LAND MANAGEMENT FOR URBAN DEVELOPMENT

INVITED LECTURES

BRISBANE, AUSTRALIA
22-24 April 1996

Australian Society of Soil Science Inc.,
(Queensland Branch)

S. A. Waring
Editor

(i)
PRESIDENT'S FOREWORD

There is no doubt that land degradation occurs where urban, semi-urban and small rural subdivisions are developed. There is also no doubt that the knowledge which soil scientists have applied to agricultural land over many years could also be applied to the management of land in urban and semi-rural areas.

The purpose of this course and the lecture notes contained in this publication is to raise the awareness of, and to bring some of this knowledge to, the notice of town planners, surveyors, developers, consultants, geographers, government policy-makers, agricultural and environmental scientists and natural resource managers.

Because many of the issues impact on society, its infrastructure and lifestyle, the social aspects of careful and responsible land management are considered.

In addition, there are various laws and Acts of Parliament concerning what can and can't be done in establishing recreational and landscaped areas around towns and cities. It is appropriate that those Acts which apply to the various situations encountered in a development be discussed to help our understanding of our legal responsibilities.

The various soil physical, chemical and biological properties can be managed to preserve and improve the qualities of the soil resource and the vegetation it supports. The ways and means of doing this by use of waste water, sewage, fertilisers and soil amendments and the role of water quality are all considered.

The Australian Society of Soil Science Incorporated (Queensland Branch) has responded with the support of the Resource Management Institute of the Department of Primary Industries, to present this course.

The Training Course Committee has devoted considerable effort and time in structuring the course for the participants. Twenty lectures involving 32 scientists have been prepared on an honorary basis, and for this the Queensland Branch is most grateful. A final hypothetical case study will involve all in attendance and should allow some of the principles to be demonstrated.

We trust that the participants will enjoy the course and also gain some information which will allow them to manage the development of urban and semi-rural recreational and landscaped areas more appropriately.

As with past courses presented by the Society, this book of papers will be available for sale after the course. We trust that this book will be useful to those not fortunate enough to attend the course.

G. Price
President
Australian Society of Soil Science Inc. (Queensland Branch) 1995/96
LAND MANAGEMENT FOR URBAN DEVELOPMENT

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The Committee expresses its thanks to Jackie for her skilful and enthusiastic work with the word processor, which contributed very significantly to the preparation of this book.
**LAND MANAGEMENT FOR URBAN DEVELOPMENT**

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ISSUES IN URBAN DEVELOPMENT -
LESSONS AT HOME AND ABROAD

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ABSTRACT

Urban development is placed in the context of the global sustainability agenda and in particular to emerging ideas about sustainable cities. The Extended Metabolism model from the Australian State of the Environment Report is used to establish some indicators on sustainable cities. These are then applied to Australian cities showing trends garnered from the SoE process and from comparisons with other cities around the world. The data indicate that there is plenty of scope to improve as well as some signs of hope.

KEY WORDS: sustainable cities, metabolism model, indicators, demographic trends, livability.

1 INTRODUCTION

Land is the most fundamental natural resource. To manage any natural resource today requires us to think in terms of sustainable development. This global concept will be used to underlie the fundamental principles of urban land management. The paper will set out how the concept of sustainability has developed, how the concept is being applied to settlements and the trends in Australian settlements. It will build mostly on material used in Australia's State of the Environment Reporting process as well as on studies conducted at ISTP on the use of urban land in cities across the globe.

2 SUSTAINABILITY

2.1 History

Sustainability's roots are many but the first elements emerged on the global arena at the 1972 UN Conference on the Human Environment. At this conference 113 nations pledged to begin cleaning up their act and most importantly to begin the process of tackling environmental issues on a global basis. The problems of chemical contamination had crossed all borders so it was no longer possible to allow DDT or PCB's or radioactivity to be released anywhere without it affecting everyone.

Concern about global consumption of natural resources was also very high. Evidence was presented at Stockholm that the scale of the human economy was now significant relative to the natural environment, eg the flow of human energy was now equal to the flow of solar energy through ecosystems, with inevitable impacts from the wastes. The effects of human activity on the biosphere were also beginning to negatively impact on human welfare. The spectre of Malthus was raised as a global phenomenon but focussed on the rapidly growing areas of the 3rd world (Ehrlich & Ehrlich, 1977).
The 3rd world were not so impressed by this new environmental globalism. They saw it as just another way to prevent them from attaining their goals for development. The 1 billion people living in abject poverty with not even enough food to eat, did seem to have some legitimate claim on a little more of the world's resources. Thus the UN established the World Commission on Environment and Development in 1983 and by 1987 they published "Our Common Future" or the Brundtland report, which first coined the phrase 'sustainable development'.

Sustainability was created as an agenda to simultaneously solve the global environmental problem and to facilitate the economic development of the poor, particularly those in the 3rd world. The process suggested can be distilled into three broad policies which have since become the basis of much global action.

2.2 Characteristics of Sustainability

1. The elimination of poverty in the 3rd world is necessary not just on human grounds but as an environmental issue. Evidence was presented from across the globe that poverty degrades the environment because populations grow rapidly when they are based on subsistence agriculture or fishing or plant collection. In the past, the population of subsistence communities was controlled by high death rates but the globalisation of health care means that there is no way forward to a new equilibrium but to reduce birth rates. This seems only to occur sustainably when families want fewer children not more and in subsistence economies children are a source of wealth and security (United Nations, 1977). Grass roots economic and social development (particularly women's rights) are necessary to break this cycle. The alternative is a constant degradation of the 'commons' as more forest is cleared, more soil is overgrazed, more fisheries are destocked (Hardin, 1968). Thus third world economic and social development is a precursor to global sustainability.

2. The first world must reduce their consumption of resources and production of wastes. The average American or Australian consumes natural resources 50 times that of the average Indian, and the poorest groups in abject poverty across the world consume 500 times less. By raising the standard of living of the global poor from 1/500th to 1/50th would not be a huge strain on resources. The primary responsibility to reduce their impact on global resources is in the rich part of the world. Of course the first world need to reduce their consumption anyway because that is the basis of their local as well as global pollution problems. Such a goal cannot be achieved without economic and social change. For example, industry cannot be frozen with 80's machinery, it needs to develop new technology for replacing CFC's, for using less energy, for switching to new renewable fuels and more efficient materials; such change requires economic and social development. Cities will not be less energy intensive if they are frozen in their sprawling 80's structures and they can only rebuild in more compact, transit oriented forms if they are growing economically and socially. Thus first world economic and social development are precursors to global sustainability.

3. Global co-operation on environmental issues is no longer a soft option. Hazardous wastes, greenhouse gases, CFC's, loss of biological diversity... are not possible to solve if some nations decide to hide from the necessary changes. The spread of international best
practice on these issues is not some management fad nor is it a conspiracy for world domination from certain industries or advanced nations, it is essential for the future of the world. Thus globalisation is a precursor to sustainability.

The sustainability movement was first and foremost a global movement. It also forced economists and environmentalists to begin finding mutually beneficial solutions as they realised that poverty had to be overcome and that a new kind of economic development had to be found. The goal became one of not 'balancing' environment and economic development (as though they were inherently antagonistic) but of 'synthesising' them. This goal has been proceeding at many different levels:

- In academic discussion on how ecological economics can be defined and formulated (for example Daly and Cobb, 1989).
- In laboratories, in industry and in management systems as they try to be innovative within the new parameters of reduced resource use and less waste ('the clean production' agenda); and
- Within governments at all levels.

These approaches are usually called 'green economics', 'green technology' and 'green planning'. When they are no longer called green we can confidently say that we are becoming sustainable.

2.3 Global Government Responses to Sustainability

In Australia, the Ecologically Sustainable Development process was begun in the late '80s involving government, industry, conservation groups, unions, social justice groups and scientists. In Canada, the Round Table on the Environment and the Economy began mapping out what the new agenda meant from the 1980's. And in New Zealand the Resource Management Law Reform process has re-examined all aspects of government from an environmental perspective. The US had to wait until Clinton before the President's Council on Sustainable Development was set up to make a cross government response to sustainability.

At a global level, after 3 years of preparatory meetings involving thousands of the world's scientists and administrators, the UN Conference on Environment and Development was convened in Rio in 1992. The 'Earth Summit' drew together more heads of government than any other in history and its final resolutions were signed by 179 nations representing 98% of the world. This is about as global as you are ever likely to get!

The documents agreed to were: a statement on sustainability called the Rio Declaration, a 700 page action plan for sustainability called Agenda 21, a Convention on Climate Change, a Convention on Biological Diversity, and a Statement on Forests (Keating, 1993).

Such plans are still working through governments, industries and communities. Most governments, including the Australian government now have an exercise to evaluate the State
of the Environment in order to ascertain progress in sustainability based on a set of indicators. SoE reports are now required by all Australian States (and all local authorities in NSW).

Although support for sustainability principles may wax and wane there are few governments who are saying we should not be trying to solve these problems - and that this must involve a simultaneous process at the global level and at the local level. The control of whaling, the prevention of toxic waste exports, and the reduction of CFC's are all global sustainability success stories which are doing just this. And the hundreds of actions suggested in Agenda 21 are giving rise to millions of local applications as each local authority seeks to provide answers in their locality (Greene, 1994).

There is no sense of any slow down of interest by the community or by government in these sustainability issues. It is only a question of how best to do it.

3 SUSTAINABLE CITIES

The principles of sustainability outlined above can be applied to cities though the guidance on how this can be done was not terribly clear in Agenda 21 or the other UN documents. It is probably true to say that the major environmental battles of the past were fought outside cities but that awareness of the need to come back to cities is now universally recognised by environmentalists, government and industry. The OECD, the ECE and even the World Bank now have sustainable cities programs, in 1994 the Global Forum on Cities and Sustainable Development heard from 50 cities and in 1996 the UN has Habitat 2 or the 'City Summit' in Istanbul where the nations of the world are meant to report on progress in achieving sustainability in their cities.1

The most fundamental principle for applying sustainability to cities is to recognise that:

sustainable cities are those that are helping make a sustainable world

Without this global context sustainability will collapse into meaning almost anything, eg how can we sustain growth in energy, how can we sustain some industry that should have died off years before, or how can we sustain highly automobile dependent, wealthy suburbs from the pressure for redevelopment. Examples of the concept being abused like this are common. Sustainable cities are those taking seriously the global sustainability agenda.

So how does a city go about assessing whether it is sustainable or not? How do you do a Sustainability Plan for a city (as Agenda 21 suggests we all should be doing by 1996)? The approach adopted here is based on the experience of the Human Settlements Panel in the Australian State of the Environment Reporting process and on the experience of doing a Sustainability Plan for Philadelphia with the graduate students at the University of

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1The Australian government has produced the Green Cities report as part of the Australian Urban and Regional Development Review. This and the fact that Human Settlements is a chapter of the State of the Environment report indicates their move towards the urban sustainability agenda.
Pennsylvania in January and February 1995 as well as awareness of the World Bank/UN Habitat project on developing sustainability indicators for cities.*

From the previous discussion the primary goal for a sustainable city is to try and fulfil the global agenda of:

**reducing the city's use of natural resources and its production of wastes whilst simultaneously improving its human livability,**

i.e. the economic, social and environmental goals of the city need to be brought together. This is set out in Figure 1 in a model that is called 'the extended metabolism of the city'. Metabolism is a way of looking at the resource inputs and waste outputs of settlements and how the different types of settlements manage resources and wastes (Wolman, 1965; Boyden et al., 1981 and Girardet 1992).

![Extended metabolism model of human settlements](image)

*World Bank 1994. Other cities to produce sustainability indicators include Seattle (City of Seattle, 1993), Hamilton-Wentworth (RMHW, 1992) and Toronto (Canadian Urban Institute, 1991).
Figure 1 sets out how this basic metabolism concept has been extended to include the dynamics of settlements and livability in these settlements.

Livability is defined as the human requirement for social amenity, health and well being and includes notions of individual and community well-being within the context of both the human and wider environment. *Sustainability for a city thus is not only the reduction in metabolic flows (resource inputs and waste outputs) it must also be about increasing human livability (social amenity and health).*

4 SUSTAINABILITY INDICATORS

With this as the fundamental goal it is possible to derive a set of practical goals or indicators for a sustainable city. The indicators proposed as being feasible and measurable each year to guide a city, are set out in Tables 1 and 2. Each one requires further explanation and detail but the basic idea can be seen. Much can no doubt be done to improve on the list which is still probably too long (44), but it is an improvement over the 150 indicators suggested by the World Bank and UN Center for Human Settlements.

Central to all these indicators is the use of urban land, though it is never an independent variable. The optimising of a city requires an integrated approach that reduces land requirements and upgrades the quality of land use whilst reducing other resources like energy and improving livability or the quality of life. Australian urban history over most of the post World War II era has been an increasing use of land per capita with an associated increase in energy use (for transport) as well as most other resources. This has been predicated on the assumption that a better quality urban lifestyle would result. This is now widely questioned and the challenge of urban sustainability is whether an attractive Australian urban lifestyle can be developed which is more efficient with land and energy. The link between land and transport energy is clearly shown in Figures 2 and 3 - one from our global cities study and the other from a study of New York.
Table 1  Goals and indicators for a sustainable city

Each Year:

1. **Energy and Air Quality**
   - Total energy use per capita reduced
   - Energy used per dollar of output from industry decreased
   - Proportion of bridging fuels and renewable fuels increased
   - Total quantity of air pollutants per capita reduced
   - Total greenhouse gases reduced (to 1990 levels by 2000 and then further reductions annually)
   - Zero days not meeting air quality health standard levels
   - Fleet average and new vehicle average fuel consumption falling
   - Number of vehicles failing emission standards reducing
   - Number of households complaining of noise reducing

2. **Water, Materials and Waste**
   - Total water use per capita reduced
   - Zero days not meeting drinking water quality standards
   - Proportion of sewage and industrial waste treated to reusable quality increased
   - Amount of sewage and industrial waste discharged to streams or ocean decreased
   - Consumption of building materials per capita reduced (including declining proportion of old growth timber to plantation timber)
   - Consumption of paper and packaging per capita reduced
   - Amount of solid waste decreased (including increasing recycle rates for all components)
   - Amount of organic waste returning to soil and food production increased

3. **Land and Green Spaces**
   - Loss of agricultural land and bushland at urban fringe decreased
   - Proportion of city under bitumen decreased
   - Amount of green space in local or regional parks per capita increased, particularly in ‘green belt’ around city
   - Amount of urban redevelopment to new development increased
   - Number of specially zoned transit-oriented locations increased
   - Density of population and employment in transit-oriented locations increased

4. **Transportation**
   - Car use (VKT or VMT) per capita reduced
   - Modal split for work journeys shows increased transit, walk/bike and car pool with decreased sole car use
   - Average distance to work declines
   - Proportion of children driven to school decreased
   - Relative average speed of transit to cars increased
   - Service kms of transit relative to road provision increased
   - Passenger kms on transit per capita increased
   - Cost recovery on transit from fares increased
   - Parking spaces per 1000 workers in CBD decreased
   - Length of separated cycleway increased
Table 2  Goals and indicators for sustainable cities

Each Year:

1. Livability Human Amenity and Health

- Life expectancy (years) increased
- Infant mortality per 1000 births decreased
- Household income increased
- Educational attainment (average years per adult) increased
- Transport fatalities per 1000 population decreased
- Reported crimes per 1000 population decreased
- Deaths from urban violence decreased
- Proportion of substandard housing decreased
- Length of pedestrian friendly streets (based on specific indicators) in city and sub centres increased
- Proportion of city/suburbs with urban design guidelines to assist communities in redevelopment increased
- Proportion of city allowing mixed use, higher density urban villages increased

Figure 2  Fuel consumption per person versus population density.
5 DEMOGRAPHIC TRENDS IN AUSTRALIAN SETTLEMENTS AND SUSTAINABILITY

The key demographic aspects of Australian settlements in the mid 1990's as identified in the State of the Environment Reporting process can be summarised in the following way.

5.1 Big Cities are Getting Bigger

5.1.1 Dominance of big cities

Australia's settlement patterns have long been dominated by the five major metropolitan capital centres (Sydney, Melbourne, Brisbane, Perth and Adelaide) and they are still getting bigger. However in recent years this dominance appears to be less evident since in relative terms their rate of growth has slowed. The proportion of Australia's population residing in these five metropolitan 'statistical' areas, as formally defined by ABS, declined marginally from 60.7% in 1986 to 60.3% in 1991 and 60.2% in 1993. These figures do not indicate the full scale of metropolitan dominance however, because the statistical boundaries do not indicate the true size of each metropolis in functional economic terms.

There has been discussion about possible counter urbanisation trends in Australia, in which the big cities lose their supremacy to a more dispersed pattern of urban development. This is not the case for Melbourne, Adelaide and Perth. Each of these cities is increasing its relative dominance in its respective state though it is slowing. In the case of Brisbane, when we add in the increasingly connected Sunshine and Gold Coast areas into the South East Queensland
(SEQ) conurbation, it is clear that this urban area is becoming increasingly dominant in Queensland too. Only in the case of Sydney is there evidence that Sydney's share of state population is declining. The metropolis no longer dominates the population of its state. In 1991 62.3% of the population of NSW was located in Sydney but, Sydney accommodated only 54.8% of the state's growth between 1986 and 1991 and 42% between 1991 and 1993, Sydney has been the major source of interstate migration to the South East Queensland conurbation. In the case of NSW the major growth nodes are along the mid to north coastline.

Thus Sydney may be reaching stabilisation in its growth - an important point in sustainability discussions on this our biggest city.

5.1.2 Tentacles of growth

There is a growing pattern of low density settlement spilling beyond the formal boundaries of each of the capitals. Most of these exurban settlers are functionally linked to the metropolis via commuting to jobs within the established metropolitan statistical boundaries. For example around 50% of the work-force resident in Ballan, Romsey Kilmore and Bacchus Marsh (all rapidly growing areas outside the official boundaries of Melbourne) commute to employment within Melbourne (refer Figure 4 for Australian Cities data).

Figure 4 Growth in kilometres travelled in Australian cities.
A second pattern is that previously independent provincial cities including Geelong, Wollongong and Newcastle, and the Gold Coast and Sunshine Coast are becoming increasingly integrated with their nearby metropolitan capitals. This is reflected in extended freeway and other transport linkages, infill settlement connecting previously disparate cities into conurbations which share economic opportunities as well as environmental resources and problems.

The populations living in these conurbations dominate Australia's metropolitan settlement pattern. By 1993 they comprised 72.5% of Australia's population and accommodated nearly three-quarters (73%) of Australia's population growth between 1986 and 1993.

The extension of our big cities into dispersed exurban tentacles of growth has severe implications for sustainability - firstly from the loss of rural and bushland to these 'hobby farms' and secondly the large increase in car dependence it assumes.

5.1.3 Migration patterns

(i) International

A major feature of the metropolises is that they have absorbed the lion's share of international migrants. International migration contributed to just over half of Australia's population growth in the late 1980s and early 1990s. By 1991 there were 651,000 overseas born persons in Australia who had arrived during the five previous years.

These persons located predominantly in the major metropolises, particularly Sydney (33.1%), Melbourne (22.4%) and Perth (12.1%). It is estimated that 90.8% of Sydney's population growth 1986-91 was due to international migration, 55.3% of Melbourne's and 67.8% of Perth's.

(ii) Inter-regional

Interstate migration is having a reverse impact. About half of the population growth in SEQ in recent years has derived from interstate migration, mainly from Sydney and Melbourne. Sixty thousand persons who were living in Sydney in 1986 had moved to SEQ by 1991 and 30,000 from Melbourne during the same period. The pattern has changed since 1991 with Melbourne contributing a much higher proportion of the recent interstate movement to SEQ.

Thus the overall results of migration trends is a shift of population to the Queensland and Northern NSW coast - a trend which is discussed later as raising severe sustainability questions.

5.2 Big Cities are Sprawling but are also Starting to Turn Inwards

5.2.1 Suburbanisation of population

Almost all of the population growth in the major metropolises is occurring in their outer regions, defined as regions where new subdivisions are occurring or people are taking up blocks from earlier developments. In other words the recent discussion about the need for
greater, more intensive redevelopment in established metropolitan areas and some encouragement on the part of governments to facilitate this, have not stopped the traditional pattern of incremental growth on the urban fringe.

5.2.2 Reurbanisation

There has however been an increasing number of dwelling units constructed in core and inner areas of the metropolises. This has reached 30 to 40% of all residential development after being very slow in the 80's and non existent in the 70's. However, this increase has barely kept pace with the decline in size of households living in these core and inner areas and the demolition of previously established dwellings. The net effect therefore is that most population growth is still occurring on the periphery in the form of detached houses. But if reurbanisation continues to increase Australian urban sprawl may well slow to much smaller amounts. Commercial development is still mostly in core and inner areas where the jobs are locating which relate to the global economy in terms of information processing, knowledge trading or productive services.

Thus there is a strong inward turning dynamic which may well be a powerful force for sustainability, particularly the land/energy/quality of life nexus discussed earlier.

5.3 Coastal Settlements are Booming

Australians have long faced the dilemma of reconciling the location of their major urban centres along the coast with concerns for the conservation and recreational values of the coastline affected. The conflict is intensifying as the number of high quality coastal areas, valued for recreational and conservation qualities, becomes limited. Whenever a coastal area is converted to a permanent settlement it effectively drives out the use of the area for recreational purposes and frequently degrades its conservation value. The Queensland and Northern NSW coastal area has seen significant loss of species and decline of coastal habitats due to the rapid growth it has experienced in recent years.

27.1% of Australia's population growth occurred in mainland non-metropolitan coastal locations between 1986 and 1991, increasing to 35.1% between 1991 and 1993. Yet in 1991 these coastal locations held only 17.5% of the total population. The main focus of this coastal urbanisation is along the north east coast of NSW, the Gold and Sunshine Coasts of SEQ and several sites further north in Queensland, including Hervey Bay and Cairns. As mentioned above most of this coastal growth derives from movements from south eastern Australia.

Older persons and retirees are an important component of the migration to SEQ, but contrary to popular perception, are not the dominant source. For the period 1986-1991 15.2% of interstate movers to the Gold Coast and 18% of those moving to the Sunshine Coast were

* This move to a post industrial or even post modern city is not being recognised by the road lobby which has pushed instead for a rash of large freeways across all Australian cities. Despite significant political set back in Queensland and NSW due to the extreme unpopularity of these "symbols of unsustainability", Melbourne and Perth are pushing ahead with their massive proposals.
aged 60+. By 1991 19.8% of the Gold Coast population was aged 60+ and 22.1% of the Sunshine Coast population. This compares with 12% of Australia's overall population.

Most of those moving to northern coastal locations are working age persons many of whom appear to have been displaced by the early 1990's recession and the restructuring of older industries in southern metropolises. They seek better opportunities elsewhere, but in the short term often find difficulty in procuring employment.

As a result of these trends, the number of persons dependent on unemployment benefits, single mother and old age pensions and other government benefits now located in coastal areas is substantial. What this means is that the flexibility of location provided by government benefits and private superannuation benefits is fuelling the relocation process quite independent of the productive base of these growing coastal communities. There is a self-reinforcing process occurring, as the provision of housing and social and physical infrastructure provides additional job opportunities, thereby attracting more job seekers to these locations.

It is hard to see this coastal growth trend as contributing to sustainability - in the environmental and economic dimensions of the concept.

5.4 Provincial Cities and Towns are Growing

Those provincial cities and towns located on the coast and catering for a recreational lifestyle market/clientele are booming. In Queensland the major growth points, other than Gold and Sunshine Coast, are Hervey Bay (adjacent to Fraser Island) and Cairns. Cairns is becoming an international city servicing international tourists through its airport and its role as a gateway to the tourist opportunities on the Barrier Reef. Other coastal cities in Queensland with an industrial or port base, like Bundaberg, Gladstone, Rockhampton and Mackay are growing but at a considerably slower rate.

Elsewhere in Australia provincial cities other than those servicing coastal recreational needs have generally maintained their position as regards population growth. Most appear to be benefiting from the relocation of residents previously located in smaller country towns and rural hinterlands. Some are also benefiting from industrial growth deriving from their relatively low land and labour costs or their proximity to primary resource producers.

These towns are using their growth to upgrade services like waste treatment and to that extent they are becoming more sustainable.

5.5 Inland Agricultural Towns and Regions are Declining

Generally the population in rural areas (defined as cropped or cultivated zones) is being maintained especially those with some linkage to larger metropolitan or provincial cities. However in the drier wheat/sheep belt population numbers are declining across all states. Most of these areas lost between 0-5% of their population between 1986 and 1991. For example, the Conargo, Jerilderie and Bland areas in the Western Riverina areas of NSW lost 12.7%, 7% and 6.1% of their population respectively between 1986 and 1991.
Population decline, both on the land and in the small rural towns servicing the farming community, is undermining the economic viability of these towns. This does little for sustainability as defined here.

5.6 Remote Settlements are Fluctuating

Very few remote settlements are growing apart from tourist centres. Even economic boom areas for mining are now mostly fly-in/fly-out settlements so areas like the Pilbara have been declining for a decade. There are few issues for sustainability as most mining developments are good environmental citizens in the 90's.

Remote aboriginal settlements are growing due to their 'return to country'. In 1966 there were only 88 discrete remote area aboriginal communities; in 1992 there were 1385.

The potential for aboriginal settlements to assist with remote area sustainability is huge but is mostly still untapped.

6 METABOLIC FLOWS AND LIVABILITY IN AUSTRALIAN SETTLEMENTS

The State of the Environment Reporting process also identified metabolic flows and livability trends, summarised in the following way.

Australian Settlements in Context

Australian settlements have higher metabolic flows - that is, they use more resources and produce more wastes - than those in other industrial nations. Australian cities use more water, energy and produce more solid wastes than average per capita levels in OECD countries. These flow levels have in general been increasing, both in total and per person, over the past few decades. Livability is also high by international standards and in general, has also been improving. However, these patterns vary considerably between and within settlements.

6.1 Big Cities

The big cities are generally more efficient in their metabolic flows than smaller cities and country towns. The large cities also tend to enjoy better livability. This suggests there is little to be gained, environmentally, by the dispersal of urban populations into other areas, especially the non-urban coastal areas, which are now growing rapidly. There is much that can be done to reduce metabolic flows whilst further improving livability within the cities.

On the other hand, the large cities, notably Sydney, are experiencing 'capacity' problems associated with photochemical smog and stormwater and wastewater that demand changes if these cities are to continue to grow even in small amounts. This is reflected in the regulation of all stormwater to be treated on site in the new Rouse Hill development. Such regulation has not extended to the airshed. There are also the global constraints which must be faced, especially those arising from the greenhouse effect and global warming.
6.2 Growing Inwards or Outwards

Within the large cities, the more compact core and inner areas consume fewer resources and produce less waste per capita than outer and fringe areas, although there are some pressures on their infrastructure. Livability levels are similar across the city, except the urban fringe, which suffers poorer social amenity (access to public transport, and health, educational, sporting and recreational facilities etc).

Unlike many United States cities, which have deteriorating cores, Australian cities are undergoing simultaneous processes of suburbs being created at the fringe, and also reurbanisation, ie. the redevelopment of older areas. Suburbanisation is still the more dominant in terms of population but reurbanisation has between 30 to 40 % of housing development and more than 50% of commercial development. This means there is an accelerating process of reurbanisation that is leading to greater livability in Australian cities whilst improving transport energy and hence air quality. A further comment on this will be made at the end of the paper.

Livability is declining in emerging 'pockets of poverty' found right across the city but mostly on the fringe. This indicates that the city needs to restructure to simultaneously avoid the problems of poverty and sustainability.

6.3 Coastal Areas

Coastal areas, particularly in northern NSW and Queensland, are expanding rapidly and less sustainably than other settlements. This is evident from their metabolic flows (which are higher than in the cities), their pressure on sensitive environments and their livability. It is clear that subsidised land development is leading to unsustainable economic development on the coast.

6.4 Small Towns

Inland, most small towns are stagnating economically, and many face significant 'capacity' problems with water and waste management, which is generally starved of adequate technological investment. A possible scenario for both coping with the growth of large cities and providing some rural towns with necessary economic and environmental resources would be to link the towns to the city by fast rail.

This process of conurbanisation is particularly suited to towns that are less than an hour's travel away from the city. While it has potential to improve livability and reduce metabolic flows, the process must be accompanied by improved infrastructure and service, or it will merely shift the problems from the urban fringe to inland towns.

More remote provincial towns - apart from tourist centres - are declining, and is reflected in their reduced livability. It suggests population decline is not good for settlements that need investment and community commitment to address long-term environmental and livability problems. Diversifying the productive base in rural areas and small country towns is an economic, social and environmental priority.
6.5 Remote Areas

Remote indigenous communities are growing and have low metabolic flows, but are experiencing some 'capacity' issues eg from untreated wastes or inadequate water supplies. They also have extremely low livability on all indicators, particularly health. Powerful cultural forces have driven this 'return to country', which has only just begun to be assisted with appropriate technology. The communities lack basic infrastructure, as well as social and economic development to improve livability. One interesting aspect for sustainability is that these remote aboriginal settlements have become test beds for renewable energy and small scale environmental technologies which are likely to have a large export future and slowly move into larger towns.

7 NEW URBAN ORDER

Perhaps one of the most significant trends from all of the above is that a process is underway to make Australian cities more compact and land efficient. This process can be understood by seeing the trends in urban form as set out in Figures 5 to 8.

![Figure 5](image)

Figure 5  Traditional walking city (up to 1850 in Europe)

![Figure 6](image)

Figure 6  Transit city 1850-1940 (dominant city form in industrial world)
Figure 7  Automobile city 1940-present (US + Australian cities mostly)

Figure 8  Future city (nodal/information city)

- Low Density
- Separated uses
- Arterial Grid and cul de sac Based
- Decentralised

- Mixed Density - high, medium & low.
  High - urban villages.
  Medium - 800m around transit stops.
  Low - DRT or cycle distance to transit.
- Integrated - residential, commercial, small scale industry.
- Sub-centralised - link by transit and telecommunications.
The transition of Australian cities began with pre 19th century walking cities then moved to the 19th century industrial Transit city with its heavy emphasis on work in the CBD and rail based suburbs. Then the 20th century Automobile City dispersed housing and jobs based on car-access. The Future Nodal/Information City seems to favour more obvious sub centres with more local self-sufficiency and good transit links. Such a city can have much more mixed land use due to the shift from polluting industries to information flows as the basis of the urban economy. But far from dispersing work the new information order seems to be bringing people together in centres where key skills and networks can be created by personal contact (always a critical role for cities). The rise of new economic light rail technologies with their electric base is likely to be the growing transport medium that can bring people to such sub centres and link them together.

The process of change will be driven much quicker by the peaking in production of world oil which now appears to be sometime in the next 5 to 10 years. (See Fig 9). Although still a lot of oil is left the second half is much more expensive and each year the whole world must be using less and less not more and more as we have been doing.

![Figure 9](image)

Figure 9  World oil production (1930-2050)
Those cities that are preparing for this change are more likely to be able to cope with the change socially and economically. Our evidence based on the update of our global cities study is that US cities are doing the least well at this change - see Fig 10. Australian cities are indeed beginning to slow down in their growth of car use and truck use as shown earlier.

![Graph showing increases in per capita VKT in cars in global cities, 1980-1990](image)

**Figure 10** Increases in per capita VKT in cars in global cities, 1980-1990

The critical point is to see that the old order is changing. The building of massive freeways in Australian cities with their inherent qualities of dispersing land use will only serve to delay our ability to cope with the new urban order. The general public can sense this but the transport engineers and road lobby are not yet facing up to it - despite State governments being brought down over the issue.

The inability to constrain car dependent, dispersed, urban development in large cities and along coastal areas is a process that has only negative consequences for sustainability.

8 CONCLUSIONS

The State of the Environment Reporting process is part of Australia’s approach to fulfilling its sustainability objectives. It shows there have been moves towards sustainability in Australian cities but there are some real continuing problems as well. Public concern remains high and thus governments will continue to be pushed to implement the sustainability agreements they have made at a global level. They will also need new professional techniques to manage these issues and demonstrations of best practice. For example the new technique of sustainable infrastructure planning, together with innovative government programs such as Better Cities and Cleaner Production, can reduce metabolic flows in all Australian settlements and increase their livability. Indicators of the State of the Environment can assist this integrated process, particularly where local capacities need to be more carefully assessed and monitored. The development of sustainability indicators to assess land development are now sorely needed.
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PLANNING AND DECISION MAKING

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ABSTRACT

This paper provides a framework of planning and decision making processes for urban land management primarily from the public sector planning perspective. It shows the importance of market failure and property rights issues in establishing the scope and efficacy of planning interventions and approaches to designing appropriate plans. It argues that economics has a very minor role in determining land management goals but a major role in determining management tools.

In reviewing decision-making processes, the paper draws attention to difficulties in designing effective community involvement programs and the disturbing lack of vertical and horizontal coordination in management regimes. Scientists enthusiasm for rational problem solving approaches must be tempered by the reality of contemporary dispersed decision-making power where the predominant process is bargaining.

A spectrum of tools is proposed, ranging from educational programs which have indirect effects on land owner behaviour to highly interventionist controls, to define the possible means of achieving land management objectives.

KEYWORDS: land use planning, property rights, planning processes, implementation.

1 INTRODUCTION

The wider application of current best-practices in urban land management would solve many of the environmental degradation and sub-optimal use of resources in cities. The obstacle to better land management is more commonly the lack of implementation of existing knowledge rather than the lack of scientific and technical knowledge per se. Better understanding of planning and decision making issues then is a high priority to improve land management and this paper reviews the legal and political context for planning and identifies the most promising avenues for achieving improved outcomes.

For various reasons, sometimes ignorance, private land managers do not adopt best practices voluntarily, unless there is a demonstrable economic benefit to them. The community, through government then intervenes in some way. The central questions then are why and how does government intervene to bring about better land management by private land owners. Governments must select legally and politically acceptable means of influencing the choice of use for particular parcels of land and the management practices of uses on that land.

In societies like Australia, democratic politics, private property rights and the free market are key institutions influencing what can be achieved in planning. To develop better land management practices it is essential to address these contextual issues before determining
plans. Rational problem solving approaches have limited application in this context and planners must accept the plurality of property, legal and political interests in determining courses of action. Top-down command planning based on sanctions and controls rarely works, and planners must prepare negotiated solutions that involve a wide range of community inputs and use other less interventionist implementation tools that are more appropriate in these circumstances.

2 WHY INTERFERE WITH PRIVATE LAND USE DECISIONS?

Many good land management practices are also beneficial to the owners of private land by increasing profitability in the short-run and protecting the long term value of property investments. But, enlightened self-interest of landowners maximising their private benefits from the use of land, is inadequate to ensure that social benefits and costs are also considered. The prevailing view in laissez-faire economic and political circles is that private land owners and the market mechanism are capable of guiding an economy in the choice of a socially optimum land use, what goods and services to produce, and what production processes to use. The recent swing to the right in many countries has been accompanied by greater faith in the market approach to land use determination and to the retreat of planning. The claim that the market can achieve an optimum is most important for planners, because if it is true, there is no role for planners. Conversely, demonstrating that markets are inadequate provides the rationale for intervention (Allison, 1975).

2.1 Markets and the Optimal Use of Land Resources

Market prices provide signals of relative marginal costs and in free market systems, the incentive to follow them. Individual producers, if they incur a cost on others by using their labour, their land or consuming manufactured outputs should pay a price equal to the cost. If they confer a benefit on others by allowing them to consume their goods and services, they will be compensated.

This kind of simple exchange system would be socially optimum if it achieved: (i) efficiency in production - optimum use of production inputs; (ii) efficiency in exchange - optimum arrangement of trade between individuals in the system; (iii) equity in distribution.

Under the assumptions of perfect markets, welfare economic theory can demonstrate that competitive economic systems are efficient. Producers will organise their production methods such that the conditions of input efficiency will be met and consumers will allocate expenditures from limited incomes so that the exchange conditions will also be achieved in the market place. Unfortunately, the assumptions required to make such a system work are so stringent that they are never met. Furthermore, equity in distribution can only be achieved by resolving questions of interpersonal utility which markets are unable to do.

2.2 Market Failure: a Rationale for Planning

It is an irony that while on the one hand the perfect free market can lead towards the socially optimum use of resources and allocation of goods in an economy, on the other hand, analysis of its failures is an effective guide to public policy. The most important and commonly recognised failure of markets relates to their failure to cope with social costs and benefits
which takes many different forms (Table 1). While the traditional welfare economics model helps identify the potential need for public intervention, it is not valid to assume that such interventions will lead to improvements. Before such a conclusion can be reached, the efficiency and effectiveness of public action must also be known. In recent times the omniscience of government has been attacked in many countries, and the naive assumption that governments act efficiently and in the "public interest" is disputed almost as much as the equivalent view of private enterprise. At the very best, arguments for intervention of the kind presented here would provide a necessary basis for intervention but not a sufficient one.

Society as a whole has a different view of its commitments compared with the individualistic view and there is constant tension between the rights and preferences of the individual compared with the needs of society as a whole. These differences in outlook between the individual _qua_ individual and the individual as a member of society could be described as schizophrenic.

**Table 1** The rationale for public intervention into land use decisions

<table>
<thead>
<tr>
<th>Cause of Problem</th>
<th>Reason for the Problem</th>
<th>Consequences</th>
<th>Remedies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lack of knowledge by consumers and producers of the outputs from land</td>
<td>Lack of information Scale economies in R&amp;D Insufficient consumer sovereignty</td>
<td>Under-use of existing knowledge Under-investment in R&amp;D Sub-optimal land use</td>
<td>Training and extension research Resource use controls</td>
</tr>
<tr>
<td>2. Restricted entry into land using industries</td>
<td>Low market thresholds Locational monopoly Restrictive practices</td>
<td>Exploitation producers and consumers Sub-optimal resource use</td>
<td>Licensing trade regulations</td>
</tr>
<tr>
<td>3. Decreasing cost industries</td>
<td>High scale economies Indivisibilities</td>
<td>Undersupply of goods and services</td>
<td>Subsidies, licensing and public ownership</td>
</tr>
<tr>
<td>4. High cost of operating a market</td>
<td>High cost of collecting payments Free riders</td>
<td>Undersupply of public goods and services, roads, water and environmental quality</td>
<td>Subsidies, licensing and public ownership</td>
</tr>
<tr>
<td>5. Absence of a market leading to externalities</td>
<td>Difficulty of defining property rights Environmental degradation</td>
<td>Pollution, resource degradation</td>
<td>Land use regulations and zoning Environmental controls</td>
</tr>
<tr>
<td>6. Dynamics (a) Instability (b) Disequilibrium conditions</td>
<td>Biophysical variability Global market s technical change</td>
<td>Low income and long term production problems. Depressed rates of adjustment</td>
<td>Public insurance and assistance Reconstruction and structural programs</td>
</tr>
<tr>
<td>7. Lack of Equity</td>
<td>Socially unacceptable income distribution</td>
<td>Social disruption and pathologies</td>
<td>Tax and welfare systems Land reform and financial assistance</td>
</tr>
<tr>
<td>8. Social time preference</td>
<td>Private time preference different from social time preference</td>
<td>Use of resources at a greater than optimal rate Unsustainable development</td>
<td>Resources controls and rents, licensing and government ownership</td>
</tr>
<tr>
<td>9. Merit Goods</td>
<td>Markets fail to reflect the social values of merit goods</td>
<td>Undersupply of conservation areas, low environmental quality</td>
<td>Subsidies, government ownership</td>
</tr>
</tbody>
</table>
3 PROPERTY RIGHTS AND PLANNING

3.1 Property Rights and Natural Resources

As a consequence of market failure, the rights of individual land owners are broadly circumscribed by land laws and specifically limited or enabled by a whole raft of economic, resources, social and environmental laws. (See Table 2) These arose gradually over many centuries as the consequence of the misuse of common property resources became evident. Property rights, so central to the operation of the western democratic free-market system are then prescribed through the political process. The institution of “private property” evolves continually as the community determines an acceptable balance between the private and public interests in land.

3.2 Property Rights and the Law

A profound difficulty in using a normative economic approach to land use policy problems stems from the way in which economics divorces the question of existing wealth and income distribution from the determination of social utility measurement and more fundamentally in that it divorces questions of economic power (wealth and income) from the ubiquitous roles of government and the law. The invention of a social welfare function by welfare economists at least shows recognition of the central relevance of distributional questions, but the dominance of the law over property rights and hence effective economic power, brings into question the use of the market signals as guides to public policy. As Samuels notes: “The power structure is a function of the law and the use of government is a function of the power structure, and income and wealth distribution are a function of law and law is a function of income and wealth distribution.” (Samuels, 1974, p.3)

<table>
<thead>
<tr>
<th>Table 2 Property rights and natural resources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air</strong></td>
</tr>
<tr>
<td><strong>Resource</strong></td>
</tr>
<tr>
<td><strong>Landscape</strong></td>
</tr>
<tr>
<td><strong>Wildlife</strong></td>
</tr>
<tr>
<td><strong>Access</strong></td>
</tr>
<tr>
<td><strong>Timber</strong></td>
</tr>
<tr>
<td><strong>Water</strong></td>
</tr>
<tr>
<td><strong>Forage</strong></td>
</tr>
<tr>
<td><strong>Soil</strong></td>
</tr>
<tr>
<td><strong>Groundwater</strong></td>
</tr>
<tr>
<td><strong>Minerals</strong></td>
</tr>
</tbody>
</table>

Land use plans often need to determine which individual’s or group’s interests are to be favoured by a change in property rights and whose are to be relatively restricted. So the distributional outcome of the Pareto assumption, which assumes existing property rights (and
income distributions) is unsatisfactory, and is intrinsically conservative. It sets aside questions of property rights and accepts the status quo.

The treatment of externalities best exemplifies the difficulty posed by property rights. It is inevitable that externality solutions must delineate and assign rights, where presumed rights are made explicit with legal sanction and force. The classic example is pollution: the polluter’s presumed right to pollute neighbours will be made explicit and sanctioned, or the neighbour’s presumed right not to be polluted will be confirmed. Whichever outcome prevails, clear questions of income distribution are involved. In the former, the polluter obtains continuing use of the environment as a waste assimilator (thus enabling higher profits), whilst in the latter his neighbour confirms his right not to have to accept other people’s emissions. Property rights questions emerge in most cases where externalities exist and the land use planners’ main task is to devise a composite allocation of property rights (use rights) and fiscal measures to deal with perceived problems.

The process of land use planning under the conditions outlined above is one of interaction between interested parties within the constraints of law and of the political organisations established to reach decisions and implement them. Even the law can change. To this extent a professional planner is more a facilitator, advocate and administrator than a normatively rational technician.

4 PLANNING PROCESSES

4.1 What is Planning

Planning is no more than charting a course of action and proceeding to implement it. It is a process of dealing with change. At its simplest then planning involves:

- determining a set of goals or values to be realised;
- assessing what options may be available to achieve those goals;
- implementing some actions; and
- monitoring the success of the actions.

While this may be stated in simple terms, the practice of planning in a pluralist society is complex and marked as much by good intentions and eventual failures, as much as outstanding achievements. The relationship between technical planning based on scientific knowledge and instrumental knowledge and the political process is poorly understood. Mostly planning is experimental.

4.2 The Rational Planning Approach

Undoubtedly in past decades the concepts of scientific management have had a major influence on the conceptions of technical planning through the rational planning approach. Rational planning is an idealistic model of decision making which is based on the premise that there should be an explicit relationship between means and ends in planning (and vice versa) and that there should be a logical presentation of an argument supported by the systematic use of evidence. Clearly this view of planning with its requirement that decisions be grounded in reason and evidence has philosophical roots in scientific method, especially
logical positivism, and it attempts to detail a functionally rational approach to decision making as a form of problem solving.

A land use decision from the public point of view can be characterised as a technical problem and solved rationally in a textbook manner like business or military planning problems - as a rational exercise of finding the action that best meets the stated objectives. Table 3 below shows the steps.

Table 3 The steps in rational planning

<table>
<thead>
<tr>
<th>Steps</th>
<th>Land Use Decision Making Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define goals and objectives</td>
<td>long term sustainability, minimum soil loss, water quality standards, economic efficiency</td>
</tr>
<tr>
<td>Formulate alternative actions</td>
<td>land care, total catchment management, financial incentives, regulations, promotion of land ethic, residue management</td>
</tr>
<tr>
<td>Forecast and evaluate</td>
<td>cost-benefit analysis, cost-effectiveness, EIA</td>
</tr>
<tr>
<td>alternatives</td>
<td></td>
</tr>
<tr>
<td>Choose the best alternative</td>
<td>Government decision, Council decision</td>
</tr>
<tr>
<td>Implement</td>
<td>change Act, enforce regulations, plan</td>
</tr>
<tr>
<td>Monitor</td>
<td>measure outcomes, soil loss, water quality</td>
</tr>
</tbody>
</table>

Despite the scientific appeal of the rational model, its reliance upon explicit statements of ends and means and its logical process of choice, it has been the target of sustained attack in recent years.

"In the 1950s and 1960s, the traditional blueprint or master plan approach was largely supplanted by the systems approach, but this like its predecessor was based on the assumption that professional experts could predict and control the outside world in the interests of the whole society ... as this was questioned, a new style of planning emerged which assumed that planning objectives were inherently contradictory and that the planner should act as advocate for a particular group, within a context where planners and their clients were both engaged in a learning process" Hall (1983) p.41.

The criticisms of the rational model cannot be denied although it is worth noting some situations in which the process is not liable to have the weaknesses claimed. Underlying most of the criticisms of the rational planning model is the view that it is naive with respect to the observed process of conflict resolution and political activity that overwhelms most land use planning. Land use planning is rarely carried out by strongly centralised agencies that can ignore pluralistic interests and survive. In situations where the planner is a single decision maker, application of rational problem solving is possible. It is for this reason that the rational model, albeit in a more elaborate form, is still paramount in business management and those branches of land use planning closely allied with professions such as civil engineering, landscape architecture, forestry and farm planning. Even the environmental impact assessment process in many countries has strong overtones of rational planning. The technical work done in these professions puts the planner in the role of a scientist who (normally) avoids questions of broad objectives and is expected to be functionally rational with a given set of objectives. The engineer may be asked to provide water storage, the
landscape architect to reconstruct a derelict landscape, the forester to prepare a management plan, the soil conservationist a watershed plan on the basis of clear instructions from the land owner. Such single decision maker situations are not uncommon (as in private enterprise) and the rational problem solving model is appropriate.

Whenever there is a plurality of interests, rational problem solving is unlikely to work. Great conflict arises when the technically functional planner attempts to apply the procedures that were successful in narrow contexts to complex questions in allocative planning. This often happens at the interface between water resource planning, mining, freeway planning and other public works plans thought by engineers to be designed in the public interest. The latter proves to be very elusive.

4.3 Planning as Conflict Resolution

The rational school of planning presumes a consensus or absolute power model of problem solving wherein policy problems are identified and a mechanism for solving them applied. The world of individual competing interests is not like this. Land use planning may be required or justified due to the failure of free markets to resolve efficiently or equitably a range of public goods, externalities and other land resource management issues, but herein lies the land use planning dilemma. If it was in the interest of individual landowners to use their land in socially efficient and equitable ways, they would do so without the need for planning intervention. Conversely, planning is necessary to achieve land use outcomes not seen as desirable by the owner. Land use planning must cope with conflict; it is inherent in any collective action to achieve socially efficient and equitable land uses.

Underlying the legal definition of private property is a more significant social one. In some nations, society expects greater freedom to be given to individuals and the free-enterprise ethic strongly influences the political feasibility of interfering with landowner’s rights. The United States and Australia are most typical of this case. Contrasting with this view is one that assumes land to be community property, perhaps in indefinite custodial control of an owner who is subject to all sorts of restrictions over land use (e.g., most European countries). Acceptance of a valid case for social control over land use reduces the degree of conflict accompanying land use, for social control over land use reduces the degree of conflict accompanying land use planning a great deal.

As the case for social control of externalities increase over time, there could be an evolving change in attitudes to private land ownership. The fortunes of land owners can change dramatically as a result of policies that can either give windfalls or wipeouts depending on who is affected and how. For example, zoning or subsidy policies can give substantial windfalls to affected landowners and related support services. Taxes and regulations or reductions in tariffs can lead to wipeouts. Public infrastructure can alter the worth of private land serviced by it, not always positively if the services are undesirable (e.g., hazardous waste dumps).

The stakes are very high and the conflict surrounding planning decisions accordingly strong. Individual landowners will be joined often by realtors, lawyers, speculators and other vested interest groups to block restrictive planning controls. Producer groups (farmers, livestock producers, timber companies) will lobby very hard for favourable policies that need not be in
the interest of consumers or of multi-commodity trade negotiations. Land use policy will be fought out in bargaining among the various groups who have a vested interest in the outcome.

From a political point of view, land use planning is relatively difficult to promote because the main beneficiaries of wise use decisions are either citizens of the future or an amorphous group who will benefit in intangible ways from planning. There are not many votes in comprehensive land use planning. On the other hand, the loss of landholder freedoms entailed by plans may affect a very clearly identified group who will oppose such activity. Planning costs votes especially when planning is painted by its opponents as an obstacle to "economic growth". Public expenditure programmes have the reverse effect, since the beneficiaries can be clearly identified (voting) landholders and citizens in the project area whereas the taxpayers (losers) are an amorphous dispersed group.

4.4 Planning as Bargaining

The controversy surrounding the rational model and the inability of the normative economic model to define social welfare criteria (amongst other things) has left planning in a vacuum. The problem has been exacerbated by the failure of many traditional approaches to perform satisfactorily in terms of implementation.

A primary feature of decision making practice in mixed economies is *bargaining* within a loosely integrated governance system. Bargaining is a process "whereby two or more parties (actors) attempt to settle what each shall give and take or perform and receive in a transaction between them" (Dorcey, 1986). The actors who are all the participants in the planning process have some power to influence decisions, even if only to vote, to embarrass, to provide information, to demonstrate or to block decisions.

The distribution of power to bargain is very uneven, being influenced by the constitutional and legal bias of the system and the economic and property rights of the actors as discussed earlier in this paper. Of great interest and relevance is the different value systems of the actors and the scope for conflict, compromise and social learning between them during the unravelling of any planning issue.

**Table 4 A typology of planning styles**

<table>
<thead>
<tr>
<th>Distribution of power</th>
<th>Strongly centralised</th>
<th>Weakly centralised</th>
<th>Fragmented</th>
<th>Dispersed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method of implementation</td>
<td>compulsory targets general rules financial inducements information</td>
<td>mixed controls</td>
<td>bargaining</td>
<td>participation in decision processes</td>
</tr>
<tr>
<td>Predominant forms of control</td>
<td>sanctions</td>
<td>restructuring decision environments</td>
<td>normative compliance</td>
<td>voluntary compliance</td>
</tr>
<tr>
<td>Mode of planning</td>
<td>plans</td>
<td>policies</td>
<td>processes</td>
<td>processes</td>
</tr>
<tr>
<td>Role of technical experts</td>
<td>bureaucratic</td>
<td>adviser</td>
<td>negotiator specialist</td>
<td>organiser and advocate</td>
</tr>
<tr>
<td>Style of allocative planning</td>
<td>command planning</td>
<td>policies planning</td>
<td>corporate planning</td>
<td>participant planning</td>
</tr>
</tbody>
</table>

*Source: Based on Friedmann (1973), 71.*
4.5 Planning Processes and the Distribution of Power

Many of the apparently conflicting views about planning can be resolved by clarifying assumptions about the distribution of power. In systems possessing a high degree of control, more deterministic planning approaches can be adopted. Not only is the decision-making process simplified in this situation but so is the implementability of decisions on planning and management. Such systems have the characteristics of a single decision-maker to the extent that no conflict over means and ends needs to be considered. Rarely do planning problems fit this description.

The degree of control is the principal axis in Friedmann's review of allocative planning defined as the *distribution of power* which ranges along a spectrum from strongly centralised to dispersed (Friedmann, 1973). (See Table 4). Problems in planning will occur whenever an agency attempts to use a style of planning that is not in accord with the distribution of power. For example, whilst a state forest agency may implement logging quotas on state forest land and achieve desired production and environmental objective, it will be less able to do so in private forest areas. At the minimum some participation from private land owners will be essential to ensure their co-operation and perhaps their compliance. There will be bargaining about policy matters, about regulations and continually during implementation.

5 PROCESS ISSUES IN LAND RESOURCE MANAGEMENT

5.1 Community Involvement

The practice of planning has changed markedly in recent years, adopting community consultative processes and involving stakeholders - more bottom up rather than top down - in contrast with the old survey-analysis-plan paradigm or even the rational planning paradigm that focussed on goals and systematic selection of alternatives. The effectiveness of plans now depends on the degree of stakeholder acceptance of plans. Most planning agencies now use a process of public consultation in preparing their plans - most readers will have been involved in these. The challenge at the present time is to optimise these processes to be efficient in the use of stakeholders time, to be transparent so that participants can see how (if at all) their preferences have been incorporated into the outcomes.

Many planners and resource managers involved in environmental planning have no training in appropriate techniques and consequently many plans are defective because they fail the final implementation test or are never really implemented at all because the community was not adequately involved and perhaps most importantly, conflict and power sharing issues were not resolved at the planning stage. The biggest difficulties seem not to be with community based stakeholders but with bureaucratic stakeholders at one level of government or across levels. As has been discovered with some genuine community planning programs (eg ICM and Landcare) there is a vast difference between community based planning and loose commitments to public involvement. The Department of Primary Industries recently published a generic guide to community consultation techniques (Carman & Keith, 1994). It contained no fewer than sixty-eight techniques. Ranging from providing information to the community to joint planning.
The challenge is twofold. Firstly, the planning system must clearly articulate the role of all stakeholders, including those in government agencies and secondly, planners must use better methods of plan making on the basis of community planning. A promising recent example of this is Albert Shire's (Gold Coast City) use of a charrette (an intensive workshop) to prepare its Coomera DCP.

5.2 Vertical Integration - The Scale Problem

There is a critical problem of spatial scale in dealing with land management. What is the boundary of a sustainable system? What can or should a small local community do about it? A system of planning based on unfettered local powers and responsibilities over the environmental and socio-economic character of development is unlikely to be optimal and sustainable. The situation could be a tragedy of the commons on a global scale. This is not to say that local action is unimportant but in an interdependent world some degree of power and responsibility must rest at a spatial scale sufficiently broad that interdependencies and trade-offs, both ecological and socio-economic, can be internalised. But at what level and what distribution of rights and powers? A city can not in a narrow sense be independently sustainable given the resource, environmental and economic transfers on which the city depends, but it could maximise its contribution to global sustainability through local energy use, land use and waste management policies that minimise impacts.

Some decisions must be made at a global level, some at a national and some at a local level. Difficulties in achieving policy coherence increases exponentially with the number of levels of government, making institutional assignment particularly difficult in federal systems such as the United States, Canada or Australia where there is a third level of government. Higher levels of government provide a framework for implementation at lower levels and as long as lower levels act consistently with the guidance from levels above, many decisions can be taken at the local level or at least conditionally delegated.

5.3 Horizontal Integration - Which Agency?

Irrespective of the level at which planning is done and decisions are made, if we have learned anything from Brundtland and Rio, environmental planning requires simultaneous consideration of ecological and socio-economic factors. Since approximately 1970, the environmental dimension of planning has increasingly been the responsibility of other branches of planning which have usurped the environmental responsibility of 'mainstream planning'. Mainstream planning with its emphasis on economic development, infrastructure, land use planning and development control has an uneasy relationship with these emergent fields and has to a considerable extent been left out of the environmental debate in many (but not all) countries. Planners have become identified with development and is seen, at least in the past, to have been professionally captured by the land development industry. Mainstream planning and these speciality fields have grown apart, theoretically, legally, administratively and in the disciplinary proponents of each field. Environmental planners are responsible for the piecemeal application of environmental impact assessment, pollution control and environmental quality standards. Integration has suffered and the chance for integrating economic, social and environmental factors reduced. (See Slocombe, 1993, 290).
Even within local governments, environmental management and expertise has been separated from planning and development control - into environmental management branch, parks and recreation or health, reflecting the sectoral separation usually found in state governments. If strongly enforced policies or even statutory plans emerge in these areas, there is inevitably a problem of coordination, inefficient development approval and determining which plan shall predominate.

Inter-agency and community conflict is common because the environmental considerations have been separated out.

6 POLICY TOOLS FOR RESOURCE PLANNING

Fundamentally, the purpose of land resources planning is to alter the land use outcome that would arise from the free play of commercial decisions made at the enterprise level. As outlined above, to achieve economic efficiency and to protect the environment - to have sustainable development - sometimes requires industry or government action to steer private decisions in other directions. Given that private individuals and enterprises are responsible for land management, the essence of planning is to influence the **behaviour** of those people in their land use and processing activities. Planning will be achieved by a combination of:

- **Education** of land owners in the need to incorporate non-traditional natural resources and environmental values into their decisions is an essential step. Many planning objectives can be achieved by voluntary actions on the part of the players providing they have relevant information. Best practice guidelines and extension programs fall in this category.

- **Economic incentives** that through fiscal or financial means in the input and output pricing signals and in the tax system whether it be local rates or company tax provisions on conservation works.

- **Land use controls** and resource use rights are more direct and intrusive means of limiting the uses of land or access to water, drainage, clearing.

- Where none of these means of influencing behaviour are practical, equitable, effective or efficient, resources and activities must be managed in the **public sector** itself which happens in the case of some classes of infrastructure (such as roads and irrigation schemes) and for nature conservation (national parks).

In practice, the resources planning initiatives outlined above combine all of these policy instruments in various ways to achieve their objectives. The forms of that intervention are many and varied and the industry should not assume that controls by government are the only or best means. There are many more sophisticated methods than crude land use controls to affect behaviour, indeed many planners believe that controls without the general support of the industry and the community are not likely to be effective or even accepted by the community.
8 CONCLUSIONS

Designing and implementing improved practices of land use and management is a complex amalgam of technical issues, property rights issues and politics. Better land use outcomes can only be achieved when technically sound solutions are adopted by private and public land managers. Gaining political and therefore general community support for land management is therefore essential.

In Australia over recent years it has become widely recognised that resources management cannot be achieved by top-down regulation of land users but can be best achieved by joint efforts involving government, land owners and community stakeholders. Programs such as Landcare (which has its urban applications), ICM, Coastcare, Waterwatch, Local Area Planning, regional planning indeed resources policy making in general, are clear evidence of these planning approaches.

9 REFERENCES


AN INTRODUCTION TO SOILS AND THEIR PROPERTIES

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ABSTRACT

An understanding of the principles of soil science is essential for dealing with the many physical and environmental challenges of urban development. In this paper, the nature of a soil profile and the terminology used to describe, classify and map soils are introduced, as are the soil orders of the Australian Soil Classification. These are important elements of the soil inventory studies for EIS and assessing the feasibility of urban development proposals.

The components of the solid, liquid and gaseous phases of the soil are summarised together with some of the basic principles of soil chemistry and soil structure. This introduction aims to provide some basic understanding of soil science together with an appreciation of its' complexity. It emphasises the multifaceted nature of soil science and the need to consult specialists to meet specific challenges.

KEYWORDS: soil profile, soil classification, soil distribution, soil components, soil chemistry, soil physical condition, specialist advice.

1 INTRODUCTION

Soils serve a variety of functions in urban and industrial development including, acting as a medium for plant growth, as a foundation for buildings and as a source and sink for water and pollutants. Increasingly, local authorities are being pressed to provide suitable areas for urban uses but are restricted by a general lack of understanding and information about the soils for which they are responsible. As a result, planning land use and management in urban environments has often been on the basis of a ‘try it and see’ approach rather than one based on a sound understanding of the medium on which the development is to occur.

Our understanding of soil properties and processes has largely been developed from research carried out on soils used for agricultural and forestry purposes. This is an important research base, much of which is applicable to urban development. However, there can be important differences between soils of urban areas and those of rural areas. Often, soils in urban areas are composed of different materials and have been man-made.

Increased awareness of environmental issues has provided an impetus for decision makers to require specific information regarding properties of soils likely to be developed for urban and industrial use. Participants in this training course may not have a detailed knowledge of the chemical and physical processes in soils nor of the specific measurements that can be made to characterise a particular soil. However, this paper aims to provide a brief overview of the composition of soils and soil processes and introduces some concepts that indicate the type of information required when assessing soils for urban development. A broad outline of the
physical, chemical and biological properties of soils is presented and is aimed at providing a basis for subsequent sections of this publication. Further information on the basic properties of soils is available in the reading list provided.

2 THE SOIL PROFILE

Soils are the weathering product of the interaction of rocks and sediments with the surface environment - the atmosphere, the climate, the surface terrain, runoff, the groundwater, the vegetation that establishes and the organisms that colonise or manipulate it. Over time these interactions result in the formation of soil profiles and their arrangement into layers or horizons.

Soil horizons are identified by their characteristic features which result from a variety of soil forming processes. The letters O, A, B and C are used to designate the major horizons, but these may be further subdivided. A simplified profile of a soil and its horizons is presented in Figure 1 below. Be aware that some soils have not developed a B horizon and have AC profiles.

- **O horizon** - an organic surface layer of plant remains not yet fully decomposed
- **A horizon** - the surface horizon or topsoil where most biological activity and root proliferation takes place. It is dark coloured and rich in organic matter and often lower in clay than the horizons below.
- **B horizon** - is a subsoil layer of lower biological activity and organic matter, but richer in clay minerals, iron and aluminium oxyhydroxides and is more dense
- **C horizon** - is the weathered parent rock unaffected by biological processes

Figure 1 Simplified profile of soil horizons

Soil profiles and their component horizons are defined and classified in the field according to their attributes, the most common ones being colour, texture (see 4.1.1), structure (see 6), accumulations, coarse fraction (see 4.1.1) and field pH (see 5.4). Australian standards of soil profile description and comprehensive designations of soil horizons are available in McDonald *et al* (1990).
3 SOIL CLASSIFICATION AND DISTRIBUTION

There are three (3) common soil classification systems used in Queensland:

1. Stace *et al.* (1968) 'A Handbook of Australian Soils';

2. Northcote's (1979) 'Key to the Recognition of Australian Soils'; and recently

3. Isbell's (1996) 'The Australian Soil Classification'.

Stace *et al.* (1968) describe 43 great soil groups using central concepts and type profiles. In the natural landscape however, many soils don't match any great soil group particularly well. Some commonly known great soil group names include black earths, red earths, solodic soils and yellow podzolic soils.

Northcote's key allows all soils to be placed in a hierarchy as an alphanumeric code, e.g. Ug 5.16, Dr 2.43. It has four primary subdivisions:

- O - organic soils
- U - uniform textured soils
- G - gradational textured soils
- D - duplex soils which reflect a texture contrast down the profile

In practice, this system has problems because it can separate quite similar soils at a high level, yet classify quite different soils as the same.

The most recent classification published is Isbell's (1996) 'The Australian Soil Classification'. This is also a hierarchical key but encompasses many concepts more relevant to the use of the soil and tries to link similar soils in its structure. In contrast to the other schemes it often requires laboratory analysis to place soils into classes. The system has been tested throughout Australia and was revised four times before its release this year. It has been endorsed nationally and all commonwealth and state agencies have agreed to adopt it. A summary of the 14 soil orders and their land use potential is presented in Table 1.

3.1 Engineering Classifications (adapted from Bridge and Probert, 1993)

These classifications take a materials approach to soils and avoid profile or genetic concepts. Major early systems were Atterberg (1913) and Casagrande (1947). Currently two schemes are in use and detailed in Kezdi (1973).

Firstly, the United States Bureau of Reclamation (1960) scheme is based on visual inspection and simple identification of particle size classes, that is, gravels, sands, silts and clays. Gravels and sands are subdivided according to the presence of 'fines' and grading. Silts and clays are subdivided according to dry strength, plasticity and dilatancy (swelling) and organic content. These tests give a qualitative assessment of the soil materials under load.
<table>
<thead>
<tr>
<th>Soil order</th>
<th>Brief description</th>
<th>Agricultural potential</th>
<th>Urban potential</th>
<th>Queensland cities and towns where encountered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthroposols</td>
<td>Man made soils</td>
<td>Low</td>
<td>Low to high</td>
<td>All urban areas</td>
</tr>
<tr>
<td>Calcarosols</td>
<td>Calcium-rich throughout</td>
<td>Low</td>
<td>Moderate to high</td>
<td>Cloncurry</td>
</tr>
<tr>
<td>Chromosols</td>
<td>Strong texture contrast ( \mathrm{I} ) subsoil ( \mathrm{pH} \geq 5.5 )</td>
<td>High</td>
<td>Moderate to high</td>
<td>Oakey</td>
</tr>
<tr>
<td>Dermosols</td>
<td>Structured subsoil ( \mathrm{II} )</td>
<td>Moderate to high</td>
<td>Moderate to high</td>
<td>Gatton, Boonah</td>
</tr>
<tr>
<td>Ferrosols</td>
<td>Structured subsoil, red or brown, high iron ( \mathrm{II} )</td>
<td>High</td>
<td>High</td>
<td>Toowoomba, Maleny, Atherton</td>
</tr>
<tr>
<td>Hydrosols</td>
<td>Prolonged seasonal saturation</td>
<td>Low-moderate</td>
<td>Low to moderate</td>
<td>Gold and Sunshine Coasts, Brisbane, Cairns, most coastal towns</td>
</tr>
<tr>
<td>Kandosols</td>
<td>Massive subsoil (structureless, coherent) ( \mathrm{II} )</td>
<td>High where water available</td>
<td>High</td>
<td>Cairns, Nambour, Palmwoods, Bundaberg, Weipa</td>
</tr>
<tr>
<td>Kurosols</td>
<td>Strong texture contrast ( \mathrm{II} ) subsoil ( \mathrm{pH} &lt; 5.5 )</td>
<td>Low to high</td>
<td>Moderate to high</td>
<td>Hills of Brisbane, Gympie, hinterland of Gold and Sunshine Coasts</td>
</tr>
<tr>
<td>Organosols</td>
<td>Organic rich soils</td>
<td>Low</td>
<td>Low</td>
<td>None known</td>
</tr>
<tr>
<td>Podosols</td>
<td>Subsoils comprise organic-aluminium and organic-iron compounds</td>
<td>Low to moderate</td>
<td>Low to high</td>
<td>Gold Coast, Sunshine Coast</td>
</tr>
<tr>
<td>Rudosols</td>
<td>Negligible soil development</td>
<td>Low</td>
<td>Low to high</td>
<td>Hills of Brisbane, Gympie, Gold Coast hinterland</td>
</tr>
<tr>
<td>Sodosols</td>
<td>Strong texture contrast, sodium affected ( \mathrm{II} )</td>
<td>Low to moderate</td>
<td>Low to moderate</td>
<td>Townsville, Mackay, Ipswich</td>
</tr>
<tr>
<td>Tenosols</td>
<td>Weak soil development</td>
<td>Low</td>
<td>Low to high</td>
<td>Hills of Brisbane, Gympie, Gold Coast hinterland</td>
</tr>
<tr>
<td>Vertosols</td>
<td>Cracking clays ( \geq 35% ) clay</td>
<td>High</td>
<td>Low to moderate</td>
<td>Dalby, Rockhampton, Redbank Plains</td>
</tr>
</tbody>
</table>

\( \mathrm{I} \) Strong texture contrast: sandy or loamy \( \mathrm{A} \) horizons abruptly overlie clayey \( \mathrm{B} \) horizon. \( \mathrm{II} \) Subsoil structure is seen as naturally forming aggregations of soil particles known as peds. \( \mathrm{III} \) Limiting factors other than soils may also affect potential land use eg climate, slope.
The second scheme is the 'Unified Soil Classification' based on Casagrande (1947). It is similar to the first scheme but is based on laboratory data. The first major division is on particle size sieve analysis into gravels, sands, silts and clays. Gravels and sands are then subdivided on the content of ‘fines’ and particle size grading. Silts and clays are subdivided according to their liquid and plastic limits (Atterberg limits) while organic soils are classified separately. Various formulas and graphs are presented in conjunction with the classification table. The scheme emphasises the prediction of the behaviour of saturated clays under loading for supporting structures, building dams and being held in retaining walls.

3.2 Soil Maps

Maps of soils are available throughout Queensland at various levels of accuracy, the reliability of a soil map being determined largely by scale. The Queensland Department of Primary Industries and CSIRO have published soil maps since the 1950s, and most are now preserved in geographic information systems (GIS).

In general soils of the intensive land use zone along the east coast are mapped in more detail (commonly 1:50 000 to 1:100 000 scale) than inland areas. The semi-arid cropping zone is mapped at greater detail (1:100 000 to 1:250 000 scale) compared to western and northern grazing lands (1 250 000 -1:500 000 scale). On a state and national basis there is the Atlas of Australian Soils published by CSIRO in 1968 at 1: 2 000 000 scale.

Soil maps can give a general indication of the soils present in an area, but detailed investigations are required to satisfy the location specific needs of an individual urban development. Blowing up and using soil maps beyond the scale at which they are published not only infringes copyright, it may also lead to misleading predictions of soil behaviour.

4 SOIL COMPONENTS

Soil is a complex material made up of four major components: mineral matter, organic matter, water and air. These components are intimately mixed and interact with each other so that it is difficult to draw a sharp distinction between them.

Figure 2 shows the typical composition by volume for two soils, a clay and a sand. The solid space is made up of mineral particles and organic matter. Soils have a porous fabric and Figure 2 shows that a considerable portion may be occupied by pores (around 1/3 and 1/2 for the sand and clay, respectively). The proportion of water to air in the pore spaces fluctuates widely according to the balance between addition of water during rainfall or irrigation and its removal by evapotranspiration and drainage.
Organic matter 1%

Organic matter 5%

Clay soil

Sandy soil

Figure 2 Composition of a clay soil and a sandy soil at average moisture contents

It is emphasised that the proportions of these components vary widely from soil to soil. For example, in a swamp or peat soil organic matter dominates the solid phase. Within a soil profile the subsurface horizons usually have lower contents of organic matter and air than the topsoil.

4.1 The Solid Phase

4.1.1 Particle size distribution of the mineral fraction

The mineral particles of soils vary enormously in size from large boulders and stones down to sand, silt and clay particles. Particles whose diameter is less than 2 mm are referred to as the fine earth fraction and are divided into sand, silt and clay fractions (Table 1). The particle size distribution or texture of a soil refers to the relative amounts of sand, silt and clay in the soil. Soils are assigned a texture class according to their relative amounts of sand, silt and clay.

<table>
<thead>
<tr>
<th>Particle size classes</th>
<th>Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel and stones (coarse fraction)</td>
<td>&gt;2</td>
</tr>
<tr>
<td>Fine earth: coarse sand</td>
<td>2 – 0.2</td>
</tr>
<tr>
<td>fine sand</td>
<td>0.2 – 0.02</td>
</tr>
<tr>
<td>silt</td>
<td>0.02 – 0.002</td>
</tr>
<tr>
<td>clay</td>
<td>&lt;0.002</td>
</tr>
</tbody>
</table>

Particle size distribution is determined in the laboratory by separating the soil particles from each other (dispersion) and determining their amounts by sieving and sedimentation methods. Particle size distribution is closely related to the texture of a soil, and an approximate indication of the particle size distribution can be obtained by assessing field texture. The soil
is moistened, moulded between the fingers and thumb until no aggregates remain and the soil is uniformly moist. The grittiness (indicative of sand), smoothness (indicative of silt), stickiness, coherence and plasticity (indicative of clay) of the soil are noted and, with practice, the soil can be assigned to a textural class (for example, clay loam). Experienced soil surveyors using the field texture method are able to obtain surprisingly good estimates of the laboratory measured percentages of sand, silt and clay.

Texture is one of the most important properties of soils affecting their use and management. To all intents and purposes it is a permanent property which cannot be readily changed.

4.1.2 Mineralogy of the fine earth fraction

It is important to note that the names listed in Table 1 apply to particle size classes and not to the type of minerals present in each class. This is sometimes made clear by the use of terms such as sand-size particles or clay-sized particles. However, a given size class in a soil may contain a mixture of mineral types and this is particularly the case for the clay fraction.

4.1.2.1 The clay fraction

The mineral components in the clay fraction are primarily clay minerals, sesquioxides, amorphous (non crystalline) minerals and clay size organic matter particles.

The clay minerals are crystalline hydroxy silicates (silicate clays) containing aluminium, iron and magnesium with other metallic elements present in small amounts. These alumino-silicate minerals are layered and are either 1:1 (a combination of a silica tetrahedral layer with an aluminium octahedral layer, eg. kaolinite) or 2:1 (an aluminium octahedral layer between two silica tetrahedral layers, eg. montmorillonite and illite). They are generally plate shaped, ranging in size down from about 2μm. The range of soil minerals that may occur in the clay fraction is large (Dixon and Weed, 1977) and identification and analysis of clay minerals requires sophisticated techniques such as X-ray diffraction.

In soils that have undergone long periods of weathering the clay fraction may contain appreciable quantities of sesquioxides. These are mainly oxides or hydroxides of iron and aluminium including gibbsite (Al(OH)_3), goethite (FeOOH) and haematite (Fe_2O_3). These minerals give weathered soils their red to brown colours, act as binding agents between clay particles and impart structural stability to soils in which they occur (eg. Ferrosols). Their surfaces commonly exhibit a strong sorption capacity for phosphate (see Section 5.5), nitrate and sulphate and soils with these minerals can remove these nutrients from effluent and reduce movement to the water table.

4.1.2.2 Sand and silt fractions

These fractions are dominated by minerals that are resistant to weathering such as quartz and the oxides and hydroxides of iron and aluminium. In temperate regions quartz may be the main mineral in this fraction unless the soil is formed on limestone in which case calcite and dolomite may dominate (eg. Calcarosols). In tropical regions iron and aluminium oxides and hydroxides are often the main minerals present and it is not uncommon to have sand and silt sized quartz coated with sesquioxides (eg. Kandosols).
4.1.3 Surface area of the solid phase

Compared to the sand and silt fractions, the clay minerals have a large surface area per unit weight, a property known as specific surface. For example, one gram of montmorillonite (a 2:1 clay mineral) has a surface area of around 700-800 m$^2$ compared to a value of about 0.01 m$^2$ for coarse sand particles. Their large surface area makes the clay minerals extremely reactive both chemically and physically. The physical and chemical properties of soils, and hence their management and land use potential, are determined largely by the clay fraction. Of great practical significance for land management in urban areas are the interactions between clay minerals and water and the constituents in the water.

Clays swell spontaneously when they come into contact with water. As they lose water on drying they shrink. Swelling and shrinking are most pronounced in montmorillonite due to its expanding crystal structure. Clay soils with high contents of montmorillonite develop wide, deep cracks on drying and are called cracking clays (Vertosols). Initially, water penetrates rapidly down the cracks but, because of swelling with water the cracks close and the soil becomes impervious. Such clays can form unstable foundations for buildings. Further details of this shrink-swell phenomena are discussed elsewhere in this training course (Wilson & McGarry, 1996).

4.2 Organic Matter

The organic components of soil all stem from the biomass (which consists of both non-living and living components) and all are carbon compounds. Figure 2 suggests that a clay soil may consist of around 5% organic matter but values of 2-3% are common in the surface of many Australian soils. The level of organic matter usually decreases quite markedly with depth below the soil surface. Despite the low levels of organic matter in most soils, it is responsible for the darkening of the surface soil, plays a major role in developing and maintaining soil structure, aids in water retention and acts as a reserve of plant nutrients. A relatively high organic matter level is desirable in any soil supporting plant growth.

The ‘end’ product of the decay of plant material in soil is known as humus and also includes organic matter produced by microbial synthesis. Humus makes up the bulk (about 95%) of the organic matter in soil. The chemical composition and structure of humus cannot be specified precisely, so a generalised chemical formula does not exist but the main constituents are carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur. The different types of humus vary mainly in the arrangement and frequency of certain functional (structural) groups which are largely responsible for the way organic matter interacts with constituents of the liquid phase. The predominant functional group is the carboxyl group which imparts acidic properties to the humus (see 5.4.1). The functional groups are also responsible for the development of negative charge on organic matter. On a unit weight basis the charge developed tends to be high and this has implications for the process of cation exchange (see 5.2).

An environmentally important feature of the structure of humus is that it has the capacity to form strong bonds (chelation complexes) with certain metals and thus has the capacity to
reduce the biological availability of heavy metal contaminants. For more detail refer to the paper by Williams and O'Connor (1996) in this training course.

Clay size minerals and organic matter (humus) are often closely associated (Figure 3). The significance of organic matter in this respect lies in its ability to form bonds between soil particles, particularly between sand grains and clay domains.

![Figure 3](Image)

**Figure 3**  
Diagrammatic representation of possible arrangements of clay domains, organic matter and quartz (sand) particles in a soil aggregate

Plant roots are probably the most obvious and significant component of the 'living' organic matter but a wide variety of organisms from viruses and bacteria up to small animals also occur in soils. The biological activity in soil is dependent on environmental conditions (eg. temperature, aeration, water availability) and the input of carbon from decaying plant material. In general, a soil that is biologically active is also one that is a good medium for plant growth.

Organic matter is usually measured by determining the carbon (C) content (%) in the soil. In most soils about 58% of organic matter is carbon. A soil test result expressed as %C can be converted to organic matter % by multiplying the %C by 1.72.

### 4.3 Biological Components

The living components of soil, the biota, are fundamental to the development and maintenance of the soil ecosystem. They play very important roles in incorporation of organic matter, decomposition, nutrient cycling and mineralisation (eg. conversion of organic nitrogen to inorganic nitrogen), and in the development and maintenance of structure. Soil organisms may be classified into three groups, on the basis of size: (i) the microbiota (<0.2 mm), including the bacteria, fungi, algae, protozoa and viruses; (ii) the mesobiota (0.2 - 10 mm), including smaller arthropods and nematodes, and (iii) the macrobiota (>10 mm),
including earthworms, molluscs and the larger arthropods. Plant roots are often included as components of the macrobiota as they are important contributors to the soil ecosystem.

When considering the soil biota in relation to development of soils for urban and industrial use, it is clear that the extent of stress (e.g. pollution) and disturbance (e.g. excavation, trampling) will determine the size and composition of the soil biota. Many of the characteristics of urban soils following development (e.g. compaction, presence of surface crust, modified pH, restricted aeration and drainage, modified temperature regimes, presence of contaminants) will have negative effects on the biology of soils. Most studies of biota in urban areas report reduced numbers of organisms and species diversity.

4.4 The Gaseous Phase

The two most important reactions involving gases in soils are biological and are (i) the respiration of plants and (ii) the decomposition of organic residues by micro-organisms. Each of these processes utilises oxygen and generates carbon dioxide. This causes the soil air to contain 10 to 100 times the concentration of carbon dioxide that is found in the atmosphere. Soil aeration is the process of gas exchange whereby oxygen is replenished to the soil air preventing oxygen deficiency and carbon dioxide toxicity. The amount of oxygen gas in a soil is depends on the quantity of air-filled pore space (see Section 5.1). Situations that may result in poor aeration include excessively high moisture content for extended periods, and the absence of sufficiently rapid exchange of gases with the atmosphere. In soils with high clay contents and poor structure, and in compacted soils, the rate of gaseous movement is often very low. Moreover, such soils allow slow penetration of water in to the soil. This prevents the rapid escape of carbon dioxide and the subsequent inward movement of atmospheric oxygen.

4.5 The Liquid Phase

Although the liquid phase will contain dissolved constituents accessible to the biological system, soil water is the principle component because of its requirement by plants. Soil water also provides the means by which contaminants can move through the soil and affect the environment.

In unsaturated soil the water is held under a negative pressure (tension) referred to as matric potential. Plant roots have to exert a greater tension than this to extract water from the soil. Therefore it is the relationship between the water content of the soil and the matric potential, not just the actual amount of water present, that is of relevance for plant growth. The point at which a plant is damaged by water stress so that it doesn’t recover when watered is known as the permanent wilting point. This is operationally defined as the water content of the soil at a matric potential of -1500 kPa.

The upper limit of water that is held in soils and which is available to plants is the field capacity. The field capacity is taken as the water content at any point in the profile that has just ceased draining. Since there can be no precisely defined endpoint to drainage, the definition of field capacity is imprecise but the concept is an extremely useful one. The water content of the soil at a matric potential of -10 kPa is often taken as an operational measure of field capacity.
The available water capacity is the difference between field capacity and wilting point and represents a reservoir that plants rely on for a supply of water. The size of the soil reservoir is called the profile available water and is determined by the rooting depth and the available water capacity of each layer of soil in the rooting zone. The available water capacity tends to be highest for soils of intermediate texture (loams to clay loams), although the soil structure (see 6) is also important.

5 PRINCIPLES OF SOIL CHEMISTRY

The soil system is composed of three phases: solid, liquid and gas. The composition and chemical behaviour of the liquid and gas phases are determined by chemical interactions with the solid phase. These chemical interactions occur mainly at the surface of the solid phase. A knowledge of the surface chemistry of soils is of significance since these reactions affect the composition of the aqueous phase interacting with the environment.

Soil chemical processes (together with biological activity) play a major role in governing the availability of nutrients essential for plant growth. At present there are 19 elements considered essential for the growth of higher plants. Three of these elements, carbon, oxygen and hydrogen, are obtained from air and water whereas, the remaining 16 elements are obtained mainly from the soil. Nitrogen, phosphorus, potassium, calcium, magnesium and sulfur are required in relatively large quantities (macronutrients), whereas iron, manganese, copper, zinc, boron, molybdenum and chlorine are needed in small quantities (micronutrients). All of these nutrients are taken up by the plant as electrically charged ions from the soil solution.

5.1 Electrical Charge on Soil Clays

Many of the minerals in the clay-sized fraction are crystalline. As with most crystals, the clay minerals are imperfect crystals and, during their formation, some of the silicon (Si$^{4+}$) atoms in the tetrahedral layer are substituted for by ions of similar size (usually aluminium, Al$^{3+}$). Similarly, some of the aluminium atoms in the octahedral layer are substituted for by magnesium (Mg$^{2+}$), without disturbing the crystal structure. This process is referred to as isomorphous substitution and gives rise to a permanent negative charge in the clay mineral.

Organic matter also carries a negative charge which increases with increasing pH. The source of this charge is the ionisation of functional groups (principally carboxyl groups) on soil humus.

The edges of the clay plate and the surfaces of iron, aluminium and manganese oxyhydroxides have hydroxyl groups (OH) that are only partially bonded. These hydroxyl groups can carry either negative or positive charge depending on whether the surrounding medium is either alkaline or acidic.

Despite the electrical charges carried by soil particles nobody receives an electrical shock when handling soil. The charges carried by the soil are balanced by charged ions from the soil solution to maintain electroneutrality. Apart from saving home gardeners from the
5.1.1 Cation exchange

The negative charge on clay-sized particles is electrostatically balanced by cations (positively charge ions) from the aqueous phase. Since these adsorbed cations can interchange with other cations in solution they are referred to as exchangeable cations. The process of cation exchange is rapid and proceeds according to the law of mass action. Increasing the amount of a cation in the aqueous phase leads to an increase in the amount of cation electrostatically held on the clay. Calcium (Ca++), magnesium (Mg++), potassium (K+) and sodium (Na+) are the most common exchangeable cations in soils and their relative abundance in surface soils is usually Ca++ > Mg++ ≫ K+. Sodium is commonly low excepting in some soils described as sodic. In strongly acidic soils (pH less than 5.5) aluminium (Al+++ ) and hydrogen (H+) ions may be the dominant cations on the exchange complex.

The cation exchange capacity (CEC) of a soil is the sum total of exchangeable cations that a soil can adsorb. The CEC is a measure of the degree of development of negative charge on soil constituents (clay minerals and organic matter) and is an important soil property as the ions balancing this charge are available for plant uptake. Thus essential plant nutrients such as calcium (Ca+), magnesium (Mg+), and potassium (K) will be held on the exchange capacity against leaching but are available to plant roots. A measure of CEC provides an indication of the overall fertility status of the soil.

Knowledge of the CEC, together with measurement of clay and organic matter contents, can also provide information about the relative contribution of clay minerals and organic matter to the fertility status of the soil. In weathered and sandy soils where the CEC is largely determined by organic matter the management of soil organic matter levels is needed to maintain fertility.

5.1.2 Anion exchange

In silicate clay systems, the proportion of positive charges present on the solid surfaces is small. In these situations anions (negatively charged ions) such as nitrate and chloride in the soil solution are not held in great quantities and are liable to be leached. However, in acidic, weathered soils, where kaolinite and sesquioxides are the dominant clay minerals, the proportion of positive charge to negative charge is higher. The positive charges make possible exchange reactions of anions such as nitrate, chloride, sulphate and phosphate. The mechanism depends on soil pH (see 5.4) and is usually of significance in clays with iron and aluminium oxide minerals.

5.2 Dispersion and Sodicity

As previously discussed, there are attractive forces between clay size particles that give rise to structural units in the soil (Figure 3). However, the net negatively charged nature of clay sized particles also means that there are repulsive forces between the particles. The nature of the cation (positively charged ion) that balances the negative charge on the clay largely determines which of the attractive or repulsive forces dominates. When the exchangeable
cations carry a single charge (eg. sodium, Na⁺) repulsive forces between the clay particles cause them to move apart. When wet the clay particles exist as separate entities and the clay is said to be dispersed. When the adsorbed cations carry a double charge (eg. calcium, Ca²⁺) attractive forces dominate between the clay, particles come close together, form stable aggregates and the clay is described as flocculated. This is the reason gypsum (calcium sulphate) is added to dispersive soils to ameliorate undesirable physical characteristics.

Soil sodicity is a concept centred around the proportion of sodium ions (Na⁺) relative to other cations in the soil. Sodium ions occur in the soil either dissolved in the soil water (soluble) or as exchangeable cations held by the negatively charged surfaces of clays and organic matter. Soils receive sodium from rainfall and irrigation water, depositing sediments and from weathering of parent rocks and sediments.

Sodic soil materials are dispersive, tend to form surface crusts, set hard and have poor internal drainage. Such soil materials are a poor medium for plant growth. Dispersion is an undesirable characteristic since dispersed clay is transported by rainwater into pores and blocks their openings. Water infiltration into the soil is drastically reduced and the soil becomes waterlogged during heavy rains.

Another consequence of sodicity and dispersion is that affected soils tend to be extremely vulnerable to erosion by runoff water. Dispersion contributes in two ways. Firstly, the formation of a surface crust lowers water infiltration and increases runoff. Secondly, the small dispersed clay particles are readily entrained by runoff and rainfall splash effects and swept away. Severe gully and tunnel erosion are common symptoms of dispersive sodic soils. When wet, the soil ‘melts like sugar’ according to many farmers.

In the urban development environment, an estimate of sodicity of soil materials is important to manage soil erosion and the establishment of plants, especially for recreational grasslands.

The most common measure of sodicity used in Queensland is the exchangeable sodium percentage (ESP) defined as follows:

\[
ESP = \frac{\text{Exchangeable Na}^+ \times 100}{\text{Cation Exchange Capacity}}
\]

Another measure of sodicity commonly used in the literature is sodium adsorption ratio (SAR). This is calculated as follows:

\[
SAR = \frac{\text{Exch Na}^+}{\sqrt{\text{Exch Ca}^{2+} + \text{Exch Mg}^{2+}}}
\]

The critical limit as to what ESP value defines a sodic soil with poor physical properties is the subject of much debate. This is because a number of other soil properties can also impact on clay dispersion. Higher salinity (electrolyte) levels in the soil can reduce the tendency of a sodic soil to disperse. The sodic soils in Queensland with a significant dispersion problem are usually all low in salinity because of leaching by rainfall or irrigation water. The critical limit accepted by many soil scientists in Queensland is an ESP >6 or SAR >3.
The amount and type of clay present also affects the dispersion impact of ESP. Very sandy soils with <10% clay and soils with very low CEC may have high measurable ESP. However, its impact on soil structure may be minimal as either the clay content is too low or the exchangeable surface available on the clay is too small.

Other factors with a moderating influence on the impact of sodicity are the presence of biologically active organic matter, higher exchangeable calcium relative to exchangeable magnesium and very high proportions of swelling clay minerals such as montmorillonite (Sumner, 1993).

In a review of sodic soils in Queensland, Shaw et al. (1994) concluded that soils with mixed clay mineralogy are most sensitive to sodium and, on the basis of particle packing, will form the least permeable soil matrix if the clay content is around 40-50%. In soils where sodium is naturally present, such as Sodosols, Vertosols, Chromosols and some Hydrosols, ESP increases with depth to a maximum in the subsoil. In Sodosols, ESP exceeds 6 in the upper B horizon, whereas Chromosols have high ESPs in the lower B horizon only. Hydrosols and Vertosols are more variable in sodicity with some forms being sodic throughout while others are only sodic at depth.

Management of sodic soils in an urban development context requires an understanding of sodicity and how to treat it. Sodicity can be tested for in the field using the Emerson dispersion test (Emerson, 1967) or the modified version of Loveday and Pyle (1973), but sodicity can only be measured properly in the laboratory. Because sodic soil materials are expensive to treat, it is advisable to bury and cover them as deeply as possible.

If sodic soil materials are to be left exposed or at shallow depth, they can be treated by adding a source of calcium to displace the sodium. Gypsum (calcium sulphate) is usually used, as it is soluble and thus reacts readily with all soils. In acid soils hydrated lime may be just as good a source of calcium, and additionally may correct a potential low pH problem.

More detailed management suggestions for sodic soils are provided in other papers in this training course.

An aspect of relevance to management of sodic soils for urban development is that the dispersive effect of sodicity is amplified by mechanical disturbance (Sumner, 1993). Cultivation and heavy machinery may reverse the positive effects of organic matter on soil stability.

5.3 Adsorption/Desorption

The processes of cation and anion exchange depend upon electrostatic attraction between the ion and the solid surface and are reversible. In oxide soils, however, phosphate, and to a lesser degree sulphate, have a chemical affinity for atoms (iron, aluminium, manganese and silicon) in the surface of the solid mineral. The formation of a chemical bond between a phosphate ion from solution and the solid surface is referred to as specific adsorption. Such a bond represents a much stronger retention of the anion than is the case for anion exchange although both processes are adsorption reactions. Phosphorus retained by specific adsorption in soils is relatively unavailable to the plant. In agriculture, specific adsorption of
phosphorus is generally regarded as an undesirable soil characteristic since it reduces the amount of added phosphorus fertiliser available to the plant. The environmental significance of specific adsorption is that the phosphorus is removed from solution, retained by the soil and the amount released to the environment reduced.

In practice there are a range of mechanisms and bond strengths that account for the retention (adsorption) of ions on the solid surfaces in soils. The adsorption process is not entirely irreversible and specifically adsorbed ions can be desorbed into soil solution depending on environmental conditions. The capacity of a soil to adsorb and desorb ions such as phosphate can be ascertained by laboratory tests and these allow calculation of loading rates for land disposal of effluents.

5.4 Soil Acidity and Alkalinity

A measurement of soil pH is usually the first test made on a soil sample and it is probably the most commonly measured soil property. The determination of pH is actually a measurement of the activity (concentration) of hydrogen ions in solution and pH is defined as the negative logarithm of the concentration of hydrogen ions. A neutral solution (for example, pure water) has a pH of 7. An acid soil is one which, when equilibrated with water, gives an acid reaction (pH < 7). An alkaline soil is one having a pH > 7.

Soil pH is used to measure the extent of acidity or alkalinity in soils. Although the pH scale ranges from 1 to 14, most soils have pH values between 3.5 and 9 (see Figure 4).

![Figure 4 Soil pH ranges](image-url)
Interest in the measurement of pH in soils arises because it has a long recognised effect on plant growth through its influence on (i) nutrient availability and (ii) the presence of toxic ions in the soil water. Soil pH is strongly correlated to the availability of all of the essential plant nutrients. The reasons for these correlations are complex, but it is sufficient to say that the availability of plant nutrients is at a maximum in the pH range 6 to 7 with problems arising in both strongly acidic and strongly alkaline soils. Soil pH is also of relevance in planning for urban development because it will have an impact on the mobility of contaminants in the environment. If restriction of the movement of contaminants is the main priority then the optimum soil pH could well be markedly different from that appropriate for plant growth and it would be best to consult a soil chemist.

Caution needs to be exercised when interpreting soil pH measurements as there are different methods in use for measuring soil pH. The ideal pH measurement would be that of the soil solution in the field (since this is the pH of the plant root environment) but this presents practical problems. The usual procedure is to make a water or dilute salt suspension with the soil and measure the pH using an electrode and meter in the laboratory. Soil pH values determined with dilute salt solutions are usually lower than those measured in water. It is therefore important to note the procedure used and/or consult an expert when interpreting soil pH values.

5.4.1 Source of acidity

A number of sources contribute to the development of acidity (hydrogen ion input) in soils. The main sources are (i) carbonic acid in water formed by the dissolution of carbon dioxide gas from the atmosphere in rainwater and the respiration of plant roots, (ii) acids produced during the decomposition of organic residues, (iii) oxidation of ammonium ions, (iv) leaching of anions and (v) oxidation of sulphide minerals (discussed in detail in the next paper, Smith and Ahern, 1996).

A large portion of the hydrogen ions (H⁺) present in soils will be initially held as exchangeable ions. However, the high hydrogen ion concentration adjacent to the clay particle means that the clay is subjected to a very acidic environment. This causes the clay to decompose with a release of aluminium (Al⁺⁺⁺) from the clay mineral. The aluminium released is then held as an exchangeable cation. In strongly acidic soils (pH < 5.5) aluminium and hydrogen ion effects predominate; aluminium is often the predominant exchangeable cation and there are usually lesser amounts of hydrogen. Both aluminium and hydrogen ions contribute to acidity in soils.

When the soil pH is low, the solubility of aluminium and manganese increases so that there may be appreciable amounts of these in solution. Both aluminium and manganese can be toxic to plants and high levels of one or both of these are often responsible for poor plant growth on strongly acidic soils. The biological availability of heavy metal contaminants is also greater at low pH.
5.4.2 Alkalinity

An absence of extensive leaching during soil development leaves the cation exchange capacity dominated by calcium, magnesium, potassium and sodium. These cations tend to give the soil an alkaline reaction. If calcium and magnesium are dominant the alkaline effect is relatively weak and soil pH values will be in the range 6.5 - 8.5. Soil pH values above 7 are commonly associated with the presence of carbonates in the soil. Soils containing free calcium carbonate have pH values (measures in water) of between 7 and 8.5. A pH value in excess of 8.5 usually indicates the presence of significant amounts of exchangeable sodium and the soil pH may be as high as 9 or 10 (see Figure 4). Since high sodium levels in the soil are detrimental to soil structure (see Wilson and McGarry, Chapter ??) a pH value in the range 8.5 -10.5 raises the possibility of soil structural problems. However, a neutral or acidic pH value does not necessarily exclude the presence of excess sodium.

5.5 Soil Salinity

A soil property commonly measured is the electrical conductivity (EC) of a soil:water extract. This measurement is a convenient method of determining the level of soluble salts (salinity) in the soil. Saline soils contain sufficient soluble salts to restrict plant growth and the soluble components are largely made up of chloride and sulfate salts of sodium, calcium and magnesium. Salinity is discussed in further detail by Wilson and McGarry in Chapter ??.

6 SOIL PHYSICAL CONDITIONS

Weathering of parent material produces mineral particles ranging in size from stones, gravel, sand, silt to clay. The solid particles are rarely found as separate units except in very sandy soils. Rather, the individual particles are bound together to form units of soil structure known as soil aggregates or peds (see Figure 3). Soil structure refers to the size, shape and arrangement of aggregates. The aggregates are separated by pores or voids and by natural lines of weakness; pores also occur within aggregates.

Although soil structure has a profound impact on the physical processes in soils (for example, water movement), it is described in qualitative terms and cannot be measured quantitatively. In some soils, eg. Vertosols, soil structure alters dramatically with changes in moisture content. It is possible, however, to measure other soil properties closely related to structure, such as porosity and bulk density.

6.1 Bulk Density, Porosity and Air-filled Porosity

Bulk density is a measure of how closely the soil particles are packed together and is defined as the weight of a unit volume of dry soil. In this case, the entire soil volume (volume of solids plus the volume of pores) is taken in to account and bulk density is expressed in units such as g cm$^{-3}$ or t m$^{-3}$. The main factor affecting bulk density is the packing arrangement of the soil particles, which is determined by soil structure. Two soils can have the same texture, mineralogy and organic matter content, yet their bulk densities may be very different. One of the soils may be loose and porous imparting a low bulk density whereas the other soil may have little or no structure, closely packed particles, with a resultant high bulk density.
The bulk density of surface sands and loamy sands usually ranges from 1.20 to 1.80 g cm$^{-3}$, depending on structural condition. The usual range for clay loams and clays is 1.00 to 1.60 g cm$^{-3}$. Bulk density usually increases with depth and values as high as, or even in excess of 2.0 g cm$^{-3}$ occur in compact subsoils. Permanently wet soils may comprise up to 80% water and have low bulk densities ranging from 0.6 to 0.8 g cm$^{-3}$. These soils have no discernible structure and will only develop structure on draining and drying. On drying these soils shrink irreversibly in a process known as soil ripening. Such soils may subside unevenly causing problems for urban development (see Wilson & McGarry, 1966).

Total pore space is the volume of soil occupied by air and water. This porosity, the volume of pores per unit volume of soil, is usually expressed as the volume percentage of the total volume (pores plus solids). Porosity is less commonly reported than bulk density in soil test results. However, porosity can be estimated from bulk density if an assumption is made regarding the particle density. The particle density is the density of solids and is expressed as the weight of solids per unit volume of solids. For the majority of soils that do not contain large amounts (> 4%) of organic matter the density of the solids lies within a narrow range (2.55 - 2.75 g cm$^{-3}$ ) and is usually taken as 2.65 g cm$^{-3}$. Thus, porosity can be calculated from bulk density by:

$$\text{Porosity} = 1 - \left(\frac{\text{Bulk density}}{\text{Particle density}}\right)$$

Not only is the total porosity of importance but the distribution of pore sizes has a major impact on the movement of water into and through the soil. In general, soils of high clay content have greater porosity than sandy soils. Everyday experience, however, shows us that water moves much faster into and through sandy soils than a clay soil. This arises because of the size of pores in each soil. Bulk density allows calculation of the total pore space but it gives no indication of the pore size distribution, which depends on detailed geometry of structure.

The pore volume not occupied by water is filled with air and the volume percentage of the total volume occupied by air is referred to as the air-filled porosity (volume of soil air/total volume). Other terms used include air capacity, air space and air porosity. The air-filled porosity is obviously dependent on the water content and can be calculated from porosity and the volumetric water content as:

$$\text{Air-filled porosity} = \text{Porosity} - \text{Volumetric water content}.$$  

An air-filled porosity of around 10% (0.10 cm$^3$ cm$^{-3}$) is generally considered to be the minimum necessary for adequate aeration for plant roots.

Soil compaction is the process of reduction in the porosity (or an increase in bulk density) of a soil. Although this process often occurs as a result of surface loading from traffic or raindrop impact, it is important to realise that soil which has been loosened may also undergo compaction as a result of settling and/or slumping. Settling can also occur as a result of cycles of drying and wetting (shrinkage and swelling) that allows aggregates to pack progressively more closely together. Slumping occurs when soil aggregates weaken as a result of wetting so that disintegration of the aggregates allows closer packing.
A knowledge of soils is an essential tool to meet the physical challenges of urban development. This introduction to soil science aims to provide some basic understanding of principles together with an appreciation of its' complexity.

As apparent in this chapter, there are many subdisciplines to soil science, and various sources of specialist advice may be required for a development. Any particular development may have a requirement for a soil inventory to identify and select better areas and avoid potential problems, a soil fertility and stability assessment to revegetate areas, and/or a management plan for contaminants, acid drainage, sodic soils, salinisation, effluent disposal and erosion control.

The Australian Society of Soil Science Incorporated (ASSSI) has a national membership of about 850, with the biggest State Branch being Queensland with 212 members. Members are present in both government and private employment, and in recent years more soil specialists with an environmental focus have joined the Society.

When seeking advice on soils for urban development, it is recommended that soil science professionals with recognised qualifications and having membership of the Australian Society of Soil Science be enlisted. Accreditation of soil scientists is soon to be implemented throughout Australia and this will act as an additional criteria on which to judge the quality of potential advisers.

8 REFERENCES


**Further Reading**


ACID SULFATE SOILS - A CONSTRAINT TO QUEENSLAND 
COASTAL DEVELOPMENTS?

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ABSTRACT

It was not until the late 1980's that the environmental impacts of acid sulfate soils (ASS) gained popular acceptance. Fish kills in the Tweed River were directly linked to acid water discharges particularly from flood mitigation drains emanating from cane lands. While acid discharges from such areas is a natural phenomenon, drainage and disturbance of such soils has increased the severity of the impacts. ASS are commonly found in coastal lowlands throughout the world. Their extent in Queensland is largely unknown. In NSW, extensive areas were found in most coastal valleys during recent ‘ASS risk mapping’. Generally these soils are confined to landscapes with elevations of < 2m, Australian Height Datum (AHD), although they can be overlain by several metres of recent alluvium. Problem land uses include land clearing and drainage for agriculture, canal construction, dewatering, dredging and extractive industries. The severity of the impacts of ASS in a particular area depends on the physical and chemical nature of the sediments, the quantities of material to be disturbed, sensitivity of adjacent waterways and the local hydrology influencing off site transport. There are a number of ways of managing ASS including avoidance, prevention of oxidation, neutralisation, oxidation and treatment of leachate and reflooding ASS soils.

KEYWORDS: acid sulfate soils, coastal wetlands, fish kills, drainage.

1 INTRODUCTION

Acid sulfate soils are characterised by production of acid from soil pyrite (FeS₂) oxidation that exceeds the neutralising capacity of the soil and the pH drops, usually to <4. The often lethal cocktail of acid, iron and aluminium produced usually leaks into waterways, contaminating streams, rivers and estuaries, resulting in fish kills and destruction of other biota. While pyrite oxidation and acid generation are natural processes, their potential environmental impact can be greatly increased by man’s activities through increased exposure of ASS to oxidising conditions.

A potential acid sulfate soil (PASS) is one in which the pyrite in the soil has not yet been oxidised. As PASS are usually confined to anaerobic conditions and are found at or below the permanent watertable, they are often overlain in the upper profile by actual acid sulfate soils (AASS). When PASS occur without AASS they are more difficult to detect because they may have neutral or alkaline reaction (pH 7 or greater). In this paper, the term ASS will normally include PASS as well as AASS.
Until the late 1980's, ASS were rarely recognised for their environmental impacts, even by soil experts, in Australia (Smith, 1989). A number of major fish kills in the Tweed, Richmond and other coastal rivers of New South Wales (NSW) attributed to ASS changed this and set the scene for increasing confrontation between fishermen, farmers, developers and conservationists (Buckley et al., 1993). Scientists responded to community and government needs for more information Australia-wide, by conducting a National Conference on ASS, held on the Gold Coast (Bush & Smith 1993). Representatives from local government, fishing and farming industries, engineers, planners and resource managers, identified the need for greater care in the management of coastal lowlands likely to contain ASS.

The NSW Department of Land and Water Conservation (DLWC) has recently completed 1:25,000 scale 'ASS risk maps' for the entire NSW coastline showing that ASS distribution is widespread in coastal lowlands. The Minister for Agriculture and Fisheries regarded the issue seriously enough to warrant the formation of the ASS Management Advisory Committee (ASSMAC), and a technical committee (ASSMACTC) to coordinate activities across departments and produce a number of guidelines for identification and management of ASS (e.g., NSW EPA, 1995).

Queensland (Qld) is somewhat behind these NSW initiatives, even though there are probably greater areas of ASS in Queensland. The Qld Department of Primary Industries (QDPI), with funding assistance from the National Landcare Program (NLP), commenced mapping ASS in south east Qld in early 1996. Some small areas have already been mapped in north Qld, particularly around Cairns. The Qld Acid Sulfate Soil Investigation Team (QASSIT) is producing draft guidelines for identification, sampling, analyses, and reporting of ASS for environment impact statements (EIS) in Qld.

This paper outlines the nature of ASS occurring in low lying coastal environments, their formation, impacts arising from their drainage and disturbance and possible management options. It also examines how to design and undertake an ASS investigation as a prerequisite to developments such as drainage, soil disturbance, road works, extractive industries, or interference with water levels in coastal lowlands likely to have ASS. The paper does not deal with acid wastes from mining or quarrying pyritic rock material.

2 ASS AND THEIR FORMATION

ASS occur in coastal areas throughout the world, but do not pose a problem unless drained or excavated and allowed to oxidise. Oxidation can arise as a result of the development of land for purposes of agriculture, construction of roads, urban development and a range of other man-made influences. The exposure and oxidation of these soils can result in significant releases of sulfuric acid and increases in the concentrations of associated aluminium and iron, all of which can be extremely detrimental to aquatic and terrestrial life (Dent, 1986).

ASS form in estuarine areas typically associated with mangroves. Over the last 6,500 years, most of Australia's coastal flood plain has contained mangroves, salt marshes and estuarine plant communities which were ideal settings for pyrite production. The Queensland coastal flood plain is likely to be highly variable in ASS potential, ranging from relatively extensive
areas of high risk estuarine clays to low risk marine sands. Generally the worst ASS conditions are associated with estuarine clays.

ASS are formed from the accumulation of pyrite (FeS$_2$) in estuarine sediments where a supply of organic matter, together with sulfur from seawater and iron from terrestrial sediments are combined by bacteria (see Fig 1) to produce pyrite, which is the reactive component. Pyrite is stable until exposed to oxygen and moisture whereupon it produces sulfuric acid (Fig 2).

![Pyrite formation in estuarine sediments](image)

**Figure 1** Pyrite formation in estuarine sediments (Source: Smith *et al.*, (1995))

ASS are generally found at or below 2m AHD (Australian Height Datum = mean tide) in a soil profile and can extend to a depth of 4 or 5m or more below the surface. They can also be overlain by several metres of recent alluvium adjacent to major rivers and streams.
While sands generally contain lower levels of pyrite than estuarine clays, they can pose a substantial short-term environmental hazard if disturbed or drained, because the pyrite in sands can oxidise rapidly, leaching acid, iron and aluminium readily into waterways.

Sands also have poor buffering capacity, which means they are unable to neutralise the acid before it is leached from the profile. Buffering is generally afforded by the presence of calcium carbonate in the form of sea shells, but also from clay which consumes acid and releases aluminium and iron (Fig 3). It takes three times the quantity of calcium carbonate to neutralise an equal quantity of pyrite. However, coarse shells tend to develop an insoluble outer skin, which limits their neutralising capacity.
3 IMPACTS ARISING FROM ASS

ASS have the potential to seriously impact the fauna and flora both on and off site. The degree of impact depends on:

- the nature of the disturbed environment;
- the extent of the development;
- whether the development is major or minor, dispersed or concentrated;
- the nature of the adjacent waterways;
- the concentration and mobility of acid, aluminium and iron;
- local hydrology and ground water systems; and
- the sensitivity of the receiving waters and their biota.

Aluminium is known to kill fish and other estuarine aquatic life (Sammut & Melville 1994). Iron is also a major problem as it is mobilised from ASS and precipitates in estuaries coating aquatic biota and their habitat. Iron has been shown to coat fish eggs and clog fish gills causing suffocation. Iron may persist for long periods, seriously impairing ecosystem recovery long after pH increases to acceptable levels. It has been implicated in the loss of seagrasses and other macrophytes.

ASS may, if disturbed and not properly managed, lead to fish kills. Where possible, fish will avoid acidified waters, but on occasions are unable to do so if the extent of acidification is so severe as to trap them. Most of the highly publicised fish kills in Australia were recorded in coastal rivers and estuaries of NSW, particularly in the lowlands used for grazing and sugarcane production on the Northern Rivers.

While Queensland has received little publicity, many fish kills have occurred, particularly associated with disturbance of ASS in canal developments. The Pimpama River and estuary recently suffered a massive fish kill associated with the breaking of an extended drought in November 1995. Shortly after the event, the river water flowing over the barrage was measured at pH = 3.7. Water draining from a canal development below the barrage was measured with pH < 2. Fish are generally affected at pH<5.

Acidification of water leads to a reduced ability of aquatic organisms to control their body ions and water balance and this may cause mortality (Sammut & Melville 1994). Reproduction, recruitment and growth of fish and aquatic organisms can also be affected by acidic water and associated increases in aqueous aluminium and iron concentrations.

Habitat degradation can be a direct and indirect impact of acidification. The immediate response of fish to acidified water is to avoid it and seek out other habitat which may not necessarily suit their requirements. This exposes them to increased risk of predation and also increases the pressure on the remaining resources and the potential for disease outbreak.

Acidity may persist after heavy rainfall because of reduced acid-neutralising capacity of diluted tidal waters. This can cause long-term habitat degradation and affect ecosystem recovery. The estuarine systems, particularly those which are poorly flushed with tidal water and seasonally have low salinities, are considered particularly vulnerable to acid water discharges (Willet et al., 1993).
Red spot disease in fish is widespread throughout estuarine areas of eastern Australia and is characterised by red skin ulcers appearing on fish rendering them unsaleable. Research indicates that acid waters increase susceptibility of fish to fungal infections leading to such ulceration (Callinan et al., 1993).

Drainage of ASS for pasture or sugar cane production has sometimes been a futile exercise because of soil acidification and associated high concentrations of soluble iron and aluminium. In many instances, drained areas have been invaded by acid-tolerant plants such as *Casuarina* spp. unless subject to vigorous land management.

Major problems have been encountered by landscapers attempting to grow mature transplanted trees in ASS affected areas. Major golf course developments have suffered significant plant losses attributable to ASS.

Estuarine peat can pose a significant problem for landscaping because of the presence of pyrite and the associated risk of severe acid conditions. Peat may also lower pH as it can generate organic acids. Drainage and development on low lying peaty soils can be disastrous as major shrinkage can occur on drying (particularly fibric peat), causing physical damage to structures.

Substantial engineering problems have arisen with concrete structures being corroded by acid from ASS, including bridge pylons, building foundations, storage tank emplacements, flood mitigation structures and water supply and sewerage pipelines.

There is evidence that human health can be seriously impacted by consumption of acidified water high in aluminium. Graziers are acutely aware of the poor performance of cattle forced to drink such water.

### 4 PROBLEM LAND USES

Human activities with the potential to impact on the environment through disturbance or drainage of ASS include:

- agriculture;
- canal and artificial lake construction;
- land clearing and draining;
- de-watering;
- dredging;
- extractive industries;
- foundation construction; and
- peat removal.

To avoid environmental damage from ASS, such changes in land uses require a site assessment to determine the nature and extent of the problem before undertaking development design.
5 SITE ASSESSMENT

The assessment of ASS on a particular site proposed for development may involve:

- desktop assessment
- local site/land characteristics and site inspection;
- profile (soil hole/pit) characteristics;
- field tests;
- sampling;
- laboratory analyses;
- assessment of preliminary data and further sampling if ASS are present;
- generation of draft map defining the soil chemistry;
- the preparation of a detailed site assessment;
- developing management and monitoring strategies consistent with site constraints;
- the implementation of pilot projects to test the management strategies to prevent the release of acidic water and other toxic substances; and
- implement a monitoring program and have a plan to cater for worst case scenarios.

Preparation of a site assessment involves the following stages:

5.1 Desktop Assessment

This is relatively cheap and can assist in determining the likely presence of ASS. It involves consulting/collecting appropriate aerial photos, satellite imagery, maps and information on geomorphology, soils, geology, height above mean sea level vegetation, land use, hydrology, and any soil or water analyses previously done in or around the area. Computerised digital terrain models (DTM) based on accurate low level aerial photography are particularly useful.

Aerial photography can be used to identify geomorphic features such as old sand dunes, bare areas, vegetation types and areas of previous sediment deposition in the landscape. The following geomorphic criteria assist in determining whether ASS are likely to be present:

- sediments of recent geological age (Holocene);
- marine or estuarine settings; and
- landscapes not more than 5 m AHD.

If activities are proposed on soils developed from non sedimentary deposits eg. hard rock, or if the land surface is more than 5 m AHD (and no deep excavation is proposed) then only simple field/site verification will generally be required.

5.2 Local Site/Land Characteristics and Site Inspection

This should be carried out for indicators of actual acid sulfate conditions using one or a combination of the following criteria:

- extremely acid (pH<4) water on the surface, in drains or groundwater;
- iron-stained (orange-brown, ‘rusty’) drains or waterways and ochre deposits or extensive iron stains on any concrete surfaces;
• milky green or clear drain water coming from or within the site (dissolved aluminium flocculates suspended clay particles);
• pale yellow mottles of jarosite, (commonly on ped faces, cracks, root channels and drainage voids) present in any spoil heaps, drain sides, etc. left exposed to the air; and
• corrosion of concrete and/or steel structures, particularly around the water level.

Potential acid sulfate soils typically are found in low lying, swampy or waterlogged land and <2 m AHD, or deep in the profile below AASS. Under such anaerobic conditions the soil pH of PASS may be neutral.

5.3 Profile (Soil Hole/Pit) Characteristics

These can be quite informative:

• auger hole/pit inspections showing any jarositic horizons or iron oxide mottling indicate ASS;
• mid to dark greenish grey in colour, as in unripe muds (soft, buttery) or estuarine silty sands or sands indicate PASS; and
• the smell of rotten eggs (H₂S hydrogen sulfide - care needed since H₂S is poisonous gas) may indicate PASS and sometimes AASS.

AASS and PASS are often found together, usually with the AASS in the upper profile, an overlap zone of both and then PASS in the lower profile. In some relatively recent swamps with surface water, the reverse order has been found.

PASS sands generally have a low buffering capacity, so that very severe acidity may rapidly follow drainage or disturbance. However, their potential to generate long term acidity is usually less as they normally have low pyrite concentration. Sand and gravel deposits have also been shown to contain PASS silt and clay fractions (White & Melville, 1993).

5.4 Field Tests for pH

These should be conducted on the soil profile at regular intervals using low range pH indicator papers or a field pH meter and robust double reference pH electrode. An Ionode IJ42 or IJ40 pH probe has been found suitable for direct insertion into moist soil to measure the in situ pH of ASS. Alternatively, an approximate 1:5 soil:deionised water suspension can be made up in tubes, hand shaken and pH of the solution measured. If the measured pH of the suspension or soil < pH 4, oxidation of pyrite has probably occurred in the past, indicating that an AASS is present. The field pH test does not account for any pyrite that has not yet been oxidised, so oxidation of the soil with 30% or 100 volume peroxide is required to test for pyrite or PASS. (Caution: 30% hydrogen peroxide is a strong oxidising agent and should be handled carefully with appropriate eye and skin protection). The bulk reagent should be stored in a refrigerator and only a small quantity taken to the field and kept cool. Peroxide becomes increasingly unstable the more the pH rises above 4.5, so most supplies are acid stabilised. The pH of the reagent should be measured and, if necessary small quantities should be adjusted to pH > 4.5 with dilute NaOH (in a laboratory). If only low pH peroxide is available, the field test will be less discriminatory for sands and samples low in pyrite.
The field test can be done with a few mL of peroxide and a small quantity of soil in either short clear test tubes or clear tissue culture clusters. Slight heating by placing in the sun may be necessary to start the reaction. When effervescence (sometimes violent) has ceased and the reaction is complete, measure the pH of the resultant mixture. If the pH is <3, then the material is PASS (pH 3 - 4 is less discriminatory). The strength of the reaction with peroxide is only a partial indicator as organic matter and other soil constituents such as manganese can cause a mild reaction. The more the pH drops below 3, the more confirmatory the presence of pyrite.

The above tests can be made more consistent if a fixed volume of soil (using a small scoop) is used and the final volume is adjusted to give a 1:5 ratio before reading. Similarly a second scoop of soil can be reacted with peroxide and after reaction is complete the final volume adjusted to give a 1:5 soil and water ratio for pH measurement (pHox).

5.5 Sampling

The intensity of sampling required is somewhat dependant on the type of disturbance proposed and the sensitivity of the surrounding environment. The minimum number of profiles/drill holes required for most Qld ASS Environment Impact Statements will be 8-10 holes, or if the area exceeds five hectare two holes per hectare, usually designed on a grid pattern. Samples from at least every soil horizon or a minimum of 0.5m depth increments should be collected to 0.5m below the depth of the proposed disturbance or estimated drop in watertable height. Qualitative field and quantitative laboratory tests should be conducted on these samples. More detailed sampling will be required along proposed canals or lakes (50m intervals).

The sampling intensity for less intensive developments may be reduced by mutual agreement with the relevant government authorities, however, the onus will be on the developer/consultant to prove less sampling is justified and environmentally safe. Authorities are likely to seek QASSIT technical advice in Qld, requiring a QASSIT site inspection. It is therefore important when drilling preliminary holes to consult early, as this could result in mutual agreement to a much reduced sampling plan in many situations. Similarly, in NSW, involvement of EPA and other relevant Departments could be beneficial.

Marine muds can be sampled with hand operated push in type gouge auger, available from suppliers such as Dormer Engineering, Murwillumbah. The issue of sampling below the watertable, particularly on sands is a tricky one, requiring specialised equipment, and depending on the depth may need casing. The Dormer wet sand sampler can be used to the length of the tube (usually 2m). Many developers use a back hoe to dig a sample pit. Dangers such as collapsing trench sides and highly toxic hydrogen sulfide gas need extreme caution.

All samples destined for laboratory analysis should be sealed in air tight containers, placed in an esky with dry ice or in a portable freezer/refrigerator. They must be kept frozen until ready for analysis or pre-analysis drying. Quick oven drying in a forced air draft, high capacity oven at 80-85° is essential to prevent oxidation. It is essential that shell material be sieved out prior to sample grinding or the neutralising capacity will be falsely inflated. Most
shells found in ASS have a coating of relatively insoluble gypsum, rendering their carbonate content ineffective.

5.6 Laboratory Analyses

Analyses of soil (and water) are the only way of making a quantitative estimate of the potential acid generation and environmental harm. Since sulfur chemistry is the critical factor in determining the potential for ASS, this should be the focus of laboratory investigation. Analysis of total sulfur, sulfate (product of past oxidation) and sulfide (potentially oxidisable sulfur) is essential. This should be supplemented by pHw, pHox, conductivity, chloride and carbonate, while in some cases organic carbon and cation analyses are helpful.

There is no universally accepted method for analysis of pyritic material, rather a suite of techniques are used. Methods in common use have not yet been standardised between laboratories for important factors such as sample weights, extractants, ratio of soil to extractant, pH determination in suspension or filtered extract, peroxide treatment time. Nevertheless, the theoretical basis of most methods is sound, and an attempt towards standardisation, together with an inter-laboratory sample program is under way.

The principle methods for quantifying ASS risk involve either following the acid production trail (titration of initial soil acidity and acidity after oxidation) or the sulfate trail (measuring soluble/adsorbed sulfate and total sulfur, or total sulfate after oxidation). Hydrogen peroxide (30%) is normally used to quickly oxidise the soil samples, although slow oxidation requiring incubation over many weeks/months may also be used.

The sulfur assays are used to calculate the maximum acid that theoretically can be generated by the sample. For the initial assessment, it is assumed that all sulfur occurs as iron-sulfide (or pyrite) and that the oxidation of this iron-sulfide proceeds according to the complete reaction:

\[
\text{FeS}_2 + 15/4 \ 0_2 + 7/2 \ H_2O = \text{Fe(OH)}_3 + 2 \ H_2\text{SO}_4
\]

Based on the stoichiometry of this reaction, the maximum amount of acid that could be produced by a sample containing 1% S as pyrite would be 30.586 kg H_2SO_4/tonne or 630 moles H^+/tonne of soil. Such a soil, if fully oxidised and unbuffered, would require >31.2 kg of pure fine lime/tonne to neutralise the acidity generated. In practice, an engineering safety factor of 1.5 times the above lime requirements needs to be used, to allow for non homogenous mixing in the field.

When dealing with neutralising acid water bodies, lime requirement calculated from water pH can substantially underestimate the potential acidity. If a significant quantity of unoxidised iron is present, oxidation of Fe^{2+} to Fe^{3+} generates another 2 moles of acid.

Common laboratory methods in use for quantifying pyrite effects are:

- **Peroxide oxidisable sulfuric acid (POSA)** is determined by subtracting soluble (and adsorbed) soil sulfate from the total amount of soil sulfate after oxidation with 30% hydrogen peroxide. Results are expressed as S_{ox} % or kg H_2SO_4/tonne of soil.
If carbonate is present in the soil then acid neutralising capacity (ANC) needs to be determined.

The net acid generating potential (NAGP) can then be calculated by
\[ NAGP = 3.13 \times \%S_{ox} - \%ANC \]

Total sulfidic acidity (TSA); double oxidation method of Dent et al. (1996). Titration (to pH 5.5) of total potential acidity (TPA) of a 30% peroxide oxidised soil minus the total actual acidity (TAA), determined by titration of the soil to pH 5.5.

\[ TSA = TPA - TAA \]

Total sulfur can be determined by Xray fluorescence (XRF) or LECO-S; and soluble sulfate subtracted to give an estimate of \( S_{ox} \) %.

Recent guidelines by NSW EPA (1995) give risk indicator levels of 0.05 \( S_{ox} \) % (1.53kg \( H_2SO_4 \) /tonne soil) for clayey sediments and 0.01 \( S_{ox} \) % (0.31 kg \( H_2SO_4 \) /tonne soil) for sandy sediments. NSW experience with major highway constructions (e.g. Chinderah Bypass) have reinforced the need for the lower criteria on sandy sediments. Such criteria, although conservative, will generally be applied to Queensland, unless experimental evidence to the contrary is provided for a particular situation. Particular care is needed with the analysis of low value samples and usually more than one method will be required. The POSA method has advantages on such samples; pHw and pHox, and ANC are desirable to assist with interpretation of the result.

6 MANAGEMENT

Many ASS situations should be able to be successfully managed, but most require detailed investigation, detailed design and often costly management programs to ensure that adverse environmental and engineering impacts do not occur. The risks associated with implementing these strategies, given that most have not been comprehensively tested, needs to be carefully considered. Some ASS are best left as is, both on economic and environmental grounds.

The most important information required before drafting an ASS management plan is a detailed soil survey with analytical data on pyrite content by depths. The acid-producing potential of the soil needs to be quantified and evaluated in the context of the local environment including an understanding of the sensitivity of the local waterways, ground water hydrology and the chemical, physical and biological characteristics of the soils and water. Management strategies for dealing with ASS include:

- avoidance, by not developing in such locations;
- prevention of oxidation by non porous capping or maintaining the watertable;
- neutralisation with lime or where environmentally acceptable seawater;
- oxidation and leaching;
- removal of pyritic material; and
- re-flooding to create reducing conditions.

These management strategies are theoretically possible, but are largely untried and often have practical difficulties in the large scale implementation.
The assessment of a proposed development site for ASS and therefore potential environment harm or financial viability/liability involves many steps as indicated in Fig 4.

7 PILOT PROJECTS

It is a relatively simple matter to carry out a pilot project to assess the performance of ASS material when exposed to air. This can be done either in a laboratory situation or preferably, as has been done elsewhere, a pilot site may be disturbed. Through a simple leachate collection process over several months of reasonable rainfall, an assessment can be made of the quality of leachate likely to emanate from the disturbed material.

Pilot projects can be extended to a trial of remediation technology such as the incorporation of lime, either into the disturbed material or treating the leachate with a neutralising substance. Since acid events can occur quite rapidly, it is very important to design the pilot project monitoring program accordingly with a high frequency sampling.

Major parameters to be monitored include pH, iron, aluminium and conductivity. A target pH of 6 is generally considered appropriate for leachate to avoid acid impacts.

8 CONCLUSIONS

The potential for problems to arise from ASS has only recently gained widespread recognition as a land management issue for urban and other developments in coastal areas of Australia, particularly Qld and NSW. ASS have the potential to cause dramatic environmental impacts if ignored or mismanaged during drainage or disturbance of coastal lowlands.

The technology necessary to adequately identify and manage ASS is now available to developers, consultants and consent authorities.

Further definition of the nature and extent of the problem is under way in Qld and investigation and implementation of management strategies although becoming commonplace, require further development.

9 ACKNOWLEDGMENTS

Noosa Council is thanked for permission to use some of the report ‘Acid Sulfate Soils in the Noosa River Catchment’ (authored by R. Smith, R. Bush and J. Sammut) in the preparation of part of this paper.
Subject site within area of potential ASS

→ Yes/No

→ Does project involve:
  • Excavation or soil disturbance?
  • Change in height of water table?

→ Yes

→ Carry out broad scale site survey, identify potential problem areas, establish base line conditions.

→ Is it possible to avoid potential problem areas?

→ Yes → Design proposal along these lines

→ No, liaise with Council staff to ascertain likely views.

→ Unsatisfactory to investigate further, avoid potential problem areas

→ Satisfactory to investigate further

→ Design survey to quantify the area of impact and the volumes of ASS (such design is to be carried out by qualified professionals) and involve QASSIT, Council and DEH in site inspection and sampling plan,

→ Carry out survey.

→ Devise practical, economical management procedures for treatment of soils, based on the survey, including a monitoring program

→ Submit for comments or approval by the DEH and Council.

Figure 4 A procedure for developments possibly affected by ASS (Bowman, 1992)
REFERENCES


ASSESSING THE POTENTIAL IMPACTS OF DEVELOPMENT

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ABSTRACT

This paper gives a brief overview of the process of environmental impact assessment, some of the important land, soil and water related impacts of development and how these should be assessed. Changing the hydrology of an area can have major impacts on the nature of the local streams in terms of water quality, flow regime and habitat. This, in turn, will change the ecosystems of the waterway. Land clearing has a major impact on local flora and fauna and these impacts need to be minimised. Protection of the riparian zone is essential in order to maintain wildlife corridors and protect water quality. The information provided by the developer must be comprehensive enough to enable the development reviewer to determine what the impacts are and if they are acceptable. Essential factors in achieving this are discussed.

KEY WORDS: environmental impact assessment, runoff, hydrology, riparian, wildlife corridor, buffer

1 INTRODUCTION

Since 1990 Queensland has seen a great increase in emphasis on impact assessment covering a wide variety of proposed developments. Environmental impact assessment has been part of the Queensland State Development and Public Works Organisation Act 1971-1981 for a long time. The recent emphasis has been driven principally by legislative reform, initially the Local Government (Planning and Environment) Act 1990 and more recently the Environmental Protection Act 1994, but it also reflects the community’s growing concern about the environmental impacts of Queensland’s rapid population growth and associated development. A knowledge of soil science is valuable to those carrying out the environmental assessment, preparing an environmental impact statement and reviewing an environmental impact statement.

This paper gives a brief overview of the environmental impact assessment process, including its objectives, key principles and the basic methodology, and discusses assessment of potential impacts of development with particular reference to changes in hydrology, changes in water quality and land clearing. The legislation applying to environmental assessment in Queensland will be described in a subsequent presentation.

2 ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment was developed in the United States of America in the early 1970s as a tool to help resolve environmental disputes. Such disputes arise due to differences in opinion over best use of land and other resources, and are characterised by uncertainty and

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2 Copies of Queensland Government Acts are obtainable from Goprint, Brisbane.
the risk of irreversible harm, a wide range of participants, and effects on public as well as private interests.

2.1 Environmental Impact Assessment Process

The environmental impact assessment process is able to address the above issues in two ways. Firstly, environmental impact assessment involves a process of scientific investigation and analysis that reduces the uncertainty about the effects of a proposed development. Secondly, environmental impact assessment is a social process which allows all interested parties to be part of the evaluation of the development and its impacts. The community has a particular role as a ‘watchdog’ on the process, making it more transparent. The transparency of the process is the greatest guarantee the environmental impact assessment will be conducted in an effective manner (Martyn et al., 1990).

ANZECC 1991 (p2) defined environmental impact assessment as “a process for the orderly and systematic evaluation of a proposal including its alternatives and objectives and its effects on the environment including the mitigation and the management of those effects. The process extends from the initial concept of the proposal through implementation to completion and, where appropriate, decommissioning”.

The environmental impact assessment process is intended to assist and improve decision making, although it is not a decision making process in itself. It is most effective when it is used in conjunction with other tools of environmental management, such as strategic plans, catchment management plans, standards for environmental quality, and codes of practice.

2.2 Objectives of Environmental Impact Assessment

The objectives of environmental impact assessment in Australia are identified (ANZECC, 1991, p3) as follows:

- to ensure that decisions are taken following timely and sound environmental advice;
- to encourage and provide opportunities for public participation in environmental aspects of proposals before decisions are taken;
- to ensure that proponents of proposals take primary responsibility for protection of the environment relating to their proposals;
- to facilitate environmentally sound proposals by minimising adverse impacts and maximising benefits to the environment;
- to provide a basis for ongoing environmental management including through the results of monitoring; and
- to promote awareness and education in environmental values.
2.3 Environmental Impact Assessment and Ecologically Sustainable Development

Ecologically sustainable development has been recognised by governments in Australia as a statement of objectives aimed at influencing all decision-making (ANZECC, 1991). Ecologically sustainable development is a key part of the Australian Intergovernmental Agreement on the Environment (1992), and is the object of the Queensland Environmental Protection Act 1994. Environmental impact assessment is seen as one way of achieving the objectives of ecologically sustainable development. It is the responsibility of the proponent to demonstrate that the proposed development is ecologically sustainable, that is, the development will improve the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.

2.4 Methodology of Environmental Impact Assessment

The methodology of environmental impact assessment describes the stages involved in the assessment process (UNEP, 1988):

1. Screening: This is the first and simplest level of evaluation to determine the extent of assessment required. It may be an administrative procedure where projects of a certain type or size, or in a particular location, automatically require assessment, or it may involve a preliminary investigation or consultative process to determine whether the proposal is likely to have environmental impacts.

2. Scoping: This identifies all the relevant issues which need to be examined in the environmental impact assessment, and the level of investigation required.

3. Prediction: This stage characterises the direct and indirect impacts of the proposal in terms of predicted changes to the environment. Prediction draws on data and techniques from the natural, physical, social and economic sciences. The sophistication of the prediction methods should be in proportion to the scale of the potential impact and the significance of the receiving environment, and should include an estimation of the reliability of the findings in terms of probabilities or margins of error.

4. Evaluation: During this stage, the significance or importance of the predicted changes is assessed against some value system. This may be done, for example, by comparison with regulations, accepted criteria or guidelines; consistency with government policy, State planning policies and local government strategic plans; and consultation with key stakeholders.

5. Mitigation: Consideration needs to be given to means of avoiding, preventing, reducing or compensating for each of the adverse impacts. An environmental management plan, or soil and water management plan, may be part of the material submitted with an application for approval of the development.

6. Communication: Consultation involving all interested parties has become an essential part of any assessment process. Consultation may include public meetings, displays, advisory groups, written submissions, workshops, surveys or public inquiries, and depends on the location, nature and size of the proposed development.
7. **Monitoring:** Monitoring is important as it enables comparison with environmental objectives for the receiving environment and comparison with predicted outcomes. A monitoring program to assess impacts during construction and as part of the ongoing environmental management for the project should be considered as part of the environmental assessment of the proposed development.

A document presenting the outcomes of the first five stages usually forms the basis of the consultation and review processes which comprise stage six. The environmental impact assessment report generally includes the following sections:

- project description - a description of what is proposed in sufficient detail to allow independent assessment of its feasibility, infrastructure requirements, and wastes generated;
- project justification - the objectives of the project and a description of feasible alternatives to the proposal, in sufficient detail to demonstrate why the preferred option was selected;
- description of the existing environment - the site and any other areas directly or indirectly affected by the proposal, in sufficient detail to allow independent review of the predictions and evaluations made in the environmental impact assessment;
- assessment of potential impacts - provides a report of the prediction and evaluation studies;
- environmental management - includes the proposed environmental management plan and any proposed monitoring;
- source of information - all sources must be documented. Often, detailed technical reports are attached as appendices, so that the main text can be written in a style suitable for non-specialist readers.

3 **ASSESSMENT OF POTENTIAL IMPACTS**

The proponent has the responsibility of preparing and presenting the case for the evaluation of the proposal. As previously indicated, it is the responsibility of the proponent to demonstrate that the proposed development is ecologically sustainable. The proponent needs clear advice from government as to what studies are required - the terms of reference, and, as far as possible, what environmental values are to be protected and what levels of impacts will be acceptable. The community needs to be consulted to seek local knowledge and history, and to determine the acceptability of the proposal and the relative importance to the community of the different issues.

One issue of concern is that of independence. How independent is the assessment made by the consultant employed by the developer? This issue is more likely to be resolved if the process is transparent and consultative. Unfortunately, many developers continue to challenge the need to conduct environmental studies, as an additional cost imposed on the
development. However, there are advantages to the proponent, as well as to the community, if the need to investigate and describe environmental impacts is accepted as a part of the project cost (McDonald & Brown, 1989).

A study of the existing environment may enable the developer to maximise the advantages of the site, avoiding inappropriate uses. If natural features of a site, such as remnant bushland, waterways and lakes, and wildlife corridors, are protected and enhanced during the development phase, these can be promoted as a selling feature. Once a basic concept is developed, the prediction and evaluation phases may be used to refine the design so as to minimise potential impacts. This reduces the potential for conflict and assists in the approval process. Where environmental assessment is integrated into the project planning process, future problems are likely to be avoided, along with the high costs of mitigating impacts after they occur.

Catchment hydrology, water quality, catchment soil characteristics, catchment landuse, riparian vegetation, and local fauna and their habitat all influence the nature and health of the ecosystems, and changes can have negative impacts.

4 CHANGES IN HYDROLOGY - IMPACTS AND THEIR ASSESSMENT

In the past, urban drainage systems have been regarded as functional entities for efficient collection and disposal of storm runoff water, with little intrinsic value. However, appropriate management of the urban drainage system now needs a multidisciplinary approach. The drainage system must still fulfil the traditional role of preventing and controlling flood flows in urban areas, as well as satisfying the growing recognition of the intrinsic values of the urban aquatic ecosystem.

4.1 Changes

It has been estimated that urbanisation covers between 30% and 50% of catchments with impervious surfaces. This increase in the amount of imperviousness will generally increase both the volume and rate of runoff. Rutherfurd and Ducatel (1994) reported that many studies had established that urbanisation has a greater impact during smaller, more frequent storms than in rare events such as the 1 in 100 year average recurrence interval (ARI) flood, where the saturated ground conditions of the pre-urbanised catchment would closely resemble the relatively impervious ground conditions of the urban environment. The ratio of urban to rural catchment flows exhibits an exponential decay relationship with increasing ARI. The ratio is noticeably higher for ARIs of less than 5 years (Sharpin & Morison, 1995a).

A paired catchment study in Canberra showed that low density urbanisation decreased by 30 times the lag time between rainfall and runoff, with the difference between pre and post-urbanisation runoff decreasing with the size of the event (Codner et al., 1988).

4.2 Potential Impacts

Changes in catchment hydrology can cause increased flooding, erosion of stream banks and changes to the flow characteristics of the stream. Flood flows cause widening and deepening of the waterways, straightening of natural bends, and changes in the nature of the stream
substrate. All of these changes can have major impacts on the stream ecology. Where a stream bed once may have had sandy areas and silt areas, slow flow areas and riffles, shady stretches and sunny stretches, a diverse fauna and flora would have existed. Hydrological changes can destroy all of these different habitats and their communities. These changes also lead to pressure to "engineer" the channel, further destroying habitat features such as pools and riffles.

Rutherfurd and Ducatel (1994) outline 'natural river engineering', and describe a successful 'retrofitted' natural river engineering project in the upper reaches of Gardiners Creek at Box Hill in Melbourne. However, the cost of transforming the two kilometres of Gardiners Creek from a major public liability into a delightful public asset was over $500 000 in the 1980s. A better option for the budget and the environment is to design the project using available best management practices and avoid future problems.

Changes in flow paths and inundation patterns have a negative impact on vegetation types such as mangrove forests and melaleuca forests. Studies in the Northern Territory have found that changes in the balance between fresh water and saline water will change the community characteristics of mangrove forests (Hanley, 1994).

4.3 Assessment of Impacts

In assessing the impact of hydrological changes, it is necessary to know the characteristics of the waterway and its ecological systems, determine what changes are likely to occur, investigate measures which can prevent or reduce the changes, and demonstrate the acceptability of any potential impacts.

Mathematical models are often used to predict changes in hydrology and the effect of mitigation measures, such as dry retardation basins, wet basins, etc. The instream placement of these basins may also have potential impacts, which need to be assessed. These are outlined by Sharpin and Morison (1995b).

5 CHANGES IN WATER QUALITY - IMPACTS AND THEIR ASSESSMENT

Many major studies have been carried out to determine the effects of land management on the quantity and quality of water (Boughton, 1983) and the effects of organic pollution and excess nutrients in the aquatic ecosystem (Hynes 1960, Cullen 1976 and Arthington et al., 1982). Management and control of non-point source pollution depends upon an understanding of the physical and bio-chemical processes involved in the production, transport and final disposal of pollutants (Boughton, 1983).

In recent years greater emphasis has been placed on the management of non-point sources of pollution, both in the rural and urban environments. There is an increasing recognition of the intrinsic value of urban drainage systems, and a recognition that management should include an emphasis on enhancement and protection of the urban aquatic ecosystem.

Local Government, communities and water managers have become more proactive in areas where there are large urban populations and receiving waters are sensitive to organic and nutrient enrichment. More recently, State environment protection legislation has placed more
emphasis on control of pollution from diffuse sources and this, in turn, will prompt further action in managing stormwater.

5.1 Potential Impacts

During the construction phase of a development, soil is exposed to the elements and considerable quantities can be washed into the waterways. High sediment loads entering the waterways cause a number of problems. Sediments may smother the benthic communities, causing the death of some fauna and potentially changing the community structure. The increase in turbidity caused by the suspended sediment decreases the amount of light reaching the bottom of the stream. This in turn impacts on the availability of light for submerged macrophytes and algae, and hence impacts on plant growth.

Sediments entering the waterway not only cause an increase in turbidity in the streams, but they carry significant quantities of adsorbed nutrients and organic materials. Most of the loss of nitrogen (usually > 90%) occurs as forms of organic matter in eroded sediments and organic suspensions (Rose & Dalal, 1988). Eutrophication of surface water may occur when nutrients such as nitrogen and phosphorus cause increased algal growth. Increased algal growth may cause depletion of oxygen which results from the respiration and decay of this aquatic flora. Deoxygenation in turn alters the diversity of aquatic life and the water composition, and shifts the decay of organic material to the anaerobic process (Arthington et al., 1982).

5.2 Reducing the Impacts

The most effective way of controlling pollution is prevention in the first place, or control at source. The impacts of urbanisation on water quality can be reduced by both minimising the quantity of stormwater generation and accumulation of contaminants, and by reducing the rates at which such materials are moved off site.

Other best management practices in current use include controls integrated into the drainage system and management of the receiving waters.

Erosion control and stormwater management, and their relationship to water quality, will be addressed in detail in subsequent presentations.

5.3 Assessing the Impacts

To assess the impacts of a development on water quality, it is necessary to know the existing water quality characteristics of the waterway and the environmental objectives to be met, to determine inputs from the development and to predict changes due to those inputs, during both the construction and operational phases. The Department of Environment and Heritage and Department of Primary Industries have significant water quality data sets from around Queensland, particularly for major streams and rivers. This data is available on request.
6  IMPACTS FROM LAND CLEARING

The immediate impacts of land clearing include exposure of soil to potential erosion, loss of vegetation and habitat for local fauna. When assessing the impacts, each of these issues needs to be addressed. It is not appropriate to simply provide long lists of flora and fauna that one would expect to find in the area to be developed. It is necessary to know what fauna and flora are found there, however, the impact assessment has to predict the impacts on the flora and fauna that will be caused by the clearing of the vegetation, demonstrate that the development is ecologically sustainable and that the resulting impacts are acceptable to the community.

6.1  Soil Erosion

Large scale clearing of land leaves the land exposed to soil erosion, by both wind and rain, with the potential for causing major impacts on downstream water quality. In order to assess the potential for soil erosion, it is necessary to know the characteristics of the soils, the seasonal rainfall characteristics and topographical features of the land. Predictive tools can then be used to model stormwater runoff quantity and quality.

Erosion losses of soil may vary widely depending on many factors, which include soil type, slope of land, ground cover and tillage (Cullen, 1983a), rainfall detachment and entrainment processes (Rose & Dalal, 1988).

The potential for soil erosion can be reduced by minimising the amount of land cleared at any time. Where significant clearing has to take place in order to change land profiles, the developer should endeavour to plant a cover crop as soon as possible after disturbance to reduce the potential for erosion. The use of contour banks, diversion drains, etc. will also decrease the potential for erosion.

Some agencies in other states have restrictions on land disturbance to minimise the likelihood of sediment pollution, for example, the NSW Department of Housing requires:

- the retention of vegetation beyond 5 (preferably 2) metres from the edge of any essential works, stockpile areas and access points;

- temporary rehabilitation on lands likely to remain unattended for more than 60 days (Soil Loss Class 1 lands) before continuation of site works; and

- completion of permanent rehabilitation programs within 20 working days (Soil Loss Class 1 lands) from completion of works.

Time frames are more stringent on other soil classes.

Local Councils and Environment Agencies in some states require any development application to include a soil and water management plan. This is a plan to demonstrate what actions will be implemented to:

- minimise erosion - e.g. through use of mulches, cover crops;
• reduce stormwater runoff - e.g. through the use of retention basins; and

• reduce impacts on downstream water quality - e.g. through the use of silt fences, settlement basins and filter cloth.

The soil erosion issue will be addressed in more detail in a subsequent presentation (Truong & Witheridge, 1996).

6.2 Vegetation, Fauna and Wildlife Corridors

In assessing the impacts of development on the flora and fauna of an area, it is important to identify the communities that are present, their representativeness in protected areas and the presence of any rare and threatened species in the area. The Department of Environment and Heritage maintains a database of rare and threatened species and can provide information on request. Advice should also be sought from the National Parks and Wildlife Service of the Department in relation to local protected areas.

If a large area of bushland is to be cleared, an assessment of the impacts on local flora and fauna will be necessary. Questions such as the following will need to be answered:

• By how much will the clearing reduce the local bushland area and what impact will this have on local fauna?

• Will the clearing remove all or nearly all of the area covered by certain ecosystem types, e.g. all of the melaleuca wetland or all of the ridge top eucalypt forest?

• Will the clearing leave a remnant of bushland with an overall edge to area ratio which is too high, thus rendering the remnant unsustainable?

• Will the clearing create further remnants of bushland without connecting corridors to other bushland areas?

• What opportunities are there for creating or retaining connecting corridors?

• What local fauna should be considered when making decisions about wildlife corridors?

• If there is a need to provide or retain a wildlife corridor, how wide is wide enough?

• What potential is there for rehabilitation of vegetation and habitat?

In order to make assessments about the need for, and width of, wildlife corridors, an understanding of the behaviour and territorial and feeding needs of the animals is required.

6.3 Riparian Vegetation and Buffers

The riparian zone can be defined in a number of ways, but is usually used to encompass a broad band of vegetation adjacent to a watercourse (Catterall, 1993). Riparian vegetation can
perform a multitude of functions including control on stream channel stability, a filter for sediments and nutrients, water purification (e.g., bacteria and pathogens) and provision of terrestrial and stream habitat. Riparian vegetation also provides a source of nutrients in the form of leaf litter and shade which controls instream plant growth.

Authorities have realised the value of the riparian vegetation and generally require the retention of some riparian vegetation as a part of any development approval. However, if removal of the riparian vegetation is to be carried out, then justification and an assessment of the impacts on each of the functions outlined above would be required.

The stream sediment load, particularly following storms, can arise from overland flow erosion or from bank erosion and so riparian vegetation is important in maintaining channel and stream stability. While streamside vegetation is often 5-10 m in width, maximum benefits are achieved at widths of 20-30 m (Department of Conservation and Environment, 1990). Barling and Moore (1993) summarised the buffer width and extent reported in various studies for differing soil types, geology and slopes. Vegetation helps to stabilise the stream bank, maintains a stable alignment and reduces erosion and sediment loss to the stream.

Vegetation, especially grasses and groundcovers, can act as a natural filter trapping sediment as the water flows across. By trapping the sediments in the riparian vegetation nutrient loads entering the waterway are also decreased. McNeill (1993) found that riparian vegetation also played a role in the management of waterway pollution in relation to pathogens and bacteria.

The ecosystems within riparian areas can be so diverse and complex that they are sufficiently different from their surrounding areas to be described as distinctive (Gregory & Pressey, 1982). Riparian vegetation plays an important role in the structure and function of stream ecosystems. It creates a diversity of food sources for instream fauna by providing leaf litter to the stream as well as attracting insects to the riparian zone. Reduction of water temperature and light through shading affects instream primary production, and the relative contributions of instream production and supply from the surrounding terrestrial ecosystem to the food chain (Arthington, et al., 1993). This in turn can change the instream community structure.

Protection of the riparian vegetation is important for creating linked habitat networks connecting other ecosystems and remnant bushland. Riparian vegetation also provides critical habitat refuges within which species can be maintained during drought and fire (Catterall, 1993). For the purposes of providing a viable riparian corridor, Catterall (1993) suggested that 100 m on each side of the waterways is desirable. However, if 30-100 m only is to be protected on each side of the stream bank, Catterall suggested that an ecological assessment should be required to demonstrate the long term viability of the riparian zone.

7 CONCLUSIONS

Environmental Impact Assessment is a powerful tool for environmental protection. While the process does not prevent developments from having environmental effects, it does ensure that decisions are based on relevant information, and encourages environmentally sensitive project design.
The ideal impact assessment report should be comprehensive, but without unnecessary or unimportant details. The report should be simultaneously intelligible to the general reader, and provide the reviewer with enough information to evaluate the proposal and to demonstrate that the proposed development is ecologically sustainable. Communication in the impact assessment process should include consultation with the relevant advisory agencies and with the affected community at the commencement of the process, and is the best way to ensure not only that the study meets the requirements, but also that the project will be acceptable.

In assessing the impacts of a proposed development, it is necessary to know the characteristics of the environment, determine what changes are likely to occur, predict impacts due to those changes, investigate measures which can prevent or reduce the impacts and demonstrate the acceptability of any residual impacts.

8 REFERENCES


CONTAMINATED LAND IN QUEENSLAND

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ABSTRACT

Contaminated land has become a key public health and environmental issue in Australia since the early 1980s. National Guidelines were published in 1992 that provide a strategic framework for the prevention, assessment and management of contamination. The assessment process incorporates a combination of soil quality guidelines and a site specific approach. The Queensland Government has adopted the policy framework and developed contaminated land legislation that incorporates the National Guidelines for the assessment and management of contaminated land. The policy framework at National and State level is being updated to include developments in scientific knowledge and broader policy issues.

An application for rezoning is the trigger for a Site Investigation Report on prescribed purpose sites. Subsequent remediation provides an ongoing clean up of past contamination. The Environmental Protection Act 1994 provides a mechanism to prevent or limit future contamination and has resulted in a growing tendency for industry and corporate bodies to commission environmental audits and to implement environmental management plans. The most common contaminants involved are petroleum industry residues, pesticides, and other chlorinated hydrocarbons, heavy metal residues, acid wastes and specific inorganic non metals. Remediation is mainly based on characterisation and quantification of contaminants, excavation and disposal to appropriate landfills. Shallow water table contamination occurs in a small percentage of cases. The major cost factors are excavation, cartage and disposal fees. The future clean up trends involve increasing on site treatment, bioremediation, neutralisation, stabilisation and possible recycling.

KEY WORDS: contaminated land, legislation, ANZECC/NHMRC Guidelines, site specific approach, investigation thresholds, remediation, liability, rezoning, environmental audit and management, common contaminants, maximum contaminant levels, permissible levels for landfill disposal, disposal costs.

1 INTRODUCTION

Contaminated land became a key public health and environmental issue in Australia in the early 1980s. Many of the problems arose where land had been developed for a sensitive purpose without contaminated land issues being addressed. In a number of cases there was potential for adverse health impacts on the local community. Community dislocation was often extensive with many members of the community suffering considerable stress and financial hardship.

Government responses to contaminated land issues were usually made in response to community alarm and media attention and tended to be poorly coordinated. The result was often unsatisfactory to all involved. The community saw the Government as being slow to
respond and uncaring. Government was working in a policy vacuum, unable to adequately communicate the “real” issues to the community and provide effective measures to protect public health.

The experience in Queensland was similar to other States. The most notable case was at a former gold mine at Mount Taylor, south of Brisbane. The gold mining operations included a cyanide extraction process where the waste was disposed to a tailings dam. After closure of the mine an open cut was used as a landfill for hazardous waste, receiving acid tar sludge from a sump oil re-refining process. The land was subsequently sub-divided for housing. Community alarms about a potential “toxic time bomb” were raised when acid tar surfaced under some houses. The community was dissatisfied with the Government response, viewing the findings of a number of major scientific studies with scepticism. Finally, after an extended period of investigation, some of the local community were relocated and the waste contained under an impervious cap.

National and State Governments recognised that the ad hoc approach was unsatisfactory and that there was an urgent need for clear policy guidance for contaminated land. The policy was essential to ensure that issues were dealt with proactively, protecting public health and the environment while potentially saving the community considerable social and financial costs.

This paper provides an overview of the policies and legislation implemented at National and State levels to address contaminated land issues. The Contaminated Land Act, 1991 and Section 8.3A of the Local Government (Environment and Protection Act) 1990 require a site investigation in relation to rezoning of land that is being, or has been, used for a prescribed purpose. The results of such investigations are submitted to the Hazardous Wastes and Contaminated Sites Section (HWCSS) of the Department of Environment (DE) for appropriate reclassification on the Contaminated Sites Register (CSR). The owner and relevant Local Authorities are notified of any changes and a Site Contamination Report (CSR) is issued by the Director, Waste Management Branch and sent to the consultant.

In addition to these investigations there are other activities in environmental issues associated with site contamination. Much baseline consulting work in this field comprises investigations related to the following:

(i) Environmental Audits.

These investigations are carried out to identify and quantify existing contamination and assess the contaminating potential of existing facilities and activities. The types of sites involved include:

(a) Major Shopping Complexes
(b) CBD Highrise Buildings
(c) A range of light, heavy and general industrial complexes.
The main triggers for these assessments involve the implementation of Total Quality Management (TQM) in corporate and other business organisations and by financial institutions in relation to lending for purchase, development, redevelopment and extension to the properties.

(ii) **Environmental Management Plans (EMP)**

These are prepared to remediate or limit existing contamination and to prevent further contamination by existing activities and facilities and frequently flow on from the Environmental Audit Programs in order to satisfy:

(a) TQM requirements
(b) Mortgage requirements
(c) As a requirement in anticipation of the granting of environmental licences or authority in compliance with Section 41, *Environmental Protection Act 1994*.

(iii) **Construction Environmental Management Plan (CEMP)**

These are specific for construction and development sites and are required to provide operational procedures in order to prevent or minimise environmental damage to the site and surrounding features by management of the following:

(a) Heritage features
(b) Flora/fauna
(c) Noise
(d) Dust
(e) Land contamination related to on site storage and dispensing of products such as fuel and lubricants. Contamination due to spillage, breakdown, service and maintenance of equipment. Erosion damage due to water run on or runoff from the site.

2 **NATIONAL APPROACH**

In 1992 the Australian and New Zealand Environment and Conservation Council (ANZECC) and the National Health and Medical Research Council (NHMRC) published the “Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites”. The Guidelines provide a policy framework for the various governments and promote a consistent approach throughout Australia and New Zealand. The aim of the Guidelines is to inform and educate government, industry, unions and the general community about the issues and factors to be considered in the assessment and management of contaminated land, and to protect the community and the environment.

2.1 **Prevention**

The costs of remediating contaminated land may be very high and it is therefore advisable to institute controls on contaminating activities and to prevent contamination from occurring. This may be achieved by early identification of potentially contaminating activities and the introduction of procedures that provide for the minimisation of impacts by hazardous substances. These procedures would typically involve changes to the industrial processes,
spill containment, appropriate waste management procedures and accident contingency plans. The licence conditions for industry provide the main legislative vehicle for implementing the prevention component of the policy.

2.2 Assessment and Management

The ANZECC/NHMRC Guidelines provide a list of specific industries and activities that have the potential to cause contamination. Planning authorities should require an assessment of such land when a change to a sensitive use is proposed. Typical examples of potentially contaminating activities are gas work sites, smelters, service stations and cattle dips.

The Guidelines combine a general approach, setting out assessment and management requirements typical of a broad range of contaminated sites, with a specific approach for complex sites where soil clean-up criteria and clean-up methods are best determined on a site specific basis.

The components of the assessment and management process are:

- A site history which details the past and present activities on-site including industrial processes, storage tanks and waste disposal areas;
- A site inspection which identifies site features including topography, surrounding uses, stained areas, vegetation stress and potentially contaminating activities;
- An overview of the geology and hydrogeology of the site with specific details about soils types and groundwater;
- Site investigation and sampling details including sample locations, soil profiles, sampling collection, storage and preservation methods, and laboratory analyses sheets including quality control data;
- An assessment of results of the investigation in relation to potential hazards to the community and environment;
- Management and remediation of identified areas of contamination;
- Validation testing of the site to verify the success of the remedial works; and
- Effective communication with the affected public during all of the above.

A comprehensive site history forms the basis of the assessment process. The site history should flag areas of concern, providing an insight into the contamination that is likely to be present. The site history combined with the geology and hydrogeology of the site, and the findings of the site inspection should be used to establish a sampling program.

The sampling program should be conducted meticulously to ensure that the samples are representative of the site. Analyses should only be conducted by quality assured laboratories.
using methodology appropriate to the sample matrix and analytes. Results should be presented clearly, using tables and plans.

The results of analyses are compared with the investigation thresholds that have been set by ANZECC/NHMRC for various contaminants. The investigation thresholds are set conservatively to be protective of the community and the environment under the sensitive circumstances. Table 1 below lists the investigation thresholds currently set by ANZECC/NHMRC.

Table 1  ANZECC/NHMRC investigation thresholds

<table>
<thead>
<tr>
<th>Substance</th>
<th>Environment mg/kg</th>
<th>Health mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Cadmium</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Chromium</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Manganese</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Tin</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Dieldrin</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>PAHs</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>PCBs</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sulphate</td>
<td>2000</td>
<td></td>
</tr>
</tbody>
</table>

The investigation thresholds may be used as default clean-up levels for small sites where the degree of contamination is minor and a site specific assessment of the risks is not justified. For larger sites involving complex patterns of contamination, a risk assessment may be the most appropriate approach, with site specific factors addressed in the assessment to predict likely impacts and to determine clean-up levels. The risk assessment should be conducted in accordance with the protocol described by El Saadi and Langley (1991).

Where the assessment shows that hazards may exist, then it is necessary for management of the contamination to occur. There are a number of management options available:

- On-site treatment followed by replacement on-site;
- Off-site treatment followed by replacement on-site;
- Off-site treatment followed by use at another site;
- Containment on-site; and
- Containment off-site, for example at a landfill.
The choice of option is dependent on the nature of the contamination and the availability of suitable technology. The remedial works must be conducted in a way that does not contaminate other land.

The validation sampling program is conducted after the remedial works to verify its success. As with the sampling investigation program, sufficient samples must be collected in such a way as to be representative of the remediated site and analyses conducted at quality assured laboratories.

2.3 Liability

ANZECC published a position paper on financial liability in April 1994. The main recommendations made were:

- Governments should not intervene to direct remedial action at sites where the contamination does not pose any threat to the current users of the site, the community or the environment;

- Planning authorities should have appropriate procedures in place to ensure that potentially contaminated land is assessed and remediated, where necessary, when a more sensitive land use is proposed;

- Legislation should enable governments to require remedial action on sites which pose a risk;

- Wherever possible, the polluter should be required to pay for remedial works. If the polluter is insolvent or unidentifiable then the person in control of the site should pay the costs of any necessary remedial works; and

- Lenders should not be held liable for remedial works on action sites if they have not taken an active role in the management of the polluting industry.

2.4 Future Directions

The Guidelines were developed in an evolving form, with the intention being to make amendments to the Guidelines as scientific, technical and policies matters developed. ANZECC/NHMRC are currently in the process of reviewing the structure of the Guidelines. The proposed structure involves the separation of the policy framework from the technical aspects of the Guidelines. The new structure will provide a clearer information package and better serve the many users of the current Guidelines. It will also allow for a more efficient amendment of the technical aspects of the assessment and management process.

Standards Australia are currently developing a Standard for the sampling of contaminated sites. The draft Standard sets out procedures for investigating sites by creating checklists for site histories, inspections and sampling strategies. The draft also includes some statistical equations for determining sample numbers and recognises the site specific component for assessment.
3 QUEENSLAND LEGISLATION

The legislation in Queensland has been developed in accordance with the National approach. There are three pieces of legislation that provide for the management of contaminated land:

- *Environmental Protection Act 1994* (EP Act);
- *Local Government (Planning & Environment) Act 1990* (LG(P&E) Act); and

The EP Act provides for ecologically sustainable development and addresses the management of current activities so as to minimise environmental harm. The LG(P&E) Act provides the trigger mechanism for investigations into potentially contaminated lands at change of zoning, sub-division or consent use and for the assessment of environmental impacts of proposed developments. The CL Act provides the framework to manage contaminated land in the State. The purpose of the CL Act is to provide a system to identify and manage land that has been contaminated and to prevent further contamination.

The objectives of the CL Act are to:

- Define contaminated land;
- Prevent further contamination of land;
- Identify all contaminated land in Queensland and maintain a public register of identified land;
- Enable assessment and management of contaminated sites on a site specific basis to ensure the land does not present a hazard to health and the environment; and
- Provide for recovery of costs of investigation and remediation of land from those who caused the contamination and from others.

3.1 Prevention

The EP Act provides the main vehicle for prevention of contamination from existing industry, principally through licensing of environmentally relevant activities. Licence conditions require that industry minimise environmental impacts including those to land. The LG(P&E) Act, through the impact assessment process, is the main tool used to prevent contamination from new industry. The CL Act provides offence provisions, prohibiting contamination of land unless it is conducted in accordance with another piece of legislation. Penalties of up to $60,000 are provided for in the CL Act for unlawful contamination of land. It is expected that industry and the community will reap long term savings, minimising clean-up costs and providing for a more beneficial use of land.

* Copies of Queensland Government Acts are available from Goprint, Brisbane.
3.2 Assessment and Management

The CLAct, through the Contaminated Sites Register, assists in determining whether an assessment is required for a site. Under the CLAct, owners or occupiers of land are required to notify the Department of Environment (QDE) of contaminated land. Local government, Government Departments or other statutory authorities must notify QDE of land within its jurisdiction that is or is likely to be contaminated. Supporting information regarding the potential contamination and use should be provided with the notification. A list of activities, called prescribed purposes, which are likely to cause contamination is provided in the legislation. The activities are based on those provided in the ANZECC/NHMRC Guidelines.

Assessments may be provided to QDE for review under the following circumstances:

- The site is undergoing a change of use and an assessment is provided to QDE for review and determination as to whether the proposed use is acceptable to QDE;

- The owner of a site has voluntarily conducted an assessment and requires a review by QDE with a view to changing the classification of the land; or

- The site is causing a hazard to human health or the environment and QDE has requested that a site assessment report be provided.

In most cases the site assessments are triggered as a result of a requirement by the local authority under the LG(P&E) Act..

Assessment should be conducted in accordance with the CHEM Unit Guidelines (CHEM Unit, 1992). These Guidelines are consistent with the National Guidelines, as previously described in section 2.2. The environmental scientist conducting the assessment and management program requires specialised skills developed from training and field experience.

The magnitude of the investigations will vary with the site. For a small fuel storage, only limited sampling may be necessary to establish if contamination exists. However for a large complex site the number of samples, types of analyses, data assessment and remedial works are likely to be extensive. On these sites it may be necessary to involve a variety of scientists with skills in specific areas, for example a hydrogeologist, historian, chemist, soil scientist, toxicologist and engineer.

It is important that the environmental scientist reports the process of assessment and management in a transparent manner. QDE, and people with an interest in the land, are then able to conduct a logical review of the works, ascertain that they have been performed to a high standard and be satisfied that contaminated land issues have been addressed. If QDE is satisfied with the findings of the scientist then a Site Contamination Report is issued.

The Contaminated Sites Register is used as a database to record land through the identification, assessment and management process. The Register uses a system of classifications to record land. These classifications are:
- "Possible" where land, or its locality, has been reported to be contaminated but no further information is available to QDE to classify the land.

- "Probable" where the land has been used for an activity that is known to cause contamination, in the main prescribed purpose activity sites. The vast majority of sites on the Register have this classification.

- "Confirmed" where an assessment has shown that the land is a hazard to human health or the environment and action is required to remediate the land.

- "Restricted" if management procedures can be instituted for the contamination to allow for the use of the land. Examples of management procedures include control of the land use or containment on site beneath a concrete slab or clay cap.

- "Former" if the land has been remediated and validation sampling verifies that the land is no longer contaminated.

- "Released" if the land was thought to be contaminated but an assessment has shown that it was not.

The details contained on the Register include the Lot-on-Plan description of the land, street address, ownership details and prescribed purpose use. The Register is accessible by the public for all sites except "possible sites". "Possible sites" are not available as the allegation of likely contamination has not been sufficiently substantiated.

The public is able to search the Register through direct access to the Government Information Centre (CITEC), or by application to QDE. A statutory fee of $15 is charged for each search of the Register.

### 3.3 Liability

The CLAct establishes a hierarchy of liability for contaminated sites where assessment and remediation is necessary. The hierarchy is based on the polluter pays principle established in the ANZECC Guidelines.

### 3.4 Future Directions

A number of areas requiring amendments have been identified since the commencement of the CLAct. The introduction of the EPAct has centralised environmental legislation and it is proposed that the CLAct be incorporated into the EPAct to provide the public with a more coordinated approach to environmental protection. Additional areas that are being reviewed include the liabilities of lenders, further identification and definition of prescribed purpose activities, mechanisms to encourage the management of on-site contamination and strengthen dispute resolution procedures for the public.

From an operational perspective, QDE has recently initiated a project to enable the provision of better services to users of the Register. The new service is most applicable to properties containing a cattle dip. Because the Register records Lot-on-Plan description of land,
searchers of the Register may gain the false impression that all of a large rural property is affected by a dip when in fact only a very small portion of the land in the immediate vicinity of the dip is. QDE is currently establishing a Geographic Information System (GIS) system where the location of the dip will be recorded on the GIS system. This information will be available to the public as part of the search service. The project is being conducted in conjunction with the Queensland Farmers Federation.

4 MAJOR CONTAMINANTS

The major contaminants encountered during Site Investigation Reports on prescribed purpose and other sites in Queensland are:

4.1 Organics

(i) Total Petroleum Hydrocarbons (TPH)
Alkane fractions (C₅-C₉, C₁₀-C₁₄, C₁₅-C₂₈, C₂₉-C₃₆).
Common Sources: Fuel, oils and greases associated with industrial activities

(ii) Organo Chlorine Residues (OCs)
Primarily DDT, Dieldrin, Heptachlor
Common Sources: On farm use and storage, cattle dips and general usage as termiticides and other pesticides

(iii) Less Frequently Encountered Compounds include:

(a) Polyaromatic Hydrocarbons (PAH)
Common Sources: Tars, gas generation works

(b) Polychlorinated Biphenyls (PCB)
Common Sources: Transformers, hydraulic oils

(c) Aromatics: Benzene, Toluene, Ethylbenzene, Xylene (BTEX)
Common Sources: Motor spirits, industrial petroleum solvents

(d) Organo Phosphate Residues (OPs)
Common Sources: Mainly in storage areas for on farm uses and cattle dip operations.

4.2 Inorganics

(i) Heavy Metals
Cu, Pb, Zn, Cr

Common Sources: Workshops, light and heavy industry, sandblasting, foundries, mining leases, tanneries etc.

(ii) Non Metallics
As, CN SO₄/S
Common Sources: Cattle dips, railway easements, gold mining and extracting plants, acid oil waste disposal areas, drum cleaning plants.

(iii) Less Frequently Encountered Contaminants include:

(a) Heavy metals Cd, Hg, Ni

Common Sources: Galvanising works, battery works, printers, ex-laboratory sites, electroplating works.

(b) pH, acid sulphate soils

Common Sources: Landfill sites, lowland development sites.

(c) Asbestos

Common Sources: Building sheeting, lagging of steam pipes, A/C ducting, kiln door seals.

4.3 Further Investigation and/or Clean Up Levels

Some of these data are provided by ANZECC/NHMRC but the lack of (as yet) comprehensive data sets makes this source unsatisfactory in most cases.

In the absence of data from these sources, the most commonly used data for further investigation and clean up levels are the internationally accepted criteria, Dutch Indicative Values for Concentration Levels, eg:

Dutch A - Reference value in the context of clean up
Dutch B - Indicative value for further investigation
Dutch C - Indicative value for cleaning up.

Some examples are shown in Table 2 for common contaminants.
Table 2  Indicative values for concentration levels

<table>
<thead>
<tr>
<th>MATRIX SUBSTANCE</th>
<th>SOIL (mg/Kg) O.D</th>
<th>Groundwater ug/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>As</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Cd</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Hg</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>Pb</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>Cu</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td><strong>Organics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAH (Totals)</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>OCs (Totals)</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Fuels</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Mineral Oil</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Inorganics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur (Total)</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>CN (Total Free)</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>CN (Total Complex)</td>
<td>5</td>
<td>50</td>
</tr>
</tbody>
</table>

5  SITE RULES

The rules governing Site Investigation Reports are predominantly those that satisfy the requirements of:


(ii) Quality Assurance:

(a) Related to the published guidelines for the Assessment of Contaminated Land in Queensland, together with compliance with Schedules I and II of the Contaminated Land Regulation, 1991.

(b) Relevant procedures associated with the requirements of the Australian Standards for quality assurance ISO 9001; 1994.

(iii) Specific requirements associated with:

(a) Commercial and industrial clients

(b) Government departments

(c) Local authorities
Some of the more common rules are:

5.1 **Workplace Health and Safety 1989**

These vary widely depending on the nature of the site and the contaminants that are present or likely to be encountered. Specific investigations may involve all or some of the following:

(i) Exclusion barriers and signage.

(ii) Licensed scaffolding.

(iii) Depending on the presence and nature of dust, fumes, fibres, personal protective equipment (PPE) which can range from:

   - simple hard hat and safety shoes, through to
   - full PPE and self-contained breathing masks.

(iv) In the case of asbestos removal, exit decontamination chambers and negative air pressure sealed workface cocoons.

(v) Water filled site excavations have to be treated to prevent mosquito breeding.

5.2 **Quality Assurance**

The following procedures and requirements are commonly applied to Site Investigation Reports:

(i) The project is supervised by a consultant who is a member of a Prescribed Organisation (Schedule II, the Contaminated Land Regulation 1991.)

(ii) Sample location and analyte selection are based on existing and past activities on, or adjacent to, the site.

(iii) Adequate procedures need to be taken to prevent contamination and deterioration of samples during retrieval and handling.

(iv) Sample storage and delivery require appropriate preservation of environments and Chain of Custody Documentation.

(v) Analytes are determined by laboratories that have NATA registration for the determination concerned.

5.3 **Client Requirements**

Many commercial organisations, government departments and local authorities have specific rules that are binding on consultants during site investigations, reports and audits, e.g:

(i) Induction training and security screening.
(ii) Daily reporting to the appropriate environmental manager, or site supervisor

(iii) Wearing of specified PPE. For example, to work on Queensland Railway (QR) Properties requires:

   (a) An induction course with an examination and issue of a yellow Basic Awareness Training Card

   (b) Daily reporting to the QR Site Supervisor

   (c) PPE including safety boots, hard hats and orange reflective vests.

6 REMEDIATION COSTS

The costs associated with Site Investigation Reports (and Remediation) can be grouped in two broad phases:

- Site inputs and activities
- Disposal costs

6.1 Site Inputs

Typical inputs and cost percentages include:

- Consultancy fees 40% - 60%
- Laboratory costs 10% - 25%
- Subcontractors - drillers, excavators, carriers etc 15% - 30%

In actual dollar costs for the total of the above components, the majority of Site Investigations Reports can range from around $2,500 - $30,000. In a small percentage of sites, these costs can exceed $100,000 and upwards. (It is noted that Thiess have been awarded the clean up of Maralinga atomic test site on a quote of $20,000,000 plus).

6.1.1 Typical examples

The following examples are drawn from investigations that are current or have been completed by Baseline. These are also normal for the majority of the industry.

(i) Rezoning rural land (farms) to Residential A Stage I investigation $2,800 - $4,500

   When sampling indicates the absence of problem levels of analytes of environmental concern.

(ii) Cattle dips Stages I - V Site investigations $6,000 - $14,000
(iii) Fuel stations with leaking underground tanks $12,000 - $23,000
(iv) Ex Local Authority landfill and acid oil waste disposal $75,000

6.2 Disposal Costs

In many cases, the disposal charges levied by Local Authorities constitute the majority of Site Investigation costs. Brisbane City Council charges are a fairly good guideline in this respect.

Depending on the nature and concentration of contaminants together with the volume of spoil and Toxicity Characteristic Leachability Procedure (TCLP) results, charges can vary eg.

(i) Disposal to landfill tip - $10/tonne
(ii) Disposal to Lined Landfill (Rochedale) - $55/tonne
(iii) Neutralisation/Stabilisation at Willowwong then to Gurulmundi - $160/tonne

Some typical examples from experience are:

(a) Cattle Dip

Input Costs $13,700
Disposal Costs $67,000

(b) Transport Depot

Input Costs $18,000
Disposal Costs $32,500

(c) Ex Landfill and Heavy oil waste disposal

Input Costs $ 42,000
Disposal Costs $150,000

Some common examples(for disposal) of analytes of concern into landfill or lined landfill are listed in Tables 3 and 4.
Table 3  Permissible concentrations for landfill disposal

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Maximum Levels in Solid Industrial Refuse (mg/kg)</th>
<th>Unlined Landfill (Hardfill)</th>
<th>Lined Landfill (Rochedale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTEX (Benzene)</td>
<td>500</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>TOTAL PHENOLS</td>
<td>250</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>TOTAL ORGANOCHLORINE PESTICIDES</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>TOTAL ORGANO-PHOSPHORUS</td>
<td>&lt;10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>TPH (Alkanes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C&lt;sub&gt;6&lt;/sub&gt; - C&lt;sub&gt;9&lt;/sub&gt;</td>
<td>500</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>C&lt;sub&gt;10&lt;/sub&gt; - C&lt;sub&gt;14&lt;/sub&gt;</td>
<td>5,000</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>C&lt;sub&gt;15&lt;/sub&gt; - C&lt;sub&gt;28&lt;/sub&gt;</td>
<td>10,000</td>
<td>50,000</td>
<td></td>
</tr>
<tr>
<td>C&lt;sub&gt;25&lt;/sub&gt; - C&lt;sub&gt;36&lt;/sub&gt;</td>
<td>10,000</td>
<td>50,000</td>
<td></td>
</tr>
</tbody>
</table>

Table 4  Permissible leachate levels for landfill disposal

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Allowable TCLP Levels (mg/L)</th>
<th>Unlined Landfill (Hardfill)</th>
<th>Lined Landfill (Rochedale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum Hydrocarbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metals/Non Metals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.5</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.05</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>10.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>0.5</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>0.01</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>50.0</td>
<td>500.0</td>
<td></td>
</tr>
<tr>
<td>Inorganics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyanide (total)</td>
<td>1.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Sulfate</td>
<td>2,500.0</td>
<td>5,000.0</td>
<td></td>
</tr>
<tr>
<td>Nitrate</td>
<td>100.0</td>
<td>1,000.0</td>
<td></td>
</tr>
<tr>
<td>Aromatics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BTEX</td>
<td>5.0</td>
<td>50.0</td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>0.1</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>
7 SHALLOW GROUNDWATER COMPLICATIONS

It is our experience that contamination of ground water occurs in surprisingly few cases. In the main, remediation verified by validation analysis occurs at a depth well above the water table. This is particularly so in the case where contamination has a surface origin eg. cattle dips as opposed to underground fuel storage. In the first case contaminants are usually confined to the top 1.0m of the profile in the latter the contamination source can be 3.0m below the surface at the base of the tank pit.

Some complications related to experience are best demonstrated by examples.

(i) **Perched Water Tables (1.5m-3.0m)**

Associated with ex landfill acid oil waste disposal in old billabong at Everton.
- (a) Volume between 80,000 - 200,000 litres
- (b) pH 2.5 - 3.0
- (c) TPH 6000 mg/L
- (d) Pb 600 mg/L

**Remediation**: Pump to intermediate storage, neutralize pH and dispose to BCC sewer. The general water table at approximately > 4.5m will be assessed and if necessary monitored by a consultant hydrologist.

(ii) **Underground Tank Storage**

In excess of 300,000L diesel fuel tank storage with long term leak. Ullage in 2000 m³ pit is water saturated sand

- (a) Contamination at levels in excess of 7% diesel fuel
- (b) Tank pit unlined but excavated into heavy grey brown clay

**Remediation**: Monitoring bores intersected water table at 3.0 meters around perimeter of the pit. There was no evidence of movement of contamination from the confines of the pit.

The lessee oil company removed part of the tank pit cover and located and repaired the leaks. After replacing the cap the situation was left as is.

(iii) **Ex Bus Maintenance Depot**

Underground fuel storage removed and partial remediation carried out by lessee oil company.

- (a) Water table between 3.5-5.0m contaminated with short chain alkanes
- (b) Levels, direction of flow and velocity of water table ascertained by monitoring bores
Remediation: Due to conflict between owner and lessee, no progress in over 18 months.

- elapsed time may have resulted in self cleansing
- levels are such that pumping to sewer is permissible
- spray irrigation onto adjacent parkland is also a possible option

8 CONCLUSIONS

National and State policies have been developed to address contaminated land issues and protect public health and the environment. The policies provide a strategic framework which address liability and management issues. The approach establishes management principles and soil quality guidelines. The Queensland Government introduced legislation in keeping with the National policy. The legislation provides for the prevention, assessment and management of contaminated land. National and State policies are currently under review with amendments proposed that address policy development, community concerns and evolving scientific knowledge.

The application of the requirements of such legislation e.g. Contaminated Land Act 1991 and Section 8.3A of the Local Government (Environment and Protection) Act 1990, has resulted in a significant and ongoing rehabilitation and remediation of the ‘brown environment’. Subsequent environmental legislation is helping to prevent future contamination. Current landfill disposal is costly and imposes pressures on local authorities and concern to environment bodies. As the gap between landfill disposal costs and on site treatment narrows the latter will become the more acceptable method.

9 REFERENCES


FIELD OBSERVATIONS - EARLY WARNINGS OF A LEMON

P.R. Wilson¹ and D. McGarry²

¹ DPI, Bundaberg, Qld, 4670.
² RMI, DPI, Indooroopilly, Qld, 4068.

ABSTRACT

The recognition and interpretation of limitations to urban development in the field are important steps in the planning process. Field observations on slope, flooding, wetness, permeability, depth to hard rock, rockiness, shrink-swell potential, erosion, salinity and mass movement can be used to identify development possibilities and assist in defining problems early.

KEYWORDS: urban development, field observations, flooding, wetness, permeability, shrink-swell, erosion, salinity, mass movement.

1 INTRODUCTION

Urban development, particularly in the high growth areas of south-east and coastal Queensland, continues to increase pressure on local authorities, land managers and other planners in the application of their planning function.

An important role of planners and those supplying data for planning purposes is the recognition and interpretation of development limitations. These personnel are aiming to minimise dangers and costs both to the community and the environment, but cannot spend excessive time on complex measures. In this lecture we aim to highlight the effects of limitations on urban development, and to link these to visible land attributes in the field. The emphasis on visible attributes is intentional, to provide rapid diagnosis of immediate and potential problems. The possibility of doing some field tests are also mentioned which can be undertaken to confirm observations in the form of quantifiable data.

2 URBAN REQUIREMENTS

Urban development covers a wide variety of uses. These include residential, industrial, tourist, commercial and recreational land use. Each has different requirements with land attributes affecting each use in different ways. Field information, gathered at a broad scale, can be used to identify general development and land use possibilities. However, field information is of minimal use in specific site planning, e.g., at a street or individual housing block level. The field information will assist in the initial definition of problems.

General consideration for urban development include both engineering and waste disposal issues.
These include such areas as:

- building foundations (slab, stumps, piles)
- shallow excavations
- roads and/or parks
- earth dams
- on-site effluent disposal
- sewage lagoons
- sanitary landfill
- intensive-use areas (picnic areas, playgrounds)
- walking paths and trails
- camp sites
- golf courses

Earth resources such as topsoil, sand and gravel, and road-fill are not part of this lecture. The field observations that may pinpoint limitations affecting the engineering uses and waste disposal, and land degradation are:

- Slope
- Flooding
- Wetness
- Permeability
- Rockiness
- Shrink - swell
- Erosion
- Salinity
- Depth to hard rock
- Mass movement

Each of these will be briefly considered in the following section. The last section will then detail the types of observations that may be collected for each.

3 LIMITATIONS

3.1 Slope

Slope influences the type of construction (slab, stumps, piles), intensity of development and efficiency of services. It also affects other limitations such as erosion, mass movement and off-site drainage.

3.2 Flooding

Previous maximum flood height, frequency and duration determine possible damage to structures or services, difficulties of stormwater discharge and effluent disposal.

3.3 Wetness

Site drainage and depth to seasonal/permanent watertables influence foundation types, differential settlement of foundations and roads, drainage measures, runoff, slope instability, access difficulties, flooding, dampness in buildings and effluent disposal.

3.4 Permeability

Soil hydraulic conductivity (permeability) influences aspects listed under “wetness” but is particularly relevant to on-site effluent disposal. Excessive or slow permeability can lead to disposal problems and the requirement for alternative disposal methods.
3.5 Depth to Hard Rock

Soil depth influences the ease of supplying underground services (water, sewerage, electricity, etc) and effluent disposal.

3.6 Rockiness

The size and amount of coarse fragments in the soil or loose rock below the overburden influence foundation type, effluent disposal and ease of installing services (boulders in shrink-swell clays are particularly troublesome).

3.7 Shrink-swell

Foundations and underground services will be affected by soils with shrink-swell potential. Suitability for foundation material will also be affected by compressible soils, dilatancy or where subsidence is likely.

3.8 Erosion

Water erosion, coastal erosion, flood/stream bank erosion and sediment deposition affect site stability and can lead to severe damage to buildings, stormwater systems, culverts, roads and other services such as water and sewerage.

3.9 Salinity

Salinity is an indicator of soil permeability and landscape hydrology. Saline soils can have a high erosion hazard, effluent disposal problems, cause corrosion and be visually unacceptable.

3.10 Mass Movement

Mass movement, such as soil creep, landslips and earth flows, affect site stability.

4 FIELD OBSERVATION

Associated with each of the above limitations are a range of land attributes. Recognition of these attributes in the field will assist in early definition of possible problems and may lead to alternate site selection or on-site remedial/preventive practices.

4.1 Indicators of Slope

Slope of the land is an easily measured attribute. At the simplest level, gradients may be assessed from contours on topographic maps. Full topographic surveys could be budgeted into projects when deemed necessary.
4.2 Indicators of Flooding

Assessment is made from either the period of inundation, flood height or flood frequency. Detailed quantitative data is commonly not available and most assessments are derived from local knowledge or landform, hydrology and climate. Table 1 outlines general indicators of flooding.

Table 1 Generalised indicators of flooding

<table>
<thead>
<tr>
<th>Geological Indicator</th>
<th>Landform Indicators</th>
<th>Soil Indicator</th>
<th>Climate Indicators</th>
<th>Hydrological Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent alluvium (Qa)</td>
<td>Floodplains -</td>
<td>layered soils</td>
<td>rainfall amount, patterns and probabilities</td>
<td>catchment size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>minimal profile development</td>
<td>influence from cyclones and rain depressions</td>
<td>debris, water stains</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2.1 Landform

Flood plains are alluvial plains characterised by frequent active erosion and aggradation deposition by channelled or overbank stream flow (McDonald et al., 1990). Terms such as “frequently active” are used to mean that flow has an average recurrence interval of 50 years or less.

Elements of a flood plain include; stream channel, plain, bar, scroll, levee, back plain, swamp, ox-bow, flood-out, meander plain, covered plain, anastomotic plain (see McDonald et al., 1990 for definitions).

Frequently, soils subject to frequent aggradation are characterised by sedimentary layering in the profile, for example, bands of sand, or soils with minimal profile development other than a darkening of the surface due to organic matter. Also, soils are frequently very deep (>1.5m).
4.2.2 Hydrology and climate

The size of the catchment (from maps) and the amount and duration of rainfall patterns can indicate relative frequency, duration and seasonality of floods.

Simple field observations, such as debris deposits (in trees and against bridges) and water stains on trees can indicate recent flood heights.

4.3 Indicators of Wetness

Wetness is a function of soil permeability (see section 4.4) and various land attributes which affect the supply to, and removal of water from, the site. Climate and landform are the common determinants.

Soil attributes indicating the level of soil permeability (see section 4.4) may be difficult to assess in the field and cannot be based solely on visible morphology in the soil profile. Mottling, soil colour and segregations, sometimes, but not always, reflect drainage status. Vegetation type and salinity may also be useful indicators. Long term field measurements of water-tables are often not practical. Table 2 summarises the climate, landscape, soil, vegetation and salinity attributes that individually, or better, cumulatively, may be used to indicate wetness.

Table 2 Indicators of wetness.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Likely indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
<td>Relative regional differences</td>
</tr>
<tr>
<td>Rainfall amount and distribution</td>
<td></td>
</tr>
<tr>
<td>Landscape</td>
<td>relatively better drained</td>
</tr>
<tr>
<td>steep slopes, short slopes, upper slopes, high relief</td>
<td></td>
</tr>
<tr>
<td>low slopes, long slopes, level, low relief, drainage depressions, swamps, floodplains</td>
<td>relatively poorer drained</td>
</tr>
<tr>
<td>Soil morphology</td>
<td>well drained</td>
</tr>
<tr>
<td>bright colours (red, brown), no or few mottles, no segregations,</td>
<td>imperfectly/poorly drained</td>
</tr>
<tr>
<td>large mottles, numerous mottles, pale colours, manganiferous/ferruginous segregations</td>
<td></td>
</tr>
<tr>
<td>slow permeability (see Table 3)</td>
<td>relatively poorer drained</td>
</tr>
<tr>
<td>high permeability (see Table 3)</td>
<td>relatively better drained</td>
</tr>
<tr>
<td>Vegetation</td>
<td>imperfectly/poorly drained</td>
</tr>
<tr>
<td>wetness tolerant vegetation (tea trees, sedges)</td>
<td></td>
</tr>
<tr>
<td>Salinity</td>
<td>(see Table 7)</td>
</tr>
</tbody>
</table>
4.3.1 Climate

Rainfall patterns and evaporation clearly determine the amount of water and water distribution patterns. This factor is mainly important when comparing relative differences between regions or where elevation or orientation of mountains to prevailing winds creates marked differences locally.

4.3.2 Landscape

Steep short slopes, high relative relief and upper slope positions promote the shedding and rapid runoff of water. Therefore, landscapes with some or all of these components can be expected to be relatively better drained than lower slopes, long slopes, low relative relief, drainage depressions and swamps where water tends to accumulate.

4.3.3 Soil attributes

Mottles, soil colour and segregations (accumulations in the soil due to concentrations of some constituent) are often used to indicate soil wetness. However, these factors may be a relict feature, not reflecting the current status.

Wilson (1982) showed that mottles, soil colour and segregations are strongly correlated to water-table heights in soils of alluvial origin. Generally, as mottles become more numerous, larger or more prominent, the period of waterlogging increases. Also, as soil colour changes from bright red and brown to yellow to grey, the soils become wetter. Some segregations, particularly iron and manganese, are soluble under waterlogged conditions and tend to accumulate in parts of the soil subject to frequent watertable fluctuations.

4.3.4 Vegetation

Native vegetation is usually adapted to the local climate and soil environment and often to soil wetness. Local knowledge of species tolerance to wetness can be a reliable indicator. For example, tea trees (Melaleuca species) and sedges indicate wetness.

4.3.5 Salinity

Accumulation of salts on the soil surface indicates the presence of shallow saline groundwater. Evaporation causes capillary rise of water and salts from a seasonal or permanent watertable close to the surface (see section 4.8).

4.4 Indicators of Permeability

Soil permeability is the potential of the soil to transmit water internally either vertically or laterally. It is determined by the saturated hydraulic conductivity of the least permeable layer. Permeability can be inferred from soil attributes (Table 3).
Table 3  Soil attributes indicating permeable and impermeable soils

<table>
<thead>
<tr>
<th>Soil attribute</th>
<th>Likely indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>high clay content</td>
<td>slowly permeable soils, often associated with “wetter” soils</td>
</tr>
<tr>
<td>mixture of montmorillonite/kaolin clays</td>
<td></td>
</tr>
<tr>
<td>coarse structure (&gt;20mm)</td>
<td></td>
</tr>
<tr>
<td>columnar, prismatic structure</td>
<td></td>
</tr>
<tr>
<td>hardsetting surface with high fine sand content</td>
<td></td>
</tr>
<tr>
<td>soapy feel when wet (sodic soils ESP &gt;6)</td>
<td></td>
</tr>
<tr>
<td>pH &gt;8.5</td>
<td></td>
</tr>
<tr>
<td>moderate to high salt content in subsoil</td>
<td></td>
</tr>
<tr>
<td>very firm consistency</td>
<td></td>
</tr>
<tr>
<td>pale soil colours, mottling (see wetness)</td>
<td></td>
</tr>
<tr>
<td>numerous lime, gypsum segregations</td>
<td></td>
</tr>
<tr>
<td>dispersive soils</td>
<td></td>
</tr>
<tr>
<td>sandy textures</td>
<td>moderately to highly permeable</td>
</tr>
<tr>
<td>high montmorillonite or kaolin clay content</td>
<td></td>
</tr>
<tr>
<td>strong fine structure</td>
<td></td>
</tr>
<tr>
<td>porous structure (earthy)</td>
<td></td>
</tr>
<tr>
<td>non soapy feel</td>
<td></td>
</tr>
<tr>
<td>acid to neutral pH</td>
<td></td>
</tr>
<tr>
<td>low salt content in subsoil</td>
<td></td>
</tr>
<tr>
<td>friable</td>
<td></td>
</tr>
<tr>
<td>bright colours (coastal areas), no mottles</td>
<td></td>
</tr>
<tr>
<td>no segregations</td>
<td></td>
</tr>
<tr>
<td>non dispersive soil</td>
<td></td>
</tr>
</tbody>
</table>

4.4.1 Soil attributes

Permeability is usually reduced with increasing clay content by decreasing the proportion of large pores (Greacen and Williams 1983). However high clay content soils dominated by the clay mineral montmorillonite are often well structured and relatively permeable. Soils with kaolinitic mineralogy are usually more permeable than soils with mixed mineralogy.

The grade and type of soil structure as described by pedsize, shape, arrangement and stability largely determines the macropore space and consequently hydraulic conductivity / soil permeability. For example, fine strong structure has a much greater permeability than coarse columnar or prismatic structure due to the presence of a greater proportion of pore space.

Surface soil horizons normally have greater permeabilities than the horizons below, often because of the increased biological activity and organic matter, leading to more porous and stable soil. In such situations, recording the depth of these more permeable surface horizons is important. However, some surface soils lose structure very easily on disturbance and surface seals develop if left uncovered by vegetation, for example, massive surfaces with a high proportion of fine sand.

Sodic soils have limited permeability through structure instability and dispersion and alteration of the pore size distribution (Abrol et al., 1978). Sodicity is expressed as ESP (exchangeable sodium percent), ie. the ratio of exchangeable sodium to the cation exchange capacity. Strongly sodic soils (commonly where ESP>15) are often associated with high soil pH (pH >8.5). On the other hand, neutral to acid pH (pH<7.5) tends to indicate moderate to
high permeabilities. Field observations such as coarse structure, very firm consistency when dry, or slippery/soapy feel when wet are related to sodic soils.

Soil chlorides, electrical conductivity and salt profiles have been used to predict permeability. The accumulation of salts in a soil profile in a “high” rainfall region would indicate a limited depth of regular wetting and therefore, poor permeability.

Soil colour and mottles may reflect the drainage status in soils. Highly permeable soils often have bright colours with few to no mottling while slowly permeable soils may have paler colours with mottles (see section 4.3).

Segregations, such as lime and gypsum, often accumulate in soils below the zone of regular wetting. In moderate to high rainfall areas (>600 mm), the presence of these segregations is usually associated with sodic horizons. Lime is also associated with alkaline pH (pH>8).

4.5 Indicators of Depth to Hard Rock and Rockiness

The depth to rock is easily observed in a soil core, or roadside cutting, quarry etc.

The size and abundance of rock fragments is easily observed on the soil surface but often difficult to assess accurately below the surface.

4.6 Indicators of Shrink-swell

Shrink - swell properties are associated with high clay content soils (>35%) that are dominated by montmorillonite type clays. These clay minerals expand on wetting and shrink on drying, often resulting in the presence of surface cracks, slickensides (polished aggregate faces in the subsoil), lenticular structure (lense-shape) and gilgai ('melonhole' country). Observations of the in-soil features should be to a depth of 1.3 m or deeper for those interested in deep foundations.

Soil properties indicating high and low expansion or volume changes are listed in Table 4.

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Likely indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>surface cracking</td>
<td>high volume change</td>
</tr>
<tr>
<td>slickensides</td>
<td>low volume changes</td>
</tr>
<tr>
<td>lenticular structure</td>
<td></td>
</tr>
<tr>
<td>gilgai</td>
<td></td>
</tr>
<tr>
<td>sandy to loamy textures</td>
<td></td>
</tr>
<tr>
<td>single grain or earthy or polyhedral structure</td>
<td></td>
</tr>
<tr>
<td>organic soils</td>
<td></td>
</tr>
<tr>
<td>bright colours (coastal areas)</td>
<td></td>
</tr>
</tbody>
</table>
4.6.1 Surface cracks

On partial drying, deep cracks may form. These may extend from the surface to depth, and these may be vertical or follow a “Z” pattern, or they may solely be on the soil surface. Cracks may be 1cm or many centimetres wide and can extend to a depth of 0.5m or even up to 1m or more.

If the surface is strongly self mulching (a mass of loose granules), or if the soil is cultivated, or often in texture contrast soils with massive surfaces, the cracks may not be evident at the surface. Also, if soils are wet for extended periods, cracks may not be evident.

High sodium levels in montmorillonite clays are associated with a high degree of cracking or expansion. Montmorillonite type clays are generally indicated by a high cation exchange capacity to clay ratio (>40 meq/100g clay).

4.6.2 Slickenside, lenticular structure, gilgai.

When cracking soils are wetted, water commonly runs into cracks so that the soil re-moistens both from below and from above. The clay swells and the cracks close, generating pressure. The swelling of one horizon before another creates movement of one part of the soil against another. The result is soil movement in an intermediate direction at an angle from the horizontal. This is probably the origin of smooth stress planes on soil aggregate faces (slickensides), gilgai and lenticular structure. Gilgai is microrelief consisting of either microbasins and microknolls (normal gilgai, melonholes), or of microvalleys and microridges that run parallel to the slope (linear gilgai).

4.7 Indicators of Erodibility

The potential for water erosion is dependant on the interaction of rainfall, soil erodibility, slope, slope length and surface management practices. Coastal erosion and flood / stream bank erosion are not considered here. Table 5 outlines land and soil properties as indicators of potential water erosion.

<table>
<thead>
<tr>
<th>Land properties</th>
<th>Soil Properties</th>
<th>Likely indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>steep slopes (depends on soil erodibility)</td>
<td>slowly permeable (see permeability)</td>
<td>erosion prone</td>
</tr>
<tr>
<td>long slope length (&gt;300m)</td>
<td>highly dispersible (see permeability)</td>
<td></td>
</tr>
<tr>
<td>run-on areas (concentrated flow)</td>
<td>shallow soils</td>
<td></td>
</tr>
<tr>
<td>evidence of erosion (terracing, rills, gullies, deposition)</td>
<td>wet soils (see wetness)</td>
<td></td>
</tr>
<tr>
<td>cleared / no surface cover</td>
<td>sealing surface</td>
<td></td>
</tr>
<tr>
<td>well vegetated with good surface cover</td>
<td>highly permeable</td>
<td>stable</td>
</tr>
<tr>
<td></td>
<td>non dispersible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>well drained</td>
<td></td>
</tr>
<tr>
<td></td>
<td>deep soils</td>
<td></td>
</tr>
</tbody>
</table>
4.7.1 Rainfall

The amount, intensity and distribution of rainfall will determine the distribution of erosive rainfall. Data should be collected from the nearest meteorological station, with the aim of gaining as long a record of data as possible.

4.7.2 Soil erodibility

Soil erodibility is a complex phenomenon dependant on surface infiltration characteristics, permeability of the soil below the surface, water holding capacity and soil wetness.

Infiltration and permeability (see section 4.4) determine the amount of water entering and moving through a soil. Slow infiltration (surface sealing) and slow permeability promote high runoff and erosion.

Soil wetness (see section 4.3) and water holding capacity give an indication of the amount of rainfall a soil can absorb before runoff occurs. For example, wet soils cannot absorb extra water while a deep dry soil can normally absorb a larger amount of rainfall.

4.7.3 Slope

Slope and slope length are attributes easily measured. As slope length and/or slope increase, the potential for erosion increases due to the increase in runoff and its velocity. Slope length can be manipulated by the use of man-made structures, such as contour banks.

4.7.4 Surface management and vegetation

Surface management practices, in particular the retention of vegetation, aim to increase infiltration, slow surface flow and protect the soil surface. Bare, disturbed surfaces are most prone to erosion.

4.8 Indicators of Salinity

The water intake in any landscape achieves a dynamic equilibrium with water lost from the landscape (plant uptake, evaporation, runoff and leakage to groundwater). Salts stored in the soil or in the weathered rock are also part of the balance as groundwater movement is the main salt-transport mechanism.

Tree clearing and irrigation (including effluent disposal) are major ways of disturbing the hydrologic balance. Any increase in water movement to groundwaters results in raised watertables, and these in turn can lead to an accumulation of soluble salts in the surface or near-surface horizons of soils in discharge areas.

The potential for increasing salt levels largely depends on soil wetness (Section 4.3), soil permeability (Section 4.4), landform features, geology and climate. Vegetation can be a useful indicator, as plants vary in their susceptibility to increasing salt in the soil (Section 4.8.3).
4.8.1 Landform

Sensitive landforms can be commonly pinpointed through the presence of some restriction to groundwater flow. This causes the watertable to rise near to the soil surface, resulting in a discharge area with evaporative concentration of salts (Shaw et al., 1996). Figure 1 illustrates landforms often at risk of developing salting. Hydrologically sensitive landscapes often show evidence of past seepages or shallow watertables. The advantage of using landforms to diagnose susceptibility is that landforms can be readily observed.

Basalt form

Both seepage and watertable salting can occur where basalt overlies less permeable rock, where regions of variable permeability occur within the basalt, or where the basalt is in contact with adjacent formations.

Catena form

Discharge areas can occur in the lower slope or at break-of-slope positions where soils or geologic features restrict water movement. Lower slope soils may be sodium- and salt-affected.

Alluvial fans

Discharge areas can occur where subsurface water encounters deep clays or more recent alluvia.

Catchment restriction

Salting can occur upslope of natural or artificial restrictions that narrow the width or depth of the catchment throat. Salting can occur upslope of roads or stock routes that have compacted the soil.

Alluvial valley

Salting can occur where the valley is very flat and the hydraulic gradient is very low.

Stratigraphic form

Small seepages and salted areas can appear on hillslopes where water flow encounters layers of rock with reduced permeability.

Figure 1 Landform types associated with historic indicators of salting. (Shaw et al., 1987)
4.8.2 Geological indicators

Most dissolved salts occurring in natural waters originate from salts in rainfall and weathering of rocks near the land surface. High salinities occur in many of the fine-grained sedimentary rocks (mudstones, shales). General interpretation guidelines are provided in Table 6.

Table 6 Generalised interpretation of shallow groundwater and saline hazard areas from maps using geological features. Source data for geological indicators can be obtained from 1:250 000 geological maps and special purpose maps (for example, regolith maps, mineral exploration maps). (Shaw et al., 1996).

<table>
<thead>
<tr>
<th>Critical areas commonly requiring identification</th>
<th>Discharge areas</th>
<th>Salt sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recharge areas</strong></td>
<td><strong>Clay alluvia in broad, flat valleys</strong> (Qa, Qc, Qi, Qs, Cza, Czs)</td>
<td><strong>Fine-grained sediments</strong> of marine origin</td>
</tr>
<tr>
<td>rock outcrops in elevated landscapes - particularly basalt, sandstones and limestones</td>
<td>estuarine sediments and adjacent low lying areas (Cze)</td>
<td>deeply weathered or lateritised rocks</td>
</tr>
<tr>
<td>deeply - weathered intrusive rocks - particularly granite and granodiorite</td>
<td>margins of basals in upper landscape positions</td>
<td>coastal mud flats (Qm)</td>
</tr>
<tr>
<td>strongly jointed or fractured rocks</td>
<td>coastal mud flats (Qm)</td>
<td>carbonaceous sediments (such as coal and carbonaceous mudstones, siltstones and shale)</td>
</tr>
<tr>
<td>strongly jointed or fractured rocks</td>
<td>peat deposits</td>
<td>playas and sabkha sediments (Qs)</td>
</tr>
<tr>
<td>lateritised rocks (Ql, TI, Czl)</td>
<td></td>
<td>playas and sabkha sediments (Qs)</td>
</tr>
<tr>
<td>sand and gravel units (Qa, Qb, Qd, Qt, Ts, Czg, Czs)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Landforms commonly at risk**

<table>
<thead>
<tr>
<th>Basalt landforms</th>
<th>Constricted catchments</th>
</tr>
</thead>
<tbody>
<tr>
<td>margins of Tertiary basalts (Tb, Czb) and older, deeply weathered basalts in elevated landscape positions</td>
<td>just upstream of ‘pinched out’ areas in broad Quaternary alluvium (Qa)</td>
</tr>
<tr>
<td>margins of lateritised rocks in upper landscape positions (Ql, TI, Czl)</td>
<td>broad areas of Cainozoic sediments (Czs) as above</td>
</tr>
<tr>
<td></td>
<td>stringers of sediment along drainage lines with restricted linear extent</td>
</tr>
<tr>
<td></td>
<td>outcrop of basement (deeper) rocks at or near the land surface along drainage lines.</td>
</tr>
</tbody>
</table>

4.8.3 Vegetation

Certain species are commonly found on salt-affected soils, and can be useful for identifying salt outbreaks. Where plant species are identified that are salt tolerant or that compete more effectively under saline conditions, salinity may be occurring at the site. The presence of salt-sensitive species in surrounding areas, but absent from a location, may indicate salting. Further site investigations should be undertaken to determine whether salinity is in fact occurring, and to what extent.
The publication - *Plants and salinity in Queensland* (currently in press) is a useful guide. Where plant species indicative of wet sites are present such as tea trees, the risk of watertable rise to the surface if the vegetation is cleared is high.

4.8.4 Climate

In Queensland, watertable salting is mainly confined to lands receiving 600 to 1500mm of rain annually, with the most marked effects occurring in lands receiving 700 to 1100 mm of rainfall (Shaw et al., 1996).

4.8.5 Soil attributes

Soil attributes indicating wetness and permeability are discussed above. Table 7 summarises the soil properties typical of recharge and discharge areas.

**Table 7 Soil properties typical of recharge areas or current historic discharge areas. (Shaw et al., 1996)**

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Likely indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>mottling</td>
<td>permanent, periodic, or historic discharge area</td>
</tr>
<tr>
<td>gleying</td>
<td></td>
</tr>
<tr>
<td>manganiferous staining</td>
<td></td>
</tr>
<tr>
<td>numerous CaCO₃, silcrete, manganese or iron nodules</td>
<td></td>
</tr>
<tr>
<td>near soil surface</td>
<td></td>
</tr>
<tr>
<td>fluffy soil surface</td>
<td></td>
</tr>
<tr>
<td>surface salts</td>
<td></td>
</tr>
<tr>
<td>bare wet areas with dead vegetation</td>
<td></td>
</tr>
<tr>
<td>mottling</td>
<td>shallow seasonal or fluctuating watertable,</td>
</tr>
<tr>
<td>gleying</td>
<td>possible discharge area</td>
</tr>
<tr>
<td>indicators intensifying with depth, and soil</td>
<td></td>
</tr>
<tr>
<td>becoming saturated with water</td>
<td></td>
</tr>
<tr>
<td>variable pH</td>
<td></td>
</tr>
<tr>
<td>moderate to high salt content in subsoils</td>
<td></td>
</tr>
<tr>
<td>permeable soils (eg. sands, lithosols,</td>
<td>recharge area</td>
</tr>
<tr>
<td>krasnozems, non-saline soils generally)</td>
<td></td>
</tr>
<tr>
<td>shallow soils overlying weathered or fractured rocks</td>
<td></td>
</tr>
<tr>
<td>weathered soils</td>
<td></td>
</tr>
</tbody>
</table>

4.9 Indicators of Mass Movement Potential

Mass movement includes all relatively large downslope movement of soil, rock or mixture of both. For example, landslips (slumps), earth flows, debris flows, creep. Such mass movements of material occur most readily where there is abundant groundwater and clays to provide lubrication.

4.9.1 Soil creep

Creep is the slow, imperceptible downslope movement of earth materials under the influence of gravity (Chorley et al., 1984). Soil creep is one type of mass movement that can operate
over the entire landscape. It involves the movement of soil as a viscous fluid or as a plastic, and the vertical movement is usually greatest near the surface.

4.9.2 Landslips

Landslips can be described as movement or sliding along a curved fracture surface. Water can be an important transport agent. The initial landslip is frequently converted to a flowing type movement which in turn becomes an earth flow or debris flow (Chorley et al., 1984).

These mass movements generally require a mantle of soil, a steep slope and soil moisture sufficient to permit flow. During heavy rain, saturation reduces the cohesion of the slope material, and seepage and porewater pressure leads to a reduction in shearing resistance. A majority of mass movements in the Lockyer Catchment were triggered by the 1974 flood rains (Shaw, 1979).

Lithology and geological structure also influence mass movement. For example, shale outcrops are more susceptible to failure than sandstones, layered rocks dipping towards a slope-face are more susceptible. Weathering and rock character are also important factors in determining mass movement type and frequency. For example, fresh rock may cause rock slides and deeply weathered rock may more commonly be associated with landslips and flows. Montmorillonite type clays tend to have higher velocity slide movement than other clay minerals.

Sedimentary rocks with inter-bedded permeable and impermeable layers (Figure 2) and basalts (Figure 3) represent a majority of landslips in south east Queensland.

Figure 2 Diagrammatic Section showing landslips related to particular geological strata, Lockyer Valley (Hughes, 1980). (Interbedded sandstones and shales of the Heifer Creek member of the Marburg Formation have weathered to form benches on resistant sandstone beds, and steep slopes on underlying softer shale beds. The sandstones are permeable and the shales impermeable, and water consequently is discharged from the sandstones, saturating the steep slopes beneath the sandstone outcrops. Where stability has been further decreased by removal of vegetation, landslipping frequently occurs).
Vegetation is also important in determining the potential for landslips. In particular, deep rooted species make slopes more resistant to movement. In the Lockyer Catchment, more than 90% of all movements occurred on land cleared in the recent past (Shaw 1979, Willmont 1982).

Most mass movement occurs on intermediate slopes (>30% to <100%). Steeper slopes generally have thin rocky soils so there is minimal material to constitute movement. In lateritised basalts, slopes greater than 15% are at risk (Hughes 1980) while gentle to moderate slopes (7% to 27%) are at risk on inter-bedded shales and sandstones (Willmont 1982).

In summary, relief, slope, rock type, climate and zones of weak rock need to be considered. Many of these factors are subsurface and it is extremely difficult to pinpoint where a landslip will take place.

5 CONCLUSIONS

Field observations can provide cost effective early warnings of likely problems in potential development areas. These observations, based on landscape, soils and vegetation of an area within a set climatic regime, provide rapid assessment with minimum requirements for specialised apparatus or technical skills. It is the decision of the developers and planners to determine the need for more detailed measurements of critical attributes. Failure to heed these indicators in the early phase of a development may lead to the need for costly remedial actions at a later stage.

Figure 3  
Diagrammatic Section showing landslipping developed in lateritised basalts, Toowoomba area (Hughes, 1980). (Lateritised basalts have weathered to deep clays overlying fresh basalts. An impermeable layer has developed at the top of the fresh basalt. The lateritic clays are very permeable and allow fast water intake, causing saturation of the clays above the impermeable layer. This zone is marked by springs on the slopes of the range. Under very wet conditions landslipping occurs in the lateritic clays, particularly in the saturated zone above the impermeable layer).
6 REFERENCES


PLANNING ISSUES FOR RURAL LANDS

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ABSTRACT

The fringe of Australia's cities and towns is a battleground of competing interests: between farmers and land developers over control and ownership of the land; between farmers and conservationists over the conservation of biodiversity; between landholders and local governments over land use rights; and between farmers and residents over agricultural practices. This paper deals with four issues in this transition zone: protection for agricultural land; conflict over land management practices; fragmentation of rural land by subdivision; and conditions placed on new residential developments. Each of these issues has a resource management focus, and each issue has a planning solution. The implementation of the proposed solutions requires appropriate policies, a comprehensive information database, and political will, or, in other words, the support of the community.

KEY WORDS: planning, agricultural land, subdivision, agricultural practices, separation areas, buffers, development conditions, urban fringe, resource management, resource protection.

1 INTRODUCTION

Australia is and always has been, one of the most highly urbanised countries in the world in terms of the proportion of the population living in large urban centres. The extensive sprawling urban areas are viewed by most Australians as home and represent their most familiar landscape. By contrast the coastline is the most important recreation area while Australians have very mixed feelings about rural areas. While to some it is the source of their food and national wealth; to others it is the source of national myths, aboriginal culture and identity; and to others it is an environmental battleground where survival of soils, forests and wildlife is at stake.

Of course it is all these things, and because of this diversity, the rural lands of Australia are the subject of intensive study and debate. However one rural area that is subject to the most active change is the urban fringe, the vast transitional area between urban and rural where land use is ill-defined, planning controls are weak and speculation for land development and subdivision is common. Because of Australians love affair with the suburban lot with its large backyard, swimming pool and green lawn, urban densities are very low by world standards and the urban areas merge with rural areas across large areas of rural residential settlement.

This paper deals with four issues in the urban fringe which have received policy attention in recent times. The strategies to address these issues all require an understanding of soil properties and behaviour for their successful implementation. These issues are:

- Protection of good quality agricultural land;
- Conflict over land management practices;
• Fragmentation of rural land by subdivision; and
• Appropriate conditions on development

These issues are generally concerned with agricultural production in this area of conflict but also deal with questions of environmental management such the disposal of effluent from residential areas.

Agriculture in Queensland is mixed and varied and a dominant land use and landscape feature. Almost 88% of the State is used for some form of agricultural production (cropping and grazing) which generates over $5,000 million in gross value of production per year. However the area of good quality agricultural land suitable for sustainable cropping covers only 8.2% of the State (14.2 million ha).

The Australian Bureau of Statistics reports that 1.5% of the State (2.58 million ha) is used for intensive cropping. Grazing and mixed grazing covers approximately 87% of the State and is dominated by the beef and wool industries. The carrying capacity of the land varies considerably and this is dependent mainly upon pasture type.

In the more closely settled areas of the State, the demands of an expanding population for additional urban land are significant. For example on current lifestyle and urban density trends, the additional population in South East Queensland, will occupy an additional 155,000 ha over the next 20 years. Put another way, each year 7,500 ha of bushland, agricultural land and other rural land will be consumed for housing and other urban purposes.

As a result of these pressures, rural and good quality agricultural land is under constant demand for development purposes. Between 1980 and 1990, 6,600 ha of assigned sugar-cane land was converted to non-rural uses and a further 12,400 ha was converted to other rural uses (Coleman & Edwards 1991).

Agricultural production areas are also residential areas for those that live and work on the farm. Family farms predominate, generally worked without employed labour. Crop production is increasingly a highly mechanised activity, with declining on-farm employment.

The result of these trends is that the rural landscape is often a complex mix of agricultural, residential, light industrial, conservation and recreation land uses. The land use and planning issues are also complex and defy simple solutions.

2 PROTECTION OF GOOD QUALITY AGRICULTURAL LAND

Agricultural land is acknowledged by Governments at all levels as an important national resource because of its existing and potential contribution to national income, global food production, rural communities and an attractive rural landscape. Good quality agricultural land is a finite and diminishing resource that should be conserved and managed for the benefit of agricultural industries of significance to the state and the nation (Queensland Government, 1992).

Urban development pressures are currently a major contributor to the alienation and reduced productivity of rural lands. The land resource is also under pressure from agricultural
practices which, in some localities, are responsible for degradation of the resource. These processes threaten both the long term productivity and availability of the land resource and the quality of water resources through sedimentation and the movement of nutrients and pollutants.

In order to achieve a consistent and workable framework for the protection of agricultural land, it is important that agreement is reached on both the definition and means of identification of those lands which should be protected.

2.1 Definition of Good Quality Agricultural Land

A wide variety of terms and definitions are currently used in the planning literature which refer to areas of agricultural land. The most common terms are good quality agricultural land and prime agricultural land.

*Prime* agricultural land refers to the 'first grade or best quality' (Macquarie Dictionary). *Good quality* agricultural land is a broader definition and includes land with a greater range and degree of limitations within the bounds of land suitable for sustainable agricultural use. On the basis that the prosperity of established agricultural industries is dependent on a range of agricultural lands (not just prime lands), the term *good quality agricultural land* has been adopted in Queensland to define those lands which require identification and planning attention.

In Planning Guidelines for the Identification of Good Quality Agricultural Land issued by the Department of Primary Industries (DPI) and Department of Housing, Local Government and Planning (DHLGP) in association with State Planning Policy 1/92, *good quality agricultural land* is defined as:

... land which is capable of sustainable use for agriculture with a reasonable level of inputs and without causing degradation of land or other natural resources. (DPI & DHLGP,1992).

Within this definition the terms *agriculture* and *sustainable* have the following meanings:

*Agriculture* is the use of land for crop or animal production, and *sustainability* is the ability of the (agricultural) system to maintain its productivity with no net decline over many decades, even if subjected to stress or perturbation. (Hamblin, 1991).
Figure 1

Agricultural land classifications in use in Queensland.

The relationship between prime and good quality agricultural land is shown in Figure 1 in the context of agricultural land classifications currently used in Queensland. A description of the agricultural land classes adopted in the Planning Guidelines (DPI and DHLGP, 1993) is given in Table 1.

Table 1

<table>
<thead>
<tr>
<th>CLASS</th>
<th>DESCRIPTION</th>
<th>GOOD QUALITY AGRICULTURAL LAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td><strong>Crop Land</strong> - Land that is suitable for current and potential crops with</td>
<td>All Crop Land is good quality agricultural land.</td>
</tr>
<tr>
<td></td>
<td>limitations to production which range from none to moderate levels.</td>
<td></td>
</tr>
<tr>
<td>Class B</td>
<td><strong>Limited Crop Land</strong> - Land that is marginal for current and potential</td>
<td>Limited Crop Land is good quality agricultural land where</td>
</tr>
<tr>
<td></td>
<td>crops due to severe limitations; and suitable for pastures. Engineering</td>
<td>required for particular crops of local significance.</td>
</tr>
<tr>
<td></td>
<td>and/or agronomic improvements may be required before the land is</td>
<td></td>
</tr>
<tr>
<td></td>
<td>considered suitable for cropping.</td>
<td></td>
</tr>
<tr>
<td>Class C</td>
<td><strong>Pasture Land</strong> - Land that is suitable only for improved or native</td>
<td>Pasture Land may be good quality agricultural land where</td>
</tr>
<tr>
<td></td>
<td>pasture due to limitations which preclude continuous cultivation for</td>
<td>pastoral industries are the predominant primary industries</td>
</tr>
<tr>
<td></td>
<td>crop production; but some areas may tolerate a short period of ground</td>
<td></td>
</tr>
<tr>
<td></td>
<td>disturbance for pasture establishment.</td>
<td></td>
</tr>
<tr>
<td>Class D</td>
<td><strong>Non-Agricultural Land</strong> - Land not suitable for agricultural uses due</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>to extreme limitations. This may be undisturbed land with significant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>habitat, conservation and/or catchment values or land with very steep</td>
<td></td>
</tr>
<tr>
<td></td>
<td>slopes, shallow soils, rock outcrop or poor drainage.</td>
<td></td>
</tr>
</tbody>
</table>


Good quality agricultural land in Queensland is land that is capable of sustainable use for sugar-cane, fruit, vegetables, field crops, cotton, grain, hay and fodder or dairy production without causing degradation of land or other natural resources.

These lands fall predominantly within Class A, but Class B land in the coastal cane growing areas are also considered to be good quality agricultural land. Areas of high quality grazing land (Class C) have also been defined as good quality agricultural land.
2.2 Identification of Good Quality Agricultural Land

A framework for the protection of agricultural land requires the identification of good quality agricultural land at two levels of detail. One is at a strategic planning scale where the land resource areas to be protected need to be clearly indicated. The other is at the detailed level for development assessment on a site by site basis.

Information for strategic planning must identify areas of good quality agricultural land which are required for agricultural use. Concepts of physical suitability and availability should be included in this process of identification.

Land resource studies provide an assessment of physical suitability; but the assessment of availability of agricultural land is more complex involving consideration of land tenure, holding sizes and other socio-economic factors. Such assessment is not currently practical at the broad scale as these factors are subject to seasonal and economic variation.

The identification of good quality agricultural land at a more detailed level is appropriate for determining rezoning or development approvals. Detailed information collection for this purpose is the responsibility of development proponents, but processes for checking the accuracy of information submitted should also be in place. The collection and checking of detailed land resource information may result in adjustments to the broad-scale strategic planning information. Specifications for such detailed land resource surveys are contained in the Planning Guidelines (DPI & DHLGP, 1993)

2.3 Land Availability for Agriculture

In urban fringe areas, where fragmentation into small allotments and encroachment of urban uses into agricultural areas has resulted in an mix of land uses, there are particular planning difficulties. While land converted to or zoned for urban uses is clearly unavailable for agriculture, the availability of other urban fringe areas for agriculture is less predictable.

In this context, the fact that individual allotments are too small for a particular form of commercial agriculture should not make them unavailable for agricultural production. The State Planning Policy 1/92 states that 'the fact that existing farm units and smallholdings are not agriculturally viable does not in itself justify their further subdivision or rezoning for non-agricultural purposes'. The policy advocates amalgamation of lots to form viable holdings as the first option for small lots. The use of these lots for hobby (part-time) farming may also be encouraged in preference to further subdivision; or alternatively, more intensive agricultural uses such as nurseries or flower production can utilise the smaller allotments.

Criteria similar to those used in the LESA system in the US (USDA, SCS, 1983) are currently being developed by DPI to identify areas which are not available for agricultural purposes due to tenure, subdivision, institutional or land use constraints.
2.4 LEGISLATIVE FRAMEWORK

The key parts of the planning framework for the protection of agricultural land in Queensland consist of State Planning Policy 1/92 titled *Development and the Conservation of Agricultural Land* which was released in December 1992, and planning schemes prepared by individual local governments of which the key components are the strategic plans and development control plans. The intention of the State Planning Policy is to encourage local governments to give adequate consideration to the need to conserve good quality agricultural land in the preparation of planning schemes, the determination of proposed amendments to schemes, and the determination of subdivision and development applications in agricultural areas. The State Planning Policy does not advocate the 'down zoning' of land to protect agricultural land resources. In this sense, no loss of existing land users rights is proposed.

Planning measures to control land use in Queensland may be described as 'uncompensated regulatory measures' (Willis, 1983). The planning system regulates land use and development in particular areas, or zones, in the overall public interest. When the planning system confers particular use rights on certain areas of land after careful consideration of community needs, compensation is not generally payable to landholders whose development rights are limited. Individuals who believe that their interest in premises is 'injuriously affected' by a planning scheme provision may make a claim for compensation to the local government within 3 years of the provision taking effect.

Rural land holders occupying good quality agricultural land on the fringe of expanding urban areas may be financially disadvantaged by land use controls which restrict permitted uses to agricultural and related uses. These controls may result in land valuations below that of comparable poor quality agricultural land. In these circumstances, some land holders believe that such restrictions on land use and valuation are unfair and are grounds for the payment of compensation.

Whilst compensation for the protection of agricultural land is generally not payable under the Queensland planning system unless land is down-zoned, there are nevertheless grounds to support the provision of incentives to rural landholders to maintain land in productive agricultural uses. These grounds are that the wider community derives unpaid-for benefits from agricultural land uses through affordable food and enjoyment of attractive rural landscapes, open space and clean air. These costs may be offset by providing incentives to maintain land in agricultural production.

Financial incentives are based on the need to encourage landholders to maintain land in agricultural production when there is an opportunity cost of doing so through forgoing the development value of rural land. Where there is a need to increase holding sizes to maintain farm viability, incentives to encourage farm restructuring by the amalgamation of titles may also be appropriate.

Incentives usually take the form of rate concessions, taxation concessions and reductions in application fees and stamp duty, but measures such as transfer of development rights have also been used in other countries.
The State Planning Policy stresses that good quality agricultural land is not an absolute constraint on development; but that these resources should not be built on unless 'an overriding need in terms of benefit to the community can be demonstrated for the development at the particular location'. The determination of 'overriding need' is the responsibility of the local government in the first instance on the basis of the State Planning Policy, the strategic plan and considerations of available alternative sites. Examples of overriding need include areas designated for urban development on strategic plans; areas zoned for urban development; and areas justified for urban development on the basis of population projections and absence of alternative sites on non-agricultural land. Other examples include major tourism or mining developments which could provide opportunities to diversify the economic and employment base of an area and support a growing industry; or major infrastructure (roads, railways and water supply dams) which usually have specific siting/location requirements.

Development rights for non-rural uses can be obtained by changing the zone in which an allotment is located from a rural zone to an appropriate zone in which a desired development use is permitted. With the advent of State Planning Policy 1/92 and the preparation of Strategic Plans by most Local Governments in Queensland, the rezoning of areas identified and designated in strategic plans as good quality agricultural land is now more difficult to achieve.

3 CONFLICT OVER AGRICULTURAL LAND MANAGEMENT PRACTICES

3.1 Sources of Conflict

Intensive agriculture is not dissimilar from other forms of industry in the generation of noise, dust, odour and other wastes from production processes. All rural land holders have an obligation to the community to manage their land in a manner which maintains its productive capacity, safeguards the health and safety of employees and neighbours, and avoids causing environmental harm. Many of these obligations are formalised in legislation such as the Workplace, Health and Safety Act and the Environment Protection Act. However conflict between agricultural uses and uses such as residential, conservation and industrial land is not unusual. Common sources of conflict are listed in Table 2, the most frequent being spray drift, noise, dust and odour.

Most farmers have felt secure in their occupation of rural land and their right to manage their land as they saw fit in order to earn a living from their labour and skills while maintaining the productivity of land and water resources. However in recent years, rural residential living and general fragmentation of rural land has brought a large number of new settlers into rural areas. Pressures from neighbours on farmers to modify or eliminate certain practices has led to less efficient farming practices, increased costs, reduced productivity, and, in some cases, the cessation of farming.
Table 2  Sources of land management conflict in urban-rural fringe areas

<table>
<thead>
<tr>
<th>Impacts on farmers</th>
<th>Impacts on residents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vandalism</td>
<td>Dust</td>
</tr>
<tr>
<td>Dog attacks on stock</td>
<td>Smoke and ash</td>
</tr>
<tr>
<td>Urban run off onto farmland</td>
<td>Pesticide spray drift</td>
</tr>
<tr>
<td>Theft of produce and stock</td>
<td>Animal and spray odours</td>
</tr>
<tr>
<td>Illegal rubbish dumping</td>
<td>Machinery noise</td>
</tr>
<tr>
<td>Modified farm practices</td>
<td>Animal waste disposal</td>
</tr>
<tr>
<td>Production loss near boundary</td>
<td>Farm machinery on roads</td>
</tr>
<tr>
<td>Competition for groundwater</td>
<td>Scare or hail cannons</td>
</tr>
<tr>
<td>Septic waste contamination</td>
<td>24 hour operations</td>
</tr>
</tbody>
</table>

There is a clear responsibility on farmers to exercise a duty of care to the environment and not cause environmental harm. However certain activities practised by even the most careful and responsible farmer will impact on adjacent residential areas through unavoidable odour and chemical spray drift and noise impacts.

In many cases where urban development is encroaching onto rural areas, two distinct planning issues arise. One is the management of existing conflicts caused by a mix of land uses; the other is the prevention of future conflicts likely to be caused by expanding residential areas or changes in agricultural management practices such as night time crop spraying or greater use of agricultural chemicals.

Existing conflicts are best managed by negotiation between neighbouring groups to agree on acceptable practices. Such agreements may be difficult to achieve and expert mediation may be necessary. Legal action should be viewed as a last resort. Potential conflicts may be avoided by separating potential conflicting uses through planning controls which restrict the range of allowable uses in neighbouring zones or by implementing buffers between conflicting uses.

3.2 Design of Separation Areas

State Planning Policy 1/92 Development and the Conservation of Agricultural Land requires Local Governments to devise measures to avoid or ameliorate conflicts between agricultural land uses and development. Principle No 8 of the policy states:

"Local Government planning provisions should aim to minimise instances of incompatible uses locating adjacent to agricultural operations in a manner that inhibits normal farming practice. Where such instances do arise, measures to ameliorate potential conflicts should be devised wherever possible"

Separation areas and buffers are legitimate planning tools. In general planning practice, they are utilised to ensure long-term protection for facilities with high capital inputs and industries with noxious outputs such as sewage treatment works, abattoirs, tanneries and rendering works. They are also used to protect intensive animal and plant production facilities such as mushroom farms, feedlots piggeries and poultry sheds.
Conflicts between residential and agricultural land uses are likely to occur in the following situations:

- where residential land directly abuts agricultural land;

- where residential land uses occur within a distance from agricultural land such that they are likely to be affected by agricultural activities (this will include situations where these land uses are separated by a feature such as a road or reserve); and

- where residential allotments are dispersed within an agricultural area

Separation areas should be used primarily to protect reasonable and practicable farming practices; to provide for the optimum conditions for future residents in urban areas located adjacent to agricultural production areas; to develop a well defined interface between rural and residential areas; to minimise the impact of agricultural activities on residential and other sensitive urban areas; and to minimise complaints that may arise from such impacts. When designing separation areas, consideration must be given to the following principles:

- Forward planning documents should aim to minimise the interface between residential and agricultural land uses;

- Separation areas should be located within development and be provided and funded by the initiator/proponent of that development; and

- Separation distances should be determined on the basis of the most intensive sustainable use of the agricultural land (excluding intensive agricultural uses) regardless of current use.

Where possible, a performance based approach can been taken in the determination of appropriate separation distances between agricultural and residential areas. Reference should be made to the draft Planning Guidelines: Separating Agricultural and Residential Land Uses where compliance levels and separation distances are drawn from relevant State and Federal legislation. For example, developments should be located or designed 'such that chemical spray drift does not adversely affect community public health and safety'. Acceptable measures to achieve this can include a separation distance of open ground of 300m between the development and agricultural land or at least 30m where a vegetated buffer is implemented (Figure 2). This can be achieved on larger allotments by specifying a building envelope; or the use of a vegetated buffer designed according to the Planning Guidelines: Separating Agricultural and Residential Land Uses (DPI & DHLGP, 1995).
Figure 2  Vegetated buffer between agricultural and residential land
4 RURAL SUBDIVISION

4.1 Impacts of Small Rural Allotments on Agriculture

Changes in seasonal conditions and market prices result in fluctuations in income received from the sale of agricultural commodities. Diversification of production is the key to the survival of farms dependent on fluctuating commodity prices. High value crops such as subtropical fruit crops may be profitable on areas as small as 10 hectares, while sugar-cane and broad-acre crops such as wheat, barley and sunflower require approximately 70 hectares of production to generate a satisfactory income. Subdivision controls need to provide for holdings sufficient in area for local farming systems so that long-term profitability based on a range of seasonal conditions is possible.

The economics of viable holdings is not strictly a planning issue, but rural subdivision policies should discourage the fragmentation of the land resource into small uneconomic holdings. Subdivision controls need to provide flexibility for land owners to achieve production efficiencies through adjustment in holding sizes in response to economic or market conditions, provided that complementary land use controls can prevent the intrusion of conflicting uses into agricultural areas.

Fragmentation of the rural land resource into small parcels and the use of these parcels for residential purposes has three detrimental effects on agricultural industries.

1. The incidence of conflict over agricultural management practices is increased by the mix of residential and agricultural land uses. The boundary effects of small allotments around the edge of an agricultural operation can severely limit the ability of agricultural producers to conduct normal management practices when the amenity of scattered domestic dwellings is to be protected;

2. The ability of agricultural industries to restructure in response to changing economic and market conditions is severely limited in areas of small allotment size and mixed uses. These conditions result in increased land prices and holdings which may consist of a number of allotments spread over a large area interspersed by residential uses; and

3. There is direct loss of agricultural land resources through the spread of 'de facto' rural residential development into agricultural areas.

Table 3 provides a summary of minimum subdivision sizes adopted by local governments in south-east Queensland and the discretionary provisions used to vary subdivision size.
## Table 3  Minimum subdivision sizes in rural zones

<table>
<thead>
<tr>
<th></th>
<th>General</th>
<th>Cropping</th>
<th>Horticulture / hobby farming</th>
<th>Discretionary subdivision allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Family</td>
</tr>
<tr>
<td><strong>Gold Coast</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gold: C: 20ha</td>
<td>Rural: B: 3ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beaudesert</strong></td>
<td>Rural: 100ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boonah</strong></td>
<td>Rural A: 40ha</td>
<td>Rural B: 16ha</td>
<td>Rural C: 8ha</td>
<td></td>
</tr>
<tr>
<td><strong>Brisbane City</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-urban: 4ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Caboolture</strong></td>
<td>Rural: 16ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Caloundra</strong></td>
<td>Rural: 40ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Esk</strong></td>
<td>Rural: 65ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gatton</strong></td>
<td>Rural General Farming: 40ha</td>
<td>Rural Agriculture: 16ha</td>
<td>Hobby Farming A: 4ha</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hobby Farming B: 2ha</td>
<td></td>
</tr>
<tr>
<td><strong>Ipswich City</strong></td>
<td>Rural: 16ha</td>
<td></td>
<td>Non-urban: 10ha</td>
<td></td>
</tr>
<tr>
<td><strong>Kilcoy</strong></td>
<td>Rural A: 200ha</td>
<td>Rural B: 80ha</td>
<td>Rural C: 12ha</td>
<td></td>
</tr>
<tr>
<td><strong>Laidley</strong></td>
<td>Rural A: 16ha</td>
<td>Rural B: 4ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Logan City</strong></td>
<td>Rural (Catch.): 20ha</td>
<td></td>
<td>Rural: 2ha</td>
<td></td>
</tr>
<tr>
<td><strong>Maroochy</strong></td>
<td>Rural A: 12ha (&gt;10%) Rural A: 20ha</td>
<td>Rural B: 4ha (&gt;10%)</td>
<td>Rural B: 10ha</td>
<td></td>
</tr>
<tr>
<td><strong>Noosa</strong></td>
<td>Rural Pursuits: 40ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pine Rivers</strong></td>
<td>Rural: 16ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Redcliffe City</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Redland</strong></td>
<td>Rural: Non-Urban: 20ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Toowoomba City</strong></td>
<td>Rural (Esc.): 40ha</td>
<td></td>
<td>Rural: 4ha</td>
<td></td>
</tr>
</tbody>
</table>

It is apparent from Table 3 that there is little consistency in either the naming of zones or subdivision controls across the state. The range of nomenclature used to identify rural zones adds unnecessarily to the public's confusion with planning schemes, and would be relatively easy to remedy. Subdivision controls tend to reflect local differences, but some minimum subdivision sizes are well below the area required for a viable farm operation.

Holding sizes for agricultural enterprises have developed over time through property adjustment in response to economic and market forces, and provide an indication of the current viable farm size for individual enterprises or mixed enterprises. The median holding sizes for particular farming activities in South East Queensland are shown in Figure 3.
4.2 Small Lot Subdivision

The effectiveness of subdivision controls in maintaining allotment sizes in rural areas is weakened by many local planning schemes through generous discretionary subdivision provisions. These provisions allow councils to approve the subdivision of small allotments in rural areas for a range of purposes. Most commonly these allotments are approved to allow the construction of a dwelling for family members, but other purposes such as rural homesites are also included.

Discretionary provisions in planning schemes are normally included to allow consideration of special circumstances which cannot be covered by a general policy. By definition, such provisions should only be used in exceptional circumstances. However there is wide acknowledgment that these subdivision provisions, particularly those which allow for subdivision for family purposes, are commonly used by applicants to create and dispose of rural allotments without being subject to the rezoning process. These practices have resulted in the fragmentation of rural land and unserviced ribbon development. Whereas some local laws restrict 'family' allotment approval to those who are involved in rural production, many of these allotments are subsequently sold-off to the open market. The practice of allowing the subdivision of allotments for other family members who are not engaged in farm activities is inappropriate and only leads to unnecessary fragmentation of agricultural land. The approval of multiple dwellings on a single allotment is preferable to the creation of new allotments.

In some areas, discretionary subdivision approvals are justified on the grounds of providing farmers in economic difficulties with a cash injection to allow them to continue farming during economic downturns or to relocate. This use of subdivision approval as a form of social welfare is inappropriate, particularly where the long term effects of such policies on rural industries are the inhibition of restructuring of holdings and the introduction of conflicts referred to previously. Financial hardship is better targeted through schemes such as the household support provisions of the Rural Adjustment Scheme.
5 CONDITIONS ON RESIDENTIAL DEVELOPMENT IN RURAL AREAS

5.1 Development Impacts in Rural Areas

Rural residential development is residential development in a rural or non urban setting generally on larger sized allotments than urban residential development. The emphasis is on the use of the land for residential purposes rather than for full or part time agriculture. Allotment size can vary from 2,500m$^2$ lots serviced with reticulated water, sewerage and sealed roads to 16 ha subdivisions with limited services, unsealed roads, in isolated locations. Housing standards and lifestyle choice can also vary, and development may be clustered in an estate or around a community centre or may be dispersed through a rural area.

The increased demand for rural residential living can be attributed to increased accessibility resulting from increasing mobility (highway construction and inexpensive fuel), rising affluence and leisure time of the community, recognition of the investment values of limited resources such as land, and a perceived decreased attractiveness of urban environments (Coughlin & Keene, 1981).

Planning issues of rural residential development include competition for agricultural land for residential activities, and environmental and social problems associated with isolated, poorly serviced developments.

Rural residential development is a legitimate land use, provided that development is confined to those areas considered as suitable for this form of land use. When planning rural residential development, a number of issues should be investigated to ensure that environmental impacts are reduced.

5.2 Baseline Studies Required

Residential development affects the hydrological balance and land surface characteristics. The increase of impermeable surfaces and changes to drainage patterns can accelerate soil erosion, siltation and sedimentation of watercourses and dams, and increase the risk of flooding. Salinity outbreaks resulting from changes to the hydrological balance may take 50 years or more to appear. Salt affected soil is unproductive. Salinisation can become so high that only salt tolerant species will grow. Thus, detailed baseline studies are essential to ensure that the site is suitable for rural residential development and to ensure that all environmental impacts are negligible.

5.2.1 Land resource assessment

An assessment of land resources of the site is required to determine whether good quality agricultural land is affected, to prepare an erosion control plan and to assess the impacts of waste water disposal on the environment.

The land resource survey should meet the standards specified in Section 6 of the Planning Guidelines: The Identification of Good Quality Agricultural Land (DPI/DHLGP, 1993); and soil analysis of representative soil profiles to 1.5m should be taken for each soil identified.
5.2.2 Erosion control plan

Soil erosion can be a major problem due to the highly dispersive and unstable nature of many soils in Queensland. Proper layout design to minimise soil movement and to minimise silt loads entering drainage lines should be implemented. Temporary drainage works, should be constructed on sloping ground or near drainage lines during construction.

An erosion control plan which meets the standards set out in draft guidelines for Soil Erosion and Sediment Control for Construction Sites (Institution of Engineers, Australian Institute of Agricultural Science, 1995) should be prepared that describes the erosion control measures proposed during the construction and operation phases of the development.

5.2.3 Effluent disposal

An assessment of the suitability and sustainability of the site for the proposed treatment and disposal of effluent to Australian Standard 1547 (Disposal Systems for Effluent from Domestic Premises) should be prepared.

The assessment should demonstrate that irrigation of effluent and/or landscaping irrigation onto designated disposal areas will not adversely affect the hydrology of the area. If necessary, a revegetation plan to restore the hydrological balance should also be prepared.

5.2.4 Hydrological balance and salinity

Due to the potential impact of increased peak flow and total runoff from development sites, stormwater runoff from all hard surfaces (including roads, roofs, driveways, etc.) should be controlled to ensure that all such runoff is drained or piped to stabilised waterways.

In areas that may be affected by salinity, it is important that provisions are made to minimise the movement of excess water through the landscape. An assessment of the salinity potential of the site should be prepared. Where salinity potential is identified, an Electro Magnetic Induction survey should be undertaken to identify high salinity and shallow watertable areas. In the case of the latter, the assessment should indicate the extent and quality of groundwater. The assessment should demonstrate that increases in deep drainage from the addition of effluent, storm water and landscaping irrigation will not lead to rising saline watertables either in the subdivision or on adjacent lands.

Input data to this assessment includes the proposed allotment density per hectare and percentage of the area designated for roads, drains, public parks and open space etc; and the anticipated supply rate of reticulated water per allotment (eg 1000 litre/household/day).

5.2.5 Rehabilitation

In those cases where extensive disturbance of the land surface occurs during development, a rehabilitation program should be implemented to repair disturbed areas. Vegetation compatible with local species should be re-established in disturbed areas.
Topsoil should be stockpiled to assist the revegetation program and measures to prevent erosion losses from the stockpile should be implemented to reduce sedimentation of water courses. Depth of stockpiled topsoil should not exceed 1.5m to reduce microbial breakdown.

5.3 Rural Residential Development Abutting Watercourses

Rural residential development abutting rivers and creeks should only be approved when the following criteria can be met:

- Water use by multiple riparian rural residential owners should not deplete water supply to bone fide agricultural users;
- Riparian vegetation and wildlife corridors should be protected;
- Public access to water based recreation opportunities should be maintained; and
- Stream water quality should be protected.

Local governments can achieve these outcomes by obtaining developer contributions to riparian parkland, implementing setbacks for allotments and houses from watercourses; and purchase of land for public purposes.

6 CONCLUSIONS

Planning issues in rural areas are similar to those in urban areas but require closer attention to land use allocation and environmental management. Rural land issues are more concerned with resource management and planning and, as such, rely much more on an adequate resource information database for the development and implementation of appropriate solutions.

As an important component of this database, knowledge and understanding of the soils resource is essential for addressing each of the issues discussed in this paper. Land managers, planners and Local and State Governments must have access to a comprehensive coverage of soils data at an appropriate scale to address these issues in a consistent and effective manner. Successful land use solutions are dependent on three things: good policies, adequate information, and sufficient will by decision makers to implement and monitor the policies. Without adequate information, the implementation of policies cannot be effective.

7 ACKNOWLEDGEMENTS

I would like to acknowledge the assistance of Phillip Kohn and Sue-Ellen Dear in the preparation of this paper, particularly in relation to the material on land availability for agriculture and conditions on rural residential development. This paper has been drawn from a number of sources, particularly the Policy Paper on Agricultural Land prepared for the Regional Framework for Growth Management in South East Queensland, the SEQ 2001 Project (RPAG, 1993).
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A NATURAL RESOURCE APPROACH TO LOCAL GOVERNMENT PLANNING IN GATTON SHIRE

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Gatton Shire Council, Gatton, 4343.

ABSTRACT

This paper profiles the recently-gazetted planning scheme for Gatton Shire and features the innovative approaches to land use planning that were adopted, including performance-based scheme provisions.

The author then emphasises the natural resource approach in terms of the plan preparation process (inputs) and the product that is the new Gatton planning scheme (outputs). Examples are provided to demonstrate how soil information was used in the scheme's supporting documents and a low density urban subdivision development.

The paper demonstrates a tangible example of innovation in local government land use planning and of how natural resource assessment and land management issues can be translated into a modern and responsive planning scheme and result in sensitive development.

KEYWORDS: vegetation, approach, natural resource, performance, vision, effluent, land management, stability, erosion.

1 INTRODUCTION

This paper highlights a natural resource approach to local government land use planning. It focuses on the recently gazetted planning scheme for Gatton Shire and the scheme preparation process. It overviews each of the four fundamental approaches used, identifies the innovative features of the scheme, and highlights the natural resources approach.

The paper is generally descriptive rather than analytical. Its purpose is to present some non-traditional ideas and planning approaches that are of interest, and perhaps, inspiration, particularly in the area of natural resources and land management.

2 BACKGROUND

2.1 Shire Profile

Gatton Shire is situated in the Lockyer Valley of South-East Queensland, approximately 90 kilometres west of Brisbane. The Shire has an area of almost 1,600 square kilometres and a resident population of over 15,000 people. The Shire is characterised by the fertile alluvial plains of Lockyer Creek and its tributaries, and the steep foothills and escarpment of the Great Dividing Range which forms part of the Shire's western boundary. Much of the land is steep and retains its natural vegetation cover.
The Shire has a mainly rural character. Most urban and other intensive land uses are situated across the northern half of the Shire, particularly along the Warrego Highway corridor. The Shire’s economy is based on primary production, including cropping, grazing, quarrying and forestry. The Lockyer Valley is referred to as the “Salad Bowl District” and produces a wide range of irrigated horticultural crops.

Gatton is the principal town of the Shire and the Lockyer Valley. It is fully serviced and enjoys a range of community facilities, including the University of Queensland’s Gatton College. The town has experienced a reasonable growth rate and good quality development. Outside of Gatton, Withcott has grown strongly as a dormitory area for Toowoomba. It offers a semi-urban lifestyle and includes highway-oriented retail development. The other urban settlements in the Shire are the township of Helidon, the village of Grantham and the smaller village of Murphy’s Creek. The Shire also contains an extensive scattering of land zoned for rural residential purposes, much of which remains undeveloped.

The new planning scheme which comprises a Strategic Plan, the scheme provisions and four (4) Development Control Plans (DCP’s) was gazetted on 8th December, 1995.

2.2 Planning Issues

The most significant issues identified in planning for the Shire included the following:

- Identification and maintenance of an identifiable Shire image and character;
- Identification and protection/enhancement of elements of the natural environment having significant conservation value;
- Protection of good quality agricultural land and water resources;
- Rehabilitation and prevention of land degradation;
- Achievement of more sustainable on-site wastewater treatment and disposal practices;
- Provision for urban expansion, particularly at Gatton, Withcott and Helidon, with appropriate levels of water supply, wastewater disposal and other services;
- Consolidation of rural residential development in existing zoned areas;
- Introduction of a planning scheme offering more positive guidance and direction for future land use and development;
- Recognition of changes in legislation, including new local government, planning and environment, and environmental protection legislation, and further proposals for completely new integrated planning legislation;
- Recognition of the greater awareness of and concern for environmental and social consequences of development and of planning decisions generally; and
• Recognition of trends toward regional and sub-regional planning co-operation, and national approaches to land use issues.

3 INNOVATIVE PLANNING APPROACHES

3.1 Outline of Approaches

Practical implementation of older ‘traditional’ land use controls, such as the 1981 Gatton planning scheme, fostered the awareness that such measures did not reflect community aspirations or provide adequate guidance for decision making. Recognition of numerous inadequacies of the traditional regulatory approach to land use planning created a desire to break away from that approach and seek a better alternative. A more innovative approach was sought to overcome deficiencies, establish a platform for the future of the Shire and guide growth and development.

The overall approach adopted is a synergistic product of four (4) important components, each of which is identifiable. These approaches, which were established early in the planning process, involve:

• a strong underlying natural resource approach which accounts for natural physical and environmental attributes;

• recognition of the broader planning context within which local land use planning occurs and the longer term implications of such planning;

• establishment of a strategic planning framework founded upon accepted principles and a long term vision for the future of the Shire; and

• a focus upon preferred outcomes and results coupled with flexibility in the method of attainment of quality development - a performance approach.

3.2 Natural Resource Assessment

As a rural Shire, Gatton is very much dependent upon its natural physical and environmental resources. These resources are essentially non-renewable and site-specific. Accordingly, this planning approach seeks to protect the sustainable use of natural resources by:

• establishing the capacity of land to sustain broad types of land use (through a sieving process which took into account a wide range of natural resource attributes which were then reduced to geological units, landform, agricultural suitability and vegetation), and then

• determining the suitability of particular parts of each broad area for specific uses having regard to:
  • existing land use patterns and trends;
  • availability of transport and utility infrastructure;
  • accessibility to community and commercial facilities;
• projected land use demand; and
• requirements of particular land use types.

This paper discusses the natural resource approach in sections 4 and 5.

3.3 Recognising the Broader Planning Context

It was recognised that local land use planning must be consistent with proposals, trends and initiatives at the State, regional and sub-regional levels. This approach has involved working closely with various State agencies, regional organisations and adjoining Councils in the course of developing the new plan. The scheme has regard to the regional and sub-regional context, State Government legislation, policies and initiatives, and the importance of retaining land use options beyond the life of this plan.

<table>
<thead>
<tr>
<th>What was Considered</th>
<th>How this Translated into the new Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>• SEQ2001 Project</td>
<td>• strategies consistent with sub-regional/ regional directions</td>
</tr>
<tr>
<td>• WESROC and EDROC initiatives</td>
<td>• incorporation of published standards and guidelines (e.g. AMCORD, Queensland Urban Drainage Manual)</td>
</tr>
<tr>
<td>• State Government legislation, policies and initiatives</td>
<td>• Designation of “Investigation Areas” to maintain viable future growth options</td>
</tr>
<tr>
<td>• servicing costs and need for co-ordinated services provision</td>
<td></td>
</tr>
<tr>
<td>• wider implications of local planning decisions retaining future land use options</td>
<td></td>
</tr>
</tbody>
</table>

3.4 Setting the Strategic Planning Framework - Vision and Principles

A number of meetings and workshops were held with the Council where consideration was given to the Shire’s natural resources and the broader regional perspectives. After workshopping ideas and further refinement, a Vision Statement was agreed upon. This Vision has been embodied in a number of Strategic Aims as follows:

(1) To preserve and enhance the rural character and significant natural features of the Shire;

(2) To recognise and protect the natural resources of the Shire, including good quality agricultural land and extractive materials, for effective utilisation;

(3) To properly recognise and encourage responsibility for the environment and its natural features;

(4) To support a prosperous and productive economic base which builds upon the Shire’s established strengths;

(5) To promote development in discrete centres which convey a sense of community and identity; and
To promote quality and diversity in lifestyle based upon access to convenient and efficiently provided services and facilities.

The Strategic Aims are based on a foundation of “Principles” which are intended to guide the planning scheme and to remain constant throughout the life of the scheme and beyond. These Principles were adopted early in the review process and relate to issues of Environment, Community, Economics and Quality.

For each of the Strategic Aims, a set of Strategic Objectives and General Strategies has been determined. Together with the Vision and Principles, these establish the broad planning framework and overall preferred direction for the Shire’s future growth, in both the short and longer term. Each of these elements has been incorporated into the Strategic Plan.

<table>
<thead>
<tr>
<th>What was Considered</th>
<th>How this translated into the Draft New Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>• long term implications of present planning decisions</td>
<td>• prominence given to “forward” planning documents, particularly the Strategic Plan and Development Control Plans</td>
</tr>
<tr>
<td>• future needs and aspirations for land use and development</td>
<td>• Strategic Plan which includes:-</td>
</tr>
<tr>
<td>• fundamental/constant “good planning” principles</td>
<td>- statement of Vision</td>
</tr>
<tr>
<td>• past, present and anticipated future land use trends</td>
<td>- Principles</td>
</tr>
<tr>
<td></td>
<td>- strategic Aims and Objectives</td>
</tr>
<tr>
<td></td>
<td>- general Strategies</td>
</tr>
<tr>
<td></td>
<td>• statements of preferred future character for broad and local areas</td>
</tr>
</tbody>
</table>

3.5 Adopting a Performance Approach

Dissatisfaction with the existing prescriptive planning scheme and traditional mechanisms created a desire for a more effective alternative approach. This required a paradigm shift from the negative (preventing what is not wanted) to the positive (promoting what is preferred).

The alternative of a primarily performance-based approach has been adopted with a scheme which:

- has greater reliance upon preferred future direction and character, through “forward planning” documents;

- establishes clear objectives and performance oriented criteria for development; and

- focuses upon “what” is to be achieved by development and “where” it is to occur rather than on “how” it is to be carried out.

This approach recognises that there may be a number of ways in which development can meet desired environmental, social and economic standards, provided those standards are identified
and clearly expressed. In this approach, presenting what desired standards are to be met is considered more important than prescribing how such standards should be met.

This approach was adopted for the whole of the scheme including the Strategic Plan and the four Development Control Plans, as well as the scheme provisions.

<table>
<thead>
<tr>
<th>What was Considered</th>
<th>How this Translated into the Draft New Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>dissatisfaction with traditional approaches, particularly zoning</td>
<td>avoidance of scheme amendment by way of rezoning through:-</td>
</tr>
<tr>
<td>preferred focus on outcomes and impacts of land use/development</td>
<td>- having a reduced number of zones (from 22 to 8)</td>
</tr>
<tr>
<td>model documents such as AMCORD</td>
<td>- having no necessarily prohibited uses</td>
</tr>
<tr>
<td>State Government encouragement</td>
<td>- tying most zones to Development Control Plan areas, and</td>
</tr>
<tr>
<td>desire to enhance approval processes</td>
<td>- giving prominence to statement of intended land use character</td>
</tr>
<tr>
<td></td>
<td>- documents written almost entirely in performance format</td>
</tr>
</tbody>
</table>

4 NATURAL RESOURCE APPROACH - PROCESS AND INPUTS

4.1 A Local Mandate

As well as being a rural area and economically dependent upon agriculture, Gatton Shire and the Lockyer Valley has a strong local emphasis on its natural resources, or physical and environmental attributes. Early identification of the significance of natural resources was made possible through:

- the collective experience and local knowledge of the Council, including elected members, staff and in house resources;

- a body of resource documents which address these attributes;

- a strong local emphasis on the land supported locally by infrastructure such as DPI, CSIRO and Gatton College;

- an increasing awareness of land and water related issues fostered by community-based groups such as the Lockyer Watershed Management Association and the Lockyer Resource Management Group and through Integrated Catchment Management principles; and

- increasing public awareness of environmental issues generally.
4.2 Commissioned Studies

In addition to the above resources, specific studies were commissioned over time. In the late 1980's, the Council had studies undertaken by relevant State departments into:

- agricultural suitability;
- minerals and extractive materials;
- slope stability (Great Dividing Range area); and
- vegetation and fauna habitats.

These were complimented by further assessments within the past three years of:

- visual landscape significance;
- land use and effluent management;
- Gatton town environs; and
- suitability of areas for industry.

Soil information is fundamental to many of these studies. The assessment of agricultural suitability is based primarily on soil characteristics such as depth, erodibility, stoniness, texture and drainage. Good quality agricultural land in the Shire is confined mainly to the alluvial soils. The slope stability assessment also relies upon soil information such as clay composition, permeability, plasticity and the presence of cobbles, boulders and debris. This information was related to landslide events and characteristics to produce slope stability classifications.

The effluent management and land use study, partly funded under an Integrated Catchment Management program, also examined soils within the study area from the perspective of on-site wastewater disposal. The study area included the Shire's rural-residential areas and unsewered townships. Options were produced for on-site effluent disposal, sewerage or common effluent drainage schemes, as well as detailed designs for on-site systems.

4.3 Planning Study

The task of assembling and relating this significant body of natural resource information is reflected in the planning study report prepared in conjunction with the new scheme. Evidence of the emphasis on physical and environmental attributes exists in the extract from the table of contents included in Appendix 1. This section comprises almost one quarter of the planning study written document.

The various elements were also compiled and related on the basis of land units, following work by Shaw (1979) and Lockyer Resource Management Group (1994). These works were expanded by incorporating the findings of the commissioned studies and analysis and relating these to the identified land units. An example of the synopsis tables derived for each land unit is included in Appendix 2. Geology and soil attributes are included in the tabulated land units. The planning study report also identifies for each land unit, broad planning guidelines which incorporate land uses and land management that should be encouraged and those that should be discouraged (refer to Appendix 2).
4.4 Mapping Attributes and Constraints

The natural resources data was compiled on a geographic information and mapping system.

Much of the data in this form was acquired from many of the original sources, the SEQ Regional Resource Unit and the Broadhectare Study through various means such as begging, borrowing or buying. The result is a comprehensive compilation of attribute information relevant to the Shire.

Broad land capability was assessed using a sieving process to identify constraints. Because of the significant correlation of attributes and their consistency in relation to underlying geological characteristics, the broad land units were used to encapsulate a range of attributes and represent several constraints to urban and rural residential development.

Land use suitability was then identified by incorporating other information and constraints touched on in 3.2 above. This process also identified ‘investigation areas’ which have broad capability (opportunities) for urban and rural residential development.

5 NATURAL RESOURCES APPROACH - PRODUCT AND OUTPUTS

5.1 Strategic Planning Framework

The natural resource emphasis is reflected in the strategic planning framework adopted in the scheme. The Strategic Plan includes a statement of vision and principles and strategic aims and objectives within which the natural resource approach is embodied. Evidence of this is contained in the Strategic Aims displayed in section 3.4 above and within the stated principles in the ‘Environment’ category as follows:

(1) Natural resources are finite and should be managed accordingly;
(2) Responsibility for the environment rests with all stakeholders;
(3) The natural environment determines the built environment;
(4) Potential adverse environmental impact should be addressed by development.

5.2 Strategic Plan Designations

The Strategic Plan is, quite fundamentally at the Shire-wide scale, based upon the natural resource assessment, physical constraints analysis and broad capability identification. The plan designations reflect this. Three of these designations their descriptions and elements to be regulated appear below.

Designation: Rural Landscape

Description: This is the most extensive preferred dominant land use area. It includes land with particular natural attributes such as steep slopes, significant topographical features, significant vegetation and underlying geology associated with environmental hazards and land degradation. This category also includes land of significant visual landscape quality, and areas of complex suitability categories for agriculture shown in the planning study as potential agricultural land.
Elements:  
(1) Land Use  
(2) Subdivision  
(3) Location and Site Suitability  
(4) Land Capability and Management  
(5) Visual Amenity  
(6) Services  

Designation: Rural Agriculture  
Description: This preferred dominant land use area includes land regarded as good quality agricultural land, which is generally suitable for long term agricultural production with few limitations.

Elements:  
(1) Land Use  
(2) Land Availability  
(3) Subdivision  
(4) Land Management  

Designation: Investigation Area  
Description: This preferred dominant land use area includes land which is generally not affected by broad scale constraints and which may be suitable for development in the future.

Elements:  
(1) Land Capability, Suitability and Availability  

5.3 Expanded Area of Influence  
The planning scheme document goes beyond the traditional regulation of land uses and involves consideration of land management. The scheme also incorporates provisions which have generally not been attempted within existing planning schemes. In particular, the scheme provisions include:

- regulation of vegetation clearing and timber harvesting;  
- measures applying to agriculture and grazing on steep land;  
- prevention of rural subdivision generally (unless meeting a stringent test of ongoing viable agriculture);  
- requirements for the preparation of site specific Land Management Plans; and  
- a relationship between development and effluent disposal capability.  

5.4 Environmental Regulation  
Where relevant, the scheme also includes provisions relating to:

- environmental impact assessment;  
- areas of environmental significance;  

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• visual amenity;
• geotechnical aspects and slope stability; and
• bushfire.

5.5 Detailed Land Management

The planning scheme includes a requirement for an assessment of the attributes of the site, identification of possible implications of the development and measures proposed to address these. This is embodied in a Land Management Plan for each subdivisinal development in rural-residential and in low density urban situations, such as Withcott. The relevant scheme provisions are shown in Appendix 3.

Land Management Plans are required to assess

• soil types and suitability;
• hydrogeology (including salinity);
• surface drainage patterns;
• land stability and erosion; and
• vegetation

and to propose measures in relation to:

• water supply;
• wastewater management;
• road and allotment layout;
• stormwater drainage;
• stability and erosion control;
• vegetation management;
• revegetation; and
• bushfire management

Such an assessment was required for a small lot (3,000m²) rural-residential development of some 280 allotments over an area of around 130 hectares near Gatton. The assessment identified soils with severe erosion potential and areas of significant existing erosion and a potential for salinity downstream on agricultural land. The land management assessment also identified vegetation communities worthy of protection, an area of site contamination and potential problems with on-site effluent disposal. The identification of such aspects and the measures proposed to adequately address them caused substantial redesign of the proposal.

In relation to erosion control alone:

• the roads and allotment layout was redesigned;
• stormwater drainage proposals were modified to contain flows and prevent erosion;
• protection measures were required at discharge points, as well as to minimise erosion and soil loss during construction; and
• rehabilitation of the existing degraded areas was required.
6 BENEFITS

What benefits are expected to flow from the new Gatton planning scheme to stakeholders?

The community gains:

- a tangible expression of vision and future direction;
- the recognition, protection and management of significant character elements;
- preservation of options in future decision making;
- affordable and sensitive development; and
- efficient service delivery.

The development industry gains:

- clear direction with flexibility in attainment of objectives;
- greater certainty in forward planning documents;
- reduced approval times;
- ‘up-front’ identification of issues, elements and criteria; and
- no requirement for rezoning.

The rural sector gains:

- protection of good quality agricultural land;
- protection from encroachment by incompatible development; and
- identification of issues and requirements for non-rural land use in rural areas.

Other stakeholders interested in the natural resource approach, such as the planning profession, local government, State departments and soil science professions, gain a tangible product that shows one way the approach may be emphasised within local government planning instruments.

7 CONCLUSIONS

The Gatton Shire planning scheme has only recently been gazetted and has had limited day-to-day use. Nevertheless, the scheme incorporates what are believed to be many innovative and worthwhile features such as:

- a carefully considered and clearly expressed vision for the Shire’s future and Statement of principles;

- a performance approach that is consistent across the whole scheme and, in being prescriptive only in terms of outcomes, allows maximum flexibility in how to achieve those outcomes;

- facilitation of development without the need for scheme amendment (rezoning) applications.
The planning scheme, particularly the Strategic Plan, is also based upon a natural resource approach which is integral to the planning process and the scheme documents. This approach is evidenced at several levels within the scheme.

Benefits are perceived for various stakeholders and the scheme is considered to provide one operational example of how a natural resource approach can be incorporated into modern and responsive local government land use planning.

8 REFERENCES


9 APPENDICES

APPENDIX 1: EXTRACT - PLANNING STUDY TABLE OF CONTENTS

5.0 PHYSICAL & ENVIRONMENTAL FEATURES
5.1 Introduction
5.2 Natural Characteristics
   5.2.1 Climate
   5.2.2 Vegetation
   5.2.3 Fauna
5.3 Land Resources
   5.3.1 Topography & Landforms
   5.3.2 Geology & Soils
   5.3.3 Land Degradation
5.4 Water Resources
   5.4.1 Catchments
   5.4.2 Surface Water
   5.4.3 Groundwater
5.5 Agricultural Suitability
5.6 Slope Stability
   5.6.1 Introduction
   5.6.2 Geology
   5.6.3 Landslide Characteristics
   5.6.4 Stability Classifications
   5.6.5 Planning Implications
5.7 Visual Landscape
5.8 Land Units
<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Located in the north of the Shire.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANDFORM</td>
<td>Ranges from steep hills (25% slope) to low hills (5-10% slope) with numerous rocky gorges. The area drains into several streams including Alice, Sandy, Redbank and Buaraba.</td>
</tr>
<tr>
<td>GEOLOGY</td>
<td>Triassic - Jurassic sandstone which underlie the Jurassic sequence throughout the study area (Willmott 1987).</td>
</tr>
<tr>
<td>SOILS</td>
<td>Generally shallow, stony, low fertility sandy soils with deeper red, white and yellow sandy soils on lower slopes.</td>
</tr>
<tr>
<td>VEGETATION</td>
<td>The vegetation growing on this unit includes Vegetation Mapping Units (VMU) 4b (Spotted gum) and 5 (Blackbutt). This area is largely unchanging and is the most complex and botanically interesting of the eucalypt vegetation units within the Gatton area. Therefore some consideration should be given to the conservation of these units, especially 5. (Wilkinson and Grimshaw 1992).</td>
</tr>
<tr>
<td>HABITAT</td>
<td>Include open forest and grassland. Open forest is an important habitat with just over half of the bird species found in the shire making major use of this habitat. The grassland habitat is not as important, although it is susceptible to change, e.g. burning, grazing, mowing etc. (Wilkinson and Grimshaw 1992).</td>
</tr>
<tr>
<td>AGRICULTURE</td>
<td>Mostly Classes C2 and D. Generally unsuitable for agriculture, particularly cultivation. Grazing of native pastures possible at sustainable stocking rates.</td>
</tr>
<tr>
<td>MINERAL/ROCK RESOURCES</td>
<td>Sandstone suitable for facing stone is well known from the Helidon district. Sizeable areas are underlain by potentially suitable stone, but the quality of the material varies over short distances (Willmott 1987).</td>
</tr>
<tr>
<td>WATER</td>
<td>Run off water is of a very high quality from a salinity point of view and could be used for urban purposes if suitable dam sites are available.</td>
</tr>
<tr>
<td>SPECIAL FEATURES</td>
<td>The steep and rocky landscape is very beautiful. Areas of bushland in State Forests are valuable nature conservation and recreation areas.</td>
</tr>
<tr>
<td>LAND DEGRADATION</td>
<td>This area is largely treed and has very few degradation problems. It was over cleared in the 1920s with resulting woody weed invasion (especially wattles). Some erosion has been observed but the source of this is unknown.</td>
</tr>
<tr>
<td>PRESENT LAND USE</td>
<td>Dominant land uses are State Forest and Timber Reserve, commercial timber production on public and private lands and grazing of native pastures. Less dominant uses are sandstone mining, sand and gravel extraction, orchards on associated alluvium and passive recreation and nature conservation.</td>
</tr>
<tr>
<td>VISUAL LANDSCAPE</td>
<td>Very high visual landscape rating. Protection of vegetated slopes and ridgelines from clearing and closer settlement desirable. (Greenspace 1993).</td>
</tr>
</tbody>
</table>
APPENDIX 2 (continued)

Planning Guidelines

Land Uses Encouraged

- Grazing (managed to maintain ground cover) on private land and Timber Reserves.
- Commercial forestry practised as selective logging for mill logs.
- Orchards on suitable areas.
- Extractive industries with management plans for waste management, erosion control and rehabilitation.
- Flora and fauna habitat and recreation areas, where recreation activities are of low environmental impact. One pertinent area to conserve is Timber Reserve 451 Parish Lockyer (Wilkinson and Grimshaw 1992). The development of a management plan for the identification and retention of sufficient habitats to conserve rare species and wildlife corridors is encouraged.
- Limited rural retreats on existing holdings with management plans for fire, waste disposal (sewage, garbage, water) and erosion and to reduce the human impact on significant environmental areas.

Land Management Encouraged

- Maintenance of ground cover in grazed areas to minimise erosion.
- Coordinated and controlled burning.
- Maintenance of good water quality.
- Conservation of soil and vegetation by service providers.
- Control of impacts of extractive industries.

Discouraged

- Commercial clear felling for logs or wood chipping.
- Further subdivision.
(5) (a) Unless the Council considers a proposal to be for minor development, each approval to subdivide land within the DCP area shall be subject to the preparation and implementation of a Land Management Plan.

(b) (i) The Land Management Plan shall satisfy the Council that all the likely significant effects of proposed on-site stormwater and wastewater management measures on the natural environment have been identified and addressed.

(ii) Such a plan shall compromise:

(A) A description and assessment of the environmental capability of the site having particular regard to:

- soil types and suitability,
- surface drainage patterns,
- hydrogeology (including salinity),
- land stability and erosion, and
- vegetation, and

(B) A description of the measures proposed to take into account the findings of the environmental assessment, particularly with respect to:

- water supply,
- wastewater management
  including
  - suitability and sustainability
  - water balance and effects of irrigation of effluent on hydrology
  - potential pathogens - treated or untreated effluent
- road and allotment layout,
- stormwater drainage
- stability and erosion control (including those measures proposed during the construction and operation phases),
- management of key areas of vegetation.
- revegetation, and
- bushfire risk management
ENVIRONMENTAL LEGISLATION

R. Hesse

Department of Environment, Brisbane, 4000.

ABSTRACT

Government policy, most commonly expressed through legislation, establishes the rules by which planners, regulators, developers, land managers and all those responsible in some way for resource management or allocation must behave.

In addition to Acts, policy may be established by subordinate legislation, e.g. Environmental Protection Policies and statutory plans; agreements between parties, e.g. the National Strategy on Ecologically Sustainable Development; or simply as policy of governments.

KEYWORDS: environment, protection, management, ecologically sustainable development, planning, nature conservation, cultural heritage, coastal protection.

1 INTRODUCTION AND OUTLINE

The objectives of key environmental, nature conservation, coastal and heritage protection Acts, responsibilities of land managers, and planning and management opportunities provided in each of them will be presented briefly.

There is a common theme underlying all legislation which I will discuss and that is an obligation to the principles of ecologically sustainable development, achievement of which is the Department of Environment and Heritage’s raison d’etre.

The paper is divided into ‘themes’ and key Acts administered by the Department of Environment and Heritage. My discussion will also touch on complementary State Acts and similar or complementary Commonwealth Acts.

Where the policy is presented in some detail under Commonwealth initiatives, e.g. impact assessment, relevant State policies are also discussed and vice versa, e.g. protection of the Great Barrier Reef Marine Park is discussed with the Queensland Government’s initiatives as for coastal protection and management.

Several appendices set out standard criteria for decisions about development and land management relevant to the key Acts.
2 SUMMARY OF POLICIES AND ACTS FOR ENVIRONMENTAL PROTECTION AND MANAGEMENT

Significant policies and key Acts are:

1. Commonwealth Initiatives
   - National Strategy for Ecologically Sustainable Development
   - Inter Governmental Agreement on the Environment
   - Environmental Protection (Impact of Proposals) Act
   - World Heritage Protection Act

2. State Initiatives

   Environmental Protection and Management
   - Environmental Protection Act

3. Nature Conservation
   - Nature Conservation Act

4. Coastal Protection and Management
   - Coastal Protection and Management Act
   - Marine Parks Act
   - Great Barrier Reef Marine Park Act (Commonwealth)

5. Cultural Heritage
   - Heritage Act
   - Cultural Record (Landscaes Queensland and Queensland Estate) Act

3 COMMONWEALTH INITIATIVES

3.1 Ecologically Sustainable Development (ESD)

The National Strategy for ESD (Commonwealth of Australia, 1992) defines the concept as:

'using, conserving and enhancing the community’s resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'.

The Commonwealth and all State and Territory Governments and local government through the Local Government Association have endorsed this strategy which carries with it the obligation:

**to ensure that ESD principles and objectives are taken into consideration when making policy determination.**

* Copies of Commonwealth Acts may be obtained from AGPS, Canberra and for Queensland Acts, Goprint, Brisbane.
ESD principles for decision makers are included at Appendix 1.

Australian responses to ESD include:

- Inter Governmental Agreement on the Environment (IGAE);
- National Greenhouse Response Strategy;
- National Strategy for Conservation of Australia’s Biological Diversity;
- National Waste Minimisation and Recycling Strategy; and
- National Forest Policy.

All are recognised by Queensland and have implications for planners and land managers as well as decision-makers.

The Commonwealth Government has in place a number of Statutes in addition to its powers under the constitution which enable it to give effect to obligations which it has endorsed on behalf of Australia. These include:

- World Heritage Act
- Australian Heritage Commission Act
- Great Barrier Reef Marine Park Act
- Australian National Parks and Wildlife Act
- Endangered Species Act
- Environmental Protection (Impact of Proposals) Act
- National Environmental Protection Council Act

All of these enable/require the Commonwealth Government to be satisfied that long term ESD objectives will not be compromised.

3.2 The Inter Governmental Agreement on the Environment (IGAE)

In 1992 all Governments concluded the IGAE to:

- facilitate a cooperative national approach to the environment;
- enable better definition of the roles of the respective governments;
- reduce the number of disputes between governments on environmental matters;
- create greater certainty for government and business decisions; and
- achieve better environmental protection.

With respect to impact assessment (IA), the Agreement establishes a number of principles including:

- certainty about the process to improve consistency between governments and avoid duplication;
- application of IA to projects, programs and policies; and
- IA to address cultural, economic, social and health factors as well as the traditional “environmental” issues.
Appendix 2 elaborates on the principles contained in Schedule 3 of the IGAE.

3.3 Commonwealth Legislation for Impact Assessment

*Environmental Protection (Impact of Proposals) Act*

In force since the mid 1970's, this Act is concerned with ensuring that in all Commonwealth Government decisions, proper account is taken of environmental consequences. Administrative procedures pursuant to the Act provide for a hierarchy of assessments according to potential impacts. These range from an environmental report, through a public environment report, to an environmental impact study and, at the top, an inquiry.

An environmental assessment is completed by the Department of Environment, Sport and Tourism (EST) and the process concludes with a recommendation from the Minister for EST to the action minister. The decision is a matter for the latter.

During 1995 the Commonwealth reviewed its IA process having regard for the IGAE and has decided on some reforms with others (not yet specified) to follow.

3.4 Queensland Legislation for Impact Assessment

*State Development and Public Works Organisation Act*

This Act has wide ranging powers and functions, the majority of which are not specifically relevant here. However, it deserves mention because it provides the head of power for impact assessment in Queensland.

Wording in the Act obliges decision-making authorities to have regard for the environmental consequences of their decisions. The definition of the environment is all-encompassing: it is intended to ensure that impacts should consider not only bio-physical conditions and effects, but also social and economic aspects. Deliberately broad in meaning, the obligations under the Act are meant to cover not only decisions relation to development applications, but also decisions about such matters as legislation (policy), programs, e.g. programs to enhance economic development in particular parts of the State, and plans including statutory planning schemes of State and local governments.

With the emphasis by governments on achieving ESD, it is more likely that the Act will be used to require strategic and cumulative impact assessment at one end of the spectrum, and technical and management assessment at the other, in addition to assessment of the merits of projects. Administrative procedures provide for a responsible authority and advisory bodies to oversight and make input respectively to the IA process. The Act is silent on public involvement, but in practice the public has an opportunity to comment at least when a draft impact assessment report is complete. Increasingly public input occurs earlier and is more ongoing and consultative.
Over time, specific provisions dealing with impact assessment have been included in a number of Acts including the Local Government (Planning and Environment) Act. This deals with procedures for assessment of projects which have their main impacts at a local rather than State or regional level. Separate complementary provisions exist under the Mineral Resources Act and are concerned with outcomes. A procedural guideline has been published to ensure that mineral projects are properly evaluated; assessed against consistent criteria; that management is best practice; and management is put in place for the life of a project.

The Queensland Government is re-assessing requirements for IA in the context of its review of planning legislation, i.e. as part of the Planning, Environment and Development Assessment (PEDA) Bill and as a proposed amendment to the State Development and Public Works Organisation Act. These have yet to be finalised.

3.5 National Environmental Protection Council

Passed in response to IGAE, the Act provides for a National Environmental Protection Council. Mirror legislation is expected in each State - that for Queensland has been enacted. The Council's purpose is to achieve a consistent way throughout Australia through cooperation.

3.6 Australian and World Heritage

Australia adopted the World Heritage Convention in 1974 and in so doing committed to the identification, protection, conservation and preservation of World Heritage properties. Queensland's World Heritage properties include the Great Barrier Reef region, the Wet Tropics and Fraser Island.

Specific criteria with respect to cultural and natural values and integrity conditions are laid down for listing which may occur over land or water of varying tenures. Listing does not constrain pre-existing land rights provided they do not threaten the values for which the area has been nominated.

The World Heritage Convention has no power to manage. However, the convention obliges the nominating Government to ensure that effective measures are taken to protect a listed area. These are laid down in Article 5 of the convention - details of which are appended. (Appendix 2). Additionally, where it appears likely that harm will occur, the Commonwealth may regulate to prevent such an occurrence, e.g. “Oyster Point” near Cardwell.

Management Plans and administrative arrangements for protection are in place for all Queensland's World Heritage places and special legislation exists for the Great Barrier Reef (discussed in the context of Coastal Management) and the Wet Tropics - Wet Tropics Heritage Protection and Management Act. Both provide for ministerial councils (Commonwealth and State ministers), a management authority, scientific and advisory committees and a management agency. Management obligations for World Heritage Properties are set out in Appendix 3.

The approach taken to protecting all such areas is similar: strategic plans to establish policies and usage parameters; more detailed zoning, regulation or management plans for sections
within the listed area; and regulations to enable development and activity proposals to be assessed and, if approved, to be subject to management obligations.

In addition to protection of world heritage values, the Commonwealth is concerned about protecting national heritage. *The Australian Heritage Commission Act* provides for the assessment, nomination and protection of the national estate. The values of any property listed must be taken into account by the Commonwealth Government in relation to any decision by that Government. A scheme of financial grants to assist with management and protection measures is a significant part of this Act.

Two Commonwealth Acts of some significance to land managers are the *Australian Nature Conservation Act* and the *Endangered Species Act*. The significance of the latter stems from measures to protect vulnerable, rare, and threatened species of flora and fauna. Complementary provisions exist for both under Queensland’s *Nature Conservation Act*.

4    STATE INITIATIVES

4.1    Environmental Protection

*Environmental Protection Act*

Its intent is to achieve ecologically sustainable development. Objectives include:

- protection of the environment; and
- integration of environmental protection into resource and infrastructure development and decision-making of all government agencies.

In more detail the Act provides:

- a legal framework to achieve ecologically sustainable development, with obligations imposed on State and local governments to consider ESD principles and other relevant matters when decisions are made;
- for adoption of national standards;
- flexibility to address new threats to the environment by establishing a social consensus on the most appropriate response from government and the community;
- for regular ‘State of the Environment’ reports;
- for the integration of environmental protection with environmental management planning and land use planning processes;
- a set of principles for sound environmental management; and
- an obligation for involvement by the community along with that of business, land holders, and governments. It uses the term ‘environmental stewardship’ which obliges acceptance of responsibility for, and commitment towards, good environmental practices on everyone. Emphasis is placed on avoiding, minimising and repairing damage.

Industries - irrespective of whether they are subject to formal licences under the Act - are responsible for their environmental performance. Codes of practice for groups of industries e.g. various primary producers such as piggeries, intensive feedlots, aquaculture and the sugar industries, are currently developing codes of practice. Industry, including government
agencies, has been encouraged to implement quality control and environmental management systems in accordance with international standards (at present the ISO 14000 series).

The Act is concerned primarily with activities which cause, or have the potential to cause environmental harm in its broadest sense. These activities are defined as "environmentally relevant" and are listed in a schedule to the interim regulation. They necessitate assessment and approval to undertake the environmentally relevant activity.

Depending on the degree of perceived risk to the environment, responsibility for authorising some of these activities is devolved to local Government. Others are likely to be delegated to government agencies, and memoranda of understanding (MOU) between Department of Environment and Heritage (DEH) and several Departments are in preparation, e.g. a MOU with the Department of Minerals and Energy was signed in February 1996.

A further key principle of the Act is responsibility for breaches. Rather than licensing companies, responsibility is sheeted to the corporation i.e. all Board members and Chief Executive Officers. In their defence, Chief Executive Officers/Board members may be able to show that 'due diligence' has been exercised. This concept derives from trade practice law and has been accepted in Australia. The seven principles of due diligence are:

1. Need for a pollution prevention system.
2. Establishment of such a system.
3. Operation of the system.
4. Reporting (monitoring).
5. Knowledge by responsible officers of relevant environmental laws and standards associated with their activities.
6. Personal responsibility for ensuring compliance with systems and standards.
7. Implementation of due diligence. This necessitates a thorough understanding of the activity and risk.

Environmental Protection Policies (EPP's) are contemplated and already four have been drafted. These deal with water quality, air, noise and waste (drafts of all but the last have been released). National standards and procedures for establishing criteria for determining values of affected environment are used. The Act itself defines standard criteria for air, noise and water, but the EPP's go further and are accompanied by guidelines for their application.

4.2 Nature Conservation

Nature Conservation Act

The purpose of this Act is to conserve nature in its broadest sense over the whole of the State not just certain species of plants or animals or areas set aside as reserves. It stresses protection of habitat and recognises the contribution of private land holders and individuals.

Objects of the Act

- protecting biological diversity of native wildlife and its habitat by:
- dedicating and declaring protected areas;
- prescribing protected and prohibited wildlife;
- managing areas in accordance with certain principles, declared intent and conservation plans and agreements.

- providing for ecologically sustainable use of protected wildlife and areas through conservation plans;
- identifying critical habitat and areas of major interest;
- research and data gathering and analysis; and
- generally encouraging nature conservation.

Ecologically sustainable use requires compliance with three criteria:

- the capacity of wildlife, or an area, to sustain its natural processes;
- maintenance of life-support systems; and
- assurance that benefits to-day do not diminish the potential to meet the needs of future generations.

The Act provides for the designation of a system of reserves meeting international criteria established by the International Union for the Conservation of Nature (IUCN). The objective is to ensure that viable, representation samples of all biogeographic regions are protected in perpetuity. Within this system is a hierarchy for which different management objectives apply. These are outlined in Table 1.

### Table 1 Major classifications of protected areas and measures

<table>
<thead>
<tr>
<th>Tenure</th>
<th>Protective Instrument</th>
<th>Special Management Areas</th>
</tr>
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<tbody>
<tr>
<td>Crown Land</td>
<td>• National Parks</td>
<td>National Parks (Scientific)</td>
</tr>
<tr>
<td></td>
<td>• Conservation Parks</td>
<td>* National Parks (Aboriginal land)</td>
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<tr>
<td></td>
<td>• Resource Reserves</td>
<td>* National Parks (Torres Strait Islander Land)</td>
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<td></td>
<td>Any tenure</td>
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<tr>
<td></td>
<td>• Nature Reserves</td>
<td></td>
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<tr>
<td></td>
<td>• Co-ordinated Conservation areas</td>
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<tr>
<td></td>
<td>• Wilderness areas (adjacent areas which may be thought of as buffers)</td>
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<tr>
<td></td>
<td>• World Heritage management areas</td>
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<td></td>
<td>• International Agreement areas</td>
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</tbody>
</table>

* Recognition of Aboriginal and Torres Strait Islander interests is established under the *Aboriginal Land Act* and the *Torres Strait Islands Land Act* and *Native Title Act*.

Inside reserves, management varies in line with usage with ‘zones’ defining what may or may not occur.
A State Planning Policy is in preparation to set out policies, criteria and guidelines for resource planning and management; assessment of values; criteria and guidelines for the classification of wildlife; and methodologies for undertaking studies, monitoring, recording and reporting. Release of a draft has been expected for some time.

4.3 Coastal Protection and Management Act

The legal vehicle for implementing coastal protection and management policies, the Coastal Protection and Management Act relies on:

- a State Planning Policy;
- a State-wide coastal management plan;
- regional coastal management plans; and
- development control.

Objectives

- protection, conservation and rehabilitation management of the coast and its resources and biological diversity;
- accord with the National Strategies for ESD in the use of the coastal zone;
- enable coordination/integration with other legislative initiatives; and
- facilitate the dissemination of knowledge regarding coastal resources and processes and the impacts of human activities on them.

Definition of Coastal Zone

The definition of the area to which the Act applies, is significant. viz. The coastal zone includes 'coastal waters and all areas landward of them in which there are physical features, ecological or natural processes or human activities which affect, or are likely to affect, the coast or coastal resources.' (In effect entire catchments of coastal streams.) Also important are coastal districts which are 'areas declared within the coastal zone requiring special management and development control'.

Before declaring Control Districts consideration must be given to:

- the area’s vulnerability to erosion by the sea or wind-induced effect;
- whether or not development should be permitted;
- public access;
- foreseeable impacts and natural hazards;
- tenure;
- Aboriginal and Torres Strait Islander traditional or customary use; and
- planning and development management.

Principles underscoring the Act are:

1. Areas of high ecological, cultural, heritage or scenic values on the coast should be conserved and protected from land uses and development that would significantly reduce those values. All natural processes having a significant impact on forming and
maintaining the features of the coast should be allowed to operate unhindered by land use and development. Where coastal development occurs, it must be designed to minimise any disruption to natural coastal processes.

2. Development should be avoided in areas subject to coastal erosion and in areas prone to coastal inundation from storm surge; development should be restricted and/or appropriately designed to take account of periodic inundation.

Standard criteria for decisions on the coastal zone are given in Appendix 4.

4.4 Marine Parks Act

The purpose of this Act is to identify and protect marine values through designation of marine parks over State tidal waters and coastal lands up to the limit of highest astronomical tide (HAT), and to regulate activities in such areas. It was declared to complement the Great Barrier Reef Marine Park Act, but its form and provisions are closer to the planning controls of the Local Government (Planning and Environment) Act. For instance, planning relies on zoning and regulation of uses pursuant to provisions of zoning plans. However, it goes further: (environmental) management plans may be prepared for particular areas such as sensitive areas or areas subject to intensive recreational or fisheries use.

Marine parks are multiple use reserves, not "marine national parks" although areas within a marine park may be zoned to achieve an equivalent level of protection.

Queensland marine parks have been declared over practically all Queensland waters - with the exception of several port areas within the Great Barrier Reef world heritage area - all marine parks are subject to planning and development controls which directly mirror or supplement those applying to the Great Barrier Reef Marine Park Act. Queensland marine parks also have been declared in the Great Sandy Region (Hervey Bay) and Moreton Bay.

4.5 The Great Barrier Reef Marine Park Act (Commonwealth)

Following nomination of the Great Barrier Reef Region for world heritage listing, the Commonwealth passed the Great Barrier Reef Marine Park Act in 1975. This provides for the progressive declaration together with plans for management and regulation of use and development of sections of the Great Barrier Reef region.

In 1995 the Commonwealth approved a long-term strategic plan to provide the basis for future directions. This strengthens the similarities with Queensland planning legislation.

Commonwealth jurisdiction extends to mean low water. Around Queensland islands, the Commonwealth interprets this as low water around the island itself: Queensland has adopted the international definition and where there are fringing reefs, identifies low water as the outer drying edge of this reef. Queensland waters are measured from this line. There is thus a substantial area, responsibility for which is disputed. However, for administrative purposes, the two Governments work co-jointly, generally deciding co-jointly and issuing a single decision. This tends to avoid inconsistent approvals.
Approvals issued under the marine parks Acts allow works to be undertaken and activities to operate. In deciding applications, the authorities must have regard to the values and conservation intent for the subject and affected areas. These are spelt out in the relevant zoning and management plans. Inconsistent activities will not be countenanced.

Two other coastal Acts which should be mentioned are the Beach Protection Act and the Harbours Act. They should be mentioned because the former has long been the Act concerned with protecting the coast against natural erosive forces - winds and tides - and for regulating land development where it is clear that human activities are likely to have a detrimental effect. The Harbours Act is mentioned because it deals with development and activities such as dredging, in tidal waters. This Act is concerned primarily with enabling and providing a mechanism to deal with applications. Criteria for assessment of applications have related to avoidance of areas vulnerable to coastal erosion and to protection of coastal navigation opportunities.

Both of these Acts are subsumed by the Coastal Protection and Management Act and are intended to be rescinded when new planning legislation in enacted: they have been retained to enable development applications in the coastal zone to be processed. It is not intended to repeal the Marine Parks Act.

4.6 Cultural Heritage

Queensland Heritage Act

This Act aims to conserve Queensland’s significant cultural heritage which is defined as a 'place or object, area or relic assessed as such because of its historic scientific or social significance or other special value to the present community or future generations'. Standard criteria for the assessment of cultural heritage, in particular the significance of places is given in Appendix 5.

Cultural Record (Landscapes Queensland and Queensland Estate) Act

The purpose of this Act is to provide for:

- preservation and management of all components of “Landscapes Queensland within the Queensland Estate”; and
- to promote understanding of the historic continuum within Queensland.

Landscapes Queensland is defined as:

- 'areas or features which show evidence of man’s impact; and
- areas or features which are of significance to man for any anthropological, cultural, historic, pre-historic or social reason and includes items of the Queensland Estate.'

- Queensland Estate means 'evidence of man’s occupation in Queensland at least 30 years old but not made as a facsimile, or made since 1987 for purposes of sale, or that is not of pre-historic or historic significance'.
Regional Landscapes—Queensland Committees may be set up to advise on:

- declaration of "designated landscapes areas";
- their use and management; and
- inclusion on the register of nominated items of the Queensland Estate.

No such committees have been established as far as I can ascertain.

Established uses on land containing items of the Queensland Estate may continue provided they pose no threat to the items. This is significant for land managers and those making decisions about development.

In practice where such items are known to exist or where they are discovered in the course of land management activities or development, work is obliged to cease and should only resume after action in accordance with DEH's advice has occurred. This may include avoidance, removal or recording of the item(s).

To date, attention has focussed on assessment work and development of a register of sites and items and measures to protect them. No regional Landscape Committees have been set up and much of the potential of this Act has not been realised.

5 CONCLUSIONS

The above Acts and policies should be regarded as complementary to statutes in draft and in place administered by other Departments. For example, the proposed Natural Resource Management legislation.

A distinguishing feature of Acts administered by the Department of Environment is their concern for environmental protection with the Act of that name also required to implement ecologically sustainable development.

6 REFERENCES


7 APPENDICES
APPENDIX 1: ESD GUIDING PRINCIPLES FOR DECISION-MAKERS

- decision making processes should effectively integrate both long and short-term economic, environmental, social and equity considerations;
- where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
- the global dimension of environmental impacts of actions and policies should be recognised and considered;
- the need to develop a strong, growing and diversified economy which can enhance the capacity for environmental protection should be recognised;
- the need to maintain and enhance international competitiveness in an environmentally sound manner should be recognised;
- cost effective and flexible policy instruments should be adopted, such as improved valuation, pricing and incentive mechanisms; and
- decisions and actions should provide for broad community involvement on issues which affect them.

APPENDIX 2: INTER-GOVERNMENTAL AGREEMENT ON THE ENVIRONMENT - KEY PROVISIONS OF SCHEDULE 3: ENVIRONMENTAL IMPACT ASSESSMENT

Twelve matters to ensure consistency are enumerated in a Schedule to the IGAE. The main ones are:

- application of IA to both public and private proposals;
- guidelines to determine -
  - the type of proposals likely to be subject to IA; and
  - the level of assessment;
- guidelines on assessment criteria to cover -
  - ESD
  - human health
  - local and national standards and guidelines
  - protocols and codes of practice
  - statutory requirements
- a mechanism to arrive at project-specific IA requirements;
- certain time lines;
- levels of assessment commensurate with environmental significance;
- public consultation and mechanisms to resolve issues;
- IA to be a basis for setting environmental conditions, establishing monitoring and management programs; and
- developing industry guidelines.
APPENDIX 3: MANAGEMENT OBLIGATIONS FOR WORLD HERITAGE PROPERTIES FROM ARTICLE 5 OF THE CONVENTION

- To ensure that effective and active measures are taken for the protection, conservation and presentation of the cultural and natural heritage situated on its territory, each State Party to this Convention should endeavour, insofar as possible, and as appropriate for each country:

(a) to adopt a general policy which aims to give the cultural and natural heritage a function in the life of the community and to integrate the protection of the heritage into comprehensive planning programs;

(b) to set up within its territories, where such services do not exist, one or more services for the protection, conservation and presentation of the cultural and natural heritage with an appropriate staff and possessing the means to discharge their functions;

(c) to develop scientific and technical studies and research and to work out such operating methods as will make the State capable of counteracting the dangers that threaten its cultural or natural heritage;

(d) to take the appropriate legal, scientific, technical, administrative and financial measures necessary for the identification, protection, conservation, presentation and rehabilitation of this heritage; and

(e) to foster the establishment or development of national or regional centres for training in the protection, conservation and presentation of the cultural and natural heritage and to encourage scientific research in this field.

The Commonwealth has passed the World Heritage Properties Conservation Act to give effect to its commitment and has interpreted management commitments in the following way.

- to protect, conserve and present the World Heritage values of the property;
- to integrate the protection of the area into a comprehensive planning program;
- to give the property a function in the life of the Australian community;
- to strengthen appreciation and respect of the property's World Heritage values, particularly through educational and information programs and to keep the community broadly informed about the condition of the World Heritage values of the property; and
- to take appropriate scientific, technical, legal, administrative and financial measure necessary for achieving the foregoing objectives.
APPENDIX 3 (continued)

In achieving these primary objectives, due regard is given to:

- ensuring the provision of essential services to communities within and adjacent to a property;
- allowing uses of the property which do not threaten the world heritage values and integrity;
- recognising the role of current management agencies in the protection of the property; and
- involving the local community in the planning and management of the property.

APPENDIX 4: COASTAL PROTECTION AND MANAGEMENT STANDARD CRITERIA AND PLANNING SCHEMES

1. Development in the coastal zone must minimise any adverse impacts on the ecological, cultural, heritage and scenic values of the coast. In particular, the development of coastal wetlands and visually prominent features, notably undeveloped headlands, should be avoided.

2. Undeveloped areas of the coast may be developed only when it can be clearly demonstrated that:

- the development is dependent on a coastal location and no feasible sites are available within developed areas; or
- the need for development in terms of public interest overrides all other considerations and no other site is suitable for the proposed use.

3. Within existing settlements, undeveloped sites adjoining the foreshore should generally be retained for coastal-dependent development where such sites are suitable for that type of development.

4. Continuous urban development along the coast should be minimised. A compact and contained settlement form should be encouraged and undeveloped areas which provide strategic visual breaks between built-up areas on the coast should be identified and protected from urban development.

5. Within existing built-up areas, development should not change the character of the built environment in a way that significantly increases the visual impact of the overall settlement on the coast.

6. Tourism developments requiring a coastal location should be located in or adjacent to existing or proposed urban areas or designated tourist development nodes, unless there is a clear justification for an alternative location.
7. Public access to the coast and opportunities for diverse recreation experiences at the coast should be retained. In addition, new coastal developments must provide public access to the coast consistent with conservation objectives and standard of public safety.

Planning Schemes

1. Strategic plans for the State, regions and local government areas adjacent to/or affecting the coast will be expected to contain policies and provisions that are consistent with the above objections and criteria.

2. When development applications are being determined, objectives and standard criteria must be taken into consideration. Where a planning scheme does not contain adequate provisions to control development and its impact on the coast, the State Government will be guided by the objectives and standard criteria.

3. Planning schemes for local government areas must take account of planning guidance and development requirements set out in State and regional coastal management plans, any regional planning guidance and provisions for Control Districts. They will be required to designate proposed locations for any new development in the coastal zone and support such designations by appropriate policies and development requirements to minimise any adverse impacts of development on coastal values.

4. Where potential for land use conflict is evident, planning schemes should contain development criteria that include measures to alleviate such conflict.
APPENDIX 5: QUEENSLAND HERITAGE ACT

STANDARD CRITERIA FOR ASSESSMENT OF CULTURAL HERITAGE SIGNIFICANCE OF PLACES

The place -

- is important in demonstrating the evolution or pattern of Queensland’s history;
- demonstrates rare, uncommon or endangered aspects of Queensland’s cultural heritage;
- has potential to yield information that will contribute to an understanding of Queensland’s history;
- is important in demonstrating the principal characteristics of a particular class of cultural places;
- is important in exhibiting particular aesthetic characteristics valued by the community or a particular cultural group;
- is important in demonstrating a high degree of creative or technical achievement at a particular period;
- has a strong or special association with a particular community or cultural group for social, cultural or spiritual reasons; and
- has a special association with the life or work of a particular person, group or organisation of importance in Queensland’s history.

Responsibility for assessment is a function of a Queensland Heritage Council membership of which is prescribed with the intention of drawing together a body of expertise, land interests, industry and local government, the last because protection will inevitably rely on planning provisions as well as development control.
LOCAL GOVERNMENT (PLANNING AND ENVIRONMENT) 
ACT 1990

J. Chadwick and G. Ballard

Department of Local Government and Planning, Brisbane, 4000.

ABSTRACT

While the Local Government (Planning and Environment) Act sets the regulatory framework for planning in Queensland, the instruments made under the Act put the policy and regulatory flesh on the skeletal bones of the legislation. A key instrument in this framework is the local government planning scheme.

KEY WORDS: objectives, state planning polices, planning schemes, strategic plans, zoning, development control plans, local planning policies, development control, permitted use, permissible use, consent, prohibited use, rezoning, combined applications, subdivision, conditions, appeals, compensation.

1 INTRODUCTION

The Local Government, (Planning and Environment) Act* envisages that detailed land use planning and development control will be achieved through a number of statutory instruments, namely State Planning Policies, planning schemes and local planning policies.

This paper will discuss the role and features of the Act and the instruments created under it. In particular, the paper will examine the role and structure of planning schemes, which are the key instruments recognised in the Act.

2 OBJECTIVES OF ACT

The objectives can be determined from reading both the long title of the Act and the objectives statement. The long title is at the front of the Act and states:

An act to provide for town planning and related environmental matters in local government areas, including the City of Brisbane, and for related purposes.

The objectives statement is set out in section 1.3. It states the objectives are:

a) to provide a code by which a local government or the Minister may undertake the planning of an area to facilitate orderly development and the protection of the environment; and

b) to provide an adequate framework for a person to apply for approval in respect of a development proposal and to provide for appropriate appeal rights in respect thereof.

* Copies of Queensland Government Acts are available from Goprint, Brisbane.
Some points to note include:

- the operation of the Act is limited to local government areas;

- the objectives principally focus on process. The objectives mainly deal with the mechanical and administrative aspects of the system—the Act establishes a code for undertaking planning; it sets up a framework for decision making etc. The references to an overriding policy within which the system should operate are brief—ie the Act is intended to facilitate orderly development and protection of the environment. The Act itself provides no further guidance as to what these terms mean in the context of the planning system;

- planning is a voluntary activity. It is not mandatory for a local government to have a scheme.

3 STATE PLANNING POLICIES

State Planning Policies (SPPs) are a relatively recent feature of Queensland planning legislation, having been included in the Act in 1992. The scope, role and structure of SPPs is potentially very broad, although the limited number produced to date have tended to follow a common approach.

Part 1A.1—3 of the Act deals with the preparation and approval of SPPs. The Governor in Council is empowered to make SPPs in relation to "town planning and related environmental matters that are, in the Governor in Council's opinion, of State significance". Other than this State significance test, there are no other limitations to the scope and format of SPPs. There are also no requirements to publicly notify draft SPPs before they are made, although extensive consultation with key stakeholder groups has preceded those policies made to date.

Local governments are required in the Act to have specific regard to relevant SPPs when they are assessing applications for rezoning, consent and subdivision. The Department of Local Government and Planning also reviews draft planning schemes to ensure they adequately reflect the provisions of SPPs.

To date, only three State Planning Policies are in force. These are:

- Development and the Conservation of Agricultural Land;
- Planning for Aerodromes and other Aeronautical Facilities; and
- Protection of Koalas in the Koala Coast.

All 3 SPPs establish policies and criteria which must be taken into account when planning schemes are being made, and in decision making on individual development applications. Significantly, all 3 SPPs expressly allow any existing development commitments obtained through development approvals, and within planning schemes, to stand.

Each SPP is supplemented by non-statutory planning guidelines which give more detailed guidance on interpreting the policies in the SPPs, and information required to develop planning schemes in accordance with the SPP.
SPPs, and particularly the agricultural land SPP, have figured in a number of key development decisions and planning appeals. The Planning and Environment Court has given significant weight to SPPs in determining appeals.

SPPs are not the only State statutory policy instrument. Other instruments include, for example:

- Environmental Protection Policies under the *Environmental Protection Act 1994*;
- Nature Conservation Plans under the *Nature Conservation Act 1992*; and
- Coastal Management Plans under the *Coastal Management and Protection Act 1995*.

Despite the existence of these other policy mechanisms, SPPs remain a useful general policy tool, particularly where:

- issues arise for which other more specific policy tools are inappropriate; and
- multiple State policy issues (involving for example balance between environmental protection and infrastructure provision) require an integrated solution.

4 PLANNING SCHEMES

Planning schemes are the key instrument in the planning and development assessment system established by the *Local Government (Planning and Environment) Act*. They are prepared by local governments for all or part of their areas and are largely administered by those local governments. Their principle role is to provide a locally based system for planning and regulating development and land use.

The Act requires planning schemes to include:

- a strategic plan;
- zoning maps; and
- provisions for the regulation, implementation and administration of the scheme.

A scheme may also include:

- one or more development control plans; and
- one or more regulatory maps.

Planning schemes must be supported by planning studies which should be publicly available, but do not form part of the scheme.

Before explaining in detail the role and function of these components, it is helpful to identify three broad functions performed by a planning scheme. These are:

- a policy function. This includes establishing planning goals, objectives and criteria, as well as explaining how these ends will be met through planning scheme processes and
other actions. In particular, policy provisions will explain how any statutory discretions in the scheme are likely to be exercised;

• a statutory (regulatory) function. This includes establishing a head of power for development control (i.e., a requirement to apply for development approval), provisions indicating in what circumstances approval is required, and statutory controls over matters such as height, bulk, density etc.; and

• an administrative function. This includes establishing the form in which applications must be made, information to be supplied with applications, assessment processes (other than those included in the Act), and other miscellaneous administrative provisions.

These 3 functions do not necessarily translate directly to scheme structure. Often, one of the scheme components described above may perform more than one of these functions, just as a single function may be scattered throughout the structure of a scheme. Nevertheless, these functional distinctions constitute a useful starting point for better understanding the role and structure of planning schemes.

4.1 Strategic Plans

Strategic plans have been a required component of planning schemes for about 15 years, although the Act allows the Minister to give a local government dispensation from the need to prepare a strategic plan as part of its scheme in certain limited cases.

Strategic plans are intended to establish the broad policy directions for the planning scheme area as a whole, and as such fulfill an exclusively policy function. They are a framework document which is intended to establish a policy context within which the rest of the scheme will operate. They typically consist of a map showing the broad preferred patterns of dominant land use for the local government area as a whole, supported by written goals, objectives, criteria and implementation strategies.

4.2 Zoning Maps and Associated Regulatory Provisions

Planning scheme areas are typically divided into a number of zones which are illustrated on zoning maps. The written provisions of the planning scheme establish those forms of development (usually identified with reference to an exhaustive set of definitions) which are "as of right", require consent of the local government, and are prohibited in each of the zones. These provisions usually appear in the form of zoning tables.

These regulatory provisions are commonly supplemented by policy provisions explaining the intent of each zone, which act as a guide in establishing the general character of development intended to be achieved in that zone.

In addition to the tables of zones, planning schemes also contain other detailed regulatory provisions establishing matters such as height and density limits, parking standards and so on. These standards might apply to individual defined uses, throughout a particular zone, or throughout the planning scheme area as a whole.
Planning schemes also typically contain regulatory provisions concerning subdivision.

4.3 Administrative Provisions

Although the Act establishes many of the provisions governing the way planning approvals are obtained, planning schemes also contain additional information including application processes, information required to be supplied with specific types of applications, additional heads of consideration, and keeping of registers.

4.4 Development Control Plans

Local governments may include development control plans in their planning schemes to provide detailed guidance on specific localities or issues.

Development control plans can take a number of forms, and include policy, regulatory and/or administrative provisions. Many development control plans are like a "strategic plan in microcosm", containing only policy guidance about the way discretion will be exercised in development assessment. However some development control plans are more complex, containing not only policy guidance, but superseding the zoning and regulatory provisions in the areas in which they apply.

Development control plans are usually used as a local planning instrument to provide detailed planning guidance for specific localities within a planning scheme area, such as commercial centres or inner city areas undergoing urban renewal. Occasionally development control plans are used to provide guidance on a specific issue, such as residential densities, throughout an entire planning scheme area.

4.5 Regulatory Maps

Regulatory maps are a form of mapping which may be included in planning schemes in addition to zoning maps. They have direct regulatory effect, unlike strategic plan maps and (most) development control plan maps, which give policy guidance only. Regulatory maps may for example be prepared to control building height or density in defined areas.

4.6 Preparing, Administering and Reviewing Planning Schemes

A local government must pass a resolution before preparing a planning scheme. The Act also allows the Minister to direct a local government to prepare a scheme, although this provision has never been used.

When a draft planning scheme is prepared, it is usually reviewed by the Department of Local Government and Planning on a preliminary basis, to ensure that State interests have adequately been reflected in the scheme. This preliminary review is not required by the legislation, but is intended to ensure that the State government has no major difficulties with the scheme before it goes on public display.

A draft planning scheme together with planning studies used to prepare it are placed on public display for 60 days. Any person may make a submission on the scheme, and all
submissions must be considered by the local government. When the local government has reviewed submissions, the scheme and any proposed amendments are forwarded to the Minister for the approval of the Governor in Council.

The relevant local government is responsible for administering the planning scheme, including receiving and processing applications for rezoning, planning consent and subdivision. The State government is not generally involved with the day to day administration of schemes, other than to process scheme amendments including rezoning applications approved by local governments.

Local governments are required to review their planning schemes within seven years of their introduction, and report on the results of the review to the Minister. If a review does not result in the preparation of a new scheme, the local government must in any case start preparing a new scheme within 10 years.

5 LOCAL PLANNING POLICIES

Local planning policies are intended to support the administration of the planning scheme and are subordinate to it. The Act requires local planning policies to have application throughout the planning scheme area. This is intended to prevent planning scheme policies being used as a comprehensive local planning instrument instead of development control plans, and limits the range of instances in which local planning policies can be used.

Public advertising of draft local planning policies is not required. A local planning policy is only required to be notified and publicly available after it is made. Local planning policies are most often prepared to explain in detail how discretions in planning schemes will be exercised. A local planning policy may for example explain how the adequacy of parking or landscaping provision in proposals will be assessed.

6 DEVELOPMENT CONTROL

The Act provides a decision making framework for development proposals. There are some general points to note:

- the operation of the Act is limited to new uses. The Act does not give a retrospective power to regulate existing uses. Existing lawfully established uses are protected (section 3.1(1));

- the need for approval to be obtained is decided by local governments through their individual planning schemes (or if there is no scheme by the interim development control regulation, if it has been adopted by the local government). The scheme is therefore an integral and fundamental component of the planning system;

- the Act identifies certain categories of uses (eg permitted, permissible etc). However, the Act is not a complete system. It does not limit schemes only to the development control processes specifically identified in the Act. Schemes can and do contain application and approval processes for related things like the relaxation of development standards (eg site cover standards); and
• a scheme does not, in law, have to contain all of the categories identified. Most do but it is not mandatory.

6.1 Permitted Uses

These are also commonly known as as-of-right uses. Permitted use is defined in section 1.4 as:

*means a use of premises which may be undertaken pursuant to a planning scheme without the approval of the local government notwithstanding that the local government may require an application for the setting of conditions or the issue of a certificate of compliance or in respect of any other matter.*

Some points to note about permitted uses:

• not all permitted uses must go through an application process. In practice the majority of permitted uses listed in schemes do not involve any planning application process section;

• there are no public objection or appeal rights against permitted uses. However, applicants may appeal against any conditions imposed;

• the practice has been for schemes to set out use controls in tables, with a separate table for each zone in the scheme. Traditionally, permitted uses are listed in column 111 of the tables. That column is sometimes divided into 2—column 111a lists uses that do not require any planning application (eg single dwellings in residential zones are commonly listed in this column), column 111b lists uses requiring applications for the issue of conditions.

If a scheme requires an application for conditions (ie a column 111b type application), the process is set out in section 4.1, and in particular subsections (5)—(8) are relevant. In short, these sections require an application for conditions to be decided within 40 days or it is taken to have been approved without conditions.

6.2 Permissible Uses

These are also commonly known as consent uses. Permissible use is defined in section 1.4 as:

*means a use of premises which may only be undertaken pursuant to a planning scheme with the approval of the local government granted pursuant to section 4.13.*

Some points to note about permissible uses:

• all permissible uses must be publicly notified and members of the public have objection and appeal rights;

• public notification is carried out by the applicant;
applications may be approved, approved with conditions or refused.

Sections 4.12 and 4.13 deal with the process for making and assessing applications. Section 4.1 is also relevant. Applications must be publicly notified for at least 10 working days. Applicants must submit a statutory declaration stating that notification has been carried out in the prescribed way. The local government must then decide the application within 40 days of receiving the statutory declaration, although provisions exist for the local government to extend the 40 day period.

An important amendment was made in 1992. Section 4.13(5A) requires a local government to refuse an application if:

(a) the application conflicts with any relevant strategic plan or development control plan; and

(b) there are not sufficient planning grounds to justify approving the application despite the conflict.

There is a 2 step process for granting approval. When the application is decided the local government must notify the applicant and objectors of its decision. If no appeal is lodged, the local government must issue a town planning consent permit. In most cases this must be done within 14 days of the ending of the appeal period.

6.3 Prohibited Uses

Prohibited use is defined in section 1.4 as:

means a use of premises which by virtue of the zone in which the premises are situated, is a use which is not a permitted use or a permissible use.

As the definition shows, prohibited does not actually mean prohibited. It simply means it is not permitted or permissible. Under the Queensland system of development control, prohibited is in effect an invitation to apply for rezoning.

6.4 Rezoning by Applicant

This is a type of hybrid land use application. In its purest form it involves changing the zoning of land from one zone to another. However, over time a number of other things have also been included within the rezoning concept. Section 4.3(2) lists these, they include amending—a development control map, a regulatory map, a specific purpose zoning (eg a Special Facilities zone), and conditions attached to a rezoning or staged rezoning. The effect of many rezonings is to grant a land use right (ie the zoning makes a desired land use a permitted use under the planning scheme). In these cases a rezoning application is effectively a land use application.
Some points to note about rezonings:

- the process for making and deciding applications is similar to consent applications—applications must be publicly notified by the applicant (the notification period must be at least 20 working days, compared with 10 working days for consent applications). The assessment period (40 days) is the same as for consent and permitted use applications. Also, the same provisions about refusing applications that conflict with relevant strategic plans or development control plans strategic plans apply to rezoning as apply to consent applications. However, while there are similarities there are also some important differences:
  - the heads of consideration against which applications are assessed are set out in the Act (section 4.4(3)). This is not the case for consent applications. These matters are left to schemes to determine;
  - a rezoning requires Governor in Council (GinC) approval. After an application is decided by a local government it must be sent to the chief executive, Department of Local Government and Planning. The chief executive must forward it to the GinC for approval. The GinC may approve the amendment of the planning scheme or refuse to approve the amendment. The power to approve also includes power to make such modifications as the GinC considers appropriate. If the amendment is approved, the approval must be given by order in council; and
  - the GinC is not bound by the decision of the court in relation to an appeal against a local government rezoning decision. This means an appeal decision to approve a rezoning can be overturned by the GinC. However, if an application is refused, either by the local government or the court that is the end of it, the GinC does not become involved;
  - staged rezoning (sections 4.6—4.9) the Act makes provision for rezonings to be staged. This means an application to rezone land to, say, create a large housing estate can be approved in stages. The first application will outline the overall proposal and include a staging plan. The first approval is dealt with the same as for any other applicant initiated rezoning. If approval is given the first stage is rezoned. Further applications may then be made for the remaining stages. The process for assessing these subsequent stages differs from the normal rezoning process in that there is no public notification of the application. Applications for subsequent stages must be made with 5 years of GinC approval of the 1st stage rezoning.

6.5 Combined Applications

The Act allows a person to combine several applications into 1 application. For example, to carry out a development it may be necessary to rezone land, subdivide and also apply for conditions for a permitted use. It is possible to combine all of those applications into 1. Section 4.11 sets out the requirements.
Some points to note about combined applications:

- if a component of a combined application (eg the rezoning component) requires public notification the whole application must be notified;

- if an application is notified objections may be made in respect of any component or the whole application. Appeal rights are available to objectors;

- if a component of the application involves rezoning the approval has no effect until GinC approval is granted for the rezoning; and

- if a component of the application involves rezoning and the rezoning is refused, the remaining components are also refused.

6.6 Subdivision

Part 5 of the Act deals with subdivision. Subdivision is defined in section 1.4 as:

means the division of land into parts by means of:

(a) sale, transfer or partition; or

(b) any agreement, dealing or instrument inter vivos (other than a lease for any term not exceeding 5 years without the right of renewal) rendering different parts thereof immediately available for separate disposition or separate occupation; or

(c) the creation of indefeasible title under the Land Title Act 1994 for a part of the land; or

(d) the excision of land from an allotment for dedication to the Crown.

Some points to note about subdivision:

- applications are decided by local governments. There is no public notification and public appeal rights are not available. Local government has 40 days to decide an application, although there are provisions for this time to be extended by the local government;

- the heads of consideration for applications are set out in the Act (section 5.1(3));

- subdivision is a 2 or 3 step approval process. Step 1 is the approval of the subdivision design. This is a planning assessment. If there are no works (eg the subdivision is a simple boundary adjustment involving no new roads or drainage works) then Step 2 involves the sealing of the survey plan. A plan of survey suitable for lodging in the Titles Office and certified by a licensed surveyor must be submitted to the local government for approval. The plan must be “sealed” (ie approved and endorsed with the seal of the local government) if the plan conforms with the previous approval (ie the stage 1 approval) and with the requirements of the Act. Once sealed, the applicant is responsible for lodging the plan with the Titles Office for registration. The Act says this must be done within 6 months of sealing. If it is not, the plan must be re-sealed by the local government before it can be lodged for registration. The registration process is set out in the Land Titles Act;
if works are involved subdivision is a 3 step process. Step 1 is as described above. Step 2 involves approval of the engineering drawings and specifications for the works. Step 3 is plan sealing;

• the Act makes provision for subdivisions to be staged. This means an overall staging plan is approved together with the first stage of the subdivision. Subsequent stages must then conform with the approved staging plan;

• the provisions about refusing applications that do not conform with relevant strategic plans and development control plans also apply to subdivision applications.

6.7 Conditions

The Act makes provision for local governments to impose conditions when approving applications, or when dealing with permitted uses for which applications must be made for conditions. Section 6.1 sets out the test for deciding if conditions are lawful. The basic test set out in section 6.1(1)(c) says:

the local government is not to:

subject its approval of that application to a condition that is not relevant or reasonably required in respect of the proposal to which the application relates, notwithstanding the provisions of a planning scheme.

There is much case law about this test. It is pretty much a universal test that is applied by courts throughout the country and in other countries with similar legal systems. A point to note is that the test of reasonableness and relevance applies despite the provisions of a scheme. This means a local government must apply the test even if a scheme provision purports to oblige a local government to apply a particular condition. That condition is unlawful if it does not pass the reasonableness and relevance test.

7 APPEALS

Part 7 of the Act deals with appeals. Appeals are to the Planning and Environment Court which is a District Court level jurisdiction. Unlike other States, Queensland’s appeal body is fully judicial. All cases are heard by judges. In the other States planning appeals are either dealt with by tribunals comprising legal and non-legal members, by courts comprising both judicial and non-judicial members, or through a Ministerial appeal process.

Applicants have broad appeal rights. In simple terms an applicant may appeal any decision made by the local government about their application, including the imposition of conditions. Applicants may also appeal a failure to decide an application within time. Objectors have the right to appeal against local government decisions in relation to rezoning and consent applications and combined applications with a component involving a rezoning or consent application.
Section 3.5 deals with compensation. The Act says:

Where a person:
(a) has an interest in premises within a planning scheme area and the interest is injuriously affected:
   (i) by the coming into force of any provision contained in a planning scheme; or
   (ii) by any prohibition or restriction imposed by the planning scheme; or

(b) has incurred expenditure pursuant to a town planning certificate given to that person by a local government pursuant to section 3.3 which expenditure is rendered abortive (in whole or in part) by reason of any error, omission or inaccuracy in the certificate;

the person is, subject to compliance with this section, entitled to obtain from the local government compensation in respect of the injurious affection or expenditure and may claim that compensation in accordance with this section.

Some points to note about compensation:

• there is a wide range of circumstances in which it is not payable. These are set out in section 3.5(4) and include, provisions in schemes that prescribe the space about buildings, or limits the size of allotments or number of buildings, or the height, density or design of buildings. Compensation is also not payable where subdivision is prohibited or restricted;

• compensation is payable by the local government. This applies even if a scheme provision that may attract compensation has been included by the GinC;

• the onus of proving that compensation is not payable in any case is upon the local government.

• claims for compensation must be made to the local government within 3 years of the action giving rise to the claim;

• a decision on a claim must be made by the local government within 40 days. It may:
   (a) grant the claim in whole or part; or
   (b) reject the claim in whole or part; or
   (c) acquire the land pursuant to section (9); or
   (d) by resolution, propose to amend the planning scheme pursuant to subsection (2A); or
   (e) effect any combination of paragraphs (a), (b), (c) or (d).
CONCLUSIONS

The planning system in Queensland needs to be understood with respect to the totality of laws and instruments governing the making and implementation of planning policy. While the Local Government (Planning and Environment) Act establishes a broad regulatory framework, planning policy of State, regional and local application is found in State Planning Policies, local government strategic plans, development control plans and local planning policies. Detailed regulatory and administrative provisions consistent with the Act are also found in the zoning and associated provisions of planning schemes, some development control plans and regulatory maps.
OTHER LEGISLATION OF RELEVANCE TO URBAN AREAS

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ABSTRACT

This paper outlines the principles being adopted in the development of: the draft Natural Resource Management Legislation (which will amalgamate eight existing Acts administered by the Department of Natural Resources); the key elements and provisions of the State Development and Public Works Act 1971; the Fisheries Act 1994; the Land Act 1994 (and associated tree clearing guidelines); the Rural Lands Protection Act 1985 and the Mineral Resources Act 1989.

In each situation comment is provided on the application or potential application of these Acts and policies in urban situations. It is clear that each of these Acts and policies has relevance to urban environments. However as there are no clear guidelines which apply across all the Acts and which can be followed in all situations, it is essential that planners, developers, government bodies and urban individuals are aware of the potential applications and consciously seek to accommodate these provisions when dealing with urban situations.

KEY WORDS natural resource management, fisheries, mineral resources, land act, tree clearing, rural land protection, planning, allocation, protection, urban areas, sustainable management.

1 INTRODUCTION

Many areas of policy and legislation impact on the use and management of natural resources in urban areas. Policy and legislation associated with the Environmental Protection Act 1994, the Local Government (Planning and Environment) Act 1989 and the Coastal Protection Act 1995, which have been detailed by previous speakers (Chadwick & Ballard, 1996 and Hesse, 1996), will exert major controls in urban areas.

A range of other Acts such as the proposed Natural Resource Management (NRM) legislation, Mineral Resources Act 1989*, State Development and Public Works Organisation Act 1971, the Land Act 1994, the Fisheries Act 1994 and the Rural Lands Protection Act 1985, will all impact to a greater or lesser extent on urban areas. The purpose of this paper is to examine the nature and the extent of these impacts.

These Acts will provide for a number of strategies aimed at achieving ecologically sustainable development including:

- impact assessment for proposed major developments;

* Copies of Queensland Government Acts are available from Goprint, Brisbane.
establishment of standards for use and management in areas adjacent to or adjoining urban areas, such as mineral resource development and floodplain management;

- protection of critical natural resources such as mangroves from urban encroachment;

- the protection of urban areas from degradation, such as that caused by declared weeds and pests;

- linking between urban and rural areas in the use and management of natural resources.

2 PROPOSED NATURAL RESOURCE MANAGEMENT POLICY AND LEGISLATION

The natural resources of land, forests, and water support the development of agricultural and forestry industries which are essential to the economic prosperity and well-being of the community.

The ability to sustain the economic contribution from the use of natural resources, and provide security for future investment, will depend on maintaining their quality and availability, protecting them from degradation and managing their use to protect the wider environment. Even though significant steps have been taken to better care for natural resources, not all are being managed sustainably in all cases. Much more must be done, and preferably in a manner that integrates the management of all natural resources. At the same time the community wishes to be more involved in the decision-making processes for State owned or controlled natural resources and to see individuals take greater responsibility for management of all natural resources.

The Government's NRM policy provides for the ecologically sustainable use and management of natural resources. The policy provides for individual responsibility and action, and the involvement of the community in decision making for natural resource use and management. In the case of the management of privately controlled natural resources such as freehold land, and vegetation on these lands, the major emphasis is on the adoption of non-regulatory strategies with the use of NRM legislation in severe or critical situations. However regulation will be routine and necessary where the allocation and management of State owned or controlled water and forest resources and quarry materials are involved.

2.1 Objects of Proposed NRM Legislation

These are to:

- protect the sustainable productive capacity of natural resources while allowing for their sound economic development;

- ensure the impact of the use of natural resources on other resources is consistent with ecologically sustainable development principles; and

- ensure fair access to and allocation of natural resources, while recognising commercial, recreational, social, cultural, traditional and environmental uses of the natural resources.
The proposed natural resource management legislation will amalgamate eight existing Acts which are currently administered by the Department of Primary Industries (DPI). These include:

- Soil Conservation Act 1986;
- Soil Survey Act 1929;
- Water Resources Act 1989;
- River Improvement Trust Act 1940;
- Forestry Act 1959;
- City of Brisbane (Flood Mitigation Works Approval) Act 1952;
- Brisbane Forest Park Act 1977; and
- Sawmill Licensing Act 1936.

It is proposed at this stage that most of the mechanisms from seven of these eight Acts will be incorporated into the NRM legislation. However, the inconsistencies between similar mechanisms in the various Acts (for example, for the issuing of licences) will be reviewed and mechanisms that are no longer relevant to the modern management of natural resources will be repealed.

The eighth Act, the Sawmill Licensing Act 1980, which provides for the stabilisation of the timber industry through the licensing of sawmills, is currently being reviewed in the public arena. National competition policy may have a significant influence on the future of sawmill licences.

In addition to those mechanisms in the eight Acts, the proposed legislation will:

- adopt the principles of ecologically sustainable development;
- provide for integrated use and management of land, water and forests;
- link with other Acts for the management of natural resources, such as land use planning, environmental protection, nature conservation and fisheries legislation.

The new mechanisms which will be incorporated in the NRM legislation to provide for ecologically sustainable development and the sharing of natural resources in an environment of increasing competition for natural resources include:

- a planning process for the sharing of State owned or controlled water and forest resources and quarry materials between competing uses;
- making provision for environmental requirements when sharing natural resources;
- property rights in water including resource security, and the trading of entitlements in an open market;
- management of critical areas which have the potential for severe degradation;
• management of floodplains where there is a risk of severe degradation of the natural resource or damage to infrastructure; and

• adoption of the principles of integrated catchment management.

2.2 NRM in Urban Situations

In terms of land management for urban development, NRM policy and legislation is significant in the following areas:

• the sharing of water between competing uses;

• management of floodplains;

• linkages between NRM plans developed for rural areas and newly developed urban areas;

• situations where urban communities will influence NRM decisions; and

• coordinated management between urban and rural areas.

2.3 Sharing of Water Between Competing Uses

Increasing demands, both rural and urban, are being placed on limited water resources and there is increasing competition for the use of scarce water resources. Water requirements for environmental purposes will need to be met in the future.

NRM proposes a planning process for the sharing of water for the following purposes:

• riparian requirements (owners of land immediately adjacent to a watercourse have a riparian right to take water for stock and domestic purposes);

• environmental requirements for the maintenance of basic ecosystems;

• consumptive uses, such as for urban, irrigation, mining, industrial and recreational uses; and

• reserved for public purposes (for future uses).

During the planning process any person within the catchment area for the water supply will be able to make a submission on the sharing of the water to the Executive Officer of DPI. These submissions will be considered when preparing the final sharing plan.

As part of the process for allocating water to consumptive users, it is proposed that local governments will receive a bulk allocation consistent with their existing requirements. Local government planning schemes will need to take account of the availability of water and water allocation plans will need to meet where possible the future needs of planning schemes.
In the future it is proposed that when all the water has been allocated in a catchment, that additional requirements be met through better use and conservation of existing water allocations and through the purchase of additional water from other users in an open market.

2.4 Management of Floodplains

Flooding of floodplains results in degradation of natural resources (soil erosion, stream bank erosion) and damage to infrastructure. It is proposed that NRM plans be developed and implemented to manage the situation for floodplains where such problems exist. The NRM plan would develop the principles for overall coordination and management of the floodplain and would identify technical and other natural resource characteristics that must be accounted for in the development of the floodplain. The *Water Resources Act 1989* currently provides for this. In addition the plan would also identify flood risk categories for the floodplain for which local government could apply appropriate development controls.

Any proposed structures that would impact on the floodplain would need to be licensed. These may include the construction of earthen levee banks by individuals in rural areas or flood mitigation works by local governments in urban areas.

It is proposed that where it is appropriate, that each NRM plan for a floodplain be incorporated into the local government planning scheme and the licensing for works be undertaken by local government.

The proposed Act will also establish a permitting system where landholders wish to destroy vegetation, excavate or place fill in a “watercourse” as currently defined in the *Water Resources Act 1989*. A “watercourse” is a river, stream or creek in which water flows permanently or intermittently, upstream of the point to which the spring tide normally flows and refloows.

2.5 Linkages between NRM Plans Developed for Rural Areas and Newly Developed Urban Areas

The NRM legislation is being designed primarily for use in rural areas. NRM plans for runoff coordination between properties for instance (currently prepared under the *Soil Conservation Act 1986*) will only be prepared for rural areas and in some cases for rural residential areas.

Problems will arise when a subdivision is proposed in a rural area with a statutory NRM plan for runoff coordination. Where the subdivision is for a part of the planned area, it will be necessary to revise the plan to ensure that the water flow is coordinated between the rural and proposed urban areas. Where the proposed urban area consumes the entire NRM plan area, it may be most appropriate to revoke the plan. The plan for a rural area typically incorporates above ground earthen waterways and contour banks which are mostly inappropriate in the urban situation. In urban areas these measures will be replaced with underground pipes and concrete drains. Similar decisions will need to be made where urban development is proposed in rural areas that have been mapped as “critical” before any clearing or development can occur. A critical area by definition, is an area which has the potential to
degrade severely if developed or cleared. They would include areas such as steep land slopes, fragile lands, and underground water intake areas.

2.6 Situations where Urban Communities will Influence NRM Decisions

A good example of the interaction between production and conservation interests in the community arises in the case of State forests. Because of the increasing demand for recreation and the protection of nature, urban communities will have an increasing say in the multiple use decisions for State forests. The NRM legislation proposes that plans be prepared for State forests detailing the uses to which they will be put. State forests may be used for a range of purposes, including:

- timber production;
- areas being set aside for nature based recreational and tourism purposes;
- nature conservation and wilderness areas;
- the use of specialised management purposes such as a Scientific Area or Feature Protection Area;
- watershed protection; and
- activities such as grazing, bee keeping.

During the planning process, any person who has an interest in a State forest will be able to make a submission on the proposed uses of the State forest to the Executive Officer of DPI. These submissions will be considered when preparing the final resource sharing plan.

In view of current community concerns on biodiversity, it can be expected that there may be an increasing emphasis on uses other than timber in many of these State forests. State forests such as those in the Brisbane Forest Park are used for recreation, nature conservation and timber production, whereas Daisy Hill State Forest to the south of Brisbane has recently been solely used for recreation and nature conservation.

2.7 Coordinated Management Between Urban and Rural Areas

NRM policy and legislation will provide for mechanisms such as integrated catchment management and landcare which provide links for coordinated management of resources between rural and urban communities.

Plans developed for integrated catchment management will provide an overall guideline for use and management of an entire catchment including both rural and urban areas. Such plans will not have any legislative standing, but other legislative mechanisms (such as NRM plans or local government planning schemes) will be used to implement particular aspects of these plans where voluntary mechanisms have failed.

In some situations it may be appropriate to establish a NRM Statutory Body which will be the equivalent of a River Improvement Trust under the River Improvement Trust Act 1940. These bodies will be able to raise funds and to undertake works and activities as indicated in a catchment plan. Such bodies will operate in rural and urban areas.
3 MINERAL RESOURCES ACT

The Mineral Resources Act 1989 which came into force in 1990 is the principal statutory control over mining in Queensland. The Act provides for improved environmental performance and requires explorers and miners to minimise environmental damage at every stage from exploration through mining to rehabilitation. The principal objectives of the Act which applies to mining on all land tenures are to:

- enhance and facilitate prospecting and exploring for and mining of minerals;
- enhance knowledge of the mineral resources of the state;
- minimise land use conflict with respect to prospecting, exploring and mining;
- encourage environmental responsibility in prospecting, exploration and mining;
- ensure an appropriate financial return to the state from mining; and
- provide an administrative framework to expedite and regulate prospecting and exploring for and mining of minerals.

It is argued that through providing effective environmental management before, during and after exploration and mining, the Mineral Resources Act 1989 provides a mechanism to achieve a balance between the community’s need for mineral products and the maintenance of a healthy environment.

An environmental management policy for mining in Queensland has been developed by the Department of Minerals and Energy in consultation with the Queensland Mining Council. The principal objectives of the policy are: that mining and rehabilitation should aim to create a landform with land use capability and/or suitability similar to that prior to disturbance unless other beneficial land uses are predetermined and agreed; mine wastes and disturbed land should be rehabilitated to a condition which is self-sustaining; and surface and ground waters that leave the lease should not be degraded to a significant extent - that is downstream water quality should be preserved.

With respect to mining leases the Minister responsible for the Mineral Resources Act 1989 can assess an Initial Advice Statement and may require the proponent to prepare an Environmental Impact Statement prior to lodging a Mining Lease Application. Applications for mining leases must include acceptable statements relating to the protection of the environment and to the progressive and final rehabilitation of disturbed areas - an Environmental Management Overview Strategy (EMOS). The EMOS is a strategic planning document for the life of the mine and is required to provide statements of acceptable environmental impacts, control strategies and performance measures for the control of the environmental impacts.

Once a mining lease is granted the leaseholder submits a plan of operations conforming with the EMOS and an audit report certifying that the plan complies with the EMOS.

3.1 Application in Urban Situations

All mining activities carried out in or near urban areas are bound by the provisions of the Mineral Resources Act 1989 as well as other legislative provisions such as the Environmental Protection Act 1994.
A suite of technical guidelines has been prepared to provide direction to miners on the best environmental management practices to be adopted. These guidelines provide direction on mining in both rural and urban areas.

4 STATE DEVELOPMENT AND PUBLIC WORKS ORGANISATION ACT 1971

This statute in addition to the Local Government (Planning and Environment) Act 1990 provides for impact assessment for new developments. The following statement on the State Development and Public Works Organisation Act 1971 was extracted from a document released for public consultation by the then Queensland Department of the Premier, Economic and Trade Development in September 1995.

Section 29 of the Act firstly bestows a responsibility on the Co-ordinator General to 'co-ordinate departments of the Government of the State and local bodies throughout the State in activities directed towards ensuring that in any development proper account is taken of the environmental effects'. It secondly conveys a clear responsibility on departments and local bodies (ie. local governments, port authorities, electricity boards and the like) in considering applications for development, or in considering the undertaking of works, to take environmental effects into account 'when it appears that such development or works is likely to have major environmental effects'. This covers both private and public sector projects.

Section 29 also requires local bodies to have due regard to "such policies and administrative arrangements as may be approved from time to time". The power under Section 29 for the Minister to issue 'policies and administrative arrangements' is subject to those policies and arrangements being compatible with other legislation. Thus, Section 29 has broad application, but its 'policies and administrative arrangements' are not mandatory.

The Department of Environment (DOE) currently holds delegated responsibility for Section 29. The impact assessment requirements of the Local Government (Planning and Environment) Act 1990 were introduced at a later date to ensure that all local governments adopted a consistent approach.

5 LAND ACT AND TREE CLEARING GUIDELINES

The Land Act 1994 allows for the management of non-freehold land and the creation of freehold land. It streamlines administration and management of non-freehold land and makes land sustainability a key factor in decision making. Although the Act generally applies to non-freehold land, most freehold land contains a reservation to the State for minerals. To this extent this Act applies to all land including land below high-water mark.

Land to which this Act applies must be managed for the people of Queensland by having regard to a set of principles that includes:

Sustainability
- Sustainable resource use and development to ensure existing needs are met and the State's resources are conserved for the benefit of future generations.
Evaluation

- Land evaluation based on the appraisal of land capability and the consideration and balancing of the different economic, environmental, cultural and social opportunities and values of the land.

Development

- Allocating land for development in the context of the State's planning framework, and applying contemporary best practice in design and land management; and

- When land is made available, allocation to persons who will facilitate its most appropriate use that supports the economic, social and physical well-being of the people of Queensland.

Protection

- Protection of environmentally and culturally valuable and sensitive areas and features.

The Land Act 1994 contains important provisions aimed at achieving resource protection and sustainability. In particular, lessees have a responsibility for a duty of care for the land (which may be met by following the Code of Practice for Agriculture once finalised), are required to perform all of the conditions of the lease, and must obtain a tree clearing permit for clearing of any trees other than for routine management purposes (as defined in the regulations). Applications for permits must be assessed against criteria specified in the Act and against any State broadscale tree clearing policy and local guidelines that are in place.

Management of trees on unallocated State lands and on reserves, deeds of grant in trust, roads, licences, permits and leases on which the State owns the trees must be consistent with the following principles:

- to maintain the productivity of the land;
- to allow the development of the land;
- to prevent the degradation of the land;
- to maintain biodiversity;
- to maintain the environmental and amenity values of the landscape; and
- to ensure public safety.

State Cabinet, in seeking to achieve a balance between the above principles, agreed on the 18 December 1995:

- to a Preliminary Tree Clearing Policy for the State;

- the formation of a State Trees Group to support the completion of local guidelines and any adjustments to the Preliminary Policy before it becomes the Broadscale Tree Clearing Policy (the group will also design a process for conducting a review of the Broadscale Tree Clearing Policy in 1997);

- the continuation of the development of local guidelines; and
• the establishment of a an interdepartmental committee to examine assistance measures for lessees who are adversely affected by Government regulations/policies.

The Preliminary Policy has been approved as a reference document and to provide guidance for the development of local guidelines. In addition it is being used as a reference document in the issuing of permits to clear trees under the provisions of the *Land Act 1962* until the policy and local guidelines are finalised after June 1996 and the relevant sections of the *Land Act 1994* commence.

Local guidelines are being developed through community participation in local working groups. These working groups are identifying habitat, vegetation, soil, and catchment areas for which specific guidelines are needed and will establish limitations for inclusion in the local guidelines on criteria such as:

- maximum slope gradient above which clearing is not permitted;
- minimum distance from watercourses that clearing is allowed;
- which vegetation types should not be cleared (including endangered and vulnerable types and types that cannot be developed for sustainable production);
- percentage of vegetation types that can be cleared;
- special situations or conditions that apply to clearing, for example, any guidelines for thinning.

Initially consultation on the Preliminary Policy was to be progressed until June 1996 by which time local guidelines were to be completed. Government has now indicated that even though target dates have been set it is not important that the final recommendations be made within the time frame and that 'getting it right' was the top priority.

### 5.1 Application in Urban Situations

It is worth noting that very little land occupied or being managed for urban development would be subject to the tree clearing provisions of the *Land Act 1994* and as a consequence there is minimal impact of this Act on urban development issues. Obviously any leasehold or state owned lands in urban situations are subject to the provisions of the Land Act. Local Governments however are increasingly employing the power they have under the *Local Government Act 1993* to create local laws to control vegetation clearing with both the rural and urban areas in their jurisdiction. A model local law on vegetation clearing, to facilitate a consistent approach across the State, has recently been finalised.

### 6 FISHERIES ACT

The objectives of the *Fisheries Act 1994* include:

- ensuring fisheries resources are used in an ecologically sustainable way;
- achieving the optimum community, economic and other benefits obtainable from fisheries resources; and
- ensuring access to fisheries resources is fair.
The *Fisheries Act 1994* contains a number of provisions and powers which can impact upon the use, development and management of urban areas.

### 6.1 Declaration of Fish Habitat Areas

The Act contains powers to declare fish habitat areas in marine or freshwater areas and adjacent lands. Once they are declared, no works of any nature may be undertaken within the areas without a permit being issued by the Executive Officer of DPI. Furthermore, the powers of the Executive Officer to issue a permit are limited to works which do not have long term or significant impacts upon the areas in question. Essentially, therefore, once a fish habitat area is declared, no substantial activities can be undertaken which would physically impact upon the area. It is permissible however, to undertake fishing activities and boating activities within the area, but not for example, to remove vegetation, to dig or channel in any way, to pump sand and material from or into the area, or to deposit or impact in any other physical way upon the integrity and quality of the area.

Prior to the declaration of such areas, extensive consultation would be undertaken with all stakeholders with an interest in the area and the results of this consultation taken into consideration as part of the decision making process.

### 6.2 Licensing of Aquaculture Activities

The Act requires that any commercial aquaculture activities being conducted either in a marine area, freshwater area or in areas on Crown, private or leasehold land require licensing under the legislation. Prior to such licences being issued, environmental impact statements may be required and such activities would obviously also have to conform with local government requirements and zoning etc. The purpose of the legislation is not to necessarily restrict the development of aquaculture farms, but to ensure they are environmentally sound and technically viable prior to licences being issued. Furthermore, there can be environmental impacts on associated areas, for example near shore areas or river areas, which can impact upon other uses.

Aquaculture activities are decreed to be environmentally relevant activities under the provisions of the *Environmental Protection Act 1994*, and so have to be licensed. It is proposed that the environmental management aspects of the licensing system under the *Fisheries Act 1994* be reconciled or merged with the *Environmental Protection Act 1994* licences.

### 6.3 Construction of Dams, Barrages etc.

The Act also requires the issue of a licence under the legislation for the construction of any works which block freshwater or marine areas from natural flow. This is clearly designed to protect fish stocks and the movement of fish up and down river systems and in coastal areas. An environmental impact assessment may be required prior to consideration of the issue of such licences or approvals and licences, may be issued subject to various conditions about the construction of fishways within the overall construction and other maintenance issues.
6.4 Protection of Marine Habitat

The legislation provides total protection for all marine plants as defined under the Act. This definition includes not only mangroves and seagrasses, but also plants growing adjacent to marine or riverine areas which have a connection with the fishery. This in effect means there can be no removal of such marine plants without a specific permit and approval from the Executive Officer of DPI. Such approvals are given only after individual consideration of the circumstances involved. Where it is associated with a large development, an impact assessment is undertaken. The purpose of such protection is to maintain the viability of critical fisheries.

7 RURAL LANDS PROTECTION ACT

The Rural Lands Protection Act (1985) and Regulations (1989) apply to all land in Queensland although travelling stock permits only apply to stock routes or stock reserves. In particular the Act provides for the management of and control of pest plants and animals, regulating introduction of pest plants and animals, the establishment of the Dingo Barrier Fence and the Rabbit Fence and the management of stock routes and associated reserves. It includes laws for the control, prohibition, sale, keeping and regulation of the spread of 'declared' plants and animals.

The Act is administered by the Minister for Natural Resources, although the operations and enforcement of the Act and Regulations are largely delivered through local governments. In particular local governments ensure that declared plants and animals are controlled on private and municipal land in their own local government area. They also have responsibility to manage stock routes, reserves and travelling stock and regulate the movement of travelling stock. The Department of Natural Resources monitors control of pests on State land and the performance of local governments on private and municipal lands as well as undertaking strategic or emergency control measures when required.

Both rural and urban landholders have a responsibility under the Act to control declared plants and animals on their land and to obtain permits to travel stock on stock routes or agist stock on stock routes or reserves.

Officers such as local government weed/pest officers and stock route supervisors and land protection officers from the Department of Natural Resources have the power to enter onto private land, (where approved) the power to issue notices to control pests and (where approved) the power to enter land to control declared pests. If the local government undertakes the work, costs are recoverable from the landholder. Officers also have the power to seize straying stock.

An up to date list of declared plants and animals can be obtained from the local office of the Department of Natural Resources, however it should be noted that as individuals and land owners, it is an offence to: sell a declared plant or part thereof; introduce a prohibited (P1) declared plant; introduce declared (A4) animals without a permit; keep or sell declared (A3) animals without a permit; or travel or agist stock on stock routes or stock reserves without a permit. Individuals must comply with a notice to control declared plants or animals on their land or under their control.
CONCLUSIONS

Planned and responsible land management for urban development is essential to achieving sustainable, aesthetic and harmonious rural and urban environments. As has already been shown there is a wide array of legislative and policy provisions which impact directly or indirectly on urban situations. The Acts and policies discussed in this paper all have some relevance to urban situations, however the level of direct impact varies significantly. It is important therefore that planners, developers, government bodies and urban users are aware of these Acts and policies and actively explore their relevance and application to any particular urban situation being addressed. No general all encompassing advice can be provided on the specific application of these Acts - rather individuals need to be conscious of the existence of these Acts and policies and their application or potential applications in urban situations.

REFERENCES


CUSTOM - MADE SOIL PROFILES

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ABSTRACT

Where custom-made soils are used, the assumption is that their performance will meet the expectations of diverse client groups. Indeed, custom-made soils should out-perform soils already present at development sites, or serve as effective substitutes when insufficient soil remains for landscaping or is totally lacking. Moreover, profiles can be specified to 'perch' water tables while simultaneously providing good root-zone conditions, high resistance against compaction / deformation, and excellent drainage. Unless there is attention to detail, appropriate quality assurance, and good management, results may be disappointing.

This paper provides brief details on specifications used for some custom-made soils, including information on materials used for such soils, and on key physical and chemical properties. Water movement and drainage are discussed, supported by several diagrams on both issues. There is guidance on establishing ground cover and on renovation and maintenance, particularly for high-value turf areas. The importance of making detailed site inspections prior to the commitment of landscaping services, supported where necessary by laboratory tests, is emphasised. Forward plans should include provision for major refurbishments or the rebuilding of custom-made soils modified adversely by long-term use.

KEY WORDS: chemical properties, custom-made soils, drainage, 'perched' watertable, physical properties, renovation, root-zone materials, soil profiles, sub-grade, turf species.

1 INTRODUCTION

It is a human trait to intervene in natural landscape processes for a variety of reasons. Modifications to enhance agricultural productivity (clearing, draining, levelling, ploughing, fertilising, irrigating) have occurred on all the settled continents. The Hanging Gardens of Babylon, one of the seven wonders of the ancient world, were testament that trees, flowers and other vegetation can and have grown well under 'custom-made' conditions, designed to meet the visual aspirations of individuals and communities. While the properties of the 'soil' used in the Babylon Gardens have been lost to antiquity, much is now known on 'tailoring' soils to the needs of urban developments, landscaping, sporting fields and the like. Ultimately, plant growth on such soils is determined by other environmental considerations such as climate, fertility, hydrology, disease, ecology and management.

There is an old adage that 'the answer lies in the soil'. This paper accepts the substantive truth of this saying by identifying and explaining many of the properties that impact on custom-made soils, their specifications and overall management. Such soils have become commonplace because of the inadequacies of many natural soils or the absence of fertile soils.
at most development sites. Custom-made soils also provide an opportunity to dispose of wastes such as bio-solids, newspaper cellulose, timber wastes and the like.

2 SOIL PROPERTIES

Natural soils are a complex continuum of loose particles of mineral and organic components that mantle the earth's surface, except where interrupted by water, shifting sand, salt, perpetual ice exposed rocks, and more recently by roads, concrete slabs and buildings. They reflect the effects of climate, topography (or relief), vegetation, man and other biota acting on parent rocks and the soil itself. It follows that soils vary in appearance and in their ability to supply nutrients, water, air and anchorage for plant roots.

2.1 Soil Profiles

Dig a pit, excavate a site, or cut and fill an area for development and it is quickly observed that the upper part of most soils differ from lower segments, the original parent material or even a buried soil. Moreover, the appearance and nature of soils change progressively or abruptly with depth, as does the distribution of plant roots. This orderly sequence from the natural soil surface to the non-soil beneath is called the soil profile. A schematic example is shown in Figure 1, complete with brief descriptions of typical segments (termed horizons).

<table>
<thead>
<tr>
<th>O1</th>
<th>Organic horizon of undecomposed organic matter.</th>
</tr>
</thead>
<tbody>
<tr>
<td>O2</td>
<td>Organic horizon of partially decomposed organic matter or thatch. (O1 and O2 horizons are usually absent on disturbed sites)</td>
</tr>
<tr>
<td>A1</td>
<td>Mineral dominated horizon at or near the soil surface with an accumulation of humidified organic matter that darkens the soil mass. With disturbance, the A1, A2 and A3 surface horizons are often mixed.</td>
</tr>
<tr>
<td>A2</td>
<td>Subsurface horizon that has lost organic matter, clay particles, iron or aluminium through eluviation, with concentration of resistant sand and silt-sized particles. Platy structure common.</td>
</tr>
<tr>
<td>AB</td>
<td>Transitional to the B horizon, or C horizon if B is not present, but more like the A horizon than the B or C. If A3 and B1 are present but cannot be separated, an AB horizon is designated.</td>
</tr>
<tr>
<td>B1</td>
<td>Transitional to the A, but more like the B horizon.</td>
</tr>
</tbody>
</table>
| B2          | Mineral horizon, characterised by one or more of the following:  
• illuvial concentration of clay, iron, aluminium or humus, alone or in combination;  
• residual concentration of iron and aluminium oxides or silicate clay;  
• coatings of iron and aluminium oxides that impart darker, redder colours; and/or  
• alteration of parent material through physical and chemical means with formation of granular, blocky or prismatic structure. |
| C           | Mineral horizon, other than bedrock, which may not be similar to the presumed parent material. Has been affected by soil forming processes but may be otherwise weathered. There could be intense gleying or reduction of iron compounds, accumulation of carbonates (such as calcium carbonate) and/or sulfates/sulfides, etc. |
| R           | Underlying consolidated bedrock that is continuous. However, some fracturing is likely. |

Figure 1 Hypothetical soil profile with descriptions of principal horizons
Boundaries between horizons of *gradational* soils may spread over several centimetres and can be difficult to see, whereas in texture-contrast or *duplex* soils, the boundary between the A and B horizons is sharp and easily noticed. In general, A horizons exhibit more biological activity, have less clay, and contain a better balance of essential plant nutrients than corresponding B horizons. In contrast, B horizons typically contain higher levels of chloride, exchangeable sodium, undesirable characteristics from a plant-growth viewpoint. B horizon soil segments also tend to be physically harder when dry and stickier when wet, and often contain mottles (localised patches, blotches, or streaks of colours that contrast with the dominant or matrix colour). Mottles are indicative of soils with poor internal drainage in their natural state, although earth works at development sites can alter the natural drainage characteristics of soils.

In practice, development sites occur in previously undisturbed locations, on land used or modified for a variety of agricultural and industrial pursuits, on reclaimed land, where buildings and roads previously existed, in planter-boxes, and even on suspended slabs of buildings (Figure 2). It follows that soil profiles at such sites should not be taken for granted. Neither should apparent knowledge be based on hearsay, or on a superficial site inspection. The site should be inspected carefully, never assuming a profile trend similar to Figure 1. Only then should development or redevelopment plans be costed and finalised, supported where justified by test corings and laboratory analyses.

Where earth works have already occurred or are planned, the soil profile may be truncated or buried. If truncated, only portion of the A horizon or the B or the C horizon or even bedrock may be at the surface. Plant growth in such ‘soils’ will be restricted, due to poor physical conditions, too much or too little soil moisture, and/or inadequate soil fertility. Alternatively, the surface may have been replaced by a relatively loose mixture of particles of different aggregate size and shape, derived from various horizons, possibly overlaying a prior soil. Often, ‘fill’ of imprecise specifications and consolidation can cover part or all of the site.

If there are no records or equivalent photographic or video evidence, the site visit may need to be ‘supported’ by a drilling and drainage evaluation program, to depths commensurate with the intended use of the site.

### 2.2 Physical Properties

The physical properties of custom-made soils and root-zone mixes are particularly important. These include texture, structure, porosity, aggregation, moisture holding capacity, drainage, stickiness, degree of plasticity, compaction, bulk density and temperature.

Soil texture reflects the proportions of coarse sand, fine sand, silt and clay size fractions. By convention, the sand, silt and clay particles total 100%, ignoring contributions from organic matter. That is, the percentage applies only to the dry weight of the mineral portion <2 mm.

Most soils have a proportion of particles of different sizes, that in turn influence the texture-class name (see Figure 3). For example, soils are called sands if sand-size particles make up 70% or more of the <2 mm size fraction. In contrast, clay soils contain at least 35% clay-size fractions. Loams are more difficult to define but ideally should have about an equal balance of sand, silt and clay. Gravelly soils (gravels up to 75 mm dia) are described by preceding the textural class name with terms such as gravelly clay loam (>20% of gravel present) or very
gravelly clay loam (>50% of gravel). The same percentages apply to stones, the term used when the stony particles exceed 250 mm dia.

Figure 2 Examples of large-scale construction sites, showing that considerable changes to natural soil conditions can occur.
Texture class diagram showing the proportions of sand, silt and clay in each soil texture class.

Aggregates are moderately stable collections of different particles, typically cemented together by organic substances, iron oxides, carbonates, etc. Natural aggregates are termed peds, the shape, size and aggregation of which determines natural soil structure. Both granular (spheroidal) and single-grain (structureless) soils have rapid water infiltration rates. In contrast, soils with prismatic and blocky structures have moderate infiltration rates whereas soils with platy and massive structures have slow infiltration rates. Where custom-made soils interact with natural or modified soil profiles, the association between texture, structure and water infiltration / drainage warrants close attention.

For landscaping, soils with a high clay content rate poorly on physical grounds as a medium for plant growth. This is because such soils are inclined to pack tightly (compaction), drain poorly, and set hard on drying. While they typically hold more water than lighter textured soils (Figure 4), plants find much of the water difficult to remove. This predisposes towards slow root growth, exacerbated by a shortage of soil-oxygen and a consequential slowing of root respiration. Indeed, the balance between the supply of oxygen and the availability to plants of soil-water, influences the suitability and selection of soils for plant growth.

Loamy sands, sandy loams and loams are recognised as good root-zone media, as they have sufficient larger particles to enhance both soil aeration and the extraction of water by plants. None-the-less, all soils will eventually dry to a point when permanent wilting of plants occurs. This permanent wilting point (PWP) is controlled by the soil’s physical and chemical properties, but is also influenced by the type of plant being grown. Typically, the PWP is lower in sandy soils than it is in clay soils (Figure 4), lower for plant species adapted to arid soil conditions relative to plants from humid environments, but higher in strongly saline soils relative to equivalent non-saline soils.
Soil strength reflects the ability of soil to resist or endure an applied force. This varies with moisture status (weaker when wet; stronger on drying), the soil’s composition and bulk density. The preferred compromise is a soil that permits its displacement by growing roots while resisting deformation, particularly at the surface, due to the ‘traffic’ associated with normal use. Garden soils can have a lower strength than the root-zone preferred for grasses.

The degrees of stickiness, plasticity, and the tendency to crack are further considerations. Stickiness can vary from non-sticky through to very sticky, with non-sticky to slightly sticky surfaces preferred to moderate to very sticky soils. Plasticity (the ability of soil to change shape and retain the new shape after the stress is removed), is a soil property linked to the amount and type of clay-sized particles present. Soils with normal plasticity (negligible change) are generally preferred for landscaping and related uses. An undesirable characteristic of clay soils is their tendency to ‘crack’ on drying-out, as the forces involved can shear plant roots and cause the soil surface to develop unplanned irregularities.

Finally, soil temperatures, which typically lag behind changes in air temperatures, influence plant growth. For example, horizontal root development is favoured over vertical growth in early spring, when the temperatures of surface soils tend to be warmer than corresponding sub-soils. In contrast, when air temperatures are falling, surface soil temperatures are inclined to be lower than soil temperatures at depth. Artificial heating or cooling systems can be installed, while surface mulches are inclined to make soils cooler than equivalent bare soils.

2.3 Chemical Properties
Plants obtain their carbon, hydrogen, oxygen, and sometimes their nitrogen from the air and water, but the soil (or growing medium) usually provides all other essential macro (phosphorus, potassium calcium, magnesium, sulfur) and minor (iron, zinc, copper,
manganese, boron, chlorine, molybdenum, sodium, cobalt, silicon) nutrients. A soil's ability to supply these nutrients in a correct balance is a measure of its fertility, which is an outward expression of a complex interaction of chemical, physical, biochemical and environmental processes.

Most plants perform poorly under extremely acidic (~4.0) and very strongly alkaline conditions (~9.5). Potentially-toxic chemical conditions can also result from elevated soil salinity, strongly sodic conditions, high monomeric aluminium concentrations, excess manganese, and elevated concentrations of some toxic metalloids (e.g. arsenic) and heavy metals (e.g. copper, zinc). Fertilisers and/or amendments can provide or restore the chemical fertility of the soil or root-zone media, provided that toxic conditions are absent or controllable.

3 WATER MOVEMENT AND DRAINAGE

Water moves both as a liquid and a vapour, and at times may freeze solid, usually resulting in its immobilisation. Irrespective of whether sourced from rain, irrigation, floods, seepage or normal runoff, liquid water entering the soil moves in response to (a) positive or gravitational pressures, including its own weight; and (b) negative forces influenced by surface tension and cohesion between water molecules. The roughly spherical shape of rain and other water droplets are examples of positive surface tension forces at work. In contrast, the absorption of water by unsaturated soil mixtures, analogous to removing excess water with a dry sponge or blotter, are examples of a negative curvature in the air-water interface. Moreover, surface tension and cohesiveness are responsible for water movement into fine soil pores.

The size and distribution of soil pores and soil layers must, by accident or design, permit water entry, movement, storage and, concurrently, the water needs of plants. Simultaneously, air in the root zone must be capable of exchange with the atmosphere. That is, air and water should co-exist, although the degree of coexistence is determined by soil type. For example, approximately half the soil volume of silty loam soils is pore space.

Considerable quantities of water on or beneath the land surface are moved by gravitational (positive) forces via natural flow, pipes, drains, cracks in the soil fabric, etc. Moreover, one or more of these will continue to move water while the positive force exists. Much less but nevertheless important quantities of water move in soils as thin films under negative forces. Movement ceases when the positive and negative forces balance.

Uniform downwards movement of water is expected in soils with homogenous pore sizes. However, this is not the case when soil profiles (natural or custom made) are stratified into layers with different pore sizes at their interface. When an advancing wetting front reaches a continuous layer with finer pore sizes, resistance slows the rate of movement but does not prevent it. Water movement stops, however, when a layer of coarse material (larger pore sizes) is encountered, and only resumes when the adjacent soil approaches saturation. This soil/water property is exploited to 'perch' the water table in what would be otherwise sandy, droughty soils, such as those specified for golf-putting greens and greens used for lawn bowls and the like. See Figure 5 for various examples of the effects of different particle sizes and layers on water movement in stratified soils.
Renovation of existing areas by drilling or coring, with or without subsequent topdressing/s, also affects water movement. A comparison of wetting fronts around a sand-filled core hole exposed to the surface and a similar sand-filled core hole 'buried' by subsequent topdressing is shown in Figure 6. Obviously, sand-filled core holes should remain exposed to the soil surface if enhanced water entry is to be one of the benefits to accrue from coring.

Figure 7 shows that in furrowed soils with free water in the hollows, the soil water moves initially in different directions. The movement is upwards to dry soil above the surface water, a process that continues when evaporation dries the soil. The initial movement into dry soil beneath the free water is almost always radially away from the point where the water was applied, subsequently moving downwards when the wetting fronts join. Nutrients and/or soluble salts contained in or added to the water typically move in the same directions, unless assimilated by plants and other biota or sorbed on soil surfaces.

Drainage of excess or unwanted water is essential if good plant or turf growth is to be sustained over a range of environmental and site conditions. This applies to water leaching through the custom-made profile, to water associated with rising water tables, as well as to overland flow. The latter can sometimes be avoided or 'trained' by surface drains, hilling or other earthworks.

Figure 5 Effects of (a) different particle sizes, and (b) layers of different pore sizes on water movement in different types of stratified soils.

Figure 6 Wetting fronts around a sand-filled core hole exposed to the surface and a similar sand-filled core hole 'buried' by subsequent topdressing.
Controlling sub-surface free water is more complex and expensive. Typically, a pattern of drainage pipes (minimum of 100 mm dia, desirably of corrugated poly vinyl chloride) should be laid along the line of maximum fall (created by earth-works if necessary). For high value or heavy 'traffic' areas, lateral drainage trenches in addition to the main drains or pipes are recommended, often as close as five metres apart. The lateral drains should extend to the perimeter of the area in question. Again, these drains should be in water-collecting depressions or constructions, similar to that shown in Figure 8. Preventing excess or unwanted water from entering the area is a good strategy, remembering that government regulations pertaining to the disposal of runoff and drainage water must be followed.

Figure 7  Water movement in furrowed soils with free surface water at the surface.

Figure 8  A preferred method of installing drainage piping beneath custom-made soil (a) and examples of drainage layouts (b). Note the uniform-size gravel layer above and surrounding the drainage pipe, installed in a trench (≈ 200-250 mm depth) within the natural landscape or in a uniformly compacted sub-grade.
4 MATERIALS FOR CUSTOM-MADE SOILS

Commonly used materials for custom-made soils include sands and gravels of various particle sizes and shapes, peats and peat mosses, barks, sawdust, biosolids, natural soils (typically surface horizons or selected layers from deep alluvia), composts, zeolites such as clinoptilolite due to their high cation exchange capacity, etc. A much wider range of materials is used for potting mixes (see Handreck and Black 1984), including plastic foams, vermiculite (a naturally flaky mineral, exfoliated by rapid heating after crushing and grading), perlite (a low bulk-density product, manufactured by rapidly heating volcanic glass), cotton-seed hulls, etc. Brief details on some of these materials follow.

4.1 Sands

Sands are the most commonly used coarse material. They retain relatively little water, have high water infiltration rates, and low inherent fertility. Quartz-derived sands are preferred due to their inertness and resistance to weathering, but are not available in many areas. Sands made of weakly cemented particles or soft, easily weathered minerals should be avoided when there are alternatives. The presence of shell or limestone particles in the sand will tend to buffer the mix towards neutral to alkaline pH values, which can be a disadvantage if intending to grow plants that prefer acidic conditions. Note that sand-sized particles derived from freshly crushed rock often have edges sufficiently sharp to damage plant roots and sporting equipment.

Ultimately, the use of sands to achieve appropriate levels of air porosity (see Appendix 1), water movement and moisture retention depends upon the particle size distribution. This can range from a uniform sand through to a mixed distribution of coarse sand, fine sand, organic matter, silt and clay. Note that sand particles predominantly below 0.2 mm dia are best avoided when silt and clay particles are present, as such mixtures are prone to compact. Irrespective of the particle size distribution, the bulk density of sands typically range from 1.5 - 1.7 g cm$^{-3}$.

4.2 Peats

Peats, formed by the chemical and biological decay of mainly plant materials, mosses and reeds, are acknowledged soil amendments for many custom-made soils (Table 1). They classify into two broad categories; (a) those where the anatomy of the parent substance is still recognisable; and (b) those which have decayed to the point that the original 'plant' parts are not identifiable. Obviously, there are intergrades between the two extremes. The end product of the decomposition process is referred to as humus.

<table>
<thead>
<tr>
<th>Type of peat</th>
<th>Level of decomposition</th>
<th>Approx. pH</th>
<th>Water absorption capacity (%)</th>
<th>Nitrogen content (%N)</th>
<th>Value as a soil modifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphagnum moss peat</td>
<td>Minimal</td>
<td>3 - 4</td>
<td>1500 - 3000</td>
<td>0.5 - 1.5</td>
<td>Poor</td>
</tr>
<tr>
<td>Reed-sedge peat</td>
<td>Intermediate</td>
<td>4 - 5.5</td>
<td>500 - 1200</td>
<td>1.5 - 3.0</td>
<td>Good</td>
</tr>
<tr>
<td>Peat humus</td>
<td>Well advanced</td>
<td>5 - 7.5</td>
<td>150 - 500</td>
<td>2.0 - 3.5</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
Moss peats (sphagnum), reed - sedge peats, and/or peat humus (fully composed peaty material) or substitute organic materials are often included in root-zone mixes at rates of 5 - 20% by volume. Benefits arising from their use (Waddington 1992), provided low inherent fertility and typically strong acidity – pH 3 - 5; occasionally up to pH 7 – are taken into account, include increased moisture and nutrient-holding capacity of sandy soils, better water infiltration into clay-dominated soil mixes, decreased bulk density, improved root penetration, more microbial activity, and a potential slow-release source of plant nutrients.

Some of the disadvantages of peats are their relatively high purchase cost, the extra care and effort required when mixing to obtain a uniform mix, while decomposition ultimately results in an undesirable decline in air-filled porosity and a consequential increase in root-zone compaction.

4.3 Barks and Sawdusts

These relatively cheap timber by-products are used to reduce the bulk density of the mix, but not usually in excess of 20%. Barks and sawdust increase both moisture holding capacity and air filled porosity. Cation exchange capacity will probably increase over time, while the presence of fresh bark and sawdust typically results in the immobilisation of nitrogen, often leading to a deficiency of this element. It follows that weathered or composted material is preferred to fresh material. Aging under moist conditions for around six-weeks minimum is usually sufficient to inactivate plant toxins that can be present in some barks. The pH of bark is initially around 4 - 5, moving to higher values on weathering.

Some caution is necessary, particularly with sawdust, as treatments to preserve the wood or to retard the chances of fire can be toxic to plants. Boron and arsenic toxicities are the most likely, but nowadays, chemical tests can quickly resolve such questions. Nitrogen stress frequently occurs if supplementary nitrogen additions are overlooked.

5 SPECIFICATIONS OF CUSTOM-MADE SOILS

Air, water and smart management are important prerequisites when preparing to grow ornamental plants and turf. So too is the selection (Table 2) and specification of root-zone materials. Nowadays, many specifications for both sub-grades and root-zone materials are available, ranging from simple ‘recipes’ for garden soils (Table 3) through to highly developed guidelines for high-quality, high wear, turfed areas used for golf putting greens (Appendix 1). Turf cricket pitches have their own unique characteristics, some of which have been described by Harris and Bond (1960) and Handreck and Black (1984)

6 GROUND COVER

Vegetative cover over the land surface helps to stabilise banks and minimise erosion, mud and dust in situations including roadside verges, airfields, sporting fields, parks and gardens, etc. Beauty and attractiveness are additional attributes.

Custom-made soils can help overcome site limitations, as can the spreading of mulches (Figure 9) to effectively create or enhance the soil’s O horizon. However, the choice of plants and their subsequent agronomy will also influence the outcome. Important considerations include the purpose of the ground cover, the adaptability and/or robustness of the preferred
Table 2  Evaluation table for selecting soil suitability for non-critical landscaping around buildings and nearby areas (adapted from Donahue et al. 1983).

<table>
<thead>
<tr>
<th>Item affecting suitability</th>
<th>Good</th>
<th>Fair to average</th>
<th>Poor to fair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistency when moist</td>
<td>Very friable to friable</td>
<td>Firm</td>
<td>Very to extremely firm</td>
</tr>
<tr>
<td>Texture</td>
<td>Fine to very fine sandy loam, loam, silt loam, sandy clay (if clay is 1:1 dominant)</td>
<td>Clay loam to sandy clay (if clay is 2:1 dominant), silty clay (if clay is 1:1 dominant)</td>
<td>Coarse sand, loamy sand and silty clay (if clay is 2:1 dominant)</td>
</tr>
<tr>
<td>Thickness of root-zone material / soil</td>
<td>&gt;40 cm</td>
<td>20 - 40 cm</td>
<td>&gt;20 cm</td>
</tr>
<tr>
<td>Coarse fragments (% by volume)</td>
<td>&lt; 3%</td>
<td>3 - 15%</td>
<td>&gt;15%</td>
</tr>
<tr>
<td>Stones covering soil surface</td>
<td>Nil to &lt;0.1% of surface</td>
<td>0.1 - 1.0% of surface</td>
<td>&gt;1.0% of surface</td>
</tr>
<tr>
<td>Root-zone class drainage</td>
<td>OK if not poorly drained</td>
<td>OK if not poorly drained</td>
<td>Poorly to very-poorly drained</td>
</tr>
<tr>
<td>Slope</td>
<td>&lt;8%</td>
<td>8 - 15%</td>
<td>&gt;15%</td>
</tr>
<tr>
<td>Soil pH of soil/water extract</td>
<td>6.5 - 7.5</td>
<td>≈ 4.5 - 5.0 or ≈ 7.5 - 8.5</td>
<td>&lt;4.5 or &gt; 8.5</td>
</tr>
<tr>
<td>Electrical conductivity of 1:5 soil/water extract</td>
<td>0.5 dS m⁻¹</td>
<td>1.0 dS m⁻¹</td>
<td>1.5 dS m⁻¹</td>
</tr>
<tr>
<td>Potentially toxic soil chemical conditions</td>
<td>Very low levels of chloride, sodium, aluminium, arsenic and toxic heavy metals</td>
<td>Moderate levels of one or more potentially toxic elements</td>
<td>Elevated levels of one or more potentially toxic elements</td>
</tr>
</tbody>
</table>

Table 3  Examples of top-soil mixtures recommended by different organisations and individuals.

<table>
<thead>
<tr>
<th>Source</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial 1</td>
<td>Sandy loam (45%); Hoop pine sawdust (15%); Hard-wood sawdust (15%); Poultry manure (10%); bio-solids stored for at least one year sometimes used as a substitute); sugar-mill mud (5%). <strong>Fertiliser</strong>: Urea &amp; mixed fertiliser (15N:4.3P:11.3K: 13.6S) @ 1.5 kg m⁻² each.</td>
</tr>
<tr>
<td>Commercial 2</td>
<td>Sandy loam (45%); Aged lignified plant material (35%, as aged cellulose, aged bagasse, aged feed-lot manure, or aged sawdust, where ageing is for a minimum of five weeks plus three-weeks storage); Organic material (15% as cellulose, bagasse, feed-lot manure, sawdust, hay, grass. wheat stubble, or cotton-seed meal). <strong>Fertiliser</strong>: Urea &amp; mixed fertiliser (15N:4.3P:11.3K: 13.6S) @ 1.5 kg m⁻² each.</td>
</tr>
<tr>
<td>Commercial 3</td>
<td>Sandy loam (55%); Aged lignified plant material (4%, as aged cellulose, aged bagasse, aged feed-lot manure, or aged sawdust, where ageing is for a minimum of five weeks plus three-weeks storage). <strong>Fertiliser</strong>: Urea &amp; mixed fertiliser (8N:1P:4K) @ 1.5 kg m⁻² each.</td>
</tr>
<tr>
<td>Nature's Earth soil enhancement medium</td>
<td>Aged cellulose, composted bark fines, composted greenwaste, composted hardwood sawdust (used to improve poor quality site soils).</td>
</tr>
<tr>
<td>Nature's Earth top dressing</td>
<td>Selected sand, aged cellulose, screened ash, cow manure (a dual purpose mix for top-dressing of established lawns, or for use beneath new turf: screened to &lt; 4mm).</td>
</tr>
</tbody>
</table>
species, and the level of subsequent care and maintenance that can be provided. Table 4 provides examples for turf grasses on some of these aspects while Table 5 does likewise for a selection of pasture grass species appropriate for sites in more remote and difficult areas, such as bank stabilisation and mine-spoil rehabilitation. See Anon (1988) for further examples of grasses, legumes and fodder crops. Soil tests can be used to indicate whether applications of fertilisers to overcome deficiencies of nutrients such as phosphorus, nitrogen, potassium, and perhaps some minor nutrients are needed.

Whenever possible, the surface soil at the time of plant establishment should be moist, firm, granular and relatively free of soil clods, large stones and unnecessary debris (Beard, 1973). Phosphatic fertilisers and necessary minor nutrients are best applied at this stage, to ensure that they are incorporated into the root-zone during rotary tilling, discing, harrowing, shaping and perhaps rolling. Establishment from seed tends to be more uniform when the surface is mulched to minimise surface crusting, to retain moisture, and to prevent surface erosion. Sodding, the term used to describe the planting or covering of an entire area with pieces of sod (or turf), will quickly transform an area. Of course, the underlying root-zone material must permit the rapid development of a strong rooting system.

When establishing grass such as Tifdwarf bermudagrass sprigs on golf putting greens and bowling greens, the initial grass cover can lack the desired smoothness and firmness. Frequent topdressings are helpful but another approach is to use a very heavy roller, such as a one to two tonne commercial asphalt roller. The rolling should be in two directions, but only after the sprigs have established well, typically three weeks to a month after planting.

![Image](https://example.com/image.jpg)

**Figure 9** In semi-arid regions and/or where hard-setting soils are present, the establishment of ground cover can be enhanced by mulching the surface soil with moist hay.

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### Table 4  Characteristics of some turf grass species

<table>
<thead>
<tr>
<th>Common and (scientific name)</th>
<th>Warm or cool season preference</th>
<th>Shade tolerance</th>
<th>Maintenance</th>
<th>Trafficability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Turf grasses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bahiagrass (<em>Paspalum notatum</em>)</td>
<td>warm</td>
<td>fair</td>
<td>low</td>
<td>fair</td>
</tr>
<tr>
<td>Bent (<em>Agrostis</em> spp.)</td>
<td>cool</td>
<td>fair</td>
<td>high</td>
<td>fair</td>
</tr>
<tr>
<td>Buffalo (<em>Stenataphrium secundatum</em>)</td>
<td>both</td>
<td>high</td>
<td>medium</td>
<td>poor</td>
</tr>
<tr>
<td>Carpet grass (<em>Axonopus affinis</em>)</td>
<td>warm</td>
<td>fair</td>
<td>medium</td>
<td>good</td>
</tr>
<tr>
<td>Green Couch / Greenless Park Couch (<em>Cynodon dactylon</em>)</td>
<td>warm</td>
<td>poor</td>
<td>medium</td>
<td>good</td>
</tr>
<tr>
<td>Perennial ryegrass (<em>Lolium perenne</em>)</td>
<td>cool</td>
<td>high</td>
<td>medium</td>
<td>fair</td>
</tr>
<tr>
<td>Qld Blue Couch (<em>Digitaria didactyla</em>)</td>
<td>warm</td>
<td>poor</td>
<td>medium</td>
<td>good</td>
</tr>
<tr>
<td>Tifdwarf Couch (hybrid cultivar of <em>Cynodon dactylon</em> x <em>C. transvaalensis</em>)</td>
<td>warm</td>
<td>poor</td>
<td>medium</td>
<td>good</td>
</tr>
<tr>
<td><strong>Grass substitutes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotula (<em>Cotula australis</em>)</td>
<td>not too hot</td>
<td>high</td>
<td>high</td>
<td>fair</td>
</tr>
<tr>
<td>Lippia (<em>Phyla nodiflora</em>)</td>
<td>both</td>
<td>poor</td>
<td>medium</td>
<td>fair</td>
</tr>
<tr>
<td>Artificial turf</td>
<td>both</td>
<td>high</td>
<td>low</td>
<td>good</td>
</tr>
</tbody>
</table>

### Table 5  Adaptations and seeding rates for some tropical and sub-tropical pasture species used to provide ground cover (adapted from Anon 1988).

<table>
<thead>
<tr>
<th>Common and (scientific name)</th>
<th>Seeding rate (kg ha⁻¹)</th>
<th>Adaptation or tolerance</th>
<th>General comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Frost</td>
<td>Drought</td>
</tr>
<tr>
<td>Bahai grass (<em>D. aristatum</em>)</td>
<td>2-4</td>
<td>G</td>
<td>F</td>
</tr>
<tr>
<td>Creeping blue grass <em>insculpta</em></td>
<td>1-4</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Indian blue grass <em>B. pertusa</em></td>
<td>1-2</td>
<td>P</td>
<td>VG</td>
</tr>
<tr>
<td>Kikuyu clandestinum (<em>P. clandestinum</em>)</td>
<td>1-2</td>
<td>G</td>
<td>F</td>
</tr>
<tr>
<td>Molasses grass <em>M. minutiflora</em></td>
<td>2-4</td>
<td>P</td>
<td>F</td>
</tr>
<tr>
<td>Pangola grass <em>D. decumbens</em></td>
<td>-</td>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>Rhodes grass <em>C. gayana</em></td>
<td>1-4</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

F = fair; G = good; P = poor; VG = very good; P = poor
7 RENOVATION AND MAINTENANCE

No custom-made soil will retain its initial physical and chemical characteristics indefinitely. Sub-optimum growth of ornamental plants and turf grasses usually results. It follows that renovation and maintenance are constant companions of those who rely on custom-made soils.

Root-zones degraded by compaction, inappropriate fertility, and/or excessive thatch will be less able to support the good growth of ornamental plants and turf than will disease-free, well-drained, fertile soil with good aeration and moisture characteristics. Potentially toxic (to plants) concentrations of copper and/or zinc may also develop from the over-use of heavy metal based fungicides such as cuprox and mancozeb. Moreover, complex root-zones can develop on golf and bowling greens from multiple topdressings, combined with occasional corings or similar activities (Figure 10). Wheel tracks, particularly those that occur when the root zone is wet, often cause premature compaction with consequential adverse effects on growth. Irrespective of the cause, major renovations or even rebuilding the profiles will eventually be necessary to remove or disperse layers of buried thatch, multiple layers of sand topdressing, excess heavy metals, and sometimes less suitable soil introduced by soding, flooding and the like.

If a black layer develops in the root zone of turfed areas, anaerobic conditions and the corresponding accumulation of organic matter and sulfides (a reduced form of sulfur) are the probable causes. Little plant root growth, if any, occurs in such layers, although microorganisms can persist and ultimately act to further clog soil pores. A well-drained root zone in conjunction with judicious irrigation to avoid waterlogging will prevent the development of such layers.

Figure 10 A diagrammatic example of how custom-made soil profiles can be modified over time by a series of topdressings and corings.
Topdressing of turfed areas with either straight sand or a sand / organic mix is undertaken to remove surface imperfections and to help prevent the undesirable accumulation of thatch in the root zone. Indeed, some of the best areas of turf receive frequent light topdressings throughout the active growing season. Topdressing can also impart similar surface properties or ‘feel’ to areas developed on different root-zone materials.

Periodic cultivation and/or coring helps maintain a well aerated, uncompacted root zone, the type of culture and intensity of use or visual importance determining the level of care typically provided (Figure 11).

![Figure 11 - Relationship between the types of use and typical levels of care provided.](image)

Cultivation is a drastic measure used primarily to overcome soil compaction in gardens and the like. Plants sensitive to root damage may not survive this form of maintenance. Coring is a ‘plant-friendly’ form of cultivation achieved by the use of a vertically-inserted hollow tyne, tube or drill. The resultant is a hole or cavity in the root zone, until at least 90% of the holes are refilled with sandy topdressing materials. Core to core distances can be as close as 75 - 100 mm, with core diameters of 5 - 20 mm and typical penetration depths of 70 - 100 mm. For larger areas of turf, rotating knives or saw-teeth are often used to cut vertical slits through turf and soil, achieving thatch control and soil aeration in a single operation. A fairly dry soil is preferred for grooving operations, since a considerable quantity of soil and thatch is brought to the surface, usually for subsequent removal.

A limitation of most renovations is the depth of penetration of the coring or grooving equipment used. Indeed, compacted zones can develop below the normal renovating depth. For high-value areas in particular, deep coring is now a recommended procedure to improve rooting, aeration and water movement through the entire root zone material. Other aspects on maintenance such as fertilisation and the control of diseases are beyond the scope of this paper.

Notable exceptions to the foregoing are cricket wickets, where consolidation of the soil is standard practice during the playing season. A build-up in salinity can be expected when either sub-surface drainage is inadequate and/or irrigation plus rainfall inputs are less than water losses by evaporation and transpiration (Harris and Bond 1960). Coring in a manner
that encourages the leaching of soluble salts from the wicket rather than just facilitating deep drainage represents good practice, assuming that the underground drainage is effective.

8 CONCLUSIONS

Custom-made soils range from simple root-zone mixtures for gardens to complex, highly specified combinations of materials arranged in layers to achieve good growth, excellent drainage and high resistance to wear. The technology exists to ‘tailor’ such soils with a high degree of certainty that they will perform to expectations, provided due care is paid to site preparation, construction and maintenance.

Before specifications are completed, however, the site or area being developed should be inspected thoroughly. Truncated soil profiles, adverse soil chemical conditions, uneven consolidation of ‘fill’ material, and poor drainage are examples of site variables that can adversely affect the subsequent performance of the custom-made soils. Good drainage (surface and sub-surface) is of paramount importance.

The choice of materials for preparing custom-made soils is wide, although sands and organic materials such as peat, composted bark, bio-solids and other by-products are commonly utilised. Washed gravels are the dominant materials utilised in the preparation of sub-grades and drainage systems generally. For broad-scale developments such as mine-spoil rehabilitation, a surface mulch of hay, with or without cultivation, may be the only economic option to provide improved seed-bed conditions.

Most companies specialising in the supply of landscaping materials have pre-mixed ‘blends’ of garden soils, topdressing materials and the like. For non-critical situations, these ‘blends’ will usually meet relevant needs, although fertility levels and physical properties may need to be validated by a soil testing laboratory. For turfed areas such as golf and bowls greens, however, the materials used should match the best available specifications as closely as possible. Moreover, mixing operations should be completed prior to final placement on site. The finished surface should be free of compaction zones created by the use of machinery or from motor vehicles.

When custom-made soils are exposed to the elements, vegetative cover should be established at the earliest appropriate opportunity. The main reason is to prevent damage to the soil surface, particularly from water erosion. Local experience should be sought before finalising the choice and commencing the establishment phase. Turf, for example, can be established from seeds, sprigs, sods and runners, ideally in spring to early summer.

Finally, the properties and performance of custom-made soils will change over time, usually in a negative direction. Renovation and maintenance practices can offset this decline through actions such as topdressing, cultivation and/or coring. Quite complex soil profiles can develop through a succession of topdressings, corings, back-filling of core holes, and the incorporation of thatch. It follows that long term planning should include provision for rebuilding or refurbishing all custom-made soils, timed to commence when renovations no longer return the expected positive response.
9 REFERENCES


10 APPENDIX

<table>
<thead>
<tr>
<th>Source</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Golf Assn, 1993 revision (Anon 1993; Hummel Jr. 1993).</td>
<td><strong>Drainage</strong>: Drainage trenches to be about 150 mm wide and a minimum of 200 mm deep, with lateral drainage lines not more than 5 m apart. Spoil from the trenches should be removed from the sub-grade cavity. There should also be a perimeter drain line at the low end of the gradient. If a geo-textile fabric is required, this should be installed prior to placement of the drainage pipes onto a layer of gravel (minimum of 25 mm). Pipes should have a positive slope of 0.5%, and be covered subsequently with the same type of gravel (see Sub-grade section below).</td>
</tr>
<tr>
<td><strong>Sub-grade</strong>: The subgrade is required to facilitate water movement to the drainage system, and should conform to the general slope of the intended finish grade. The base of the sub-grade (thoroughly compacted and covered by a geo-textile fabric if the clay, sand or muck soil base is unstable) should be approximately 400 mm below the proposed finish grade, or as much as 450 - 500 mm when an intermediate layer is necessary. The surface of the gravel blanket must conform to the proposed finish grade, with other portions not as critical. Both crushed stone or pea gravel are acceptable as the drainage blanket, provided the material has good mechanical stability. A minimum of 65% by volume of the washed gravel particles should be sized between 6 - 9 mm, not more than 10% &gt;2 mm, and not more than 10% of gravel particles &lt;2 mm. If properly sized gravel is not used, an intermediate layer of relatively small gravel (90% to fall between 1 - 4 mm) should be included.</td>
<td></td>
</tr>
<tr>
<td><strong>Root-zone Composition</strong>: Physical properties of 35 - 55% total porosity, 15 - 30% air-filled porosity, saturated conductivity of 150 - 300 mm hr⁻¹ (normal range) to 300 - 600 mm hr⁻¹ (accelerated range)*, and approximately 2 - 4 % organic matter by weight (range 1 - 5%; preferably peat with a minimum organic matter content of 85% by weight). The ‘soil’ component should have a minimum coarse (0.5 - 1.0 mm) to medium (0.25 - 0.50 mm) sand content of 60%, with not more than 20% fine sand (0.15 - 0.25 mm), 5% very fine sand (0.05 - 0.15 mm), 5% silt (0.002 - 0.05 mm) and 3% clay (&lt;0.002 mm). Moreover, total particles in the range very fine sand to clay should not exceed 10%, while total fine gravels (2.0 - 3.4 mm) plus very coarse sand (1.0 - 2.0 mm) particles should be no more than 10%, including a maximum of 3% fine gravels and preferably none. The preferred depth of root-zone material is 300 mm. Also, the root-zone material must be mixed thoroughly (including any necessary basal fertilisers such as lime, phosphorus and potassium) before placing the moist ‘mix’ in position.</td>
<td></td>
</tr>
<tr>
<td><strong>Placing and Finishing</strong>: Rootzone materials should be spread from one corner or one side to avoid unnecessary ‘travel’ over the prepared sub-grade. Small, tracked equipment is preferred to minimise damage to the sub-grade and to prevent localised compaction from tyre marks. The surface should be ‘firmed’ and levelled to the desired tolerance, although some ‘sinking’ during the first few months can be expected. Sterilisation may be justified to minimise the chances of disease and to control nematodes, when these are likely to be present. Plant turf seed, sprigs or pieces of turf as soon as possible.</td>
<td></td>
</tr>
</tbody>
</table>

The approximate proportions of particles for the root-zone are as follows:

- Nil gravel, <5% very coarse sand (1.0 - 2.0 mm), between 10 - 30% coarse sand (0.5 - 1 mm), between 60 -70% of medium sand (0.25 - 0.5 mm) and fine sand (0.1 - 0.25 mm) combined, and between 5 - 10% of silt (0.002 - 0.05 mm) and clay (<0.002 mm) particles combined. Note that 30% of particles between 0.1 mm and <0.002 mm are permitted. 

▲ The accelerated range should be chosen when water quality is poor and/or where high rainfall events are common, as they are in many sub-tropical and tropical regions.
USE OF FERTILIZERS AND AMENDMENTS

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Incitec Fertilizers, PO Box 140, Morningside, Qld, 4170.

ABSTRACT

The low fertility status of many Australian soils and the fact that many sub-soils are even less fertile than surface soils, make it necessary to use fertilizers and soil amendments to encourage the healthy growth of plants used in landscaping and recreation areas.

A thorough knowledge of fertilizers and soil amendments, their chemical and physical properties and reaction in soils is beneficial as it allows better decisions to be made on choice of product, rate, timing and placement for the chosen plant species, its location and purpose.

If the soil’s fertility status is unknown, or growth problems which need diagnosis are occurring, soil analysis can be used to modify and improve fertilizer programs.

KEYWORDS: fertilizer, amendment, soil analysis.

1 INTRODUCTION

All plants require an adequate supply of certain essential elements, called plant nutrients, in order to produce healthy growth and reproduce. Some nutrients, namely nitrogen, phosphorus, potassium, sulfur, calcium and magnesium, are called the macro-nutrients. The micro-nutrients are iron, manganese, zinc, copper, boron, molybdenum and chlorine and are required in much smaller amounts than the macro-nutrients.

Several good references provide the details of the availability of nutrients, how the plant extracts each nutrient from the soil, their function in plants, symptoms of deficiency and toxicity and amounts generally required by crops and pastures, (Mengel and Kirkby, 1987 and Bergmann, 1992).

The role of fertilizers and soil amendments is to provide the additional amounts of nutrients to assist plants growing in soils which may lack one or more nutrients, to produce a higher yield or better quality produce.

The successful management of landscaped areas and recreational grasslands requires a consideration of the chemical and physical properties of soil in which plants are to be grown. Basic fertilizer programs are available from fertilizer suppliers and the garden experts for most situations, e.g. lawns, flower gardens and the like, although these programs may need to be altered in some circumstances.

The analysis of soils to determine their fertility status and the analysis of plant tissues (usually leaves) for their total nutrient concentration are valuable aids to assessing the needs for fertilizers and soil amendments in agriculture. While the use of soil and plant analysis is
well researched and widely used in agriculture, this is not always true in recreational and
landscaping areas. However, sufficient is known to allow soil analysis to be useful in
assessing the overall fertility status of the soil. In particular, it can indicate the soil’s
phosphorus status and hence may indicate a need for phosphorus fertilizer. Soil analysis can
also indicate whether acidity, sodicity or salinity problems exist, suggesting a need to use soil
amendments such as lime and gypsum or a need to improve drainage.

The analytical methods should be the same as used elsewhere (Rayment and Higginson,
1992), but reliable interpretation data may not be available, and skilled consultants with
expertise in the management of recreational areas may not be trained to interpret the
analytical results. Nevertheless, there will be times where soil and plant tissue analysis will
be of use, particularly in trouble-shooting or problem-solving roles. In these situations, it is
best to take two samples, one from the good and one from the poor area. When the area of
concern is relatively large, (several hectares), or growth problems which need diagnosis exist,
soil and/or plant tissue analysis may be used.

The means of assessing the soil physical aspects of importance and the management of them
are covered by other presenters at this course, [Powell & Aitken, (1996) and Wilson &
McGarry, (1996)].

For the most effective and economic use of fertilizer and soil amendment products, it is
necessary to have an understanding of the properties of the these products, their reaction in
soils, their necessity for plant growth and their responsible use in establishing and
maintaining appropriately vegetated landscapes. Hence, a description of commonly used
products, typical application rates, and methods and timing of application are provided, to
help developers understand the importance of each product in each situation.

2 A VAILABILITY OF NUTRIENTS

The various physical and chemical properties of soils, including the availability of nutrients
to plants change over time in response to temperature, moisture and biological activity.

The complex nature of soils and those factors which affect the availability of nutrients to
plants require some explanation, if one is to understand the principles of fertilizer and soil
amendment use.

Plants take up nutrients from the soil solution, so by definition, the nutrients are in a water­
soluble form (as ions). However, as plants take up nutrients, the concentration of each in the
soil solution is reduced. Each is then replenished by a corresponding amount, which is
released from the solid phase, to restore the equilibrium between the solution and solid
phases. The ease by which the solid phase of a nutrient is released into the soil solution is an
important soil property, especially for phosphorus and potassium.

The ability of a soil to hold on to nutrients is called its exchange capacity. In general, sandy
soils have a low exchange capacity, and clay soils have a high exchange capacity.

Another soil characteristic which has a major influence on nutrient availability is the soil pH,
or more correctly, the pH of the soil solution. At the extremely acidic end of the pH range,
say less than 5.0, nutrients such as phosphorus, calcium, magnesium, molybdenum and boron are much less available, and some, for example manganese, iron and aluminium may reach levels which are toxic to plants. At the extremely alkaline end of the pH range, say greater than 8.5, nutrients such as phosphorus, copper, iron, manganese and zinc are much less available.

Generally, plants grow best when the soil pH is in the range 5.5 to 7.0, at which level most of the nutrients are at their optimum of availability. An understanding of this complex subject can be gained through the figure which was first proposed by Truog, (see Figure 1). This has had many forms and should only be taken as a generalisation. The thickness of the horizontal band represents the solubility of the nutrient. The solubility is directly related to the availability of the nutrient in an ionic form that may be taken up by the plant.

Figure 1  The effect of pH on the availability of nutrients to plants (Bidwell 1974).

Information Bulletins available from Incitec Fertilizers explain some of these principles. Soil pH and the need to change it are covered in the Lime and Dolomite Bulletin. The nutrients and the factors affecting their availability are explained in the various bulletins, Boron, Calcium, Copper, Iron, Magnesium, Manganese, Molybdenum, Phosphorus, Potassium, Sulfur, and Zinc.
3 FERTILISERS

The main fertilizer products available are standard commodity lines, readily available through any fertilizer dealer. They usually contain one or more of the major plant nutrients, nitrogen (N), phosphorus (P), potassium (K), sulfur (S) and calcium (Ca).

The manufacturing processes, properties and uses of fertilizer products used in Australian agriculture are covered in detail in Glendinning, 1990.

3.1 Nitrogen Products

There are three main solid or dry N-containing fertilizer products used in Australian agriculture (Table 1). Although Table 1 shows the analysis of some of the Incitec range of products recommended for supplying N, other products and brand names may be equally useful and effective.

Table 1 Nutrient contents of N fertilizer products

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>% N</th>
<th>% Other Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>CO(NH₂)₂</td>
<td>46</td>
<td>-</td>
</tr>
<tr>
<td>Incitec Nitram</td>
<td>NH₄NO₃</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>(ammonium nitrate)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incitec Gran-am</td>
<td>(NH₄)₂SO₄</td>
<td>20.2</td>
<td>24% S</td>
</tr>
<tr>
<td>(ammonium sulfate)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.1.1 Rates of application

The rates of application of nitrogen vary widely depending on the situation, plant species and the way the fertilizer is applied. Many ornamental trees and shrubs and leguminous plants require little or no additional N as fertilizer.

Grassed areas, especially lawns where clippings are removed, may require up to 50 kg/ha of N, applied at this rate 3-6 times per year. Such applications can be spaced further apart in the winter months when cold weather slows plant growth, and the number of applications can be reduced in non-irrigated situations and where the clippings are not removed.

3.1.2 Application methods

Nitrogen fertilizers are generally broadcast evenly and watered into the soil or if plants are arranged in rows, the fertilizer may be banded along the rows and watered into the soil. Small amounts can be banded near to, but not in direct contact with, seeds and seedlings at establishment (planting). Around established trees, nitrogen fertilizer should be applied uniformly to the entire root zone (no closer than 30 cm to the trunk, to just beyond the edge of the canopy). The nitrogen fertilizers listed in Table 1 are soluble and therefore can be applied in solution through the irrigation water, a technique known as fertigation.
3.1.3 Timing of applications

The frequency and timing of application depend on the situation (plant species, soil type, irrigation practices). For irrigated lawns for example, nitrogen may need to be applied every 6-8 weeks during the growing season, i.e. over summer, if good, healthy green lawns are required.

3.2 Phosphorus Products

There are four major fertilizer products which are used to supply soluble phosphate to soils (refer Table 2) which also shows their nutrient contents. Other brands and other phosphate products may be equally useful and effective.

<table>
<thead>
<tr>
<th>Name</th>
<th>% P</th>
<th>% Other Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incitec Super, or Superphosphate</td>
<td>8.8</td>
<td>11% S, 20% Ca</td>
</tr>
<tr>
<td>Incitec Trifos, or triple superphosphate</td>
<td>20.7</td>
<td>1.2% S, 15% Ca</td>
</tr>
<tr>
<td>Incitec Starterfos, or monoammonium</td>
<td>22</td>
<td>10% N, 2.3% S</td>
</tr>
<tr>
<td>phosphate (MAP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incitec DAP, or diammonium phosphate</td>
<td>20</td>
<td>18% N, 2% S</td>
</tr>
</tbody>
</table>

3.2.1 Rates of application

When establishing plants with a high P demand, rates around 50 kg/ha of P are likely to be recommended. Lawns generally require around 30-40 kg/ha at establishment, and thereafter about 10-20 kg/ha of P per annum.

Many shrubs and trees thrive with little or no added P, for example, plants like some Australian natives belonging to the Myrtaceae and Proteaceae families generally require little or no fertilizer P, and their growth may even show toxicity symptoms when P fertilizer is applied. In contrast, many eucalypt species are very responsive to applied phosphorus. Hence one needs to plan the types of plants to be grown in an area so that plants of similar P need are planted together.

A soil test will provide a reasonable guide to the soil P status.

3.2.2 Application methods and timing

Phosphates are less mobile in soils than the nitrogen compounds and need to be placed close to the root zone of young developing plants. On low P soils, for annual plants with a high P demand, the phosphate needs to be applied at or just prior to planting and placed close to where the plant’s growing root system will have access to the fertilizer band. Therefore, in many cases, when plants are grown in rows, phosphate fertilizers are banded along the row.
For tree crops, the fertilizer can be mixed into the soil at the sites of establishment. For lawns and other large scale areas, phosphates may be broadcast and incorporated by cultivation.

Around established trees, the fertilizer can be applied uniformly over the entire root zone around the trees; on lawns it can be broadcast-applied. Annual application is normally all that is required, although it is customary to apply it in combination with nitrogen and potassium and therefore it may be applied more regularly.

### 3.3 Potassium Products

Three potassium salts are commonly used as fertilizers (Table 3) which also gives the nutrient contents of each.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Nutrient contents of K fertilizer products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>% K</td>
</tr>
<tr>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>Muriate of Potash (Potassium chloride)</td>
<td>50</td>
</tr>
<tr>
<td>Sulfate of Potash (Potassium sulfate)</td>
<td>41</td>
</tr>
<tr>
<td>Potassium Nitrate (Nitrate of Potash)</td>
<td>38.3</td>
</tr>
</tbody>
</table>

The choice of which products to use depends on the soil type, the plant’s tolerance to chloride, irrigation water quality and the price of the product. Muriate of Potash is by far the cheapest K source.

#### 3.3.1 Rates of application

Many soils, particularly loams and clays, have a plentiful supply of potassium, so in many cases, K fertilizer is not recommended. Where it is required, rates of 25-100 kg/ha of K are recommended, the rate depending on the K needs of the plants.

Potassium is most likely to be required on sandy soils, and where lawn clipings are removed. A considerable amount of potassium can be lost in this way where plant dry matter removal is high.

#### 3.3.2 Application methods

Potassium is usually required early in the plant’s life, so is usually applied in a mixture or blend with one of the phosphate fertilizers at or just prior to planting.

Around established trees, apply uniformly to the root zone, (no closer than 30 cm to the trunk, to just beyond the edge of the canopy). In lawns, it is customary to broadcast potassium, where required, at the same time as nitrogen, and to water the fertilizer into the soil. Because
potassium fertilizers are fairly soluble, they can be broadcast and watered into the soil or may be applied through fertigation.

### 3.3.3 Timing of applications

Potassium fertilizers, where needed at plant establishment, should be applied as a band, away from the seed or seedlings so that the roots are not damaged. Alternatively, the fertilizer may be broadcast and incorporated just prior to planting.

Where practical, potassium may be applied in small doses, say 10 kg/ha of K at regular intervals (once every 4-6 weeks) depending on need. Where required, potassium fertilizers should be applied only once a year on clay soils, and more frequently, at lower rates on sandy soils, the timing depending on the soil’s K status, the rainfall incidence and the plant’s K requirements.

### 3.4 Complete Fertilizers

The term complete fertilizers, in the context of this lecture, is used to describe any compound or blend of fertilizer products, which contains each of N, P, K and S and occasionally other macro or micro-nutrients. They are available as compounds (all nutrients compounded into each granule) or as blends (of two or more distinct products, e.g. diammonium phosphate (DAP) and Muriate of Potash). Complete fertilizers provide the convenience of applying two or more of the macro-nutrients in a single application. Some examples are listed in Table 4.

#### Table 4 Analyses of complete fertilizers

<table>
<thead>
<tr>
<th>Name</th>
<th>% N</th>
<th>% P</th>
<th>% K</th>
<th>% S</th>
<th>%Ca</th>
<th>%Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incitec Q5</td>
<td>5.1</td>
<td>5.7</td>
<td>4.9</td>
<td>13.0</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>Incitec CK55</td>
<td>13.2</td>
<td>14.7</td>
<td>12.3</td>
<td>13.0</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Incitec CK88</td>
<td>14.8</td>
<td>4.3</td>
<td>11.3</td>
<td>13.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incitec CK77(S)</td>
<td>13.0</td>
<td>2.2</td>
<td>13.3</td>
<td>18.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrophoska Blue TE</td>
<td>12.0</td>
<td>5.2</td>
<td>14.1</td>
<td>4.0</td>
<td>5.0</td>
<td>1.2</td>
</tr>
</tbody>
</table>

### 3.5 Calcium, Magnesium and Sulfur

Of calcium, magnesium and sulfur, all of which are also regarded as macro-nutrients and therefore essential for plant growth, sulfur is given more prominence than the others in the fertilizer industry. Sulfur is usually supplied together with N, as in sulfate of ammonia or with P and Ca as in superphosphate or with K, as in sulfate of potash or with Ca as in gypsum.

Additional calcium and magnesium are usually provided by applying soil amendments such as lime (Ca only), dolomite (Ca and Mg), gypsum (Ca only), magnesite (Mg only) and magnesium sulfate (Mg only).
3.6 Slow Release Fertilizers

The slow release fertilizers are designed to release the contained nutrients over specified times, say over 3, 6 or 9 months, depending on the plant species and its requirements. Slow or controlled release fertilizers such as Osmocote and Nutricote are used in nursery situations and with potted plants, reducing the number of fertilizer applications required and greatly reducing the risk of fertilizer burn to plant roots. Their cost generally precludes their use elsewhere.

3.7 The Micronutrients

The micronutrients, also referred to as trace elements, are boron, copper, iron, manganese, molybdenum and zinc. Chloride is also a trace element, but is unlikely to be deficient.

Micronutrients are often required in agricultural situations, especially in areas of intensive horticultural production. Various micronutrient products are available, e.g. oxides, oxysulfates, sulfates and chelates (organic complexes). Soluble trace elements, e.g. sulfates and chelates can be applied in solution to the soil or as dilute foliar sprays. If knowledge of the soil type, plant susceptibility, visual symptoms, or soil or plant analysis indicates a need for one or more of the micronutrients, expert advice should be sought on how best to apply the nutrient.

4 SOIL AMENDMENTS

Soil amendments are those materials which are used in very large quantities to change some fundamental chemical or physical characteristic of the soil. Examples are lime, dolomite, gypsum and organic materials, usually recommended to be applied several months in advance of planting at rates exceeding 1 t/ha and incorporated (well mixed) by cultivation to 10-20 cm depth, to encourage dissolution and close contact and therefore reaction with the soil (refer Table 5). The properties of these materials and the purpose for their use need to be known. These materials, applied at the rates suggested, also add to the soil an abundant quantity of Ca, Mg or S, which should correct any deficiency of these nutrients.

Table 5 Properties of Soil Amendments

<table>
<thead>
<tr>
<th>Material</th>
<th>Chemical Formula</th>
<th>Ca%</th>
<th>Mg%</th>
<th>N.V.*</th>
<th>Solubility g/100 mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burnt lime</td>
<td>Quick CaO</td>
<td>70</td>
<td>-</td>
<td>130-150</td>
<td>0.13</td>
</tr>
<tr>
<td>Slaked lime</td>
<td>Hydrated Ca(OH)₂</td>
<td>54</td>
<td>-</td>
<td>100-130</td>
<td>0.17</td>
</tr>
<tr>
<td>Lime</td>
<td>Agricultural CaCO₃</td>
<td>30-40</td>
<td>-</td>
<td>70-100</td>
<td>0.0013</td>
</tr>
<tr>
<td>Dolomite</td>
<td>CaCO₃/MgCO₃</td>
<td>13-20</td>
<td>8-10</td>
<td>70-110</td>
<td>0.032</td>
</tr>
<tr>
<td>Gypsum</td>
<td>CaSO₄·2H₂O</td>
<td>16-22</td>
<td>-</td>
<td>-</td>
<td>0.26</td>
</tr>
</tbody>
</table>

* N.V. = Neutralising Value (see text).
4.1 Lime

Lime or limestone is calcium carbonate, a naturally-occurring mineral, which is mined, then crushed to various ranges of particle size.

Its main use is to neutralize acid soils, but it is also useful in counteracting Ca deficiency. If the soil pH is below the optimum range for the plant species to be grown, it may need adjustment. It is the carbonate which is the neutralizing component of the material. The neutralizing value is determined chemically and is the amount of acid required to neutralize the product relative to that required to neutralize pure calcium carbonate (given as 100).

The Ca, Mg and Neutralising Values (N.V.), given in Table 5, vary widely, because the material occurs naturally and may contain earthy material or soil. This information is provided on the pack, or with each bulk delivery.

One other important property, which is determined by the supplier, is the fineness of grind of the material. The finer grades of liming materials have a much greater surface area, so react more quickly with the soil. The most effective liming materials have at least 70% (by weight) finer than 0.25 mm. The finer materials are more costly as it takes longer to grind the lime into the finer grades.

Other liming materials are burnt lime (calcium oxide) and slaked lime (calcium hydroxide). These are much finer and more reactive than the carbonates.

4.2 Dolomite

Dolomite or dolomitic limestone is a mineral which combines calcium and magnesium carbonates. It reacts similarly to lime in acid soils. Its main purpose is to increase the pH of soils which are too acidic for healthy plant growth, but it contains a significant amount of magnesium (usually more than 8% by weight). Hence, it is usually recommended when soil magnesium values are low, and may help alleviate Ca and Mg deficiencies.

4.3 Gypsum

The other soil amendment of significance is gypsum, calcium sulfate. Gypsum has no neutralising value, it doesn’t alter the soil’s pH. It is used primarily to amend the physical properties of clay soils which have been affected by high levels of sodium, and consequently are difficult to cultivate and set hard when dry.

Gypsum is more soluble than lime, so releases calcium ions into the soil solution in such abundance that they replace the sodium on the clay surfaces, thus changing the soil into a more-friable, better-drained and more-easily cultivated medium for plant roots to grow and absorb water and nutrients. As gypsum contains both Ca and S, it is often used to correct deficiencies of one or both of these macro-nutrients.
4.4 Organic Amendments

Organic amendments are made from sources such as animal manures, decaying plant material, composted plant or animal residues and sawdust. They all contain various amounts of all plant nutrients, but many of the nutrients may not necessarily be available to plants.

Organic amendments, naturally, are not of a regular composition, as they are composed of biological materials of varying composition. In many cases, biological organisms are still active within the material, in the process of decomposing it.

Organic amendments are usually spread and incorporated into the soil to increase the soils' organic matter content and provide a regular, but usually slowly available supply of plant nutrients. The organic amendments may be used as a mulch to protect the surface soil from erosion, to protect plant roots from extremes of heat or cold and to retain moisture around the root zone of plants.

Some organic materials, such as sawdust, actually compete with plant roots for nutrients such as N, which is required to assist the soil micro-organisms to breakdown the sawdust.

Garden and household waste, such as lawn clippings, composted vegetable material and prunings are useful as mulching material, which often provides a steady supply of nutrients, when incorporated into garden beds or planting holes for new trees or shrubs, where it is usually desirable to mix the compost or mulch with soil.

4.5 Rates of Application

Rates of application of soil amendments should be related to the need for change, the magnitude of the change and the ability of the soil to resist change, (its buffer capacity) determined by the amount of soil organic matter and the amount and type of clay mineral. The magnitude of the change will also depend on the plant species to be grown and their tolerance of acidic soils.

Typical rates of application of liming materials for the main soil textural classes are:

<table>
<thead>
<tr>
<th>Texture</th>
<th>Rate (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.5 - 2.5</td>
</tr>
<tr>
<td>Loam</td>
<td>1.25 - 3.75</td>
</tr>
<tr>
<td>Clay loam &amp; clay</td>
<td>2.5 - 7.5</td>
</tr>
</tbody>
</table>

A special test for the buffer pH of a soil is useful in determining a specific rate for a specific pH target.

Gypsum rates usually vary from 1-10 t/ha depending on the severity of the problem, depth of incorporation, and the value of the plants being grown. Where the intention is to reduce surface crusting, 2.5 t/ha is a common rate. If the intention is to improve the tilth to a greater depth, i.e. throughout the topsoil, necessitating incorporation to 15 cm or more, 7.5 to 10 t/ha is typically applied.
4.6 Application Methods

Most soil amendments are applied broadcast, using a spinner type applicator, over bare soil, which is then cultivated to incorporate or mix the material into the soil, usually the top 10-25 cm.

If the material is not incorporated, it takes a long time to effect a change, due to its low solubility.

4.7 Timing of Application

Because these soil amendments are fairly insoluble, they take a long time to react, so need to be applied 2-3 months in advance of planting, so the soil pH or other attributes have time to adjust.

The rates of chemical reactions increase when the temperature rises and there is ample moisture. Hence, if the soil is dry, soil amendments will not dissolve, and as the temperature falls, so do the rates of dissolution and reactions.

The best times to apply these products, if there is a choice, are the warmer and wetter months of the year, as long as it is sufficiently in advance of the proposed planting time.

All the fore-going indicates a need to plan well ahead. If it is intended to analyse the soil to confirm the need to apply a soil amendment, take the soil sample 6 months before planting seeds or transplanting shrubs or trees. The results should be returned in 2-3 weeks so an interpretation can be made and recommendations developed. This should then give time to prepare the site, well in advance of planting.

5 DETERMINING SOIL FERTILITY STATUS

The most appropriate means of determining the soil’s chemical fertility status is by the use of soil analysis. The capacity of the soil to supply nutrients to plants may also be assessed by analysing the plant’s leaves for their nutrient content, or the sap in the petiole (leaf stalk), the analysis of fruit or produce and the rate of growth and production of the plant, (e.g. number, quality and shelf-life of flowers). Apart from plant tissue analysis, there is less interpretative data available for these techniques than for soil analysis for the species which are used in the landscapes under consideration at this course.

The analysis of water, used to irrigate recreational areas, can indicate its suitability for use on a soil type or for watering plants, or solving problems indicated by poor plant growth or particular symptoms. Hence, water analysis is another useful management tool.

There are four key aspects to the successful use of soil, plant or water analysis. These are - sampling, analysis, interpretation and the development of a recommendation.
5.1 Soil Sampling

The key to soil sampling is to ensure that the sample taken is representative of the area of concern. This means taking a sufficiently large number of cores or sub-samples (usually 20 or more) so that the mean of any analysis does not change greatly if another set of sub-samples is taken from the same area.

The cores must be taken to the correct depth, usually the surface 10 cm for grassed areas and 15 cm or more for garden beds or tree plantings. The depth to sample is also dependent on the interpretation data available.

The sampling equipment i.e. sampling tubes, corers or augers, buckets (plastic) and plastic sample bags must be kept clean.

The person sampling must avoid non-typical areas or areas which may have been contaminated. If, in the course of site preparation, topsoil has been removed from some parts, exposing subsoil, it would be wise to sample both separately. If topsoil is to be imported and applied to a reasonable depth, e.g. 15 cm, over the area, the new topsoil should be sampled.

The samples should be taken at least 3 months after the last liming application and 2 months after the last fertilizer application.

Once collected, the sample(s) should be despatched to the laboratory as soon as possible. In addition to the sample, it is most helpful if information such as intended use, management strategies such as irrigation type, topography and aspect of the site, depth of surface soil and its previous history as far as plant types grown, fertilizer and soil amendment application, are provided. This helps the person interpreting the results to focus on the most important aspects of the analysis.

5.2 Soil Analysis

The question of which chemical analyses are the most appropriate requires some discussion. Most soil testing laboratories have set suites of analyses for various situations. Some analyses, e.g. pH, electrical conductivity and phosphorus are almost always analysed. Other analyses, e.g. nitrate - nitrogen, sulfate-sulfur, potassium, calcium, magnesium and sodium, are often analysed, whereas the micro-nutrients, copper, zinc, manganese, iron and boron are less often analysed.

When a soil is to be analysed for the first time, it is suggested, that a full-range suite of analyses be conducted. This allows the interpreter to be fully aware of any potential problem areas, such as extremely low values or extremely high values.

The methods of analysis of soils are very specific. Most nutrients enter plant roots via the soil solution. As the plant absorbs water from the soil, those nutrients which are dissolved in the soil solution, enter the root cells. The chemicals used to extract each nutrient have been chosen for their capacity to extract that part of the total pool of each nutrient, which closely resembles that which is available to plants. This fraction is referred to as the “plant-
available” nutrient. Between soils, there are large differences in the total amount of each nutrient and this bears little or no relationship to plant growth.

When choosing a laboratory to analyse soil, it is important to ensure that the analytical methods used are appropriate, i.e. they are methods which estimate the plant available nutrient status of the soil and can be interpreted.

Variability exists within soil samples and between laboratories and errors can occur in the determination of analytical results. Many laboratories seek registration with the National Association of Testing Authorities (NATA) and accreditation by the Australian Soil and Plant Analysis Council (ASPAC) to help ensure their laboratory procedures and analytical methods are appropriate, and they generate reliable results.

A useful reference to the standard methods used in Australian laboratories is the Handbook on Methods of Soil and Water Analysis, by Rayment and Higginson, 1992.

Results of analyses are normally returned in 2-3 weeks.

5.3 Interpretation of Results

Once the results of the chemical analysis of the soil are available, a competent interpreter should be able to interpret the results and provide an appropriate soil amendment and fertilizer program. Such advice will need to be sought from a consultant or fertilizer supplier specializing in the management and nutrition of landscaping and recreational parklands.

5.4 Development of Recommendations

The recommendations should reflect the use of the area, the needs of the plants growing or to be grown and the climatic regime as well as the nutrient status of the soil.

The recommendation should provide the client with the appropriate products to apply, their rate of application, and how and when they should be applied. The fertilizer program needs to be provided sequentially (in time) and with the minimum of explanation, so it is brief, clear and without confusion.

6 SOME KEY FERTILIZER MANAGEMENT ISSUES

6.1 Pre-Plant Preparation

Consider the origin of the soil. If the topsoil, has been removed, exposing the subsoil, or a considerable amount of fill has been used, the fertility is likely to be low. Topsoil itself varies considerably in its fertility, with sandy soils and soils low in organic matter typically having a low nutrient status.

Before planting low fertility sites, ascertain the species and their requirements. If nutrient demand will be high, e.g. many exotic species and lawns, raise the general fertility level first by incorporating organic materials, soil amendments and multi-nutrient fertilizer mixtures.
Superphosphate can be used to increase P status and Muriate of Potash to increase K status. These products may be applied as close as 1-2 weeks prior to planting.

Soil acidity and poor soil physical characteristics indicate a need for lime, dolomite or gypsum. Ensure they are applied at least 3 months before planting, spread evenly and incorporated to the desired depth.

For Australian native plants, low fertility soils are often suitable, i.e. no fertilizers may be needed.

For high fertility soils, usually, no fertilizers or soil amendments are necessary.

Ensure amendments and fertilizers are incorporated through the potential root zone.

6.2 At Planting

Many species of plants are sensitive to fertilizer (most being soluble salts) in contact with the seed or seedling roots. So generally, fertilizers are not recommended at planting, unless they can be applied in a band separated from the seed or seedling by being placed 5 cm to the side of and 5 cm below the seed.

Phosphorus fertilizers are best applied at planting, or if the planting sites are known, they can be applied pre-plant and mixed into the soil at the intended planting site.

6.3 Post Planting

Fertilizers providing nitrogen and potassium may be applied by broadcasting and watering into the topsoil and root zone to give additional nutrition to plants. However, care needs to be exercised, fertilizers can damage plants even when well established, if applied at too high a rate. So fertilizers should be spread evenly (not concentrated in one small area), to avoid root damage, and watered in after application especially to lawns to avoid leaf burn.

For highly productive situations, annual applications of phosphates may be required to sustain healthy plant growth. This applies particularly to grassed landscapes (lawns) and fruit trees.

6.4 Environmental Concerns

The possible over-fertilization of recreational areas, e.g. golf courses, has been the focus of increasing attention in recent years. Nitrogen is the main culprit, particularly on sandy soils where, if applied at a rate higher than plant needs and/or heavy rain occurs and/or excess irrigation is applied soon after application, it may be leached below the root zone and into the ground water.

If the slope at a site is steep and the soil is unstable, erosion may carry nutrients, either in solution or attached to eroded soil particles (sediment) into streams and waterways, to induce weed or algal growth or other problems with aquatic organisms. Such losses will be greatest on unconsolidated bare slopes.
7 CONCLUSIONS

Information for guiding the effective, responsible use of fertilizers and soil amendments is available to those who prepare, established and maintain landscaped and recreational grasslands and vegetated areas.

A knowledge of the roles and properties of fertilizers and soil amendment products helps in understanding how these products should be used, in terms of the rates, timing and methods of application.

Soil testing is a useful guide to the fertility status of a soil and an indicator of the need for fertilizers and soil amendments.

8 REFERENCES


ABSTRACT

Increasing population inevitably leads to increasing demand upon environmental assets. This impact can be lessened via a number of remedial mechanisms. In either urban or rural settings, or a combination thereof, rehabilitation/landscaping works can aid in the long term viability of the local and regional landscape and enhance, rather than threaten, the integrity and viability of nearby remnant vegetation. Existing knowledge on the ecological processes and functions occurring within the remnant vegetation mosaic provide essential models for the establishment of vegetation in these rehabilitation/landscaping works. The provision of planting schemata and strategies should be designed around this ecological framework and then translated into practical implementation programs. Failure to do so will result in scepticism on the part of those who would otherwise have willingly accepted such activities on their lands. The empowerment of the community with this ecological knowledge and the rehabilitation technology is the only viable means of ensuring success of any rehabilitation/landscaping program.

KEY WORDS: revegetation, landscape ecology, remnant vegetation, corridors, water use and renovation.

1 INTRODUCTION

As population increases, it is readily apparent that human impact upon the environment must alter with respect to both spatial and temporal scales of disturbance of natural processes and functions. Sparse, low populations with higher proportions of rural residents allow for greater environmental buffering of impacts than is practised by denser, increasingly urbanised population centres. Consequences of expanding population are too often seen as restricted to negative impacts upon ecological functions and processes. A narrow perspective on the spectrum of opportunity or constraint provided by demographic change has led to the common misconception that all impacts associated with increasing populations (and urbanisation) are inevitably negative upon natural biota and landscapes. Past practices of design and resource management have reinforced this perception. This paper will attempt to illustrate some approaches to these issues which may provide windows of opportunity for altered perspectives on design and landscape management.

2 LANDSCAPE MANAGEMENT

In urban settings, wastes created by our daily activities can be removed from the source via a wide variety of technologies eg. reticulated storm water and sewage systems are discharged into the hydrological cycle at some point removed from the source of origin of pollutants. Population density precludes the establishment of such infrastructure in many rural areas.
Thus, residents in rural landscapes are more often confronted with the realities of dealing with waste products of their daily activities, than those people closeted within our cities and larger towns. This may account for the more innovative schemata currently available and apparent for waste disposal and natural resource management, on a per capita basis, in rural and rural residential areas than in major urban centres.

Cosmetics are often deemed to be a primary factor in landscape management works in urban areas. Environmental benefits may accrue incidentally from such works, with these prerogatives increasingly mooted as foci of proposed development schemes. Their mitigatory effects, however, appear to be of lesser consequence in urban areas than is seen in more sparsely populated areas. Disposal of wastes generated by urban living via landfill, recycling, marine and freshwater outfall is the norm with on-site utilisation far less feasible and accepted than in less densely populated areas. Obviously, with a larger area available for waste disposal and environmental buffering in non-urban areas, the opportunities presented for on-site management of our daily products is more practicable.

It is widely acknowledged that south east Queensland is one of the most rapidly expanding urban areas in Australia. Traditionally, settlement patterns have focussed on the Australian coastline. Initially, this was an artefact of necessity with proximity to freshwater supplies and transport (principally shipping in the early days of settlement) essential for the expanding population. As the diversity of transport options and establishment of infrastructure (eg. dams and water reticulation, roads and regional centres away from the coast) expanded, populations increased in rural areas to supply local and international markets.

Recent trends have seen a reversal of this decentralisation with ever increasing proportions of the population concentrated in coastal, urban areas. There has also been substantial inter-urban migration in recent years, particularly into the south east Queensland region. Regardless of the foundations of these trends, there are dramatic consequences for the remnant vegetation mosaic and therefore ecological process and function at a local and regional scale. It is therefore worthwhile considering some of those aspects of the landscape which should be considered in any landscaping/rehabilitation plan.

Current land tenure is seen by some as one of the more significant impediments to achieving effective landscape management. This should not be the case. It is certain the much of the remnant vegetation of significance is not necessarily within the public lands of most regions. Thus, private landowners and land managers will have an essential role to play in future remnant vegetation management. It is clear that reliance upon the existing conservation reserves will result in a high cost management programs in the future.

That rural land use has left such biological riches present in the landscape is partly a reflection of the poor resources available for human utilisation, and partly the awareness of primary producers of the role of certain landscape elements in productivity eg. riparian vegetation. Some land use activities, however, actively threaten the remaining natural or near natural elements in the study area. Often to rectify these land degradation issues can prove costly in terms of time and resources. Remedial action is most effective if undertaken prior to loss of the "free ecosystem services" which repair the ills invoked upon the landscape following the reduction in the extent of an artificial input into natural systems or its removal. It should be noted, however, that these impacts rarely act in isolation from each other and the
impact is most typically cumulative, rather than simply additive. The need to address the totality of issues is therefore paramount.

The regional reserves will have to be maintained as isolated "zoos" and "botanical gardens" if current land clearance trends continue and land use patterns alter in the manner seen in recent years. They will lose the essential ecological processes and functions which maintain their identity in the landscape and ensure resilience in the face of existing natural disturbance regimes and increasingly threatening artificial disturbance regimes. The community cannot bear the cost of such management and would not wish our natural resources to become so utterly dependant upon active and continuous intervention to ensure their continued existence in the region.

Threatening processes at a regional scale are artificial fire regimes, grazing displacing native biota and causing large scale landscape alterations, urbanisation causing loss of habitat and producing damaging inputs into remnant habitat, artificial nutrient, sediment and hydrological inputs displacing native flora and fauna, and, feral flora and fauna threatening the viability and integrity of the natural biota. To address these threatening process, a number of mechanisms are available for either mitigation or removal of the threatening impacts. Often, actions or degree of implementation of proposed alterations to current or potential land use will determine if the result will be mitigatory or protective. Encouragement via mechanisms such as rates incentives, and community involvement in landscape management through to legislative protection of the most valuable biotic components is urgently required.

Residents, land managers and other stakeholders should be informed of the biotic resources of their area. This knowledge can then be incorporated into future management decisions. An inevitable consequence of this education process is the identification of the most significant sites worthy of preservation. This can be achieved via a number of mechanisms ranging from voluntary management agreements involving no change of land tenure, but with adequate recompense for landowners disadvantaged by possible changes in land use patterns, through to acquisition and more rigidly controlled management of the biotic resources.

There exists great potential for rehabilitation of sites currently degraded or to change land use practices which threaten the long term viability and integrity of biotic resources. The primary starting point would be to rectify problems associated with the hydrological cycle. Artificial nutrient and sediment inputs reduce the water quality of both the freshwater and estuarine resources. This has broad implications for the long term productivity of the landscape. It is not inconceivable that current trends in land degradation can be reversed and water quality improved via the adoption of more appropriate runoff management strategies.

Given the lack of background material to formulate detailed and well structured decision pro formas, we must rely upon basic ecological understanding. Put simply, the focus must be directed at solutions which have the following attributes:

- Be scale appropriate for the site and region;

- Consider the interactions between the biota and the landscape (not simply the biota in isolation); and
- Allow for flexibility in design and management given the known, but unquantifiable disturbances which will impact upon the determined values of the region in the future.

Thus, if the functional attributes of each entity within a region are identified, and their ecological integrity and resilience be comprehended to the best of the available capacity of the persons involved, then some assessment can be made of the potential for loss, change or repair of those systems.

We will always be faced with the prospect of contiguous areas of urban and rural lands with remnant bushland. When urban developments encroach on remnant bushland or are contiguous with the dwindling bushland resource, some obvious consequences appear. Weeds are but one of the many examples of these impacts. Weeds, however, provide us with a useful model of the problems of interactions between remnant bushland and urban areas. In addition to direct weed invasion, alteration to drainage patterns, nutrient dynamics across the landscape and altered fire regimes, eutrophication of streams, fundamental structural and floristic change, and loss of the former biota are common features of remnant vegetation. These changes and losses are most apparent and dramatic when the remnants are small and isolated.

All of the above scenarios of loss of biota, alterations to the former vegetation mosaic etc. must be avoided. The long term objective should be to reverse the current patterns and trends of broad scale landscape degradation and attempt to return the fundamental "free ecosystem services" or ecosystem self-repair mechanisms. These natural repair mechanisms are innate in natural ecosystems as they have been induced via eons of evolutionary selection pressure. If these processes had not been induced over geological time scales, then we would have no evidence today of stability in the face of natural disturbance regimes within communities such as rainforests, heathlands, Melaleuca forests etc. Some of these, such as the rainforests of the region have persisted in the face of climatic change over millions of years. This resilience can only be lost with excesses across the landscape invoked by Homo sapiens.

Ultimately urban developments must not threaten remnant vegetation through acute, active means such as direct loss of vegetation or chronic, passive vectors such as altered hydrological cycles, nutrient and other pollution, and feral flora and fauna invasions. In particular, storm water, nutrients and other pollutants must not be allowed to enter the hydrological cycle without adequate and appropriate buffers. Novel designs and a change in both political and social will are required for these innovations to become either mandatory or demanded by the population in general. It is hoped that occasions such as the current forum will provide stepping stones for the dissemination and acceptance of these critical ideals.

3 REMNANT VEGETATION

Remnant vegetation has a multiplicity of roles in the landscape eg. habitat for flora and fauna, amenity for residents and visitors, stabilisation of urban, rural and natural ecosystems. South east Queensland, for example, is faced with the real prospect of losing virtually all of its remnant vegetation, outside the Crown Estate, early in the next millennium - just 5 years away (Catterall & Kingston, 1993). This region of Queensland is, after the wet tropics, one of the most biologically diverse landscapes in Australia. Despite the majority of the landscape having been cleared or substantially modified in the past, there are still significant remnants
of the original vegetation mosaic remaining scattered across the region. Out of this scenario of rapid expansion of urbanised population in the region, and the incursions into remnant bushland, a number features of the landscape have emerged:

- All remnant vegetation now has some biological value and conservation significance regardless of its condition;

- Regionally, the loss of remnant bushland has become of critical concern;

- The current reserve system of remnant bushland is neither adequate or appropriately managed to ensure long term viability and integrity of the biota;

- Further losses of bushland will result in the local extinction of some vegetation types with their component flora and fauna; and

- The "free ecosystem services" provided by remnant bushland are being compromised to the detriment of the population existing and settling in this region.

All of the aforementioned points should elicit a change in policy and directions of land management options in this region. To date, it has not. Whilst the ecological consequences of these trends are self-apparent, the political and social ramifications of change appear to be the greatest stumbling block to urgent and realistic change.

4 RIPARIAN AREAS

It is worthwhile considering some of the aspects of remnant vegetation management in the light of the ecological role such areas play in overall landscape stability and management. From the perspective of *Homo sapiens*, the riparian areas are the most critical for landscape management. This is not simply due to increased awareness of erosion and land degradation resulting from past excesses in the riparian zone. The riparian areas form a critical buffer between the terrestrial landscape and the aquatic systems upon which we so fundamentally depend. Degradation and substantive alteration of the hydrological cycle has obvious terminal consequences for human populations. This is seen globally every day. Technological solutions are not providing satisfactory outcomes when the basic biological components of the systems have degraded beyond the point of self repair. In addition, any remedial activity is exceedingly expensive and the successful long term outcome remains in doubt.

It has also been recognised that the riparian areas are critical for a significant proportion of the remnant flora and fauna as habitat, movement corridors or refuges when their preferred habitat is disturbed or destroyed. Unfortunately, the resource richness of these riparian zones also makes them most vulnerable to invasion of weed species. These are the sites where extensive invasion by both exotic and native weed species (feral flora and fauna) has occurred. The patch dynamics of remnant vegetation removed from the drainage lines in the landscape provides some indication as to the real threats and losses over time due to the increasing spatial and biological isolation of such remnants.
5 CORE HABITAT

The more sizeable remnants (> 10 ha) are a useful starting point in considering the viability and integrity of the remnant patches within the region. The principles of island biogeography have been applied to such patches with the largest patches ("islands") considered to have the greatest probability of containing the largest proportion of the original landscape. These patches are a dynamic, yet stable, manifestation of the former diverse, but contiguous vegetation mosaic. The size and shape of these remnants is critical in maintaining some of these attributes. A "core area" (which varies amongst the components within each remnant patch) is essential to maintain the individual components of the ecosystem within remnants. This core area must be of a size which displays adequate robustness in the face of disturbance events such as fire, competition from feral plants (weeds) and animals, storms etc. The origin of these disturbance events is irrelevant, although the influence of anthropogenic disturbance can be far more detrimental than the natural disturbance regime within which these ecosystems evolved and were maintained. The critical factor is the ability of the remnant patch to provide the wherewithal for the continued viability of the extant components of the patch (be they residents or migrants). The role of patches for migrant components is the most problematic to resolve from either an inventory or a management perspective.

6 HISTORICAL FACTORS AND ECOLOGICAL BALANCE

Disturbance is a natural part of ecosystem functioning. It maintains diversity in many vegetation types e.g. rainforests and heathlands. Additional anthropogenic disturbances can unbalance, disrupt, retard or destroy the natural recovery processes. This factor is seldom, if ever, considered in current management models. Many disturbance related features have changed following the colonisation of Terra australis by Homo sapiens some 50-60,000 years or more B.P. Fire is one of the most dramatic of these with Aboriginal peoples introducing artificial fire regimes, and subsequently these regimes were changed with European occupation of the landscape with differing management prerogatives for grazing, land clearance etc.

In addition, the last 200 years have seen a rapid increase in the rates of introduction of flora and fauna with consequent rapid declines in natives species numbers and the worst record for extinctions within certain faunal groups (e.g. mammals). Today we even see species native to Australia posing significant environmental threats (Olsen & Drane, 1995) e.g. Schefflera actinophylla (Umbrella Tree) (See, 1994), Eucalyptus torelliana (Cadaghi) (Chamberlain, 1994) and Manorina melanocephala (Noisy Miners) (Low, 1994). This issue must be considered when assessing the value and requirements of remnant vegetation. Ultimately, patches must be of a sufficient size to withstand disturbance events (both natural and anthropogenic) and to buffer the impacts of immigration of feral flora and fauna. No prescriptions can yet be offered for varying vegetation types, but obviously eucalypt forest requires a different core area for its component flora and fauna than rainforest or mangrove communities.

Reliance upon current knowledge of the ecological principles related to biodiversity maintenance in remnant vegetation, taken in conjunction with horticultural information on the species selected for particular plantings, will ensure a successful outcome for future landscape rehabilitation works. An expanding body of information on specific species attributes will
continue to provide much needed data to refine what, in many instances, remain relatively crude "guesstimating" of the ecological amplitudes of our native flora and fauna. Ultimately, generic guidelines could be prepared to indicate the most suitable species, establishment and maintenance methodologies, and ecologically significant landscape elements which will be the focus of works given the edaphic and biotic conditions extant formerly on the site. This will concurrently provide a series of benchmarks whereby the success or failure of the project can be reviewed at regular intervals. It is vital that some success/failure standards are established so that pro-active intervention is instigated at the earliest possible opportunity to rectify any potential difficulties. The later that these issues are identified and solutions proffered, then the more expensive (in terms of time, energy and resources) and less likely a successful outcome from any additional remedial works.

7 "CORRIDORS"

When discussion turns to the concept of "corridors", it should be stated that it is considered that the term "ecological linkages" is a more appropriate and meaningful description for entities described and perceived as "corridors". There has been a popular misconception that when considering "corridors", there has to be a physical connection between one vegetation patch and the next. This is not necessarily true. It must be remembered that these "ecological linkages" are viable connections between the various components of the natural landscape. They can occur within and between sites within the natural landscape mosaic in addition to their role linking remnant patches now surrounded by cleared or human-modified landscapes. The location of "corridors" connecting remnant vegetation patches is seen as a major factor in regional conservation strategies (Catterall & Kingston, 1993).

There is increasing evidence that some physical "corridors" without an adequate "core" habitat area linking two remnants may pose a more significant threat to the viability and integrity of the remnant patches than those emanating from the surrounding lands (Simberloff, et al., 1992). This is due to the role of narrow "corridors" in harbouring and maintaining populations of weeds and feral animals that would not be supported in the modified landscape. This relates to the former discussion on the core area/patch shape/edge length concept for recognition of minimum size of ecologically sustainable remnant vegetation patches.

It is imperative that the differential "core area" requirements of the individual components be adequately addressed along with their individual habitat preference. For example, "edge" species have greater access and greater spatial extent of habitat than "core area specialists" in a landscape dominated by remnants of the original vegetation mosaic. Some fauna have become more compliant in their habitat requirements. This is clearly illustrated by fauna such as the possums, *Pseudocheirus peregrinus* (Common Ringtail Possum) and *Trichosurus vulpecula* (Common Brushtail Possum) which inhabit urban and rural landscapes in breeding populations, whereas *Phascolarctos cinereus* (Koala) is not recognised as a breeding resident of such habitats. The focus of this discussion is on ecological linkages, rather than "corridors" although the term "corridor" will be used in relation to issues of a generic nature. If the role of "corridors" or ecological linkages is to be adequately considered, then the following matters must be addressed:

- What species of fauna/flora are expected to utilise the "corridor"?;
• What habitat requirements do they have within their movement or residential "corridors";
• What is the "core area" for an effective "corridor" for the fauna/flora utilising it?;
• What are the temporal (diurnal, seasonal) patterns of use of the "corridor"?; and
• How do natural and artificial disturbance regimes impact upon utilisation of the "corridor"?

Until these questions are answered, then the designation and demarcation of "corridors" in the landscape must remain speculative, as must the specific roles they perform for all of the species within the remnant patches.

The above information is almost totally lacking for most species of Australian flora and/or fauna, let alone for the functioning ecosystems to which the flora and fauna contribute as interactive entities. Some general observations and conclusions, however, can be made regarding the likely utilisation of the remnant vegetation mosaic within the region. This may assist in concentrating efforts for repair of presently fractured ecological linkages which are considered of importance. In particular, the design of urban "corridors" of landscaping and vegetation reinstatement could potentially perform some of the functions of the former ecological linkages of the now defunct vegetation mosaic.

For some fauna and flora, individuals of species may be important eg. single remnant trees of *Ficus* spp. may be critical for migratory frugivorous pigeons such as *Ptilinopus regina* (Red-crowned Pigeon) and *P. superbus* (Purple-crowned Pigeon). Thus, an opportunity would be provided for the incorporation of specific taxa in planting schemata to either encourage target fauna or enhance the likelihood of their return over a larger proportion of the landscape. These instances are not pursued extensively herein other than to raise the matter when considering rehabilitation plantings that these features of natural ecosystem functioning not be ignored.

The needs of single species, however, should not take precedence over the requirements of the diverse array of flora and fauna found in the numerous habitats extant within the region. As with all environmental issues, a holistic, rather than a reductionist, approach is essential if ecologically meaningful solutions are to be effected.

The most obvious series of sites which perform an important role as ecological linkages are the riparian areas. The obligate riparian fauna are virtually totally dependant upon these sites for movement and breeding. Some fauna species, eg. small mammals and some birds, are prevented from moving between forest patches by the lack of a forest canopy cover and/or the barrier imposed by vegetation such as grasslands, cultivation, pasture and urban areas. This barrier can be removed by selected re-instatement of canopy cover and structural attributes in the vegetation which would encourage restoration of these movement "corridors". In addition, this would provide sites for the colonisation of both flora and fauna in a habitat that has been greatly modified, degraded or lost within the region.
Other than their multiplicity of biotic values, riparian communities also impart landscape stability on this interface between the terrestrial and aquatic environments. The most obvious solution to current trends is to reverse the degradation of the riparian resource and reinstate vegetation along those areas most threatened at the present time. This would benefit primary producers by stabilising and reducing the number of stock watering points to the river and smaller tributaries in the study area, hence reducing management costs and logistics. It would assist in the remediation of loss of water quality as a consequence of the degraded nature of the riparian zone. The riparian vegetation plays a crucial role in water renovation prior to entry of nutrient and sediment laden runoff into streams and estuaries.

So, in the absence of any prescriptive measures available, what should we base our decisions upon when matters environmental cross our respective paths? The answers, whilst appearing relatively simple, are fraught with hazards for the unwary or inadequately or inappropriately informed. When considering regional matters, it is considered to be almost totally fallacious to rely on current structures such as the "R.A.T.S." (Rare and Threatened Species) schemata to provide the framework for ecologically substantive solutions to these dilemmas. We must take a holistic approach to the problem, as this is the only mechanism available for interpreting regional landscapes: be they flora, fauna, human demographic patterns or sociological interactions between these elements.

The solution to the dilemma of determining the minimum core area of remnant patches, or minimum width of physical connections between these remnant patches, has largely been resolved. The dramatic reduction in spatial extent of native vegetation types ensures that ALL remnant vegetation has biological significance (including those areas exhibiting degradation as a result of past non-natural disturbances).

Thus, all patches should be afforded protection, and the degraded areas rehabilitated until such times as adequate and appropriate information is available that quantifies the role a particular vegetation remnant plays in the regional ecosystem. Riparian vegetation, and those vegetation types of highest conservation significance (rainforest and associated ecotonal communities, heathlands, Melaleuca wetlands and marine terrestrial interface vegetation e.g. foredune and mangrove communities) should remain sacrosanct in the landscape, and any current degrading influences in sites containing these elements be removed post haste.

The Crown Estate contains substantive areas of remnant vegetation in coastal areas and their management is primarily a State Government responsibility. Disregarding legal responsibility for a moment, however, it is clear that a strong moral responsibility lies with local authorities to ensure that these areas are managed appropriately by the array of agencies and persons responsible for land management. The ecological linkages between the coast and the hinterland have been fractured across much of the region. This matter requires urgent attention and allocation of considerable resources to rectify this unfortunate situation. In addition, the latitudinal connections must be addressed in order to formulate ecologically meaningful management strategies.

8 WEEDS

The role of weeds should not be neglected. As stated previously, weeds may actually stabilise some steep, degraded slopes, but they pose a direct threat to the efficacy of the proposed
ecological linkages. It is imperative that the ecological linkages maintain or create near-natural conditions for their effectiveness to be realised. With dense, persistent weed infestation, the movement of flora and fauna between remnant patches (the oft stated primary objective of these ecological linkages) will be compromised. The maintenance of such sites will also become prohibitively expensive should weed control be the primary concern of subsequent management. It is considered that maintenance of existing linkages, and reinstatement of currently fractured linkages, bear these considerations as issues of paramount importance.

There is increased invasion of weed species, both exotic and native species of acknowledged weeds and "new" introductions of garden escapees. The lessons of *Mimosa pigra* (Giant Sensitive Plant), one of the top ten environmental weeds in Australia (Humphries, *et al.*, 1991), in the Northern Territory still remain unlearnt. This species was in Darwin gardens for many years, before finally acclimatising and hence spreading and becoming one of Northern Australia’s most serious environmental and agricultural weeds. Other garden introductions in Australia’s “top ten” include *Crysanthenoides monolifera* (Boneseed and Bitou Bush), *Eichornia crassipes* (Water Hyacinth), and *Myrsiphyllum asparagoides* (Bridal Creeper). The majority of the others such as *Cenchrus ciliaris* (Buffel Grass) are deliberate agricultural introductions which have subsequently become serious environmental weeds. Many such weed species lurk in urban gardens. The recent expansion of naturalised populations of *Eucalyptus torelliana* (Cadaghi) and *Schefflera actinophylla* (Umbrella Tree) throughout coastal south east Queensland should act as timely reminders to be cautious with our alteration to the distribution and dispersal of the world’s biota. It never ceases to amaze that little, if anything, has been learnt from examples such as *Baccharis halimifolia* (Groundsel), *Lantana camara* (Lantana), *Cryptostegia grandiflora* (Rubber Vine) and the numerous other garden escapees which now occupy thousands of square kilometres of arguably the most unique biological landscape in the globe.

Exotic flora and fauna need to have their populations reduced or removed from remnant vegetation. The success of this process can be enhanced by more appropriate plantings and management of domestic animals. It is clear that current and future residents and land managers should be supplied with information detailing the biological riches of this area in order to empower the community with more enlightened management of those natural resources. This is considered ultimately to be one of the most effective means of educating landowners and encouraging more appropriate land use practices into the future which will not only reduce current threats to the biota, but also provide potential avenues for the reinstatement of lost or degraded critical ecological elements of the landscape.

9 BACKGROUND TO CASE STUDIES

Whilst the focus of this training course is land management for urban development, the essential lessons to be incorporated into that landscape have been derived from activities in rural and natural landscapes. We know that a considerable number of species of flora which threaten agricultural productivity and the viability and integrity of remnant bushland have originated from urban horticultural sources (Humphries, *et al.*, 1991). One of the most basic of tenets in urban development models should be that no further introductions of such species should occur as a consequence of urban landscaping activities. Therefore, our knowledge of the agronomic capacities of flora utilised for landscaping purposes should ensure that exotic
or native species which have no likelihood of threatening rural or natural landscapes are the only taxa utilised for such plantings. Unfortunately, almost every recent urban development contains a plethora of species which threaten either one or both of these landscapes. The nursery and landscaping industries must take the primary and leading role in reversing this situation.

With the view that we have a range of suitable species at our disposal for utilisation in urban landscapes, how should our designs meet landscape management criteria, and which of these criteria are the most critical?

10 REVEGETATION/LANDSCAPING

As indicated previously, tenure should not be seen as a constraint, the nature of the landscape should be the primary determinant. It is clear that different land tenures call for different approaches and procedures when dealing with land management issues. It is critical that adequate and appropriate land management agreements are firmly in place before stakeholders commit their restricted and valuable resources to any project. Individual private landholders whilst reaping some of the benefits of revegetation projects should not be encumbered with unnecessary costs and land management restrictions as a direct consequence of proposed landscape rehabilitation activities. There are innumerable, but few currently implemented, models for compensation for landholders in such situations. The available monetary based models such as rate relief, direct compensation and land purchases are restrictive to the extent that negotiation between parties frequently fails to resolve the all important outstanding land management issues and the consequent benefits of altered perspectives and management. As innovation in design is required in urban situations to capture more of the resources currently transported off-site, negotiation between landholders and other stakeholders must enter a new era for satisfactory resolution of the substantial land management issues faced across the globe.

Once these matters have been resolved and a course of action for revegetation or landscaping determined, then the primary strategy should be one of habitat matching. With even the most simplistic understanding of the remnant vegetation mosaic and its associated soils, it is feasible to design a planting schemata matching species and sites.

The horticultural understanding of our native flora and its edaphic associations has expanded dramatically in recent decades. This has partially been an artefact of our increased ecological understanding of natural ecosystems, but primarily as a consequence of increased community awareness of our native flora and fauna and desire for the incorporation of these elements into urban and degraded landscapes.

The principle most pertinent to the issue of rehabilitation and/or landscaping plantings is which plant is the most appropriate and most likely to thrive in a given situation. A number of factors assist in the determination of this site-species matchmaking. The known tolerance of particular flora for site conditions such as soil type, hydrological status and extant microclimate is perhaps the first phase of species selection. This will yield a wide variety of taxa and growth forms which can then be assessed for relevant qualities of suitability within a particular site. This preliminary list can subsequently be refined on the basis of known
planting successes for particular species mixes on similar sites. The final phase should be establishing the availability of the desired taxa in nurseries or other sources.

The phase most lacking in some landscaping activities is the utilisation of species providing more than cosmetic appeal. Water use and renovation on site has received only limited consideration in the design phase of current landscaping activities. Often these benefits have been gained fortuitously, rather than in a planned fashion. This is the area perceived to have the greatest potential for enhancement of current landscaping schemata and methodologies. The altered runoff and drainage patterns in many urban areas provide opportunities for retention and utilisation of water, nutrients, sediment and other products on site before these materials enter the "mainstream" hydrological cycle - the creeks, rivers, lakes and associated waterways.

Similar criticisms could be applied to some landscape rehabilitation projects. There are currently many successes in this field, but also several examples of unnecessary or likely failures. These failures have often resulted from a lack of adequate or appropriate planning and technological input in the early phases of these projects. Rehabilitation plantings can be undertaken for the remediation of sites or as demonstration trials to illustrate the potential of such works. Many projects designed to fulfil the former criteria will be unlikely to achieve their objectives, and can even mitigate against the latter goal.

A purely hypothetical example of the problem described above is the situation where a local Landcare group may wish to rehabilitate a local riparian area. These sites are often dominated by a plethora of weed species. If the site is clearly a demonstration trial with long term commitments of funding and community resources of energy, skill and enthusiasm, then any riparian site might be suitable. Lack of future support for maintenance of isolated plantings will lead to eventual replacement of the rehabilitation works with the weed dominated landscape which existed prior to commencement of the project. This is obviously an undesirable outcome from an educational demonstration or any other perspective. Landholders will be discouraged from implementing similar commendable plantings on their properties and funding sources will be more reluctant to allocate resources to projects with limited likelihood of success. The solution to these problems is in the design phase.

The natural ecological processes of biodiversity maintenance should be utilised to enhance the rate and diversity of the rehabilitation process where applicable. The incorporation of frugivore attractant flora in planting schemata can rapidly introduce a greater diversity of flora onto a site. This can have disadvantages if the frugivores draw their major food resource from adjacent large tracts of weed infested land. Species dispersed in this manner include Celtis sinensis (Chinese Elm), Cinnamomum camphora (Camphor laurel), Schefflera actinophylla (Umbrella Tree) and Ligustrum sinense and L. lucidum (the Privets). Again, proximity to large viable native vegetation remnants can reduce this negative impact and increase the positive benefits to be gained by the establishment of species which will attract native flora dispersers.

It is essential to locate demonstration trials or rehabilitation works contiguous to, or in near proximity to, sizeable viable vegetation remnants. Then, it is necessary to plant with the correct suite of species based upon the ecologically sound principles detailed above. This may require a staged sequence of works. There are many adequate models for rehabilitation
plantings along riparian areas which simply require appropriate site and species selections. It is critical that the local landscapes of soils and vegetation be utilised as models for the selection of species for any given rehabilitation or landscaping site. With these simple guidelines, the number of failed rehabilitation plantings and/or expensive maintenance programs for isolated demonstration trials can be substantially reduced in number and frequency.

11 CASE STUDIES

11.1 Case Study 1

Using knowledge of biotic determinants to establish the most effective mechanisms for reinstating vegetation in the most critical components of a degraded landscape. The remnant vegetation mosaic of Noosa Shire (Olsen, et al., 1995) and the associated soil landscapes (LRAM, 1995) were mapped and entered onto a Geographic Information System. This yielded a number of valuable land management products. It was possible to identify the extent of physical constraints to land utilisation such as known and likely occurrences of acid sulphate soils. In addition, it was feasible to develop a schemata for reinstatement of vegetation across those sections of the landscape where contiguity of vegetative cover has been lost and in critical areas for buffering our terrestrial impacts before they are dispersed via the hydrological cycle in freshwater and marine ecosystems. The procedure can be illustrated by a simple visual assessment of some of the GIS products and can be confirmed by more rigorous analytical procedures provided by the innate abilities of GIS technology.

The spatial extent of the remnant vegetation mosaic within Noosa Shire can be clearly identified on GIS mapping. This can then be compared with satellite imagery to identify areas of gains and losses in a similar manner, but at a finer scale of resolution, to the methodology employed by Catterall and Kingston (1993). The riparian corridors are seen as the most urgent requiring attention from a landscape management perspective for maximisation of social, economic and environmental benefits. The narrow and fractured nature of the riparian zone in Noosa Shire is not atypical of the situation found around coastal Australia, particularly the more densely populated sections of the east coast. The former vegetation mosaic has also been fractured across substantial portions of the hinterland and along the coastal fringe. Identification of sites and schemata for repair of damaged or degraded ecosystems can be achieved via a simple analysis of the data gleaned from the procedures utilised in the development of the Noosa Shire GIS. Streams along with the associated riparian vegetative cover and soils provide the essential building blocks for models of planting schemata to be applied across similar sites (assuming constancy of vegetation, soils, climate and hydrology).

From this base, sites can be prioritised on the basis of criteria such as urgency for rehabilitation due to location in the higher energy parts of the catchment, sites with higher probability of long term success (e.g. proximity to remnant vegetation, restricted size of site requiring treatment, suitable information on establishment of selected species in the conditions prevailing on the site, restoration of continuity in fractured riparian vegetation etc.) or community need. All of these factors can be utilised during interrogation of the GIS to develop a strategy for dealing with landscape repair issues at both local and regional scales.
Several criteria need to be applied to increase the efficacy of any proposed vegetation reinstatement works:

- Community empowerment throughout the project and in the future;
- Proximity to substantive blocks of viable remnant vegetation (> 100 ha);
- Surrounding land use and tenure; and,
- Existing vegetation in the local area in similar topographic situations on similar substrates.

With these issues considered, it is possible to identify areas such as sections of Six Mile Creek and other streams in the region, along with the fringes of waterbodies such as Lakes Cootharaba and Cooroibah and their catchments which require rehabilitative works or protection of their remnant vegetative cover. This information can then be imparted to local stakeholders. The technology to plant trees and ensure adequate long term survival and viability of such works is available, but rarely applied. As mentioned previously, this is more often due to lack of community empowerment in the process and inadequate consideration of ecological process and function than desire and technical ability to grow and plant seedlings. The long term efficacy of such works must be a priority if the stakeholders' resources are not to be eroded by unnecessary failures. The residents and land managers within Noosa Shire are the crux of the solution to all of the land management issues within the region.

Once sites have been identified which are located adjacent, and preferably contiguous to, a block of remnant vegetation, such as Cooloola National Park, then the process of species selection can commence. Adjacent or contiguous sites with remnant vegetation on similar substrates and topographic situation will act as models for species selection. The successional processes known or inferred from these sites can be incorporated into planting schemata with all successional phases incorporated into the initial plantings. Reliance upon only early successional species has been shown to be less effective than use of the full spectrum of successional species (Kooyman, 1991). Some sites such as Melaleuca wetlands may require more simplistic designs initially whilst repair or restoration is attempted on the former hydrological regime of the site. Prescriptive guidelines should be avoided, and generic models developed to allow for flexibility in design across differing scenarios and for proactive decision making to deal with unforeseen circumstances throughout any particular program.

11.2 Case Study 2

Utilising the opportunities provided by on-site effluent disposal - Leiner Davis Gelatine Pty Ltd Plant at Bromelton.

Unlike the former scenario where the extant and former vegetation and landscape resources provided the models and the opportunity for repair of degraded or lost components of the ecosystem, this case study will present an approach to on site utilisation of resources where site conditions have provided opportunities for utilisation of species other than those currently or formerly found within the natural biota of the site.

During the operation of any industrial process, waste is generated. The generic model applied for this waste in the past has been disposal via reticulation into waterways or disposal in soil based landfill systems. In the disposal system currently employed by Leiner Davis Gelatine
Pty Ltd at Bromelton, the effluent is being utilised in a more environmentally benign fashion yielding an economic return additional to the products of the industrial process. Some 38,000 trees (31 irrigated ha and 15 non-irrigated ha) along with more than 70 ha of irrigated *Chloris gayana* pasture were established on the site prior to full operational status of the gelatine production process. As with the Noosa Shire Case Study, soils were a major determinant of the species mix utilised on any given site. Identification of the soils mosaic provided the basic building blocks for development of a planting schemata (Figure 3). Knowledge of the local flora and the predicted alteration to soil nutrient and water status lead to the selection of the following soil-site-plant species mixes (Landscape Elements):

- **Riparian Zone** - alluvial soils - Canopy Trees - *Grevillea robusta, Castanospermum australe, Casuarina cunninghamiana, Melaleuca bracteata* and *Eucalyptus tereticornis*; Shrub Species - *Acmena smithii, Mallotus philippensis, Callistemon viminalis* and *Hymenosporum flavum*; Ground Cover Species - *Lomandra longifolia*.

- **Drainage Lines** - cracking clays with occasional apparent extant salinity problems - *Callistemom salignus, C. viminalis, Eucalyptus camaldulensis, E. moluccana, E. robusta, E. tereticornis, Melaleuca bracteata, M. quinquenervia, Casuarina cunninghamiana* and *C. glauca*.

- **Pondage Areas** - weisenboden soils - A similar suite of species was utilised as those for sites likely to experience salting problems along drainage lines - *Eucalyptus camaldulensis, E. moluccana, E. robusta, Lophostemon suaveolens, Melaleuca bracteata, M. quinquenervia, M. linariifolia, M. nodosa, Casuarina glauca* and *Callistemon salignus*.


- **Hilltop/Slopes Forestry** - stony prairie soils - The high value rainforest cabinet timber species, *Gmelina leichhardtii, Grevillea robusta, Lophostemon confertus, Melia azedarach, Rhodosphaera rhodanthema, Elaeocarpus angustifolius* and *Flindersia schottiana* were utilised on the hilltop and the following mixture on the lower slopes *Eucalyptus grandis, E. cloeziana, E. saligna, E. dumii, E. microcorys, E. resinifera, E. citriodora, E. maculata, Grevillea robusta, and Lophostemon confertus*.

Generally, the riparian strip was planted amongst existing remnants of the riparian vegetation or immediately adjacent to these remnants at the crest of the riparian levee banks along the Logan River. All of the species were planted in clumps of 4-6 individuals in a random manner to fill gaps in the existing vegetation and to expand the existing riparian margin up to the margins of the agroforestry and other works on the rest of the property. *Callistemon viminalis* and *Lomandra longifolia* were restricted to plantings closest to the stream edge, whereas the other species were utilised along the crest of the levee bank as well as across the slopes down to the river. The individual clumps were placed no closer to each other than 10m
ie. at a maximum density of 2500 plants/ha. However, the typical planting density on most sites would not be expected to exceed 1500 plants/ha. Where extensive areas were currently free of any vegetation, a lower planting density was employed initially, with infill plantings following the first wave of established clumps of trees. Some limited areas of the crests of the riparian levee banks were planted to drier forest communities of *Alphitonia excelsa*, *Eucalyptus maculata*, *E. crebra* and *E. moluccana*. In some instances, these areas were bare of trees. In such circumstances, the density of planting in the clumps did not differ from other riparian plantings, but it was necessary to increase the number of clumps planted per hectare.

Planting design for the drainage lines was similar to that of the riparian strips except that there were no gaps to fill and the clumps were composed of only 2-3 plants and designed to eventually form a contiguous belt of vegetation fringing the drainage alleys. The main species to be utilised for these areas were tree or shrub species. Ground cover species are expected to establish through natural accretion of native species following development of the forested corridors along the drainage lines. The better alluvial soils have the following species: *Callistemon salignus*, *C. viminalis*, *Casuarina cunninghamiana*, *Eucalyptus robusta*, *E. tereticornis*, *Melaleuca bracteata*, and *M. quinquenervia*. Less fertile sites with soils known to have potential salting problems or existing salinity apparent were planted with a similar suite of species, but with the addition of some more salt tolerant species viz: *Callistemon salignus*, *Casuarina glauca*, *Eucalyptus camaldulensis*, *E. moluccana*, *E. robusta*, *Melaleuca bracteata* and *M. quinquenervia*.

Where a shrub layer was desirable, *Melaleuca linariifolia* and *M. nodosa* were utilised for both soil types. Some drainage lines had a requirement for a ground cover species if they were likely to be subject to regular run-off. The use of shade tolerant pasture species may be preferred in these situations following future farm management reviews. Planting densities will not be as high as the riparian areas with a maximum of 600-800 plants/ha (2-3 individuals spaced at approximately 5, 10 or 15 m intervals). Similar densities were utilised for the pondage areas, although landscaped areas were less dense (500-700 plants/ha). Regular spacing will be avoided so that more dense copses of plants may be established on sites suspected of requiring a more rapid establishment of a stable, tree cover.

The primary focus of the forestry strips was to convert water and nutrients supplied in the form of effluent irrigation into commercial sawn timber. The biomass thus produced can be utilised by sawmillers and other wood processors in the region as well as meeting some of the local residents' needs for products such as firewood from coppice growth following the first harvest. The strips were established as two parallel rows of trees evenly spaced (5m apart) with 5m between individuals in adjacent rows. The two rows will be offset so that the trees will be alternate to each other to reduce competitive interactions and assist in management and harvesting. This will result in a planting density of 380-400 trees/ha. This is the only planting which will be regular in its configuration.

The on-going monitoring of the relative growth and survival performance of all plantings will be enhanced by a proposed research project which will detail the nutrient and water uptake and content of pasture tree and shrub species. Models can then be derived from this data in conjunction with soil and water analyses to further improve the successful agroforestry aspects of this effluent disposal system. From these models, it will be possible to extrapolate
the results from this site to broader applications for on-site utilisation and disposal of effluent, both urban and industrial.

Of the above species planted on the site, the following are known food trees for koalas - *Eucalyptus camaldulensis*, *E. crebra*, *E. grandis*, *E. maculata*, *E. microcorys*, *E. moluccana*, *E. resinifera*, *E. robusta*, *E. tereticornis* and *Lophostemon confertus*. Many other species such as *Callistemon* spp., *Castanospermum australe* and *Grevillea robusta* act as attractants to nectar feeding birds and many species provide nectar and pollen for bees and other fauna. It is anticipated that the riparian areas in particular will increase in species diversity with natural accrual of species dispersed onto the site. This is a common method of utilising frugivores (seed dispersers specifically) to assist regeneration of degraded areas as detailed in Case Study 1.

The application of effluent across this range of sites will alter the edaphic factors such as soil moisture and transient nutrient status. This provides the opportunity mentioned previously to take advantage of these altered conditions. It should be cautioned that the same principle of "home spun is best" is applied in this scenario with respect to species selection across the range of existing and altered site conditions. No exotic tree or shrub species are utilised other than introduced pasture species in the agroforestry component of this on-site effluent disposal operation. This is the essential difference from the Noosa case study where local genotypes and cultivars of species of known occurrence and abundance are used as the basis for planting schemata. This difference is considered to be a critical component of the long term success of the agroforestry operation.

Whilst no introduced trees or shrubs have been utilised, there are a number of native species which are either not found in the local region or were not present in such numbers on the site previous to land clearance for the former grazing use of the property. Specifically, they include species such as *Melaleuca quinquenervia* (water use) and *Casuarina glauca* (water renovation). These species were chosen on the basis of their known environmental tolerances and ecophysiological capacities. Native species known to be environmental weeds in remnant vegetation such as *Eucalyptus torelliana* and *Schefflera actinophylla* were specifically excluded from any landscape or other plantings.

Native species from other regions were utilised due to their greater capacity for tolerance of the altered conditions within the effluent disposal areas and their known or perceived capacity for water use and remediation. These latter two areas are a continuing focus of research on the site. It is important to know which species are the most effective for removing nutrients and water resulting from the gelatine production process. Soil and ground water studies confirm the buffering capacity of the existing agroforestry system, but more precision is desired so that results might be more readily extrapolated to other similar situations. In coming months and years, the nutrient status of pasture and woody vegetation established on the site will be assayed to identify the precise utilisation of water and nutrients by the various species currently planted and others likely to be trialled in the future.

It is the altered site conditions which are seen in this instance as an opportunity rather than a constraint on species selection and agronomy. Current knowledge of the agronomy of many of our native species in agroforestry situations is albeit rather limited. Fewer limitations exist for an increasing number of native species utilised in landscaping of urban areas. Thus, with
the insight gained from our understanding of the natural tolerances and capacities of the native flora, design of landscaping schemata designed to capture water, sediments and nutrients on-site is now a more practicable option.

12 CONCLUSIONS

The two case studies have illustrated contrasting situations where our knowledge of the natural biota and its intimate relationship with edaphic factors has enabled designs to be developed which deal with pressing land management issues. Whether it be mitigation of current land use activities and rehabilitation of degraded landscapes or opportunities for on-site retention and disposal of effluent, the utilisation of the right plant in the right place can provide a biological solution which is readily miscible with current engineering designs. Further research is required to identify those species most efficient at bioremediation, water use and renovation in the latter case study, whilst we can rely on the expanding body of ecological and biogeographic knowledge of our native flora to deal with planting designs for the former study.

Urban landscapes are increasingly adopting such methodologies as above with runoff being utilised in artificial wetlands or constrained by engineering structures such as gross pollutant traps. These design features all point to an optimistic future where the creators of altered resource patterning and waste production are becoming more responsible and empowered to address these issues on-site. As the community at large benefits from these works, more equitable economic models are required so that more stakeholders and landholders will be prepared to implement these opportunities, and the success rates of such activities will be markedly improved in the future.

13 REFERENCES


ABSTRACT

Land disturbance by construction activities can increase soil erosion from 2 to 40,000 times the undisturbed rate with sediment being the principal transport mechanism for pollutant spreading.

In addition to Federal, State and Local Government statutory requirements, there is an increasing demand from the community for more effective and aesthetically pleasing erosion and sediment control measures in urban area.

During a storm turbidity is the most obvious sign of erosion which is caused by the fine silt and clay particles in the sediment runoff, whereas after the storm, public complaints are usually associated with the settlement of coarse sand and gravel particles. Thus effective on-site erosion and sediment controls will need to deal with the disturbance, transportation and settlement of both the fine and coarse sediment particles.

Background on erosion processes, conventional engineering technology and more recent developments in bio-engineering techniques in erosion and sediment control are presented. The emphasis is on the adaptation and selection guidelines of these techniques for the urban environment.

This paper aims to address the basic principles of urban erosion and sediment control and to provide an introduction to the various soil erosion and sediment control guidelines that are about to be published in Queensland.

KEYWORDS: erosion, sediment control, bio-engineering, engineering structures, groundcover drainage

1 INTRODUCTION AND OBJECTIVES

With increases in population and living standard, large areas of lands are converted each year to urban and industrial uses such as housing estates, shopping centres, schools, factories and infrastructures such as rail lines and expressways. During this period of conversion, land is disturbed and often exposed to water and wind erosion.

The extent of erosion depends on the soil type, land slope, climatic factors and construction methods. On-site erosion can delay work and increase cost while off-site effects such as air and water pollution can cause significant environmental damage.

The main objectives in soil erosion and sediment control in the urban environment are to prevent controllable erosion and to minimise off-site sediment damage. Soil conservation
measures and stormwater management techniques that prevent or minimise the effects of concentrated flow, reduce slope gradient and slope length, or provide protective ground cover, are the keys to effective erosion and sediment control.

In the short term the aim is to reduce or minimise the damaging effects of these forces on the bare surface, while the long term aim is to strengthen both the surface and the soil mass against these erosive forces. To be effective both engineering (constructed) and bio-engineering measures are needed. However, there is an increasing demand for bio-engineering techniques - particularly in the urban environment, not only for aesthetic reasons, but also because it is very cost effective in most situations.

2 THE NEED FOR URBAN EROSION AND SEDIMENT CONTROL

Land disturbance by construction activities has resulted in soil erosion increases from 2 to 40,000 times the preconstruction rate (Goldman et al., 1986) with sediment being the principal transport mechanism for a range of pollutants entering watercourses (Kingett Mitchell, 1992). Therefore, there is an urgent need for applying erosion and sediment controls during all soil disturbing activities.

2.1 Government Regulations

Both Federal and State governments now have strict statutory requirements to reduce/prevent damage to the environment including urban areas. But most importantly, all local governments will be required to have guidelines for their own localities to control erosion and sedimentation. For example the Brisbane City Council will soon release a Best Management Practice guideline for erosion and sediment control. This guideline was prepared for the Brisbane City Council by Griffith University (School of Environmental Engineering) and DPI (Marsh et al., 1995).

Complementing these guidelines will be the guidelines prepared by the Queensland Division of The Institution of Engineers, Australia, and a set of standard drawings prepared by the Queensland Division of the Institute of Municipal Engineering, Australia.

2.2 Structural Stability

Erosion can destabilise the structural stability of the land. Both structural and non structural techniques are needed and often they reinforce each other. For example, engineering designs and structures associated with stormwater management often require the support of bio-engineering methods which provide an important function because of their direct influence on the soil, both at the surface by protecting and restraining the soil, and at depth by increasing the shear strength of the soil mass.

2.3 Environmental Damage and Pollution

Many forms of erosion need to be controlled on a construction site including: sheet and rill erosion, gully and tunnel erosion and also landslip (mass movement). All of these forms of erosion can occur simultaneously on one site resulting in the washout of streets and
underground utilities, buried lawn and access roads, clogged drainage ditches and stormwater drains, and pollution to streams, beaches and coastal water.

2.4 Aesthetic Improvement

An eroded site is often ugly, and the term eco-vandalism has been used. While engineering structures provide structural stability, the functional and harsh look of many of these structures can be “softened” by incorporating bio-engineering techniques in their design.

2.5 Commercial Value

A well landscaped and stable development will certainly improve the commercial value of a site.

3 CAUSES AND REMEDIAL MEASURES

Table 1 summarises the processes and control measures needed for the main types of erosion.

<table>
<thead>
<tr>
<th>Type of Erosion</th>
<th>Causes</th>
<th>Resulted From</th>
<th>Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>High velocity at ground level</td>
<td>Lack of surface protection including barriers</td>
<td>Adequate surface cover or barriers</td>
</tr>
<tr>
<td>Water</td>
<td>Rain drop impact</td>
<td>Lack of surface cover</td>
<td>Adequate cover (&gt;75%)</td>
</tr>
<tr>
<td></td>
<td>Overland flow (runoff)</td>
<td>Rainfall &gt; infiltration</td>
<td>Increase water infiltration</td>
</tr>
<tr>
<td></td>
<td>Landslope</td>
<td>High flow velocity</td>
<td>Reduce velocity by cover and barrier</td>
</tr>
<tr>
<td></td>
<td>Erodible soil</td>
<td>Clearing steep slopes</td>
<td>Soil conservation measures e.g. contour banks, vegetative hedges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land shaping (batters)</td>
<td>Engineering and vegetative measures (hydromulching etc)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physical and chemical properties</td>
<td>All of the above</td>
</tr>
</tbody>
</table>

Both wind and water can cause soil erosion, but in Queensland significant wind erosion is restricted to arid areas. On the other hand, water erosion is widespread from the wet and dry tropics of the north to the sub tropics of the south.

In general, erosion caused by water can occur in one or some combination of the six forms described below.
3.1 Raindrop Splash Erosion

The impact of raindrops on bare soil surfaces detaches soil particles which can be removed by runoff water. This is a major source of turbidity in stormwater runoff.

3.2 Sheet Erosion

This is the uniform removal of soil in thin layers from sloping land.

3.3 Rill Erosion

Small and shallow channels formed from the concentration of flow on uneven surfaces.

3.4 Gully Erosion

These are channels larger and deeper than rills.

3.5 Land Slide

This is the mass movement of soil on unstable slopes during high rainfall periods.

3.6 Stream Bank Erosion

This form of erosion in urban environment often results from changes in catchment hydrology.

4 EROSION AND SEDIMENT CONTROL TECHNIQUES

To satisfy all the needs listed above and to provide effective long term stability, bio-engineering, non-engineering and traditional engineering techniques can be used.

In the context of this paper:

• bio-engineering means the use of vegetation for erosion control by itself and to reinforce traditional engineering structures.

• engineering methods involve the design and application of traditional structures needed for stormwater management, runoff control and steep slope stabilisation.

Every site differs in topography, soil type and in the activity to which it is subjected. Therefore, control measures must be tailored for each individual site.

4.1 Bio-engineering Measures

Due to both the aesthetic effect and to the community concern about the environment, bio-engineering or eco-engineering is becoming a preferred option of land stabilisation, especially in the rural environment. Vegetation alone will not eliminate all the problems of erosion and
sedimentation, but when used in conjunction with good engineering practices, these problems will be greatly reduced.

In general, to be effective as a control measure, plant species used in erosion and sediment control should have the following desirable characteristics:

- Fast and easy establishment under harsh and often hostile environments.
- Fast growing to provide surface cover and root enforcement.
- Fast spreading of runners, stolons etc.
- Deep rooted.
- Tolerant to drought, heat, frost and other adverse conditions.
- Fast recovery following rain, frost etc.

The three main roles of bio-engineering techniques in soil erosion and sediment control are:

- Soil surface protection
- Soil mass reinforcement, and
- Water spreading and sediment trapping

4.1.1 Soil surface protection

Vegetative cover provides the most effective, both aesthetically and economically, form of protection against water erosion on disturbed lands particularly steep slopes. Ciesiolka et al., (1987) highlighted the role of vegetative cover in protecting degraded agricultural lands. The same can be applied to disturbed lands within the urban environment.

The major beneficial effects of vegetative cover are:

- **Interception:** Ground cover provided by foliage and plant residues absorbs rainfall energy, preventing soil detachment by raindrop splash and also by retaining a proportion of rainfall thus reducing the quantity of rainfall reaching the soil surface.

- **Infiltration:** Soil moisture depletion through plant water use and improvement of soil porosity by living vegetation improves water infiltration thus delaying the onset of runoff and reducing the quantity of runoff water.

- **Retardation:** Plant stem and foliage increase surface roughness thus retarding overland flow of water and reducing wind velocity at the soil-air interface.

A good gauge of the influence of vegetation in preventing soil erosion can be obtained by examining the Universal Soil Loss Equation (USLE) (Wischmeier & Smith 1965). The annual soil loss from a site is predicted according to the following relationship.

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\[ A = R \times K \times LS \times C \times P \]

where:  
- \( A \) = computed soil loss (e.g. tonnes per hectare per year)
- \( K \) = soil erodibility value
- \( LS \) = slope-length and steepness factor
- \( C \) = vegetation factor, and
- \( P \) = erosion control practice factor

The USLE provides a method of estimating soil losses while also providing information on the relative importance of each of the parameters in affecting erosion. With this information the extent to which each factor can be changed or managed to limit soil losses can be estimated. The climatic (R) factor, topographic (LS), and erodibility (K) factor only vary within one order-of-magnitude. The vegetation or cover (C) factor, on the other hand, can vary over several orders-of-magnitude as shown in Table 2. Moreover, unlike the other factors, the cover (C) factor can be radically decreased by the selection, method of installation, and maintenance of a particular cover system. Factor C values tend to change with time following certain types of surface treatment such as mulching, seeding, and transplanting. For example, factor C values for grass may decrease from 1.0 (for fallow, bare ground) to about 0.001 between time of initial seeding and full establishment with a dense, grass sod.

### Table 2  
**Cover index factor (C) for different ground cover conditions**

<table>
<thead>
<tr>
<th>Type of Cover</th>
<th>Factor C</th>
<th>Percent$^{(2)}$ Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>None (fallow ground)</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Temporary seedings (90% stand):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ryegrass (perennial type)</td>
<td>0.05</td>
<td>95</td>
</tr>
<tr>
<td>Ryegrass (annuals)</td>
<td>0.1</td>
<td>90</td>
</tr>
<tr>
<td>Small grain (annual rye)</td>
<td>0.05</td>
<td>95</td>
</tr>
<tr>
<td>Millet or sudan grass</td>
<td>0.05</td>
<td>95</td>
</tr>
<tr>
<td>Field bromegrass</td>
<td>0.03</td>
<td>97</td>
</tr>
<tr>
<td>Permanent seedlings (90% stand):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sod (laid immediately)</td>
<td>0.01</td>
<td>99</td>
</tr>
<tr>
<td>Mulch:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay rate of application, tonnes/hectare:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; 0.5&quot;</td>
<td>0.25</td>
<td>75</td>
</tr>
<tr>
<td>&quot; 1.0&quot;</td>
<td>0.13</td>
<td>87</td>
</tr>
<tr>
<td>&quot; 2.0&quot;</td>
<td>0.02</td>
<td>98</td>
</tr>
<tr>
<td>Small grain straw</td>
<td>2.0</td>
<td>98</td>
</tr>
<tr>
<td>Wood chips</td>
<td>6.0</td>
<td>94</td>
</tr>
<tr>
<td>Wood cellulose 1.5</td>
<td>0.06</td>
<td>90</td>
</tr>
<tr>
<td>Fibreglass</td>
<td>1.5</td>
<td>95</td>
</tr>
</tbody>
</table>

$^{(1)}$From USDA Soil Conservation Service, 1978

$^{(2)}$Percent soil loss reduction as compared with bare ground
4.1.2 Soil mass reinforcement

The protective role of vegetation in the stability of slopes has gained increasing recognition (Coppin et al., 1990). Greenway (1987) provides a good summary of the hydromechanical influences of vegetation as related to mass stability. These influences are considered whether they exert a beneficial or adverse effect.

The beneficial effects of woody vegetation on the mass stability of slopes are listed below:

- **Root reinforcement**: Roots mechanically reinforce a soil by transfer of shear stress in the soil to tensile resistance in the roots.
- **Soil moisture depletion**: Evapo-transpiration and interception in the foliage can limit the buildup of positive pore water pressure.
- **Buttressing and arching**: Anchored and embedded stems can act as buttress piles or arch abutments to counteract downslope shear forces.
- **Surcharge**: Weight of vegetation can (in certain instances) increase stability via increased confining (normal) stress on the failure surface.

The primary adverse influence on mass stability associated with woody vegetation is the concern about external loading and the danger of overturning or uprooting in high winds or currents. This problem is likely to be more critical for large trees growing on relatively small dams and levees. The practice of coppicing is widely used in Europe to mitigate this adverse effect of vegetation on slope stability. Coppicing is a timber harvesting or pruning method that involves the production of new trees from old stumps. This practice leaves the root system intact while generating smaller, multiple stems from the cut area (Gray, 1995).

4.1.3 Water spreading and sediment trapping

Thick vegetative barriers retard flow velocity and spread concentrated flow across the slope. When flow velocity is reduced, both bed load and suspended sediment load in runoff water will deposit hence a vegetative barrier is a very effective sediment trapping measure.

The use of vegetative barriers in sediment control is not new, but due to the lack of suitable species, its application has been very limited. Recently Vetiver grass (*Vetiveria zizanioides*) has shown to be particularly suitable for this purpose. Queensland and overseas studies have shown that Vetiver, when planted as hedges on the contour, spreads concentrated runoff water and traps its sediment load. Therefore the planting of this species can replace or supplement some engineering measures particularly on steep slopes (Truong et al., 1995).

4.1.4 Functional roles of vegetation

The envisaged role of vegetation on a slope largely dictates the choice of species and their subsequent management. Clear role definition is important because it has major cost, ground preparation and timing implications (Table 3). Most roles, other than grass swards for surface
stabilisation, require more than one growing season for implementation and also require longer-term management implications (Bayfield, 1995).

Table 3  Some functional roles of vegetation on slopes (Bayfield, 1995)

<table>
<thead>
<tr>
<th>Role</th>
<th>Vegetation Type</th>
<th>Ground Preparation</th>
<th>Time to Establish</th>
<th>Management and Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface stabilisation</td>
<td>grass</td>
<td>minimal</td>
<td>3 months</td>
<td>cut 2-6 times/year</td>
</tr>
<tr>
<td>Deeper stabilisation</td>
<td>trees/shrubs</td>
<td>planting in slots or ledges</td>
<td>2-10 years</td>
<td>coppice or thin after 5-15 years</td>
</tr>
<tr>
<td>Amenity: wildflower swards</td>
<td>grasses and forbs</td>
<td>removal of fertile or weedy topsoil</td>
<td>2-3 years</td>
<td>cut 1-2 times/year</td>
</tr>
<tr>
<td>Dwarf shrubs</td>
<td>trees/shrubs</td>
<td>nurse crop of grasses on infertile soil</td>
<td>3-8 years</td>
<td>burn/cut on 10-15 year cycle</td>
</tr>
<tr>
<td>Amenity: trees/shrubs</td>
<td>trees/shrubs</td>
<td>open planting in pockets of topsoil</td>
<td>5 years</td>
<td>prune/thin/fell when too large (10-50 years)</td>
</tr>
<tr>
<td>Noise: attenuation/screening</td>
<td>trees/shrubs</td>
<td>close planting in topsoil</td>
<td>2-5 years</td>
<td>coppice or thin when too large (5-20 years)</td>
</tr>
</tbody>
</table>

4.2  Engineering Methodology

The seven principles of effective soil erosion and sediment control are:

Minimise disturbance;
Drainage control;
Erosion control;
Sediment control;
Revegetation;
Field implementation; and
Development of erosion and sediment control programs.

As revegetation has been presented earlier, this section will discuss the remainder.

4.2.1  Minimise disturbance

Where possible, the development should make the most of existing topography to avoid extreme land shaping and surface modifications. Retaining existing vegetation cover and limiting site disturbance will also reduce on-site erosion and the maintenance requirements of major sediment control structures.

The overall aim is to reduce the Total Area-Time-Exposure = \[ \Sigma (\text{area of disturbance} \times \text{exposure time}) \].

 Appropriately staged earth and construction works can reduce the soil exposure time, as well as the total area of soil exposed at any one time, it can also significantly reduce construction
delays during wet weather. Where possible, major land disturbances should be scheduled for
the least erosive periods of the year. Developments should also be staged so that any
disturbance is confined to manageable areas, especially during the wet season.

In locations where erosion risk maps have been prepared as part of the planning process,
disturbance of designated “high” or “extreme” erosion risk areas should be avoided, especially during the wet season. Any planned disturbance to extreme erosion risk areas should be reviewed with extreme caution by developer, designers and approving authorities. Protection of high-risk, non disturbance areas may require fencing and/or well-displayed warning signs.

4.2.2 Drainage control

A significant proportion of the sediment runoff from construction sites can result from just
one or two storms per year. Therefore, it is generally ineffective to rely solely on “low-flow” type sediment controls because these controls may fail during the 1 in 1 year or 1 in 2 year storm events.

Proper stormwater management forms the basis of most erosion and sediment control programs. The overriding principles for managing stormwater within an urban development relate to the control of runoff volume, velocity and location, as well as the safe disposal of stormwater onto stable areas.

- **Runoff volume**: The efficiency of most erosion and sediment control measures can be improved by a reduction in either the peak discharge or total discharge volume. Runoff volume can be reduced by the diversion of up-slope runoff around the work site, by limiting the introduction of impermeable surfaces, and by increasing groundwater infiltration.

  A variety of measures for detaining stormwater flows are available to offset increases in runoff volume and peak discharge. Roof tops, parking lots, playing fields, roadsides, ponds and enlarged stormwater channels can provide storage capacity for stormwater runoff. Permanent or temporary detention basins can reduce peak runoff discharge, aid groundwater recharge, and provide limited treatment of stormwater pollution. Non-contaminated sealed surfaces, such as roofs, should be connected to the permanent drainage system as soon as they are constructed.

- **Runoff velocity**: The adverse effects of high runoff velocity can be reduced by either reducing stream velocity, or by increasing the scour resistance of the surface material.

  Stream velocity can be reduced by:

  - Reducing the depth of flow (y or R)
  - Reducing bed slope (S)
  - Reducing discharge (Q), or
  - Increasing the surface roughness (Manning’s n)
Noting the above parameters are used in the Manning's equation:

\[ Q = \text{Velocity} \times \text{Area (A)} = \left(\frac{1}{n}\right) \times A \times R^{\frac{2}{3}} \times (S_0)^{\frac{1}{2}} \]

Scour resistance of the surface material can be increased by:

- Lining the soil surface with an erosion resistant material (riprap, geotextile fabrics, etc.)
- Improving the growth and cover of vegetation (good pre-planting soil preparation)
- Reinforcing existing vegetation cover (geotextile mats)
- Improving the soil structure (adequate soil testing and good on-site soil management)

- **Runoff location:** It is very important to consider both the location of the many overland flow paths on a work site, as well as the often tortuous travel path of bypass flow. Bypass flow usually occurs when a sediment trap is blocked with debris or sediment, or when the storm exceeds the structure's design rainfall intensity.

Due to the damage that can be caused by bypass flows, on-grade gully inlet sediment traps should be designed and used with extreme caution, especially during the wet season. Consideration should always be given to the adverse effects of the hydraulic failure of any drainage, erosion or sediment control structure. Wherever possible, stormwater drainage paths, as well as bypass flows from sediment traps, should not discharge onto, or near, unstable areas or fill slopes.

On-site drainage patterns generally have two major components: overland flow and concentrated channel flow. Both components **must** be addressed in order to achieve effective drainage and erosion control. To achieve this, both existing and proposed site drainage patterns must be known, especially the points of flow entry to, and exit from, a work site. If existing and final flow paths are clearly defined on site plans, then their successful incorporation into the planning and design phases will be more readily achieved.

- **Diversion of runoff:** One of the most effective forms of erosion and sediment control is the diversion of unpolluted, up-slope, stormwater runoff around exposed surfaces or contaminated areas. To divert up-slope waters, Perimeter Banks, Diversion Channels or Catch Drains can be installed adjacent to up-slope property boundaries, and above batters, quarried areas, gullies and partially completed overland flow channels.

The size of major sediment traps, such as sediment basins and ponds, depends on both the total hydraulic inflow rate and the settlement characteristics of the sediment. They are therefore sized on the effective catchment area and **not** the area of disturbed land. Thus, it is beneficial for uncontaminated stormwater runoff to be diverted around the site in order to reduce the effective catchment area directly connected to the basin.

High and extreme erosion risk areas should also be protected from unexpected rainfall by installing temporary Diversion Channels or Catch Drains at the end of each day's
work. In addition, Catch Drains can be used to divide large areas into hydraulically manageable subcatchments.

- **Timing:** The early construction of the temporary drainage system, and preferably also the permanent stormwater management system, should be the general aim when planning a development layout and construction schedule. These controls should be functional and stable before up-slope earthworks commence. This will reduce soil erosion on completed down-slope works, and will allow upslope sediment-laded runoff to be directed to sediment traps.

All active drainage channels should be appropriately stabilised as soon as they are constructed. Channels can be initially stabilised with either velocity control structures such as Check Dams, or with scour-resistant linings such as erosion control mats, or turf.

- **Outlet structures:** Outlet protection may be required on pipe and channel outlets to reduce discharge velocity and minimise bed and bank scour. Pipe outlets may need to be set back into the watercourse bank to allow for future bank erosion or stream migration. Consideration should also be given to the eventual conversion of an outlet structure into a “mini-wetland” type outlet. Such outlets can become effective low-flow treatment systems.

When riprap is used for outlet protection, a minimum size of 200 mm is normally recommended. Smaller rock sizes may be dislodged and migrate downstream causing bed erosion and damage to aquatic vegetation. Disturbances to natural watercourses and riparian zones should be minimised wherever possible.

### 4.2.3 Erosion control

Erosion control measures should be incorporated into all stages of a development to minimise sediment generation. Erosion control is not just a post construction activity.

It is generally desirable and more cost-effective to prevent erosion than to concentrate on trapping sediments. This applies particularly to areas where the soils have a high proportion of silt and clay size particles, or where the soils are highly dispersive. Erosion control measures are an effective means of on-site sediment control, while drainage control is the most effective means of erosion control. However, good drainage controls will not prevent soil erosion and turbidity caused by raindrop impact.

For many soils with a high clay or silt content, the control of erosion at the source is the only feasible strategy for minimising downstream impacts. It is extremely difficult and expensive to trap these fine sediments once they have been disturbed and are in suspension.

- **Ground cover:** Soil erosion can be greatly reduced by covering the soil to protect it from the effects of raindrop impact, overland flow and wind. Exposed flat areas with medium to high clay content soils will require protection from raindrop impact, especially during summer periods when storms of high rainfall intensity are expected. Medium grade slopes require protection from both raindrop impact and the effects of
concentrated stormwater runoff. Bank slopes steeper than 4(H):1(V) will generally require the protection of erosion control mats during revegetation, unless turf is used.

Soft ground covers are the most common form of erosion control and are used on moderate slopes not exposed to concentrated overland flow. Soft ground covers include vegetation, mulch, and a large variety of naturally-based or synthetic erosion control mats.

Existing vegetation should be utilised as permanent or temporary buffer zones wherever possible. If tree clearing is required well in advance of future earthworks, then tree clearing methods that will minimise disturbance to the existing ground cover should be employed.

On recently vegetated or exposed earth surfaces, erosion protection can be increased by roughening the soil surface to increase infiltration and delay the formation of rutting. Surface roughening can be applied by simply walking a tracked vehicle up and down an exposed slope. This technique can be used on subsoils as well as topsoils, both before or after seeding.

4.2.4 Sediment control

Sediment control measures should be functional before up-slope work commences. Generally these measures are the first controls established on-site, followed by drainage controls, site clearing and then the stockpiling of topsoil.

A sediment trap generally will be required at or near the final point of discharge from the construction site. Consideration should of course be given to the trapping of sediment at other points on the site so as to prevent blockages of the site’s drainage system. Sediment should be trapped as close to its source as possible.

The choice of which sediment control technique to use should be based not only on establishment cost, but also on its maintenance and possible replacement cost. Regular maintenance will be required after each runoff-producing storm event. Suitable maintenance access will need to be provided to these control measures.

- **Coarse and fine sediments:** The trapping of coarse sediments on a construction site is possibly the easiest task in on-site erosion and sediment control. While it is very difficult and often impractical to stop turbid runoff from leaving a work site, it is usually physically and economically practical to prevent the off-site transportation of coarse sediments from storms up to the 1 in 1 year to 1 in 2 year events.

The effectiveness of the various sediment control measures generally depends on the nature of the source material. This material can be either the topsoil or subsoil depending on the type and stage of the earthworks. Many Australian subsoils are highly dispersive making them difficult to control when disturbed.

Dispersive soils are structurally unstable in water and readily disperse into their constituent particles (sand, silt and clay), with those particles finer than about...
0.005mm (clay and fine silts) staying in suspension for long periods. Substances such as gypsum often need to be added to sediment-laden waters to induce flocculation, and finally particle settlement.

Another important attribute of soils that can influence the effectiveness of sediment retention structures is the proportion of particles finer than 0.02 mm. Particles that are finer than 0.02 mm are relatively difficult to trap in sediment basins without the use of chemical dosing and sufficient settlement time. These particle sizes also readily pass through most sediment traps such as sediment fences. Thus soils containing a high proportion of fine soil particles (say, 33% < 0.02 mm) require a greater emphasis on erosion control measures to offset the expected low efficiency of the on-site sediment controls.

The most efficient and economical method for controlling fine sediments is good site and soil management, and effective on-site drainage and erosion control. Alternative control techniques include: chemically treated sediment basins, and the use of water pollution control ponds, wetlands and in some cases, lakes (e.g. the ACT).

- **Site and soil management:** Effective site management includes the appointment of a responsible on-site officer; the posting of on-site erosion and sediment control requirements at the construction entrance and site office area; controlling site entry and on-site traffic movement; dust control; street sweeping (not washing), and possibly the most difficult and frustrating activity, coordinating and controlling the installation of the utility services (electricity, gas, communication cable, etc.).

Sediment tracked onto public roads by construction vehicles is one of the most common sources of public complaint. Sediment runoff can also occur as a result of inadequate drainage controls on access roads. The resulting off-site sedimentation can cause traffic safety hazards as well as problems to the stormwater network and receiving waters. Entry and exit points should be limited to the minimum number possible.

Entrance and exit points should be stabilised with coarse gravel and stone, or have a vibration grid installed. Overland flow should be directed away from the road surface. Stormwater runoff from the entry/exit control points should be directed to a secondary sediment trap or filter system. Sites containing heavy clay soils, or sites with the potential to damage critical environmental areas, may require the installation of a wash rack in order to control the tracking of sediment onto public roads.

All construction roads, parking areas and entry/exit points should be stabilised as soon as possible. Roads and access tracks should have adequate drainage, and on-site traffic should be limited to designated routes to limit rutting, erosion, and the tracking of sediment off the site.

Site generated dust problems are usually controlled with the use of water trucks. Dust may also be controlled with temporary vegetation, mulch or erosion control blankets.
Effective soil management includes the stripping and stockpiling topsoil; drainage controls up-slope of stockpiles; sediment fences and/or a catch drains down-slope of stockpiles; subsoil treatment and scarified surface treatment prior to the application of topsoil; and adequate soil treatment prior to revegetation.

- **Sediment traps**: Most sediment traps or barriers operate by ponding water and allowing gravity-induced particle settlement. On small sites, these measures can be the last line of defence and thus should be monitored closely for their effectiveness. The existence of excessive amounts of sediment within these traps may indicate ineffective on-site erosion or drainage controls. In general, most sediment traps are designed for “sags” (low point on the flow path) as opposed to “on-grade” (inlet along the slope) situations. These traps should allow for full sediment blockage and 100% flow bypassing.

A Sediment Fence should be constructed to temporarily pond water upstream of the fence in order to allow the settlement of coarse sediments. Sediment fences that are operated as filtration systems can be subject to regular blockage and structural failure. In general, sediment fences have little impact on fine silts and clay particles, and as such, the often used term “silt fence” is now considered misleading. Wherever possible, sediment fences should be located along the contour and at least 2 m from the toe of a constructed embankment. If located against the contour, sediment fences will concentrate overland flow directing it along the fence line. This may lead to failure of the fence line and/or concentrated bank erosion.

Sediment Basins and Ponds require special attention because of their size and potential to release large quantities of sediment if damaged. Sediment basins are usually the last line of defence. Their location on the site should be given special consideration during site planning. The final use of the land on which the basin is situated also requires special consideration.

4.2.5 Field implementation

The effort and expense of creating an Erosion and Sediment Control Program can all be wasted if the program is neither implemented, adequately supervised, nor suitably maintained. A lack of maintenance is possibly the most common reason for the failure of an erosion and sediment control program.

4.2.6 Erosion and sediment control program

Erosion and Sediment Control Programs should include, Soil and Water Management Plans, Supporting Documentation and Specifications and Construction Details. Before preparing an Erosion and Sediment Control Program, the designer should have a sound understanding of the requirements of state and local legislation, site planning principles and the principles of erosion and sediment control.

An Erosion and Sediment Control Program outlines how erosion and the resulting sediment will be controlled during and after the land disturbance. The Program must be designed by someone capable of firstly, visualising and understanding the changes that will occur during
the development; secondly, planning and designing the appropriate control measures; and finally, effectively communicating this information.

These programs and associated plans may range from a simple plan with accompanying notes for small sites (say <0.1 ha), to detailed comprehensive plans for a complex development on large sites (say >1 ha) or in areas of high ecological value. An Erosion and Sediment Control Program should form part of the final engineering design drawings, and should be documented in the Schedule of Rates, or Bill of Quantities.

5 SPECIFIC EROSION AND SEDIMENT CONTROL MATERIALS AND TECHNIQUES

5.1 Materials for Erosion Control

5.1.1 Chemical surface stabilisers

Most chemical stabilisers are soil binders, providing a thin surface crust. The advantages of these methods are that they provide instant protection, and are suitable for temporary stabilisation while the construction progresses. They are generally most effective against dust control at industrial sites, and sand blasting and movement on canal estate developments. These sites can be stabilised vegetatively later.

The main disadvantage of these chemicals is that the crust must remain intact to be effective. Therefore, no traffic of any kind is permitted. In addition specialised machinery is generally needed for their application.

5.1.2 Mattings (Fibrous netting materials)

Mattings are essential tools in land stabilisation. There are two types, one for surface laying and the other to be buried under the topsoil.

The ideal matting should provide:

- High percentage surface cover to protect the soil surface from erosive rainfall and runoff;
- Thick cover to intercept splashed soil particles;
- Spongy texture with open space throughout the material to allow light penetration and seedling emergence; and
- Highly absorptive and flexible after wetting so the matting remains a good contact with the soil surface it is protecting.

The aim of the buried type of matting is to hold the topsoil on steep slopes. They are normally made of bulky and spongy synthetic materials. The matting is pinned and covered with topsoil. This matting is not suitable in areas with high intensity rainfall as it is not very effective in retaining the top soil under heavy rain.
5.1.3 Mulching

Mulching is the use of plant residue or other suitable material to cover the soil surface. Mulch has the same effect on soil erosion control and vegetation establishment as matting. In fact matting is a mulch substitute which is normally more expensive but commonly used when mulch is not available, or is unsuitable for steep slopes.

Mulch materials include sugarcane bagasse, a mixture of sawdust and planer shavings, shredded newspaper, hay, straw, paper pulp and fibreglass.

5.2 Sediment Control Practices

5.2.1 Sediment controls suitable for sheet flow include: (in general order of preference)

- **Buffer zones**: highly desirable when land is available.

- **Sediment fences**: interception of sheet flow, widely used on most disturbed slopes and adjacent to impervious areas and building sites which are subject to sediment-laden runoff; also used to filter concentrated flow within recently constructed roadside channels.

- **Straw bales**: straw is usually used in preference to hay. Bales are generally only suitable when sediment fences are considered inappropriate.

- **Grassed filter strips**: adjacent to impervious surfaces subject to sediment-laden runoff including new subdivision roads and some pathways; adjacent to drainage chutes, and also used as sheet flow filters for newly seeded embankments.

5.2.3 Sediment controls suitable for concentrated flow includes: (order of preference generally governed by site conditions)

- **Brushwood banks**: to stabilise existing gully erosion.

- **Filter dams and sediment weirs**: filter dams should be incorporated in most diversion channels carrying sediment-laden runoff and in newly formed roadside drainage channels; sediment weirs may be used to stabilise gully erosion.

- **Gross pollutant traps**: upstream of lakes, wetlands, sensitive environmental areas and some waterways.

- **Sediment barriers**: used adjacent to sag or field inlets and culvert inlets - they have questionable value adjacent to on-grade roadside inlets unless bypass flows can be adequately controlled.

- **Sediment basins and ponds**: usually located at the lowest elevation of the development.
6 SELECTION CRITERIA FOR BEST MANAGEMENT PRACTICES (BMP)

A wide range of erosion and sediment control problems has resulted in a variety of technology designed to provide solutions. How is the final decision made on which technique to use? Should cost always be the limiting factor? Can dissimilar approaches be compared for the same application?

Harding (1995) developed an Erosion Control Benefit Checklist (ECBC) to determine the most appropriate BMP for each situation.

The ECBC attempts to separate and take account all the variables which impact the decision making processes. The variables are:

- Acceptance: environmental acceptance, visual impact, institutional acceptance;
- Cost: material, preparation, installation;
- Effectiveness: density, runoff, sediment yield etc.;
- Installation: durability, strength, ease etc.;
- Vegetation: native species, germination, growth rate etc.; and
- Operation: maintenance, irrigation etc.

7 CONCLUSIONS

Erosion caused by land disturbance in urban area can be very severe and damaging. However these damages can be effectively controlled when appropriate bio-engineering and conventional engineering technology are properly planned and implemented.

8 REFERENCES


IMPROVING URBAN STORMWATER QUALITY

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ABSTRACT

This paper gives a brief overview of water quality related urban stormwater issues. A data summary from studies overseas (USA), other Australian States and Brisbane, which indicates the quality of stormwater runoff as an event mean concentration, is used to demonstrate the problem. The principles of stormwater management are discussed and a range of management actions are presented. A diverse range of stormwater best management practices is evolving across Australia. In this short presentation it is impossible to describe all of these practices, their advantages and disadvantages, however, there are a number of manuals from other states which have all the information needed to design and implement these best management practices. These manuals are identified in the paper and will be on display at the course. Ongoing monitoring and maintenance are essential elements in implementing a successful stormwater management system. A summary of what is currently being done in south east Queensland is presented.

KEY WORDS: stormwater, runoff, water quality, best management practices, monitoring,

1 INTRODUCTION

In the past urban drainage systems have been regarded as functional entities for efficient collection and disposal of storm runoff water, with little intrinsic value. There is, however, an increasing recognition of the intrinsic value of urban drainage systems, and a recognition that management should include an emphasis on enhancement and protection of the urban aquatic ecosystem. Conflicts have also arisen between developers and community over the downstream effects of urban development, particularly the impacts on water quality in environmentally sensitive waterways.

Appropriate management of the urban drainage system needs a multidisciplinary approach. The drainage system must still fulfil the traditional role of preventing and controlling flood flows in urban areas, as well as the growing recognition of the intrinsic values of the urban aquatic ecosystem. Catchment hydrology, water quality, catchment soil characteristics, catchment landuse, riparian vegetation, and local fauna and their habitat all influence the nature and health of the ecosystems. An understanding of the relevant processes involved in each of these disciplines is required in order to develop an integrated resource management approach to stormwater management.

This paper addresses the issue of improving the quality of stormwater runoff through better planning and management practices. A range of data is presented and discussed in order to demonstrate that there is a problem, especially in terms of nutrient inputs to our waterways. The principles of stormwater management are discussed and a range of management actions
are presented. A summary of what is currently being done in south east Queensland is also presented.

2 DEFINING THE PROBLEM

2.1 Existing Stormwater Quality Data

2.1.1 Overseas data

The most comprehensive study of stormwater pollution from urban areas was the 'National Urban Runoff Program' (NURP) carried out in the United States in the early 1980s. The database for this project came from 81 sites located in 22 cities throughout the United States, and included data from more than 2300 storm events. For the most part, the presented data consisted of flow weighted average concentration of contaminant, the 'Event Mean Concentration' (EMC). (see Table 1 for a summary. The data in the table was selected for the purpose of comparison with readily available data from Brisbane and other Australian centres.)

Table 1 Summary of median Event Mean Concentration (EMC) for selected National Urban Runoff Program (USA) data

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Urban Median</th>
<th>Urban CV</th>
<th>Open Space Median</th>
<th>Open Space CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total suspended solids</td>
<td>101</td>
<td>0.96</td>
<td>70</td>
<td>2.9</td>
</tr>
<tr>
<td>Biochemical oxygen demand</td>
<td>10</td>
<td>0.41</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>0.383</td>
<td>0.69</td>
<td>0.121</td>
<td>1.70</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>1.9</td>
<td>0.73</td>
<td>0.965</td>
<td>1.00</td>
</tr>
<tr>
<td>Lead</td>
<td>0.144</td>
<td>0.75</td>
<td>0.030</td>
<td>1.50</td>
</tr>
</tbody>
</table>

(Note: All data in mg/L; CV stands for coefficient of variation, standard deviation over mean)

The NURP final report found little, if any, statistically significant differences in constituent EMCs among geographic regions, among various cities, or among storm events at a given site. The results appeared to be relatively uniform across the United States, although there appears to be significant differences between results from urban areas and those from open space/non-urban areas. The findings tended to support the need for local data before making what may be far reaching and expensive water quality management decisions.

2.1.2 Australian Data

Sharpin (1995a) summarised stormwater quality characteristics from both urban and non-urban catchments in south-eastern Australia, based on raw data from a number of published studies. Only data from events with water quality samples taken during the rising limb, peak and falling limb of the hydrograph were used in the investigation.
While Sharpin found that there was no distinct trend for urban EMCs (particularly nutrients) to be consistently and significantly higher than those from rural areas, the contrasting hydrological processes are likely to result in higher and more consistent pollutant loads from urban areas compared with rural catchments.

Some of these results, based on urban catchments only, are summarised in Table 2.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Stormwater quality characteristics from urban catchments, south-eastern Australia showing Event Mean Concentration (EMC) in mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constituent</td>
<td>Median EMC</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>240</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>0.37</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>6.5</td>
</tr>
<tr>
<td>Oxidised nitrogen</td>
<td>2.65</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>3.1</td>
</tr>
</tbody>
</table>

2.1.3 Brisbane monitoring data

A large amount of stormwater quality data has been collected from the two pilot Brisbane City sampling sites since the first was commissioned in September 1994. The EMC data from the samples analysed to date is shown in Table 3.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Stormwater quality characteristics from Brisbane urban catchments showing Event Mean Concentration (EMC) in mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constituent</td>
<td>Sandy Creek Median EMC</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>191</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>0.40</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>3.15</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>2.81</td>
</tr>
</tbody>
</table>

This data indicates that, on the basis of EMC values, Brisbane stormwater is as polluted as stormwater from other areas. Additional analysis of the pollutant loads from the Brisbane sites using the AQUALM water quality model indicated total annual pollutant loads from these sites were noticeably higher than those reported from other States. It was speculated that this was due to the higher level of runoff from Brisbane catchments compared with these other studies.
2.2 Litter From Stormwater Drainage

Although the ecological significance is unclear, there is growing community concern regarding the visual impact of litter in Australia's waterways. Consequently, there is much political pressure for measures to address this problem. Quantitative studies on litter in waterways are being carried out in a number of states. Much of the work in the southern states is being coordinated by the Centre for Catchment Hydrology (see 1993/94 Annual Report). Such studies reveal that the litter in estuarine waterways largely originates from the stormwater system rather than from deposits left by beachgoers or dumped from boats. The quantities are not insignificant. For example, Sydney's street gullies in the Central Business District alone yield about 2,000 tonnes of litter a year. Unpublished Brisbane data, based on monitoring of the two pilot urban catchments, gives figures of about 22 kg/ha/year, the majority consisting of vegetative matter. It has been suggested that the breakdown of this material may be a significant contributor to increased nutrient levels in urban waterways. Further studies on this subject are being carried out by the Centre for Catchment Hydrology (Urban Hydrology Program).

As with other stormwater contaminants, it is far more productive to reduce the volume of litter than to construct large numbers of trash racks. As well as requiring a high level of maintenance, such structures quickly become unsightly as litter accumulates.

2.3 Implications for South-east Queensland

It is useful to compare relative concentrations (EMCs) of contaminants in stormwater with those in sewage. In general, the relative impact will depend on the contaminant (see previous Tables). For instance, levels of suspended solids in stormwater are invariably much higher than the levels found in treated sewage. The situation is less clear for nitrogen and phosphorus. Traditional sewage treatment systems (without nutrient removal) would have higher levels of phosphorus and, generally, nitrogen. However, more stringent criteria for nitrogen and phosphorus levels in effluent from advanced sewage treatment facilities will result in levels more comparable with stormwater quality. Additionally, on an average annual basis, the total flow from stormwater system will exceed that from the sewerage system, and hence may contribute a greater load.

The relative quantitative impact of stormwater and sewage discharges on waterways is a matter of current research. It will be one of the outcomes of the ongoing Brisbane River and Moreton Bay Wastewater Management Study. Desk-top studies have indicated that for phosphorus and nitrogen the relative contribution from point and non-point sources are fairly comparable. This, however, will only apply to the larger waterways with point source discharges. For most smaller urban waterways, there are no legal point source discharges and the contribution of stormwater to water quality deterioration will be much greater.

3 PRINCIPLES OF STORMWATER MANAGEMENT

Managing stormwater only for flood protection is no longer an adequate response to changing community values. A much more comprehensive approach is now needed. There are a number of general principles of stormwater management to be considered.
3.1 An Integrated Approach

In many instances in the past, the drainage needs and other waterway issues were dealt with at a site specific level. There is a growing recognition of the need to take an integrated, total catchment approach to issues of stormwater management, incorporating both water quantity and quality issues, and linking these to wider urban planning inputs. Stormwater management needs to be considered as part of the total urban water cycle and for its role in ecologically sustainable (urban) development.

3.2 Treatment Train

The traditional approach for dealing with water-borne waste was to collect it and pipe it to a single point for treatment. This is still largely the approach adopted in south-east Queensland. It has some degree of success for sewage and other point sources where flows are relatively constant and predictable. It is not the case for stormwater generated wastes where the flow, especially in urban areas can vary over a wide range. This has led to the introduction of the concept of a 'treatment train' for stormwater quality control. That is, stormwater management should consist of a series of linked practices ('carriages') covering planning, source control and treatment.

Any end of pipe control measures should be the last carriage of the treatment train. For both quality and quantity considerations, if the load and volume of contaminants are reduced, all parts of the treatment train function better.

3.3 Source Control

It is more efficient and cost-effective to prevent or minimise any contamination occurring (source control) rather than attempt to correct it at the end of the pipe. In many built up areas, there is insufficient land available for end-of-pipe treatments, and source control is the only option. In greenfield developments, the goal should be to maintain or improve the pre-development (natural) volume, rate, timing and pollutant load of the runoff.

Source controls should be based on:

- regulatory and policy changes, giving greater control to local authorities over stormwater quality issues;
- sound land use planning;
- education and awareness raising;
- appropriate drainage designs, based on a storage approach rather than a conveyance approach to stormwater management, a drainage system which mimics the features and functions of natural drainage systems;
- maximising pervious areas to minimise any increases in runoff. Where impervious areas are required, runoff from these areas should not be directly connected to piped drainage. Some form of pollutant trapping interface should be installed.
4 MANAGEMENT ACTIONS

4.1 Legislative Framework

The major legislation for the protection of stormwater quality in Queensland is the Environmental Protection Act 1994*. There are a number of general and specific provisions relating to stormwater management.

General provisions include the need to prevent environmental harm, and impose on all a 'general environmental duty'. That is, if your activity could have some impact on stormwater quality, you, as an individual, share a legal responsibility for ensuring that all reasonable and practical measures are taken to prevent any environmental harm from occurring.

The draft Environmental Protection (Water) Policy for water makes a number of references to matters of stormwater management. The version available at the time of writing makes specific reference to statutory levels of contaminants for stormwater, e.g., a person must not release more than 10 L of stormwater if it contains more than 30 mg/L of suspended matter. (A number of regulatory agencies in other states specify that stormwater is contaminated if it contains more than 50 mg/L of suspended solids.) As well, it places requirements on Local Government to prepare stormwater management strategies, viz.:

Each local government that has an urban stormwater system must develop and implement a program for urban stormwater quality management that improves the quality of stormwater consistent with water quality objectives for waters in its area

In developing a program for stormwater quality management, the measures to be adopted need to include consideration of:

• objectives of the draft Environmental Protection (Water) Policy;

• integration of stormwater planning with catchment based planning and management and land use planning;

• site planning and design approaches that have regard to local needs, such as protecting environmental values, making use of stormwater for reuse;

• measures to minimise contamination, maximise infiltration, reduce velocities and remove contaminants;

• making use of drainage corridors for improved recreational values;

• investigation of opportunities to retro-fit pollution control measures and re-establish riparian vegetation; and

* Copies of Queensland Government Acts are available from Goprint, Brisbane.
• implementation of viable alternatives to release of stormwater through outlets across beaches or into waters with poor circulation.

This policy will undoubtedly be linked to the National Water Quality Management Strategy. Guidelines on Urban Stormwater Management covering these matters are in preparation, but it is uncertain when they will be finalised.

4.2 Policy Framework

Many of the existing policies of Local Authorities in South-East Queensland concentrate on the drainage needs only of stormwater management. A more comprehensive approach is now required, mirroring changes in the legislative framework. The Sydney Coastal Councils have recently published a document, ‘Interim Urban Stormwater Management. Model Policies and Guidelines’, providing a broader approach to stormwater management.

Recommended policy areas covered by the document encompass:

• water quantity parameters, e.g.:
  - rainfall, discharge, water level, velocity-depth hazard;

• water quantity control measures:
  - piping, detention/retention, overland flow paths;

• water quality parameters:
  - a guide to Councils to the key parameters they should include in an overall monitoring program;

• water quality control measures, including:
  - source controls
  - control devices within the drainage corridor;

• retrofitting issues;

• strategic planning and management, including:
  - total catchment management
  - multiple use of drainage areas
  - floodplain management
  - stormwater re-use
  - stormwater management plans

This document would be a useful model for stormwater policy development for all Local Government.

4.3 Education

Much of the impact on stormwater quality is caused through ignorance. Common practices such as washing lawn clippings and soil down the gutters, washing your car in the street, and many traditional local government practices can impact on the quality of stormwater. Public
education is a relatively low cost option for reducing such non-point source pollution. Key target groups include householders, builders, and small business, such as, shops and nurseries. It is important to move away from 'slogans' and provide alternatives to current unacceptable practices. For example, where do you wash your car if you live in a block of units?

A number of educational methods which have proven successful include:

- Awareness brochures which can be tailored to suit the entire community or specific groups within the community;
- Portable display material which can be used at related events such as Environment Day, Sea Week etc., as well as being placed in community centres and libraries;
- Activities for community groups related to stormwater awareness can be linked to existing activities such as Waterwatch, Clean Up Australia activities;
- Stencilling a message on stormwater gully pits can be an effective way to convey the message of the ultimate discharge point of stormwater. The messages can be generic, e.g. flows to creek, or specifically targeted, e.g. 'This Drain leads to Sandy Creek'.

The stormwater message needs to be incorporated and included in other related awareness programs which may have a high profile, such as, Clean Up Australia, Waterwise or Waterwatch. In some instances, conflicting signals are being sent.

4.4 Best Planning Practice

A 'Best Planning Practice' is defined as the best practical planning approach for achieving water resource (stormwater) management objectives in an urban situation. These have been largely developed in Western Australia (Whelans et al., 1994), but potentially have universal application.

Best planning practice can be used at both the strategic and design level, and encompasses:

- Integrated Stormwater Management System
  - emphasis on detention, retaining vegetated flow lines, sensitive location of discharge points and consideration of quality of receiving waters;
- Water Sensitive Residential Development Precinct
  - excludes land from development needed for natural or modified drainage, floodplains, remnant vegetation, other environmental values;
- Public Open Space Network
  - provides for inclusion and linking of stormwater management systems and integration of best management practices into landscaped public open space;
• Water Sensitive Road Layout
  - emphasise use of road system for stormwater management. Longer roads should be used on lower gradients with verges available for swales;

• Water Sensitive Cluster Development
  - reduced private open space to be re-allocated to greater public open space abutting clusters of housing. Identification and protection of land necessary to allow for an integrated stormwater system; and

• Water Sensitive Streetscapes
  - incorporate reduced frontages, reduced front verges, zero lot lines, local detention of stormwater in road reserve and managed landscaping.

By adopting these best planning practices, the efficiency of the best management practices, later carriages on the treatment train, are improved.

4.5 Best Management Practices

The Queensland Environmental Protection Act 1994 describes the ‘best practice environmental management’ as management to achieve an on-going minimisation of environmental harm through cost-effective measures assessed against the measures currently used nationally and internationally.

Due to the differing climatic patterns and nature of stormwater problems, and the wide range of receiving environments and community values, a diverse range of best management practices for stormwater pollution control is evolving across Australia.

Local Government, communities and water managers have become more pro-active in areas where there are large urban populations and receiving waters are sensitive to nutrient enrichment. More recently State environment protection legislation has placed more emphasis on control of pollution from diffuse sources and this, in turn, will prompt further action in managing stormwater.

Best management practices being implemented in Australia have generally been borrowed from around the world. Best management practices are selected according to what is to be achieved. Usually, there are two targets - water quantity and water quality. There are also short and long term best management practices. Short term practices are generally related to erosion and pollution control during the construction phase of a development, and long term practices are put in place to address diffuse pollution from the developed catchment. Some areas have concentrated on control at source, especially in new developments, others have placed more emphasis on controls integrated into the drainage system, the long term measures. However, as previously indicated, there is a need to have an integrated system of management - a ‘treatment train’.

As a consequence of constrained sustainability of local inland waters, and the strong strategic planning and management ethos of the ACT Administration, Canberra adopted a fully integrated resource management approach and leads Australia in the implementation of an integrated stormwater management strategy (Lawrence & Phillips, 1993).
Following is a list of best management practices most commonly used in urban areas of Australia (after Lawrence & Phillips, 1993). Relevant references which provide further techniques and details are also listed.

Controls at source:

- limitation of development to sustainable limits based on land and water capability assessments;

- local interception measures, including:
  - maintenance of natural interception/infiltration areas,
  - grass swales, which trap sediment, slow flows and allow infiltration,
  - control of pervious areas, and
  - use of retention basins to retain water on site and control peak discharges to the stream;

- adoption of indirect drainage paths and incorporation of buffer zones;

- implementation of erosion and sediment controls during construction;

- control of land use activities, including litter control, application of fertilisers and pesticides; and

- maintenance measures, including street sweeping and regular cleaning of stormwater gullies.

Controls integrated into drainage systems:

- measures to filter stormwater, including vegetated waterways and buffer zones;

- measures to trap gross pollutants, including gross pollutant traps, sediment traps, oil and trash

- booms, trash racks, and oil extractors;

- measures to trap pollutants, including wetlands and treatment zones;

- measures to reduce peak stormwater discharges and pollutant loads, including dry retardation

- basins and water pollution control ponds (wet basins); and

- utilisation of urban lakes as pollution control structures.

Management of receiving waters:

- integrated design of facilities e.g. size, depth and shape, edge treatment, circulation;
• use of aerators;
• provision for manipulation of stormwater discharges e.g. flushing or drainage;
• dredging to remove accumulated sediments;
• plant manipulation, including establishment of macrophytes and harvesting of macrophytes and algae;
• management of fisheries, including stocking and fishing controls;
• zoning and control of foreshore land use via buffer zones and edge controls; and
• physical/chemical treatment of receiving waters.

With so many options available, a decision has to be made on what the receiving water management objectives are, and which option suits a particular situation. Many of the detention and treatment measures designed and developed in other places may not transfer to the Queensland situation due to the different hydrological characteristics, particularly the high intensity summer storm events.

NSW Department of Conservation and Land Management (Hunt, 1992), NSW Department of Housing (McVey et al., 1993), Environment Protection Agency (State Pollution Control Commission, 1989), and the Stormwater Industry Association (Sharpin, 1995b) have excellent manuals on soil and water management, and all that is needed to use erosion and sediment controls. Other manuals for constructed best management practices have been produced in Canberra (ACT, 1990, AWWA, 1989) and Western Australia (Whelans et al., 1994). There are many commercial products becoming available to assist in stormwater treatment, especially flow controls and diversion systems, separators and monitoring equipment. Some of these are described in Wood (1995).

The Table 4 is a best management practices decision matrix which is being developed as part of a review of stormwater quality best management practices for use with urban developments within Brisbane City Council.
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<td>Medium</td>
<td>Medium-High</td>
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<td>Medium</td>
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<tr>
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<td>High</td>
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<td>High</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
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<td>Medium-High</td>
<td>Nil</td>
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</table>
4.6 Monitoring Needs

Monitoring is important because it enables comparison with environmental objectives for receiving waters quality, measurement against performance objectives of the treatment / management system, and comparison of the effectiveness of different control measures. Design and implementation of a monitoring program is a complex process.

It is important to realise that casual or ‘grab’ sampling during a storm event can be scientifically valueless. Monitoring is usually undertaken using automatic samplers, triggered by either runoff water depth or rainfall, to collect a series of water samples and corresponding flow data through the storm event. As previously indicated, data reported from other studies has consisted of flow weighted average concentration of contaminant, the ‘Event Mean Concentration’.

Design of pollution control strategies and components is generally based on outputs from catchment runoff models or adoption of best management practices which minimise or intercept potential pollutants of concern in the receiving waters. The usefulness of numerical models is somewhat limited in Australia by the lack of water quality data for specific catchments and water bodies. Any such use of models should be complemented and verified by a site specific water quality monitoring program.

In the absence of local data to demonstrate the need for, or effectiveness of, the range of pollution control options, there is growing concern regarding the cost-effectiveness of universal implementation of many of the more expensive options. Monitoring the performance of the selected treatment / management system and comparison of the effectiveness of different control measures is essential.

In order to make better decisions, there is an urgent need for monitoring of water quality of both the runoff and receiving waters for local catchments given the diverse climate, geology and soil types, local environmental values, receiving water response processes and effectiveness of treatment measures.

4.7 On-going Maintenance

Very little is known about the maintenance needs and cost of some of these newer stormwater management systems. Table 4 provides the relative maintenance costs of a range of best management practices. The principle: ‘if you can’t maintain it, don’t build it’, would apply. However, be aware that the ‘natural’ stormwater management systems are not maintenance free. In many instances, the choice of a traditional system is based more on a better knowledge of how to maintain the system rather than some inherent advantage. As well, traditional stormwater management systems shift the maintenance burden off-site, in the form of increased downstream erosion and siltation leading to loss of bio-diversity, increased flooding and high cost of waterway de-silting. Traditional cost-benefit studies are unable to incorporate these environmental costs into the calculations.
5 WHAT IS BEING DONE

At the regional level, a number of major studies involving all levels of Government have been undertaken to develop regional strategies for water and wastewater management. These include the Logan, Coomera and South Moreton Bay Regional Wastewater Study, completed in 1994, Pumicestone Passage Study, completed in 1993, and the Brisbane River and Moreton Bay Wastewater Management Study which commenced in 1995. Using the outcomes of these studies, Councils will develop specific management strategies for their own areas.

Information was sought from the larger councils around south east Queensland. A number of councils have commenced activity in the area of stormwater management in response to community demand and the proposed regulatory requirements. A summary of activities from some of these councils follows.

5.1 Brisbane City

Brisbane City Council has established a Waterways Steering Committee, consisting of Councillors and key stakeholders, to oversee the management of waterways within the city bounds. A Waterways Working Group of Council officers has also been established to develop policies and coordinate waterway issues across Council. Stormwater management is a part of the responsibilities of both groups.

A major task being undertaken by Council is the preparation of master drainage plans for small developing catchments. These plans consider not only water quantity but also water quality and other environmental issues.

Other activities being undertaken by Council include:

- requirements for erosion and sediment control during subdivision;
- water quality monitoring in a number of catchments to gather data to calibrate the urban runoff model for use as a predictive tool, and monitor the effectiveness of treatment installations;
- gully trap marking;
- education and awareness materials, posters, signs, etc.; and
- investigations into retrofitting - a number of gross pollutant traps and trash racks are being installed.

5.2 Gold Coast City

A committee has recently been established within Gold Coast City Council to develop a stormwater management policy. Investigations have commenced and reference documents being used are guidelines from:

- Institution of Engineers (Queensland Division); and
- Council of North Sydney City (North Sydney is a member of the Sydney Coastal Councils Group referred to previously (Bewsher, 1995).
5.3 Logan City

Logan City Council has adopted the *Queensland Urban Drainage Manual* to address stormwater quantity issues, with one major change. Drainage design is based on a 1 in 50 year ARI storm event rather than a 1 in 100 year ARI storm event. The Council is currently reviewing its interallotment drainage policy.

While Council is working towards a waterways policy, there is no specific stormwater management policy to address water quality issues at present.

5.4 Noosa Shire Council

Noosa Shire has established a Stormwater Management Working Group to address and improve stormwater management in the Shire. Although the Council has no formal policy at present, they are working towards the production of both a Stormwater Policy and a Stormwater Design Manual. Noosa Shire belongs to a cooperative group - Sunshine Coast Councils in Cooperation - which decided that stormwater should be addressed through an integrated approach covering the whole Sunshine Coast. However, the matter has not progressed any further, and it is thought that councils are proceeding independently to develop policies. Actions so far include:

- requirement of erosion and sediment control plans as part of the development approval process;
- preparation of master drainage plans; and
- some intermittent water quality monitoring at stormwater outlets.

5.4 Pine River Shire

Pine River Shire Council has adopted the *Queensland Urban Drainage Manual* for all new developments. The Environment Department of Council is investigating retrofitting options for existing developed areas.

5.5 Redland Shire

Redland Shire Council has a Local Planning Policy for Waterways, Wetlands and Coastal Zone. In relation to stormwater management, the Policy addresses issues such as:

- hydrology - flood control must be designed to minimise disturbance of the riparian zone and changes in flow regime of waterways;
- ecology - buffer zones are required to preserve the riparian zone, maintain species and establish wildlife corridors, any modification of waterways must maximise ecological values, and structures must not unduly interfere with ecological processes;
- water quality - developers must minimise quantities of sediment and other pollutants entering the waterways, ensure that acid sulphate conditions are appropriately addressed; and
- open space, scenic and cultural values have to be protected.
The Council does not have stormwater management plans as such, however, on site soil and water management plans are required as part of the development approval process.

5.6 Toowoomba City

Toowoomba City Council has an interallotment stormwater drainage policy covering subdivision and building sites. In addition, the Council uses the Regional Standards Manual developed by the regional Councils to address stormwater management. This is an engineering manual which addresses stormwater quantity issues rather than stormwater quality issues.

6 CONCLUSIONS

Over the last decade, urban stormwater has become recognised as a major source of pollution impacting on water quality and ecology of receiving waters. There is a significant set of data on stormwater quality to demonstrate the pollution potential from neglect of urban stormwater management.

In the community there is a growing awareness of the need to manage stormwater and the recognition of urban stormwater as a valuable resource, with opportunities for enhancement of urban open space, recreation and conservation. In some areas, consideration is being given to potential uses of harvested stormwater as a water supply for non-potable uses and groundwater infiltration.

Within the regulatory framework all individuals have a general environmental duty to prevent or minimise environmental harm. This environmental duty includes prevention of release of contaminated stormwater. There are also requirements for Councils to develop and implement a program of urban stormwater quality management, in addition to the long standing requirements for stormwater quantity management.

Best management practices for urban stormwater pollution control will increasingly be recognised as an integral consideration in future urban planning and development, with major focus on implementation of catchment wide strategies.

There is also an emerging recognition of the benefits of adopting a fully integrated urban water and wastewater management system, i.e. total water cycle management, including the planning and management of drainage corridors as multipurpose zones (Lawrence & Phillips, 1993).

Best management practices, especially when implemented on a catchment-wide basis, have cost and equity implications far and beyond the urban developer, householder and, often, the local Council. As a consequence, development of stormwater strategies will need to be undertaken with effective consultation and participation of communities and key stakeholders.

Action has commenced in Queensland. Many Councils have established committees and working groups to develop policies and implementation strategies. To assist in this process there are many very useful policy documents and design manuals available from interstate.
REFERENCES


ON-SITE DISPOSAL OF EFFLUENT

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²Resource Management Institute, DPI, Indooroopilly, QLD 4068

ABSTRACT

In non-sewered urban and rural residential developments, domestic wastewaters are treated and disposed of on-site. Surveys indicate that the performance of domestic systems needs to be significantly improved to overcome potential public health and nuisance problems caused by failing systems. The on-site disposal of domestic effluent needs to be considered as an integral part of the land development process. Individual soil and site assessment needs to be undertaken to assist in the design and sizing of effluent disposal systems. An important implication from the consideration of land capability for on-site effluent disposal is that individual lot sizes will need to be larger in future developments of this nature.

KEY WORDS: septic tanks, soil absorption trench, aerated wastewater treatment systems, irrigation, nutrients, pathogens, allotment size, groundwater.

1 INTRODUCTION

In non-sewered urban and rural residential developments, domestic wastewaters are usually treated and disposed of on-site. The traditional method of treating wastewaters is an all-purpose septic tank where partial treatment of the raw waste occurs followed by a soil absorption system where the effluent from the tank is disposed primarily below ground into the soil. Evapotranspiration systems are also used for effluent disposal in some locations.

Within Australia, approximately 12% of the population relies on on-site wastewater systems. The high percentage of urbanisation in this country generally means that reticulated sewerage can be provided for most developing urban areas. However, there are an increasing number of situations where there will continue to be a reliance on on-site effluent disposal. Such situations include rapidly developing urban areas on the outskirts of large cities, rural/residential lifestyle developments, small rural communities and villages, and isolated residences.

Apart from the obvious public health implications arising from inadequate effluent disposal, there is concern that effluent in surface and groundwaters is contributing to a number of environmental management problems in parts of Australia. Detailed surveys on the performance of on-site systems undertaken by Geary (1992) and Jelliffe et al., (1995) report widespread failure of effluent disposal systems. These failures result from poor maintenance, poor local authority guidance, and the adoption of inadequate design standards, procedures and guidelines. In addition, monitoring of waterbodies receiving runoff from unsewered residential development by public health bodies (Beard et al., 1994) and local government authorities (Maroochy, Coffs Harbour etc.) supports the survey results that on-site systems are contributing to current water management problems.
It is generally accepted that the poor performance of effluent disposal systems results from an inadequate understanding of the key characteristics of soils, and a lack of adherence to the variable design guidelines which are available. In the United States (where approximately 30% of the population is unsewered) there is a history of research into effluent disposal using soil based systems. While much of this work is relevant in this country, there are significant differences between soils, climate and groundwater hydrology in both countries. Limited research has been undertaken in Australia into the relationship between the key characteristics of soils and their effluent disposal capabilities. However, substantial research on the fate and transport of biological and inorganic contaminants in Australian soils has been undertaken by Brouwer and Bugeja (1983), Martens and Warner (1995) and Gerritse et al., (1995).

2 REGULATORY REQUIREMENTS

Domestic wastewater regulations in Australia are generally administered by local authorities, although policy advice and the approval of treatment and disposal systems is the responsibility of State Departments. While a number of these State departments have prepared Codes of Practice for septic tanks to assist local authorities, little guidance is provided on site assessment and the sizing of effluent disposal systems. An overview of the regulatory requirements for on-site systems in Queensland is provided by Beavers (1995).

As a result of the lack of a standardised approach, some local authorities have prepared their own requirements for effluent disposal. Many local authorities however have not adequately addressed the issue of on-site effluent disposal in planning or practice. The poor understanding which exists between soils and their effluent disposal capabilities, and the inconsistent approach to system management have led to the high failure rate of systems and the reported impacts to the environment.

Australian Standard 1547 (1973) deals with the Disposal of Effluent from Small Septic Tanks. This document briefly describes types of disposal systems but does not consider important land capability criteria, alternative system designs for problem soils or aspects of sizing disposal systems. In 1994, a revised version of this document was produced by Standards Australia. While this version attempted to address many of the deficiencies of the 1973 version, there were still a number of major difficulties in the approach outlined (Geary, 1994). Standards Australia (in association with Standards New Zealand) has prepared a new draft standard dealing with effluent disposal. This new document (which is currently available for comment) will be a guide to local authorities but there is no requirement for them to adopt it as policy.

3 EFFLUENT DISPOSAL SYSTEMS

3.1 Soil Based Treatment/Disposal Systems

The conventional domestic on-site system has two components: a septic tank, used to provide partial treatment of the raw waste, and the disposal field, where final treatment and disposal of the liquid discharged from the septic tank takes place. Both are generally installed below ground surface (Figure 1). The passive anaerobic pre-treatment of wastewaters in the septic tank results in the removal of approximately 40-60% biochemical oxygen demand (BOD), 50-70% suspended solids (SS), 10-20% nitrogen (N), 30% phosphorus (P) and a reduction in numbers of biological contaminants (Laak. 1986). The effluent from the tank percolates through the soil
where renovation occurs prior to it reaching surface or groundwaters. The inefficient use of the renovative capacity of the soil can result in the transport of biological and chemical contaminants over substantial distances.

Figure 1  Conventional septic tank/disposal system (Adapted from Kreissl, 1982).

3.1.1 Forms of nutrients

The forms of nitrogen and phosphorus in treated effluent are particularly important because of the effect on nutrient mobility and hence potential to cause contamination in surface and groundwaters.

Irrespective of the type of on site disposal (absorption trench vs irrigation), a septic tank is an essential component of the treatment system. The septic tank is an anaerobic digester (Figure 1) which allows solids to settle to bottom of the tank as sludge, accumulates oil and grease as a semi aerobic scum layer, and hydrolyse the complex organic compounds into simpler compounds producing ammonium, methane and carbon dioxide in the process.

Table 1 shows the changes in concentration and forms of $\text{BOD}^*$, Suspended Solids, and N and P from the raw influent entering, and the semi treated effluent exiting a domestic septic tank (from Zieball et al., 1974). Note that whilst the BOD is halved to about 160 mg/L, it is too high to surface apply or to discharge to water (sewage treatment plants produce a BOD of about 20 mg/L). Total Solids have been reduced by a factor of 5 showing the effects of settling, whilst Volatile Solids (a measure of odour producing reactive organic material) have reduced by a similar amount reflecting settling and decomposition processes. The nitrogen and phosphorus amounts and forms are particularly interesting in that ammonium now dominates the nitrogen forms, whilst orthophosphate P dominates the phosphorus forms. The nitrogen concentration appears to increase (from 40 to 50 mg/L - an experimental artefact) whilst the phosphorus concentration has decreased from 20 to 15 mg/L (reflecting settling in the sludge).

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$^*$ BOD, is the oxygen required for oxidising effluent for 5 days in a reaction vessel at 20°C.
Table 1  Changes in form and composition of domestic effluent entering and leaving a septic tank (from Zieball et al., 1974).

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<th>Parameter* (mg/L)</th>
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<tr>
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<td>NO₃⁻-N</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>PO₄⁻-P</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Org-P</td>
<td>11</td>
<td>3</td>
</tr>
</tbody>
</table>

*BOD - Biochemical Oxygen Demand; SS - Suspended solids; NH₄⁻-N - Ammonium nitrogen; Org-N - Organic nitrogen; NO₃⁻-N - Nitrate nitrogen; PO₄⁻-P - Orthophosphate phosphorus; Org-P - Organic phosphorus.

The environmental consequence of the NH₄⁺-N and PO₄⁻-P forms of nutrients is that ammonium (NH₄⁺) can be readily nitrified to highly mobile nitrate (NO₃⁻), in the unsaturated aerobic zone, which often underlies the absorption trench organic mat (bio mat) in sandy textured soils, and hence can be leached to the groundwater.

For orthophosphate (PO₄⁻), the mobility reduces because the P is in a form which can be immobilised by adsorption and precipitation reactions, collectively referred to as phosphorus adsorption (Barrow 1989).

3.2 Alternative Treatment and Disposal Systems

A number of variations to the conventional system have been developed over the years. These variations to the way in which effluent is distributed or dosed, often result in improved system performance. One important variation in Australia is the evapotranspiration system which relies not only on soil absorption to assimilate effluent but also on evaporation and transpiration by vegetation (Figure 2). This system is typically constructed closer to the surface and effluent is distributed in a bed rather than trenches. As in all effluent disposal systems, the uniform distribution of effluent is critical to the performance of the system.

In addition to variations to this conventional system, a range of alternative treatment and disposal systems are available. These include additional treatment after the septic tank such as sand mounds, aerated systems, wetlands and a variety of alternative disposal methods such as mounds, surface irrigation and shallow placement systems. A full description of alternative systems is provided by the United States Environmental Protection Authority (1980).
3.3 Aerated Wastewater Treatment Systems

Aerated wastewater treatment (AWT) systems are small self-contained proprietary biological treatment systems which rely on mechanical devices to provide mixing, aeration and pumping of effluent. AWT systems are based on either two tanks or a single tank where effluent is subjected to accelerated aerobic breakdown. A final effluent is produced using various combinations of pumps, fans, airblowers, contact media for bacterial growth, and settlement and chlorination chambers. With the required management and maintenance (including periodic sludge removal), the final effluent produced should be clear and non-odorous and should meet quality criteria approved by the State Department of Health.

The number of AWT systems has increased substantially in recent years and there are approximately 20,000 units in N.S.W. alone. However, they are not well suited to intermittent use and effluent quality is reduced as a consequence of shock loads which may occur due to episodic hydraulic or organic loading. AS1547 (1994) has recommended the following quality criteria for the final effluent from these systems: not greater than 20 mg/L biochemical oxygen demand, not greater than 30 mg/L suspended solids, not less than 0.5 mg/L free residual chlorine (after 30 minutes contact) and not greater than 10 organisms per 100 ml for thermotolerant coliforms (i.e. faecal coliforms).

After chlorination, effluent from these systems is typically land applied using surface or subsurface irrigation. In general, a minimum area of 200 m² should be used and the land area should be appropriately landscaped and used solely for the purpose of irrigation.

With the increase in the number of these systems, local government has been finding the administration and management of these systems difficult. Apart from maintenance, there are also reported difficulties with the effectiveness of the chlorination system, and the adequate sizing of the landscaped area for irrigation in relation to hydraulic and nutrient loads. Surveys of the disinfection performance of aerated systems reported in Rawlinson (1994) suggested that a high percentage of systems failed to meet the residual chlorine and faecal coliform requirements, while Martens and Warner (1995) recommended disposal areas larger than 200 m² to reduce the risk of nitrate leaching to groundwaters.
3.3.1 Nutrients and secondary treatment

Aerated wastewater treatment systems and sand mounds supplied with septic tank effluent operate on the same general principle as the unsaturated zone beneath absorption trenches on sandy soils. That is, the organic material (as measured by BOD or Volatile Solids) is oxidised to CO₂, whilst the NH₄⁺ is nitrified to nitrate, and the remaining organic P to PO₄-P.

Table 2 compares the concentration and nutrient forms of effluent from the various treatment processes and it is evident that BOD, Suspended Solids and Faecal Coliforms are (usually) many fold lower in the aerobically treated effluent, but that total N and P maximum concentration are about the same. There is much wider variation in the N and P levels in the AWT and sand mound effluent reflecting the potential for NH₃ volatilisation, NO₃⁻ denitrification during resting times in the aerobic reactor, and PO₄-P phosphorus adsorption and precipitation (and removal) in the sludge.

Table 2  
Comparison of effluent quality from septic tanks, aerobic waste water treatment system and a sand mound (from Beavers and Gardner 1993 and Otis et al., 1974).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Septic Tank</th>
<th>AWT</th>
<th>Sand Mound</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>120 - 150</td>
<td>5 - 80</td>
<td>1 - 10</td>
</tr>
<tr>
<td>Suspended Solids</td>
<td>40 - 190</td>
<td>5 - 100</td>
<td>5 - 20</td>
</tr>
<tr>
<td>TKN³</td>
<td>50 - 60 (0%)¹</td>
<td>25 - 50 (80%)¹</td>
<td>30 - 50 (85%)¹</td>
</tr>
<tr>
<td>TP³</td>
<td>10 - 15 (90%)²</td>
<td>7 - 12 (85%)²</td>
<td>5 - 10 (90%)²</td>
</tr>
<tr>
<td>Faecal Coliform</td>
<td>10²-10⁷</td>
<td>10 - 10³</td>
<td>10 - 10³</td>
</tr>
<tr>
<td>Org/100ml</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Nitrate-N as a % of Total nitrogen.
(2) Orthophosphate-P as a % of Total phosphorus.
(3) TKN - Total Kjeldahl nitrogen, TP - Total phosphorus

However, a distinguishing characteristic of the aerobically treated effluent is the dominance of the NO₃⁻-N form comprising between 80 and 95% of Total N, compared with NH₄⁺-N dominance for the septic tank effluent.

In all three effluents (i.e. septic, AWT, sand mound) there is little difference in the predominance of the water soluble PO₄-P (between 85 and 90% of Total P).

Consequently when aerobic treated effluent is irrigated onto dedicated disposal areas, nitrate leaching can be expected if the hydraulic loading rates are considerably in excess of the irrigation demand, as is currently recommended by AS1547.

4     DESIGNING EFFLUENT DISPOSAL SYSTEMS

On-site disposal of effluent requires that site specific assessments be undertaken to determine the best site and the most appropriate disposal system. Land capability assessments of proposed sites should include considerations of: soil type and texture, site slope, flooding frequency, depth to water table and depth to bedrock. Also of importance are allotment size, climate,
proximity to watercourses and setback distances from other buildings, swimming pools and fence lines.

In Victoria and Western Australia, land capability rating tables for on-site effluent disposal have been produced (Wells, 1987), although it is not clear whether such tables are used in practice. The NSW Department of Conservation and Land Management is currently producing a series of maps (1:25000) on site suitability for effluent disposal from the extensive soil landscape mapping programme undertaken over the last few years. These maps will provide a useful guide to land developers and local government, however, detailed lot assessment of site suitability will still be necessary.

4.1 Soil Based Systems

A simple set of design criteria does not exist for the design of sub-surface disposal systems receiving septic tank effluent. Whilst AS1547 provides a prescriptive approach for system design, there still remain several difficulties concerning the interpretation and understanding of the key concepts in soil based effluent disposal systems. Nonetheless, there are a number of important factors which should be examined in any consideration in the design of soil based systems and these are discussed below.

**Hydraulic Capacity of Soil** - This parameter is usually the limiting design parameter for soil based systems. It is defined as "the volume of water that can be continuously infiltrated into the soil without raising the groundwater level above selected levels". It is influenced by soil and hydrogeological conditions and is most likely to be limited in soils of low hydraulic conductivity or shallow depth. If the design loading rate of effluent exceeds the hydraulic capacity of the soil, the disposal system will fail.

The hydraulic capacity of the soil has in the past been assessed by ad-hoc methods in the field or by percolation testing. More recently, field measurements of permeability (saturated hydraulic conductivity) have also been used for this purpose. While the percolation test has generally been discredited as a measure of the effective absorption properties of soil (Healy & Laak, 1974), it is still often used. The percolation test overestimates the hydraulic conductivity of fine grained soils and therefore overestimates hydraulic capacity.

Alternative design criteria based upon the measurement of permeability have not gained widespread use simply because of the need to undertake a large number of measurements, and the complicated nature of the testing. AS1547 states that if soil testing is not possible, the permeability of the soil may be determined from the textural classification of the soil. Representative permeabilities for the various soil textural classes are given in the Standard. In the United States there has been a move away from soil testing towards the use of soil morphology as a guide to assessing the hydraulic capacity of soil. This approach uses soil texture and structure and features such as mottling and depth of soil to assign effluent loading rates to different soil types.

**Purification Ability of Soil** - Soil is regarded as an excellent medium for the breakdown or renovation of biological and inorganic contaminants in effluent. However, its ability to purify effluent is not completely understood. It is generally assumed that purification will occur with a minimum depth of 1 metre of unsaturated soil underneath the disposal area and that fine grained
soils such as clays with their higher specific surface area (m²/kg) are far more effective than soils with coarser grain sizes. Whilst fine grained soils may be better suited for effluent purification, their hydraulic capacity is generally low and effluent loading must reflect this.

As a result of the difficulties in evaluating soils for their purification abilities, most approaches to the design of soil based systems focus on the **hydraulic functioning** of the effluent disposal system.

**Hydraulic Load** - The hydraulic load is the volume of wastewater generated by a household. This can be either measured or calculated based upon the number of bedrooms or individuals in the household. Standard design figures are provided in documents such as AS1547. The choice of these flow design allowances will depend upon whether a reticulated supply is provided and what type of fixtures are installed in the residence. Households which rely on a limited supply of potable water use significantly less than those households receiving a reticulated supply.

**Long Term Acceptance Rate For Effluent** - In the determination of the hydraulic capacity of the soil, testing is normally undertaken with clean water. Effluent from the septic tank will not be assimilated into the soil in the long term at the same rate as clean water. This is because of the organic matter present in the effluent, and other factors such as wastewater chemical composition, climate, dosing rate and soil properties. The nature of the organic mat which develops above the trench/soil interface and which is essential for the purification of effluent is more thoroughly discussed by Kristiansen (1982).

The Long Term Acceptance Rate or LTAR of the soil is therefore significantly lower than the measured permeability based on physical testing or the inferred permeability based upon soil morphology. A number of curves have been developed which are based on empirical correlations between measured soil permeability and measured long term infiltration rates for a limited number of septic tank systems and these are shown in Figure 3. As mm/d is numerically equivalent to L/m²/d, a system constructed in a soil with a measured or inferred permeability of 0.05 m/d or 50 mm/d (using curve AS1547) should be designed for a LTAR of approximately 10 L/m²/d. In this case, the loss of infiltration accounted for in the design of the system due to build up of organic matter is approximately 80% of the measured or inferred permeability.

Unfortunately many Australian soils exhibit low permeabilities and are very poor for soil absorption. Survey results suggest that the principal reason for system failure is hydraulic overloading. This is supported by research (Caldwell Connell Engineers, 1986) which suggests that in the long term, soil based systems relying on soil absorption will fail if loaded in excess of 10 to 20 L/m²/d. This is because the organic mat which accumulates at the interface between the effluent and the underlying soil controls the rate at which effluent permeates through the unsaturated soil. This biomat clogging represents the most conservative approach and results in the use of loading rates which may be significantly less than the measured or inferred permeability.
Sizing of Absorption Systems - Using the example of a soil with a measured or inferred permeability of 50 mm/d, it is possible to size a disposal system using parallel lengths of trenching. According to the curve from AS1547 (Figure 3), the LTAR for this soil is 10 L/m²/d. For a three bedroom household assume a hydraulic load of 750 L/d (5 persons @150 L/d). Trench length L (metres) may be determined from the relationship between the design daily flow Q (Litres/day), the LTAR (L/m²/day or mm/day) and the selected trench width W (metres) using the following relationship:

\[ L = \frac{Q}{(LTAR \times W)} \] (1)

On the basis that the soil is able to accommodate 10 L/m²/d, the surface area required for the disposal of this effluent volume is 75 m². Assuming that conventional trenching is proposed (absorption is provided by trench bottom only) and that the trench is 1 metre wide, 75 lineal metres of trenching will be required for this soil type. The trenching can then be arranged within the allotment, provided sufficient land area exists. This approach results in substantially larger land area requirements for on-site effluent disposal compared to the present ad-hoc methods of estimating trench lengths. The implications for future land development in non-sewered urban and rural residential developments are that allotment sizes will need to be larger to meet on-site effluent disposal requirements.
Aerated Wastewater Treatment Systems

AWT systems approved by the State Department of Health are required to meet certain effluent quality criteria and to be regularly serviced and maintained. Under these conditions, effluent quality should be clear and non-odorous and meet bacteriological guidelines suitable for irrigation above or below ground (<10 faecal coliform/100ml).

AWT systems have been widely accepted as a viable treatment alternative option in many parts of Australia. However, there still remain difficulties with their management. Failure to regularly service and maintain systems results in poor quality effluent which may cause public health and nuisance problems. Surveys on the performance of AWT systems have been summarised by Rawlinson (1994) and the author reports high numbers of systems failing to meet effluent quality criteria set by the regulatory authorities.

The disposal of effluent from AWT systems which meets the set quality criteria is required to be distributed evenly to a level, landscaped area of at least 200 m$^2$. Effluent must not be used to grow vegetables or fruit for human consumption, and must not be sprayed in areas used for passive or active recreational purposes. Many of the existing approved systems do not meet these requirements and surface runoff of poor quality effluent occurs (Martens & Warner 1995).

There has been concern for some time that the minimum requirement of 200 m$^2$ for irrigation is inadequate for some locations and that systems continue to spray irrigate during wet weather periods. Work undertaken by Gardner and Littleboy (1995) using a water balance approach has found that this disposal area is far too small to transpire the majority of effluent applied in most climatic zones in Australia. Martens and Warner (1995) also concluded that the size of the disposal area is critical for successful infiltration and assimilation of effluent and that disposal areas should be calculated on the basis of soil type, soil permeability and a nitrogen balance.

The approach outlined in AS 1547 (1994) for the calculation of an irrigation area does not take into account the major components of the water balance, but rather relies solely on the determination of soil permeability. Once permeability has been measured or inferred, the irrigation area sizing curve (Figure 4) is used for the appropriate design irrigation rate. The size of the irrigation area is calculated from the following equation:

$$A_i = q_w/DIR$$

where $A_i$ is irrigation area required (m$^2$)  
$q_w$ is total quantity of effluent generated in week (Litres/week)  
DIR is design irrigation rate (mm/week)

Using this approach the required minimum irrigation area for many soils is in excess of the 200 m$^2$ required by the local authorities. The key factor in this determination is a knowledge of the permeability of the soil to receive the effluent, and this is acknowledged as difficult to determine. The Standard does not consider other factors in this calculation which are known to be important such as evaporation, transpiration, rainfall and the other components of the water balance. Given the frequently reported effluent quality problems with AWT systems, it is appropriate that a water balance be calculated to determine land area requirements for individual disposal systems.
5 NUTRIENT GENERATION AND DISPOSAL

On site disposal systems have historically ignored the concept of ecologically sustainable development in that no attention has been paid to the amount and fate of nutrients applied to the disposal (absorption trenches) or reuse areas (from aerated wastewater treatment systems).

Mass balance concepts using measured inputs and storages often provide the most precise estimates of nutrient generation (Gardner & Casey 1995). Whilst this concept can be applied to intensive rural industries relatively easily, it is very difficult to measure the inputs and storages by humans in urban environments. Consequently the amount of waste produced by an average urban or rural residential household is calculated from the composition of the raw waste water (or the septic tank effluent) and the average daily effluent volume production. Variation in composition with time, and decoupling of effluent volume measurement from its composition can give rise to considerable uncertainties.

Figure 4 Irrigation area sizing curve (Source: AS1547).
5.1 Previous Studies

In a Western Australia study of 5 households over 15 days, Whelan and Titamanis (1982) calculated average production of 3.8 kg nitrogen N/person/year and 0.6 kg phosphorus P/person/year. For an average household of 3.5 person, this is equivalent to 13.3 kg N/year and 2.1 kg P/year. The information was collected from the absorption trenches or soak wells, and consequently underestimates the N and P remaining in the sludge in the septic tank. Other estimates of nutrient production include 8.25 kg nitrogen/person/year (Walker et al., 1973) and 0.8 kg phosphorus/person/year (Otis et al., 1974).

One of the more detailed waste generation surveys was undertaken by Witt et al., (1974) in rural Wisconsin. Their estimated annual production figures (measured before any pre-treatment in the septic tank) were 2.2 kg N/person/year and 1.5 kg P/person/year which is equivalent to 7.7 kg N/year and 5.3 kg P/year for a typical family.

Sources of these loads are listed in Table 3 and it is evident that the dishwasher/laundry contributed about 75% of the total phosphorus load whilst the toilet contributed about 70% of the total nitrogen load. Considering the reduced phosphorus concentration of current day washing detergents, it is expected that the P production figures are too high.

Table 3 Per capita production of organic material and nutrients from various household sources (from Witt et al., 1974)

<table>
<thead>
<tr>
<th>Parameter*</th>
<th>Toilet</th>
<th>Kitchen</th>
<th>Dishwasher</th>
<th>Laundry</th>
<th>Bath</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>10,700</td>
<td>8,350</td>
<td>12,600</td>
<td>14,780</td>
<td>3,090</td>
<td>49,520</td>
</tr>
<tr>
<td>TS</td>
<td>28,470</td>
<td>13,760</td>
<td>18,160</td>
<td>48,430</td>
<td>4,590</td>
<td>113,410</td>
</tr>
<tr>
<td>VS</td>
<td>19,730</td>
<td>9,730</td>
<td>10,545</td>
<td>19,455</td>
<td>3,600</td>
<td>63,060</td>
</tr>
<tr>
<td>TN</td>
<td>4,140</td>
<td>425</td>
<td>490</td>
<td>725</td>
<td>300</td>
<td>6,080</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>1,115</td>
<td>32</td>
<td>54</td>
<td>30</td>
<td>40</td>
<td>1,270</td>
</tr>
<tr>
<td>TP</td>
<td>550</td>
<td>420</td>
<td>820</td>
<td>2,150</td>
<td>36</td>
<td>3,975</td>
</tr>
<tr>
<td>PO₄-P</td>
<td>300</td>
<td>180</td>
<td>380</td>
<td>520</td>
<td>20</td>
<td>1,400</td>
</tr>
</tbody>
</table>

*BOD - Biochemical Oxygen Demand; TS - Total Solids; VS - Volatile Solids; TN - Total nitrogen; NH₄-N - Ammonium nitrogen; TP - Total phosphorus, PO₄-P - Orthophosphate phosphorus.

For the purposes of this paper we will accept the net production figures of Whelan and Titamanis (1982) and assume an average household production of 13 kg N/year and 2.1 kg P/year.
5.2 Nutrient Loading Rates and Leaching

Assuming an average density of 15 septic tanks/km² (Rawlinson 1994), a 50m² absorption trench length per household and the preceding nutrient generation figures, the equivalent loading rates over the subdivision are 195 kg N/ha/year and 32 kg P/ha/year, whilst the specific loading rates in the absorption trenches are 2600 kg N/ha/year and 420 kg P/ha/year.

As there is apparently little loss of nitrogen after it exits the absorption trench, and minimal plant N uptake from the trench itself, these specific N loading rates are exceptionally high by agricultural standards and are likely to lead to contamination of groundwater, and in some cases, surface water.

In studies of the leachate composition beneath septic absorption trenches located on sandy soils, nitrate-N levels are invariably high (about 30-50 mg/L) for a number of metres beneath, and next to the trench (Whelan & Barrow 1984, Magdoff et al., 1974).

There appears to be little opportunity for the NO₃ rich leachate beneath absorption trenches to denitrify because of an inadequate labile carbon source to feed the denitrifying bacteria¹ (Keeney 1986) as most of the organic C in waste water is consumed by aerobic oxidation in the soil profile at approximately the same rate that NO₃ is created (Magdoff et al., 1974).

Consequently the NO₃ is leached unchanged to the groundwater where concentrations greater than 10 mg/L NO₃-N will exceed drinking water standards (ANZECC 1992). Flowing groundwater can dilute the NO₃-N concentration in the leachate, but if the aquifer flow is small relative to recharge rate, and aquifer dispersion ability is small (e.g. a coarse textured aquifer) leachate from subdivision can cause downgradient NO₃-N concentrations to exceed potable water standards. Analytical and numerical groundwater models can estimate these contaminant concentrations as a function of housing density and aquifer hydraulic characteristics (Anderson et al., 1987).

In many of the soils available for subdivision in south east Queensland, physical characteristics make them unsuitable for agriculture (a consequence of applying the Protection of Good Quality Agriculture Land policy), and they often contain slowly permeable clay subsoils. Opportunities for nitrification from NH₄⁺ to NO₃⁻ are expected to be limited in such subsoils and most of the N may be retained as NH₄⁺ on the clay cation exchange complex. Data for this hypothesis is meagre, but a similar lack of N mobility occurs in heavily loaded dairy effluent disposal strips (Gardner, 1995). More often, the problem in these soils is absorption trench surcharge during wet periods causing surface and subsurface (perched water tables) runoff. These processes have been examined in detail in New South Wales by Martens and Warner (1995).

¹ As a rule of thumb, nearly equal parts of organic C and NO₃-N are required for the denitrification process.
5.2.1 Sustainable nutrient loading rates

Ecological sustainability criteria suggest that acceptable effluent loading rates for nutrients should not exceed the sum of their removal in biomass + soil storage + allowable losses (gaseous and leaching).

5.2.1.1 Nitrogen

Nitrogen is often the most complex nutrient to calculate allowable loading rate because it can be stored in the plant, in new soil organic matter, lost via gaseous pathways during irrigation (ammonia volatilisation) or after irrigation (denitrification), leached below the root zone (as nitrate) and slowly converted (mineralised) from the organic form to inorganic forms (NH$_4^+$-N and NO$_3^-$-N) available for plant uptake and leaching. A schematic of this very complex process is shown in Figure 5.

![Nitrogen in Effluent](image)

**Figure 5** Schematic representation of nitrogen components, storages and interchanges for a soil irrigated with domestic effluent.

When applying effluent onto the disposal area, the objective is to maximise plant uptake and minimise nitrate leaching below the root zone. Unfortunately AS1547 calculates disposal area on soil permeability criteria with the smaller areas corresponding to the more permeable soils (Petrozzi & Martens 1995). This calculation method will maximise nitrate leaching opportunities.

Septic tank effluent is unsuited for irrigation because of odour and high pathogen levels (Table 2). AWT and sand mound effluent is suitable for surface irrigation (but see later proviso on disinfection efficacy) and the majority of the nitrogen is in the nitrate and ammonium forms (Table 2). Consequently the right hand side of Figure 5 is of major interest, with denitrification and plant uptake being the major N “sinks”.

Denitrification requires anaerobic conditions (absence of free oxygen), a labile carbon source and adequate temperature (≥20°C) for the microbiological mediated reactions to occur (Keeney, 1986). Dedicated effluent disposal areas in Queensland are likely to fulfil these
requirements, with the extra carbon source coming from decomposing plant material growing on the irrigation area. However there appears to have been no research work done specifically in this area.

On the basis of agricultural experience, recovery of applied nitrogen in pasture and crop trials ranges from 60-80% (Henzell et al., 1970) with higher figures applying when multiple nitrogen applications reduce the opportunity for large denitrification events (Strong et al., 1992).

For aerobically treated sewage effluent applied in small doses on most days of the year, the 80% recovery figure is recommended.

Plant uptake of nitrogen depends on the plant yield (or biomass) and the nitrogen concentration in the various plant parts. Table 4 compares nitrogen uptake for trees (eucalypts and pines) and pasture. For trees, net uptake of nutrients reduces substantially (to about 20-30 kg N/ha/year) when the leaf biomass stabilises at canopy closure. This stage occurs in 2 to 4 years in effluent irrigated eucalypts and pine trees respectively (Myers et al., 1994). Grass pasture on the other hand closes its canopy within weeks and grows vigorously provided it does not become rank. N uptake of 300 kg N/ha can be expected in the six warmer months of the year (Gardner, 1995).

Table 4 Nutrient uptake from effluent irrigated eucalypts, pine trees and grass pasture.

<table>
<thead>
<tr>
<th></th>
<th>N (kg/ha)</th>
<th>P</th>
<th>Time Period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalypts*</td>
<td>180</td>
<td>20</td>
<td>2.5</td>
</tr>
<tr>
<td>Pines*</td>
<td>350</td>
<td>35</td>
<td>4.0</td>
</tr>
<tr>
<td>Pastures</td>
<td>300</td>
<td>30</td>
<td>0.5</td>
</tr>
</tbody>
</table>

(*Source: Myers et al., 1994).

Provided the plant material on the effluent disposal area is harvested and removed on a regular basis (years for trees, months for pasture), it will provide a sustainable and recurrent sink for nitrogen.

Using mass balance principles it is relatively straightforward to calculate the amount of excess nutrients applied in effluent to a disposal area. For example, for a minimum effluent disposal area of 200m² per household, the loading rate is calculated as:

\[
\text{Nitrogen Loading Rate} = \frac{13 \text{ kg } N / \text{ year}}{200m^2} \times 10,000 \frac{m^2}{ha} \text{ .................(3)}
\]

\[
= 650 \text{ kg N/ha/year}
\]
After allowing for 20% losses due to denitrification (i.e. 80% recovery) the

Net Load to soil = 650 x 0.8
= 520 kg N/ha/year

If trees are growing in the disposal area, annual N uptake is about 100 kg N/ha/year (Table 4).

Hence nitrogen (potentially) available for leaching is

Potential Leaching = 520 - 100
= 420 kg N/ha/year

Assuming there are 10 allotments per hectare (10% roads, 900m² allotments), the spatially averaged catchment scale leaching is approximately

\[
\text{Catchment Scale Leaching} = 420 \frac{\text{kg}}{\text{ha yr}} \times \frac{200 \times 10}{10,000} \frac{\text{m}^2}{\text{m}^2} = 84 \frac{\text{kg}}{\text{ha/year}}. \tag{4}
\]

If the allotment density/hectare was halved (or the disposal area size doubled) the (potential) catchment scale N leaching would be halved to about 40 kg/ha/year. It is unlikely that even this rate is environmentally sustainable if the groundwater resources of the subdivision are used for potable or agricultural purposes.

Commenting on a related problem of groundwater contamination in American subdivisions, Yates (1985) argued that the major method for controlling the impact of septic systems is the density of on-site systems. This argument applies equally well to nutrient loading from effluent irrigation areas.

An alternative to trees (and shrubs) is pasture, and assuming an annual uptake of 400 kg N/ha, the potential N leaching loss is reduced to 120 kg N/ha/year on the disposal area. At subdivision scale, the values are 12-24 kg N/ha/year depending on allotment density.

Clearly regularly harvested and removed grass in the disposal area will have considerably less environmental impact than trees, shrubs or landscaped gardens which are either not harvested, or done so on an irregular basis (e.g. branch pruning).

Practical application of this advice would require a change in some local government rules which currently require dedicated landscaped areas for effluent irrigation because of concern about the health hazards. These concerns are well founded, and before grass irrigation could be generally recommended, disinfection efficacy of aerobically treated effluent must become more reliable (Jelliffe 1995a).
5.2.1.2 Phosphorus

As a rule of thumb, the phosphorus uptake by plants is 8 to 10 times less than nitrogen uptake (Table 4). However Australian agricultural soils are notorious for their ability to immobilise P (Barrow, 1989). This capacity varies widely from low levels in many sandy soils to high levels in strongly weathered clay soils e.g. ferrosols. In addition the phosphorus storage capacity is strongly responsive to the concentration (mg/L) of water soluble phosphorus (the orthophosphate form) in the soil solution. The relationship between phosphorus sorbed by the soil and the phosphorus solution concentration is termed a *Phosphorus Adsorption Curve*.

Table 5 tabulates the phosphorus sorption capacity for three typical soils for a range of solution phosphorus concentration. Using bulk density data, the mg P sorbed/kg soil has been converted into units of kg *phosphorus stored/hectare of soil/metre of soil depth*.

**Table 5** Phosphorus storage capacities (kg P sorbed/ha/m soil depth) for 3 soils of varying P fixing capacities, equilibrated with a range of phosphorus concentrations in the soil solution.

<table>
<thead>
<tr>
<th>Solution Concentration (P mg/L)</th>
<th>Krasnozem(^{(1)})</th>
<th>Vertisol(^{(2)})</th>
<th>Podzolic(^{(3)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>1,650</td>
<td>156</td>
<td>315</td>
</tr>
<tr>
<td>0.5</td>
<td>3,750</td>
<td>715</td>
<td>675</td>
</tr>
<tr>
<td>1.0</td>
<td>4,425</td>
<td>910</td>
<td>825</td>
</tr>
<tr>
<td>5.0</td>
<td>6,750</td>
<td>1,690</td>
<td>1,200</td>
</tr>
<tr>
<td>10.0</td>
<td>7,950</td>
<td>2,470</td>
<td>1,455</td>
</tr>
<tr>
<td>30.0</td>
<td>10,500</td>
<td>4,550</td>
<td>1,950</td>
</tr>
</tbody>
</table>

*kg of P stored/ha/metre of soil depth is calculated assuming a Bulk Density of 1,500 kg/m\(^3\) for the Krasnozem and Podzolic and 1,300 kg/m\(^3\) for the Vertisol.

(1) Ferrosol, (2) Vertosol, (3) Kurosol using the new Australian classification (Isbell 1996).

The phosphorus loading rate to a 200m\(^2\) disposal area is

\[
\frac{2.1 \text{ kg P/year}}{200 \text{m}^2} \times \frac{10,000 \text{ m}^2}{\text{ha}} = 105 \text{ kg P/ha/year}
\]

From Table 4, the P uptake by trees is about 10 kg/ha/year. Hence the net P loading to soil

\[
= 95 \text{ kg P/ha/year}
\]
From Table 2, over 90% of the P in aerobically treated sewage effluent is in the reactive \( \text{PO}_4^-\)P form with a concentration of about 10 mg \( \text{PO}_4^-\)P/L. From Table 5, the P storage capacity of a sandy soil (Podzolic top soil) at this concentration is about 1500 kg P/ha/metre.

If we assume slug flow conditions, which implies that no phosphorus moves downwards until the storage capacity of the upper soil layers are filled (Ryden & Pratt 1980), phosphorus leaching can be described as:

\[
P \text{ front advance} = \frac{1500 \text{ kg/ha/m}}{95 \text{ kg/ha/year}} \]

\[= 16 \text{ years/metre soil depth}\]

For grass with a P uptake of 40 kg P/ha/year, the corresponding figure is 23 years/metre of soil depth.

The environmental consequences of these leaching rates (when reduced from disposal area to subdivision scale levels) is site specific, depending on the depth to the water table, the beneficial use of the aquifer, and the separation distance (from the disposal area) to a surface stream.

For example, Whelan (1988) in a study of septic tank leachate on a calcareous soil from Western Australia reported soil solution concentrations of 15 mg P/L at 8m depth, with similar levels occurring in the underlying aquifer (Whelan & Parker, 1981). The ANZECC (1992) standard for phosphorus concentration in potable water is 0.1 mg/L.

However in a study on lateritic derived sandy and duplex soils in Western Australia, Gerritze et al. (1995) concluded that the high P adsorption capacities would limit P travel times to multiple decades for distances of 5 to 30m. Moreover the \( \text{PO}_4^-\)P levels in the surface streams of the subdivision were very low (<0.005 mg/L) suggesting no adverse effects of septic effluent.

In summary where shallow aquifers adjoin environmentally sensitive freshwater bodies (such as Lake Wyeba in Noosa Shire), considerable care should be paid to the phosphorus budget. However, the many adsorption sites for phosphorus in soils and aquifers suggest that adverse groundwater consequences of P leaching are likely to be the exception rather than the rule.

6 PATHOGEN REDUCTION BY SEWAGE TREATMENT

The primary (but not only) concern for on site disposal of sewage is human health. Pathogens of interest include bacteria, viruses, protozoans and helminths. Table 6 lists the major pathogens of interest and the diseases they cause. Because of the expense (e.g. $600 per virus assay) or difficulty (e.g. Cryptosporidium) in measuring these pathogens, the bacteria \( \text{E.coli}^* \) is used as a surrogate for faecal contamination, and disinfection efficacy.

\[^* \text{Escherichia coli} \text{ is a ubiquitous bacteria in the gut of warm blooded animals.}\]
Table 6  Principal Pathogens of Concern in Municipal Wastewater and Sludge (from USEPA 1989).

<table>
<thead>
<tr>
<th>Organism</th>
<th>Disease/Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
</tr>
<tr>
<td>Salmonella spp.</td>
<td>Salmonellosis (food poisoning) typhoid fever</td>
</tr>
<tr>
<td>Shigella spp.</td>
<td>Bacillary dysentery</td>
</tr>
<tr>
<td>Yersinia spp.</td>
<td>Acute gastroenteritis (include diarrhoea, abdominal pain)</td>
</tr>
<tr>
<td>Vibrio cholerae</td>
<td>Cholera</td>
</tr>
<tr>
<td>Campylobacter jejuni</td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td>(pathogenic strains)</td>
<td></td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td></td>
</tr>
<tr>
<td>Poliovirus</td>
<td>Poliomyelitis</td>
</tr>
<tr>
<td>Coxsackievirus</td>
<td>Meningitis, pneumonia, hepatitis, fever, common colds etc</td>
</tr>
<tr>
<td>Echovirus</td>
<td>Meningitis, pneumonia, hepatitis, fever, common colds, diarrhoea, etc</td>
</tr>
<tr>
<td>Hepatitis A virus</td>
<td>Infectious hepatitis</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>Acute gastroenteritis with severe diarrhoea</td>
</tr>
<tr>
<td>Norwalk agents</td>
<td>Epidemic gastroenteritis with severe diarrhoea</td>
</tr>
<tr>
<td>Reovirus</td>
<td>Respiratory infections, gastroenteritis</td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
<td></td>
</tr>
<tr>
<td>Cryptosporidium</td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td>Entamoeba histolytica</td>
<td>Acute enteritis</td>
</tr>
<tr>
<td>Giardia lamblia</td>
<td>Giardiasis (include diarrhoea, abdominal cramps, weight loss)</td>
</tr>
<tr>
<td>Balantidium coli</td>
<td>Diarrhoea and dysentery</td>
</tr>
<tr>
<td>Toxoplasma gondii</td>
<td>Toxoplasmosis</td>
</tr>
<tr>
<td><strong>Helminth Worms</strong></td>
<td></td>
</tr>
<tr>
<td>Ascaris lumbricoides</td>
<td>Digestive and nutritional disturbances, abdominal pain, vomiting, restlessness</td>
</tr>
<tr>
<td>Ascaris suum</td>
<td>May produce symptoms such as coughing, chest pain and fever</td>
</tr>
<tr>
<td>Trichuris trichiura</td>
<td>Abdominal pain, diarrhoea, anaemia, weight loss</td>
</tr>
<tr>
<td>Toxocara canis</td>
<td>Fever, abdominal discomfort, muscle aches, neurological symptoms</td>
</tr>
<tr>
<td>Taenia saginata</td>
<td>Nervousness, insomnia, anorexia, abdominal pain, digestive disturbances</td>
</tr>
<tr>
<td>Taenia solium</td>
<td>Nervousness, insomnia, anorexia, abdominal pain, digestive disturbances</td>
</tr>
<tr>
<td>Necator americanus</td>
<td>Hookworm disease</td>
</tr>
<tr>
<td>Hymenolepis nana</td>
<td>Taeniasis</td>
</tr>
</tbody>
</table>

There is considerable evidence of pathogen and nutrient export from underperforming septic absorption trenches and AWT’s. For example, in a study of 12 catchments in Sydney, Martens and Warner (1991) reported that nitrogen and phosphorus export in *surface runoff* from septic system catchments were between 50-90 times larger than that in a similar sewered catchment (Table 7). Bacterial contamination was also higher in the septic trench catchments indicating *direct contamination*, presumably from surcharging septic trenches in the shallow (<1m) soils.
Table 7 Combined flow weighted pollutant loads (kg/ha/yr) leaving catchments with different effluent disposal practices (from Martens and Warner, 1991).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Sewered</th>
<th>AWTS*</th>
<th>Septic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/ha/year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia N</td>
<td>0.00</td>
<td>0.01</td>
<td>0.06</td>
<td>1.70</td>
</tr>
<tr>
<td>TKN</td>
<td>0.01</td>
<td>0.04</td>
<td>0.10</td>
<td>1.91</td>
</tr>
<tr>
<td>Total P</td>
<td>0.00</td>
<td>0.01</td>
<td>0.03</td>
<td>0.86</td>
</tr>
<tr>
<td>BOD₅</td>
<td>0.04</td>
<td>0.53</td>
<td>0.28</td>
<td>4.90</td>
</tr>
</tbody>
</table>

*Aerobic wastewater treatment system.

Similar types of results were reported in a 1991 study by the Coffs Harbour City Council where monitoring of faecal coliforms in creeks showed a 10 fold increase in E.coli for a rural residential catchment (1250 organisms/100ml) compared with a rural catchment, which in turn was similar to a reticulated sewerage catchment (Rawlinson, 1994).

A later NSW North Coast study by Beard et al., (1994) of four river systems draining catchments variously served by septic tanks, rural residential and reticulated sewerage, all showed violative levels of faecal coliform, but with the highest per capita level occurring in the two septic tank catchments.

In a study at Benalla, Victoria, the Rural Water Corporation (1993) found groundwater contamination in areas where septic tank density exceeded 15 tanks/km² (i.e. >1 tank/6.7 ha). Nitrate-N levels were up to 17 mg/L in the upper aquifer (10m deep) and appeared to contribute about 20% of the nitrogen load in the nearby Murray River in low flow periods. Unacceptably high levels of faecal coliform were also recorded in the nitrate contaminated aquifer.

It could be argued that septic trench contamination of surface and groundwater are to be expected on slowly permeable soils (via trench surcharge) and highly permeable soils (via high drainage flux beneath the trenches). The reasons for off site effects from AWTs are less clear cut.

6.1 Methods of Pathogen Reduction

The E.coli concentration in septic tank effluent is $10^2$-$10^6$ organisms per 100 ml (Table 2) making it unsuitable for effluent irrigation. However once the effluent passes through the biomat in the absorption trench, and a further 50cm or so of unsaturated aerobic sandy textured soils, E.coli concentrations are often reduced to very low levels. Figure 6 shows the decrease in E.coli beneath a septic absorption trench in a calcareous sandy soil in Western Australia (Whelan and Parker 1981). Similar results on the bacterial disinfection efficacy of the absorption trench biomat and 50-100cm of unsaturated fine (<1mm) uniform sand have been reported for Wisconsin soils (Bouma et al., 1972), and for 60cm thick sand mound filters (Ziebell et al., 1974) provided the loading rate is ≤ 50 L/m²/day (Ball 1991).
Figure 6 The distribution of faecal coliforms in the absorption trench, the biomat layer and the sandy soil profile below the trench. (from Whelan & Parker, 1981).

Aerated waste water treatment systems on the other hand reduce E.coli levels by chlorinating the clarified effluent using a target concentration in excess of 0.5 - 2.0 mg/L of free chlorine for 30 minutes. However studies of disinfection efficacy undertaken in NSW and Queensland, showed AWT failure rates of between 40 to 70% (Rawlinson 1994, Jelliffe 1995a).

Considering that viruses are much more resistant to disinfection than bacteria (Ashbolt 1995), and that protozoan cysts such as Giardia are likely to be carried over in poorly clarified effluent (i.e. suspended solids > 30 mg/L). there should be real concern about pathogen transport in surface runoff from effluent irrigation areas.

Septic absorption trenches on the other hand depend completely for the soil to purify the septic tank effluent. Aerobic conditions are essential for bacterial death (anaerobic ponds are poor disinfectors) and sedimentation, straining and adsorption appear to be the major filtering processes (Gerba et al., 1975).

Viruses on the other hand are up to 1,000 times smaller than bacteria, and electrostatic adsorption to organic matter and clay particles, followed by microbial attack appear the major decay process (Yates & Yates 1988). However viruses are variably charged particles, and their positive charge reduces, and hence their mobility increases, when effluent pH increases above 5 (most sewage effluent is neutral to alkaline).
There are many instances in the North American literature which have established the dominance of inadequately treated groundwater as the cause of waterborne outbreaks of disease (Craun 1985). The majority of these outbreaks are caused by bacteria and viruses from septic field leachate (Yates 1985) suggesting that the disinfection efficacy of unsaturated soil is uncertain, especially at high septic tank densities (≥ 15 septics/km²).

6.2 Set Back Distances for Septic Adsorption Trenches

The most useful methods for controlling groundwater contamination are setback distance and density of septic tanks per hectare (Yates 1985).

Beavers and Gardner (1993) developed a simple model for calculating set back distances of septic tanks from potable bores and streams etc. based on the survival time of viruses in groundwater. The viral death rate-time relationship is the strongest one established to date in the literature (Yates & Yates 1988) and it is strongly influenced by temperature (of the groundwater).

Figure 7 shows the log-linear relationship for various temperatures using data reported by Yates and Yates (1988). For septic leachate with a virus concentration of about $10^4$ plaque forming units/1,000 ml, a seven order of magnitude reduction in concentration would be required to meet WHO drinking water standards. For an aquifer at 18°C, this will take about 34 days. For higher quality effluent from an aerobic sand filter or AWT, a 3 orders of magnitude reduction in virus concentration is required, which will take about 15 days (Figure 7) at 18°C.

![Figure 7](image-url) Relationship between relative virus concentration and travel time through groundwater of various temperatures. Note that the virus decay constant $k$ (day⁻¹) is the slope of the lines (temperature dependent). (from Beavers & Gardner, 1993).
The setback distance from a disposal area to a potable bore or stream bank can be calculated from a modified form of Darcy’s Law (Freeze & Cherry 1979).

\[ D = \frac{(tKi)}{n_e} \]  

where

- $D$ = setback distance, (m).
- $t$ = travel time, days, defined by Figure 7.
- $K$ = saturated hydraulic conductivity (m d$^{-1}$).
- $i$ = hydraulic gradient (m m$^{-1}$).
- $n_e$ = effective porosity of the aquifer (m$^3$/m$^3$).

Using parameter values typical of a permeable aquifer ($K_s = 5$m/day), Beavers and Gardner (1993) calculated setback distances from a potable bore of 220m for a septic absorption trench and 98m for AWT effluent. Corresponding allowable allotment sizes were 20 ha and 4 ha respectively.

7 IMPLICATIONS OF ALLOTMENT SIZE FOR ON SITE DISPOSAL

The conceptual structure to analyse the surface and near surface water quality aspects of domestic effluent irrigation as a function of climate, soil type and allotment size has yet to be developed. Consequently it is difficult to give scientific advice to regulatory agencies and local authorities on acceptable type and density of on site effluent disposal systems.

A bold attempt has been described by Jelliffe (1995b) who estimates phosphorus export from septic trenches during surcharge events (climate plus trench failure driven), scaling the phosphorus mass upwards by septic tank density, and the phosphorus concentration downwards by dilution from catchment runoff, to arrive at a predicted stream water quality.

Using this approach on a sandy clay at Landsborough (Queensland) and slowly permeable clay at Wauchope (NSW) returned minimum acceptable allotment sizes of 4,500m$^2$ and 17,000m$^2$ respectively.

Whilst numerous criticisms can be made of the parameter values adopted (e.g. % of failing septic trenches) and some assumptions used (e.g. no nutrient retardation by vegetation and soil) it provides a very useful conceptual structure on which to build more physically rigorous runoff/water quality modules which could then be packaged for local government use.

Assessing the effects of on site disposal on groundwater contamination in shallow aquifers is considerably more straightforward than surface water quality predictions. Provided allotment density, deep drainage (from septic trenches or irrigation areas) and leachate quality are known or estimated, time/space predictions of developing nitrate plumes are relatively straightforward using well established groundwater models. The models may be either analytical (e.g. Domenico & Robbins 1985) or numerical (e.g. Anderson et al., 1987). For pathogens, the more simply calculated setback distance using the Beavers and Gardner (1993) approach can be used to calculate minimum lot size for septic trenches.

Estimating allowable allotment size for AWT systems is more difficult as the offsite effects are dependent on system maintenance (e.g. pathogens), system design (e.g. N and P reduction) and soil hydraulic properties (runoff vs deep drainage for excess water on the irrigation area).
However on nutrient and hydraulic loading criteria, an irrigation area of at least 500m$^2$ is required. Combining this with hard surface areas of about 500m$^2$ (i.e. roofs, driveways etc) and statutory set back distances gives a *minimum* allotment size of about 2500m$^2$. If the soil is likely to generate substantial runoff from the effluent irrigation area, (e.g. cracking clay or impermeable texture contrast) then an additional 20-30m of downslope buffer distance is required to dilute transported effluent (Martens & Warner, 1995). This is equivalent to about an additional 1500m$^2$ giving a total minimum allotment area of 4,000m$^2$.

8 CONCLUSIONS

Septic absorption trenches and AWT's are the most common methods of effluent disposal in unsewered areas.

The evidence to support the environmental sustainability of septic absorption trenches is meagre. Catchment scale studies have almost invariably shown much higher nutrient and E.coli levels in surface streams compared with those draining catchments using other forms of effluent disposal. It is uncertain if these excessive impacts are due to trench surcharge from inadequate design and maintenance. If not, then improvements in site assessment and trench design as described in this paper are unlikely to make a substantial improvement in stream water quality.

At the other end of the spectrum, groundwater contamination in aquifers underlying *permeable soils* has frequently occurred if septic tank density exceed 15/km$^2$ (i.e. 1 per 7 ha). However other investigations suggest an acceptable density of 25 septic tanks/ha (i.e. 1 per 4 ha) for potable groundwater protection, increasing to 100 tanks/ha (i.e. 1 per 1 ha) where land use values exceed the need for protection of groundwater quality (Rawlinson, 1994). Whether groundwater contamination is acceptable depends on the beneficial use of the aquifer (e.g. potable, agricultural, environmental). In catchments where groundwater contamination is not an issue, environmentally sustainable size for allotments using septic tanks is probably in the range 0.4 ha to 1.0 ha.

Alternative on site systems include transpiration beds (a minority use) and AWT's. However, local authority surveys almost invariably show an effluent quality failure rate of about 50% of the AWT systems examined. Whilst many of these BOD/pathogen problems are probably resolvable using an enforceable maintenance program, the problem of excessive water and nitrogen application to too small a disposal area (e.g. 200m$^2$) as recommended by AS1547 remains. This problem can be rectified using either larger disposal areas (say 500m$^2$+) with actively transpiring vegetation (e.g. dense trees or frequently mowed grass) or a further treatment process including denitrification, and possibly phosphorus precipitation in P sensitive catchments.

With the above provisos, acceptable allotment size for AWT's are likely to be in the 3000-5000m$^2$ range - considerably smaller than the sustainable septic absorption trench density.

If society is to develop a win/win situation for environmental protection and the provision of allotments at reasonable prices, we must become more innovative in the way we collect and treat our effluent. There are many alternative on site treatment ideas in the USEPA (1980) design manual, and a recent innovation from Canada (Jowett & McMaster 1995) suggests robust AWT's can be condensed into a 3m$^3$ package.
Generally land developers are conscious of their environmental responsibilities (which is aided at times by regulatory advice) but have the difficulty of accessing unbiased, informed advice on effluent disposal. The formation of an independent on-site effluent disposal research and information centre in Australia would make a substantial contribution to filling this knowledge gap. One of the major tasks of such a centre could be the development of scientifically defensible set back distances and allotment sizes for the various combinations of on site disposal systems and biogeographical settings (i.e. soil type, depth, slope, climate, groundwater depth etc.).

9 REFERENCES


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MANAGING SECONDARY SALINITY IN SUB-DIVISIONS

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ABSTRACT

Daily water balance modelling indicates that on-site effluent disposal and re-infiltration of hard-surface run-off can have a significant impact on deep drainage, both at allotment and at catchment subdivision scale. In catchments at risk of dryland salting, increases in deep drainage due to subdivision may cause an increase in salinisation similar to that which occurred when native trees were replaced by pasture and crops. An outline of the processes and key landscape features which lead to secondary salinisation is provided, together with the results of daily water balance modelling which demonstrate the potential impact of various management options. A number of recommendations are made to make a subdivision hydrologically neutral including; increasing the disposal area size, changing vegetation in the disposal area, replacing adjacent dryland pastures with trees to create recharge credits, incorporating some form of groundwater pumping, limiting subdivision to soils which partition excess water as runoff rather than deep drainage, and installing reticulated sewerage systems.

KEYWORDS: secondary salinisation, subdivision, effluent disposal, hard surface run-off, water balance, groundwater.

1 INTRODUCTION

Catchments at risk of dryland salinity may be subject to increases in deep drainage due to the use of on-site effluent disposal areas in unsewered subdivisions, and the re-infiltration into grassed areas within the subdivision of increased runoff from the hard surface areas. This extra drainage creates the potential for an increase in salinisation similar to that which occurred when native trees were replaced by pasture and crops. Although predominantly an issue in rural residential subdivisions, any subdivision within a catchment at risk of salinisation should be assessed in terms of its potential hydrological impact. Management options to minimise deep drainage and/or run on include: increasing disposal area, using trees in the disposal area, creating recharge credits at the catchment level by replacing pastures with trees, and installing reticulated sewerage systems. Most of these options can be evaluated using daily time step water balance models, such as PERFECT (Littleboy et al., 1992) or MEDLI (Davis et al., 1995).

A common method for effluent disposal in unsewered subdivisions is irrigation onto a dedicated landscape area, after pre-treatment by aerobic waste water treatment systems (AWT). Rules specifying the irrigation system vary, but include setback distances from allotment boundaries and creeks, and a minimum effluent irrigation area of the order of 200 m². Hydrologic criteria to justify this area is usually lacking. It would be expected the design area should vary with climatic characteristics, and have some close correlation to the average irrigation demand of the local area. Another characteristic of onsite irrigation on unsewered
subdivisions is daily irrigation, whether it is required by the plants or not, where treated effluent is collected in small reservoirs which are emptied automatically via a float switch and pump.

The combination of small disposal areas and daily irrigation has the potential to substantially change the water balance within sub-divisions and the surrounding catchment. In particular, if deep drainage were to increase in a salinity sensitive catchment, wet areas and salted areas are almost certain to increase. This paper thus covers the subject areas of: secondary salinisation, water balance of disposal areas, salinity management and risk identification.

2 PRINCIPLES OF SECONDARY SALINISATION

Soil salinity reflects the equilibrium between landscape hydrology, soil properties and vegetation. All catchments approach a hydrologic equilibrium where water moving out of the catchment is in balance with water inflows. As the dominant mechanism for salt movement is water, there is a salt balance also established within a catchment. This means that accessions of salt from rainfall and weathering and the export of salts through streamflow and groundwater are in equilibrium (Shaw et al., 1987). During the period of adjustment when land use is changed within the catchment, there will be a change in the salt storage in the landscape until a new equilibrium is reached. A simple conceptual model (Figure 1) which considers the landscape in terms of recharge, transmission and discharge zones, is a useful basis for further discussions on the hydrological implications of secondary salinisation (Freeze & Cherry, 1979).

Figure 1  Simple hydrological model dividing the landscape into recharge, transmission and discharge areas
2.1 Is Secondary Salinity an Issue in this Subdivision?

Secondary salinisation is a catchment scale problem so we may need to broaden our focus to include catchment boundaries when considering the impact of subdivision. There are some simple and effective indicators which can be utilised to quickly identify if salinity is already a problem within the catchment you are considering for subdivision.

1. Vegetation can be a very effective indicator of shallow water-tables and intake areas. In some areas it is useful for indicating saline soils, although often both species composition and vigour must be considered for indicators of soil salinity. Dying vegetation can indicate rising water-tables and intake areas. Common vegetative indicators of shallow watertables include black tea tree, bullrushes and sedges. These indicators have been frequently associated with salinity problems in the Lockyer creek, Plain creek and Black Snake creek catchments in south-east Queensland. Variations in density, species composition and vigour can also indicate waterlogged or salted areas. Where salinity levels are affecting plant growth, the appearance of individual plants may indicate symptoms of chloride toxicity and/or water stress (i.e. osmotic drought).

2. Sites affected by salinity often, but not always, have characteristic surface symptoms. These symptoms include salt crystals, powdery soil surface ("puffiness"), prolonged wet areas and black staining. Inexpensive (< $100) salinity meters are available, which can be used in the field to assess if salinity in the soil is at problem levels.

3. The quality of groundwater and surface water provides an indicator of potential salinity problems. Saline creeks or dams have a characteristic appearance with clear water to depth, and often a loose sediment on the bottom. Field measurements of groundwater and surface water using inexpensive salinity meters provides an assessment of the severity of the problem. The depth of the watertable is another important indicator of salinity and/or waterlogging problems, and a quick survey of bores, wells and windmills within the catchment to measure waterlevels provides an insight into potential problems.

4. We also need to identify potential salinity problems within a catchment, even when visual symptoms are absent. Salinity research in Queensland has identified some typical landform features which are associated with secondary salinisation (Shaw et al., 1987). The important feature of discharge areas in secondary salinisation is the presence of some restriction to groundwater flow which allows the water table to rise towards the soil surface. If the watertable rises to within 1 - 2 metres of the soil surface, evaporative concentration of salts may lead to the decline of vegetation and severe salting.

A wide variety of restrictions to groundwater flow exist. The range of landscape forms commonly found in south-east Queensland (Figure 2) are:

**Catena form** - this form is associated with shallow soils in upslope positions overlying weathered parent material with soils gradually becoming deeper and heavier-textured downslope. Salting results from infiltration of water into the upslope soils and lateral movement through the weathered parent material or through more permeable soil horizons. Discharge occurs in the lower slope or break of slope positions where the heavier clays or
Landform types commonly associated with dryland salting in south-east Queensland

Figure 2
geologic features restrict water movement. This form of salting is common in the Lockyer, Bremer and Brisbane valley catchments.

**Valley restriction** - where natural rock barriers or resistant sediments offer restriction to water flow in flat valley floor situations or where existing aquifers peter out, discharge areas develop immediately upslope of the restriction. This restriction can also be man-induced through road construction across valley floors. This form of salting has been observed on the eastern Darling Downs and Lockyer Valley.

**Basalt form** - this form of salting is associated with basalt areas. Basalt frequently provides suitable water intake areas and transmission zones. When basalt material overlays relatively impermeable sediments, seepages and water-table salting are common at the interface. This form of salting is common along the eastern Darling Downs and the Burnett district.

**Stratigraphic form** - variable permeabilities in sedimentary rock layers can act as preferential flow paths or impermeable areas under increased water regimes. In this situation, small seepages and salted areas appear on hillslopes in response to variations in the permeability of different rock layers. These form has been observed in the upper catchment areas of the Plain Creek and Black Snake Creek catchments in south-east Queensland.

**Dams** - a dam can contribute to salting both upslope and downslope of the dam itself. Upslope salting occurs due to a reduced hydraulic gradient caused by the raised water level in the dam, reducing downslope flow and hence causing elevated groundwater levels. Downslope salting results from leakage of water, usually above a shallow, less permeable sub-soil layer. Sealing of dam floors would ensure there is no impact of dam construction on salinity within the catchment.

5. There are some relatively simple methods for assessing the extent of salinity problems within a catchment or subdivision. A measure of soil or water salinity using an electrical conductivity meter can be conducted in the field, and results obtained almost instantaneously. For soil samples, a mixture of 1 part soil to 5 parts water is thoroughly shaken in tube and a measurement made with the probe placed into the upper half of the solution (DPI, 1994). This is commonly referred to as an EC_{1:5} measurement with units of dS/m. Alternatively, salinity measurements can be made directly on water samples collected from bores, wells, dams or streams.

Another method for rapidly acquiring salinity measurements across larger areas is the use of electro-magnetic induction meters (EMI). EMI measures the ability of the ground to conduct electricity. These devices can detect changes in soil texture, water table depth and salinity which can be used effectively in assessing landscapes for secondary salinity (Nicoll et al., 1993). There is no need for direct contact with the ground, so EMI surveys can be carried out more quickly and easily than many other methods for landscape assessment. However, the key to successful interpretation of apparent electrical conductivity provided by EMI is being able to determine the controlling factor/s within each landscape. General guidelines (Table 1) are available which provide a broad scale assessment of potential salinity hazard from the apparent conductivity readings.
Table 1  Typical values for EM31 readings and their likely significance. Note: This table applies to typical soils and landscapes and not to creeks, roads and other anomalies in the landscape.

<table>
<thead>
<tr>
<th>Typical EM31 reading (mS/m)</th>
<th>Likely material</th>
<th>Likely clay content (%)</th>
<th>Likely EC1.5 of subsoil (dS/m)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 20</td>
<td>Coarse sand</td>
<td>&lt; 10</td>
<td>&lt; 0.05</td>
<td>recharge area, well-leached</td>
</tr>
<tr>
<td>20 - 40</td>
<td>Earths</td>
<td>&lt; 20</td>
<td>&lt; 0.15</td>
<td>recharge area, leached</td>
</tr>
<tr>
<td>50 - 80</td>
<td>Light clays</td>
<td>up to 40</td>
<td>&lt; 0.25</td>
<td>recharge area, leached and permeable</td>
</tr>
<tr>
<td>80 - 130</td>
<td>Heavy clays</td>
<td>45 - 60</td>
<td>&lt; 1.2</td>
<td>transmission area, slowly permeable</td>
</tr>
<tr>
<td>80 - 120</td>
<td>Heavy clays</td>
<td>40 - 80</td>
<td>&lt; 0.6</td>
<td>low recharge, slowly permeable</td>
</tr>
<tr>
<td>130 - 200</td>
<td>Surface salt and low salinity groundwater</td>
<td>variable</td>
<td>3 - 8 surface</td>
<td>discharge area, may give lower reading than expected due to thin depth of surface salt</td>
</tr>
<tr>
<td>200 - 300+</td>
<td>Surface salt and high salinity groundwater</td>
<td>variable</td>
<td>4 - 10 surface</td>
<td>discharge area with high subsoil salt content</td>
</tr>
</tbody>
</table>

EMI is best used in association with other information about the soils, geology and groundwater of the site. Values of apparent conductivity measured in EMI surveys cannot be compared across catchments (i.e. a medium reading may indicate recharge areas in one catchment, but salinity in another catchment). To interpret maps of apparent conductivity it is always necessary to assess geology, geomorphology, soil types, hydrologic indicators and patterns of vegetation and crop growth.

3  SALINITY IN SUBDIVISIONS

3.1  How do I Know if Subdivision will Lead to Salinity Problems?

Any change in land use which alters the amount of water moving in the landscape has the potential to lead to secondary salinisation. If significant areas of trees are removed in the process of subdivision, especially in sensitive catchments, salinity hazard should be assessed. There are three potential sources of excess water from a completed subdivision which must be disposed of in some manner. The most obvious is the effluent generated from domestic residences. This effluent is often disposed of using absorption trenches for septic effluent, or dedicated irrigation areas for aerobic waste water treatment systems. Another source of excess water is the additional hard surface runoff generated from roofs, roads and paving. This hard surface runoff is generally diverted as run-on onto grassed run-on areas, and in effect is the same as irrigation. The third source of water is the extra water added to a system from the irrigation of gardens and lawns. The supply of mains pressure reticulated water to subdivisions encourages the establishment of irrigated gardens and lawns. Due to inefficiencies in every irrigation system, there will be an increase in deep drainage from landscaped blocks in comparison to “native” gardens where watering is minimal.
3.2 What is the Likely Impact from Effluent Irrigation?

The sustainability of using irrigation to dispose of effluent and hard surface runoff is strongly dependant on having an excess of evaporation over rainfall for the majority of the year. Although this concept can be used as an initial screening for the size of irrigation and storage areas, it is simplistic to assume that all rainfall is effective in replacing the water lost by evaporation. Rainfall is partitioned into soil runoff, soil storage and deep drainage and the difference between potential transpiration and effective rainfall defines the irrigation demand of an area. Potential transpiration is a function of atmospheric demand (Class A pan evaporation) and a crop factor which reflects canopy cover and vigour. Crop factors can vary greatly, for example, from about 1.0 for a closed Eucalypt canopy to 0.6 for a poorly maintained irrigated pasture (Gardner & Littleboy, 1995). A crop factor of 0.6 would more accurately reflect the canopy characteristics of most on-site effluent disposal sites. A knowledge of crop factors and long term daily climate data will allow calculation of long term average monthly irrigation demand for various localities using a daily time step water balance model such as PERFECT or MEDLI.

Figure 3 shows the long-term (100 year) average monthly irrigation demand for grass (0.6 crop factor) at three different climate regions in Australia — Cairns, Coffs Harbour and Bendigo. Superimposed on these graphs is the constant effluent irrigation application (750 litres/day) to either a dedicated 200 m² area (equivalent to 114 mm/month) or a 500 m² area (equivalent to 45 mm/month) (Gardner & Littleboy, 1995).

![Figure 3](image_url)

Average monthly irrigation demand and effluent application rate for three different climatic zones in Australia (from Gardner and Littleboy, 1995).
It is evident from Figure 3 that the effluent supply to 200 m$^2$ exceeds irrigation demand at Coffs Harbour for all months of the year, 7 months in Cairns and 9 months in Bendigo.

The partitioning of excess effluent between runoff and deep percolation depends on the soil hydraulic properties and the time series nature of the rainfall event. But whatever the partitioning, it is clear that transpiration will not be the major sink for effluent applied to this undersized area of 200m$^2$. One solution is to increase the effluent irrigation area until the varying monthly irrigation demand equals or exceeds the constant irrigation supply for the majority of months. Such a response is clear in Figure 3 for a 500m$^2$ disposal and where supply now exceeds demand for 7 months at Coffs Harbour, 3 months at Cairns and 5 months for Bendigo.

Alternatively, the vegetation in the disposal area can be manipulated to maximise transpiration, e.g. densely planted trees have a crop factor of about one. Trees will increase annual irrigation demand to 1475mm, 660mm and 1135mm for Cairns, Coffs Harbour and Bendigo respectively, compared with 900mm, 340mm and 720mm for grass (Figure 3). For a 500m$^2$ disposal area, effluent supply will now exceed irrigation demand for only 2 months at Cairns, 5 months at Coffs Harbour and 5 months at Bendigo (data not shown). The lack of response at Bendigo to a large treed disposal area is because the Mediterranean climate causes a surplus of rainfall over evaporation for the late autumn to winter periods irrespective of crop cover and irrigation supply.

### 3.3 Partitioning Surplus Irrigation into Runoff and Deep Drainage

It is important to identify the likely partitioning of excess irrigation into runoff and deep drainage to allow assessment of the likely environmental consequences. For example, Geary and Gardner (1996) noted that many AWT effluents failed pathogen standards, and runoff of this effluent from one neighbour’s yard to another could pose a definite health hazard.

Alternatively, the excess irrigation could be partitioned into increased deep drainage with consequences on degraded groundwater quality and secondary salinisation. The critical factor for managing secondary salinity in sensitive catchments is an estimate of the change in deep drainage from natural conditions to developed condition (commonly from trees to pastures). It only requires a small change in deep drainage to greatly exacerbate existing or potential salinity problems. Effluent supplied in excess of irrigation demand will be partitioned into runoff and deep drainage depending on the soil hydraulic properties and the time series nature of rainfall events.

The long term average annual deep drainage response to effluent disposal and run-on from hard surfaces can be calculated using a daily time step water balance model. Figure 4 shows the results of using PERFECT to calculate long term deep drainage response for grassed effluent disposal areas located on two contrasting soil types, across a range of climatic zones (Gardner & Littleboy, 1994). Given that the effluent production will remain relatively constant (750 - 1000 litres per day) an increase in the disposal area from 200m$^2$ to 1000m$^2$ will reduce the effective irrigation supply from 3.75 mm/day to 0.75 mm/day (assuming 750 litres/day effluent production). The impact of soil type and climate is evident from the results.
in Figure 4. Deep drainage increases with decreasing effluent disposal area, with the magnitude of the response varying with climate and soil type.

For example, for a (permeable) Red Kandosol site at Cairns, the pre-subdivision dryland deep drainage is very large at 530 mm/year increasing to 660 mm/year for a 500m$^2$ disposal area, thereafter increasing sharply to 1000 mm/year for a 200m$^2$ area. Despite this very high deep drainage figure, it is only twice that occurring under dryland subdivision conditions. Often soil types and hydrogeological conditions co-evolve to transmit these high natural percolation values, and the water-logging implications of doubling recharge may be small in this case.

![Graph showing estimated deep drainage under a grassed disposal area of varying size for a Red Kandosol and a Sodosol at four locations (from Gardner & Littleboy, 1994)](image)

Figure 4 Estimate of deep drainage under a grassed disposal area of varying size for a Red Kandosol and a Sodosol at four locations (from Gardner & Littleboy, 1994)

In contrast, deep drainage at Bendigo and Armidale increase 4 fold (from 80 mm/year to 310 mm/year) and 10 fold (20 mm/year to 180 mm/year) respectively, from dryland conditions to a 500m$^2$ disposal area. There is a further sharp increase (10 fold and 40 fold respectively) as the disposal area decreases to 200m$^2$.

Dryland salinisation is already a well established problem in the Bendigo town area (Dyson, 1983) and increases in deep drainage of these magnitudes (4 to 10 fold) would almost
certainly cause widespread water-logging and salinisation were these increased percolation figures to occur over the whole subdivision.

Figure 4 also shows similar relative increases for the less permeable Sodosol profile, but the absolute figures are much smaller. For example at Bendigo, deep drainage is expected to increase from 40 mm/year under dryland pasture to 150 mm/year for a 500m$^2$ grassed disposal area, and to 280 mm/year for a 200m$^2$ disposal area. Nonetheless, this is a 4 to 7 fold increase in deep drainage and almost certainly would cause substantial increases in water-logging and salinisation. In dryland conditions, increases as small as 10 mm/year (due to tree clearing) have caused large non-linear increases in soil salinisation (Kennett-Smith et al., 1994).

3.4 Run on from Hard Surface Runoff

When residential areas are developed, there is an increase in the surface area generating 100% runoff — such areas are roofs, driveways, paths and paved areas. Runoff water from these hard surfaces can either be allowed to discharge to a “run-on” area, or diverted into table drains on road margins. There will be increases in drainage rates from those areas receiving runoff water from these domestic hard surfaces, and this increase is inversely related to the area receiving the runoff water. As for effluent disposal, increasing the “run-on” area will cause a reduction in effective irrigation supply. The amount of deep drainage will be a function of soil type, climate and irrigation demand (which can be modified by vegetation types).

Table 2 shows the expected partitioning of excess rainfall on a Red Kandosol grassed run-on area in Toowoomba (average rainfall 980 mm/year). Many large (> 2000m$^2$) allotments have about 500 m$^2$ of hard surface, with the balance area for effluent disposal and gardenscape. If all the runoff from the 500m$^2$ land surface were diverted onto 500m$^2$ of gardenscape, this is equivalent to doubling the rainfall of 980 mm/year on this garden area. Hence the rainfall scalar is 2. Alternatively, if the run on area were 1000m$^2$, the effective rainfall is increased by 50%, giving a rainfall scalar of 1.5. Note that the run-on garden scape is completely separate from the dedicated effluent irrigation area.

<table>
<thead>
<tr>
<th>Run-on area (m$^2$)</th>
<th>Rainfall Scalar</th>
<th>Effective rainfall (mm/year)</th>
<th>Runoff (mm/year)</th>
<th>Drainage (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>2.0</td>
<td>1961</td>
<td>258</td>
<td>424</td>
</tr>
<tr>
<td>1000</td>
<td>1.5</td>
<td>1471</td>
<td>109</td>
<td>221</td>
</tr>
<tr>
<td>2000</td>
<td>1.25</td>
<td>1226</td>
<td>61</td>
<td>133</td>
</tr>
<tr>
<td>$\infty$</td>
<td>1.0</td>
<td>981</td>
<td>26</td>
<td>86</td>
</tr>
</tbody>
</table>

It is evident that as the rainfall scalar changes from 1.0 (dryland conditions) through to 2.0 (run-on area = hard surface runoff area), the predicted deep drainage from MEDLI has increased from 86 mm/year to 424 mm/year — a 5 fold increase. In comparison, the expected deep drainage on a grassed effluent irrigation area is 280 mm/year for a 500m$^2$ area, and 1000 mm/year for a 200m$^2$ disposal area.
We have done similar calculations for a less permeable Sodosol profile, with the estimated deep drainage figures ranging from 12 mm/year (dryland grass) to 112 mm/year (rainfall scalar of 2). In comparison, predicted deep drainage from the grassed effluent disposal area increased to 60 mm/year (for 500m$^2$) and 350 mm/year (for 200m$^2$ area).

It is clearly evident that poorly planned drainage of hard surface runoff can have a similar deep drainage/secondary salinisation potential to that of undersized/undertranspiring effluent irrigation areas. However, the water quality of such drainage would be much lower in nitrogen (and pathogens) than that from the effluent disposal area.

3.5 Scaling up from Allotment Size to Catchment Scale

The preceding analysis applies only to the actual effluent disposal (or run on area) and these are only a small fraction of the total subdivision area.

To fully assess the impact of excess irrigation, we need to scale up from the actual disposal area to the total subdivision area. As the disposal area increases, separation regulations cause the allotment size to increase. Consequently, the number of allotments per hectare of subdivision decreases. These relationships are shown in Table 3 for disposal areas ranging from 200m$^2$ to 1000m$^2$ per allotment.

Table 3 Comparison of on-site effluent and runoff disposal area, allotment size and number of allotments per hectare of subdivision

<table>
<thead>
<tr>
<th>Effluent Disposal Area (m$^2$)</th>
<th>Allotment Size (m$^2$)</th>
<th>Allotments per hectare*</th>
<th>Deep drainage per disposal area (mm/year)</th>
<th>Deep drainage per subdivision (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>2000</td>
<td>4.5</td>
<td>100</td>
<td>9</td>
</tr>
<tr>
<td>500</td>
<td>4000</td>
<td>2.25</td>
<td>100</td>
<td>11.3</td>
</tr>
<tr>
<td>750</td>
<td>6000</td>
<td>1.5</td>
<td>100</td>
<td>11.3</td>
</tr>
<tr>
<td>1000</td>
<td>10000</td>
<td>0.9</td>
<td>100</td>
<td>9</td>
</tr>
</tbody>
</table>

*after allowing 10% of subdivision for roads etc.

The information from Table 3 can then be used to convert depth of deep drainage per unit of disposal area to equivalent depth of deep drainage per unit area of subdivision. For example if 100 mm/year deep drainage occurs on a 200m$^2$ disposal area, this is equivalent to an increase in deep drainage of 9 mm/year over the whole subdivision. In dryland conditions, increases as small as 10 mm/year (due to tree clearing) have caused large increases in secondary salinisation.
MANAGING SECONDARY SALINITY IN URBAN DEVELOPMENTS

4.1 How do we Manage Deep Drainage in Subdivisions?

There are several management options available to local authorities and developers to minimise the amount of deep drainage from subdivision in catchments sensitive to salinity problems. These include:

- a scaled down reticulated sewerage system (e.g. Community Effluent Drainage) would allow more control of the collection and disposal of effluent;
- increasing the disposal area and allotment size to reduce the effective irrigation supply from effluent and hard surface runoff;
- ensuring hard surface runoff is diverted into table drains and removed quickly from the site into natural watercourses to minimise infiltration; and
- incorporate areas of trees into the subdivision, either to increase irrigation demand in the disposal area or to provide a recharge credit in other parts of the catchment.

Table 4 illustrates the impact of some of these management options for a Red Kandosol soil at Toowoomba. For example, increasing the grassed (crop factor of 0.6) effluent disposal area from 200m² to 750m² limits the catchment scale increase in drainage to 10 mm/year. Alternatively, replacing the grass with densely planted trees (crop factor = 1.0) and increasing the disposal area to 500m² effectively makes the effluent area hydrologically neutral. However, for nutrient sustainability, the trees must be periodically cut and removed which will reduce the effective crop factor (and hence transpiration) during the coppice regrowth period.

Table 4 Predicted average annual deep drainage (mm/year) under dryland pastures and trees for a Red Kandosol at Toowoomba, and the predicted increase in deep drainage over the whole subdivision for a range of effluent disposal options

<table>
<thead>
<tr>
<th>Deep Drainage</th>
<th>Dryland Pasture</th>
<th>Dryland Trees</th>
<th>Recharge credit</th>
<th>Disposal area m²</th>
<th>1000</th>
<th>750</th>
<th>500</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
<td>750</td>
<td>500</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Vegetation on disposal area</td>
<td>Increase in deep drainage on disposal area</td>
<td>mm/year</td>
<td>mm/year</td>
<td>mm/year</td>
<td>mm/year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td>5</td>
<td>10</td>
<td>21</td>
<td>82</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trees</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Another approach to establish neutral hydrological impact (via deep drainage) is to replant trees in existing dryland pasture outside the subdivision, but still within the catchment. This could be expected to reduce dryland deep drainage from 86 mm/year to 40 mm/year, thereby creating a recharge credit of 46 mm/year for each hectare retreed. For a 200m² grassed disposal area, the net increase in deep drainage is 82 m/year. Hence, about 2 hectares of dryland trees need to be established outside the subdivision for each hectare of subdivision.
4.2 What Can we do with the Excess Volume of Water in the Landscape Causing Secondary Salinity?

A relatively simple groundwater balance can be undertaken to give an approximation of the volume of excess water and partitioning of its discharge which is creating the salinity problem within the catchment (Shaw et al., 1987). Table 5 shows generalised figures for a salted catchment of 1000 ha with 10% of the catchment having a high recharge rate (saturated hydraulic conductivity of 20 mm/day), 20% of the catchment having a lower recharge rate (Ks = 10 mm/day), and the remaining 70% having a low recharge rate (Ks = 3 mm/day), giving a catchment average Ks of 6 mm/day (or 0.006 m/day). In this example, subsurface outflow is likely to occur every day of the year, but recharge will only occur episodically - perhaps only 2 days each year. (Details of calculation methodology are given in Shaw et al., 1987).

Table 5 Illustrative hydraulic parameters for a generalised salted catchment of 1000 ha, with bare or seepage areas establishing hydrologic equilibrium between recharge and discharge

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Recharge</th>
<th>Subsurface Outflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic conductivity</td>
<td>m/day</td>
<td>0.006</td>
<td>10</td>
</tr>
<tr>
<td>Hydraulic gradient</td>
<td>m/m</td>
<td>1/1</td>
<td>1/100</td>
</tr>
<tr>
<td>Area</td>
<td>m²</td>
<td>10 x 10⁶</td>
<td></td>
</tr>
<tr>
<td>recharge surface area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>discharge cross-sectional area</td>
<td></td>
<td>5 x 10²</td>
<td></td>
</tr>
<tr>
<td>Flow period (days)</td>
<td>days</td>
<td>2</td>
<td>365</td>
</tr>
<tr>
<td>Volume of water</td>
<td>120 ML/year</td>
<td>18.2 ML/year</td>
<td></td>
</tr>
</tbody>
</table>

The difference between recharge and subsurface outflow (here, 120 vs. 18 ML/year) is the volume of water that the system must remove in other ways. In this example (a salted catchment draining into Lockyer creek), the system has compensated with increase discharge by:

- increased surface seepage which causes the bare wet area (≈10 ha);
- increased soil evaporation from the raised watertable level (for a net soil evaporation rate of 2 mm/day, 73 ML/year of water can be removed from 10 ha of bare discharge area); and
- increased evapotranspiration from treed areas in the low salinity part of the discharge area, upslope of the bare discharge area.

There are several alternatives for the removal of this excess water which will ultimately depend on both the quantity, quality and availability of the water. Reclamation of this salt-affected catchment will require the removal of the bare area discharge component of this equation, by lowering the water table. Suitable groundwater removal options will be

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dependant on groundwater supply and quality. Vegetation management options could also be
developed which reduce the recharge component of the groundwater balance, or increase the
discharge component via plant uptake from the groundwater.

The use of vegetation in discharge areas to remove excess groundwater is often promoted, yet
little experimental data is available to support the efficacy of this approach. Recent
information (Thorburn, 1996) suggests that groundwater uptake by vegetation in discharge
areas with shallow water table is limited to 50 - 400 mm/year (± 1 mm/day). Considering that
the excess water volume may be of the order of 100 ML/year (Table 5), we would require
between 25-200 ha of trees to generate the desired level of groundwater uptake. This is a
significant proportion of the catchment that would be required specifically for tree planting.
Another concern is the long term sustainability of vegetation in discharge areas as salts
accumulate within the root zone during the transpiration process. The planting of trees in
recharge areas is also an option, but quite large areas are often required to significantly
impact on watertable levels (Doherty & Stallman, 1992.)

Groundwater pumping can also be a viable option for management of salinity problems. To
assess if pumping is a viable option we need to determine:

- the volume of water that needs to be pumped to reclaim the affected area;
- how easily this volume can be extracted, using standard pumping technology;
- quality of water to be pumped; and
- the options available for using and/or disposing of water of this quality (e.g. irrigated
  pastures)

Doherty and Stallman (1992) report on a very successful application of this approach in a
salted catchment on the eastern Darling Downs.

4.3 How do we Estimate Recharge to Provide a Water Balance?

To determine if secondary salinisation is likely to be a concern in subdivision it is important
to predict the water balance prior to the development. Since the groundwater characteristics
of the system are unlikely to change, the estimation of recharge (deep drainage) is the key
component of this water balance. Shaw and Thorburn (1985) developed the SaLF model for
predicting deep drainage using empirical regression equations based on clay content, clay
type, sodicity and rainfall. These relationships describe deep drainage (Dd) using an equation
of the form:

\[ Dd = \left( a \frac{Dr}{ESP^c} + b \right) \times Dr \]

where: Dr is the annual depth of rainfall and a, b and c are regression coefficients
which vary with clay content and clay mineralogy, and ESP is exchangeable
sodium percentage.

The SaLF model cannot predict the changes in deep drainage with a change in vegetation type
or land use. However, it does allow us to estimate the deep drainage expected for various soil
types with increased quantity and changed quality of irrigation water. This may be useful for
estimating the impact of effluent disposal and hard surface run-off on recharge from grassed
areas, which is similar to the land use of the soils used to develop the original regression equations.

However, daily water-balance models (such as PERFECT and MEDLI) will provide a more robust tool for examining the likely impact of subdivision on recharge, as they allow a prediction of the impact from variations in irrigation and vegetation type on all components of the water balance (deep drainage, run-off, evaporation and transpiration). Daily water balance models were used to generate the examples used in this paper.

4.4 How do I Determine that Salinity will not Become an Issue in the Future?

Even with the best planning, it is important to monitor subdivisions within sensitive catchments to ensure any developing salinity and/or waterlogging problems are quickly identified and managed. It is always easier to manage a salinity problem before it develops, rather than waiting until visual symptoms of salinity occur. The best on site monitoring is ground water levels measured by piezometers inserted to different depths at different locations in the landscape (Figure 5). Existing bores and wells can also be used.

![Diagram of a piezometer](image)

**Figure 5** Diagrammatic section of a piezometer to monitor watertable fluctuations

A piezometer is a device to measure pressure within an aquifer system. An open tube-well only indicates the free water table height of a phreatic aquifer (not a confined or semi-confined aquifer). Because water tends to flow from areas of high pressure potential to low
pressure potential, the levels recorded in piezometers are useful for indicating the direction of water flow in a catchment. Piezometers commonly consist of PVC pipe inserted into an open drill hole (Figure 5). The bottom section of pipe is slotted to allow water entry, and gravel is packed around the slots. This gravel pack prevents hole collapse and provides good hydraulic conductivity for water movement into the pipe. Above the gravel pack a watertight seal (either concrete or bentonite) is inserted to hydraulically isolate the aquifer of interest and prevent leakage from the soil surface. After the sealing layer is in place, the rest of the hole is backfilled using waste soil from the drill hole (Geritz, 1985). An example of water level responses within a salt affected catchment on the eastern Darling Downs is shown in Figure 6. Depth to water table is usually considerable in recharge areas, with marked seasonal fluctuations. Water table depth in transmission areas is intermediate between depths in recharge and discharge area with some response to rainfall, but less than recharge areas. In discharge areas, the water table is at, or close to, the soil surface, with subdued seasonal fluctuations. Monitoring over longer time periods will provide an assessment of the impact of changed land use on water table levels. Once water table levels rise to within 2 metres of the soil surface, symptoms of waterlogging and/or salinity will become visible at the soil surface. The implementation of management options is recommended before water table levels in discharge areas rise to within 5 metres of the soil surface.

Figure 6 Typical water level response (as hydraulic head) for recharge, transmission and discharge areas in relation to rainfall near Dalby.
5 CONCLUSIONS

The use of on-site effluent disposal in unsewered subdivisions has the potential to exacerbate dryland salinity in catchments vulnerable to hydro-salinity problems. The commonly accepted 200m² disposal area is generally far too small to ensure effluent supply matches irrigation demand in most climate zones of eastern Australia. Re-direction of hard surface run-off onto grassed run-on areas also has the potential to exacerbate dryland salinity problems. Management options to make a subdivision hydrologically neutral include: increasing the disposal areas; changing vegetation grown on the disposal areas; planting trees in adjacent dryland pasture areas to create recharge credits; limiting subdivision to soils which partition excess effluent irrigation and hard surface run-on as runoff rather than deep drainage; incorporating some form of groundwater pumping (biological or mechanical); ensuring all run-off is diverted into drains and natural water courses; and installing a partial (e.g. Common Effluent Disposal) or complete, reticulated sewerage systems. Before new subdivisions are approved, it is strongly recommended that a site specific water balance and catchment scale hydro-salinity assessment be undertaken to ensure the development will be ecologically sustainable in terms of salinity, water quality, land stability and pathogen levels. The water balance models PERFECT or MEDLI are well suited to some of these tasks.

6 REFERENCES


MODELS AND MULTI-OBJECTIVE DECISION MAKING FOR RESOLUTION OF RESOURCE MANAGEMENT CONFLICTS

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ABSTRACT

The increasing role by community groups in catchment scale decision making on sustainable resource use and management requires much more comprehensive tools for managing ecosystems on a temporal and spatial scale. Integrated Catchment Management (ICM) is being strongly promoted in Australia as a strategic framework where individuals, groups and government agencies with a vested interest in catchment outcomes can make group decisions on regional and strategic development and management strategies for sustainable resource use.

For these decisions to be effective on a catchment scale, there is a need for multi-objective decision making tools to optimise as transparently as possible the diverse needs and expectations of stakeholders. In such a participatory decision making environment, the challenge is to convey data and simulation model outcomes in a useful manner for evaluation of "what if" scenarios for resource use and management strategies. Biophysical processes and simulation modelling, resource use options, economics, policy and social preferences and goals are important components of multi-objective decision making.

KEYWORDS: biophysical models, ecologically sustainable development, integrated catchment management, decision support, multi-objective decision making

1 INTRODUCTION

The strong emphasis on environmental sustainability for agricultural, urban and industrial issues has resulted in the need to evaluate the consequences of proposed developments and current practices. In Australia, the agreement by all States and the Commonwealth to the principles of Ecologically Sustainable Development (ESD) has put increasing pressures on agriculture. The proposed Natural Resource Management legislation for Queensland will incorporate acceptable minimum codes of practice for agriculture.

Natural resource management is a complex equilibrium between a range of diverse processes. Ecological sustainability and development comprise a fine balance between competing objectives. A change in one management option can change other parameters. For example, the shift to minimum till and stubble retention in cropping systems has dramatically reduced runoff and erosion from agricultural fields. Reduction in runoff has resulted in increased drainage below the root zone with consequent rising groundwater levels in sensitive landscapes, movement of agrochemicals to groundwater, and the mobilisation of salts in the unsaturated zone due to increased water movement through the soil profile.
Since catchment scale issues involve all the catchment stakeholders, comprising the community, producers, industries, urban community and government agencies, a decision system whereby resource management issues can be openly examined and evaluated is required. In particular, the downstream or the catchment-wide consequences can become an important consideration of how site management should be undertaken to meet a range of sometimes competing objectives. In situations where land developments are proposed for already degraded lands, such as eroded or salted lands, there is pressure to restore the land to a situation where the degradation is reversed. This is particularly the case where there is impact downstream and there is considerable benefit in a restoration of a hydrologic and ecosystem balance to the development.

This paper outlines the models and background factors determining the style of multi-objective decision support systems in Australia to resolve resource use and management issues.

2 BACKGROUND

Several government and community initiatives that have been taken in Australia over the last ten years have been significant in determining the direction for development of decision support systems (DSS) for natural resource management.

2.1 Community Involvement in Decision Making

The Landcare movement began in Australia with government support in 1989 (McDonald & Hundloe, 1993). The 1990's has been called the 'Decade of Landcare' (Commonwealth of Australia, 1991) Landcare has been quoted by several authors as being "one of the most significant developments in land conservation in Australia (Curtis et al., 1994).

One of the national goals of landcare is:- "All Australians working together in partnership for sustainable land use". Responsibilities are spelt out for Commonwealth and State governments, and landcare groups as a partnership approach (Commonwealth of Australia, 1991).

This cooperative focus has been expanded to land, water and vegetation management through a government sponsored movement called Integrated Catchment Management (ICM). The ICM movement comprises local stakeholder groups forming committees to develop strategies for implementation of sustainable catchment management practices. It is an outcome of government policies which strongly promote regionalisation and participatory democracy in local decision making. One of the principles of ICM is:- "In a democratic society, sound land and water management is best achieved through the informed action of individual users and managers of these resources" (Queensland Government, 1991).

Thus with this framework of strong community and stakeholder participation in natural resource management, and the range of different objectives of the various stakeholders, there is a major requirement for sound technical data and multi-objective decision support systems to allow appropriate and sustainable resource management options to be selected. These community and stakeholder groups require the presentation of technical and socio-economic issues in a readily understood manner to facilitate making decisions on complex issues.
2.2 Ecologically Sustainable Development

The Australian Government and all state governments are signatories to the concept of Ecologically Sustainable Development, ESD, (Commonwealth of Australia, 1992). Proposals under the ESD agreement need to demonstrate that they have a net beneficial effect economically and environmentally. This can only be done using technically validated examples and simulation models of the effects under different resource management options with adequately quantified socio-economic inputs and non-market valuations of natural resources.

Additionally, environment protection legislation requires proposed developments to submit an Environmental Management Plan. The plan is an agreement between the proponent, the government agency responsible and the community. The plan comprises a statement of a policy on environmental sustainability for the various elements of importance, performance criteria on which compliance with that policy can be assessed, monitoring procedures from which performance can be assessed, and reporting and corrective actions that will be implemented should the specified criteria not be met. At this stage, best management practices are usually specified as a means of showing compliance, or for implementing corrective action.

A more technically sound decision process is required to assess the likely effectiveness of these performance management options, their acceptability to the regulatory authorities, and the corrective actions that may be required as the number and complexity of interdisciplinary issues increase. For this aspect to be achieved, simulation models and objective decision making is needed.

The formulation of new Natural Resource Management legislation in Queensland will integrate a range of existing acts into a new policy and legislation on the sustainable use and management of natural resources (DPI, 1994). Two of nine principles in the formulation of this legislation are:

- The holders and users of natural resources are primarily responsible for the resources held under their care.

- Natural resource management is best achieved through effective processes of cooperation and coordination within government, between government and the community, and within the community.

For an increased number of stakeholders with different and sometimes competing objectives, it can be extremely difficult to reach a near consensus view on the most appropriate strategy for management of the resources. Also in decision making at this level, the technical understanding by stakeholders is very diverse and whether soundly based decisions can be made without technical input and a formal and objective decision process is open to question (Foran & Stafford Smith, 1990).

In summary, a major requirement for sustainable natural resource management on a catchment scale is sound technical and decision making support for community based groups in a participatory decision making context. A similar approach is required for project based
developments to ensure that proposed actions will be sustainable. These issues are setting the background for the development of multi-objective DSS in Australia.

Public concern over environmental consequences has resulted in an increased scrutiny of development proposals with a requirement for greater understanding and predictive certainty of the consequences identified.

3 CONCEPT

Consideration of processes at a catchment scale, with an increased number of stakeholders involved and more complex natural processes to be assessed, means decision making has jumped an order of magnitude in complexity.

There is a plethora of models that simulate land and water issues at a range of both scales and complexity. It would not be possible to address each of these models in this paper, or probably even a lifetime, however some overall aspects of modelling land and water issues can be addressed. These types of models will be referred to as biophysical models in that they simulate biological and physical (soil and water) processes.

Firstly, one must understand some underlying concepts of modelling. The term model is a general expression that can have a range of definitions for different disciplines. Generally, a model is a theory, hypothesis or structured idea that can be expressed as a role, relationship or an equation (Chorley & Haggett, 1967). A common feature of all models is that they represent a simplified view of reality. Processes that are considered to be of lesser importance to the model developer are often ignored during development of the model. Therefore, the construction of a model results from a selective attitude to information and less important signals are often eliminated to enable the model developer and user to see responses from a system as a whole (Chorley & Haggett, 1967). Therefore, a model contains subjectiveness in that it emphasises particular features of a system and gives prominence to these features. It may also distort and obscure other features (Chorley & Haggett, 1967) and present the refined results of particular points of view (King & Kraemer, 1993).

A model of a biophysical process is an ordered set of operations that describe the essence of a process in terms of observable or verifiable inputs and outputs (Burrough, 1992). Underlying concepts within a model must be simple enough for operation and comprehension by users but complex enough to accurately mimic the system under consideration. Virtually all biophysical models are a mixture of mathematical relationships that model biophysical relationships. For example, many erosion models estimate soil loss as the product of runoff volume and sediment concentration and include processes such as runoff estimation, detachment of soil particles, sediment transport in runoff and deposition of sediment.

A major advantage of a biophysical model is that it is based on the knowledge and experience of numerous individuals on particular processes in a system. Such a model integrates physically-based and conceptual models, data from extensive field trials and knowledge and experience gained from numerous research projects. Such a model has many other advantages including:

- it can be examined for flaws in the logic of the model;
• it can be tested against field data to ascertain how well it mimics reality and whether the important processes have been incorporated into the model;

• the sensitivity of individual processes in the model can be evaluated;

• it can be given to other individuals to test its rigour;

• it can be operated with parameters that highlight major biophysical factors; and

• results from a biophysical model can be replicated by different operators.

Decision support systems can be defined (after Thompson et al., 1992) as the integration of expert knowledge, management models and timely information to assist in making day to day operational and long range strategic decisions. Key concepts are the ability to evaluate "what if" questions and to predict the effects of decisions.

An integrated approach to DSS is illustrated in Figure 1 where data, geographical information systems (GIS), models, information and DSS are linked on a multi-disciplinary basis.

![Diagram](image)

**Figure 1** A schematic framework linking data through GIS and models to a decision support system illustrating the involvement of different stakeholders and different disciplines.
Decision support systems have most frequently been used to assist in making decisions on complex environmental problems, poorly formed problems or where the choices are numerous. Janssen (1992) considers DSS are necessary where the complexity of the system, the time scale of the processes and the diversity of the effects are beyond the imagination of most people. Decision support systems can assist in evaluating the untried options for situations where traditional practices are more likely to be adopted than innovative practices or new managements with greater environmental sustainability, because of a lack of awareness of alternatives.

Van Diepen et al., (1991) discuss a variation of the linear programming model and decision theory, called multiple-goal programming, that has been applied in the case of conflicting objectives in regional land use planning. This approach is broadly similar to that discussed later of Lane et al., (1994).

Some principles of multi-objective decision making that need to be adopted in the context of environmental management are as follows:

- Decisions need to be made by the stakeholders using a transparent and rigorous system with decision making variables tied to scientifically sound system responses. This means that the consequences of actions are based on measured or predicted responses so that effective and balanced decisions can be made;

- A catchment or ecosystem scale is required. Some changes in catchment response to resource management are very slow, for example salinity, so that good predictions of small changes over long time periods are needed (not a simple task);

- A multi-disciplinary approach is essential so that consequences across a very wide range of issues can be considered;

- Risks need to be quantified as far as possible so that the impacts of a proposed management change can realistically be evaluated;

- Models are needed to adequately integrate climate variability (particularly rainfall) and spatial variability. Models are only tools and while the literature is full of detailed specific models which assist in understanding, the outcome needs to be assessed in conjunction with other economic and social preference variables and criteria within a decision support system; and

- The presentation method needs to be as simple as possible with the complexity and functionality present but not intrusive into the decision process.

The Resource Assessment Commission (1992) evaluated the use of multi-criteria analysis for natural resource management in Australia. They considered that multi-criteria analysis provided a structured yet flexible approach and was particularly useful for complex natural resource management issues. It was considered an additional advantage where an understanding of the divergent social values will assist in arriving at a sound decision.
A weighting scheme for the comparison of not directly comparable values was considered a difficulty with the approach. In reality, this difficulty is also a strength where different criteria can be compared.

There is an increasing trend towards defining an appropriate valuation of environmental resources (Commonwealth of Australia, 1995). Future strategies will require the full market costs of the use, maintenance and replacement of environmental resources. Such a move would better reflect the costs of sustainable development.

4 OPTIMISING THE FORM OF A MO-DSS

There are several dilemmas to be resolved in the technical and biophysical aspects of a multi-objective DSS (MO-DSS) design as a result of the background given above. They can be identified as:

• space-time scale integration;
• model complexity-outcome accuracy; and
• awareness - technical detail-group decision making.

These issues are discussed in Shaw et al., (1995b). There is a compromise between spatial applicability and the degree of detail in the models required. Simple models appear a useful compromise.

Often in evaluating sustainable agriculture and environmental risks, the consequences over long time periods are required. There is an enormous scale and time problem when using deterministic classical soil physical approaches to water movement based on the concepts of short time and point measurement. This is illustrated in Figure 2 from Shaw et al., (1995a) where the time and space changes from point scale and hourly-based to century-based soil physics and catchment scale processes is in the order of millions of scale factors. A DSS needs to give big picture, predictive outcomes of the consequences of developments on environmental issues in the first instance. For high risk situations, currently developed point and deterministic mechanistic models can be used for additional quantification where required.

Hatton et al., (1994) were critical of building complex hydrological models for landscapes because of the degree of parameterisation required and the enormous difficulties and uncertainties in spatial scaling which is probably a non-linear function with distance and landscape features.
Figure 2  Time and space relationships for various processes which impact on agriculture and the sustainability of natural resources (Shaw et al., 1995a).

4.1  Awareness - Technical Detail - Group Decision Making

The involvement of a broad range of stakeholders in decision making on natural resource management issues requires at least a minimum level of awareness of the issues for informed debate. There is commonly a lot of general information available but the usefulness of this information is often inadequate except for rudimentary decision making. Whittaker (1993) described the relationship between the quantity of data and the relative usefulness and value of data. Information is only of use if it is organised and relevant to the issues at hand.

Multi-stakeholder decision making imposes other significant complexities. Group decision making in the presence of multiple conflicting objectives is complex and difficult (Lewis & Butler, 1993) as optimisation of individual judgements and preferences may not align, leaving consensus and compromise methods as an important decision process. In this case, Lewis and Butler cite Beck and Lin (1983) who proposed techniques for group decision making that both maximised agreement, and minimised regret about a proposed decision. Minimising regret was a straightforward procedure and Lewis and Butler (1993) indicated that the procedures were particularly appropriate for large scale ranking problems.

Group decision making processes identify a multitude of options that may or may not be appropriate for further consideration. This is because the frame of reference or the scope and understanding of the systems approach on a spatial scale may be limited.
Thus a scaled approach in complexity is required. Where the issues can be identified in yes/no terms, simple 'back of the envelope' calculations and expert opinion may suffice. Where the interactions between processes or managements are more complex, more quantitative, broader scale and complex models with associated greater data requirements are necessary. There has been a major emphasis on deterministic process modelling of more recent times which has led to an exaggerated credibility of models compared to more empirical or intuitive techniques. Johnson (1995) expressed it as "intuitive techniques for exploring data in a spatial context have often been ignored in favour of elegant formal modelling".

5 DSS APPROACHES TO NATURAL RESOURCE MANAGEMENT ISSUES IN AUSTRALIA

Published guidelines, handbooks, expert systems, decision support systems and spreadsheet based 'what if' scenarios, have all been used to assist in decision making for many years. For simple issues, a one page guideline is quite adequate. Where the decision maker has to optimise on essentially single issues with limited interactions, simple DSS are appropriate. Where the issues are difficult to conceive, expert systems models and decision support systems come into play. Where there are a number of stakeholders whose decisions for their own interest also impact on other stakeholders, the appropriate decisions are increasingly more difficult to make and multi-objective decision support systems are required.

Biophysical models are valuable tools to investigate interactions between processes and management options. However, there is no such thing as an ideal model for modelling land and water processes. However there are a number of major issues that must be addressed when choosing the most appropriate model for a land and water application.

Firstly, compiling the required data for a model is a time-consuming task. There is a delicate balance between the level of complexity of a model and the resolution and scale of data required to run the model. Usually, increased model complexity results in increased data requirements. Care must be taken because any output from a model is only as good as its inputs, commonly referred to GIGO (Garbage-in, Garbage out).

Secondly, the complexity of many biophysical models means that it is difficult for an inexperienced model user to apply models. The fact that someone can use a word processor, spreadsheet or database does not mean that person can use a model. Proper application of models usually entails gaining experience, either first hand or through training courses. Also, the model user will face many dilemmas and uncertainty when applying a model for the first time. Often, these dilemmas need to be resolved in conjunction with the model developer or someone familiar with the model.

Finally, biophysical models operate at a range of dimensions. One-Dimensional (1-D) models simulate a single point in the system and assume that there is no interaction with surrounding points. Extrapolation to paddock sized areas is possible with the assumption of homogeneity in climate, soils, landforms and management. In Australia, there are many published examples 1-D models including SWIM (Ross, 1990) and PERFECT (Littleboy, et al., 1992). The one-
dimensional water balance model from PERFECT has also been applied to predict the environmental consequences of effluent disposal (e.g. Gardner et al., 1995).

A quasi two-dimensional model attempts to simulate processes occurring with a spatial dimension in a simplified way. In Australia, MEDLI is an example of a quasi 2-D model that has been specifically developed to design land-based effluent disposal systems for feedlots, piggeries, dairies, sewage treatment plants and other industries producing effluent (Davis et al., 1995). MEDLI simulates an effluent disposal system including effluent generation, treatment, storage and land disposal. A spatial dimension is implied in that the effluent generation, treatment, storage and land disposal areas are linked with effluent passed from on area to the next. Another example of a quasi 2-D model is CREAMS (Knisel, 1980) that was developed in the United States to estimate the export of nutrients in runoff and sediment from agricultural areas.

Two-Dimensional models represent a biophysical system in two dimensions and permit spatial interactions. For example, grid based models hydrology models such as ANSWERS (Beasley et al., 1980) and AGNPS (Young, 1994) divide a catchment into uniform grid cells. A 1-D hydrology model is applied to each grid cell to estimate runoff and infiltration. In contrast to 1-D runoff models, a 2-D model also considers the influences of upslope areas in the prediction of surface runoff. Water is routed through the catchment along defined channels to the catchment outlet. 2-D models are particularly useful for estimating runoff volumes, peak runoff rates, sediment concentration and water quality from small catchments.

Three-Dimensional models are 2-D models that also include the effects of subsurface processes. In Australia, examples of such models are TOPOG (O'Loughlin, 1986), THALES (Grayson et al., 1992), WAVES (Dawes & Short, 1993). These types of models are particularly useful for simulating biophysical systems where the interaction with groundwater is desired. For example, evaluating different tree planting options in a catchment with the aim of reducing water table height.

Almost without exception, problems in applying biophysical models for land and water issues relate to whether an inappropriate model was used, GIGO principles and correct model parameterisation.

For scenarios where the interaction of rainfall, cropping practices and nutrition inter-relate, resulting in crop yields that may be economically marginal, modelling approaches are needed to integrate the variables. A classic case of this approach is water balance crop yield models for example PERFECT, Littleboy et al., (1989).

Cropping systems modelling has been a very common form of decision making tool for paddock scale productivity. Carberry et al., (1991) have linked cropping systems models to economics for the semi arid tropics. This approach is particularly useful when combined with rainfall prediction. The advantage of this modelling approach is that climatic variability over time can be used to develop probabilities of economic returns amongst other things. Also climate can overshadow many management practices and is responsible for the high variability in runoff and hence erosion which are issues for catchment scale land sustainability.
There are no multi-objective DSS approaches commonly available for natural resource management issues in Australia. A wide range of agricultural productivity DSS are available which have not been discussed here. The following are DSS that provide aspects of natural resource management issues. These are, briefly;

**PRIME**
Planning; Research; Implementation; Monitoring and Evaluation is a procedure for developing Integrated Catchment Management Plans by stakeholder groups developed by Syme *et al.*, (1994). It is a staged decision framework. PRIME is a decision support process rather than a software based DSS.

**ALES**
Automated Land Evaluation System developed by Rossiter (1990) which is an expert system framework for land evaluation. Johnson *et al.*, (1994) integrated economics and biophysical data with ALES. The process uses diagnostic attributes and decision trees to relate land characteristics to land use requirements based on expert knowledge.

**LUPIS**
Land Use Planning and Information System has been developed to solve land allocation problems, in particular where more than one land use is proposed within a planning area. It takes into account the site specific land attributes of the area (Ive *et al.*, 1989; Ive, 1992).

**ASSESS**
A System for Selecting Suitable Sites was developed as a rating procedure to select radioactive sites in Australia (Berry, 1994). It comprises a series of GIS layer coverages, called themes, and a flexible weighting and optimisation procedure to determine the desired outcomes against a set of defined criteria.

**AEAM**
The original Adaptive Environmental Assessment and Management concepts from Canada as reported by Grayson and Doolan (1995) have been used at a catchment scale in some areas of Australia. The AEAM process is aimed at providing links between communities with a problem and the technical resources available. The ability to interactively progress the planning phase overcomes some of the community scepticism and impatience if long time periods are spent in planning (Syme *et al.*, 1994).

**CMSS**
Catchment Management Support System is a catchment scale model for estimating nutrient loads in runoff, particularly of phosphorus and nitrogen. It is based on data for nutrient generation rates and areas to calculate loads (Davis *et al.*, 1991).

**LANDASSESS**
This was developed to examine the effects of grazing management strategies on vegetation and soil properties and sustainability, and the profitability of production at a paddock scale Bellamy *et al.*, (1993). LANDASSESS incorporates a knowledge based system which is based on qualitative reasoning to assist in decision making, a series of submodels and GIS.
LANDS
Land Analysis and Decision Support is a comprehensive land information and planning system developed in Canada by Moon et al., (1990). It was designed to assess land suitability options and for agriculture and incorporates a data management system, an expert system for land suitability, a detailed modelling and economic analysis module, an optimisation module and a geographic information system. It can be applied from the property to the regional scale, Moon et al., (1994).

6 DECISION OPTIMISATION PROCESS

Evaluation of options on the basis of "what if" scenarios is required with stakeholder negotiations leading to accepted decisions. Algorithms and processes for decision optimisation are presented in the literature (for example Bana e Costa, 1990; Janssen, 1992). Lane et al., (1994), in a collation of several papers from his group, developed a prototype MO-DSS for the US water quality initiative. Their system considered some innovative approaches to the ranking of alternative management options and assessment of the important multi-objective decision variables chosen by the stakeholders (Yakowitz et al., 1992, 1993).

There is a long history world wide where the consequences of resource management changes are not adequately assessed before developments begin. This is partly because of the complexity of the issues and the need for a true multi-disciplinary approach. Because the time frame for developments is often short and stakeholders need to see action on the ground quickly, approaches like this are an important development in the new paradigm of finding technically sound management options for ecologically sustainable development of catchments.

7 CONCLUSIONS

The ongoing shift in decision making to involve all stakeholders on the complex equilibrium between resource management for productive use and sustainability will require the development of decision support systems that incorporate biophysical models with socio economic and social preference models.

There are a number of technical difficulties yet to be addressed in temporal and spatial scale applicability of models and in incorporating a multi-disciplinary approach to give an integrated and holistic decision process.

8 REFERENCES


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