DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

GUIDELINES TO THE MANAGEMENT OF THE SALINE THREATENED WETLANDS OF WESTERN AUSTRALIA'S SOUTH WEST

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1.0 INTRODUCTION

Much of Western Australia's South West is in a low rainfall area which is bounded on the west by the Darling Scarp. It extends northwards to Northampton, south to Esperance and east to Southern Cross (Fig. 1). Salting of soils in this area is an historic phenomenon, and it has been caused by clearing of native vegetation (Malcolm, 1982). As a result all wetland reserves there have been impacted and their biologies simplified. Thus, depending upon the perspective from which they are viewed, they are areas of diminished biological values and therefore do not warrant any special attention by management resources. Alternatively, the fact that many continue to survive as environmental entities albeit tenuously, imparts to them great values as venues where it is now easier to investigate and understand causal relationships between fewer biophysical elements of the salted landscape. Mitigating techniques being learned, have application all through the South West where salting is devastating large areas of farmland.

Figure 1.

2.0 CAUSES OF SALTING

The main origin of soil salts is by accession from the rainfall, and having arrived on the landscape, movement of salts through the soil determines where sufficient will accumulate to cause damage to plants or aquatic animals, Salt movements are determined by soil type, topography and hydrology. Prior to clearing, vegetation by evapotranspiration maintained a lowered water table, and above this, salts accumulated in the shallow soil profiles, the rainfall being too low to leach them away into the water table below. Clearing of vegetation at settlement generally caused water tables to rise. This has mobilised soil salts which have concentrated at the surface of low lying parts of the landscape in the flow lines and lakes where the wetland reserves naturally enough have also been set aside. Here, relatively impermeable clay soils are also usually found, and they can act as a barrier separating surface waters from deeper underground water usually of much poorer quality, unless of course waters underground have already risen to such an extent that they are mixing freely with waters at the surface, where flows of water are obviously more manageable than underground flows. Thus it is important that the integrity of the clay substrates should be retained as a barrier between waters above and below ground.

Almost all of the clearing within the low rainfall areas of the South West has taken place during the 1900's (Fig. 2). Much of this was affected by machinery which became readily available as surplus stock after the Second World War. Thus the full effects of clearing in most of these areas has yet to be experienced.

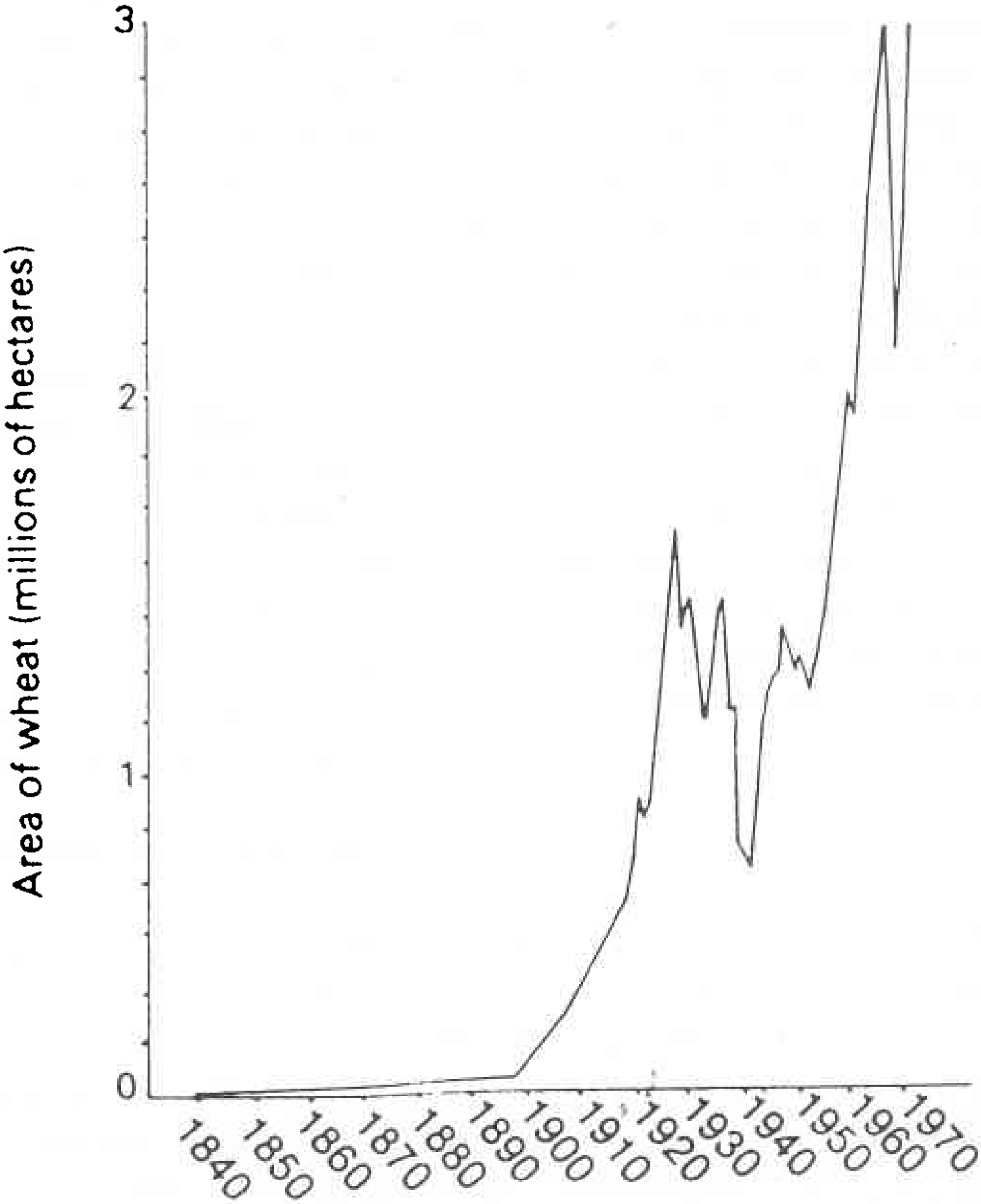


Figure 2. –Area sown to wheat in Western Australia—1840 to 1977. (W.A. Yearbook, 1975).

Some of the marginally saline wetlands listed below still survive in a delicate environmental equilibrium which can be tipped by inapropriate land uses on privately owned land on their catchments where sometimes such uses can be legally regulated. Some years ago a Whittington interceptor drain on private land adjoining Lake Toolibin Nature Reserve was constructed so as to use the lake as a drainage sump. The former Department of Fisheries and Wildlife successfully instigated a test case on 14/7/1982 at the Narrogin Court against the land owner and the Whittington contractor. Prosecutions were launched under clause 46 ℓ (drain construction) and clause 46e (flow of water) of the Wildlife Conservation Regulations. The second offence is an ongoing one relating to a flow of water whenever it may occur. It is more desirable however, to solicit cooperation of the farming community by advising them that they have a vested interest in mitigating salinity effects on wetland areas near their farms, as the detrimental effects of salinisation tend to be cumulative, and if unchecked may eventually affect good farm land nearby.

3.0 STANDARDS OF WETLAND QUALITY

In a stream environment, the potential threats are to quality of water (by salinity, pollutants, etc.) and to quantity of water (by removal or diversion of the water source or by silting due to the effects of erosion). Such an environment may be of limited value as a waterbird refuge due to lack of appropriate vegetation and protection afforded by large open areas of water.

The requirements of an impoundment used as a summer refuge by waterbirds are some loafing sites free of disturbance by people, with vegetative cover very close to water of minimal quality. The requirements of a nursery impoundment are more stringent where regimes of water quality and water levels and the relationship of the nest site to the impoundment's shorelines are important.

Habitat for mature water birds is related to water depth. Some birds like wood duck are relatively independent of water while others are restricted to an impoundment's shallow margins or to its deeper water. Diving birds do not utilise water deeper than 4 metres. On the other hand, the filter feeders can be found anywhere throughout the impoundment. Such distributions are governed by feeding preferences.

In order to reproduce successfully most waterbirds depend upon freshwater animals (mainly freshwater invertebrates) as a food source to provide protein unavailable in vegetation alone. Moreover all juvenile waterbirds during their early stages of life rely upon the freshwater environment for protection from predators and they depend upon aquatic invertebrates for food.

The main principles involved in the management of a breeding impoundment are:

1. Brood Production

   Some birds nest in terrestrial vegetation away from the impoundment. When the young leave the nest, both parents will walk with them to the waterbody. Many do not survive this hazardous journey. Survival can be optimised by vegetative cover and absence of obstacles. Habitat should be varied by emergent and terrestrial vegetation with complex re-entrant margins in order to maximise shoreline length. Mudflats should not be too wide so that broods are open to predation as they make the journey from the nest to the impoundment.

2. Water Levels

   Water levels which fluctuate too rapidly can be harmful. It is true that some birds construct floating nests which they anchor to emergent vegetation. Others however construct fixed nests within centimetres of water. Sudden rises in water can drown eggs or young.

Subsequent attempts at nesting would then be out of harmony with the flooding cycle. If the impoundment dries up at summer, the parents will be forced to desert the juveniles. If the juveniles cannot fly they are left to perish in the dired up wetland.

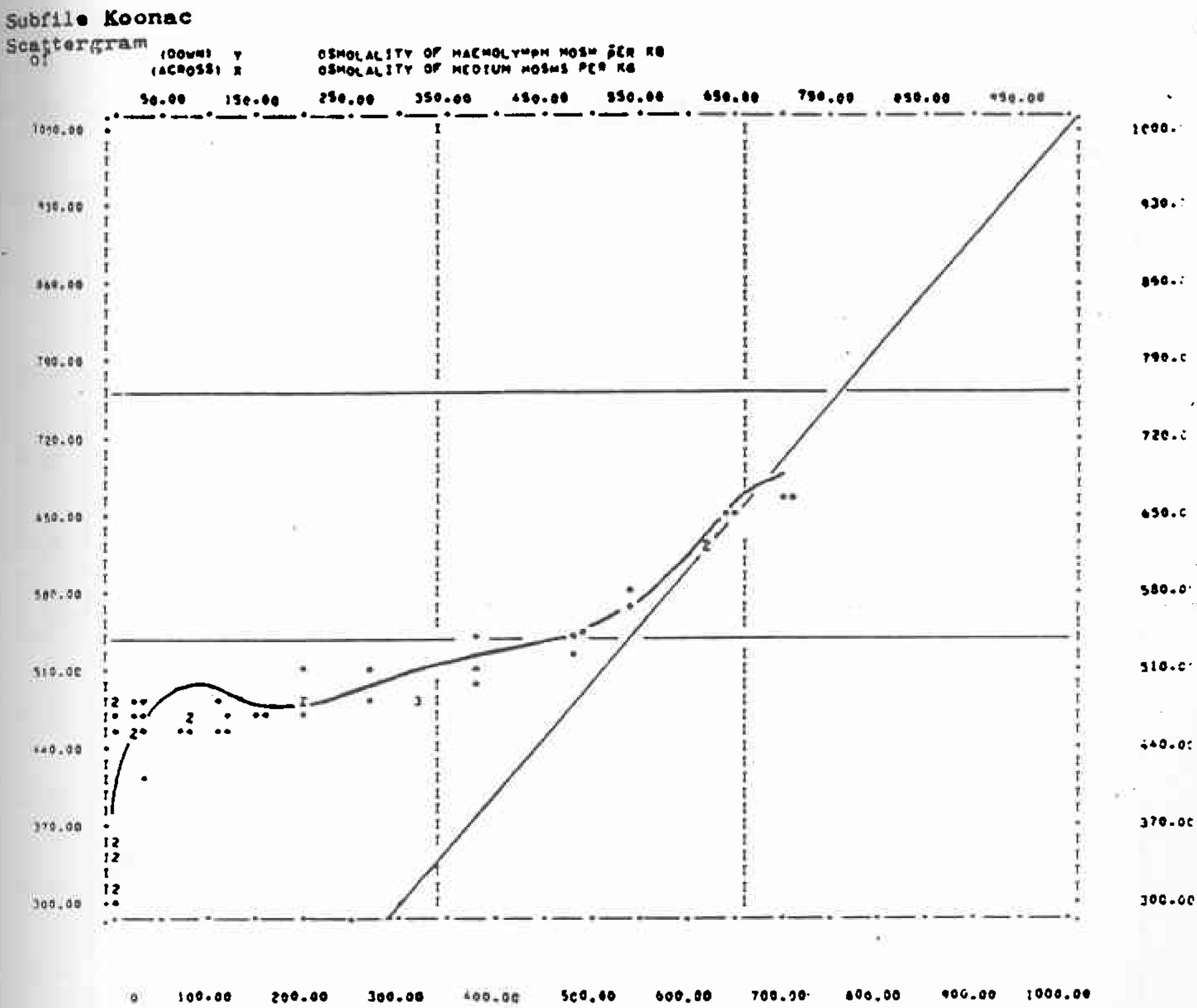
3. Water Quality

Pennak (1953) has described the boundaries of habitat in terms of salinity for those invertebrates which live in the fresh waters of North America: many common species in almost all Orders of freshwater invertebrates may be found in waters whose salinities range from 20 to 400 mg/1. (.0826 - 0.834 mmhos/cm at 20°C.) Above 9 000 mg/1 (13.939 mmhos/cm at 20 °C.) the osmoregulation mechanisms of most invertebrates begin to break down and concentrations beyond 25 000 mg/1 (35.765 mmhos/cm at 20° C.) are usually lethal. These data mean that at salinities between 10 000 mg/1 and 30 000 mg/1 (15.628 - 41.713 mmhos/cm at 20°C.) species diversity of freshwater fauna becomes depauperate.

Such tolerances are generally consistent with the effects of ambient sea water solutions on the ability to regulate the salt concentration in the blood by two macroinvertebrates of the South West (Goodsell, 1984). One of these animals, the koonac (Cherax plebejus) is a native crayfish of the ephemeral wetlands, and in the summer drought they retreat to the watertable inside burrows which they plug with earth at the ground surface. The other, the marron (Cherax tenuimanus) lives in permanent surface water. Figs. 3. and 4. show the osmotic response of the blood to different concentrations of sea water. Detailed comparisions of the curves (Goodsell, 1984) has shown that although they are different, the animals' responses to salty water are generally comparable. Two mechanisms of the blood's concentration are ionic permeability, and the generation of a small voltage between the animals and their media. These are plotted against each other for the marron in Fig. 5. Physiological optima for these animals occur at a concentrations which correspond approximately at pH 7.5 (a common environmental pH):

	Ambient Concentration in mmhos/cm at 20°C.
Koonac	.987
Marron	2.022

Between ambient concentrations corresponding with V=O (Fig. 5.) and 10.655 mmhos/cm at 20° C, membrane integrity breaks down, indicated by a short circuiting effect as permeabilities to Na+ elevate, and the effect becomes most pronounced at concentrations of 27.862 and 34.799 mmhos/cm.



m mhos/cm 4.66 9.67 14.54 19.28 23.88 28.307 32.68 36.88 40.94 44.87

(Note. 1000 mosms / kg approximately equals 100% seawater)

Figure 3. Koonac: Trajectory described by polynomial equation.

The straight line is the isosmotic line.

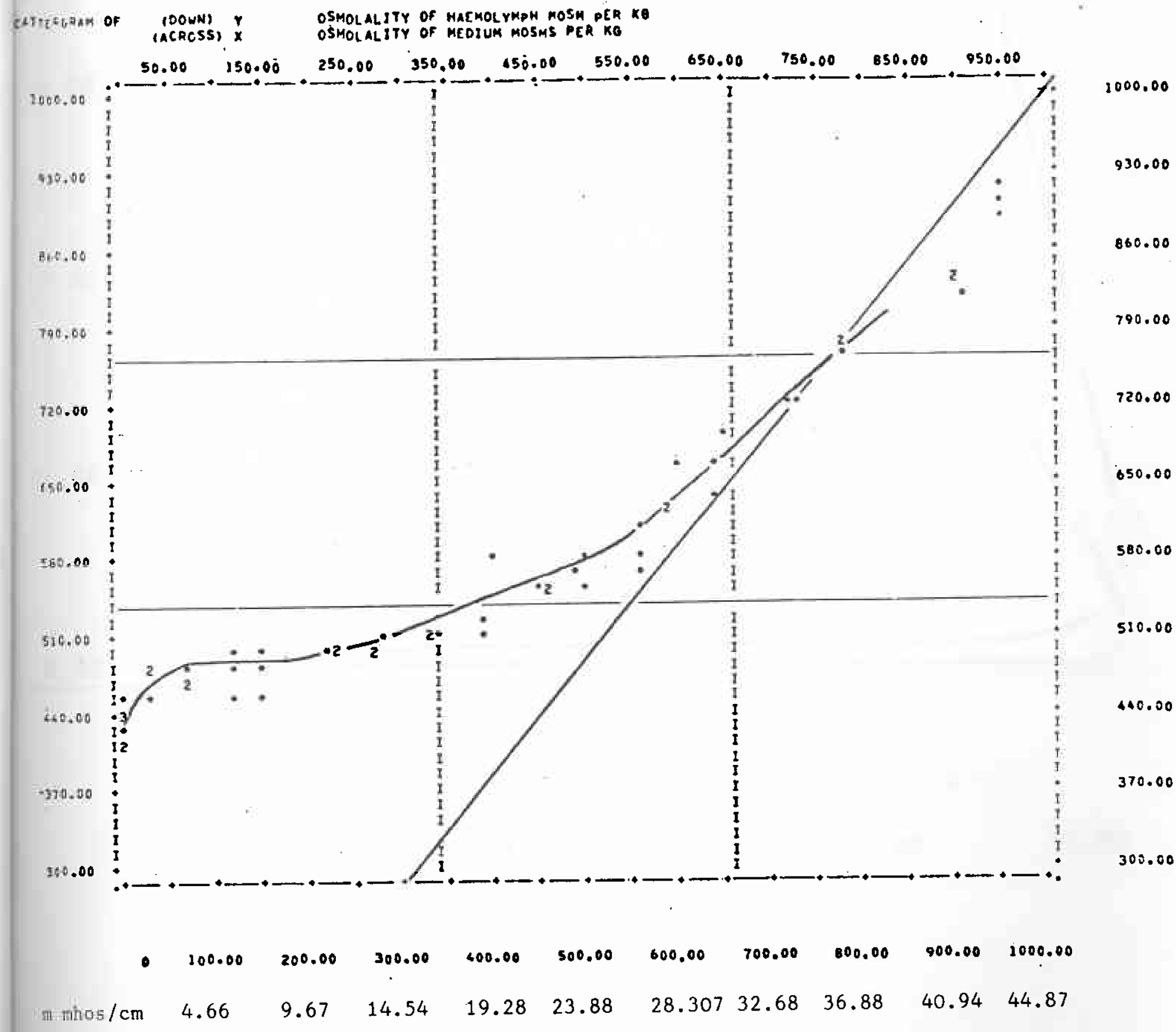


Figure 4. Marron: Trajectory described by polynomial equation.

The straight line is the isosmotic line.

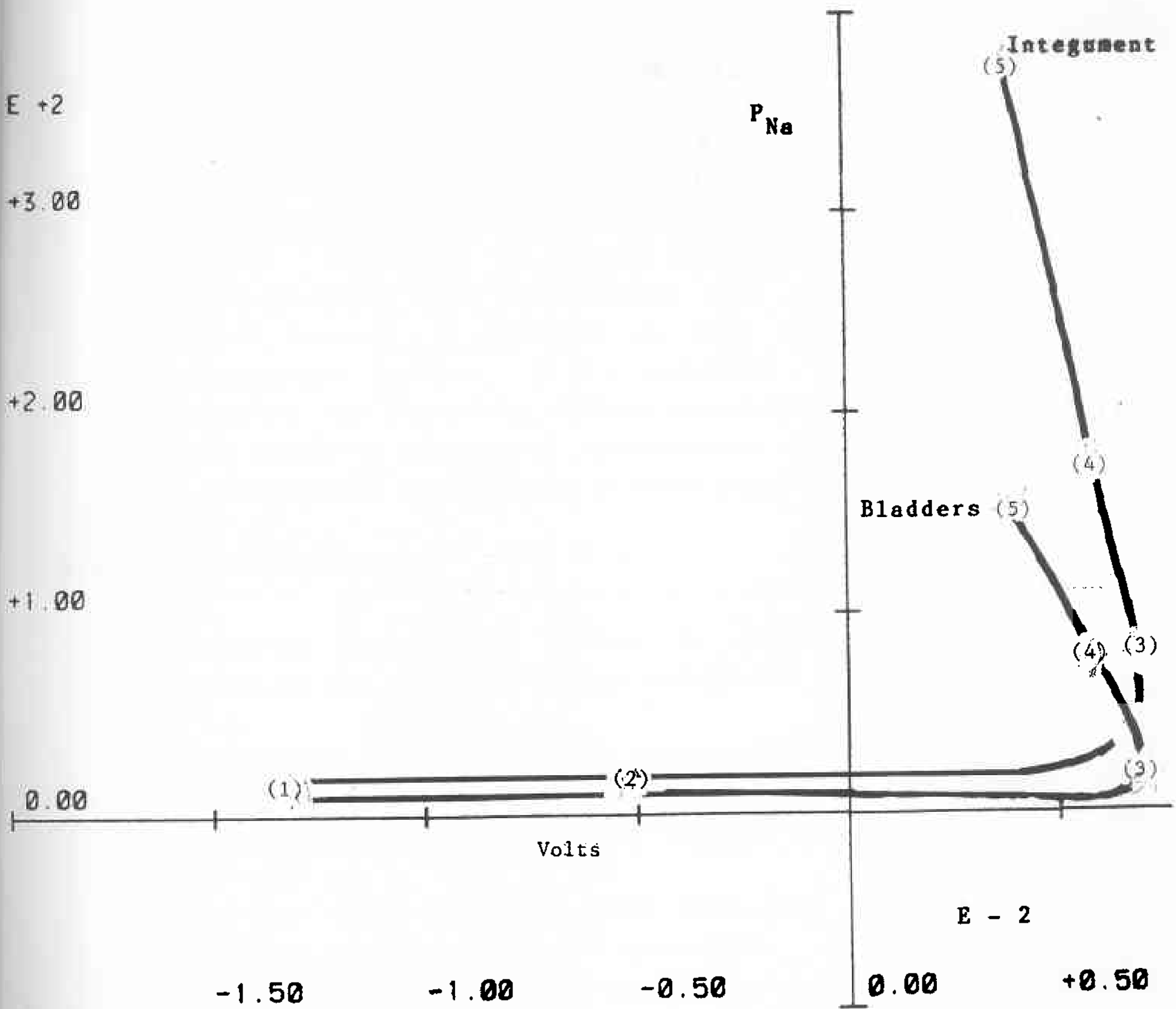


Figure 5. Potential difference in Volts (x) V Permeability to Na (Y) of integument and bladders in cms $24hrs^{-1}$ per absorption area of the respective organs for standard 1 Kg marron. Conductivity in m mhos/cm at 20°C of ambient concentrations indicated by numbers in brackets (1) .353, (2) 4.403, (3) 10.655, (4) 27.862, (5) 34.797

These curves provide water quality standards by which the biological value of water for the koonac and the marron can be evaluated. These are biological baselines upon which the wetlands can firstly be categorised and then managed. Such standards may not have applied to these wetlands in their pristine condition, unfortunately this information very likely has been lost forever. In pressing on with their biological management however, it is necessary to accept the reality that a modified wetland system of the South West now supports an altered invertebrate biology which is successfully supporting a diverse aquatic avian fauna.

4.0 WETLAND MANAGEMENT

Conceptually the wetland system is comprised of units belonging to one of the following categories:

1. Breeding
2. Feeding
3. Loafing
4. Drought
5. In the water deficient South West some wetlands are used by people for aquatic recreation.

The very first strategy therefore is to allocate a purpose to each wetland and to manage it to that end. Few units accommodate water of such high quality that they can be managed for the purposes of breeding and feeding. Consequently, it would be futile to attempt to manage most which are salted for purposes other than migration or loafing. This approach, by recognising that all units have a contributory role, should effect the full realisation of the system's potential values.

In the field, mitigating strategies can be aimed at causes of salination in the catchment, or at effects within the wetland reserve. At Lake Toolibin Nature Reserve, for example, the purpose of installing a system of piezometers throughout the catchment was the identification of fragile areas where the underground waters were very close to the ground's surface.

These areas have subsequently been subjected to strategies aimed at groundwater control by purchasing land and then revegetating. Another measure suggested there has been to mechanically dewater below the lake's clay floor by means of windmills. This of course would transfer the salinity problem somewhere else. The same criticism has also been levelled at Whittington interceptor drains which are based on the principle of truncating the impermeable soil profiles and diverting overland flow into the deeper groundwater. Inevitably water thus diverted can be expected to surface and cause problems somewhere else lower in the landscape. On the other hand, if water is allowed to run off the catchment's upper slopes during winter, again it may cause waterlogging of the flats and valleys downslope. The resulting waterlogging is likely to lead to bare moist areas in spring and these in turn may exacerbate salting of the lower parts of the landscape.

In most situations it can be expected that a saltland treatment aimed at the effect within the wetland will most likely be only palliative. To be effective the water table must be lowered further than 1-2 metres below ground surface, to prevent capilliary rise of underground water and concentration of salts at the soil surface. The capilliary effect is exacerbated by the compacting of soil by grazing stock. Within the wetland, dewatering can be effected by vegetation or by mechanical means, but cost can be expected to make the latter option infeasible.

A cost effective example of groundwater control can be cited at Benger Swamp Reserve where the underground waters are as saline as sea water (30 000 mg/l). In the winter, the natural cycle of flooding of the swamp is assisted by Water Authority board structures, and fresh waters thus impounded float on the heavier saline waters underground. At the onset of summer, surface waters begin to salinate by evaporation and becoming heavier, they tend to mix with saline waters underground. Subsequently, dewatering of accumulating saline waters is essential for the swamp's protection, and defend upon drainage of the swamp early in summer. This is facilitated by removal of the Water Authority's board structures in December and afterwards the swamp is farmed as a means of removing bulrushes which tend to spread throughout the swamp's open water areas. These contribute so much to the swamp's purpose as a nursery. The swamp's summer drainage has at times led to the stranding of young birds, and their fate is a recurring emotive issue of people who do not understand why the swamp must be drained. Subsequent mortalities of juveniles can only be minimised by ensuring that the swamp is flooded as early in the winter as possible by reestablishing the Water Authority's board structures at the swamp's drain outlets as soon as the swamp's seasonal farming activities have terminated. Birds nest opportunistically in response to rising water levels, and an early nesting means that the young are able to fly away with their parents when the swamp's waters are drained away at the onset of summer.

Establishing vegetation on salt scalded areas can vary from impossible to difficult. The species best suited to initially colonise a site are those of the samphires. These also provide food and habitat for many birds of the Wheatbelt. In Wonnerup Estuary swans nest year after year and the only nesting material is of samphire which grows prolifically there. I am familiar with salted clay areas which farmers have done no more than fenced from stock and allowed to revegetate naturally by samphire, blue bush and salt bush. There is no doubt that the inexpensive procedure of excluding stock can achieve dramatic results.

The principle of revegetating in order to lower the water table by evapotranspiration appears to be the most cost effective means of groundwater control. The foliage of an exotic, the tamarix, is sterile because these trees can survive even on badly salted land. Once they have established and affected the water table, they act to prove the way for native species which are not so salt tolerant. Management of saline wetlands should accept that any vegetation, even that of exotics, is better than no vegetation.

Another problem involving lack of vegetation was resolved on the Broadwater Reserve by using swans as indicators of nesting success (Tingay et al, 1977). After eggs were laid on naturally constructed nests, catchment land uses caused water levels to rise too quickly for the birds to maintain the level of the nests above the surface of the water which inundated and killed the eggs. This inability was exacerbated by lack of nest building vegetation due to salting and grazing. A second nesting produced cygnets too young to fly away with the parents when the swamp dried up where they perished. Artificial nests were built out of old car tyres and then PWD structures were used to regulate water levels just below these artifical nests. While this management procedure was being implemented, nesting of all species throughout the swamp was not impaired by the fluctuating water level problem.

In some of the saline wetlands, it is infeasible to manipulate water levels or qualities. One example is at Lake Dumbleyung which rarely fills high enough even to experience outflow events. The lake acts as a salt sump for hundreds of square kilometres of salinated catchment, and over a flooding cycle the salt concentration of the lake varies from 10 000 to 250 000 mg/litre. Management can do no more than protect the reserved shorelines, and supervise boating use of the lake when it fills with water.

The cited examples illustrate that specific management problems can only be considered on their merits while taking into account ecological, economic, social and political environments within which each wetland exists.

5.0 PRIORITY AREAS

The objectives of an initial inventory for the purpose of ongoing monitoring programmes are:

1. To determine wetland quality.
2. To allocate each wetland a purpose (breeding, feed etc.).
3. To establish trends in ecological condition.
4. To interpret causal relationships.
5. To determine environmentally fragile areas.
6. To determine if wetland condition can be stabilised by feasible management procedures.

An initial inventory should take into account:

1. Fencing of the boundaries.
2. Water Quality,
   Permanence,
   Depth,
   Fluctuations,
   Sources, and
   Routes into and out of.

3. Size and bathymetry of the impoundment.
4. Vegetation communities and their ecological condition.
5. Aquatic fauna.
6. Terrestrial fauna.
7. Storage of data in ADP format. A vegetation monitoring format has already been designed, and can be slightly modified in order to store biophysical data collected from a wetland reserve and it's catchment.

After these initial reserve inventories, these questions should be addressed:

1. What is each wetlands's purpose.
2. Should each reserve be monitored and should each catchment be inventoried.

If catchment warrants inventory, the following should be considered and/or mapped:

1. Vegetation, topography, and soils.
2. Identification of environmentally fragile areas.

Decisions could then be made whether or not piezometers and permanent vegetation monitoring quadrats should be established, and subsequent investigations could lead to:

1. Erecting fencing.
2. Informing surrounding landowners of the values of an intact wetland and it's catchment from economic perspectives.

3. Using the expertise of other government authorities to design and install wetland rehabilitation structures and procedures. Under the Soil Conservation Act, groups can be established based on local authority areas, and comprised of land owners. The purposes are to rehabilitate degraded land. Projects are funded at higher Government levels. It would be desirable for the Department to exploit this funding source.
4. Catchment acquisition.
5. Planned land uses and management procedures on each wetland (i.e. conservation uses, recreation uses).

With the above objectives in mind, for the past two weeks I have gathered information in relation to wetland reserves of the South West from the following sources:

1. Wildlife Research Centre's Wetland Group.
2. Reserve Files.
3. Departmental officers, including my own knowledge.
4. Conservation Through Reserves Committee's Reports to the E.P.A.
5. E.P.A. Recommendations.

I have compiled by local Government areas a provisional list of wetland reserves of the threatened areas of the South West (Table 1). Their ecological quality indicate that they can be provisionally allocated purposes of breeding and feeding. Each of these reserves, however, depends upon it's larger catchment system. Data which are not available from the documentation are those of the reserves' and their catchments' hydrologies, topographies and vegetation. Each of these reserves therefore warrants immediate field inventory.

TABLE 1

PROVISIONAL LIST OF BREEDING AND FEEDING WETLAND RESERVES OF THE SOUTH WEST, WARRANTING IMMEDIATE INVENTORY. IN BRACKETS, LOWEST NUMBERS INDICATE WETLANDS OF HIGHEST PRIORITY.

Local Authority		Reserve Name	Reserve Number	Reserve Area (Ha.)
Albany	(13)	Mettler	26 894	402
Bevereley	(10)	Dobaderry	34 442	1 896
"	(10)	"	37 306	1 307
Carnamah	(19)	L. Logue	29 073	4 835
"	(20)	L. Indoon	20 072	271
Cranbrook	(15)	Warrenup	1 931	251
"	(14)	Kulunilup	26 677	612
"	(15)	Pindicup	26 679	281
"	(15)	Noobijup	26 680	183
"	(15)	Cobertup	26 681	151
"	(15)	Pinticup	26 682	75
"	(6)	Yarnup	29 601	62
"	(15)	Galamup	6 549	222
"	(15)	Bokarup	14 739	146
"	(15)	L. Unicup	25 798	3 306
Corrigin	(9)	Unnamed	12 900	61
Dandaragan	(11)	Namming	28 558	5 432
"	(17)	Watheroo	24 229	1 633
"	(17)	"	24 450	2 903
"	(17)	"	24 451	39 788
"	(18)	Nambung	24 522	3 910
"	(18)	"	28 393	11 955
"	(18)	"	29 149	1 626
"	(18)	Unnamed	27 216	1 576
"	(18)	Unnamed	12 473	65

Local Authority		Reserve Name	Reserve Number	Reserve Area (Ha.)
Dandaragan(con't)	(18)	Wanagarren	31 675	11 137
"	(18)	Wongoderra	26 248	439
"	(12)	Eneminga	27 394	741
Gingin	(21)	Yurine	9 676	30
"	(24)	Wannamal	9 838	86
Irwin	(1)	Arrowsmith Lake	Crown Land	Unkown
Katanning	(16)	Kwobrup	26 020	1 333
"	(7)	Coyrecu	28 552	471
Kent	(4)	Kent	29 020	1 528
"	(4)	L. Bryde	28 667	1 315
"	(4)	Lakeland	29 023	1 529
"	(4)	Lakeland	29 024	1 579
"	(4)	Lakeland	29 025	207
"	(4)	L. Bryde	29 026	32
"	(4)	L. Bryde	29 021	107
"	(16)	Kowbrup	14 522	319
"	(25)	Chinocup Dam	18 803	979
"	(26)	Chinocup Lake	28 395	19 825
"	(5)	Yaalup	10 129	2 509
Kondinin	(1)	L. Cronin	36 526	1 016
Manjimup	(22)	L. Muir	31 880	11 311
"	(23)	Kodjinup	26 678	626
Murray	(8)	Nine Mile	16 907	116
Wickepin	(3)	L. Toolibin Reserves	Several	1 215
West Arthur	(2)	Wildhorse Swamp	1 740	258

6.0 PROPOSALS FOR SPECIFIC PROJECTS

1. The underground source of Lake Cronin's fresh water supply should be confirmed. It's catchment should be delineated and the role of vegetation of the lake's surrounds in maintaining the lake's fresh water should be elucidated.
2. The source of the fresh water for Lake Coryecup should be elucidated.
3. The source of the fresh water for Lake Bryde water reserve, and the Lakeland Complex of nature reserves should be elucidated.
4. The water table contours and salinities of underground waters of the Lakes Unicup/Muir complex of wetlands should be inventoried and mapped.
5. Lake Toolibin has a dynamic biological environment related to fluctuating qualities and quantities of surface and underground water. During the past 10 years data have been collected from 22 permanent quadrats in relation to vegetation and hydrology. This is an ongoing study and it should be updated by an examination of each sampling quadrat, and an interpretation of causal relationships affecting vegetation dynamics.
6. Wildhorse Swamp Nature Reserve is at the junction of the Arthur, Balgorup and Blackwood Rivers. It is of 258 ha. and it's purposes are Recreation and Conservation. The bulk of this reserve supports pristine woodlands of wandoo and to a lesser extent powder bark wandoo. The reserve also accommodates almost exactly half of Wildhorse Swamp which is ephemeral and marginally saline (17.4 mmhos/cm at 20^{o}C). The swamp is in what appears to be an ancient sand filled billabong of the Arthur River, and water appears to flow through underground. This would explain why salt does not accumulate there. Almost all that can be cleared of the

swamp's catchment has been cleared so it's salt budget must be at equilibrium. Half of the swamp is on private property and has been trampled and denuded by grazing sheep. The swamp supports vegetation of Melaleuca rhaphiophylla and Melaleuca laterita. The swamp is unique in the South West in that it supports hundreds of native koonacs whose burrows pit the swamp's clay floor. The range of the koonac 35 years ago (Shipway, 1951) occupied an area bounded by the coastline between Perth and Albany, extending to a point 300 kilometres east of Busselton. Salinity has reduced their former range to an extant distribution between Perth and Albany along a coastal strip bounded approximately by the eastern border of the Darling Scarp. The koonac has a sedentary burrowing habit and depends on extensive burrow systems reaching into the water table and it's vulnerability to changes of underground water quality explains the animal's disappearance from the eastern Wheatbelt where it was formerly distributed.

The koonac spends summer in the plugged burrows at the water table. When the swamp floods at winter the animals emerge from their burrows to reproduce, and return to their burrows when the swamp dries up. The swamp's biophysical environment would be in continual flux, but at the same time should be a relatively simple one to investigate, supporting just a few aquatic bird species, very likely due to the lack of open deep water. Almost all the swamp's faunal biomass would be represented by it's koonac population. It would be relatively simple and inexpensive to install a system of permanent vegetation quadrats in conjunction with nested piezometers to monitor the dynamics of salinities and hydrologies underground and at the surface. The objective of this monitoring project would be to identify causal relationships between the swamps biophysical elements. This would represent valuable baseline data, the like of which for local environments, are completely unavailable.

7.0 DEVELOPMENT OF MANAGEMENT PRESCRIPTIONS

A management prescription of a saline threatened wetland would have two main objectives:

1. To prevent salt accumulation in it's surface waters by managing relevant attributes of the landscape.
2. To maximise the contribution by the wetland unit to the biological values of the South West wetlands.

The rationale upon which the management prescription should be developed would be to evaluate the effect on water quality by the catchment's land uses, by interpreting causal relationships across the landscape. The initial step to take therefore, provided that appropriate documentation is available, would be to review the history of the catchment and the effects of any clearing on water quality. It could be expected that records of clearing would be available in old airphotos. If these can be reviewed in conjunction with rainfall, evaporation and water quality records, then an estimation can be made of where and how much of the catchment should be vegetated, if the quality of water is to be protected.

If historical documentation is deficient, then observations in the field would reveal ecological conditions, and should also indicate historical trends in condition. It would be obvious for example, if vegetation has been killed by salting, or if any disturbances have caused non-indigeneous species to intrude and replace native vegetation. It might eventuate that such a review and/or field investigation would immediately indicate that the wetlands salt budget is in debit, and that it's ecological status is safely protected by an adequately vegetated catchment. No further action would then be required, apart from procedural and/or ad hoc investigations by Departmental officers.

Other indicators of trends in condition would be recorded changes in use of the wetland by bird species. For example, blue wing shovellers, musk ducks and blue bill ducks are good indicators of water quality because they feed almost solely on invertebrate animals. Historical disappearance of such species would indicate deteriorating condition of a particular wetland.

After these initial investigations, it would follow that the second step in the preparation of a management prescription for a breeding or feeding wetland would be the decision of whether or not it's ecological conditions could adequately maintain those two purposes. No matter the trends, if condition is good, then the catchment warrants examination.

The next step would be to map the catchment's vegetation and topography. In this way, it's basic units of land/vegetation could be delineated and identified. This should also involve discriminating between degraded or infact units. For this initial mapping purpose, vegetation need only be classified in terms of the structural formations of species of it's obvious strata (Muir, 1977). Permanent vegetation monitoring quadrats could then be established across a representative range of land/vegetation units. CALM's Chief Scientific Officer should be consulted however, prior to committing the Department to a monitoring programme.

A monitoring unit should be a rectangular or square quadrat. It's aerial dimension, and standardised spatial orientation (NS and EW) means that data analyses are statistically tractable. Corner 1 is at the NW corner, and then clockwise each corner is numbered consecutively. Quadrat sizes should be such that they support a representative portion of species found in an intact unit of land/vegetation. To date, species area analyses of woodlands in the South West indicate that a 20 m x 20 m quadrat supports more than 85% of species. In any event, before selecting a particular sized quadrat, that it is representative should be confirmed by species area analyses.

The parameters which should be sampled within each quadrat are numbers of species, and structural details of those perennial individuals which intercept a line transect extending from corner 1, then 2, 4, 3 and back to 1. This is a distance of 19.6 metres in a 20 m x 20 m quadrat. Details of intercepting perennial individuals collected are Life History Stages, Life Form, Height to Top and Bottom of the Crown, Circumference at Breast Height, Crown Intercepts, and Relative Foliage Cover. Some explanatory definitions are:

1. Cover (C)

$$= \frac{\text{Area of projected canopies of individuals}}{\text{Area of ground supporting these individuals}}$$

or by the line transect technique

$$= \frac{\text{Total of intercept lengths of projected canopies of individuals}}{\text{Total transect length}}$$

2. Relative Foliage Cover (R.F.C.)

$$= \frac{\text{Area of projected foliage of individuals}}{\text{Area of projected canopies of individuals}}$$

3. Projective Foliage Cover (P.F.C.)

$$= \frac{\text{Area of projected foliage of individuals}}{\text{Area of ground covered by individuals}}$$

It follows that

C x R.F.C. = P.F.C.

Data sheets have been designed for the field coding of vegetation data collected by the procedures described here. It is also intended to design more sheets during the development of this programme, that have the capability to accommodate in standardised format other relevant data.

Ideally, permanent quadrats should be stablished in conjunction with a system of piezometers whose purpose would be to monitor groundwater dynamics. The parameters of interest would be salinities and contours. From the latter flow lines, rates of flow and environmentally fragile areas could be interpreted. The design of the piezometer system would require the expertise of local Agricultural Department officers who could not proceed with their design until the catchment map had been completed.

The piezometer/vegetation monitoring system would have the main purposes of providing data that could be used to interpret:

1. Causal relationships between groundwater and vegetation.
2. Causal relationships between groundwater and those fauna which rely on the water table.
3. Whether or not the underground water level and quality is at stability.
4. Groundwater intake and discharge sites. The latter would occur where the contours of the groundwater and ground surface intercept.

A prescription to manage surface water should be evolved in liaison with officers of the Water Authority. If it is desirable to prevent the discharge of salty water, then this could be implemented by one or combinations of the methods which have been discussed above (Part 4.0). If the discharge of salty water cannot be prevented, then structure might be necessary to divert these flows away from, or through the particular wetland. Finally, it might be necessary to implement water conservation techniques. In such case, fresh waters could be impounded by structures built at water outlets, but waters thus impounded would need to be released before they become too salty due to evaporation. Moreover, water conservation could be implemented in conjunction with techniques aimed at regulating water depth at steady levels.

A wetland management prescription could only be refined by ongoing programmes of biophysical monitoring, and some of these are discussed above. A more profound understanding of a wetland's biology however can be achieved by another type of labour intensive monitoring which involves examining populations of aquatic invertebrates. Their presence makes vertebrate diversities all the richer, and they are influenced by vegetation types as well as water qualities. On wetland nature reserves, monitoring of invertebrate populations must be based on the fact that the Department's first priority is to conserve each wetland. Consequently, an invertebrate monitoring programme, however successful from an academic perspective, would represent a misdirection of Departmental priorities, if it was implemented on a wetland which was eventually destroyed by salination. For this reason, only those wetlands which are known to be stable, should be candidates for monitoring of invertebrate populations. In any event, any initiatives taken to implement such monitoring should be the subject of the Chief Scientific Officer's advice.

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