minimal root growth, especially by annual species, thereby reducing their ability to uptake soil nitrate from deeper in the root zone (Helyar 1990).

Product removal
Removal of produce (grain, animal, pasture and trees) from a given area of land will take alkaline material with it, that if not replaced leads to soil acidification (Slattery *et al.* 1991, Moody and Aitken 1997, Noble *et al.* 1999). The most striking example is if a lucerne pasture is cut for hay and 8 t/ha is removed in one year; it will take 0.5 t/ha of lime to replace the lost alkalinity (Slattery *et al.* 1991). The removal of trees and shrubs over large areas of the landscape represents a significant amount of product removal, and will accelerate the acidification of many different soil types.

Soil texture
Soil texture plays an important role, in that the potential for the leaching of excess nitrogen is higher in light sandy soils compared with clay soils. If rainfall is correspondingly high on sandy soils then acidification is hastened (Helyar 1990). Therefore soil texture and rainfall zone determines to a large extent the rate at which soils will acidify on a regional basis.

Extent, severity and impacts in the region

Soils in the high rainfall regions of the Goulburn-Broken Catchment in Victoria have been acidic for many thousands of years because of their granitic origin; however a rapid decline in pH has been recorded since land clearing and with the use of intensive legume pastures and crops. The major soil types within the region comprise red duplex (located in the north and central areas), yellow duplex (located in the central area) and friable leached earths and loamy soils (located in the southern and mountainous areas).

Soil pH decline has been highest in the region on the red duplex soils that have been subject to broadacre cropping and intensive pasture activities (Table 4.1). For those red duplex soils used for intensive horticulture the risk of sub-soil acidification is of real concern where high rates of fertiliser nitrogen are applied along crop rows. Soil pH has changed very little on the more highly buffered yellow duplex and friable earths subject to permanent pasture production (Table 4.1). It must be noted however, that the yellow duplex and friable earths are already strongly acidic, with some examples of pH_{Ca} values of 4.5 or lower.

Table 4.1 Goulburn-Broken CMA soil type, land use and threat of acidity.

Soil Types and % area	Current Land Use	Acidity Threats
Red duplex 55%	Dry land cropping and pasture, irrigated pasture, horticulture, uncleared, forestry	-The red brown earths are the major soil type in the Riverine plains (lower Goulburn-Broken) and include a range of rainfall zones. Regardless, the susceptibility of this soil type to medium rates of acidification is well documented under all forms of dry land agriculture. Irrigated fruit production has highly acidified the crop rows where fertiliser practices have been sub-optimal. There is a significant risk of subsoil acidification.
Yellow duplex 30%	Dry land pasture and cropping, uncleared, forestry	-The majority of these soils are granitic in origin and are highly acidic. Leaching potential is high and sub surface as well as topsoil acidification is a reality. -In the mid Goulburn-Broken, acidification of soils under annual pasture and crops is high. With perennial pasture species the potential is low/medium. -Uncleared areas are acidifying very slowly but under forestry the poor buffering capacity of these soils should be cause for alarm.
Friable leached earth 15%	Uncleared, forestry, dry land pasture and cropping	-In the upper and mid Goulburn-Broken area annual pastures and crops have caused medium acidification in the topsoil and will continue to do so. Soils in the upper regions of the Goulburn-Broken area are more acidic to begin with.

The major impacts from declining soil pH on both agriculture and the community in the future are likely to include:

- Increased nitrate contamination of groundwater and the potential for reduced water quality,
- Reduced farm yields, leading to reduced farm income and regional export earnings,
- Reduced options for agriculture,
- Reduced vegetation cover, leading to accelerated runoff and erosion,
- Irreversible clay loss if soils are allowed to acidify below pH_{Ca} 4.0,
- Decreased land values,
- Increased infrastructure costs,
- Increased risk of salinisation resulting from reduced ground cover in recharge zones.

The extent of acidic soils within the Goulburn-Broken catchment is not known in detail and only a broadscale map (Map x) based on soil samples collected over many years gives an indication of the degree of surface soil acidity across the region. This map shows that the most strongly acidic soils are located in the high rainfall areas of the region and the least acidic soils are in the northern riverine plain areas of the region as described by soil type in Table 4.2.

Table 4.2 Percentage of surface soils affected by acidity in the Goulburn-Broken region.

Soil type	**pH_{Ca} <4.5**	**pH_{Ca} 4.5 -5.0**	**pH_{Ca} 5.0 -5.5**	**pH_{Ca} 5.5 - 6.0**
Red duplex soils	20	40	40	
Yellow duplex soils	20	60	20	
Friable earths	unknown, but			

	100 likely			

Priority areas

Highly productive soils in the riverine plains that consist mostly of red duplex soils are susceptible to high rates of acidification due to the intensive nature of broadacre cropping and horticultural enterprises currently practised in this area. In addition, the already highly acidic yellow duplex soils that support similar intensive crop and horticultural industries will have the potential to acidify subsoils and thus become economically more difficult to ameliorate in the future. Specific recharge areas within the region will be priority areas for acidic soil amelioration if groundcover, and in particular acid-sensitive lucerne crops, are to be grown to control dryland soil salinity within the region.

Management options

The options to manage acidic soils are very much dependant upon the type of land-use currently applied to them. There are opportunities to consider broadscale land-use changes if the benefits to both agriculture and the environment are to be realised. Some of the options for managing soil acidification are identified as follows.

1. Legumes are good sources of biologically supplied nitrogen; therefore farming systems need to adopt suitable rotations that allow all of the biologically fixed nitrogen to be used by subsequent crops. The use of deep-rooted perennial plants will assist in reducing nitrates leached to the groundwater and waterways, thus reduing the acidification rate when used in high rainfall environments within the region. There is a need to investigate the use of native perennial plants in unproductive and strongly acidic soils that are too costly or difficult to ameliorate with lime due to terrain or sub-soil acidity problems.

2. Apply enough fertiliser to match the needs of the plant, which can be identified from soil and plant tissue analyses. Clearly there are preferred management practices that have not been adopted across the region that need to be applied in the first instance. Secondly there is a need to identify more effective management systems that conserve nutrients and minimise nitrate leaching, and thus reduce the rate of acidification.

3. Provide adequate ground cover (>70%) over summer; the retention of stubbles is a good example that will maintain valuable carbon levels, which is essential for good soil buffering.

4. Plant more perennial vegetation that is able to access nitrogen from deep in the soil profile. Investigate the use of intercropping choices with a perennial/annual mixes and/or tree and shrub component.

5. Adopt management practices appropriate for the soil type; increase the organic matter content of sandy soils and do not over fertilise all soils.

6. Attempt to replace alkali lost in product removal by applying lime, and consider the strategy of feeding hay back to stock rather than exporting it from the paddock.

Erosion

Nature of the problem

Erosion of the earth's crust is a naturally occurring process, that has resulted in the reshaping of the landscape over many thousands of years and is continuing at a very slow rate, this is commonly termed 'geological erosion'. The impact of human intervention on the landscape has resulted in more rapid rates of erosion than that attributed to geological weathering and is termed 'accelerated erosion'. In Australia, accelerated erosion has led to the loss of valuable surface soil that is limited in this fragile and highly weathered continent. Soil erosion occurs whenever the soil is denuded of vegetation and exposed to the impacts of wind and rainfall causing surface loss of soil particles. The movement of these soil particles has three major impacts on the environment. Firstly the loss of surface soil causes a general decline in the productive capacity of the soil, due to a loss in soil structure and nutrient content. Secondly the movement of large amounts of soil particles to waterways leads to a decline in water quality with the transportation of adsorbed nutrients and toxic pollutants. Thirdly the final destination of sediments results in the choking of waterways and the concentration of chemical pollutants to public utilities such as reservoirs, lakes and harbours.

Good soil structure is essential for the provision of water and oxygen to the soil and thus the ability of the soil to support plant growth. A well structured soil contains many pores, enabling plant roots to explore a larger surface area of the soil to access water, nutrients and oxygen. When soil structure is degraded through the use of farm machinery (tillage and compaction) or the long-term application of soil conditioners (fertilisers, chemicals), then the integrity of the soil structure is significantly compromised. The erosion of the soil surface will lead to a loss of organic matter leaving the soil more susceptible to dispersion and compaction. In many cases the net result is a loss of productive vegetative ground cover leading to exposure of the soil surface to wind and water erosion.

When compaction or inappropriate tillage practices degrade the soil structure, water infiltration is usually reduced leading to waterlogging. Often surface water runoff will also increase as a result of soil degradation. This excess of surface water runoff can result in increased soil particles being transported with the water and lead to losses in soil carbon and nutrients from that soil system. Consequently plant growth will decline and further exacerbate the erosion problem.

Some soil types are more susceptible to erosion loss than others and this is primarily determined by the nature of the parent material that has formed the soil and its subsequent development through processes such as water movement and wind blown deposition of soil particles from other parts of the landscape. For example the cropping soils in the lower Goulburn-Broken catchment disperse readily when exposed making them much more susceptible to water erosion than soils in the mid or upper Goulburn-Broken which are non-dispersive. The soils in the lower Goulburn-Broken are classified as Sodosols, they contain a high percentage of sodium, which causes them to become dispersive and require careful management to prevent erosion losses. The coarse sandy soils in the mid and upper Goulburn-Broken are derived from sandstone and granite and are easily detached by wind and water if exposed by aggressive agricultural practices, mining operations or earthworks for roads and buildings.

Agricultural practices and infrastructure barriers (roads, mines and urban development) have contributed greatly to the movement of water and soil particles in our landscapes and have made a significant impact on soil losses over the past 200 years of settlement. In the Goulburn-Broken region there are many important waterways that carry fresh water to the Murray system. In recent years this fresh water has been contaminated with large quantities of clay minerals and soil nutrients, the direct result of accelerated erosion in our catchments.

Causes of erosion

The main causes of soil loss are related to a decline in perennial vegetation. Annual crops and pastures allow the soil surface to become exposed over the summer months, making them very susceptible to erosion. Water erosion begins with raindrops striking unprotected ground with enough energy to displace soil aggregates and reduce water penetration, resulting in runoff and the transportation of soil particles into waterways and away from the soil surface. Poor agricultural practices in some parts of the landscape have led to a rapid rate of soil exposure and subsequent soil loss. The use of excessive tillage in high rainfall agricultural soils would be one example. Conservation cropping and stubble retention have alleviated this problem, however greater gains can still be made by maintaining vegetation over summer months and increasing the organic matter content of soil.

There are a number of different forms of soil erosion as caused by the movement of water over soil surfaces.

Sheet erosion
Where there is a loss of a fairly uniform layer of soil from the land surface by rainfall and runoff this is called sheet erosion, often as a result of heavy rainfall on exposed soil surface, especially during the summer months. For the Goulburn-Broken catchment this would be more likely in the mid and upper regions.

Rill erosion
If the loss of soil is more confined to numerous small channels across the soil surface and often associated with banks, this is termed rill erosion. Rill erosion is likely when recently tilled soil has been exposed to a storm event. The upper and mid Goulburn-Broken are most prone to this type of erosion.

Gully erosion
When rills become very large, generally deeper than 300 mm they are termed gully erosion. This form of erosion is generally in upland slopes where normal watercourses have been altered in some way such that the volume or frequency of water flow has dramatically changed. The upper Goulburn-Broken is most susceptible to this form of erosion.

Tunnel erosion
Tunnel erosion occurs when subsurface soil is removed by water while the surface soil remains intact. Dispersive soils of the lower Goulburn-Broken are most susceptible to this type of erosion.

Streambank erosion
Streambank erosion is the loss of soil from the stream bank as a direct result of water flow. The grazing of stock in watercourses can accentuate this type of erosion, but changed water flow patterns due to irrigation demands will also have an impact. All watercourses in the Goulburn-Broken are susceptible to this type of erosion, although the mid and lower regions would be effected more by stock and irrigation practices. The likely occurrence of different forms of soil erosion for the Goulburn-Broken regions is shown in Table 1.

Table 1 Likely occurrence of different forms of soil erosion for the Goulburn-Broken regions

	Goulburn-Broken Region		
Erosion type	Upper	Mid	Lower
Sheet	√	√	
Rill	√	√	
Gully	√		

Tunnel		√	√
Streambank	√	√	√

Wind erosion has been a major cause of landscape change in the Goulburn-Broken region over many thousands of years. Sand particles blown from the west have been deposited onto the soil surface over much of the northern aspects of the region, creating sand and sandy loam soil surface horizons.

Extent, severity and impacts in the region

The extent of soil erosion in the Goulburn-Broken region can be linked to the most dominant types of land management practice over the past 100-150 years. For example soil structural decline has been greatest in the north of the region where soil disturbance through cultivation on cropping land has been a major cause. These soils are now very dispersive in either or both surface and subsurface layers and will be easily eroded with water transport. It is fortunate that these soils are in the low rainfall area of the region, otherwise soil erosion losses could have been much higher. It is estimated that soil loss under such conditions could be as high as 50 t/ha/yr (Figure 5.1).

In the cropping regions of the Goulburn-Broken catchment the management of crop residues is an important factor in maintaining adequate groundcover to reduce the impacts of water and wind erosion. On the red duplex soils almost 54% of the total cropped area is conventionally cultivated, 22% has some form of min imum tillage adopted and only 15% is direct drilled with minimal disturbance to soil. Erosion losses can be calculated based on data provided in Figure 5.1 and Table 5.2 and are given in Table 5.3 where it can be seen that current soil losses from soils in the Goulburn-Broken catchment are approximately 37 Mt/yr for the region. More than 65% of this soil loss occurs in the lower GB region due to the direct impact of farming.

Table 2 Percentage of land area subject to various soil and stubble management practices in the upper, mid and lower regions of the Goulburn-Broken catchment.

GB Region	Fallow	Tillage			Stubble management			
		Conventional	Minimun	Direct drill	Burnt	Incorp'd	Mulched	Left Standing
Lower	5	34	22	24	22	25	4	25
Mid	-	20	-	-	10	2	1	7
Upper	-	1	-	-	5	-	-	-

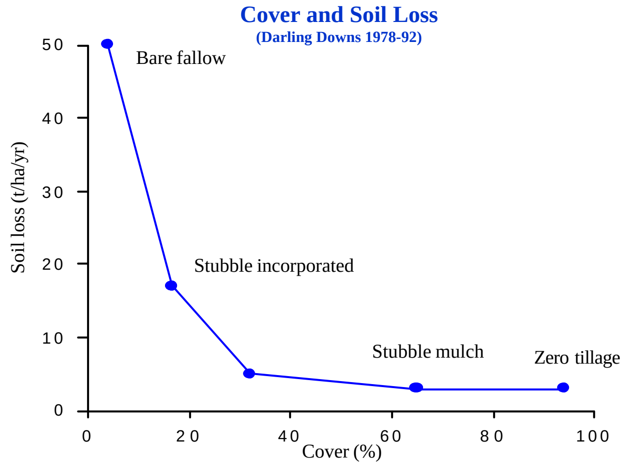


Figure 5.1 Soil losses for different percentages of soil cover

Table 3 Total soil loss for the Upper, Mid and Lower Regions of the Goulburn-Broken for different soil management practices.

Region ***Soil management practice***	**% of Area**	**Total Area** (ha x 1000)	**Soil loss** (t/ha/yr)	**Total soil loss** (t/yr x 1000)
Upper GB				
Conventional cultivation	1	110	50	5,500
Minimum tillage	0	0	6	
Direct drilling	0	0	4	
Fallow	0		50	
Mid GB				
Conventional cultivation	20	151	50	7,550
Minimum tillage	3	22	6	132
Direct drilling	7	53	4	212
Fallow	0		50	
Lower GB				
Conventional cultivation	34	374	50	18,700
Minimum tillage	22	242	6	1,452
Direct drilling	24	264	4	1,056
Fallow	5	55	50	2,750
				37,352

It is important to note that with soil loss there is a significant loss of soil fertility in the form of soil carbon and nutrients.

Soils in the south of the region are less dispersive have more permanent ground cover in the form of permanent pastures and are at generally higher elevations. They also receive on average about 200 mm of additional average annual rainfall. The potential for these soils to contribute strongly to soil erosion is high and the need to retain permanent groundcover is essential.

The impacts that soil erosion are directly related to water quality through the transport of nutrients and pollutant chemicals adsorbed to soil particles. The risk of blue green algal blooms in waterways rich in nutrients and moving slowly due to altered water flows is high. For this reason it is important to make timely use of fertilisers in agriculture and reduce the risk of soil erosion through improved practices that retain vegetative ground cover for most of the year.

Management options

The use of management practices that are considered to be best practice need to be adopted across the region, for many of these practices the 'best bet' will be inadequate and new technologies will need to be investigated. Some of the more obvious solutions are listed below.

- Adopt no-till and direct drilling cropping practices,
- Retain groundcover throughout the year, especially during the summer months,
- Match landscape with appropriate land practices,
- Include pastures in crop rotations to improve soil carbon and groundcover,
- Apply soil ameliorants to reduce surface slaking and dispersion,
- Remove livestock when soils are waterlogged,
- Maintain groundcover with rotational grazing strategies,
- Reduce cultivation activities when soil is dry and loose,
- Prevent stubble burning to maintain soil cover before autumn rainfall.

Soil and Water Contaminants

Nature of the problem

At certain sites within the catchment, the use of heavy metal elements or compounds, their extracting agents, or organic chemical sprays has resulted in the accumulation of contaminants within soils to toxic concentrations. Heavy metals such as mercury and cyanide (associated with gold mining and with sheep dips), and herbicides and pesticides such as (chlorpyriphos, parathion-methyl, azinophos-methyl, fenarimol, chororthalonil) are found at specific sites in the lower catchment but have not been studied in any great detail.

All studies on herbicides and pesticides have focussed on the persistence (or stability) of toxic parent contaminants. Pharmaceutical companies and researchers have not seriously considered the relative toxicity, stability, and mobility of metabolites in the soil environment following degradation of parent contaminants by soil microbes or soil chemical reactions (P Stork, personal communication). The fate and transport of herbicide or pesticide sprays into surface waterways or groundwater is controlled by properties of both the spray compound and the soil. The binding affinity of different pesticides to a soil and their solubility in water are preliminary indicators of their potential transport into waterways.

A study of five commonly used pesticides in intensive horticulture within the SIR (chlorpyriphos, parathion-methyl, azinophos-methyl, fenarimol, chororthalonil) has showed the presence and persistence of these compounds in surface drainage water following application to soils (Stork and Jerie, 1999). These compounds were found in surface drainage water over a full winter whenever rainfall events exceeded 10 mm. Similarly, studies of shallow well sites in the Tongala-Kyabram region of the SIR have indicated contamination of groundwater with herbicides (Watkins et al. 1999).

Biodiversity of the soil resource

The word 'biodiversity' is most commonly used by community groups, policy-makers and government to refer to the mix of above-ground plant species found in a given environment. Biodiversity is also used to refer to the below-ground flora and fauna and represents one of the most species rich compartments of terrestrial ecosystems. It would be perilous therefore to exclude below-ground biodiversity from strategies to improve soil health in the Goulbourn Broken catchment.

Soil biodiversity refers to the assemblage or consortia of soil fauna (macro, meso and micro) and flora (fungi, actinomycetes, bacteria and viruses) that inhabit the soil matrix. Soil biodiversity can refer to the assemblage of taxa (structural biodiversity) or to the assemblage of vital functions that are performed (functional biodiversity).

This consortia of organisms modify the physical, chemical and nutritional status of the soil. Aggregate stability, biopore formation, and fragmentation of organic matter contribute to reduced soil dispersion, enhanced water infiltration, greater root exploration and higher rates of nutrient turnover. These physical processes are performed by the larger organisms; the invertebrates. Chemical transformations are largely mediated by the soil biota and specifically the microflora and lead to increased availability of plant nutrients and minerals and to gaseous losses of carbon dioxide, nitrous oxide and methane. The microflora produce a vast range of secondary products such as plant hormones, antibiotics and vitamins all of which have been shown to both enhance and retard plant growth. Despite the overwhelming size and diversity of species in the soil (eg total biomass of soil biota may exceed 20 tonnes, Kirkby 2000), there are important 'indicator' or keystone species and functions that can be tracked and monitored.

The link between soil health and soil biodiversity

'Soil health is the capacity of soil to function as a vital living system within ecosystem and land-use boundaries to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health' (Doran and Zeiss 2000). In other words, soil health is essentially soil functional health, or the capacity of the biological communities to mediate the above-mentioned soil physical and chemical processes.

Defining the problem

The consequences of reduced soil biodiversity can be summarised as:

- Weakened resilience of the soil resulting in a reduced capacity to recover from disturbance (eg fires, waterlogging, pesticide use)
- Increased susceptibility of soils to disease incursions through narrowing of the genetic base and through disappearance of antibiotic producing functional groups
  (eg continuous cropping predisposes soil to disease incursions)
- Poor peformance of plant species in acid, alkaline, sodic and saline soils (at least as a side-effect)
- Reduction or extinction of vital processes such as N-fixation, P-solubilisation and S-oxidation
- Reduced capacity of soils to 'filter' contaminants posing a threat to the sustainability of the soil and water resource through pesticide and heavy metal accumulation and increased run-off.
- Loss of potentially valuable sources of pharmaceuticals, bio-fertilisers and bio-pesticides.

As with above-ground species loss, the effects of below-ground loss of species is stronger in species poor communities than in species rich communities. This is because in species rich communities, function can be shared amongst a range of species and/or one organism may be dependent on another organism to modify the environment before the second organism can live in it (Waid 1999).

Threats to soil biodiversity

Our entire plant-based production enterprise depends to a significant degree on the organisms that inhabit the soil. Yet it is these enterprises that are considered to have the greatest impact on the diversity of these organisms. The impact of these activities are unknown and may range from subtle to profound. Numerous studies in Australia and overseas have highlighted the decline in soil biodiversity from natural to agroecosystems (Pankhurst *et al* 1996 and Pokarzhevskii and Krivolutskii, 1997). This decline is connected with a decline in above ground biodiversity (from polyculture to monoculture), to a decline in soil organism biomass and total nutrients, soil perturbation and microclimate changes. Increased salinity, sodicity, acidity, alkalinity and associated elemental toxicities and deficiencies would also be expected to impact directly and indirectly (via reduction in above ground biomass) on soil biodiversity although this has not been investigated on a large spatial scale. A study utilising long-term cropping sites throughout the NE and Goulbourn Broken catchments highlighted physical disruption through tillage as the single most destructive factor impacting earthworm species richness and density (Mele *et al* 1997). The use of exotic species of both plants and animals would also be expected to reduce indigenous populations of microorganisms with the consequence being a failure of native regeneration programs.

Extent, severity and impacts in region

The decrease of soil biodiversity with increasing human influence provides some insight into the extent of the decline in the Goulbourn-Broken Catchment. We cannot predict the combined effects of management, soil chemistry and physical parameters on soil biodiversity. We can however, utilise information on the intensity of agricultural and horticultural activities and overlay maps of above-ground biodiversity, soil fertility (including chemistry and structural features), to broadly approximate the percentage of area likely to have experienced the greatest decline in soil biodiversity. The north to north western, or lower reaches of the Goulbourn-Broken Catchment are likely to have experienced the greatest overall reduction in soil biodiversity based on declines in surface soil pH, the high proportion of dispersive soils and the increased use of artificial fertilisers (potassium and phosphorus) (Know Your Catchments 1997). The middle reaches of the Goulbourn-Broken Catchment will also have experienced significant declines and is probably at highest risk of continued loss with intensive horticultural activities being a predominant land-use activity. The southern or upper reaches of the Goulbourn-Broken Catchment, which has the highest above-ground biodiversity, would also be expected to have the most diverse soil communities. These soils would be at risk particularly if forest and horticultural industries expand.

The likely main impacts of declining soil biodiversity *in the lower north/north western region* are:

- Weakened soil resilience resulting in reduced recovery capacity and increased susceptibility to disease incursion
- Poor peformance of plant species in acid, alkaline, sodic and saline soils (at least as a side-effect).

The likely main impacts of declining soil biodiversity *in the mid/mid-west region are*:

- Weakened soil resilience resulting in reduced recovery capacity and increased susceptibility to disease incursion
- Poor peformance of plant species in acid, alkaline, sodic and saline soils (at least as a side-effect)
- Reduced capacity of soils to 'filter' contaminants and tie-up nutrients posing a threat to the sustainability of the soil and water resource through pesticide and heavy metal accumulation and increased run-off into rivers and streams.

The likely main impacts of declining soil biodiversity *in the upper southern region are*:

- Reduction or extinction of vital processes such as N-fixation, P-solubilisation, S-oxidation
- Loss of valuable source of pharmaceuticals, bio-fertilisers and bio-pesticides
- Reduced capacity of soils to 'filter' contaminants and tie-up nutrients posing a threat to the sustainability of the soil and water resource through increased run-off

The economics of soil biodiversity

As with soil acidification and salinisation, it is extremely difficult to separate the economic losses incurred through soil biodiversity decline. A proportion of losses incurred through disease in plant-based enterprises, fertiliser and biocide applications, and nutrient and pesticide run-off in water would be attributable to soil biodiversity decline. The marketing of 'Clean Green' produce might one day be linked to the impact of farm management effects on soil biodiversity.

Management options

The responsible management of natural and managed (agro) ecosystems within the community will rely on the search for a correlation between the above and below-ground diversity. Monitoring tools and some soil biological remediation options need to be incorporated into action plans to reflect a recognition of the importance of soil biodiversity.

Monitoring tools

Mechanisms of maintaining soil biodiversity and methods of estimation and monitoring are subject to continual investigation and development. Important functional properties such as CO_2 evolution, cellulose degradation and earthworm surveys all represent useful practical tools to support land management decisions. These tools can be easily extended to researchers, land-managers and other interested community groups.

The recent explosion in genetic fingerprinting techniques coupled with the ability to handle, process and overlay a range of data sets has accelerated advancements and has increased the quality of knowledge on soil biodiversity and its depletion. Microarray technology, which allows the simultaneous screening of thousands of soil derived functional genes will provide a very powerful research tool that will significantly increase the precision of decision support systems. This technology, although in its infancy, could be offered as a commercial service in a similar way to that being offered by the SARDI-invented soil pathogen detection service.

Augmentation programs

Interventionary measures such as the augmentation of soil and plant environments with appropriate organisms (bacteria, mycorrhiza and invertebrates) is a realistic option for accelerated land recovery. Such augmentation strategies are commonly utilised in agricultural systems to improve plant performance in a range of agriculturally important crops and to assist the recovery of contaminated sites.

Implementation into programs

Incorporation of soil biodiversity into the current above-ground biodiversity policy framework and then into onground activities would be relatively straightforward. The no net loss/net gain policy can equally apply to below-ground biodiversity and information generated from on-ground survey work could be incorporated into a biodiversity database modelled on the USDA database, which maps soil microbial diversity in the Yellowstone National park (Stoner *et al* 2001). Reforestation programs would also benefit from incorporation of soil biodiversity remediation practices involving augmentation and monitoring.

A Rapid Estimation of the Potential Benefits of a Strategy to Modify Soil Health in the Goulburn-Broken Catchment

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Summary

This paper describes a process for making a rough estimate of the gross benefits that may be obtained from higher plant and animal productivity in the agro-environmental ecosystems of Goulburn-Broken Catchment if soil health is improved.

The main conclusion is that further quantification of the impact of the biophysical processes associated with soil health on the agro-environmental productivity of the resource base is required before an estimate that is really useful for allocating research and extension/implementation resources can be made. Some suggestions supporting a more comprehensive approach are given.

Physical Response to changes in soil health

Deteriorating soil health results in declining production over time. For example, the projected decline in productivity caused by rising watertables and increasing salinity for the Shepparton Irrigation Region is shown in Figure 1 (Anon, 1989). Productivity is assumed to decline at 0.9% p.a. for thirty years and 0.4% p.a. thereafter.

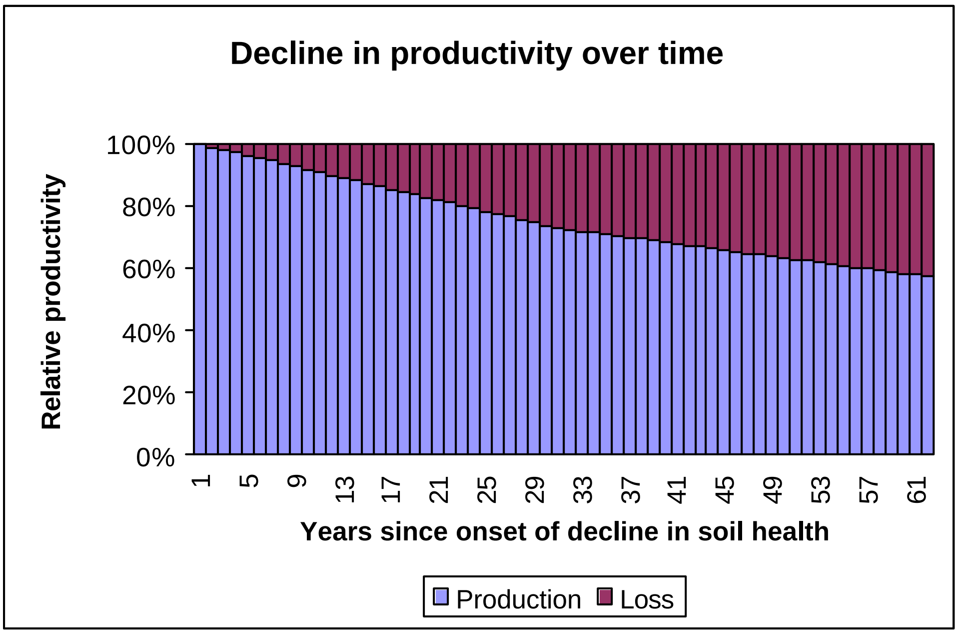

Figure 1: Hypothetical decline in productivity due to deterioration in soil health.

Non-salinity program actions affecting soil health factors

Actions considered in the North-East Soil Health Action Program (NESHAP) are liming soils, gypsum applications to cropping soils, more intensive use of lucerne in farming systems and adoption of perennial pastures. These actions are taken to reduce soil acidity, soil dispersion, increase soil organic matter and to reduce rates of groundwater accessions and leaching of nitrates.

Rate of deterioration of regional productivity due to changes in non-salinity program soil health factors

No estimate of comparable rigour to that applied for the development of salinity management planning non-intervention scenarios appears to be available for the expected rate of decline in productivity due to non-salinity factors for the Goulburn-Broken Catchment. Pending such an estimate a purely speculative rate of deterioration is assumed.

Valuation

Value of Production

The gross annual value of agricultural production based on ABS data for Statistical Local Areas largely within the catchment is $1.04 billion.

Present value of potential gross benefits

Assuming a universal rate of decline in regional productivity of 0.01% p.a. due to deteriorating soil health factors, the present value of instantaneous remediation[1] of the assumed annual agricultural losses using a 4% discount[2] rate and 50 year planning horizon is $ 40 million.

Allowance for current best practice and lags in adoption

However, much of this decline productivity may already be avoided by the use of sustainable production practices in high value enterprises. The view taken in the estimation of benefits of the NESHAP (Read Sturgess and Associates, 2000) was that dairy and horticulture best practices already manage soil health issues. After subtraction of horticulture and estimated pasture based dairy production values, the catchment gross annual value of production is $484 million and the present value of instantaneous remediation is $18.6 million. If there were a 5 year lag in adoption of remedies the present value would fall to $17.2 million.

Allowance for extent of adoption

It is important to consider whether the extent of adoption would cover 100% of the affected areas. The existing salinity management plans already support and encourage the wider introduction of lucerne and perennial grasses into catchment farming systems. The benefits of a soil health strategy would be any additional increase in productivity beyond that gained by the salinity plans. Given the rates of adoption of these existing salinity management options, despite the favourable estimates of profitability in both the salinity management plan and NESHAP economic evaluations, it may be unlikely that further increases in adoption would be obtained. One option agricultural managers can use to cope with declining productivity is to de-intensify production systems and adjust business structure. In some cases this will be a more profitable option than maintaining productivity of current systems. The new business structures and production systems may well be sustainable. There is scope for an integrated approach to the analysis of catchment management options in this regard.

Taking an optimistic assumption of 75% adoption of remediation options, the gross present value of improved soil health factors would be $12.6 million.

Public/Environmental Benefits

No attempt to estimate these benefits is made.

Costs and Net Benefits

The overall Benefit to Cost ratio for the NESHAP was 1.32. Given a similar cost situation for Goulburn-Broken options and taking the estimate of $12.6 million for the present value of benefits as credible (drawing a long bow), the cost of implementing options and the supporting coordination and extension program would be $9.6 million.

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[1] That is remedial action is timed to immediately offset degrading processes and there is 100% application of remedies across the catchment.

[2] When productive resources are scarce, early delivery amplifies the benefit as resources purchased with the benefit can be used sooner to produce more agricultural and environmental goods. Thus the benefit of delivery of goods in the future is discounted relative to immediate access to goods in the present.

On this basis the net present value of a Strategy would be $3 million.

Discussion and conclusion

This estimate is speculative but may help natural resource managers decide on priorities for investment in strategy planning, research and implementation.

The data and information used is coarse and can be refined to give a more accurate assessment of both gross benefits and the net benefits after planning, implementation and monitoring of prospective soil health enhancing programs. The assumption regarding the rate of decline in regional productivity is based purely on the notion that soil health issues are of less significance than salinity and water logging since salinity management plans have been in implementation for 10 years or more. Otherwise these issues would have been dealt with earlier. However this is not to say the issues are insignificant, just that more technical information is needed.

Information required for a more robust estimate

The additional information from scientists and geographic information systems practitioners that is required to take the refinement of the evaluation process further includes:-

- The response functions for the range of important agro-environmental ecosystem outputs to changes in soil health attributes.
- The rate and extent of change in soil health attributes in the "Non-Intervention" scenario.
- The rate and extent of change in soil health attributes in the "With Soil Health Strategy Implementation" scenario.
- The existing and likely future distribution of agro-environmental land uses in relation to land management units/soil types affected by declining soil health.
- The impact on the profitability of particular agricultural enterprises at the farm level and the implications for regional socio-economic adjustment.
- Changes in environmental values.

To the extent that private action on farms is profitable there is justification for industry funding of research and extension programs leading to increased productivity of the natural resource base. It would be possible to justify additional investment using public funds in further enhancement of natural resource quality and ecosystem services up to the public value of the additional improvement in these goods.
A detailed evaluation of private and public benefits would require considerable resources.

References

Anon (1989) *The Shepparton Region in the "Do Nothing" case*, Paper SE 9, Background papers, Shepparton Irrigation Region Land and Water Salinity Management Plan, Volume III, Rural Water Commission, Tatura

Read Sturgess and Associates (2000) *Economic analysis of the North East Soil Health Action Plan*, North-East catchment Management Authority, Wodonga