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Avon River System Fact Finding Study

Report to Avon River System Management Committee

by
P.R. HANSEN

WATERWAYS COMMISSION
184 ST. GEORGE'S TERRACE
PERTH W.A. 6000

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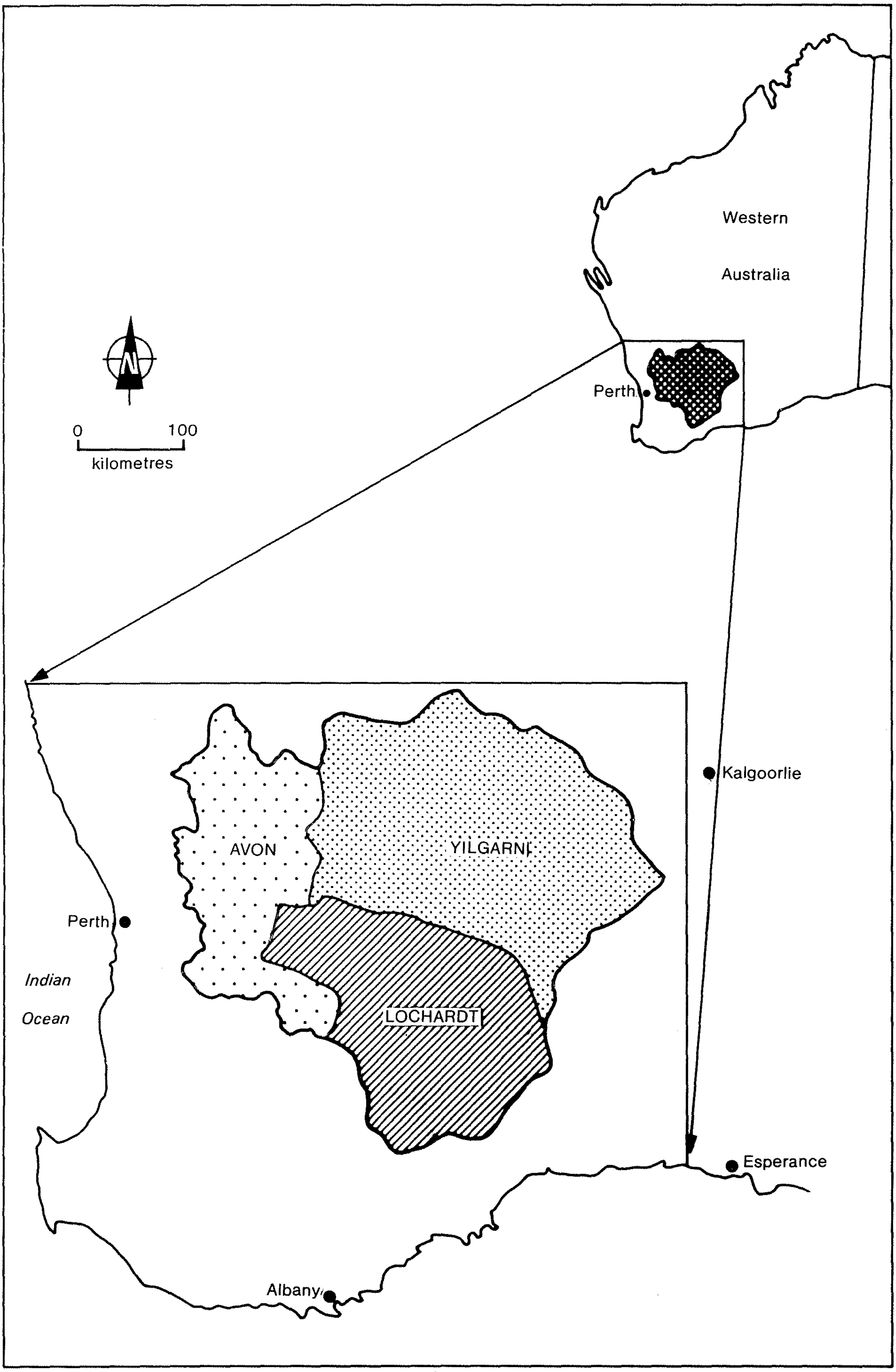


Avon River System Drainage Basin

AVON RIVER SYSTEM FACT FINDING STUDY

OVERVIEW

Developments are causing continuing changes to riverine areas. These changes are difficult to evaluate in economic terms. Comparisons between the social and, ultimately, the economic value of natural areas, and the economic and social benefits of development are difficult to make.

The aesthetic features of the river are of great value to society. Such value is difficult to assess and is not generally protected by adequate planning controls.

The riverine environment provides important recreational and tourist potential. Most of these activities are dependent on features of the natural environment. Use of these areas is increasing and is important to the regional economy, but it is often understated by management authorities.

The variability of flow has always been a feature of the Avon River system. Life has adapted to this variability. Regular floods are a feature of the regime and the ecosystems are dependent on these features for their long term survival.

Long term effects of alterations are matters of speculation, however changes to the natural features are occurring rapidly under the present land use system.

There is a need to develop a multi-objective policy for river management, considering long term river utilisation, economic benefits, social and environmental issues.

At present the natural riverine system is inadequately protected by reserves, water-quality standards or planning controls. This is especially true of the flood plains. Co-ordination of the powers already held by the many authorities could provide significant protection and adequate development control over all riverine land.

CONCLUSIONS

Solving the problems of the Avon River System must address the causes of the problems and not the obvious symptoms, as has been the approach used in the past.

The River Training Scheme was an attempt to reduce the flooding of the Avon Valley townsites. This was successful but has created further environmental and hydrological problems.

The symptoms which are causing most concern with the Avon River system are:

i. River pool siltation.
ii. River flooding.
iii. Salinisation of farming lands.
iv. Soil erosion of farming lands.

To control these symptoms the causes need to be clearly identified first.

RECOMMENDATIONS

In order to further understand the causes of the symptoms, hydrological and geophysical studies need to be undertaken. Associated with these, field trials can be initiated to determine appropriate means of controlling silt movement in the river. The following approach is recommended:

1. Initiate investigations to:

   (a) Determine the degree of erosion from the Avon River Catchment.

   (b) Measure the loss of soil to the river from various land uses.

   (c) Describe the movement of eroded silts and river sediments in the river.

2. Commence a series of tree planting field trials at suitable sites upstream of selected river pools to:

   (a) Determine their ability to trap silt.

   (b) Develop tree planting techniques including layout and design.

   (c) Assess the value of this method as a management tool for controlling silt movement in the Avon River.

The Avon River about 1920 Courtesy of the Battye Library 816B/189
Reputed to be Burlong Pool

INTRODUCTION

This interim report is intended to provide a broad examination of the effects that current and past land use and water management practices are having on the nature conservation status of the riverine eco-system of the Avon River system in South Western Australia.

Due to the geographical size of this river system and the range of land and water practices involved, this interim report can provide only a generalised overview of the interactions that are taking place. It does seek to identify the main areas where problems are occurring.

The nature of the ecosystems the river system supports and its future social value are not understood, and consequently have not been incorporated into management policies and practices.

STUDY OBJECTIVES

This report arose from a general concern about the impacts that land and water use are having on the nature-conservation values of the Avon River systems.

The study is intended to:

Identify the main environmental values of the riverine ecosystem.

Examine the main alterations that are occurring to these ecosystems.

Suggest measures that may be taken to alleviate these alterations.

The report also seeks to point out those areas where inadequate knowledge is preventing an understanding of many longer-term alterations that are occurring.

STUDY APPROACH

This study is funded by the Waterways Commission, on behalf of the Avon River System Management Committee (ARSMC).

The ARSMC was first formed in March 1984 by a group of delegates from the town and shire councils that have an interest in the Avon River systems.

The objects of the Association shall be:

1. To manage the Avon River System for social, economic and environmental reasons.

2. To reduce the RATE of water discharged into the river system by actively encouraging all recognised methods of soil conservation on rural land, and to extend these concepts to the beds of the rivers.

3. To encourage improvement of the quality of water flowing into the river system.

4. To collect, collate and make available to the public all existing information on the river system.

5. To seek financial and scientific assistance with which to further these aims.

6. To establish and review through the medium of an annual general meeting policies for implementation of the objects of the Association.

There is a considerable amount of information on various aspects of the Avon River system collected over many years. This information is held in several places, including government departments, tertiary institutions, local authorities and by private individuals.

The first task of the study is to identify as much of this information as possible, i.e., who has done what on the Avon River system, and what does it tell us?

The early period of the study was spent in visiting many of those departments and going through files, records and journals, talking to the people who have been and, still are, involved with studies on or in the Avon River system. Much of the work was found to be very 'area specific', i.e., a lot is known about a particular problem in a small area. Some of this information may be useful on a broader catchment basis, but some of it may not be.

After the city departments ceased to yield any new information, visits were made to the local government authorities who either have delegates on the ARSMC or were within the annual western catchment zone (map P7*). These visits were to assess the perceptions and attitudes of local government and, through it, community attitudes towards the Avon River system.

Other members of the community who had an active interest in the river system were also approached. This was in no way a representative sample of community attitudes, but more of an information and attitudinal gathering exercise.

This interim report is based on the information gathered by this process in the period of late October, November and early December 1985.

An important part of the Avon River System Management Committee's job is to develop policy to assist statutory bodies and land users in their decision-making and planning - a means of presenting policy through a published management programme.

* Facing page 7

Relevant information must be compiled and assessed before policy can be developed.

This fact finding study is designed to enable the Committee to perform this task.

STUDY AREA

The study area (map P57) of the Fact Finding Study is the drainage basin of the Swan/Avon River system upstream of the Swan River management area boundary.

Local government authorities within the Swan/Avon drainage basin include:

- Shire of Beverley*
- Shire of Brookton*
- Shire of Bruce Rock
- Shire of Chittering
- Shire of Corrigin*
- Shire of Cuballing
- Shire of Cunderdin*
- Shire of Dowerin*
- Shire of Goomalling*
- Shire of Kellerberrin
- Shire of Merredin
- Shire of Northam*
- Town of Northam*
- Shire of Pingelly*
- Shire of Quairading
- Shire of Swan
- Shire of Tammin*
- Shire of Toodyay*
- Shire of Victoria Plains
- Shire of Wandering
- Shire of Wickepin*
- Shire of Wongan-Ballidu*
- Shire of Wyalkatchem*
- Shire of York*

Councils visited denoted with *.

The Avon River System is comprised of the Avon, North Mortlock, East Mortlock and Dale rivers, with Spicer's Brook as a lesser tributary. These rivers usually flow for at least part of the year, each winter, i.e., they flow annually and dry up completely, or into a series of pools (Avon) over the summer.

The East Mortlock River system encompasses a large number of salt lakes in the shires of Cunderdin, Tammin, Dowerin, Wyalkatchem and Koorda. Water flow from these areas is often intermittent. The salt lakes have a large capacity and flow out of the lakes into the Mortlock, and then the Avon. This requires a 'wet' winter, i.e., above average winter rainfall.

The North Mortlock catchment basin in the Wongan Ballidu Shire also has several salt lake chains within it. Water does not flow out of these lakes in a 'normal' season, but in 'wet' seasons they can contribute water to the Mortlock.

The North and East Mortlock Rivers join just east of the Northam town site, close to the racetrack. The Mortlock flows through a section of the Northam town site and joins the Avon down river from the town weir.

The towns of Toodyay, Northam, York, Beverley and Brookton are all located on the banks of the Avon River, with all towns, except Toodyay, experiencing problems with flood water from time to time.

The eastern catchment, the Lockhardt and Yilgarn drainage basins, cover a huge area. They are predominantly low lying, slow draining salt lakes. Water flows from those two areas through the Yenyening lakes, located in the Beverley, Quairading, Corrigin, Brookton shire boundary area. Flow is irregular, perhaps 2 out of 5 years. The quantity of water involved is usually quite small, e.g. 1983 flow was in the order of 6 m^3/sec when the Avon at Brookton was flowing at 325 m^3/sec (D. Salim, 1985).

However as the catchment area is so large, given the set of circumstances, water flow from this source has the potential to be very significant, even to the extent of causing extensive flooding along the entire length of the Avon and Swan Rivers. Historical records indicate flood levels have been several feet over Burswood Island for several months (Binnie & Partner flood study, 1985).

Land Use

The western catchment, which includes the Avon, Dale and Mortlock rivers covers an area of approximately 2 million hectares. The predominant form of land use is dry land agriculture.

The major produce includes wheat and other cereals, and recently lupins. Sheep are the major livestock enterprise, for wool and meat. Pigs and cattle are also produced, but to a much smaller extent.

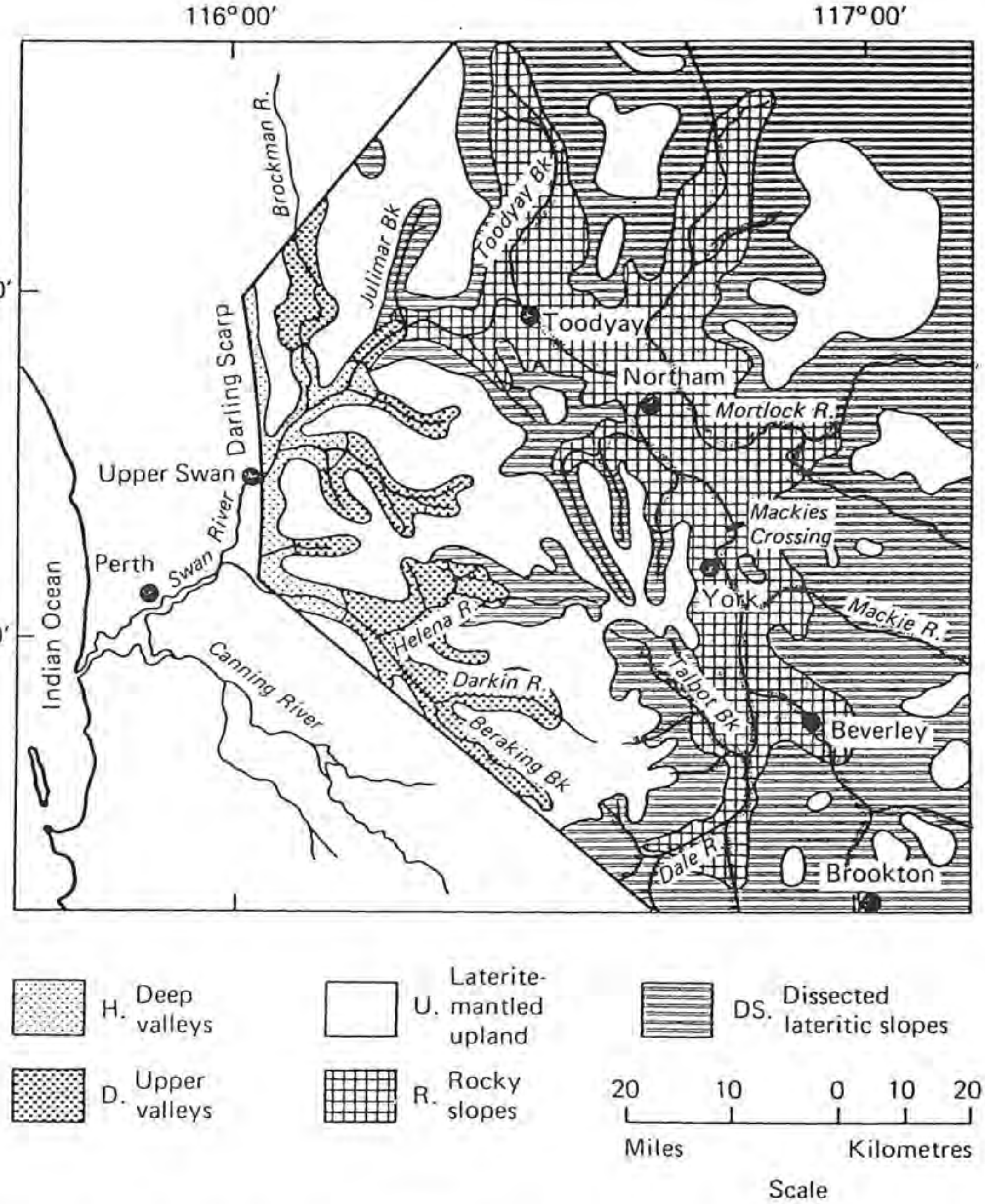
Thirteen shires in this area produced gross agricultural income of $284 million in 1982/83, approximately equal to 18% of WA agricultural income, a significant portion of which is sold on overseas markets. This indicates the economic significance of the land use to the State of WA, and even Australia.

The average property size ranges from 1,000 ha to over 3,000 ha, with an area average of 1,200 ha.

The only industry is associated with this agricultural land base, and all the towns provide services for the farming community. Without the farmers, few of the towns would survive in the area.

Geomorphology

The Swan-Avon River forms a major network draining a large area of the Great Plateau of Western Australia. This drainage system is characteristic of other river systems in south-western Australia with the inland portions having old and sluggish drainage, becoming mature in the mid sections, and sharply incised and young in the lower reaches. Land forms, and consequently soil and vegetation, are closely linked with these



Landforms and soils in the environs of the Swan-Avon River System differences in river form. Decreasing rainfall from west to east also influence soil and vegetation patterns. The pattern of agricultural development is also closely linked to the above factors. The more fertile and easily cleared soils were developed first. Salinity of soils, streams and rivers has considerably increased since the beginning of agricultural development. Salt storage occurs in the deeply weathered lateritic profiles which are common to most upland areas. Where shallow permeable soils develop from fresh rock, as in the main valley and on the sides of the Avon River, salinity is minimal, except for salts in transport along major streams and rivers (Bettenay 1985).

Salinity of the soils and ground waters has always been a problem in the lower rainfall eastern valleys, and with clearing has become increasingly important elsewhere. The generally accepted explanation for increased salinity of soil and water supplies is that the introduced crops and pastures use much less water than the deep rooted, evergreen, native species. Thus with clearing, the water table rises and mobilises soluble salt normally stored in the unsaturated zone. These mobilised upwards salts then move towards the valley. Where ground waters have risen to near the surface in the broad, flat, eastern valleys, large areas of what were previously the most productive soils have been rendered unsuitable to agriculture due to high salt concentrations and waterlogging.

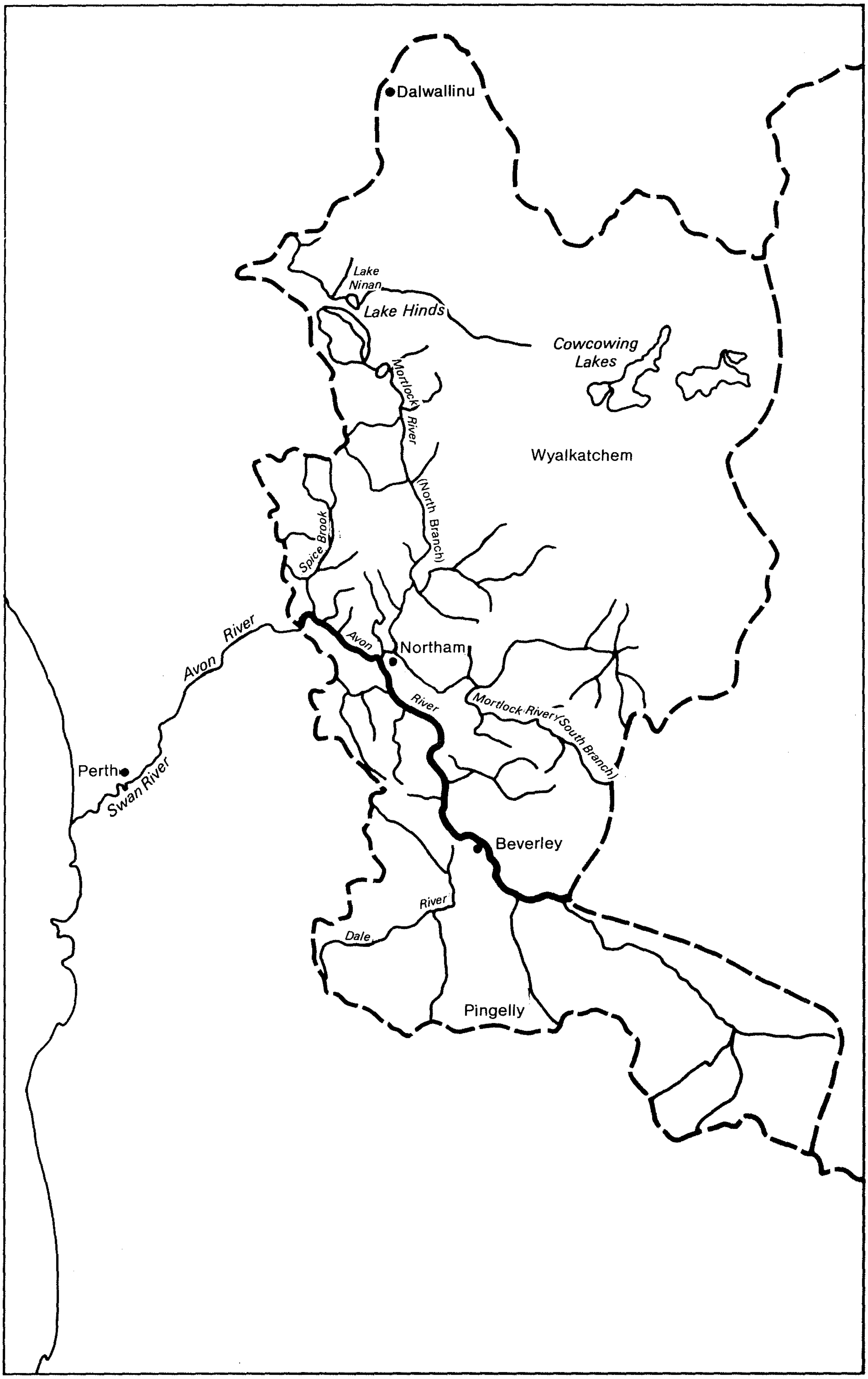
Destruction of the native vegetation in an early attempt to increase run-off into Mundaring Weir resulted in a rapid increase in the salinity of the stored water. Allowing the native vegetation to regenerate, and planting some areas with introduced pines, 'apparently' alleviated the problem (Bettenay, 1985).

THE AVON RIVER SYSTEM CATCHMENT DIVISION

The Avon River catchment area is approximately 96,400 square kilometres. Most of the catchment's climate can be classified as dry Mediterranean to semi arid, with a mean annual rainfall of 330 mm and pan evaporation of 2,300 mm (map P57).

A significant part of this catchment only contributes flow intermittently, this eastern catchment lies in a lower rainfall zone and is a relatively flat, low relief region with a series of lake formations. These tend to contain any rainfall that would otherwise become river flow.

The dry eastern catchment is comprised of two large areas, the North Eastern or Yilgan catchment and the South Eastern or Lockhardt catchment. Both these catchments eventually flow through the Yenyening Lakes and into the Avon River. Waters from these areas are hyper saline (more salty than sea-water).



Western Catchment - Avon River

The relatively wetter western catchment is comprised of

- the North Mortlock catchment basin
- the East Mortlock catchment basin, and
- the Avon, Dale, Spicer River catchment basin (the Valley proper).

The North Mortlock Catchment Basin

This catchment basin comprises most of the shires of Wongan-Ballidu and Goomalling - an area of roughly 523,000 hectares and 290 active farming properties (ABS).

The North Mortlock/Avon confluence is several hundred metres downstream from the Northam Town weir. The Mortlock flows through part of the town of Northam. The North Mortlock flows in most seasons.

The Shires of Wongan-Ballidu and Goomalling are not overly concerned about the condition of the Avon River specifically as it does not have any direct affect on them. The North Mortlock does not pose any flood problem and is not really considered as a river, but more as a drain to carry excess run-off and salt away from the area. In the Wongan-Ballidu shire there are several salt lake systems along the river. These act as natural silt traps for the river. There are no such lakes in the Goomalling shire.

The North Mortlock is saline its entire length, though long time residents comment on its once fresh origins.

Erosion from the catchment would be occurring in the wet seasons. The significance as a contributor to silt and pollution loads into the Avon is not known.

The major problem perceived in this area is that of farm land salinisation, not river quality as the North Mortlock river is for most of the year a 'dry dusty ditch'.

The East Mortlock catchment basin

This comprises the shires of Cunderdin, Tammin, Wyalkatchem, Dowerin and half of Koorda.

The East Mortlock joins the North Mortlock a few kilometres east of Northam near the race-course.

This catchment has a large number of salt lakes within the area. Water flow from the Dowerin and Wyalkatchem shires probably does not enter the Avon in normal seasons.

Localised flooding occurs in many areas, but is not an annual event. Water movement through the salt lake system is slow. A major area for concern is the salinisation of farming lands.

Erosion occurs, but is not considered to be a major problem by the local shires. Large areas are protected by the WISALT banks in an attempt to control the salinisation, which also reduces the incidence of water erosion.

The East Mortlock is considered more of a drainage line than as a river

Flooding at the Morlock/Avon confluence does occur in the wet seasons.

Both the North and East Mortlock rivers flow in most seasons, and in 'wet' years can contribute significant volumes of water to the Avon River.

The North Eastern (Yilgarn) and South Eastern (Lockhardt) catchment basins.

This very large catchment does not contribute significant volumes of water to the Avon on a year to year basis. Water flows out of the Yenyening lakes on average once in every five years. This may occur consecutively and then dry up for drought years.

The potential exists for this area to produce huge volumes of flood waters given the correct set of circumstances. The likelihood of such events is considered to be remote, i.e., less than 1:100 years.

Salinisation of farming land and local flooding are the prime areas of concern in these catchments which contain numerous salt lake systems.

Some areas are under the protection of WISALT banks and other similar engineering works which attempt to control the spread of salinity. Many of these banks are built with a slope, to act as drainage channels, emptying into the river and lake systems. The affect this will have on local flood levels is not known, but is causing concern to local farmers and shires.

Flow of saline water through Yenyening lakes is controlled via flood gates on the causeway. This has caused concern as some people want the lakes to flush naturally, others want to maintain lake levels for recreational purposes.

Without control over the hyper-saline lake water, the summer quality of the Avon River pools could be in danger. Late flow out of Yenyening results in the hyper-saline water accumulating in the permanent summer pools, reducing their value as a wildlife refuge.

The Avon River - South Branch and the Dale River Catchment Basin

This area includes the shires of Beverley, Brookton, Pingelly, Wickepin and part of Corrigin.

This section of river only flows for a short period during winter and is not generally regarded as a 'river'. Its function is to remove run-off from the area as fast as possible, to reduce the potential flooding of several town sites.

The councils are not keen to see anything done that will slow down the flow of the river and increase the flood potential in their towns.

Salinisation of farming lands is a concern in the area, with soil erosion not being perceived as a problem. The potential for tourism is not considered to be all that great as the river is empty for most of the year. The once attractive permanent pools have all silted up leaving an unattractive dry river bed for much of the year.

The Avon River - Beverley to Walyunga

This area includes the shires of York, Northam and Toodyay and contains the few remaining permanent summer pools. It offers the most attractive river to tourists in the cooler wet months while it flows. During the hot dry summer only the pool areas retain permanent water.

The loss of these pools from silt encroachment is of major concern amongst the community.

The tourist potential is considered to be very great with the need for additional development. The Avon River could become a strong drawcard for tourists.

This area also has the highest population density of the catchment which may be creating additional urban run-off and pollution problems from industry, rubbish dumps and septic systems.

Soil erosion is a problem in the wet seasons as the land is quite steep in many areas.

Flooding is taken seriously by the Northam Town as it was subject to regular inundation prior to the River Training Scheme. Flooding of Northam in 1955 was the instigator of the River Training Scheme (R.T.S.).

The pool behind the Northam weir is one of the town's major attractions in the winter months when it is full of water and water birds. The white swans of Northam are a tourist drawcard. In the summer, as the pool dries up, it quickly loses its appeal.

The pool has been dredged of silt in the past, but it has practically silted up again. Recent surveys by the Water Authority of W.A. estimate it would cost over $1 million to dredge between the two town bridges with no assurance that rapid resilting won't occur.

Northam's dilemma is that flood mitigation works (RTS) have aggravated the silt problem, any reduction of the silting will be at the expense of increased flood risk - flooding is likely to increase as silts build up and choke the river unless further silting is controlled.

Community attitudes to flooding and silting tend to alter depending on how recently flooding occurred. Recent floods make people aware of the problem and less concerned with silting. When flooding has not occurred in recent years, people's perceptions change to become more environmentally aware of the damage siltation is causing to the river environment.

The region's major tourist attraction is the Avon River. During the late summer there is nothing attractive about the river within the town site of Northam.

PRE EUROPEAN FLOW REGIMES

The Swan/Avon River system has always been a variable flow river, with peak flow occurring in July, August and September. With the river drying up a chain of disconnected, tree-lined pools, some fresh, some turning saline as the season progressed (Garden, 1979).

The highest recorded flood level of the Avon River in the Northam area occurred in 1872 when water was halfway up the Avon Bridge handrails in Northam.

The 1868 river flooded the Guildford causeway and Perth's low lying land was flooded.

In 1847 Perth Jetty submerged, on 10 August the Swan rose more than 22'5" above its average summer point.

In 1830 "Perth causeway flats [were] underwater for months". The historical records indicate that significant floods are a regular* occurrence in the Swan/Avon River system before extensive clearing of land took place within the catchment area (Binnie & Partners Flood Study, 1985).

POST EUROPEAN SETTLEMENT

The Avon Turns Salt

A substantial transformation (salinisation of the Avon) had evidently set in by 1941 and a large part of this probably occurred during the preceding decade (Kendricks, 1976).

Wood (1924) (in Kendriks) recalled that "about 1897, in the Northam-Toodyay district, I heard it suggested that destruction of the native vegetation turned the water in the creeks salt; and about 1904 I thought that I could see evidence of an increase in salinity in the Goomalling Agricultural area."

* Regular - one year in ten.

"Salinity was an increasing problem from about 1907" (Mr Oliver - Beverley - from Kendricks, 1976).

Na^+ and Cl^- are the predominant ions in the groundwater throughout the region. They are believed to have been derived largely from rain as 'cyclic salt' (Weller 1928, Williams 1967 - in Kendricks). The extension of agriculture eastward from the Meckering Line has increased the frequency of saline lake discharge into rivers, including the Avon, thus further raising their salinity. (Mulcahy 1973, in Kendricks 1976).

The major floods of 1945 and 1946 were the first occasion for over 10 years when the wheat belt lakes overflowed, discharging a large quantity of salt accumulated there in the wake of the post-1920 agricultural development of the region. Hydrological and other deterioration of the Avon was intensified as a result of these two floods (J. Masters in Kendricks, 1976).

Salinity records indicate a direct cause and effect relationship between rising salinities and the observed changed in aquatic life along the Avon river over the past half century. There is no evidence that this increasing rate of salt discharge has yet peaked (Kendricks, 1976).

Livestock Pollution

Early in February 1971, a tropical cyclone brought heavy local rain to the Toodyay district, a good deal of which ran quickly off the dry paddocks and into the Avon. Much organic material, including animal waste, was washed into the pools. About a week later, the press reported that an estimated 1,000 fish, mostly cobblers, and some jilgies had been found dead in Redbank pool.

This was attributed to oxygen depletion of the water and presumably eutrophication deoxygenation (Kendricks, 1976).

Other potential sources of river pollution, less amenable to direct observation, include chemical fertilizers, herbicides and pesticides, but nothing is known of their levels in the Avon and effects, if any, on the biota (Kendricks, 1976).

HISTORY OF THE AVON RIVER TRAINING SCHEME (ARTS)

Chronological Developments - Avon River 1907-86

Northam Weir construction and initial adjacent river training works were carried out in 1907-08.

1907	Original weir constructed.
1926	Flood level R.L. 148.75m at Northam Weir.
1935	West bank river training carried out.
1944	Weir improvement proposals submitted: Concrete sill to be constructed on existing structure.
1945	4m x 1.2m Tilting board attached to 4m x 4m crest block. This was subsequently removed, with the crest block. Proposed crest level RL 146.61m.

1946	Public Works Department made repairs to weir understructure.
1948	Proposals for weir improvements submitted.
1954/55	Downstream river clearing carried out.
1955	Public Works Department made repairs to weir understructure.
1954/56	Northam pool dredging. (Prior to upstream clearing)
1956 (Aug)	Weir collapsed - due to water penetration.
1957	Repairs carried out. Costs apportioned. 1/3 Council, 2/3 Public Works Department.
1957/58	River training programme commenced. De-snagging and cleaning river upstream of Northam.
1958 (July)	River Flood 305m^3/sec, Northam.
1960	Northam Council advised that it would take no further action in raising weir water level at this stage.
1965 (Jan)	Proposals submitted for 3 schemes for Northam Weir. 1. shutters on existing weir. 2. shutters on new concrete wall. 3. inflatable dams on existing weir with raised crest.
1965 (April)	Town Clerk advised that river training should proceed and nothing should be done to the existing weir for the present.
1965 (June)	Town Clerk reported that Council was not in favour of expending any funds on the Northam Weir at this stage.
1966	Council withdrew opposition to clearing.
1967 (Oct)	Sandbags used to raise weir. (Dave Pettersson - District Engineer).
1970	Sandbags used again to raise weir level. Clearing programme completed.
1971 (Nov)	Northam Town Council builds a bank at old 'Weir' site using fill instead of sandbags.
1971	Earth fill weir washed away.
1972 (Sept)	Mr K.F. McIver MLA requested a design and estimate of cost to be prepared for a structure to replace the existing weir.
1973 (April)	Preliminary drawings completed. Costs estimates given: 1. Stopboard and Fuseplug weir $443,000 2. Collapsible Shutter weir $680,000 3. Fabridan and Fixed Crested weir $476,000
1974 (Aug)	Avon rises to highest level for 20 years.
1974 (Dec)	Council employs Maunsell & Partners Pty Ltd to submit design for new weir and dredging operation.
1975 (Feb)	Design submitted to Council. Estimate cost $188,000. Public Works Department agrees to pay 50% (i.e., $94,000).

1980	Council appointed Tsigulis and Zuvela Pty. Ltd. to undertake planning study of Northam Weir, river and foreshore areas.
1983	Public Works Department appointed Binnie & Partners to undertake a flood study of Avon River Beverley to Toodyay.
	Stage 1 Hydrology - completion May 1983 Stage 2 Hydraulic calculations Stage 3 Production of flood maps 50% funding from Commonwealth
1984	Formation of Avon River System Management Committee.
1985/86	Waterways Commission conducts fact-finding study on Avon River system on behalf of Avon River Systems Management Committee.
1986	Binnie & Partners flood study finalised.

(Water Authority of WA, 1985)

Initiation and Maintenance of the River Training Scheme

For 13 years prior to 1972 Public Works Department, the following representations from all the Shires concerned, engaged in a programme of clearing and improving the main waterway of the Avon River to alleviate the flooding of the major towns along the watercourse (PWD 1972).

The works involved the removal of vegetation and obstructions from a strip within the watercourse, generally about one third of the overall bed width, to develop a channel of sufficient capacity to ensure discharge by the river of the flood flows. This channel has been aligned to provide for streamlined flow and to remove any sharp bends which would cause erosion at flood velocities.

The work has been carried out by bulldozers supervised by a Departmental officer and complemented when necessary by Department labour skilled in river training techniques.

The programme was substantially completed in 1970 with the river improved from West of Toodyay to Aldersyde and along the South branch to Brookton. Subsequent work has included only the tidying up of the improved sections. Annual maintenance will be necessary to prevent vegetation and the choking up of the cleared channel. Subject to satisfactory maintenance the risk of flooding in the towns of Toodyay, Northam, York, Beverley and Brookton will be greatly reduced.

The removal of vegetation and obstacles from a river bed inevitably results in some redistribution of sands along the course of the stream. The sand movement is greatest following operations and usually stabilises after three or four years. This is only one factor, however, contributing to sand movement in the Avon River. Most of the catchment area of the Avon Mortlock systems is used for farming, which has led to almost total clearing. Increased run-off from these cleared areas has resulted in the deposition of soil in the river bed and only the rigorous attention of all farmers to the normal soil and water conservation measures will alleviate the problem (PWD 1972).

During the period from 1958 to 1970 (13 years), at the request of the Councils (Towns and Shires of Toodyay, Northam, York, Beverley and Brookton), the Public Works Department cleared some 116 miles (187 km) of the Avon River to prevent flooding in the towns between Toodyay and Brookton. Subsequently, annual maintenance has been carried out - and will be required each year in perpetuity - to prevent the cleared river section reverting to its original choked-up condition (PWD 1974).

"The history of the (River Training) Scheme dates back to 1937 when the Town Clerk of Northam wrote to the Minister for Labour suggesting that unemployed men be given relief work de-snagging the river near Northam to alleviate its flood problem.

Floods in 1955 resulted in renewed interest and the shires subsequently agreed to a plan to de-snag the river from Toodyay to Brookton. The Shires were warned, I understand, that any work carried out could result in silting of the river pools. They agreed in writing to the work being carried out.

Work commenced in 1958 and was continued until 1961 when it was stopped for the affects of the scheme to be evaluated. It was resumed in 1966.

Basically the scheme involved:

i. the removal of dead trees, logs and debris, that impaired the flow of water from the water course of the river.

ii. ripping of the bed of the river in places to induce the erosion of a deeper water course." (O'Brien 1973).

"Regarding the warning about possible pool siltation, I would imagine no hydraulic engineer would risk his professional standing by not mentioning this. However no public statement was ever made that this would occur and as far as I can find out neither the Shires of Toodyay or Northam have any written record on this." (Silting resulting from the RTS) (Masters 1973).

"Well over 90% of the trees removed were living in the Glen Avon locality." (Masters 1973).

The above accounts of what happened conflict in some areas, especially in the area of potential pool siltation after river training and in what was involved in the river training - removal of dead trees as opposed to living trees.

The concern about the loss of the river pools has surfaced regularly since the River Training Scheme was undertaken. This concern was one of the instigators for this report.

There is a great deal of ignorance within the community about what is happening to the river, and even more about what is the cause of the problem.

What started out as a flood mitigation exercise has ended up as a natural disaster, not totally caused by the River Training Scheme, but it certainly contributed to the problems.

The training of the river was an attempt to solve the flood problems, instead of addressing the cause of the flooding the symptoms were tackled. The cause still exists today despite the River Training Scheme and all the additional problems it has created. This should make us more aware of the difficulties and dangers of altering a natural system without having an extensive understanding of the systems and its problems.

Any future works must be preceded by careful and intensive hydrological studies to ensure that the solution is a solution and not the start of a series of more complex problems.

Short term, low cost answers based on insufficient information are likely to create more problems than they solve.

Impact of the River Training Scheme

In its mature middle section (map P7), the bed of the Avon originally comprised alternate deeps and shallows which, in dry season, took the form of stable, permanent pools separated by dry sandy channels. The latter supported substantial growth of trees, bushes and other vegetation, notably species of *Casuarina*, *Melaleuca* and *Eucalyptus*, the roots of which, together with a great quantity of surface and buried woody debris, served to stabilise the substrate. Though no data are available on which to base precise comparisons, there can be little doubt that the near total clearing of the catchment has substantially increased the concentration, and probably the volume, of surface run-off after rain. These factors have probably intensified the erosion of soil, particularly from higher land, and contributed significantly to the accumulation of sand in the bed (Kendricks, 1976).

In 1956, the government of the day initiated the 'Avon River Training Scheme', which sought to improve the river's flood discharge capacity by the mechanical removal of sediment and vegetation from the channel between Toodyay and Brookton.

This has created a large body of unstable sand in the channel between York and Toodyay.

It means that the obliteration of most, if not all the pools in the Northam district is only a matter of time. In the past, the pools served as summer refuge for aquatic life. Now not only the fauna but the very existence of the pools, once regarded as among the district's greatest assets, is in jeopardy (Kendricks, 1976).

Problems have been developing in the Avon for a long period of time. Problems accumulate until the threshold level is reached and then something has to give way. The environment can only cope with so much, once the limit is reached, long term or even permanent damage results. Cynics might argue that little more could be done to harm the river.

The Avon, once an economic and recreational asset, has been transformed into a financial and environmental liability. A stablilised, restored Avon would mean, in time, a better human environment for the district.

Burlong Pool - Looking Downstream
Reputably 42 feet deep

Burlong Pool - Looking Downstream

PROBLEMS ASSOCIATED WITH THE AVON

Problems often accumulate slowly and unnoticed over long periods of time. When the problem surfaces it often has reached a crisis point and any improvement needs long term commitment.

The current level of knowledge on the Avon River systems is by no means extensive. A lot of the answers are not known, or even the full extent of the problems have yet to be determined.

Local knowledge gained over years of observation often provide the only available information on many areas. Contributions from the public are therefore most welcome and sought after.

The extent and significance of the perceived problems are often unclear, our state of knowledge is such that we are assuming relationships that may not be appropriate in the local environment. Obviously further study needs to be undertaken to provide a more accurate assessment of the situation before major long-term decisions can be made with confidence.

Total knowledge is never available in an environmental context such as this. This does not mean that the problems cannot be tackled, it does, however, mean that care needs to be taken to ensure that the most appropriate action is taken. Our level of knowledge is such that we know enough to tackle 70% of the problems. If a start is made on these problems real progress is possible while we work on the 30% of unknowns.

The list of problems is by no means exhaustive, but they do contain some aspects of most of the perceived problems.

The rank or order of the listing is based loosely on their perceived urgency and our ability to cope with the problem, e.g., farm erosion is easier to control than farm salinity, though salinity may be a bigger problem than erosion from the river's point of view.

The problems are:

a. Loss of the four remaining permanent summer pools from siltation and the eventual loss of wildlife habitats.

b. Damage and destruction of the riverine ecosystem from nutrient enrichment and pollution due to export from agricultural and urban areas.

c. Alteration to the natural flow of the river and consequent reduction in flooding and its effect on vegetation on the river flood plain.

d. Salinisation of waters entering the river system.

e. Public/community access and utilisation of the riverine environment.

POOL SILTATION

a) Loss of the four remaining permanent summer pools from siltation and the eventual loss of the wildlife habitat it provides.

The siltation of the once deep and numerous pools along the Avon River should rate highly as one of the most devastating man-made events ever to occur to the river.

These 16 permanent pools in the York, Northam and Toodyay Shires were once considered to be among the district's greatest assets. Now, with only four pools remaining and under threat from silt encroachment, they have become a liability (map P22).

The four pools remaining viable refuge areas are:

Northam Town Weir - Northam Town
Glen Avon Pool - Northam Shire
Millards Pool (Dumbarton) - Toodyay Shire
Long Pool (West Toodyay) Above Posselt's Ford - Toodyay Shire

To a lesser extent the Wash Pool (Smart's Pool) Northam Shire, is also important.

These pools provide the only breeding and refuge areas for waterfowl and water-related fauna of many species in the Avon River. They are all that remain of sixteen such places that existed before the Avon River Training Scheme. Three of these four pools now have weirs.

There are still many smaller pools that may or may not contain water over summer, but they are subject to rapid pollution in summer and autumn and do dry out completely in dry years. All the other pools have silted up. Even the reputedly bottomless Burlong Pool is now only a silt bed.

All water areas in the river have the increasing problem of excess nitrates and phosphates. Salinity change, though serious, is not yet the major problem among these sorts of conditions. It has, however, already affected some species of birds and plant (Masters, 1982).

Bird Life

Glen Avon Pool - 91 species, 53 breeding, of these 32 water birds or breeding recorded in river habitat (Masters, 1982).

River Flow

The speed of the river flow has almost doubled from 4.02 kph to 6.27 kph at Glen Avon. This increase in velocity increases the river's potential energy and ability to transport silt and other pollutants through, and out of, the Avon Valley, i.e., into Perth water.

The lowering of flood levels by up to 1.2 metres, denies the river access to more than half of its former flood plain. All future silt deposition which would have occurred on these areas must be carried within the river, eventually to the tidal sump somewhere near Guildford.

These adverse affects of increased river velocity will eventually result in a reduced rate of discharge due to siltation of the river down stream, and the potential flooding of the Upper Swan region (Masters, 1973).

Flash Flooding

The possibility of flash flooding has been introduced into the river system. It is now possible to have the same flood in half the time, given the right coincidental pattern of rainfall over the subsidiary stream.

The possibility of flash flooding is a consequence of removing natural restrictions (vegetation etc which slows down river velocities) from a very large portion of the river channel. The towns of York, Northam and Beverley are living with a totally false sense of security (Masters, 1972).

Pool Degradation

The influence of the RTS on the river pools has been dramatic.

Deepdale pool - formerly 0.8 kilometre long and up to 4.87 metres deep. Now completely silted up and no longer a pool.

Dumbarton Pool (also known as Millards Pool) - once a major pool 2.4 kms long with an average depth of 4.57 metres. Today (1973) it has lost a third of its capacity. It would no longer exist without the artificially built weir at the lower end.

Glen Avon Pool - The banks have silted inwards about 8.22 metres under the tree line. The pool is protected by a causeway.

Katrine Pool - about 600 yds long, the broadest part has silted into an island where formerly it was 5.4 metres.

The Wash Pool - as per Glen Avon Pool.

Egoline Pool - formerly 1.2 kms long and 3.6-4.57m deep, has progressively filled up and has lost half its capacity.

Burlong Pool - the pool best known to Northam - completely silted up and sand dredged for road works. An estimate of average silt deposited in pools over the last five years is at the approximate rate of 76,455 cubic metres per year (Masters, 1973).

Flood Occurrence/Clearing Relationships

There is no evidence to indicate that maximum river flood heights between Northam and Toodyay have increased between 1860 and 1955 (when the RTS was instigated). All major floods between 1860 and 1955 have maximum levels within 45 cms of each other, except for the July 1872 flood which was some 0.9 metre higher.

Major floods were recorded in 1847, 1862, 1872 (highest level), 1905, 1917, 1926, 1934 and 1955, with moderate floods in 1879, 1890, 1909-10 and 1915. Probably flooding occurred in 1830 and 1831 when the Upper Swan flooded (Masters, 1973).

Clearing for agriculture has often been blamed for increased flooding in the Avon. Much of the area was not cleared before the 1900s which indicates that the flood levels did not increase significantly in height or frequency with clearing (J. Masters Pers. Comm. 1985).

The River Training Scheme was instigated to reduce flooding of the town sites which were located on the natural flood plain of the river.

The consequences of this action have had a dramatic effect on the energy balance of the river. With increased rate of flow comes increased silt transportation. These mobilised silts fall out of suspension whenever the speed of flow is reduced. This happens at wide or deep areas where the channel volume increases. So silt accumulates in all the pools. Eventually all the pools will fill up and the silt will be carried down to Guildford into the Swan estuary.

Siltation here will reduce the volume of the river and increase the flood risk.

Solutions

Much of the problem is associated with the increased velocity or rate of flow of the river. If the speed of flow can be reduced to its pre-RTS rate, regenerative work may be possible.

As speed of flow is reduced, capacity to move silt is also reduced, so rate of siltation will be reduced.

To reduce the rate of flow requires the development of water retention systems on the catchment. Soil erosion control techniques work quite well at slowing down the speed of water runoff from farm land. Widespread adoptions of water management and soil erosion methods would go a significant way in reducing the rate of runoff from the catchment. The same volume of water will still flow down the river but it may take 3 weeks to pass rather than 1½ weeks. The peak levels will be reduced and replaced by a longer period of river flow.

Revegetation of the river channel whenever possible will help to reduce the rate of flow. Naturally areas down stream from high flood risk areas may need to be kept clean to allow rapid outflow of water to keep flood levels low.

Revegetation will occur along much of the river if stocking is controlled, ie access to the river by livestock may need to be restricted to allow the regrowth of the Paperbark (Melaleuca rhaphiophylla) and Sheaoak (Casuarina obesa). In the salt patches Samphire (Sarcocornia blackiana) and saltwater couch (Sporobolus virginicus) will grow quite well. Other species of salt tolerant, flood tolerant trees may need to be introduced from areas such as the Pallinup River in the south-west.

There is little doubt that these measures will increase the flood level of the river. However society will need to determine what balance of river health and flood risk is an acceptable compromise.

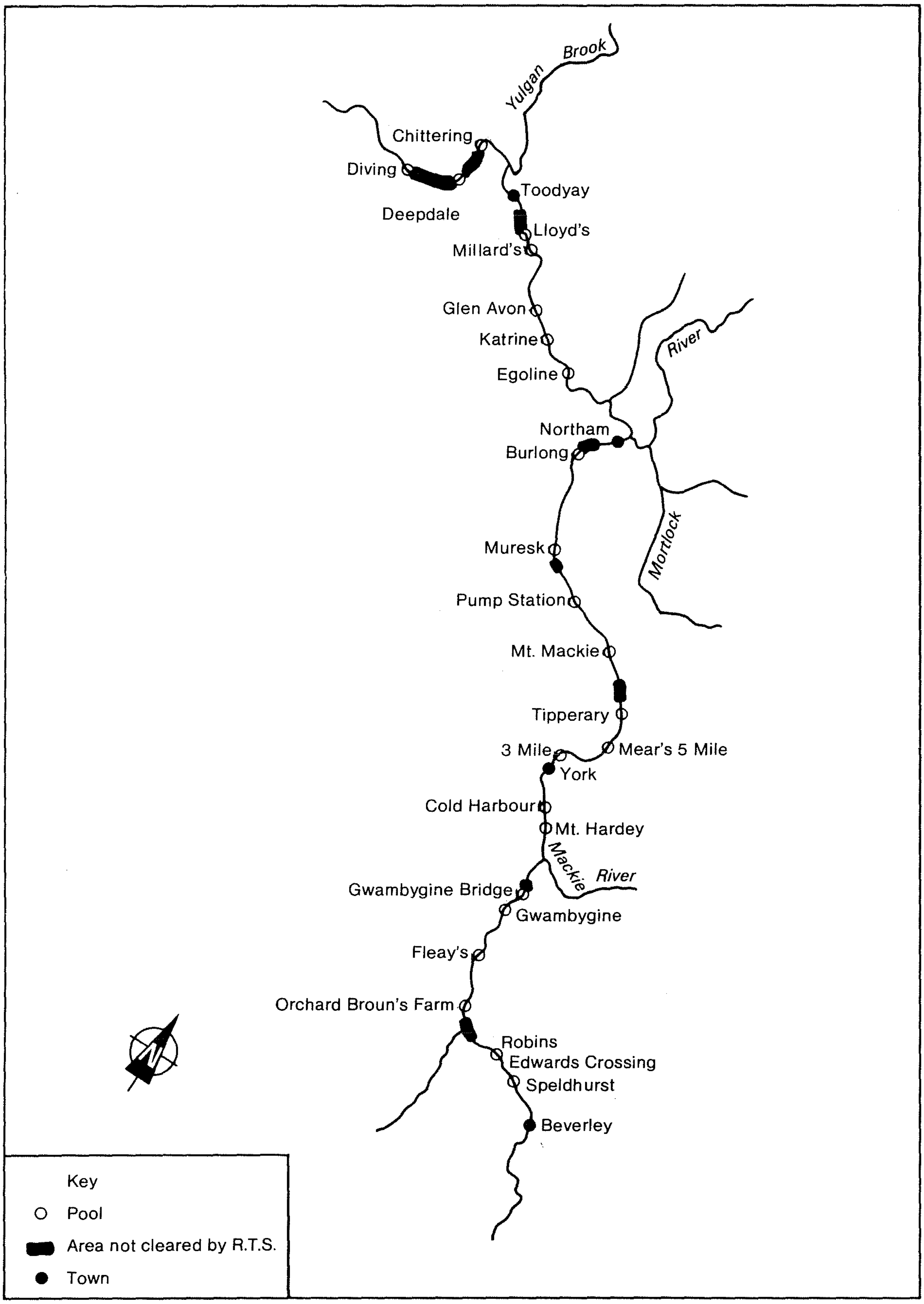
Since flood events in the Avon tend to be 10-11 years apart, people quickly lose sight of them. People forget about the damage caused by flood and build in flood prone areas. It is due to the widespread occurrence of flooding that development continues to occur within historical flood levels.

It is about time that we accept the fact that the Avon River does flood regularly and its flood levels should be clearly identified for all to see. Any development within these flood limits should be actively discouraged.

The use of weirs to act as silt traps is not an economically viable solution. The annual cost of cleaning them out soon becomes prohibitive. Even if this were not the case, the level of the river is such that even a 1.2m weir could cause significant flooding of upstream areas. With only a 7.92m drop in level between Northam and Toodyay, few sites would exist for a weir which would not increase the flood potential.

Reduction in the rate of flow will have significant benefits to the health of the river. Use of water management techniques on farming land and allowing revegetation of the river bed will enable the river to be returned to its natural state - pre RTS.

Increased flood levels back to historical levels may be unavoidable. As a society a choice has to be made between a healthy attractive river which floods on a regular 10-11 year cycle, or a drain that is lifeless and prone to flash flooding.



Avon River Pools, Pre River Training Scheme

NUTRIENT ENRICHMENT AND POLLUTION

b) Drainage/Destruction of the Riverine Ecosystem from Nutrient Enrichment and Pollution.

The most sensitive portions of the river systems are the permanent summer pools. These provide a very important refuge for many different species of animals and birds during the long hot and dry summer. Fresh water is available for drinking, for birds, from stock watering points in the area. Food tends to come from the river pools. If the pools are polluted the food source is lost, and the birds must also leave, or starve.

The smaller pools in the river usually go through a cycle of degeneration when they become isolated and stagnant. The first step of algal bloom is caused by a concentration of nutrients during the evaporation of water. As the bloom dies off bacteria feeds on the dead algae depleting the oxygen level of the water until the pool has little or no oxygen. Anaerobic bacteria then profligate and a by-product of their growth is sulphides, the most common of which is 'rotten egg gas' - hydrogen sulphide. The basic problem is low oxygen levels in the water.

The deoxygenation of larger pools does not usually occur in a normal summer. Problems arise when nutrients derived from human activity enter the pools, resulting in prolific growth of algae and other aquatic life.

Source of Nutrients

The most common nutrients that find their way into inland waters come from:

1. domestic wastes, septic tanks etc.

2. fertilizers - super-phosphates and nitrogenous

3. animal wastes - sheep manure, piggery effluents etc.

4. storm water run-off from urban catchments (town sites)

5. industrial wastes, e.g. tanneries, abattoirs, marshalling yards, municipal rubbish dumps.

Sources 1, 3, 4, and 5 can all be traced back to a readily identifiable source of pollution. The people responsible can be made to instigate pollution abatement measures to reduce the quantity of effluent entering the river system. Control measures such as disposal licences and permits must be used to successfully limit these sources of pollution.

The identification and monitoring of these sources needs to be undertaken to determine if they are adding pollutants to the river system and to what extent. If the level is considered to be excessive, steps can be taken to reduce the levels.

Source 2 - fertilizer from farmlands - It is very difficult to say which farmer applied the particular fertilizer that is entering the river system. Soil conservation and fertilizer management practices should reduce this loss.

Method of Transport into the River

Most of the Nitrogen (N) and Phosphorus (P) entering the river does so attached to soil particles eroded from the farmers' paddocks. Phosphorus binds very tightly to clay and organic matter in the soil and tends not to enter the river in solution, as it does in the sandy soils of the Peel Harvey estuary.

The main mechanism for phosphorus loss from agricultural catchments would be through surface run-off (Birch, 1983).

The ammonium form of nitrogen, like phosphorus, can also be bound to soils, thus the concentrations of ammonium is not usually high in the soil solution.

In contrast, the nitrate form of nitrogen is extremely soluble and can readily be leached down the soil profile, making losses from the catchment by this method potentially more important (Bigg & Carey 1969, Birch, 1983).

One generalisation which can be drawn from the literature on surface agricultural run-off is that "Most nitrogen and phosphorus is lost in particulate form" (Abbotts et. al. 1979) which highlights the fact that factors which minimise soil erosion will tend to minimise fertilizer losses. Minimum tillage methods of cropping reduce erosion via surface run-off.

Silt particles remain in suspension for up to 5 hours in still water and clay particles for much longer. The time of concentration of most rural catchments is less than 2 hours, and run-off control systems are designed to keep surplus run-off moving and dispose of it in a stable waterway. A significant amount of fine silt and clay (with attached nutrients and pesticides) will pass out of the farming system into the river system, even if soil erosion practices are adopted (Stephens, 1983).

Tree Belts as Nutrient Traps

The development of tree belts alongside the river has little long term value as a nutrient trap. When first established they function effectively, as time passes they themselves 'fill up' and nutrients begin to leach out of the tree belt into the river system.

Tree belts effectively reduce erosion from the area under vegetation and provide a valuable habitat for fauna. They can also be aesthetically very attractive (Cullen, 1983).

Potential for Nutrient Enrichment

The enrichment potential for nutrient export from a catchment depends on numerous factors, primarily the chemical form of the nutrients (affecting availability to plants), the rate of discharge (erosion) and the type of water body that is receiving the pollutants (i.e., a large flowing lake is less likely to have problems than a small land-locked pool).

To control the discharge of nitrogen and phosphorus and the subsequent pollution of the river system, it is necessary for the fertilizer application not to exceed the crop and soil 'bank' needs for the nutrients. Adoption of conservation practices that minimise soil disturbance and deep percolation will help reduce nutrient export.

Sub-surface discharge of phosphorus is usually small because of the high capacity of most soils to bind phosphorus (with the exception of some sandy soils, e.g. Peel Harvey area).

Having said all that, it is not known just how important nutrient pollution is in the Avon River. The potential for disaster does exist, given an unfortunate set of circumstances.

The river's ability to cope with any nutrients or pollutants will vary with its flow status. In full winter flow the quantity of nutrients that might be expected to enter the river systems (0.3% of applied fertilizer) may be mostly exported to the Swan Estuary and the ocean.

However the same nutrients in the summer pools could well prove to be disastrous.

The threshold levels for the Avon River are unknown - the quantity of N+P entering the river is also unknown, as is the retention of nutrients in the river sediments.

Pesticides

Apart from nutrient enrichment from N+P entering the river, pesticides can also cause significant long-term problems for river systems.

Pesticides enter the river system by run-off, leaching, aerial transport, misapplication, spillage and faulty disposals of wastes and containers.

The contribution made by each means has not been determined.

Nearly all pesticies, except organochlorines, degrade in water and are deposited and deactivated in sediments after some time period as far as we know (G.F. Bell, 1983).

30% of our current agricultural output would be threatened without the use of chemicals (N. Halse, 1985).

Surface run-off is recognised as the major pathway for the transport of pesticides to surface waters (Pionke & Chester 1973).

Very little information is available for pesticides other than for the persistent organochlorines.

Residues for DDT and Dieldrin may exceed recommended criteria corresponding to threshold levels of chronic sub-lethal affects in other water systems of Australia.

The most important type of pesticide in WA agriculture is the herbicide group. Fortunately this very diverse group of chemicals is of low persistence with few exceptions (Bell, 1979).

Chemical weed control along railway reserves uses chemicals which have higher residual values than those generally used by agriculture. As the railway line follows the river much of its length from Toodyay to Brookton, there may well be a potential risk of these chemicals entering the (Avon River - Vorox AA - 10kg/ha to a 3 m wide strip - both sides - August - Roundup 9 ℓ/ha).

C. Sharpe of WA Department of Agriculture has done some recent work on DDT and minimum tillage. DDT levels were detected in the water, however levels were quite low.

DDT is programmed to be phased out of the market by June 1986 to be replaced by synthetic pyrethroids for control of insect pests in crops (C. Sharp, 1985).

Behaviour of Pollutants in the River System

Under low flow conditions particulate material will be deposited on the stream bed, which thereby acts as a sink for nutrients under low flow conditions. Under high flow conditions deposited sediment is re-mobilised, stream banks erode and material is washed away. Under these conditions the stream itself may be a significant source of 'recycled' or 'resuspended' nutrients.

The very fine particulate material has been identified as significant in the transport of phosphorus, metals and some chemicals (Quigley & Brookman 1979, Allen 1979).

Identifying the source of the Nutrients

The nutrient exports measured in a river will not have come uniformly from the catchment. A variety of land uses and soil types will provide differing amounts of phosphorus and nitrogen available to be mobilised.

Runoff has a critical role in the transportation of nutrients. Interpretation of stream loads of pollutants does not provide a means of measuring land exports. The area of the catchment contributing runoff will influence nutrient export.

Unless a catchment is uniformly wet, or has a surface permeability that is comparable in magnitude to rainfall intensities, overland flow will be generated (if at all) in only part of the catchment.

Recognition of areas with surface saturation can lead to reduction in nutrient exports with appropriate treatment.

Nutrient concentrations in run-off is inversely correlated to grass length and rate of overland flow (longer grass, less run-off).

Highest nutrient concentration occurs in the summer when there are few run-off events, dung and urine persist on the pasture surface, and pastures are dry and short.

This period coincides with the river's lowest capacity to cope with nutrients or pollutant inputs.

McColl (as cited by Cullen, 1983) in New Zealand studies, found that 0.2-0.3% of phosphorus applied as fertilizer was exported down slope.

Olniers et. al. (1980) found that up to 5% of applied fertilizer could be lost - (USA studies).

Based on 1982/83 ABS fertilizer statistics a total of 8,8000 t of superphosphate was applied to the 13 shires in the western catchment. Super is 9% phosphorus giving 8,000 t of phosphorus applied.

Using a 5% loss rate - 400 t of P potential export into the river system.

Using a 0.3% loss rate - 24 t of P potential exports into the river system.

These figures are extrapolations of overseas studies and may not be relevant in our environment.

Even if they are, we don't know if these levels are excessive from the river's point of view.

<u>Comparison with Peel Harvey Phosphorus Situation</u>

Total P input into the Peel Harvey estuary in 1978 was 120 tonnes. Loss to the ocean at 60 tonnes pa, leaving an accumulation of 60 t in the estuary (Hodgkin et. al., 1980).

Not all of this accumulated P is available for algal growth in the Peel-Harvey System. Some of it occurs in the sediments. A percentage of this P is recycled later supporting algal growth. Although the sediment P has built up considerably, it is unlikely that it would, by itself, support algal blooms for more than two or three years. These blooms are considered to be largely dependent on a fresh supply of phosphorus each winter, a phosphorus supply which corresponds closely to the input resulting from winter rainfall and river flow (D.C. & E., 1984).

(Phosphorus is the nutrient that causes most problems as it is the naturally limiting element, i.e., other nutrients may exist in excess quantities but the availability of P limits any further growth of algae. With increased supply of P these other nutrients can be consumed as well.)

The level of P entering the Peel Harvey estuary does cause problems associated with active algal blooms.

The Avon River has the potential to flush significant levels of nutrients out of its system when it is in full flow, however it normally flows for only 3-4 months of the year.

The period of flow coincides with the period of fertilizer application (seeding) and to some extent chemical weed spraying.

Summer thunderstorms pose a potential threat to the river systems by causing rapid surface flow of rainfall, carrying with it nutrients and chemicals. Any pollutants that enter the river at this time of the season, when the pools are not flowing, will obviously cause more problems than the same concentrations entering in full flow periods.

Pollution of the waterway may be significant following the seasonal burning off of crop residues in the late Autumn. Extensive export of nutrients may be occurring with rainfall after burning.

There is no doubt that conservation through effective planning, with use of contours, minimum tillage and plant residue cover will reduce agricultural erosion significantly from the farmers' point of view. However, whether this level of nutrient pollution reduction is adequate from the river's point of view is doubtful.

Surveys of Wisconsin lakes (USA) concluded nuisance algal growth can be expected with concentrations of inorganic phosphorus and nitrogen exceeding 1 mg/L and 30 mg/L respectively (Sawyer 1952). Local studies suggest N levels of 10-30 mg/L and P levels of 1-2 mg/L cause rapid growth (Pitcairn & Hawkes, 1973).

Given our current state of knowledge, the potential for the pollution of the Avon/Swan Rivers exists. Their present pollution status is not known, i.e., we don't know if nitrogen, phosphorus, chemicals and so forth are entering into the river in sufficient quantities or concentrations to be causing any long-term permanent damage to the riverine ecosystem. Studies elsewhere suggest that we may well have such problems in the Avon. Only further local study will determine the extent or gravity of the problem in the Avon.

The variability in flow poses problems for any intense specific study as riverine and pool conditions alter dramatically from dry seasons to wet seasons. Hopefully any study period would be long enough to encompass a variety of seasons and their subsequent influence on the river system.

Studies under way with CSIRO and CSBP and Farmers on nitrogen use and loss may provide additional insight into the potential pollution of the river from agricultural nitrogen. Sites include Merredin, Narrogin and York (Pers. Comm. Dr. I. Fillary 1986).

Avon River 500m Upstream from Burlong Pool

Sand Excavation Burlong Pool

FLOODING

c) Alteration to the natural flow of the river and consequent reduction in flooding and its effect on vegetation on the river flood plain.

Flooding

All rivers have a natural flood plain into which excess water will flow during periods of 'peak' water flow. This peak flow tends to occur in the Avon every 10 or 11 years (This is not referring to the 1 in 100 year flood which is much greater). This fairly long cycle enables us to 'forget' the last occurrence before the next one comes along. As a consequence of our short memory, development within the natural flood plain continues to occur, despite the historical incidence of flooding.

When flooding inevitably occurs and man's development is threatened by the flood water, he has several options open to him:

1. he can put up with the recurring floods (i.e., do nothing)
2. he can move to higher ground - away from the flood plain
3. he can alter the river flow to reduce the likelihood of occurrence of the flooding.

Option 3 was adopted for the Avon River in 1955. The clearing of vegetation and ripping of the river bed was undertaken in an effort to reduce flood levels. This objective has been achieved. With considerably less resistance to flow, the speed of flow has increased from 2.5 mph to 3-3.5 mph (Glenn Avon - J. Masters). Water moves much faster and 'peak' flood levels have been reduced.

Any significant reduction in river velocity can result in increased flooding.

In other river systems of WA the State Planning Commission will not recommend any development within the 25 year flood boundary and only recreational use within the 100 year flood boundary. If this had been adopted pre-1955 there would not be a flood problem associated with the Avon River.

The problem of flooding is due, at least partially, to the relatively flat nature of the river between Toodyay and Northam. The fall is approximately 26 ft (7.9 m) in 26 miles (41.84 kms).

Flooding of town sites causes significant disruption and economic loss to those who are flooded. Since many of the Avon Valley's towns are located close to the river, well within the historical flood levels, problems and conflict inevitably arise every time the river floods.

Relocation of town sites is considered to be too costly to be an option.

Floods cause significant interruption and damage which reduces the possibility of taking no action and 'living with' the occasional flood event (once every 10-11 years).

This only leaves the option of altering the flow of the river to reduce its flood potential. The River Training Scheme (1955-1966) was the consequence of such logic.

The potential for flooding may still exist, however its frequency of occurrence has been reduced. If the sequence of events occurs and both the Mortlock and Avon Rivers happen to be in 'full flood' at the same time, Northam - or at least part of it - must be flooded. Only very expensive engineering works could prevent this. As this type of flood event is rare, the cost of such preventative works becomes far too high to be practicable.

This then leaves us with two options. Put up with the flooding, or move away from the more flood prone areas.

Development within historical flood levels should be discouraged in the future to lessen the economic and social consequences of such flooding. These flood prone areas could be reserved as public open space and passive recreation areas.

Any measures taken to reduce the rate of flow of the river in an attempt to reduce the silt transport and destruction of the permanent summer pools will result in some increase in river levels. This is due to the very flat nature of this portion of the Avon, with only 8 metres (26 feet) fall between Northam and Toodyay.

Flooding by the river is an integral part of the riverine ecosystem - without regular floods many of the trees and vegetation along the river's edge will eventually die out. A compromise between flood levels and river speed may be possible, with sections of the river being allowed to revegetate, and thus slowing the flow down and performing as filters for silts. Other sections, down-stream from town sites, could be left clear of vegetation to allow rapid flow away of water.

Any soil conservation practices on farming land within the catchment will help to hold rainfall on the land for longer than at present. This reduced run-off will help lower the level of the river and spread the period of flow over a longer time.

A complex combination of factors involving the entire catchment will help reduce peak flood levels. However we should not forget that the highest flood level in European history occurred in 1872 before any significant portion of the catchment was cleared. If the same sequence of events reoccurs the potential flood levels must be above the 1872 limit, due to the cleared catchment, rapid run-off, silted river beds, developed and enclosed flood plains.

Flood contribution from eastern catchments

The potential for the eastern catchment to flow and add significant quantities of water to the Avon exists. The occurrence of such events is considered to be remote. Consequently the Binnie & Partners' 1985 flood study chose to ignore it as a source of flood waters.

Contribution from the intermittent catchment

"The contribution from this eastern catchment to the flow peak at Broun's Farm (near Beverley) is considered insignificant. It lies in a lower rainfall zone than the western catchment and is situated in a relatively low relief region with an excess of lake formations distributed evenly along the catchment. These tend to contain any rainfall that would otherwise run-off." (D. Salim, 1985).

The average frequency between floods from Yenyening Lakes is roughly one year in five, but then the outflows tend to recur in a group until the next drought sets in.

From reported localised floods that have filled, but not overtopped valley bottom depressions near the catchment head at Southern Cross, we believe that it is unrealistic to expect those areas to contribute the 100 year flood at Walyunga; it may require a seasonal storm sequence approaching Probably Maximum Precipitation to generate a valley bottom flood-wave, whereas tributary undulations regularly create local flooding, e.g., Merredin and Corrigin (Binnie and Partners, 1985).

There can be no such thing as an absolute definition of the flood plain as catchment conditions charge. There is, in any valley, some slight risk that a thousand year flood or worse will occur in the reader's lifetime (Binnie & Partners, 1985).

The 100 year flood can more properly be described as the flood in which there is a 1:100 chance it will be equalled or exceeded on one or more occasions in any one year. It may occur next year, or not for a century or more (Binnie & Partners, 1985).

Using these guidelines, flow from the eastern catchment is not considered to be a flood threat in the normal course of events.

Avon River - Northam - Note Sand Island

Avon River Carters Pool

SALINITY

d) Salinisation of the waters entering the river system.
The soils of the Avon Valley are generally free of stored soil salts, as they are well drained and the salts have leached out over time.

The salinisation of the Avon is a direct result of the clearing of the catchment over the years.

Salinity of the soils and ground-waters has always been a problem in the lower rainfall eastern valleys, and with clearing has become increasingly important elsewhere (Williamson & Bettenay, 1979).

Cause

The generally accepted explanation for increased salinity of soil and water supplies is that the introduced crop and pasture species use much less water than the deep rooted evergreen native species. Thus with clearing water tables rise, mobilise soluble salts, normally stored in the unsaturated zone. These mobilised salts then move towards the valleys (Bettenay, 1985).

About 2% of West Australian agricultural land is saline enough to prevent normal agricultural pursuits (Dep. of Ag. Annual Report, 6/85).

It is not too clear if the area is increasing or is stable. Accurate determination of salt affected land is difficult on such a large scale. Some shires may have up to 5% of the local government area salt affected, and some properties may have over 50% of their farm salt affected. Though the total area may not be that great (i.e., approximately 2%) the impact on individual land-owners can be very significant.

$60 million has been spent on WISALT banks since 1978 in an attempt to control salinity (S. West. Pers. Com, 1986).

As farming land is salinised then the water that flows through these, mostly, low-lying areas becomes saline too. Eventually this saline groundwater and surface water enters the river system.

The river system can cope with some salinity and has been used to empty the higher saline Yenyening Lakes during periods of peak flow early in the winter.

Salinity becomes a problem for the river when flow is slow and the permanent summer pools become increasingly saline. Kendrick (1976) has discussed the change in salinity affect on species of freshwater molluscs, which no longer live in the river system due to the high salt levels.

The large eastern catchment area contains huge volumes of stored salt within the soil profile. The mobilisation of this salt with the rise in the water table eventually moves into the valleys and the lake systems. With very high evaporation rates, concentration levels of 36,000 mg/L have been recorded in the catchment.

Given a sequence of wet years, flow of higher saline water through the lake systems and into the Avon River could be potentially damaging to the Avon River environment.

Control of flow from Yenyening can be achieved in normal (non flood) seasons, which allow the release of the hypersaline lake water to be restricted to periods of high river flow relatively early in the season. This allows the very salty water to be diluted by the fresher river water and gives it time to be flushed out of the system to the ocean, leaving enough of the winter to provide relatively fresh water to fill up the summer pools and replace the saltier lakes water. If the lake flow occurs later in the winter, then the pools will remain full of very salty water and be of no use to the bird life that relies on them as summer refugia.

Long periods of saline water flow will eventually alter the species of trees that grow along the river. Unless salt tolerant species are introduced to replace the dying non-tolerant species - few trees will remain along the river. The river's aesthetic quality will be severely reduced if this occurs.

Solutions to river salinity

The majority of the salt that enters the Avon River is imported from outside the Avon Valley. The salt comes from the saline soils becoming saturated as water tables rise. These mobilised salts eventually find their way into the river systems, either as surface flow or as ground water. As the river flow slows down towards the summer, salinity levels begin to rise.

The only way to reduce river salinity is to lower the water table in the catchment so that salt can be leached down the soil profile and away from the surface and sub-surface flow. A practical method of achieving this is available according to work undertaken by soil salinity Hydrologist, Steve West (Pers. Com, 1986).

Earthworks tend to hold or direct water away from salt areas, deep drainage only exports the saltwater into the river system. With up to 1 million kg of stored salts per hectare, leaching and flushing of the stored salts would take too long and the river would be destroyed by the salinity before the salts were leached out of the system.

Revegetation may reduce the water table enough, but only if between 60 and 80% of the land area is replanted to deep-rooted perennial species. Even this has not been conclusively proven to be effective in all cases. The economics of such a move would remove most WA farmers from the land.

The use of trees on a smaller scale, say up to 20% of a farm's area, may be possible without reducing farm viability significantly as most farms have waste areas and areas of low productivity which do not warrant any other land use. This may not solve the salinity problem, but it must help to some extent. Combined with the planting of higher water utilising crop species it may go some way in alleviating farm salinity problems. Impact on river salinity may need more radical action.

The acceptable level of river salinity will depend upon its uses. If it is to be a potable water source then salt levels need to be quite low. If its only use is recreational, then salinity may not pose much of a problem. As a habitat for wildlife, salinity can create problems for many species of flora and fauna.

Technology and knowledge exists to solve salinity problems in W.A. Hydrologists can solve the problems and are doing so across the State. Each site must be assessed and treated individually.

Treatment may involve water usage, deep drainage and pumping.

Excess water disposed of into river systems is generally less saline than water in the river system already in the medium to long term. This occurs because drainage lowers the water table and takes the salt out of the flow regime which enters the drainage channels, so any water entering the drainage channels is less saline than prior to treatment (Pers. Com. S. West., 1/86).

PUBLIC/COMMUNITY ACCESS

e) Public/community access and utilization of the riverine environment.

Community access is restricted by many of the historical land titles that give ownership to the landholder to the centre of the river, not to the more usual high water level and flood level. Under these historic titles, public access can be prevented by the land owner if he so desires. Many of the titles are slowly being replaced as farms are subdivided for resale. Planning permission is only given if 10% of the land is available for public open space, usually the river frontage is claimed for this purpose. Not all farm sales come under this category, as they may not be subdivided and are sold within the existing surveyed boundaries for subdivisions.

Even with this principle of reclaiming river frontage community access is not very great for most of the river. Some sections within the towns are very well developed with excellent facilities for passive recreation, e.g., BBQs, swings, paths and toilets. Once away from the towns access is less available, with only a few picnic sites at places like Katrine.

For most of the year this level of access may well be adequate, however if further sites were developed, usage could well increase to match it, especially in the cooler spring season where everything is lush and green with the river at its best.

Summer patronage is restricted by the heat and the obvious danger of bushfires from BBQs and other fires associated with people usage.

During the Avon Descent period - August/September - access is most definitely inadequate. People park alongside roads, clamber over fences and across paddocks, stand and climb down riverbanks to reach river vantage points to view the race. The country is usually very wet at this time of the year and damage to soils resulting in potential erosion is very likely in some areas.

Spectators have little option, if they want to view the race at the more spectacular points, they have to park and walk across paddocks and stand on the riverbank.

Development of these popular vantage points perhaps ought to take priority to prevent further degradation of the riverbanks. Construction of parking facilities with rails and protected, stabilised vantage points needs to be carefully considered. Many could be closed for the rest of the year if the demand was not there, or they could form a central part of a wider system of community access facilities for river usage.

The nature of the river tends to restrict its potential uses to mostly passive type recreation, e.g., picnics, walks, nature study and the like. Areas for more active activity may be available in some areas given strict guidelines, e.g., trail bike use in sandy patches, canoeing in less important wildlife areas or times. Shooting and camping may also be plausible in some areas.

The establishment of wildlife sanctuaries where access is either prevented or restricted during breeding seasons could provide a solution to some use conflicts. The appointment of a ranger to co-ordinate and control these areas may need to be considered in the longer term.

The location and development of access sites needs to be carefully planned and co-ordinated to manage the conflict between users and nature.

With the Avon Valley developing as a tourist area, future use and access is going to increase rapidly. If facilities are not available, inappropriate use and damage may well result.

Development of heritage trails and the identification and marking of historical sites play an important part in the tourist development of the area. Naturally much of this type of activity will be close to the river due to its historical importance and aesthetic beauty.

The Avon Valley's location within easy distance from the Perth metropolitan area makes it an obvious choice as a tourist destination. Visitors from around the world are likely to visit the area when they visit Perth. At the present time recreational facilities on or near the river are limited and basic. This may add to the appeal, or detract from the overall enjoyment. Low key passive development is plausible in many areas which offer significant scenic beauty.

Community opinion is divided on the desirability of further development of tourist access. River land-owners are naturally concerned about fire hazards, stock losses, rubbish and property damage. Local business is keen to attract more people into the area whenever possible.

Beneficial Uses of the Avon River System

Recreational	Canoeing - Avon Descent & Other
	Bush Walking
	BBQ Picnics
	Bird Watching
	Wildlife Flowers
	Camping
	Cycleways
	Duck Shooting

Swimming
Nature Walks - Educational
Botanical - Flora Studies
Faunal Studies
Tourism

According to a study made by Sinclair & Smith (1980), the Avon River's water quality is acceptable for recreational and aesthetic use.

PART II

SALINITY - CONTROL METHODS

Current studies are being done by the Water Authority (I. Loh, pers. com.) and others into the appropriateness of trees in reducing soil salinity and stream salinity.

According to Loh "the areas needed to be replanted to beat salt are substantial, perhaps 30 percent of the upslope cleared area. The agronomic options are promising in the below 600 mm rainfall areas of WA."

Offsite treatment such as crops, trees and banks will only alleviate the problems of perched or surface water causing salinity, but not fully control the problems (i.e., the rise in the water table into the root zone, West, 1985).

Reafforestation can lower the water table and contribute to a lower soil and stream salinity.

Current estimates of recharge to groundwater (the source of the water causing the water table to rise) following clearing of native vegetation for agricultural purposes, suggest only a relatively small quantity of water is involved. Estimates vary between 5 and 10 percent of annual rainfall (in 600-900 mm rain fall zone). Only relatively small increases in current vegetation water consumption is needed to 'use up' this water that is recharging the groundwater table.

Recharge can be minimised with agronomic methods such as crops and pastures in low rainfall areas, with trees and discharge reduction with lower slope plantings.

Using trees to reduce groundwater recharge implies knowledge of where groundwater recharge takes place.

The groundwater systems which developed following clearing are known to be relatively localised. They form between the stream line and ridge line of most small catchments and are strongly influenced by bedrock topography. A recharge minimisation strategy using trees would have to cover most, if not all of the landscape if groundwater recharge was to be stopped completely.

Lower slope plantings give a breathing space to allow the development of economic recharge minimisation systems. In the long term, up slope recharge must be controlled if long term salting is to be avoided.

Hill slope planting of over 80 percent of land area at 1200 stems/ha showed a significant water table level reduction within three years of planting. Trees do use water from the shallow water table. In the long term salts will continue to accumulate beneath the replantings unless up slope recharge minimisation strategies are introduced (Loh, 1986).

Areas to be replanted need to be significantly larger than the actual area that is salt affected.

Trees planted to stop recharge must be able to consume the annual rainfall even in wet years. They must also be able to transpire any shallow water drainage and all saline groundwater discharge from upslope (Loh, 1985).

Salinity - control and identification

Salinisation of farming lands inevitably leads to salinisation of streams and rivers that drain farming land.

The causes of dryland salinity are often remote from its affects, i.e., extensive clearing in the area up-slope will often result in valley bottom salinisation. The valley may be 150 km across. Any action taken to reduce salinisation should be carried out on a catchment basis, with particular attention paid to high recharge areas. The identification and classification of recharge and salt susceptible areas needs to be undertaken to assist in the economics of control. Costs of treating the worst areas tends to produce much greater results per invested dollar than they do on less severely affected areas.

In high risk areas land use modification may be necessary. Cropping in salt susceptible areas may need to be controlled, trees planted in waste or low productivity areas, moisture retention practices in susceptible areas may need to be reassessed, deeprooted perennial species should replace shallow rooted annuals wherever possible, and further clearing of land should be carefully controlled.

These factors may help reduce the salt problems - implementation will be difficult.

In the case of dry land salinity and stream salinity, public control of the problem is likely to be appropriate. Forms of direct control, such as zoning, prohibition and regulation, and indirect controls such as taxes and subsidies may all have a place.

Research into the unanswered questions needs to be conducted before any long term financial and environmental commitments are made.

Areas needing further study include:

- Ways of reducing river velocity to reduce siltation of the remaining permanent summer pools and the effect this will have on flood levels within the town sites.

- Determination of the quantity and affect pollution has on the riverine ecosystem and energy balance threshold determination, with some work into pinpointing sources of significant pollution, e.g., rubbish tips etc. This could involve extensive sampling down stream from suspected sources of pollution to accurately determine quantities and effect of such sources.

- Identify sources of serious and significant pollution, including farm erosion, and reduce impact levels.

- Surveys to assess public usage and demand for increased, or changes in access to the river itself, with consideration for environmental and other impacts of any such changes in access.

- Long term study on the affect of the increasing salinity of the Avon River system and what the eventual consequences are likely to be if the salinity trend continues unaltered.

- Study into the potential flood risks from the intermittent eastern catchment with early warning system to reduce local impact of such flood events.

EROSION AND SALINITY

"Only about 30 percent of the 17 million hectares of land cleared for agriculture in WA's farming areas can be described as 'stable'. The rest is affected to varying degrees by forms of soil degradation. About 2 percent is now too saline for conventional agriculture - a result of salt accumulation caused by land clearing." (Department of Agriculture, WA, 30/6/85).

Erosion is a serious problem that is threatening the long-term productive capacity of the land, and the sediment is a major pollutant of the water which causes the erosion.

Sediment action creates a number of problems in Australia. The major ones which have an affect on the Avon are:

- deposition of sediments in stream channels, deep pools and eventually the tidal sump at Guildford.

- changes to the hydraulic efficiency of streams and rivers.

- siltation of habitats of aquatic organisms.

Most of the processes involved in the movement of sediments, nutrients and pesticides from croplands are understood (Boughton, 1983).

There is very little work done on the measuring and quantification of soil loss and sediment movements. Techniques are available to do this, but they are expensive and time consuming. So we know erosion and sedimentation occurs, but we don't know how much or how significant it is in any given location.

Erosion is a result of several natural processes which, over periods of millions of years, has gradually shaped the earth's land surface. Energy for these processes is supplied by water, wind, gravity, living organisms and frost to detach and move particles of soil and rock.

Natural erosion is held in check by plant litter on the soil surface and by the aggregation of soil particles (i.e., soil structure. Land use by man such as cultivation, grazing, recreation (4-wheel drives and motor-bikes), urban and industrial development can alter or remove these checks to erosion, unless land use management takes careful account of erosion potential.

The products of soil erosion are gravel, sand, silt, clay, organic matter and soluble chemicals. Gravel and coarse sand usually stay close to the point of origin unless they are in a stream bed. Fine sand and silt can be transported much longer distances by water. Clay and organic matter can be carried long distances by water as the particles are small enough to remain in suspension for long periods (Woods, 1983).

The filling of streams and rivers by gravel, sand and silt reduces their capacity and this can result in more flooding. This is occurring in the Avon River.

The coarse products of erosion are relatively inert (non-active) but the fine products, clay and organic matter, are chemically active. They contain most of the plant nutrients from eroded land. These particles may also carry absorbed fertilisers, agricultural chemicals and other pollutants.

These pollutants may result in eutrophication nutrient enrichment of streams, rivers, dams and pools, changes in aquatic plant and animal life and impaired water quality.

Some chemicals such as phosphate, heavy metals (copper, zinc) and many herbicides are strongly bunded on soil particles and usually only enter the river as a result of soil erosion (Woods, 1983)

Stream Sediments

In Australia stream sediment is an area that is relatively unknown. Most sediment transport takes place during short periods of high flow, which are generally not adequately covered by the relatively infrequent sampling for sediments.

Chemical Pollution

Little data is available on links between erosion and chemical pollution caused by fertilisers and agricultural chemicals. Such linkages and their significance must therefore remain as supposition, or at best qualitative, until further studies are carried out to collect and analyse relevant data (Woods, 1983).

Legal Aspects

The traditional legislative techniques for controlling pollution attach penalties to specific acts, or licence particular emissions. Neither technique is appropriate to manage non point sources of pollution. As the problem is often cumulative and by definition cannot be identified or controlled at any particular source it is very hard to say which farmer in a catchment is contributing which unit of silt or phosphorus. So attribution of individual responsibility is inequitable and difficult to prove. Since these problems result from accepted agricultural practice they become a community responsibility rather than an individual responsibility.

Control of non point sources of pollution through incentives or disincentives, although it may be authorised by legislation, is heavily dependent upon political, not environmental, factors. Experience in other Federal systems indicates that a more imaginative and perhaps draconian use of introduced legislative and administrative power may be necessary to effect perceptible change (Clark, 1983).

Most laws concerning environmental type issues give 'discretionary' powers to the Government (as does the WA Soil Conservation Act) and do not create any mandatory obligations. The decision whether to apply the law thus becomes a political one (Clark, 1983).

Legislation is nothing more than a technique of elevating policy to the status of law.

Without legislation to establish and fund extension services, no education would take place.

ECONOMICS OF POLLUTION CONTROL

A farmer or a district has no incentive to regulate themselves to ensure that Best Management Practices (BMPs) are undertaken. To do so, the district, or farm, might place itself in an economically disadvantageous position relative to other similarly situated districts or farms which do not adopt or enforce similar regulations. A district or farm can reasonably be expected to regulate problems of local importance, e.g., it would be difficult to expect farmers at Merridin to change farming practice to reduce the impact of salinity on the Avon River. This assumes that there is no economic benefit to use BMP, i.e., no increase in productivity or reduced cost by conserving fertilizer. It may be prudent to expect land users to take into account the effects their actions have on others.

Since voluntary adherence often produces few results some form or means of external controls are needed. Peel-Harvey Fertilizer Programme has been well received without legislation.
External controls may be needed for long term management.

The primary constraints to more effective management of non point sources of pollution are political, not legal, and the future will depend on the existence or absence of political resolve.

SOURCES OF POLLUTION

Point sources of pollution

These include - abattoirs, tannaries, municipal rubbish dumps, farm rubbish dumps, sewage works, railway marshalling yards.

These sources of pollution can usually be dealt with by legislative pollution control programmes, whereby discharge is licensed or otherwise permitted under conditions issued by a controlling body.

Non point sources of pollution

- These include point sources that are unenforceable or exempt from control, e.g., private septic tank discharge.
- Broad overland flow or seepage from groundwater.
- Stream and flood plain erosion and sedimentation.
- Rain contaminated by atmospheric pollution, e.g., acid rain.
- Bird droppings and wind blown dust and debris.
- Urban drainage.

The broad overland flow and groundwater seepage provides the most significant source of non point pollution in the Avon catchment. From silt to nutrients and pesticides all originate from land use in the catchment.

Non point source pollution abatement programmes arise from assessments of present and potential problems, identifying solutions, estimating costs and determining the effectiveness of implementing recommendations to achieve acceptable standards of river water quality and river environ conditions (Thompson, 1983).

Non point source pollution programmes are an essential part of a catchment management programme, and include flood plain management, point source pollution control and prevention of flooding.

Non point source pollution programmes may include both specific works and general works.

Specific works are designed to alter or improve the water quality. Usually the works are designed to correct some ever present and significant problem. They are essentially reactive to an accumulation of past mistakes which, being no longer tolerable, politically generate funds to finance the programmes, e.g., the Peel Harvey estuary.

The more general activities are designed to prevent actions detrimental to the maintenance of or attainment of environmental objectives as applied to water quality. These objectives enable beneficial uses to be available to the community, including those appropriate to a desirable ecosystem.

These activities often include:

- Administrative systems where future works or development projects need to obtain the approval of the catchment management organisation before proceeding with any development.

- The ongoing inspection and maintenance activities by the management organisation.

- The promotion of 'good practice' activities in the use of the land.

- Public awareness campaigns aimed at arousing such a sense of community responsibility that the citizen will desist from numerous minor activities which collectively cause pollution (e.g., the disposal of chemical drums in waterways).

A major problem is justifying corrective work in a commercial cost benefit sense. There is a lack of any generally accepted or consistent criteria for evaluating, in money terms, the benefits to be derived from such works. What value do you put on a permanent summer pool? Will that value change if it is the only pool left? Everyone will put a different value on the pools, depending upon their own perception of the pools' importance, and who is going to pay for any preservation works, either directly or indirectly. We may all consider the preservation of the pools as important, but when asked to put a dollar value on them we soon provide widely varying values.

Implementation of Pollution Controls

These control measures can be broadly classified into two groups, minimal or additional practices.

Minimal practices aim to achieve up to, say, a 25 percent reduction in pollution contained in run-off.

Additional practices aim to achieve some level of reduction above the minimum 25 percent level, say a 50 percent or a 75 percent reduction.

The level of pollution reduction arrived at will depend on the costs of reduction and the perceived benefits from any such reduction.

As with many things, as the degree of reduction increases, the costs in attaining further reductions increase significantly, i.e., the cost of achieving a 25 percent reduction in pollution will usually be substantially less than the cost of reducing pollution by 75 percent. The marginal cost of pollution reduction increases as the level of pollution decreases. The optimum level of abatement (pollution reduction) will depend upon the marginal cost of reduction and the marginal benefits from any such reduction, e.g., it might cost $1 million to revegetate the river and reduce the rate of pool siltation by 75 percent of what it was prior to treatment. However a 60 percent reduction in siltation might only cost $500,000. Is it worth paying an extra $500,000 for an additional reduction of siltation of ony 15 percent? (Note: these costs and percentages are purely hypothetical, actual costs and percentages are not known.)

Pollution control works often include aspects covering the urban, rural and riverine environments. Urban land use control may involve septic tank management programmes, construction of erosion controls, improved timing and efficiency of street sweeping, treatment and containment of industrial waste and settlement areas for town run-off waters.

Rural land use control programmes cover livestock waste control, improved timing and management of fertiliser and chemical applications, contour ploughing, conservation tillage, maintenance of plant residue cover, and improved disposal of chemical drums away from sensitive areas.

Riverine control covers establishment of bankside vegetation, headwards, bank and bed erosion control and fencing to exclude livestock.

A flood plain buy-back programme augmented with storage of flood waters within the flood plain are also often considered.

A Community Problem

"The detriment to a society residing adjacent to a river containing poor quality water is in the same order as not providing a sewage, street cleaning or garbage collection service. Good water quality is essential to the well-being of that society, and the considered opinion of outsiders about it. The concept that a measure of the degree of civilisation attained by a society can be gauged by the water quality of its streams is a truth that undeniably reflects its ability to practise good housekeeping within its urban and associated rurally dependent areas. Thus aesthetics and amenity considerations are of significant importance in justifying non- point source pollution instigation programmes" (Thompson, 1983).

Using the above philosophy on water quality the Avon River does not rate too highly.

The classification or assessment of environmental quality of a river and its environs is often based on a simple scale - high, moderate and negligible environmental significance.

Classification	**Guilding Principle**
Highly significant	Preservation of natural environment
Moderately significant	Maintain status quo - improve as opportunity permits
Little significance	Ensure detriments (if any) are contained, seek environmentally conscious decisions.

Under such a strategy stream reserves have been established when rural subdivision occurs. (This is policy of several shires also). This policy enables the fencing of the river, stabilisation of river banks and the establishment of trees, shrubs and grasses along the river banks forming a buffer zone to protect the river from undesirable land use practices.

Subdivisions and other developments have been planned in a manner that protects the river, i.e., housing is not allowed too close to the flood plain, enabling domestic waste water to be absorbed into the ground. Boundary lines follow the river rather than cross the river thus minimising the number of crossings and culverts needed.

Community awareness of these strategies enables them to adjust their attitudes to enhance their appreciation of the waterway as the community objectives have been clarified, explained and agreed with during public comment periods.

Sediment Control

The largest pollution load entering streams serving rural catchments is sediment. Sediment is derived from the erosion of soils in the catchment. Generally soils do not erode if there is sufficient ground cover to protect the earth from raindrop splash and sheet erosion by lowering surface water flow velocities. Hence many surface stabilisation techniques aim to replace and maintain surface cover.

Some sediment transportation is a natural phenomenon and must be accepted as normal. The major source of sediment is derived from land disturbance, ploughing, building subdivision and so on.

Erosion control relies heavily on good soil conservation practices to limit soil erosion.

Nutrient Export

Most phosphorus is exported from a catchment during periods of heavy rainfall. (Phosphorus is normally the one nutrient that is limiting growth in a river ecosystem.)

Most of this storm flow phosphorus is in the particulate rather than the dissolved form, i.e., it is bonded or attached to the eroding soil particles.

Any estimates made of phosphorus exports during periods without heavy rainfaill would be substantially less than those recorded during heavy rainfall.

Discharge is more important than concentration in controlling the export of phosphorus. There is no simple relationship between concentration and discharge.

Under low flow conditions particulate material will be deposited on the stream bed, which therby acts as a sink (or store) for nutrients under low flow conditions. Under high flow conditions deposited sediment is remobilised. Under these conditions the stream itself may be a significant source of nutrients to receiving waters down-stream.

The very fine particulate material has been identified as significant in the transport of phosphorus, metals and some chemicals (Quigley & Broeckhaven, 1983).

Silt remains in suspension for up to 5 hours in still water, and clay particles for even longer. The time of concentration in most rural catchments in less than 2 hours and run-off control systems are designed to keep surplus run-off moving and dispose of it in a stabilised natural waterway. Significant amounts of fine soil material will pass out of the farming system and into the streams, taking with it organic matter, plant nutrients (fertilisers) and pesticide residues (Stephens, 1983).

This suggests that normal soil conservation practice on farms, as recommended by the Department of Agriculture and the Soil Conservation Committee, will not go very far in reducing the nutrient loading of the waterways from farm run-off. The larger contour constructed WISALT banks which do not act as a drain are designed to hold all the run-off. These will reduce nutrient loadings of waterways. The only other system is to maintain plant residue cover at all times to prevent the mobilisation of soil particles in the first place, i.e., prevent the erosion and not try to control it after it has started as the contour bank system attempts to do.

The technology needed to maintain plant residue cover for the entire year in our dry land cereal areas is restricting its widespread acceptance. The maintenance of cereal stubble at seeding creates serious problems with seeding as most types of cultivators and seeders in use cannot cope with the often large quantities of stubble. Hence the stubbles are generally burnt prior to seeding. Even if the machinery was generally available, the incorporated stubble ties up the available soil nitrogen for several years, as the stubble is decomposed by soil microbes which need and use all available soil nitrogen in this role. Eventually tied up nitrogen will become available to the cereal crop, but meanwhile yields fall or nitrogen input has to be increased. Current profit levels do not allow this to happen. Added to this, stubbles are implicated in several wheat diseases which can reduce yields significantly.

Plant residue cover is desirable in the role of erosion control, but undesirable in the form of wheat stubble at seeding. Naturally seeding is a critical period for erosion to occur. With cultivation and no plant growth for several weeks, paddocks are exposed and vulnerable to water erosion. Little erosion occurs in September, when paddocks are well covered with crops and pastures.

Identifying the source of nutrients

The nutrients measured in a stream will not have come uniformly from the catchment. A variety of land uses and soil types will provide differing amounts of phosphorus and nitrogen available to be mobilised.

Unless a catchment is uniformly wet, or has a surface permeability that is comparable in magnitude to rainfall intensities, overland flow will be generated (if at all) in only part of the catchment. Areas of surface saturation are likely to be the source of nutrients that appear in run-off. Naturally the identification and control of these areas will help reduce the nutrient exports from the catchment.

Nutrient concentration in run-off is usually inversely correlated to grass length, i.e., a long grassy paddock will export less nutrients than a bare paddock.

Highest nutrient exports usually ocur in summer when there are only a few run-off events. Dung and urine from stock tend to remain on the pasture or paddock surface for longer in the dry periods and are quickly mobilised during heavy summer thunderstorm events.

Studies in New Zealand suggest that only 0.2-0.3 percent of applied phosphorus was exported down stream (McColl, 1977 as cited by Cull, 1983).

American studies indicate that up to 5 percent of applied fertiliser would be lost (Olners et. al. 1980).

Recently (December 1985) CSBP and Farmers Ltd and the CSIRO have commenced trials in WA to trace nitrogen use and loss in WA soils. Apart from this and the Peel-Harvey work on sandy coastal soils, little work has been done on nutrient loss from Australian farms. Nutrient export from burnt grass or stubble is also an unknown, and since burning of stubble is still widespread it <u>may</u> be a major source of nutrient export.

Swampy wetland communities provide efficient and effective filters for sediments and nutrients in water which flows through them. Many of these natural wetlands have been drained by man and few remain. They are also effective in treating storm-water run-off from urban catchments, and provide an effective means of filtering of these waste waters.

Pesticides

200,625 kg (active ingredient) of DDT were used for pest control in WA agriculture in 1982. Of this approximately 55 percent was used on cereals. Roughly one third of the area planted to cereals/lupin in 1984 was established using minimum tillage practices which tend to have the most problems with Web-worm (Hednota sp.) which is controlled with the use of DDT.

DDT will lose its registration for use in WA by June 1986, after this date use or sale of DDT will not be allowed.

A recent study by the Department of Agriculture (Sharpe, 1985) looking at DDT levels in the agricultural environment looked at sediments and water levels. Results indicated that DDT levels in both water and sediment appear to fluctuate with the times of peak water-flow in winter. In the case of water, this would be the times of high turbidity. DDT, having poor solubility in water, is absorbed on to clay colloids so giving water higher residue readings during peak flow.

The water DDT levels never exceeded the Maximum Residue Limit for potable water of 34 μg/L. Thirty-seven percent of samples were below or equal to the Australian Resources Council quality level of 0.002 μg/L while 63 percent exceeded 0.002 μg/L whilst being less than 3 μg/L.

The soil DDT levels show a rapid rise after spraying then appear to drop down over a period of two weeks after which there is little or not loss of DDT from the soil. The disappearance rate of DDT is quite slow. Low levels of residues (DDT) could be expected in the body fat of sheep grazing land sprayed with DDT.

ECONOMIC THEORIES IN POLLUTION CONTROL

The essence of many pollution problems centres around property rights and public goods (a river can be regarded as a public good as its presence benefits many while directly costing them nothing, the use of the river by one person does not prevent use by other people.)

Infringements or polluting of a public good (such as air or the river) will not readily be addressed by individuals acting on their own behalf or self interest. The public good belongs to everyone collectively and no-one individually, hence damage done by someone is against society or the public and not any one individual.

Economists also refer to discrepancies between private and social costs (or benefits) as externalities. Externalities occur when decisions (or actions) taken by one group of people (say pollution of a river from an intensive piggery's wastes) have repercussions on others (i.e., spoiling of the water quality of the river).

The normal market system does not provide appropriate incentives to make the polluters consider the damage or harm done to water users downstream. It would be very difficult for a competitor in the Avon descent to take action against a piggery owner for damaging the quality of the river (a piggery would be considered as a point source of pollution).

Non point source pollution externalities are incurred between separate owners of physically interdependent land within a given catchment and between landholders and users of the rivers and streams within and beyond a catchment.

That is, actions undertaken by someone upstream that have an adverse affect on the river not only influences his own situation, but can also have an influence on many other people quite some distance away downstream, for example the use of normal superphosphate on agricultural land in the Peel Harvey area eventually affects thousands of residents and tourists on the estuary by providing phosphorus for excessive algae growth.

Non point sources of pollution produce public 'bads' (e.g., the smell at Mandurah). The externalities situation presents two problems, first to get people to abstain (stop) from doing something that imposes costs on others, i.e., the residents have to put up with the smell or pay to have the rotting weeds moved. Secondly to get people to do something of no immediate benefit to themselves but will confer benefits to others, e.g., by using low or slow release phosphate fertilisers non farmers benefit from the reduced incidence of smelly algae - in Peel-Harvey there is a reduced cost as less slow release super is needed, so there is some incentive.

It is a result of these sorts of problems that we have such a lot of pollution occurring. The same logic can be applied to soil erosion and siltation, salinisation of waterways, nutrient enrichment of waterways and many other environmental issues. The solutions to these problems are difficult because the relationships are not easily linked together, allowing polluters to continue polluting without due regard for the welfare of others. This is starting to change in some of the heavily air polluted areas of the world, where public outcry is causing large industrial air polluters to clean up their emissions.

Intertemporal Transfers

Intertemporal transfers refer to the distribution of benefits (or costs) between the present generation and future generations. In the extreme they represent choices between development and no development, or present development versus future development.

More specifically, inter-temporal transfers are represented as choices about the degree of exploitation of land and water resources and about the maintenance of land for future generations. Many decisions such as maintaining trees and pasture cover may provide penalties to the current land owners in the form of increased costs or reduced returns, but will result in future generations receiving the benefits.

Intertemporal transfer problems are often experienced in conflict between the multiple goals of farmers. There are many instances in farming where longer term environmental objectives are not readily reconcilable with other valued goals, such as earning enough to pay the mortgage interest. Fluctuating economic circumstances for farmers are particularly relevant. Often the short term goal of economic survival does not provide the opportunity for environmental considerations. Bank Managers are quick to remove the 'non essential' erosion control expenditure from the budget in tight years. By doing so we are exploiting the future generation's assets and heritage.

Attitude and Behaviour

A positive attitude to environmental problems and their control does not necessarily mean that individuals will undertake the appropriate environmental behaviour. Attitude does not normally take into account the cost of implementing the appropriate action suggested by the attitude. Hence attitude alone cannot be regarded as a good indicator for behaviour.

Control of Non Point Sources of Pollution

The diffuse nature of non point sources of pollution presents considerable difficulties in the use of taxes or effluent regulations on individual properties.

The problem is that the measurement of soil loss is very difficult and expensive. When you consider the area involved (with over 1,725 farmers in the western catchment alone) measurement of soil loss becomes impracticable.

Subsidies to encourage appropriate land management, and for the purchase of specified inputs, often in association with land use regulations, are likely to be more appropriate policy options for soil erosion and salinity problems.

The United States has in use 'plant residue cover at time of seeding' as a guide to the potential soil loss from an area. If more than 50 percent plant residue cover is maintained until seeding, the incidence of erosion is considered to be below an acceptable level. Farmers who do not maintain this level are subjected to 'fines' or 'taxes' for soil loss based on plant residue cover.

Plant residue cover correlates closely to soil loss and is much easier to measure, using aerial photos, than soil loss.

This type of approach may be applicable in Western Australia, but local study would need to be undertaken to determine acceptable levels of erosion and what percentage plant residue cover provides for this rate, i.e. is 50 percent P.R.C. enough? or is 25 percent enough in our environment to reduce erosion to acceptable levels? What is an acceptable level for WA? Iowa State (U.S.A) uses 5 tonnes per acre as an acceptable rate of soil loss per year (approximately 1.5mm of soil loss). This sounds far too high for our shallow Western Australian soils.

Education and extension programmes are rarely sufficient as a means of moderating non point source pollution where substantial externalities are involved (i.e., non farmers' benefit). Education and extension are a necessary part of any policy involving economic incentives and regulations. There is a need for non point source polluters to be provided with information regarding the identification, causes, consequences and relevant management control practices for a particular problem (Carey, 1983).

Non point source pollution is a community problem. The control of non point source pollution can be achieved only through the action of others. This is a complex process because of the variability in attitudes and social and economic situations of the people involved.

Persuasion and Compulsion

You may need to use both persuasion and compulsion.

Self interest - what you want him/her to do, they may not wish to do for attitudinal, social or financial reasons.

Planning horizon - what you want them to do may not coincide with the rate at which they want to do it.

Attitude - what you want them to do, they may not want to do because they:

- have a negative attitude
- have a positive attitude limited by financial constraints
- a despondent attitude - they perceive the problem as being too big and complex to respond to any individual influence
- an uninformed attitude through a lack of knowledge or interest.

Treatment Options

Since the control of non point source pollution can only be achieved through the action of others, we must consider the problem from their point of view.

The environmentalist considers pollution from the point of view of the river and the land.

The landowner considers it from the point of view of the land first and the water second. Pollution is strictly a relative issue.

Non point source pollution can be considered as relative to various levels of catchment deterioration such as:

i. the rate of naturally occuring erosion or pollution
ii. the rate of accelerated erosion that may occur when commonly accepted standards of good management practices are in use
iii. the rate of erosion that may be desired by users downstream
iv. the rate of accelerated erosion that might occur under a poor management system.

(Cahill, 1983).

Any non point source pollution control management plan needs to be preventative in nature rather than reactive.

Unless it is possible to convince people that what is being attempted is necessary and sensible and will work, then we are going to be less than completely successful.

POLICY OPTIONS - SALINITY AND EROSION CONTROL

i. The provision of subsidies for approved alternative land uses, such as agroforestry and reafforestation in appropriate areas. This is not consistent with the 'polluter pays' principle, but it would be more acceptable politically than a tax option.

ii. Basing subsidies on the cause of the pollution, such as deep percolation or inappropriate land use, can encourage the adoption of preventative management practices. This could only be administered with extensive monitoring of soil water contents and groundwater levels. Alternatively the use of a model to recreate the happenings within the catchment would reduce costs of monitoring the actual environment, but would require considerable research to develop.

iii. Regulation of land clearing based on the physical characteristics of the catchment. The problem is that up to 85-90% of the catchment is already cleared. Prohibition of further clearing may be desirable in some areas.

iv. The use of a transferable quota system for tree clearing on a catchment basis to enable the establishment of a market in rights to clear land. This would be less draconian than option (iv). This may need an underlying base level of, say, 10% of each property should be under trees. If one property had only 50% of his farm cleared, he could sell clearing rights to other farmers who wished to clear additional areas of their own properties.

v. Provision of information on the financial and physical benefits and practicalities of alternative land uses could help convince land owners to change management practices.

With non point source pollutants such as salinity it is impossible to accurately determine the external damage caused by certain land use practices. Without this information it could be argued on legal and equity grounds that a farmer should not be forced to pay the full costs of alleviating a problem that cannot be directly linked to his actions. Combined with the likely resistance to taxes, policies based on subsidising appropriate land uses would be politically more acceptable, even if less effective (AWRC Project, 80/137).

SUMMARY

There are problems associated with any natural system that has been influenced by man's use of the environment. The Avon River system is no exception.

Many of the problems accumulate slowly over time, practically unnoticed by most people. There comes a time when action needs to be taken to prevent further degradation beyond the river's capacity to recover.

The management of natural resources, such as the Avon River system, is an art involving the application of inadequate data to complex situations with poorly defined objectives. There is never enough data to really satisfy ourselves (Burton, 1983).

Any steps taken to protect or improve the environmental quality of the Avon River will be taken with less than perfect knowledge of the problems and long term consequences of such actions. Benefits may not be seen for fifty, or even a hundred, years' time, which makes the cost-benefit analysis difficult.

The problems associated with the Avon River system are complex - any improvement will be slow and long term.

The problem that is seen to be the most urgent is the loss of the four remaining permanent summer pools. The urgency is perceived because once these pools silt up completely there is very little, if anything economic, that can be done to recreate them. The loss of these pools is significant from an environmental and economic point of view.

Environmentally these pools provide the only source of summer refuge for the many species of water bird in the South West of Western Australia. Loss of these refugia will inevitably result in the loss of these birds from the area, and perhaps in some instances from the State. They form a significant part of a very limited resource, and in some areas the only refuge.

Economically the permanent pools provide an excellent opportunity for tourists to view the Avon River at its best. With only minimal development, parts of these pools can become attractive passive recreational areas for bushwalking, bird watching, BBQs and the like.

The solution to the siltation of the pools, theoretically at least, involves the re-establishment of the river's former energy balance, i.e., its speed of flow needs to be reduced, the river bed vegetation allowed to regrow and local flooding to occur. These measures conflict strongly with the needs of the urban Avon Valley which sees flooding as a major disaster and something to be prevented, not increased. Rate of erosion within the catchment needs to be controlled to reduce the volume of silt and sand entering the river system.

A compromise between these two extremes may be possible.

Revegetation of the areas upstream from the remaining pools to slow down the flow of the river and to perform as natural silt traps may be possible. Whilst leaving the river downstream from the urban area relatively clear of vegetation to allow the rapid flow of water away from the towns.

The exact areas and distances required can only be guessed at without further surveying and engineering studies being undertaken. If these measures produce the required result of reduced siltation, the long term economics of dredging and some of the more desirable pools may improve. If resilting is slowed or reduced enough, justification of the $1 million expenditure to dredge Northam's weir may be plausible.

The other problem areas require additional research to provide enough information on which to base futher action.

The problem of nutrient enrichment and pollution needs to be quantified to determine the short and long term affect of these pollutants on the riverine ecosystem. Undoubtedly pollution of the river does happen from time to time, the actual affect this has on the river can only be guessed at without more research being conducted into the energy relationships and threshold levels of the river system and its permanent pools.

Pollutants may include nutrients (N + P), pesticides, erosion deposits (silt etc.), salt, and perhaps some heavy metals from town sites, rubbish dumps, railway yards and industry. The sources and quantities of each are not known with any certainty.

The problem of salinity is a very large issue as it affects a large area and number of WA farmers.

The Avon River appears to be capable of coping with saline water from the Yenyening Lakes without too much apparent disruption, providing that the outflow coincides with periods of peak flow in the Avon. This enables the saline water to be flushed out of the river system before the river stops flowing for the summer.

Increased community access has been suggested by the people who will benefit from increases in the number of tourists in the Avon Valley. To determine the need for improved access some survey work should be undertaken on current usage and public attitudes of users as to the adequacy of facilities and the desirability for more facilities, of what type? and in what areas?

There may be little justification in providing facilities that are used only during the Avon descent, even if it is the premier white water event in Australia.

The desirability and practicability of declaring the river and its banks as a national park would require extensive investigation before any informed comment can be made. Management of a linear system would also be more difficult.

This would also apply to any restrictions on land use along the river, or within the river, for grazing and cropping purposes. No doubt some damage does occur from over-grazing, but the extent and significance of such damage can only be described as low compared with the damage the River Training Scheme caused.

CONCLUSIONS

Solving of the problems of the Avon River System must address the causes of the problems and not the obvious symptoms, as has been the approach used in the past.

The River Training Scheme was an attempt to reduce the flooding of the Avon Valley townsites. This was successful but has created further environmental and hydrological problems.

The symptoms which are causing most concern with the Avon River system include:

i. river pool siltation,
ii. river flooding,
iii. salinisation of farming lands,
iv. soil erosion of farming lands.

To control these symptoms the causes need to be clearly identified first.

Causes

Salinisation of farming lands results from the clearing of the higher water use vegetation, causing a rise in the water table and mobilisation of stored soil salts, i.e., a water balance problem.

Soil erosion results from inappropriate land use in many instances.

River pool siltation is a result of past and present farm erosion putting vast quantities of silt and sand into the river system. The River Training Scheme aggravated the problem by removing the vegetation that acted as a stabilising agent for this silt and sand.

River flooding is in fact a naturally occurring event. Since clearing of the catchment, river levels rise much faster than before. Silt and sand is slowly filling up the river channel. Eventually there won't be a channel left for the river to flow in. When this occurs, flooding will become a major disaster and not just a nuisance every 10 years or so.

The source of these problems is in the catchment's land use pattern. The technology exists to control these problems.

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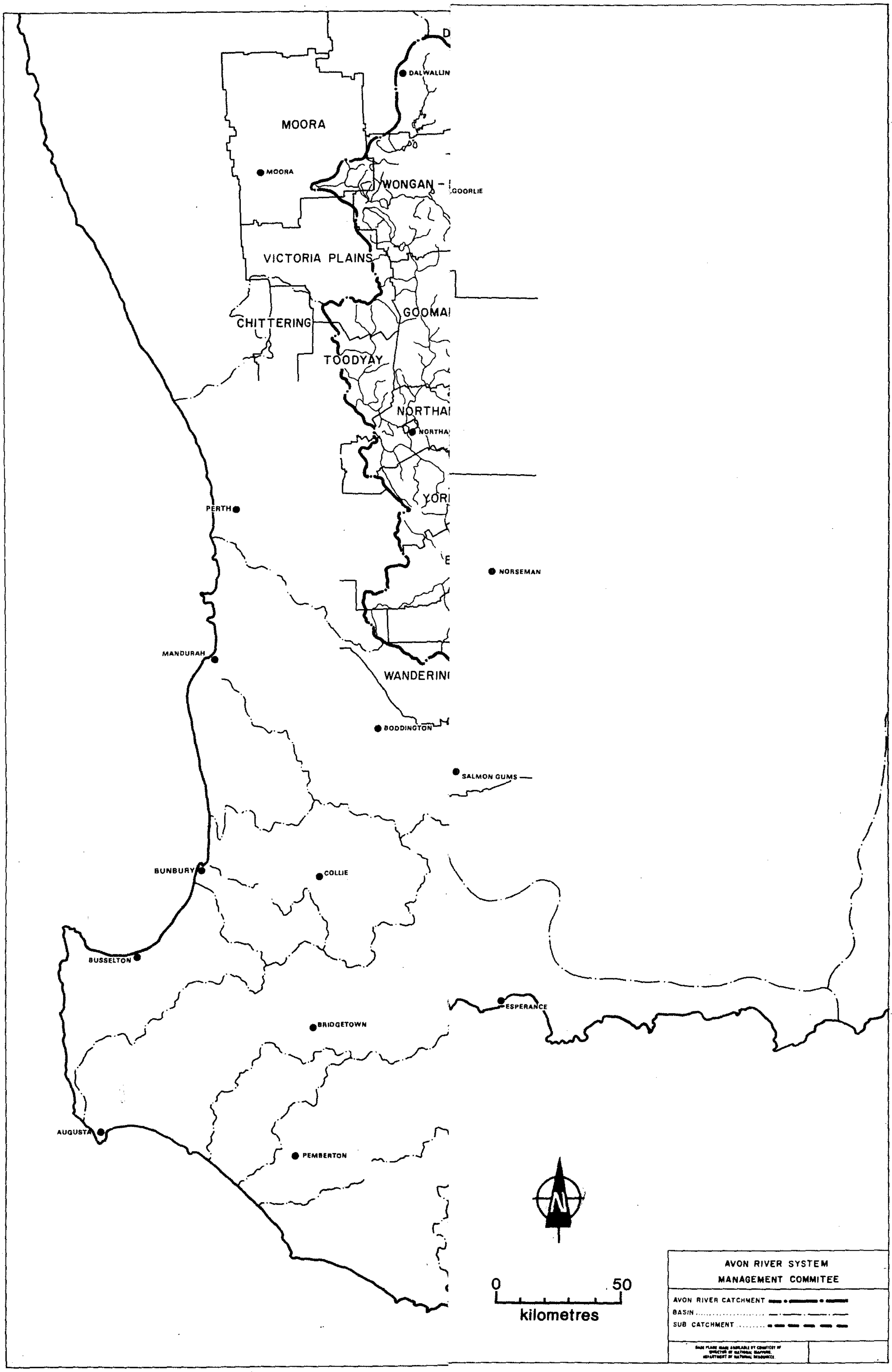


Avon River System Drainage Basin

REFERENCES

Abbott, I., Parker, C.A., & Sills, I.D. Changes in the Abundance of Large Soil Animals and Physical Properties of Soils Following Cultivation. Aust. Journal of Soil Research. 1979. 17, 343-53.

Alexander, Dr. I. Closer Settlement. Avon Valley Prospects - Proceedings of Seminar. April 1985 Northam Town Hall. Unpublished.

Anderson, G.W., & Batini, F.E. Integrating Agriculture & Forrestry. Land and Stream Salinity Seminar Proceedings. W.A. November 1980. W.A. Govt. Printers.

Anon. AGRO - Forrestry, a New Kind of Farming? Rural Research 99. June 1978 P1-9.

Anon. Agriculture & The Environment in Western Australia. Proceedings of a Meeting held in Perth on 10/10/79. Western Australian Institute of Technology, October 1979.

Anon. C.S.I.R.O. In Nitrogen Research. The Western Australian Newspaper, Saturday 14/12/85 - Country Edition.

Anon. Does AGRO Forrestry Have a Future? Rural Research, 127. Winter 1985 P21-27.

Anon. Farm Budget Guide 1986. Produced and compiled by W.A. Dept. of Agriculture and Western Farmer.

Australian Water Resource Council (1983). Workshop on Non-Point Sources of Pollution in Australia - Proceedings. Dept. of Resources and Energy. Conference Series No. 9.

Australian Bureau of Statistics, Western Australian Office. Crops and Pastures, W.A. 1983-84 No. 7321-5. Livestock and Livestock Products 83-84 No. 7221-5. Agricultural Land Use and Selected Inputs, W.A. 1982-83 No. 7411-5.

Bettenay, E. Land Form, Natural Drainage and Salinity. Journal of Agriculture 1979. W.A. Dept. of Ag.

Bettenay, E. Deep Drainage as a Method of Treating Salt Land. Journal of Agriculture 1979. W.A. Dept. of Ag.

Bettenay, E. The Natural Setting. Avon Valley Prospects. Seminar April 1985. Northam Town Hall. Unpublished.

Bligh, K.J. Rainfall Infiltration and Suspended Sediment Mobilisation Following Cultivation. Intrim Report Division Resource Management Dept. of Ag. W.A.

Bligh, K.J., Grasby & Negus. Water Erosion, Water Logging and Flooding. Journal of Agriculture W.A. No. 2 1983.

Binnie & Partners Pty Ltd. Avon River Flood Study. For the Water Authority of W.A. Unpublished 1985.

Birch, P.B. Agricultural Fertiliser Runoff and its Potenital for Causing Eutrophication of Surface Water Systems. Agriculture and The Environment in W.A. Proceeding. P. 43-49 10/10/79 W.A.I.T.

Burdass. Farm Planning for Conservation. Journal of Agriculture W.A.. No. 2 1983.

Carter et al. The Cost of Land Degredation. Journal of Agriculture. No. 2 1983. W.A. Dept. of Ag.

Carter, D.J. Preventing Wind Erosion. Farm Note 571. Dept. Ag.

Cary, J.W. Social Dilemmas in Catchment Management for Non-Point Pollution Control. Proceedings N.P.S. of Pollution. Monash University Melbourne March 1983. A.W.R.C. Aust. Govt. Publishing Service, Canberra 1983.

Clark, S.D. Legal and Institutional Framework for Control of Non-Point Sources of Pollution in Australia. Proceedings N.P.S..

Clawson, M., & Knetsch, J.L. Economics of Outdoor Recreation. The John Hopkins Press Ltd London 1966. Resources for the Future Inc.

Conference Proceedings. Avon Valley Prospects April 1985. Aust. Institute of Agriculture Scientists Muresk. Unpublished April 1985.

Condia, P. Water Quality Management in Developing Catchments. Dandenong Valley Authority No. 25 March 1983.

Costantoura, Paul. Measuring Soil Erosion - A New Approach (Caesium 137). Rural Research. Winter 1985.

Cullen, P. Research into Nutrient Exports from Land Surfaces. Proceedings N.P.S.

Davies, Dr. J. The Impact of Agricultural Development. Avon Valley Prospects - Seminar April 1985. Northam Town Hall. Unpublished.

Dumsday, Edwards, Lumley, Oram & Papst. Economic Aspects of Dry Land Salinity Control in the Murray Basin of South East Australia. School of Agriculture; La Trobe University & Soil Conservation Authority, Vitoria. A.W.R.C. Project 80/137.

Dumsday, R.G. & Seitz, W.D. Improving the Economic Efficiency of Programmes Aimed at Controlling Agricultural Sources of Non-Point Pollution. Proceedings N.P.S.

Dept. Conservation & Environment. Water Quality Criteria for Marine and Estuarine Waters of W.A. Bulletin No. 103. 1981.

Dept. Conservation & Environment. Systems Six Report. Conservation Reserves of W.A. Dept Conservation & Environment. DCE Report 13.

Department of Agriculture: Western Australia 1985. Annual Report y.e. 30/6/85.

Division of Resources Management. Level Sill Outlets. Farm Note 572 Ag. Dept. 38/83. Dept. of Ag. W.A.

Division of Resource Management.
Soil Type & Drainage) Peel
The Soil Phosphorus Store) Harvey
Alternative Land Uses) Estuary
Journal of Agriculture W.A.. No. 3 1984.

Division of Resource Management. An Assessment of Interceptor Banks. Journal of Agriculture. No. 4 1982. W.A. Dept. Ag.

Eckersley, D. What Future for a Salt Affected Catchment? Journal of Agriculture. No. 2 1982. W.A. Dept. of Ag.

Ebell, G.F. Pesticides Behaviour and Persistence in Agriculture and the Environment. Agriculture and the Environment of W.A. Proceedings. P. 51-59 10/10/79 W.A.I.T.

Garden, D.S. Northam An Avon Valley History. Oxford University Press 1979.

Garman, D.J. & Sutherland, P.B., Pesticides, Fertilisers, Heavy Metals and Salintiy - An Assessment of Non-Point Sources Problems in Australia. Proceedings of the Workshop on Non-Point Sources of Pollution. Monash University Melbourne March 1983 A.W.R.C. Aust. Govt. Publishing Service Canberra 1983.

Gee, S., Morland, R. & Nulsen, D.R. Management of Water Level and Salinity of Yenyening Lakes. Final Report of Yenyening Lakes Working Group to the Hon. K.F. McIver, Minister for Works, Lands & Surveys May 1985.

Greenwood. Plants as Pumps. Journal of Agriculture 1979. W.A. Dept. of Ag.

George et al. Effects of Surface Drainage on Dry Land Salinity. Journal of Agriculture 1979. W.A. Dept. of Ag.

George, P.R. The Dry Land Salinity Problem in North America. Journal of Agriculture 1979 W.A. Dept. of Ag.

Govt. of South Australia. A Permanent Solution to the River Murray Salinity problem.' June 1981. S.A. Govt. Printer.

Halse, N. The Current Agricultural Value of the Avon Valley. Avon Valley Prospects - Seminar April 1985. Northam Town Hall. Unpublished.

Hart, B.T. Transport of Toxic Heavy Metals and Organic Contamination by Particulate Matter in Streams. Proceedings *N.P.S..

Helman, P. & Estella, P. The Conservation Status of Riverine Ecosystems in N.S.W. (Darling/Murray). State Pollution Control Commission September 1983.

Henshke. Salt Land Statistics. Journal of Agriculture No. 4 1980. W.A. Dept. of Ag.

Hillman. A Central Midlands Catchment Study. Journal of Agriculture No. 1 1982. W.A. Dept. of Ag.

Janes, A.J. & Wallace, T.C. Direct Drilling Systems - Their Potential for Increased Cropped Area within the Avon Valley, Particular Reference to the Dollerite Free Zone. Agriculture and the Environment of W.A. Proceedings 1979.

Kendricks, G.W. The Avon: Faunal and other Notes on a Dying River in South-Western Australia. The Western Australian Naturalist Vol. 13 No. 5. April 14, 1976.

Kinsel, W.J. U.S.D.A. Natrional Modelling Projects WHY, WHAT, HOW? Proceedings N.P.S.

Krutilla, J.V. & Fisher, A.C. The Economics of Natural Environments. Ch. 3 Irreversibility and the Optimal Use of Natural Environments. Ch. 4 Further Analysis of Irreversibility: Discounting, Intergenerational Transfers and Uncertainty. John Hopkins University Press, Baltimeri, 1978.

Lee, J. Kikeros, A. & Bowers, T. Avon River Management 1983.

Loh, I.C. & Stokes, R.A. Predicting Stream Salinity Changes in South Western Australia. Public Works Dept. W.A. Land and Stream Salinity Seminar. W.A. November 1980. Govt. Printer of W.A.

Malcolm, C.W. Division Resource Management. Causes of Dry Land Salinity. Dept. Ag. W.A. Journal of Agriculture. Dept. Ag.

Malcolm, et al. W.A. Soils Store Huge Quantities of Salt. Journal of Agriculture 1979. W.A. Dept. of Ag.

Marsh et al. Wind Erosion. Journal of Agriculture. Dept. Ag.

Masters, J.R. Considerations of Public Usage of Avon River - Shires of Northam and Toodyay. Paper Addressed to Northam Shire 12/8/82 by J.R. Masters.

Masters, J.R. 1973. Comment on Department of Environmental Protection Letter to the Country Party.

Masters, J.R. Criticism of the Avon River Training Scheme. August 7, 1972. Copy of above from Northam Shire Council File of the Avon River.

Masters, J.R. River Pools Affected Shires of Toodyay and Northam. Dec. 3, 1973.

Men of Trees. 1985 Winter Plantings - Public. Men of Trees.

Moore, A.L. 1962 "Resevoir Recreation and Social Economic Growth". P. 119 iv: An Economic Evaluation of National Parks. Ulph & Reynolds 1981.

Motion, T. Recreational Potential. Avon Valley Prospects Seminar April 1985. Northam Town Hall. Unpublished.

Murray-Darling. Basin Management. Ministerial Meeting November 14-15 1985. News Release November 16, 1985 and Joint Communique.

Mulcahay, M.J. A Reivew of the Causes of Salinity in South Western Australia. Agriculture and the Environment in W.A.. Proceedings P. 3-5 10/10/79 W.A.I.T.

Mulcahy, P. Potential for Investment. Avon Valley Prospects Seminar April 1985. Northam Town Hall. Unpublished.

McFarlane, D.J. Study Tour Report. Tech. Report No. 29 Dept. No. W.A. Division Resources Management. (Soil Conservation Research in N.S.W. and Water Erosion in W.A.).

Negus, T.R. Land Classed in the Upper Great Southern of W.A. W.A. Dept. Ag. Bulletin No. 4016.

Negus, T.R. Waterways. Farm Note 68/83. Dept. of W.A.

Negus, T.R. Tree Planting for Erosion and Salt Control. Farm Note 51/82.

Negus, T.R. Direct Drilling on the Contour to Control Erosion. Farm Note 99/84. Dept. of Ag. W.A.

Nicol, K.J. Heady, E.O. & Madsen, H.C. Models of Soil Loss, Land and Water Use Spatial Agricultural Structure and the Environment. Card Report 49T, July 1974. Iowa State University Ames Iowa. U.S.A.

Nulsen, R.A. Salt Land Management - A Catchment Approach. Farm Note 133/84 Adgex 512. W.A. Dept. of Agriculture.

Nulsen, R.A. & Henschke, C.J. Division of Resource Management Department of Agriculture W.A. Ground Water Systems Associated with Secondary Salinity in W.A..

O'Brien; Brian J. Director Dept. Conservation and Environmental Protection 20/6/73. A letter to Mrs J. Hammersley Country Party of W.A. in reply to her letter to him on the R.T.S. Ref: 100/72 J.M.

Parker, Proff. L. Destruction of an Ecosystem. The Royal Society of W.A.. November 18, 1985.

Pelk, A.J. et al. Changes in Ground Water Systems After Clearance for Agriculture. Agriculture and the Environment P.W.D. Proceedings P. 95/97 10/10/79 W.A.I.T.

Piggott, M. Trees to Beat Salt. Farm Magazine Jan 1986.

Pope, C.A. Bhide, S. & Heady, E.O. The Economics of Soil and Water Conservation Practices in IOWA: Results and Discussion. Card Report 109 SWCP Series II Feb. 1983. IOWA State University Ames IOWA US of A.

P.W.D. Engineering Research Station. A Preliminary Study of the Swan/Avon River System.

P.W.D. 1974. Public Works Department (now Water Authority of W.A.). Newsletter No. 109 1/9/1974. In Swan River Conservation Board File No. 14/71. Avon River Folio 38.

P.W.D. of W.A. Stream Flow Records of W.A. to 1982. Vol. 2 Basins 613-617. P.W.D. (W.A. of W.A.).

Robertson, Dr. G.A. Land Conservation in W.A. Journal of Agriculture No. 2 1983. W.A. Dept. of Ag.

Robertson, G.A. (W.A. Commissioner for Soil Conservation) Soil and Land Conservation Act 1945-82. Farm Note 83/83. Dept. of Ag. W.A.

Rowley et al. Wind Erosion and Sand Blasting. Journal of Agriculture No. 1 1982. W.A. Dept. of Ag.

Sadler, B.S. & Williams D.J. The Evaluation of a Regional Approach to Salinity Management in Western Australia. Land and Stream Salinity Seminar W.A. November 1980. Govt. Printer of W.A.

Salim, D. Avon River at Brouns Farm. Flood Study. Report No. 2 W.R.B. 128 May 1985. W.A. Water Authority.

Schmitt, H. W.A. has Worst River Salting. The Western Australian Newspaper. June 19 and 20, 1982.

Sedgley, R.H. Smith, R.E. & Tennant, D.J. Management of Soil Water Budgets of Recharge Areas for Control of Salinity - South Western Australia. Land and Stream Salinity Seminar W.A. November 1980. Govt. Printer of W.A.

Sharpe, C.R. Pesticides Advice. Dept. of Ag. W.A. DDT Levels in the Agricultural Environment. Intrim Report - Unpublished 1985.

Sinclair, R. & Smith, V. A Baseline Study of the Avon River Around Toodyay. Murdoch University 12/80.

Standing Committee on Soil Conservation 1978. 'A Basis for Soil Conservation Policy in Australia. Report 1. of Collobarative Soil Conservation Study 1975-77.

Stephens, R.M. Modified Rural Practices to Control Non-Point Sources of Pollution (Agriculture) Proceedings N.P.S..

Stokers, R.A. Soil Salt Storage Characteristics. P.W.D. of W.A. Land and Stream Salinity Seminar W.A. November 1980. Govt. Printer of W.A.

Stoneman, T.C. Salinity in W.A. A Summary. Journal of Agriculture 1979. W.A. Dept. of Ag.

Sugden, R. & Williams, A. The Principles of Practical Cost-Benefit Analysis. Oxford University Press 1978.

Sullivan, Farming Practice and Soil Structure. Journal of Agriculture W.A. No. 2 1983.

Thompson, D.G. Non-Point Source. Pollution Mitigation a Catchment Mangement Activity. Proceedings N.P.S..

Thurlow, B.H. & Atkins, R.P. (1985). Water Quality Management of the Swan-Canning Estuarine System. Potential Impact on Urban Land Use. Unpublished Waterways Commission W.A.

Tolliday, L. Recreational Activities. Avon Valley Prospects Seminar April 1985. Northam Town Hall. Unpublished.

Toodyay Lions Club. Avon River Committee. 'Undated'.

Toodyay Naturalists Club. Policy Document - Suggestions for the Retention of Wood Lots on Rural Land 1978.

Ulph, A.M. & Reynolds, I.K. An Economic Evaluation of National Parks. CRES 1981 Monograph 4 Australian National University Press Canberra ACT.

Weeks, C.R. & Crockett, J. Urban Stormwater Pollution and Catchment. Proceedings N.P.S..

Whittington, H.S. Water Soil and Salt. Pamphlet by Elders Pastoral and W.I.S.A.L.T.S.

Williamson, D.R. & Johnson, C.D. Effects of Land Changes in Salt and Water Transport. Agriculture and the Environment in W.A. Proceedings P. 87-93 10/10/79 W.A.I.T.

Woods, L.E. Water Quality in Relation to Erosion. Proceedings N.P.S..

*Proceedings of the Workshop on Non-Point Sources of Pollution. Monash University, Melbourne (1983). A.W.R.C. Aust. Govt. Publ. Service Canberra A.C.T.

APPENDICES

The first step in any management programme would be to identify all the problem areas within each catchment subdivision. These could then be ranked according to their significance as a source of either salinity or erosion. By giving the worst areas priority, significant improvement can be made at little cost and in the short term. These problem areas can then be used as show pieces to demonstrate the effectiveness of the management techniques in controlling the problems in the catchment area.

These problem areas may need to be resumed and repair work paid for and carried out by the Government. In the long term they can be re-sold, once stabilised, if this is deemed appropriate.

I COMPREHENSIVE LOCAL STUDY

Before any changes are made and any money spent, a comprehensive hydrological and geophysical study needs to be conducted on each site to determine the appropriate management systems that are needed to solve the areas' particular and unique circumstances. A different combination of land use, deep open drains, deep closed drains, pumping, surface drainage and vegetation will be needed on each site. The cost of these improvements will usually be less than the cost of replacement land. Even if not, it may be desirable to treat them anyway.

The solving of the high priority problem sites may include non farming land, e.g., revegetation of a section of the Avon River may be considered to be desirable both as a show piece and as a means of slowing down the rate of siltation while the total catchment plan is implemented. It will take some time before significant reductions in silt loads have any beneficial affect on river pool siltation.

Acceptable Levels of Erosion Within the Catchment

Soil erosion is a naturally occurring event. It would be impracticable to expect to prevent soil erosion completely.

The 'ideal' rate of soil erosion is the rate of loss that is less than or equal to the rate of natural soil formation. Since in WA we generally have only very shallow soils which are formed very slowly any soil erosion has serious implications regarding the long-term sustainability of our farming system.

The average wheat yields for WA have not increased in the past ten years, despite vast imporovements in our technology - from weed control, seeding systems, wheat varieties and so forth. One argument used to explain our lack of yield increase is the decreasing fertility of our soils due to losses of the 'best' soil from erosion. Soil loss from paddock surfaces is imperceptible, but you only need to look at the colour of the water running down the creeks to see that soil is being lost. The small, fine particles that are the most susceptible to erosion contain the organic matter and fertilisers that are essential for plant growth.

Prevention Versus Cure

Prevention of erosion is much cheaper than reclamation of eroded lands. Soil erosion will result in long term yield reductions and cost increases as more nutrients need to be added to compensate for those washed or blown away.

Some areas may not be productive enough to warrant expensive reclamation works, but stock exclusion and revegetation can contribute to the stabilisation of these areas. Erosion control technology is well developed in Australia and around the world.

Again every situation may need a different combination of methods to control erosion to within acceptable limits.

Until we can quantify what these acceptable limits are it is going to be very difficult to determine the economic level of control needed. 100% control is too expensive and would probably exclude current land use. However the optimum level of erosion is not known for WA. It is easy to cite bad gully erosion that is in urgent need of treatment, but are these areas the most economically significant sources of soil erosion? They tend to only cover a small area and are considered to be inconvenient more than anything else. A 0.5 mm loss of top soil from a paddock could be costing the farmer much more in lost yields than any large and obvious gully.

Land Capability Classification

Classification of land areas into capability classes will help to identify the soil types and areas that need special treatment to prevent excessive erosion. A system incorporating percent slope and soil type may provide an appropriate basis for land use classification, e.g., slope greater than 10% - no cultivation recommended; slopes 6-8% - minimum tillage on the contour etc. The establishment of guidelines for land use can provide a useful basis for farm decision-making. It could also be used as a criterion for funding on soil conservation programmes, i.e., steep sloping country may need erosion control programmes just to prevent it from eroding.

Benefits

The benefits of controlling salinity and erosion are large and diverse.

Direct beneficiaries will be the farmers who stand to gain the most in the long term. Loss of available land from salt and erosion costs the farmers the most and they are usually the ones who pay the most for any preventative work, e.g., over $60 million has been spent on WISALT banks since 1978 (West, Pers. Com. 1986) in an often futile attempt to control salinity in WA. If farmers have been prepared to pay this much on an unguaranteed system that is not recognised by the Department of Agriculture or by the majority of scientists working in this area, how much would they be prepared to invest in a system that has been demonstrated to work and comes with written assurances?

Farmers are obviously keen to prevent any loss of their productive capital - whether it be from salinity, water logging or erosion - since these problems all cost the farmer every year in lost productivity, reduced yields and increased costs.

If these losses and costs can be clearly quantified, i.e., put into dollar values, each farmer can then clearly see how much he can afford to spend to reduce these continuing losses. If it was practicable to put a value of the soil eroded from the paddock, the farmer would soon be able to determine how to reduce these losses in the most economic way. Each farmer would have a different set of values and use a different method of reducing erosion.

Measurement of Erosion

The measurement of soil erosion is difficult, time consuming and expensive using the Caesicum 137 method. As a result of this, it rarely gets done except on an individual experimentation basis. General guidelines could be developed for each catchment and soil/land classification. This would set upper and lower levels of likely or expected rates of erosion for a given area and land use. Farmers could then use this as a guide to the amount of erosion occurring on their own properties.

Alternatively the relationship between plant residue cover and erosion could be established for our land use systems. In this way a farmer could be assured of reducing his erosion to an acceptable level as long as his plant residue cover exceeded a certain percentage. This percentage would vary with the type of land and land use, i.e., steep sandy soils under cultivation would need a considerably higher plant residue cover than a flat heavy soil would need to reduce erosion to within acceptable levels.

Until an accurate method of gauging the rate at which erosion is occurring and what this is costing the farmer both directly and indirectly is available, soil erosion is likely to remain a problem. People need to be able to see that something is happening before they are prepared to spend money on preventing it from continuing.

Non Farm Benefits

The control of erosion and salinity will benefit the non farm population in several ways. The level of saline water entering the river systems will fall as will the speed of flow of runoff from the catchment. The quantity of large soil particles, silts and sands being eroded will be reduced so less will find its way into the river system. Lower velocity of flow and less silt will help reduce the likelihood of increased future flood levels. Unless the silt within the river system is removed the river channel will be permanently partially filled with silt, thus its capacity will be reduced.

By revegetation of the river channel, stabilising the existing bed loads and preventing the sand from moving into the pools and weirs, the river's attractiveness will be enhanced as well as its tourist drawing ability. Spinoff effects could be significant. Fresher river water could mean improved chances for introducing fish into the pools again.

The assured economic survival of the farming community will benefit the support industries and towns within the area, with employment and other associated spinoffs.

II <u>COST COMPARISONS</u>

WA Department of Agriculture - cost of protecting WA from soil erosion using contours	$80M	(1982 prices)
Invested in WISALT banks since 1978 in WA	$60M	
Lost land resources in WA annually from salinity	$62M	
260,000 ha of once arable land now unproductive due to salinity @ $400/ha	$104M	
100,000 sq km of WA non arid zone land in need of works and/or practices to reduce soil erosion.		
Wind and water erosion and soil structure decline are costing WA $70M a year in lost production (Dept. of Ag. 1985).		
WA Soil Conservation Committee Budget	$611,000	1984/85
WA Department of Agriculture Annual Budget	$69.3M	(1985)

<u>Comparison With Other Environmental Projects</u>

Mandurah-Dawesville Canal	$30M	
Sorento Marina	$13 M	
Murray-Darling Basin Budget (SA, NSW & VIC)	$1.5M	1986/87
Possible SALT Interception Works - Murray-Darling Basin	$55M	

<u>The National Soil Conservation Programme (NSCP)</u> aims are:

1. That lands be used within their capabilities;

2. That decisions and activities be based on whole catchment/regional land management concepts;

3. That all land users and Governments meet their soil conservation responsibilities;

4. That effective co-operation and co-ordination develop between all sectors of the community involved with the use and management of land and water resources;

5. That the whole community adapt a land conservation ethic.

(Dept. of Ag. 1985)

The present lack of co-ordinated action among the authorities on overall policies for the management of the catchment means that values derived from the catchment by large sections of the community are not being included in management objectives.

There are no co-ordinated management objectives for the catchment or the river system. The government departments that are active in the area are generally concerned only about their own particular problems. The WA Department of Agriculture is concerned about increasing next season's farm profitability. The WA Water Authority is concerned about water supplies and drainage. The Department of Conservation and Land Management is concerned about the reserves, parks and forests. The soil conservation committees are restricted to local erosion problems, often constrained to artificial local government boundaries.

We don't have a single multi-disciplinary authority that has the interest or capability to co-ordinate all these areas into a cohesive catchment management plan.

The Avon River System Management Committee may provide a practical avenue for public participation in any management plan, but what is needed is a body to oversee and co-ordinate all the other departments' management objectives.

The failure to formulate multi-objective goals for river and catchment management is having serious affects on the value of the catchment and the river system, both economically and conservationally.

III WHERE DO WE GO FROM HERE?

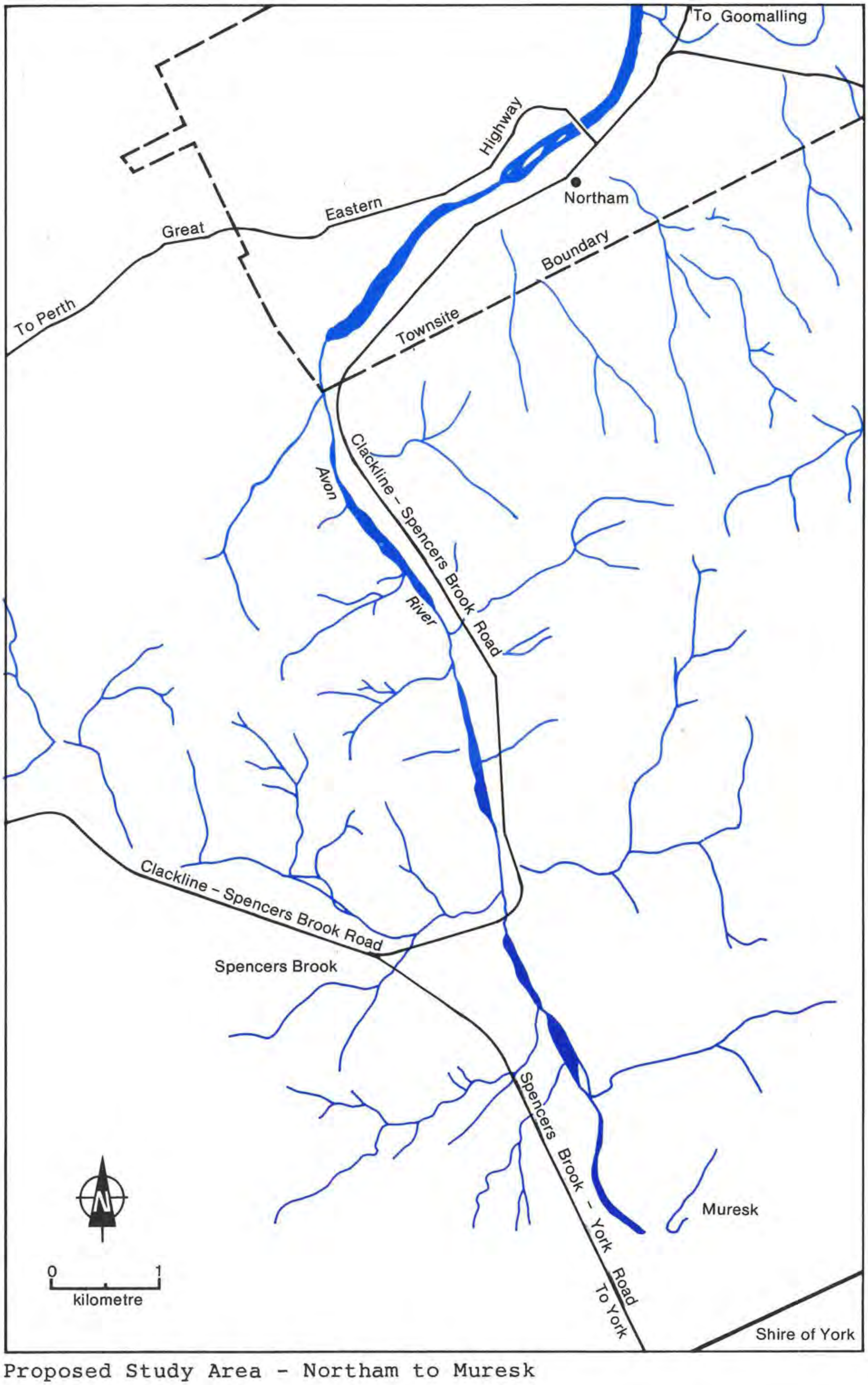
This study has highlighted the problems that exist within the Avon River Systems catchment. It has not provided any answers, either short or long term. It does suggest that certain areas need additional intensive study to provide answers to the questions raised by the study.

The logical next step is to find out what is actually happening in the Avon River Systems catchment. The study has indicated that serious problems do exist and are in need of urgent remedial action. The appropriate remedial action that is needed can only by guessed at without an intensive scientific hydrological and geophysical study of the catchment. Since the catchment is so large, perhaps a study of a smaller area may be the logical next step. Hopefully the information gathered from a smaller study will be able to be applied to the broader catchment as well.

What is proposed is that an intensive hydrological and geophysical study of a 10km length of the Avon River System (including the sub-catchment) between Burlong Pool Northam and Muresk Institute of Agriculture. This intensive study will be designed to provide as many of the answers as is possible.

The sort of information that we need includes:

- Is farm erosion contributing to the river bed silt loads?
- If so, to what extent and how significant is it in the river silt problems?
- At what rate are the river silt levels accumulating?
- What affect will river bed revegetation have on:
  - Silt movements - short and long term.
  - Flood levels - short and long term.
- Is this 10km section representative of the rest of the catchment?
  - If so, what sections?
  - If not, what sections differ and in what ways. (This will require a larger, broader secondary study).
- What type of revegetation is appropriate?
  - In what areas.
  - In what densities.
  - Covering how big a percentage of the river bed.
- If farm erosion is a significant contribution to silt levels, what soil conservation measures will be needed to reduce the problem to acceptable levels. (Assuming acceptable levels can be determined).
- This study is concentrating on the major problem of siltation and river choking. The other problems of salinity, nutrient enrichment, pollution and community access may be covered to some extent also. However, the priority must be with the silt problem unless this can be controlled there won't be a river to have any other problems with.



Proposed Study Area - Northam to Muresk

This suggested pilot study of a 10km stretch of river will highlight the direction any development will take. It will reduce the likelihood of instigating inappropriate management programmes that may produce short term benefits but long term detriments as the River Training Scheme did.

If this pilot study can not be successfully implemented, there is little point in continuing any further in the management of the Avon River System.

IV PROPOSED PILOT STUDY

Revegetation of a 10km stretch of the Avon River Burlong to Muresk

This has been chosen as an example of costs involved to; study an area, revegetate and develop a tourist area. Other locations may be more appropriate.

Assumptions

1. Revegetating of the river bed for a 10 km length will reduce the rate of sand transportation, in the short term sufficiently to prevent further siltation of the Northam Weir and perhaps justify the costs of dredging of the weir;

2. slow the rate of flow sufficiently to allow local flooding to occur and silt deposition to occur on the river banks;

3. reduce likelihood of flooding in Northam Town;

4. provide an improved habitat for wildlife;

5. provide an attractive recreational area for locals and tourists;

6. revegetation is compatible with long-term catchment management.

These assumptions have been made as there is not sufficient information available to answer the questions conclusively.

A proposed hydrological study of this section of the river is designed to answer these questions directly.

Estimates of Cost of the Project (1986 $ Dollar Values)

Land purchase - 10 kms x ½ km = 500 ha @ $185/ha	$ 92,500
Fencing - 21 km @ $1,700/km	$ 35,700
Fire Breaks - 21 km	$ 1,000
Tree Planting	$ 37,500
Hydrological Study (estimated cost only)	$ 20,000
Tourist Facilities - 2 sites (optional) (Nature trails, BBQ's, parking)	$100,000

TOTAL INITIAL SET UP COSTS	$286,700

Annual Running Costs - Estimates

Fence Maintenance - 10%	$ 3,570
Fire Breaks	$ 1,000
Trees	$ 3,750
Tourist facilities	$ 10,000
	$ 14,750

Opportunity costs of lost income to land owners is not great as the river country is generally grazed from between six to ten weeks annually. The costs of fire control, fencing, mustering and Shire rates will be greater than any income earned from grazing.

Benefits

- reduced rate of pool siltation
- enhanced natural beauty of the area
- tourism increase to view river area
- improved environment for birds and other wildlife.

NOTE : Valuation of these benefits is complex and requires field survey to put values on people's usage of these types of facilities, i.e. their willingness to pay.

Possible Long Term Detriment

Revegetation will act as a silt trap for all sands moving down river. Silt build up may eventually bury the vegetation and fill up the river channel. Unless silt entry into the river is reduced this will eventually occur regardless of revegetation. Once the river channel is full of sand widespread regular flooding will be likely.

NOTE: River channel siltation is occurring at the present time. The rate of silt accumulation is not known and the time period required for complete channel choking with silt is undetermined. The proposed hydrological study is designed to answer these questions prior to any revegetation occurring. It is important that any short-term development be sympathetic with long-term development and not just cosmetic in nature.

The short term objective of the proposed river revegetation development is to provide time for further catchment studies and development to reduce the inflow of silts and water into the river system. Despite it being a stop-gap measure, if it is complementary to the long-term catchment goals it will provide significant benefits. These benefits include those listed earlier plus the benefit of being seen to be doing something constructive about the Avon River problems. The bonus will be the provision of an attractive passive recreational area close to the roads, population centres and tourist routes.

Who Will Be Affected By The Proposed Development

(Boundary of the Proposed River Development)

Major beneficiaries will be State residents plus tourists, most of whom are locals, i.e. WA residents at this stage.

People directly influenced by proposed development:

1. Landowners along the river - eight in all.
2. Town and Shire residents - additional recreational facility - less flooding - less pool siltation - pride and prestige.
3. Town businesses - income from tourists.
4. Tourists - value of scenic beauty.
5. People involved in development and maintenance.
6. Conservationists - benefit from improved river habitat for birds and other native wildlife.

The Nature of Recreation Resources Values

The primary value of direct benefits from recreation areas are those realised by the users of the area. Such enjoyment has economic value to the extent that people express a willingness to pay for the opportunity to engage in such activities.

Aside from the primary recreation values which accrue to users, there are other economic benefits. The local economic aspects of many recreation developments to the community in the vicinity of such areas, from such things as increased sales of retail businesses, increase in the number of some types of businesses, better markets for locally produced goods, and increased employment opportunities (Clawson & Knetch 1966).

Revegetation of a portion of the Avon River will provide for multiple use, including conservation, recreation and sand/silt movement control.

Benefits from conservation and recreation uses will include:

1. Recreation - hiking, day use - picnics, BBQs, outdoor games and sightseeing.

2. Conservation - long term societal benefits - scientific reference zones for comparisons of changes and for experimentation on natural processes. Reservoir for plant and animal breeding.

Proposed Study Area - Northam to Mures

3. Educational - field trips by students at all levels of study to observe natural communities and processes
   - geological and ecological studies - man's role in the environment
   - field benefits (long-term) of more responsible use of the environment - local and other areas
   - pure acquisition of knowledge - functioning of the riverine ecosystem in rural landscapes.

4. Aesthetic benefits - non user benefits - the knowledge of its existence.
   - natural scenery provides significant pleasure to viewers.

5. Health benefits - similar to recreation benefits - both physical and mental health.

6. Water Shed Management - flood mitigation and silt control.

7. Historic benefits - assist in the retention of sites of historical importance which could otherwise be threatened by alternative land use, which in turn become tourist attractions.

8. Cultural benefits - Aboriginal sites - anthropological and archaeological studies.

9. Option Value - evaluation of future benefits.

Assessment of Broad Attitudes to Conservation

The opinions of society's leaders may be completely at odds with those of the community (Ulph 1981). If this is so, the role of population surveys become more important in indicating the needs and desires of the community to policy makers.

V WHAT IS HAPPENING ELSEWHERE

The Murray-Darling Basin Management Systems

Senator Evans announced that the Commonwealth will provide $1 million in 1986/87 for water and water related research for the Murray-Darling Basin.

The Government has agreed that a $0.5 million investigation and design programme undertaken by the River Murray Commission to reduce salinity in the river Murray should proceed urgently this year.

They also agreed to a major benchwork environmental study which will pull together all existing information, identify gaps in knowledge and indicate measures to protect and enhance the natural and cultural heritage of the Basin.

The key issues identified at the November meeting of the Murray-Darling Basin Management Ministerial Meeting were:

- Inappropriate land management which has adversely affected the land, water and ecological resources of the Basin.
- Concern for poor water quality, especially salinity.
- Degradation of the natural environment.
- The need for new institutional structures to more affectively co-ordinate inter government action.
- The need for a co-ordinated and upgraded research programme to assist in the development of management strategies.
- The need for effective community participation in the resolution of the water, land and environmental problems of the Basin.

The main task of the Ministerial Council will be to draw up detailed strategies for the management of the Basin, addressing water resources, agriculture, soil conservation, planning and environmental matters, and recreation and tourism (Murray-Darling November 1985).

The four Government signatures to the River Murray Waters Agreement have decided to shelve parochial interests and adopt a co-operative approach to better management of the Basin. The four Governments are; the Commonwealth, New South Wales, Victoria and South Australia.

VI POINT SOURCES OF POLLUTION (POTENTIAL)

Toodyay Shire:	Townsite - Urban run-off Septic Tanks - Domestic Rubbish Dump Piggeries Intensive Feedlotting
Northam Town & Shire:	Westrail Marshalling Yards Avon Valley Tannery Abattoirs Sewerage Works Municipal Rubbish Dump Urban Run-Off Piggeries Septic Tanks - Domestic Intensive Feedlotting
York Shire:	Rubbish Dump Urban Run-Off Septic Tanks - Domestic Piggeries Intensive Feedlotting

Other Shires have similar types of point source pollution.

<u>Fertiliser Usage</u> (82/83) in Annual Western Catchment

Shires of Beverley, Goomalling, Northam, Toodyay, Wongan Balidu, York, Pingelly, Wickedin, Cunderdin, Sowerin, Tammin, Wyalkatchem and Brookton.

Tonnes of superphosphate on wheat:	36,352 t
Other fertilisers	37,947 t
Tonnes of superphosphate on pasture	52,034 t
Tonnes of other fertiliser on pasture	2,163 t
Total superphosphate used 1982/83	88,386 t
Total other fertiliser used 1982/83	40,110 t

Source : ABS

Superphosphate is 9.1% phosphorus.

9.1% of - 88,386 t = 8,043 tonnes of phosphorus applied 1982/83

VII STATISTICS

Statistics for the 13 Shires 1982/83 (ABS) - Western Annual Catchment

Total Local Government area for same 13 shires	2.393 m* ha.
Total agricultural area	2.101 m ha.
Average cleared percentage of LGA	91.54%
Total population (1982/83 estimate)	20,108
Number of agricultural establishments	1,725
Gross value of agricultural commodities	$284m
Cropped - hectares	820,000 ha.
Pastured - hectares	891,000 ha.
Sheep numbers	38.66 m
Beef cattle numbers	24,439
Pig numbers	31,413
Wool - million kilograms	14.42 m kg

*m = million

VIII NOTES ON SALINITY

Milligrams of total salt per litre (= mg/L). For water mg/L is approximately the same as parts per million (PPM) for most practical purposes.

To convert mg/L to grams per gallon multiply mg/L by 0.07, ie 1,000 mg/L is approximately equal to 70 grams per gallon.

Safe upper limits of total salt in water for livestock:

	mg/L (=PPM)	grains/gal
Poultry	3,000	210
Dairy Cattle - lactating	3,500	245
Pigs	4,500	315
Horses	6,500	455
Dairy Cattle (dry)	7,000	490
Sheep - lambs, weaners, lactating ewes	7,000	490
Beef Cattle	10,000	700
Sheep - dry adult	10,500 - 14,000	735 to 980

Source : DPA Agnote 400/582 : 3/82

Seawater has about 20,000 mg/L of chloride. (1,400 grains/gal)

Notes on Forests and Parks

Shire of Toodyay	3% of area is National Park
	17% of area is forest (jarrah & wandoo)
Shire of Beverley	24% of area is forest (jarrah & wandoo)
Shire of York	24% of area is forest (jarrah & wandoo)