CRC FOR CATCHMENT HYDROLOGY
CSIRO LAND AND WATER
MURRAY-DARLING BASIN COMMISSION

ON-FARM AND COMMUNITY-SCALE SALT DISPOSAL BASINS ON THE RIVERINE PLAIN

GUIDELINES SUMMARY

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Foreword

To limit salinity increases in the River Murray, there are pressures to minimise salt leaving irrigated catchments of the Murray-Darling Basin. Part of this strategy is to store drainage disposal water in the irrigation areas themselves and use disposal basins. Unfortunately, there are no existing guidelines for siting, design and management of such disposal basins. The CRC for Catchment Hydrology and CSIRO Land and Water, with support from the Murray-Darling Basin Commission, have embarked on a project with the overall objective of producing such guidelines for the Riverine Plain of the Murray Basin.

This report is one of the key outputs from this project. It summarises the guidelines by addressing all of the main issues that should be considered in developing a drainage disposal strategy or designing a disposal basin. The guidelines give more background and detail. The importance of each of these issues is likely to vary across different irrigation areas and hence the guidelines must be interpreted in the context of local conditions.

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1. Introduction

1.1 Aim and Scope of the Summary Guidelines

This report presents a summary of more detailed guidelines for siting, design and management of local-scale basins on the Riverine Plain (Jolly *et al.*, 2000). A description of the layout of the summary guidelines is as follows:

- Section 2 provides background on the function of basins
- Section 3 develops the framework for the guidelines by outlining the underlying principles and management of risk
- Section 4 outlines strategic planning issues for land and water management planning groups
- Section 5 deals with those issues related to the siting, design and management of individual basins.

The aim of the **guidelines** is to describe the technical and financial issues that need to be considered for the effective and environmentally safe use of local-scale saline disposal basins on the Riverine Plain of the Murray-Darling Basin. They are underpinned by a set of **principles** that provide an overarching philosophy for the use of local-scale basins. The guidelines are supported by technical information obtained from research carried by CSIRO and the CRC for Catchment Hydrology and previous studies of basins in the Riverine Plain. The guidelines apply to disposal basins associated with farm subsurface drainage in irrigated areas. They do not deal with the use of disposal basins to dispose of surface drainage and runoff; sub-surface drainage from urban salinity control; or groundwater from interception schemes to protect stream salinity.

It is important to note that the authors, in consultation with a broad group of stakeholders, have developed these principles and guidelines. However, they should be considered as proposals only as they are not yet part of an agreed policy framework and as such have not received endorsement from any of the jurisdictions they encompass.

Any development of disposal basins should be carried out within the framework of the Salinity and Drainage Strategy of the Murray-Darling Basin Commission (MDBMC, 1987) and catchment *Land and Water Management Plans (LWMPs)*. It is expected that a long term disposal strategy (100-200 years) is prepared as part of all *LWMPs*. It is also very important that the community, local government, environmental protection and other regulatory and catchment management authorities are involved in the planning of the use of local-scale basins in a region. The guidelines have been developed by the authors, in consultation with a broad group of stakeholders through the Project Steering Committee and two workshops.

The guidelines are not prescriptive due to the variability in conditions across the Riverine Plain. They do not encompass social and political issues associated with these basins, as these are generally specific to individual situations and are more appropriately handled by the communities concerned, their land and water management planning groups, and local authorities. At the time of writing, there is no legislation at Federal, State or Local Government level that specifically deals with the use of local-scale saline disposal basins. However, various aspects of disposal basin siting and use may fall under a range of legislation, regulation and by-law (e.g. VIC EPA, 1994; NSW EPA, 1997). This is in addition to compliance with all local government planning rules appropriate to the area.

In this document, a number of key siting, design and management decisions will be addressed. Many of these decisions will require a range of expertise in fields such as soil, drainage, geotechnical and construction engineering, agriculture, pedology, hydrogeology and financial planning. Advice in these areas may be sought from State agencies, catchment management authorities, local government, consultants and research organisations.

2. The Functions of Disposal Basins

2.1 Background

The significance of irrigation and irrigated agriculture in the Murray-Darling Basin (MDB) is often underestimated. It represents about:

- 73% of all water used for agriculture and human consumption in Australia
- 80% of irrigated land in Australia (1.8 million hectares)
- 90% of cereal, 80% of pasture, 65% of fruit and 25% of vegetable production nationally
- $4 billion value of irrigated production annually.

The majority of this irrigation occurs in the south-central part of the Basin widely known as the **Riverine Plain.**

Sustainable irrigation requires that some water drains past the root zone of irrigated crops. This, together with leakage of water from the associated network of water distribution and drainage channels, has caused water tables to rise in the Riverine Plain and has resulted in soil salinisation, waterlogging and increased movement of salt to drains, streams and rivers. It was estimated in 1987 that 96 000 ha of irrigated land in the Murray-Darling Basin were visibly affected by soil salinisation, that 560 000 ha had water tables within two metres of the surface (MDBMC, 1987) increasing to 869 000 ha by 2015. Groundwater control to avoid these problems can be attained through engineered drainage (Tanji, 1996), such as surface drains, sub-surface drains, and groundwater pumps.

Such drainage works cause large volumes of drainage disposal water to be brought to the land surface. GHD (1990) predicted that by the year 2040, between 335 000-608 000 ML/yr of groundwater in the Riverine Plain will require disposal. The main drainage disposal options, which are in use or have been considered, are:

- by local or regional re-use - with dilution as required;
- to streams and rivers on an opportunistic basis – used in most irrigation areas;
- to disposal basins - in use in some irrigation areas; and
- by a pipeline to the sea - feasibility studies conducted.

One of the primary drainage management objectives is to minimise disposal volumes by implementing improved irrigation practices and promoting the re-use of drainage water wherever possible. However, to prevent salt accumulation in the root zone by maintaining an adequate leaching fraction, saline drainage will always be a consequence of irrigation. Some types of drainage, such as surface drainage, are suitable for re-use. Disposal basins will only be viable for disposal of highly saline water because of the high cost of basin construction and loss of productive land.

Some saline water is currently disposed of into river systems in periods of high flows and thus exported downstream. However, the salinity of pumped groundwater and drainage effluent is such that continuous unmanaged disposal to rivers and streams may result in unacceptable impacts on the environment and downstream users. The Salinity and Drainage Strategy of the Murray-Darling Basin Commission (MDBC, 1999) imposes constraints on the amount of river disposal that is possible. Moreover, there appears to be declining political and community tolerance of continued disposal to river systems. Export of saline drainage to the sea via a pipeline is an option which has been considered a number of times in the past (SRWSC, 1978; Earl, 1982; GHD, 1990). However, these studies have each indicated that this option was relatively uneconomic when compared to other available disposal options. Moreover, the impacts of this option on the marine environment remain unclear.

Saline disposal basins (also referred to as evaporation basins) have been an important option and will continue to be so into the future, at least in the short to medium term (50 years). As was shown by Evans (1989), saline disposal basins are the lowest cost option for disposing of high salinity drainage water. Hostetler and Radke (1995) collated all available hydrogeological, engineering and operational data on more than 150 existing basins in the Murray-Darling Basin. While the data for many basins is incomplete, the study provides a summary of available information:

- 107 basins were reported as being active, with a total area of >15 900 ha, a total storage capacity of >113 000 ML, and an annual disposal volume of >210 000 ML/yr.
- Of the 107 active basins, 90 were reported as being used for drainage disposal (i.e. not for groundwater interception schemes or groundwater discharge). These had a total area of >14 500 ha, represented almost all of the total storage capacity of the 107 basins, and had an annual disposal volume of >181 000 ML/yr.
- Of the 90 active drainage disposal basins, only 9 (representing 3338 ha) were located on the Riverine Plain, the rest being concentrated mostly in the Riverland (SA) and Sunraysia (Victoria) regions.

Since the publication of the Hostetler and Radke (1995) report, at least another 10 on-farm basins have been constructed on the Riverine Plain in the Murrumbidgee Irrigation Area (MIA). If disposal basins were the only way to deal with the drainage water, the GHD estimates of drainage volumes would represent between 9 and 16 times the current area of disposal basins in the Riverine Plain. Not surprisingly, drainage disposal is one of the most important components in the *LWMPs* of irrigation areas in the Riverine Plain.

In the past, use of regional-scale basins has been a common approach. These accept drainage water from multiple farms and irrigation districts, and may even be situated outside the districts themselves (hence salt is exported from the area in which it is produced). Regional basins were sometimes developed on the most convenient sites from an engineering standpoint, sometimes with detrimental environmental, socio-economic and aesthetic impacts, leading to poor community perceptions of regional disposal basins. Furthermore, there is new opinion that there is a need to depart from the existing "export the problem" mentality, and that beneficiaries of irrigation should be responsible for their own drainage management. The assumption being that this would encourage more efficient irrigation and drainage management and hence minimise the environmental and other impacts of disposal basins and irrigation on downstream users.

The above concerns have led to the use of **local-scale basins.** These can be in the form of on-farm basins that occupy parts of individual properties and are privately owned (such as those being used for new horticultural developments in the Murrumbidgee Irrigation Area). They can also be in the form of community basins that are shared by a small group of properties and are either privately or authority owned (such as the Girgarre Basin near Shepparton). It is these local-scale on-farm and community basins which are the subject of this project. While it is clear that basins can be an attractive means of disposing of saline drainage water, it is important to note that they may not be suitable for all areas. Strict siting and management criteria are required for the environmentally safe use of basins. When properly sited and managed, local-scale basins can be important environmental assets (Roberts, 1995). Previously, there has been no detailed guidelines for the siting, design and management of such basins.

2.2 How a Disposal Basin - Drainage System Functions

A disposal basin is an engineered structure used as part of an overall system aimed at controlling water tables. It allows evaporation of sub-surface drainage water and storage of the remaining concentrated salt in a defined location within the basin and in the soils and groundwater beneath it (Figure 1). Evaporation and leakage are the key processes that govern the behaviour and effectiveness of a basin.

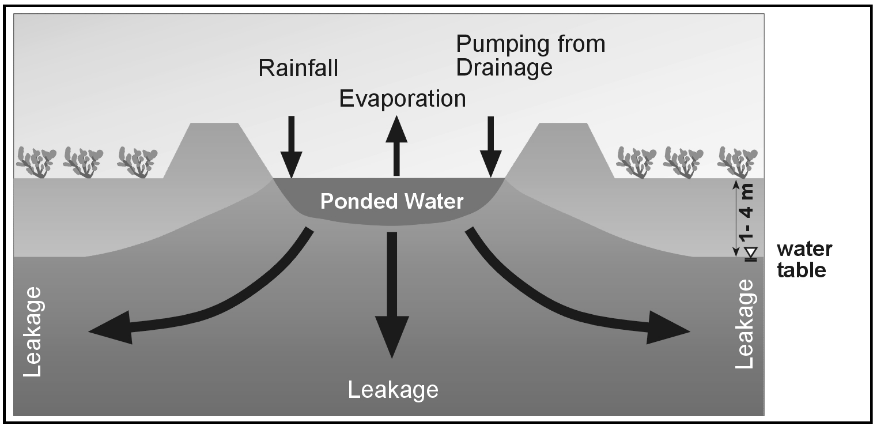

Figure 1. Conceptualisation of a disposal basin water balance.

Most basins on the Riverine Plains are *expansion limited* i.e. leakage is limited by the ability of the water to move laterally away from the basin. For these basins, shallow lateral flow of a leakage plume exceeds vertical flow. In the case where basins are infiltration limited, i.e. leakage is limited by the basin lining, vertical flow is greater. When groundwater pumping is used, vertical flow may account for 50% or more of the total leakage. *Preferential flow* paths may result in vertical flow bypassing much of the soil matrix beneath the basin and saline leakage water may reach zones of higher hydraulic conductivity (e.g. shoestring aquifers) sooner than would be expected if the mechanism was by piston-flow (Figure 2).

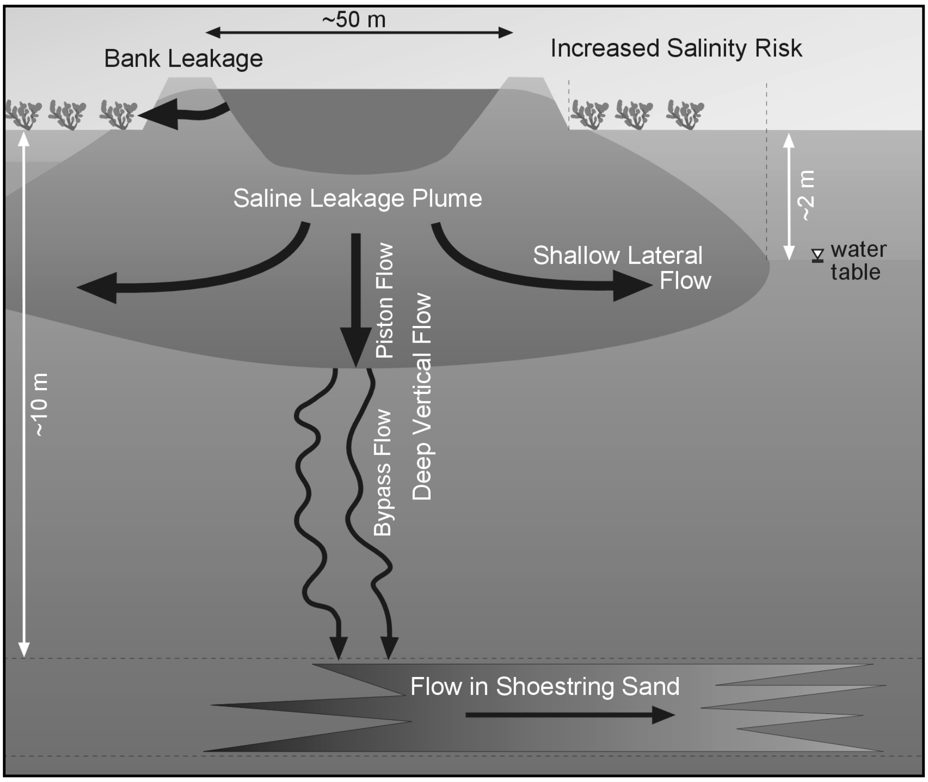

Figure 2. Conceptualisation of the main water movement processes associated with disposal basin leakage.

A small amount of controlled leakage (~0.5-1 mm/day) from the disposal basin is required to maintain evaporative disposal capacity (evaporation rate decreases markedly for hyper-saline basins). Wherever possible, basins should be sited in the drained area, in a position that minimises the leakage rate and maximises the possible time for the leakage plume to escape the drained area. Basins sited outside the limits of the drainage system should be located within a specific salt containment area equipped with effective interception and recycling works. Basins (particularly smaller on-farm basins) should have interception drains/channels close to the basin to reduce net leakage to manageable levels.

Disposal basins will not have an indefinite lifetime. If they are designed correctly, however, salinity build up in or around the basins are unlikely to be the major factors that determine the basin's lifetime. Other factors relating to the economics, technical (long-term bank wall stability) and the development of alternative (and more economical) disposal systems are more likely to result in shortening the lifetime of a basin.

2.3 Other Potential Uses for Disposal Basins

The primary purpose of saline disposal basins is to evaporate sub-surface drainage water and store the remaining concentrated salt in a defined location. Other concurrent uses may improve the financial viability of the basin, but may compromise its effectiveness for disposal. The main possible concurrent uses are aquaculture, salt production and salt gradient solar ponds. These other uses are mainly in the research and development phase, and should be considered as potential uses only. All these uses require considerable specialised expertise and have potentially high financial risks. Under no circumstances should saline disposal basins be used for disposal of other types of waste.

3. Framework for the Guidelines

3.1 Principles of Disposal Basin Use

The guidelines are underpinned by a set of **principles**, which define desirable objectives for basin siting, design and management and provide a general over-arching philosophy for the effective and environmentally responsible use of basins (Christen *et al.*, 2000a). It is recognised that, in some instances, they may contradict each other and so consideration will need to be made as to which is the most important **principle** in a given situation.

1. Evaporation basins should only be used for the disposal of saline drainage effluent, after all potential productive uses have occurred or the water is shown to be economically and environmentally unsuitable for use.
2. Salts remaining in a basin due to evaporation may be stored in the ponded water and also in the soil and aquifer system below and adjacent to the basin.
3. Salt stored below the basin should remain in the area of influence of the drainage system, or within a specific salt containment area around a basin if the basin is located outside the limits of a drainage system.
4. Leakage from a basin should not pollute groundwater with existing or potential beneficial use.
5. Water stored in disposal basins should not be released to surface drainage systems or other inland water bodies not designed as disposal basins.
6. Basins should be sited, designed, constructed, maintained and managed to minimise detrimental environmental, socio-economic and aesthetic impacts.
7. Basin owners are responsible for the consequences of the design, construction, operation and maintenance decisions related to their basin and its associated drainage system.

3.2 Risk Assessment and Minimisation

Basins are a potential risk to the surrounding environment, infrastructure, and human and other activities. For safe and sustainable use, their off-site impacts must be minimised. The most important first steps in risk minimisation are to:

- adhere to the principles listed;
- employ experienced engineering/scientific experts (who preferably adhere to a quality assurance system) for basin siting, design and preparation of management, monitoring, contingency and decommissioning plans;

- ensure that clear design standards and implementation guidelines are in place; and
- employ well supervised and experienced earthwork contractors for construction.

The most serious **environmental** risk is that of basin leakage as this may:

- contaminate groundwater below the basin;
- lead to a plume under adjacent properties or surface water features (e.g. streams, lakes, channels);
- cause local salinisation of land around the basin; and
- impact on surrounding **infrastructure** such as roads and railways, buildings and other engineered structures.

Table 1. Factors determining possible risk for disposal basin sites.

	Factors	Low Risk	High Risk	Unacceptable
1.	Locality assessment	Detailed	Simple	None
2.	Investigation and design and professional input	Locally developed guidelines	Site specific with no local guidelines available	Lay person
3.	Construction	Well supervised person with specific basin construction experience	Poorly supervised person with no basin construction experience	Unsupervised person with no earthwork storage construction experience
4.	Potential effects of leakage	Confined to drained area	Impact outside drained area	Impact on major infrastructure and environment
5.	Other environmental impacts	Good community acceptance	Partial community acceptance	No community acceptance
6.	Capital investment	Small	Large	N/A
7.	Geotechnical	Well documented and meets site suitability criteria	Uncertain but expected to meet suitability criteria	Unknown, or does not meet suitability criteria
8.	Management plans (monitoring, management, contingency, decommissioning)	Good plans, implemented and regularly reviewed	Poor plans or implementation and not reviewed	No plans
9.	Management accountability	Covenant on land title, bond, insurance	Responsibility unclear or not adhered to	Not considered
10.	Toxicants	Regular testing of basin water	Irregular testing of basin water	No testing of basin water

There are number of key factors which determine the level of risk for a disposal basin site as set out in Table 1, and assessment of these should be carried out for any proposed basin. *LWMPs* need to take a strategic approach when developing their preferred position in relation to the available options across any catchment. This will require careful consideration of the overall costs and benefits of drainage and salt disposal with due consideration to identifying who bears the risks. All basins should have monitoring, management, contingency and decommissioning plans that have been approved and regularly reviewed by a regulatory agency.

4. Issues for Strategic Planning

4.1 Strategic Assessment for Land and Water Management Plans

A procedure for *LWMP* planning for local-scale basins is shown in Figure 3 (overleaf). We emphasise that there is a need for natural resource LWMP managers, as part of their regional plans, to identify what the longer-term salt management strategy will be (100-200 yrs) and ensure that salt disposal basins are sited such that they fit in with that strategy. The role of disposal basins in a given *LWMP* will depend on the regional context, in particular its salt export situation. For example, the use of basins in a region which has existing external drainage disposal but plans new drainage development will be different to a region which must dispose of all of its drainage to basins.

When land and water management planning groups are developing strategic plans for salinity control, they should consider the following:

- level of service to be provided;
- assessment of drainage volumes to be disposed;
- identification of disposal options and constraints; and
- economic and financial assessment of options.

In assessing economic and financial options for disposal, land and water management planning groups should have already assessed the likely financial viability of drainage for crops in their area very early in the planning process. In areas suitable for drainage, all opportunities to minimise current and future disposal volumes should be considered, including:

- improved irrigation efficiency;
- water re-use; and
- whether drainage is for control of salinity or waterlogging.

Before developing policies for local-scale basins, it is important to have an assessment of those parts of any region where such basins are suitable. If a site is not suitable, then it will be difficult and expensive to engineer and manage the basin in a safe and sustainable manner. If there are insufficient suitable areas for local-scale basins in a particular region, alternative disposal methods will be required if drainage is to occur.

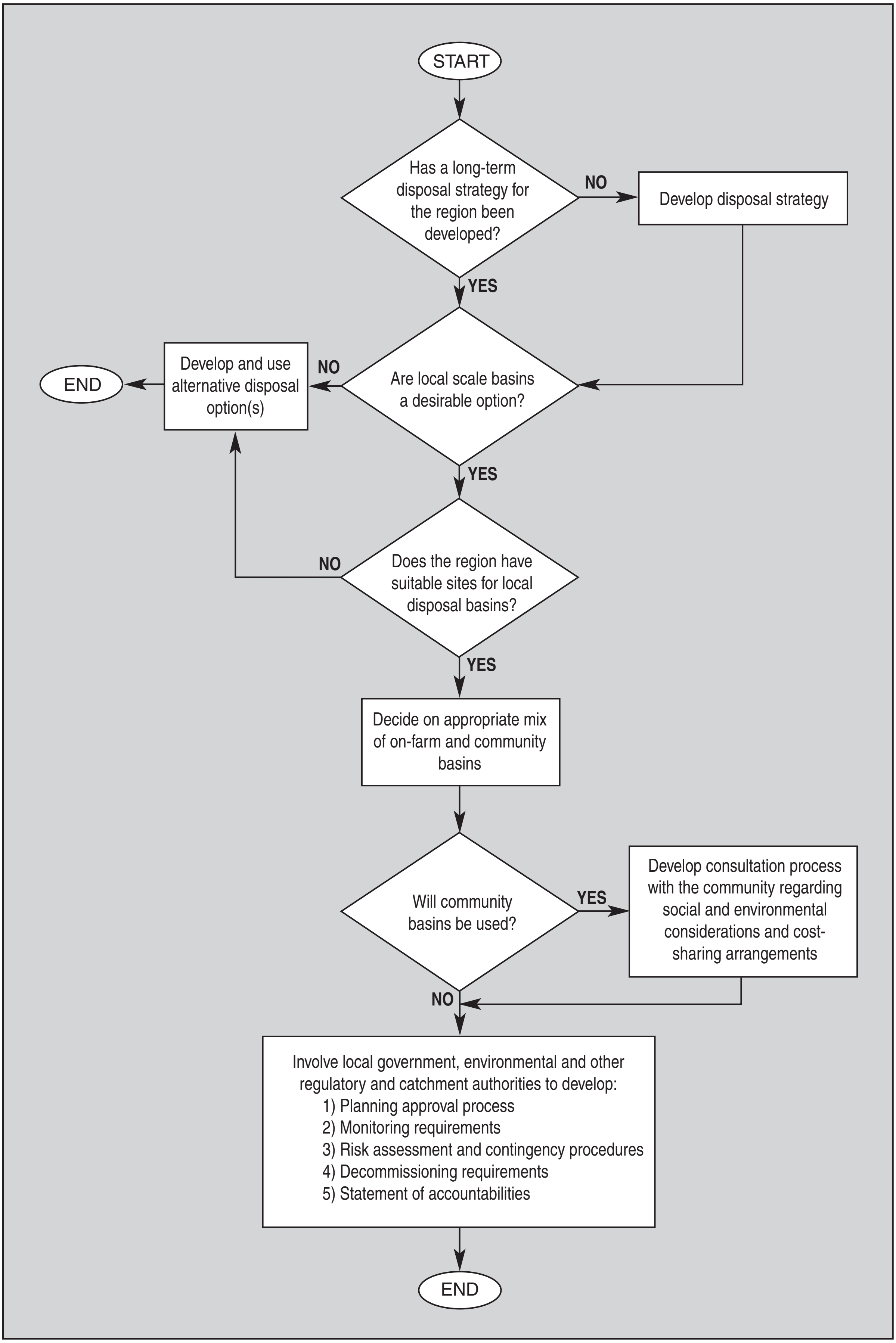

Figure 3 Schematic of the strategic planning process for disposal of drainage water

The key questions are:

1. Is there enough suitable area available for local-scale basins?
2. Can we identify in general terms where basins can be sited?

While it is difficult on a regional basis to precisely determine suitable locations for individual basins, it is possible from available spatial data to estimate the probability of finding suitable land within a given region, and its general location within a region. A GIS-based approach can be used to combine suitability criteria expected to minimise the risk of off-site effects of basin leakage. An example of this approach (Dowling *et al.*, 2000) uses criteria such as:

- proximity to surface water features (streams, drains and irrigation channels)
- proximity to infrastructure (urban areas and roads)
- watertable depth
- groundwater salinity
- soil hydraulic conductivity.

In most cases, the parameters are directly available as spatial data. However, for hydraulic conductivity surrogates such as forms of soil classification and infiltration information in rice irrigation areas may prove useful. Decisions need to be made on threshold values, based on both data quality and experience of the users. It is also recognised that for any individual basins, detailed site investigations will always be required.

Despite the limitations of the data, implications can be studied in regard to:

(i) Whether or not on-farm basins can only be used on an opportunistic basis if the chosen environmental criteria are to be satisfied? For on-farm basins to be widely used, it is necessary for suitable land to be widely available.

(ii) Whether or not community basins be used anywhere there is suitable land?

(iii) Whether there is enough suitable land in the different sub-regions to dispose of all of the drainage water produced? About 10% of the irrigated land that is drained (probably around 2-5% of the total land area) will be needed for local-scale basins. If sufficient suitable land is not available, then salt may need to be exported outside of the irrigation area to regional basins.

Such an approach is simple, can be used within the irrigation areas and would help direct discussion on the determination of relevant criteria and thresholds and thus the quantity and sizes of disposal basins required. *LWMP* groups need to be also aware that local-scale disposal basins, whether on-farm or community may, in some cases, be neither technically feasible nor financially viable. They should ensure that all proposals for new basins are based on property development plans, which include a high standard of irrigation infrastructure; and accompanied by a comprehensive financial analysis.

As drainage systems with disposal to local basins may not be financially viable, investment in improved irrigation infrastructure will be sometimes more financially attractive than investment in drainage works, especially when a basin is required. *LWMPs* need to ensure that all proposals for new basins are based on property development plans, which include a high standard of irrigation infrastructure, and are accompanied by a comprehensive financial and site technical analysis.

A financial analysis was done for horticultural developments in the MIA and for dairying in Shepparton. The MIA analysis (Singh and Christen, 2000b) showed that successful drainage with local disposal basins is:

- Best suited to crops that have high yields and prices and crops which are sensitive to waterlogging as well as salinity.
- More economically viable for existing plantings than new developments.
- Related to the standards of irrigation management.

With groundwater pumping, benefits are likely to spread over more than one farm and thus analysis of profitability needs to consider all beneficiaries. An analysis of dairying in Shepparton showed that a groundwater pumping scheme with a basin was not viable in the absence of cost-sharing arrangements with other beneficiaries (Singh *et al.*, 2000).

4.2 On-Farm or Community Basins?

In general, the **advantages** of on-farm basins are:

1. All costs of designing, operating, monitoring and maintaining the basin are borne by the primary beneficiaries of the drainage development.
2. The ownership and responsibility for the basin remains with the primary beneficiaries.
3. There is a direct cost incentive for the landholders to improve irrigation efficiency and drainage management so as to reduce drainage volumes.
4. The physical presence of the basin on-farm has a strong psychological impact on farmers irrigation management as the results of over irrigation or over drainage are immediately visible.

5. The environmental and human impacts of the basins are generally restricted to primarily the landowner.
6. There is no export of salt from the place of extraction.

In general, the **disadvantages** of on-farm basins are:

1. It may be difficult to find suitable sites.
2. These basins will generally be smaller and so leakage rates will be potentially higher. The basins have to be placed somewhere on the farm and so there is a higher probability of using unsuitable sites.
3. There are greater construction costs per basin area and larger buffer areas per basin area (due to small basins having large perimeter to area ratios).
4. They pose a potentially higher environmental and human risk due to the probability of lesser controls on their siting, management and monitoring.
5. Large numbers of on-farm basins complicate long-term regional planning and may be more difficult to decommission if a better salt disposal or storage method becomes available in the future.

In general, the **advantages** of community basins are:

1. They provide a better opportunity to find suitable sites.
2. Leakage rates will be generally lower due to larger basin sizes and the lower probability of using unsuitable sites.
3. The construction costs and buffer areas are less per basin area due to the generally larger basin sizes.
4. They pose a lower environmental and human risk due to better siting and probable better quality of management and monitoring.
5. Salt production or aquaculture are potentially more feasible as more water is available and inflows are more regular.
6. Smaller numbers of larger community basins make long-term regional planning simpler and will be easier to decommission if a better salt disposal or storage method becomes available in the future.

In general, the **disadvantages** of community basins are:

1. The requirement to get community agreement to the scheme and cost sharing arrangements.
2. Compulsory acquisition to provide appropriate siting may lead to land equity and other legal disputes.

3. The distribution of site purchase, construction, operating and monitoring costs to beneficiaries may be complex and difficult (although ownership of the land and basin by an authority or investment group can overcome this).
4. Monitoring of drainage, in terms of quality and quantity, is required in order to ensure that the drainage water is of an acceptable quality (pesticides especially) and in order to distribute costs (which should be on a *user pays* principle).
5. Since the disposal of the drainage water is remote from the farm and shared between a number of farmers, the measuring of and charging for drainage water must be sufficiently sensitive that it ensures a high standard of water management. This will ensure the basin does not have to be over designed.
6. High levels of construction, management and monitoring expertise are required due to their greater technical complexity.
7. Construction and operating costs may be higher in some situations due to need to transport water greater distances.
8. A long-term commitment on the part of the beneficiaries is required (for reasons outlined above).
9. While they pose less risk to the environment and the community, it may be difficult to obtain community acceptance due to the perception that big is bad.
10. There is export of salt from the place of extraction (but not necessarily from the irrigation region).

The choice between on-farm or community basins should consider physical, environmental and social-political issues as well as cost. Economic analyses carried out in this project suggest that there will generally be little cost difference between the two options. The key difference between the two types of basin in financial terms is in the establishment cost. For a community basin, the water is transported from the farms or shared groundwater pumps to the basin, while for on-farm basins, there is minimal transportation required. However, there is some trade-off because the construction cost of a larger basin is cheaper per unit area than a small basin. Thus, in deciding between on-farm, small community or large community basins, other environmental and/or social considerations should outweigh the negligible economic differences (Singh and Christen, 2000c). Community basins require careful decisions with regard to siting and cost sharing, to ensure equitable distribution of costs among those landholders that benefit.

A community basin may be owned and operated by either an authority, investment group, or by a group of landholders. If community basins are owned and managed by an authority, then they should have a clearly defined service agreement with its customers. If community basins are to be managed by landholder groups, it is desirable that relevant catchment planning groups provide model agreements to facilitate the process and encourage consistency in operations and cost sharing.

Management and monitoring of a single large basin is likely to be significantly easier than the management and monitoring an equivalent area of multiple smaller basins. From environmental risk management, monitoring and regional decommissioning perspectives, it may be better to have fewer large community basins than many small on-farm ones.

5. Issues for Individual Basins

5.1 Disposal Requirement

The next sections deal with those issues related to the siting, design and management of individual basins. Table 2 shows the key decisions that need to be made and how these relate to the various sections.

Table 2 Key decisions required for an individual basin

	Key Decision Required	Outcome
1.	Maximise irrigation and drainage efficiency.	drainage minimised
2.	Select most suitable site.	site selected
3.	Determine the volume of drainage water in need of disposal	_____ML/yr
4.	Determine the disposal capacity of a basin at this site	_____ML/yr
5.	Determine the required basin area	_____ha
6.	Decide on appropriate basin design.	shape / cells / interception works
7.	Develop management and monitoring plan.	leakage / water quality plans
8.	Determine impact on the financial viability of farm enterprises.	construction cost / enterprise viability
9.	Assess other possible productive enterprises for the basin.	possible enterprises
10.	Prepare contingency, decommissioning plans.	contingency and decommissioning plan

An important step in the planning of a new drainage project is to determine the disposal requirements for the proposed land use. For disposal basins, this involves the assessment of the likely quality of the drainage water and the volumes of drainage that will require disposal.

The volume of drainage produced will depend on the land use, climate, irrigation practice and the type of drainage system. When determining an appropriate value, existing data and local knowledge should be thoroughly investigated. In areas with no record of drainage works, a crop modelling exercise will probably be necessary. Allowance needs to be made for additional drainage volumes caused by local or regional groundwater flow into the drainage system and by rainfall.

An assessment of likely drainage water salinity should be carried out during project planning as this will determine the type of disposal that is appropriate. Full or partial re-use of drainage water for irrigation should be carried out where possible (and economically justified) before disposal to a basin. Drainage water destined for a basin should undergo a full analysis for trace metals, nutrients and pesticides to avoid their possible accumulation to toxic levels in the basin waters and sediment (Christen *et al.*, 2000b). Land and water management planning groups should work with local government and environmental protection authorities to set minimum investigation requirements for drainage water quality and develop guidelines on acceptable values for different situations in their region.

5.2 Disposal Capacity of a Basin

Two key biophysical decisions for local-scale basins are (Leaney and Christen, 2000a,b):

1. For a given drainage area, what land area needs to be devoted to disposal basins? If the area devoted to disposal basins is too small, then they will not be able to cope with all the drainage water required to adequately provide groundwater control. On the other hand, if too much area is used, it is likely to take out potentially productive land and hence become uneconomic. Thus, a key physical factor in the design of the disposal basin is the volume of drainage water that can be pumped into an evaporation basin over a specified period of the time (**potential disposal capacity**). This capacity includes the effects of evaporation, rainfall and leakage on the amount of drainage water that can be disposed of into a given basin but does not consider interception and recycling of shallow lateral or vertical flow. ***Design disposal capacity*** refers to the amount of drainage water that can be pumped into a disposal basin if the water returned by the interception drain and drainage system is equal to that leaked from the basin. The design disposal capacity, when matched to the required drainage for an irrigated area, determines the percentage of area that needs to be reserved for disposal basins.

2. What is a desirable leakage rate and how is this affected by siting, design and management? If the leakage rate is too high, it can lead to problems of salinisation in surrounding areas and migration of highly saline groundwater plumes. This can be partly overcome by interception and by placing the basin within the drainage network or drawdown cone of a pumping scheme. Interception means recycling of drainage water and this can become expensive. If the leakage rate is too small, the water within the disposal basin becomes very saline, decreasing the rate of evaporation of the water in the disposal basins.

The leakage rate is highly dependent on two controlling factors. For most basins on the Riverine Plain, the main controlling factor is the ability for the groundwater mound under the basin to expand outwards (expansion limited, see Section 3). This being the case, the leakage rate per unit area will reduce, as the basins become larger. At only one basin studied, Girgarre (Victoria), the leakage was limited by the permeability of the basin floor, the second controlling factor (infiltration limited). It is thought that this is due to the Girgarre basin being in the vicinity of the drawdown cone of the groundwater pumps that provide drainage to the area and hence is not limited by the ability of the groundwater mound to move away from the basin.

Thus, because most basins in the Riverine Plain are expansion limited, smaller basins can dispose of more water per unit area than larger basins due to their higher leakage rates that also allow them to maintain lower basin salinity and higher net evaporation rate (i.e. the *potential* disposal capacity is higher). The design disposal capacity, however, is only slightly higher for smaller basins. The higher leakage rates become especially significant when basins are to be sited above relatively fresh groundwater systems where contamination is to be avoided. Large basins, when placed on a similar site will leak less and therefore present a lesser threat of groundwater salinisation per unit of water disposed (although they may cause much more significant problems locally because of their size).

Care needs to be taken, particularly with small basins, to reduce the permeability of the basin floor by the use of compaction by not allowing the basins to dry and by appropriate siting of the interception channel. For heavy textured soils with some compaction of the basin floor, year-round coverage of water, and a properly designed interception drain, net leakage rates at many sites in the Riverine Plain can be reduced to ~0.5 to 1 mm/day, values which are sufficient to maintain evaporation rates.

Given the range of estimates of leakage from these basins, it is possible to estimate the disposal capacity of basins in the presence or absence of interception drains. This has been done for the Riverine Plain for a number of conditions, including variable leakage, groundwater salinity and climate. The spreadsheet model thus developed enables these determinations to be carried out for any location in the Riverine Plain that has long-term climatic data available (see Leaney and Christen, 2000a). Simulations of disposal basin behaviour predict that there is likely to be only a negligible reduction in disposal capacity when a single-bay basin is replaced with a three-bay basin system with equivalent basin area. This finding encourages the use of multiple cell basins, where the most saline bay is completely surrounded by the fresher cells, thus reducing the impacts of the saline disposal basin on the surrounding area.

A water balance model (BASINMAN) for farms with sub-surface pipe drainage and an on-farm evaporation basin can be used to find the balance whereby the basin area is large enough to reduce waterlogging in the farm to an acceptable level and not overly large, so large that the basin evaporative capacity is under utilised (Wu *et al.,* 1999). The appropriate basin ratio is highly dependent upon the required standard of protection for the cropped land and irrigation efficiency. For example, if water tables are only allowed to be less than 1m for 10% of the time, then this ratio is about 6.5% for the modelled farm in the MIA, assuming that the irrigation is efficient. For less efficient irrigation, the basin area to drained area ratio becomes larger.

5.3 Determining Basin Area

The total basin area is comprised of the *evaporative area* of a basin, and the area occupied by banks and a buffer zone immediately surrounding. *Evaporative area* depends on the expected drainage volumes, basin disposal capacity and the level of risk of crop damage if the basin is full and drainage has to cease. The drainage volume used is an annual average based either upon an average rainfall year for a low risk crop, or a wetter than average year in the case of a high risk crop. There also needs to be some allowance for particular drainage requirements at critical stages of crop growth. For the assessment, it is best to utilise the design disposal capacity of a basin. Leakage may provide additional initial capacity but in the long-term it is expected that a significant portion of leakage will be recycled back to the basin and will not be available as disposal. In these circumstances, it is sensible to err on the side of larger rather than smaller basins.

To investigate the impacts of varying climatic conditions, as discussed above, it is useful to conduct a water balance analysis on a monthly, weekly or even daily basis. This can be done very simply on a spreadsheet (Leaney and Christen, 2000a), taking into account:

- **Drainage water inpu**t – this can be a steady rate (e.g. 5 mm/day) or can be a variable rate that is linked to rainfall and irrigation (e.g. assume that 15% of all rainfall and 10% of all irrigation is drained). Also, if the basin is full then no further additions can occur.
- **Rainfall** – direct input to the basin.
- **Leakage** – the calculated design disposal potential allows for leakage from the basin when determining the basin salinity but assumes that all of this is subsequently intercepted.
- **Evaporation** – Use appropriate pan factor according to basin size and link in a salinity function.
- **Depth** – set a maximum depth of water in the basin.
- **Area** – use various areas to assess differences in disposal.

In all types of analysis, there is a degree of uncertainty and therefore often a safety factor is used to provide some insurance against this uncertainty. The safety factor in the design area will depend upon the degree of uncertainty in the design process and the potential risks to crops if the basins become full and drainage has to be stopped. If a thorough analysis is conducted initially, then there is less uncertainty and costs can be minimised. In areas with little data or local knowledge is available, then a greater safety margin is required.

A simple measure is to build a basin that is 10 or 20% bigger than initially determined, although this may not be very cost effective. A more practical method for incorporating a safety factor into the use of disposal basins may be to build a conservatively large basin but try to only use a proportion of it. If after a number of years the drainage discharge is as predicted and basin water salinity is stable then the unused, excess area of basin could be returned to production. A similar alternative is to set aside more land than is thought to be required which can be left available for future expansion of the basin. As a basin's *total area* increases, the relative proportion of *evaporative area* also increases. This can affect the choice of community and on-farm basin.

5.4 Basin Siting

Careful consideration of siting of local-scale basins can minimise the risks to the general environment and the impacts on human and other activities and meet community standards. Successful implementation also requires that costs be constrained as much as possible. It is implicitly assumed that basin siting will be considered within the framework of appropriate existing State and Federal legislation, and Local Government regulations. As per **Principle 3**, basins should preferably be sited within the area of influence of the drainage system. If the basin is to be built outside the drainage area or in an area where there is the possibility of rapid migration of the leakage plume, then there will need to be additional risk minimisation in the form of leakage control and interception.

The suitability of a site for a disposal basin depends both on the **general locality**, and the **on-site physical characteristics**. The locality assessment is a mixture of biophysical and socio-political considerations for the surrounding area. The on-site assessment is concerned with potential leakage rates, leakage plumes, and the likelihood of other environmental degradation. Site suitability criteria include shallow groundwater quality, soil permeability, aquifer hydraulic conductivity and gradient, and depth to water table. The detail of the on-site assessment is dependent upon whether the basin location is considered to be of low or high risk (Table 3). In both cases, minimum geotechnical investigations should include a good understanding of the local hydrogeology and assessment of soil suitability for bank construction and the floor treatment required to reduce leakage to 0.5-1 mm/day. For sites categorised as high risk, additional investigation of the hydrogeology and likely leakage characteristics is required. For low risk sites, minimum additional investigations required should be set by land and water management planning groups, in consultation with local government and environmental protection authorities.

Table 3. Required geotechnical investigations for low and high risk disposal basin sites.

Investigation	Low Risk	High Risk
Local aquifer assessment To provide an understanding of local hydrogeology, general extent and depth of regional aquifer and likely existence of shallow aquifers	Good, no need for extra investigation	Existing knowledge needs to be confirmed/extended by further investigation, e.g.: 1. EM34 transects at 500 m spacing 2. Bore (1 per 5 ha) holes to 20 m for aquifer determination
Leakage assessment To provide an understanding of the likely leakage characteristics	Hydrogeology indicates that leakage plume will be contained and basin sited in low risk environment. Possible investigations: 1. EM31 Survey (50 m grid) 2. Auger holes (1 per 2 ha) for soil texture, water table depth, groundwater salinity and water table depth	Hydrogeology indicates that leakage plume could spread and/or basin sited in high risk environment. Possible investigations: 1. EM31 Survey (50 m grid) 2. Auger holes (1 per 2 ha) for soil texture, water table depth, groundwater salinity and water table depth 3. Surface infiltrometer measurements (1 per 5 ha) 4. Undisturbed cores for permeability, porosity (1 per 2 ha)

5.5 Basin Design

Engineering aspects of disposal basin design involve the selection of the most appropriate basin configuration, and construction approach. It is assumed that guidelines for construction of above ground storages will be utilised where appropriate (e.g. QWRC, 1984; NSW Agriculture, 1999).

A *well designed* basin is one that:

1. does not require an excessive area to dispose of the required drainage by evaporation. This requires that the basin water salinity does not become so high that evaporation rates decline significantly. This is achieved by allowing sufficient leakage to stabilise the basin water salinity at a moderate level, but not having it so high that it causes environmental problems. A leakage rate of 0.5-1 mm/day is a reasonable compromise that satisfies both of these objectives.

2. concentrates salt up to a maximum of 180 000 mg/L over the economic life of the basin, for storage in the aquifer below the basin by leakage. This requires that leakage is not too high (e.g. in the MIA some basins only double the concentration of the drainage water due to high leakage).

3. has a well designed interception system that ensures that shallow leakage is recycled back to the basin.
4. has adequate freeboard (height of banks above the design water depth). Depending on location, 0.5 – 0.8 m is considered adequate).
5. requires minimal maintenance. The main consideration is minimising erosion of the basin banks and any open interception drains around the basin.
6. has good aesthetics and amenity or environmental value. Larger community basins or even on-farm basins can be designed and managed to be a community and ecological resource (e.g. Roberts, 1995).
7. minimises nuisance effects such as the attraction of large numbers of birds, mosquito breeding, odours and dust.

Other aspects which need to be considered with basin design include:

- minimising dust problems by maintaining water in the basin at all times, and keeping vegetation on banks and access tracks.
- improving their aesthetic appeal through use of bushes and trees as screens around the basin.
- minimising the impacts of mosquitoes and midges by siting basins away from residential areas, minimising areas of very shallow water, controlling vegetation and floating plants, stocking of the basin with fish, ensuring vegetation screens are in place around the basin, and use of decoy ultra-violet and blue-green lighting.
- minimising odours by ensuring the basin does not dry out unnecessarily and removing excessive algal growth.
- ensuring adequate fencing and signed warnings for safety reasons.
- possibly providing facilities for bird habitat.

Main points:

1. Use best practice investigation, design and construction techniques, by using experienced soil and drainage engineers and hydrogeologists.
2. Ensure that only subsurface drainage water is allowed into the basin. Surface water, either as normal runoff or as flood flows, should be excluded.
3. Maximise evaporation as much as possible by allowing a small amount of leakage.
4. Limit leakage to an acceptable level by selection of appropriate sites that have soils with low hydraulic conductivity throughout their profile.

5. Contain the leakage within the drained area surrounding the basin to avoid problems with contaminating downstream neighbouring areas and downstream water users.
6. During routine running, maintain the basin at the design depth (i.e. allow appropriate freeboard for wetter periods with low evaporation).
7. Land and water management planning groups will need to develop policies in conjunction with local environment protection authorities and local government for the approval of basin designs and for the monitoring of basin performance, and for the management of plumes from abandoned or decommissioned basins in their areas.

All proposals for a new basin should be accompanied by a:

- property development plan that includes a high standard of irrigation infrastructure; and
- comprehensive financial analysis of the impacts of the basin on the farm enterprise.

5.6 Financial Viability of Disposal Basins

Adoption of disposal basins can occur under two basic conditions, which each require separate analysis:

1. New developments, where the farmer is undertaking a new enterprise with subsurface drainage and a disposal basin.
2. Existing development where the existing crop has subsurface drainage already in place and the farmer is required to change from off-site disposal to a disposal basin.

In the former case, apart from considering the costs and benefits associated with a subsurface drainage system with a disposal basin, the profitability of an enterprise without drainage and other options such as more efficient irrigation systems should be considered. For adoption to take place, the profitability of an enterprise with a subsurface drainage system coupled with a disposal basin should be higher than other options. With groundwater pumping, benefits are likely to spread over more than one farm and thus analysis of profitability needs to consider all beneficiaries (see Singh *et al.*, 2000). In the case of an existing enterprise, the farm viability needs to be considered with the additional cost burden of a disposal basin. In this case, there is no extra benefit accruing from using a basin.

The following outline can be used to analyse the financial viability of a subsurface drainage system with a disposal basin:

1. Determine basin construction costs for the selected site.

2. Determine if the enterprise is viable with a disposal basin by including the cost of the subsurface drainage and the basin with all other enterprise costs, assessing the returns from the enterprise, and then developing a cash *flow budget.* This may include a cost-sharing mechanism for groundwater pumping.
3. Undertake sensitivity analysis of key parameters affecting farm viability such as crop price and yield, farm size and basin area.
4. Assess whether the basin area, as determined by physical analysis, is economically optimal.

The cost of a disposal basin should include:

1. Selecting a suitable site on the basis of geotechnical investigations.
2. Site survey and layout of design - including buffer areas and space occupied by banks.
3. Earthworks – stripping vegetation and removing topsoil, bank formation using a scraper, and additional compaction of banks and floor, if necessary.
4. Lateral flow interception works – open drain or horizontal pipe drain to a sump and pump, spear points or groundwater pumps.
5. Recurrent costs – pump operation, pump repair and maintenance, repair and maintenance of basin banks and public liability insurance.
6. A decommissioning cost should be estimated for each basin, and assumed to occur at the end of the design life.

These costs should then be used to develop a *cash flow budget* with an appropriate discount rate (e.g. 8%) to determine the annual *Net Present Cost* (NPC) over the life of the basin. The expected life of this type of engineering structure should be a minimum of about 30 years.

5.7 Management and Monitoring

The monitoring and management of a disposal basin has two key objectives:

1. To ensure that environmental impacts of the basin are maintained within the agreed limits set at the design stage; and
2. To ensure that the basin is functioning adequately to dispose of the drainage water at the design rate.

The most important factor in achieving the above objectives is that leakage from the basin is close to the predicted rate defined in the design and that the leakage plume remains in a defined area. We recommend, therefore, that disposal basin monitoring should focus on three main aspects:

1. Input water quantity and quality (used in estimating leakage rate);
2. Basin water quantity and quality (used in estimating leakage rate);
3. Groundwater quality (used in defining the spread of the leakage plume); and
4. Water table depth (used in assessing the speed and direction of spread of the leakage plume).

Basins should not be allowed to dry out, to prevent nuisance from dust, cracking of compacted layers, and loss of organic mats acting as seals. Basin maintenance is generally associated with repair of banks and maintenance of the lateral flow interception system (cleaning out open drains and replacing pumps). Banks may become damaged and leaky through wave erosion or biological macropores. An important aspect of maintenance and management is to minimise nuisance from disposal basins (by minimising dust, odours and insects. Basin water also needs to be monitored after the first year of operation for toxicants such as pesticides and trace metals (Christen *et al.*, 2000b). Monitoring for toxicants is important to:

- avoid risk of harm to wildlife living in or visiting the basin;
- avoid risk of consumption of contaminated fish or other aquaculture that may be carried out formally or informally in the ponds.

Basin decommissioning should be considered at the design stage in terms of long-term control of the saline leakage plume and local impacts. Multiple options need to be developed, both before construction and during the life of the basin. The key factor is that if the basin is no longer used then the saline leakage plume still needs to be managed. If a basin is decommissioned with no further water input, then assessment of the basin site for toxicants needs to be undertaken. This also needs to be undertaken for the groundwater affected by the saline leakage plume. There should be discussions with environmental protection authorities and other regulators as a basin may eventually come under the category of a contaminated site.

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