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Evaporation basin guidelines for disposal of saline water

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EVAPORATION BASIN GUIDELINES FOR DISPOSAL OF SALINE WATER

Government of Western Australia
Department of Agriculture

Swan Avon Integrated Catchment Management
Avon Working Group

Reviewed May 2006

EVAPORATION BASIN GUIDELINES FOR DISPOSAL OF SALINE WATER

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The Department of Agriculture, Western Australia (DAWA)

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A joint project with The Department of Agriculture Western Australia, Sustainable Rural Development Program and the Avon Working Group of the Swan Avon Integrated Catchment Management Program

These guidelines were produced following investigations into the feasibility and design of evaporation basins for the Western Australian wheatbelt conducted by DAWA and JDA Consultant Hydrologists (Report No. J334au.doc).

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Foreword

The management of saline discharge on agricultural catchments is a major challenge for many landholders. Although the solutions to salinity management are firmly rooted in more efficient use of water, recognition of a changing landscape must acknowledge management options for saline discharge.

In recognition of the need to address on-farm management of discharge water, the Avon Working Group of the Swan Avon Integrated Catchment Management Program commissioned a study to examine the use of evaporation basins in dryland areas of Western Australia. The study report by JDA Consultant Hydrologists on the 'Feasibility and Design of Evaporation Basins for the Wheatbelt of Western Australia' examines factors that influence design requirements for evaporation basins and then applies this information in a case study format.

This publication on 'Guidelines for Evaporation Basins' sets out the general requirements for project planning and design of structures for disposal of saline water. Interested landholders and technical service providers will find the information in this booklet useful when considering projects that form part of an integrated catchment plan.

While specific production opportunities such as salt harvesting and aquaculture can be associated with evaporation basin technology, the main intent of this publication is to define guidelines for disposal of water and the safe management of salt residues.

Water management strategies have consequences on man-made systems and the natural environment. The Avon Working Group acknowledges the 'duty of care' as a guiding principle of law that all landholders must consider when evaluating management options. Consequences of actions must be acceptable to the broader community and be subject to the laws and regulations of our land.

The information and planning process set out in these guidelines will assist in achieving a reasonable approach to on-farm disposal of saline water.

Mike McFarlane
CHAIRMAN
AVON WORKING GROUP

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4.5 Compliance with legal obligations

There are a number of legal issues that must be considered before constructing an evaporation basin. The following is a summary of some of the matters that may be relevant:

- Notice of intent to drain – if the evaporation basin is designed to take water from draining or pumping operations, the owner or occupier of the land is generally required to give at least 90 days notice to the Commissioner of Soil and Land Conservation before discharging the water. Further information on notices of intent to drain is available from local Department of Agriculture Offices.

- Environmental harm offences – a person causing serious or material environmental harm faces fines of up to $500,000 for an individual and $1 million for a body corporate. For evaporation basins, possible harmful effects may include improper disposal of salt or failure of the structure during a flood event, causing damage to neighbouring properties. To avoid risk of these fines, owners and occupiers of land should ensure any activities they undertake comply with all relevant laws. More information is available from the Department of Environment.

- Planning approval – some local governments require development approval for certain types of earthworks, which may include evaporation basins and associated drainage lines. Check with the relevant local government to see what controls apply before starting work.

- Native vegetation – if the construction of an evaporation basin requires the removal of native vegetation, or will lead to the destruction of native vegetation, a permit may be required from the Department of Environment.

- Interfering with watercourses – earthworks that interfere with watercourses (i.e. rivers, streams and creeks) may require the approval of the Department of Environment.

- Protected wetlands – wetlands (lakes, swamps etc) may be protected under State and Federal laws. Before constructing an evaporation basin that might interfere with a wetland, check with the State and Federal Environment Departments to see whether any approvals are required.

- Telecommunication services – always make sure that the excavation of a drain does not interfere with or damage telecommunication cables, as repair costs can be significant. Dial 1100 before commencing excavations that may damage these services.

- Common law – a person may be liable under the common law for damage caused to a neighbour's property by the construction, operation or failure of an evaporation basin. Therefore, the planning should consider likely impacts on neighboring properties or receiving waterways, and take such steps to prevent any unreasonable interference with other landholders. This is generally referred to as the "duty of care" or the "duty to take care" when carrying out activities that may cause damage to another person, property or the environment.

- Occupational safety and health – as with all workplace activities, the construction and operation of evaporation basins must be carried out in a safe manner. Landowners and contractors have a duty of care and should take reasonable measures to ensure the works are safe. Landowners are encouraged to discuss the nature of the evaporation basin and any associated drainage works with their public liability insurers prior to commencing the works.

1. INTRODUCTION

Evaporation basins can be used to dispose of groundwater from systems designed to manage rising groundwater levels in dryland agricultural areas.

The disposal of saline groundwater near the source of extraction provides an on-farm water management alternative to uncontrolled saline discharge to surrounding land or waterways. On-farm disposal of saline water using evaporation basins is an alternative to off-farm disposal options that may create conflict with surrounding land managers or result in unacceptable environmental impacts.

Where groundwater levels can be restricted from rising to the root zone through the pumping and disposal of saline water into evaporation basins, the potential exists to improve productivity on a localised scale.

Evaporation basins are recommended for use where groundwater discharge is to be managed on agricultural land as part of a broader catchment management plan that aims to improve productivity and the ecological health of a defined catchment area.

The application of design guidelines must consider site characteristics, water quality and environmentally sensitive areas downstream. Environmental impact assessment before construction will determine the suitability of proposed sites. Where appropriate sites are identified, design requirements can be applied to manage risks to an acceptable level.

2. AIM AND SCOPE OF THE GUIDELINES

The purpose of this guideline is to provide information and criteria for evaporation basin planning, design, construction, monitoring, and maintenance for purposes of disposal of water and storage of disposed salts in dryland agricultural areas of Western Australia. The application of the guidelines will assist in the management of saline discharge and the protection of natural resources. The guidelines have been tailored specifically for saline evaporation disposal sites located in the wheatbelt areas of Western Australia.

3. USING THE GUIDELINES

These guidelines follow the general process for planning, design, construction, monitoring, and maintenance of an evaporation basin in sequential order as shown in Figure 1. Each of the key considerations must be addressed if an evaporation basin is to be implemented successfully.

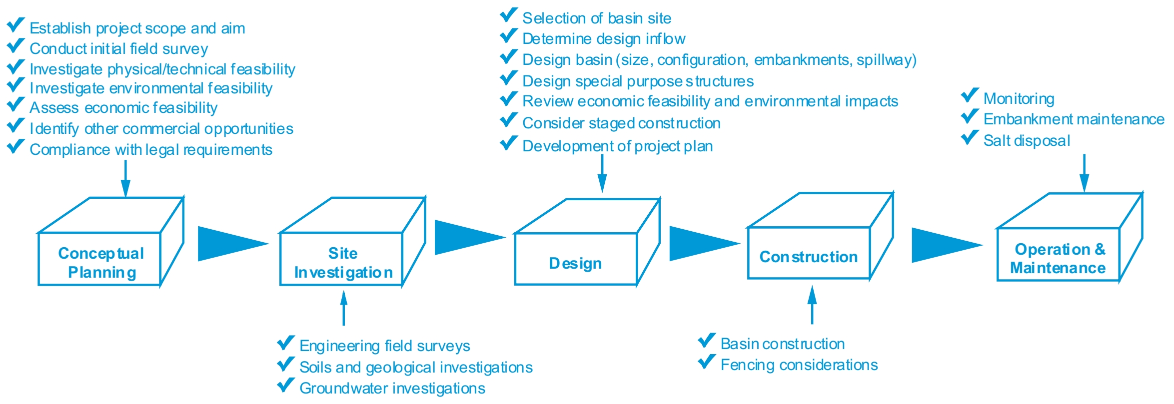

Figure 1. Process for development of an evaporation basin

4. CONCEPTUAL PLANNING

4.1 Initial Field Survey

The project scope and objectives should be clearly defined.

An initial field survey should be conducted to assist in establishing the project scope and objectives, and any possible conflicts with resource use. Surrounding areas/properties should be included within the initial survey to determine any possible detrimental effects. Discussions with landowners should be held to provide an indication of support for the project, types of improvements needed, and an indication of their priorities.

4.2 Physical, Technical, & Environmental Feasibility

An investigation of the physical, technical, and environmental feasibility of an evaporation basin on the proposed site(s) should be conducted. This investigation is an extension of the initial field survey and should include:

- a working map of the project, indicating key features and the proposed location of the basin and any associated infrastructure,
- a generalised soil and land use map, and
- an environmental evaluation and an assessment of project impacts.

Environmental evaluation requires surface water and groundwater factors to be assessed in relation to:

- the proposed evaporation basin site,
- the surrounding area and down slope environments,
- effects on remnant vegetation, land salinisation and water quality, and
- changes to the natural environment and the likely frequency, rate and extent of occurrence.

Impact assessment should include:

- anticipated improvements – location, extent and type,
- effects on existing infrastructure,
- effects of new related infrastructure (e.g. access tracks/roads, diversion banks),
- potentially sensitive issues such as proximity to property boundaries,
- predicted impact an groundwater resources,
- predicted impact on remnant vegetation,
- predicted impact on wetlands and water courses, and
- assessment of impacts in the event of a basin overflow.

Where available, data such as aerial photographs, topographic maps, cadastral boundaries, detailed soils maps, and local surveys should be used.

Risk minimisation requires examination throughout the feasibility study stage. A guide to factors that characterise risk is shown in Table 1.

Table 1. Factors determining possible risk for evaporation basin sites (after Christen *et al.*, 1998)

Criteria	Low Risk	High Risk
1) Locality assessment	Detailed	Simple
2) Design	Locally developed guidelines & professional input	Site specific without reference to guidelines
3) Potential effects of leakage	Small environmental effect	Large environmental effect
4) Size	Small	Large
5) Hydrogeology	Well documented	Uncertain
6) Management plan	Good	Poor

4.3 Economic Feasibility

An investigation into the economic feasibility of the basin should be conducted. All basins should be effective in economic terms. The value of the land, existing infrastructure, and the natural resources they protect should be greater than the cost of land sacrificed for the basin, and the construction, operation, and maintenance costs of the basin.

All expenditures and incomes associated with the development and operation of the basin should be considered. Typically the basin will have high initial capital expenditure and an ongoing operating and maintenance cost as shown in Figure 2.

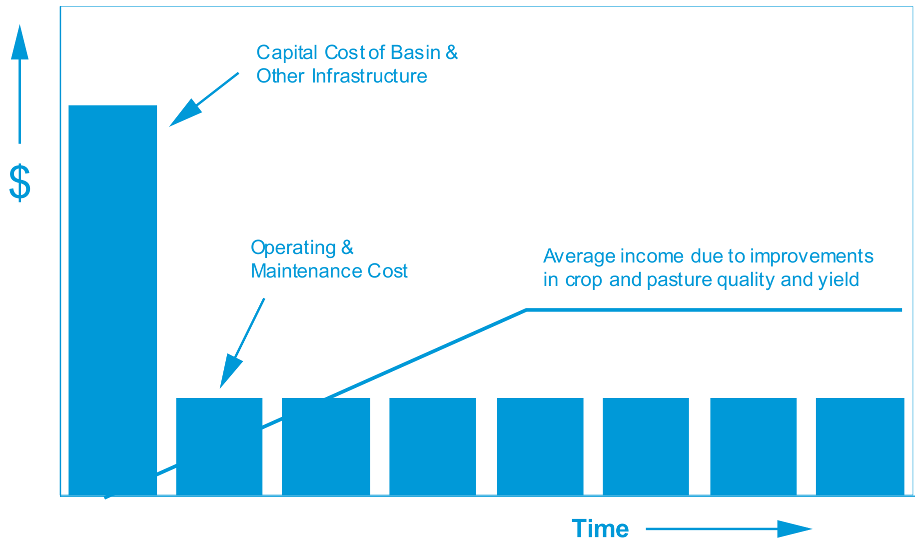

Figure 2. Expenditure and income for an evaporation basin project

Initial capital expenditure includes:

- the cost of site investigations (Section 5) and design (Section 6),
- the cost of constructing the basin (Section 7),

- The cost of constructing any special purpose structures required (Section 6.13),
- the cost of any pumps, bores, and drainage structures required to deliver the saline water to the basin, and
- the value of any productive land lost as a result of the land required for the basin.

Ongoing operating costs include:

- the cost of maintenance for the basin,
- the cost of operating and maintaining any pumps, or special purpose structures, and
- monitoring costs.

There are also likely to be decommissioning costs at the completion of the life of the basin.

Income may be generated through improvements in crop and pasture quality and yield. These improvements are likely to be gradual through time (Figure 2), and can be calculated based on estimating the area of land over which improvement is expected, and estimating the value of the improvement as a dollar value per unit area of land ($/ha).

A Net Present Value (NPV) analysis is recommended as the method to use to determine the evaporation basin's economic feasibility based on the cost information described above.

4.4 Commercial Opportunities

Commercial opportunities associated with the construction of evaporation basins include aquaculture and salt production. Evaporation basins that are intended for commercial opportunities such as aquaculture or salt production have special design requirements such as multiple cell configurations and associated infrastructure.

4.5 Compliance with Legal Requirements

All legal requirements should be strictly observed. Relevant legislation includes the Environmental Protection Act (1986), the Soil and Land Conservation Act (1945-82), the Rights in Water and Irrigation Act (1914), and the Waterways Conservation Act (1975).

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5. SITE INVESTIGATIONS

5.1 General

Based on the outcomes of conceptual planning (Section 4) detailed site investigations will be required if the evaporation basin is to proceed. The site investigation will include an engineering field survey and subsurface investigations to obtain information on soils, geology and water table elevations.

Ideally, the initial assessment to determine a preferred basin location should be an outcome of the conceptual planning undertaken in Section 4. Should this not be the case, the extent of the site investigation program will need to consider whether a single site or alternative basin sites are to be investigated.

5.2 Engineering Survey

Engineering field surveys should be conducted to gather physical information required in the design and construction phase.

Drawings and maps should be prepared showing key survey data such as topography, drainage patterns, wetlands, water courses, remnant vegetation, soils, land use, land capability, drainage area, groundwater quality, benefited areas and land ownership (cadastral boundaries).

5.3 Soils and Geology

A geotechnical engineer should be engaged to determine the permeability of the soil profile below a potential basin site and the suitability of soil for embankment fill.

Soil testing should include particle size distribution to 75 mm, Atterberg limits, standard compaction (SMDD), permeability test at 95% SMDD, and soil dispersion.

Sampling density for soil testing will depend on the required basin area and the variation in soil stratigraphy. An increased number of test pits will give greater certainty of the on-site soil stratigraphy. Sampling using an excavator will allow sampling to a depth of 5 m. A general guide for sampling density is one hole per 2 hectares.

5.4 Groundwater

A hydrogeologist should be engaged to perform groundwater investigations to determine soil and aquifer properties for groundwater pumping sites and also beneath the area enclosed by the proposed basin.

Determination of groundwater elevations should be conducted by drilling of test bores by a licensed driller. If the area affected is large, several such bores may be required. Test bores should be drilled down to bedrock or an impenetrable confining layer. A record of the soil stratigraphy should be made to provide information on the aquifer. Drilling of monitoring piezometers and observation wells is also required (Section 8.1).

The initial bores should be pump tested to determine aquifer properties. Water levels in the monitoring bore(s) should be recorded during testing. This will provide an indication of the area that may benefit from lowering of groundwater at representative pumping sites.

The number of bores required can be determined based on the coverage of each bore and the area required to be rehabilitated. This will give the total flow rate from the well system.

The salinity of the test bore groundwater samples taken at pumping depth should be determined at a certified laboratory.

6. DESIGN

6.1 General

The basin design should be based on the criterion that no leakage occurs to any groundwater that has an existing beneficial use or a potential beneficial use, nor should there be any overflow to environmentally sensitive areas.

Evaporation basins should have a shallow broad profile to maximise surface area and evaporative loss. Uncontrolled surface water inflow from an upstream catchment should be excluded unless purpose built structures are constructed to exclude flood flows. Uncontrolled inflow has the potential to overtop basin embankments and cause structural damage that may pose degradation risks to surrounding land.

Flat or gently sloping topography is generally considered the most suitable location for evaporation basins, with the preferred type of basin a bunded ring or excavated basin, with inflow pumped over the basin embankment.

6.2 Selection of Basin Site

The adequacy of the basin site should consider existing land use and the effects of the basin on surrounding ecology (Section 4.2) and community values. The site selection should consider the negative aspects associated with evaporation basins, including aesthetics and the effect on downstream properties.

Basins must not cause degradation to others. Ways in which degradation could occur include leakage to groundwater and displacement of saline groundwater to a neighbouring property.

A suitable site must have soil that can be used to form basin embankments and support these banks without substantial settlement, collapse or deformation. Soil at the bottom of the basin must be sufficiently impervious to prevent seepage that may have harmful effects.

The basin should not be located near existing drainage lines or on floodplain areas where they may have detrimental impact on major flooding or be prone to flood damage.

Evaporation basins must be located outside controlled water supply areas, and away from dams and bores, to minimise the risk of contamination.

6.3 Determining the Design Inflow

The design inflow, Qi; for an evaporation basin is calculated as the total annual quantity of inflow to the basin. This is calculated as the quantity of water pumped directly from groundwater plus groundwater collected through deep drains:

$$Q_i = Q_d + Q_p$$

where
Q_i = Design inflow (Total annual basin inflow) (ML/yr)
Q_d = Annual inflow to basin via deep drains (ML/yr)
Q_p = Annual inflow to basin via pumped groundwater (ML/yr)

$$Q_p = 0.0036 \times P_r \times H \times D$$

0.0036 = Unit conversion coefficient
P_r = Pumping rate (L/s)
D = Number of days of pumping per year
H = Number of hours pumping per day
1 ML (Megalitre) = 1,000,000 L (litres)

If pumping varies seasonally, separate seasonal inflow must be calculated and then summed to determine annual inflow (Q_i).

6.4 Basin Life

The analysis used to derive criteria in these guidelines is based on a 50-year design life.

The design life of the evaporation basin is defined by the period of time that the basin can maintain an adequate freeboard as salt accumulation reduces the available storage capacity. This will vary from site to site, however, the design lives based on the basin design methodology are typically 50 years.

The extended life of the basin is defined as the indefinite period of time for long-term on-site salt storage.

6.5 Sizing the Basin

The size of the basin required to dispose of the removed groundwater should be calculated based on the values of three parameters: the Annual Design Inflow (Section 6.3), the groundwater salinity, and the evaporative potential (or Potential Net Evaporative Loss) at the site.

Contours of the Potential Net Evaporative Loss across the wheatbelt, defined as the annual pan evaporation minus average annual rainfall, are shown in Figure 3.

The required basin area (A_{100}) for a 100 ML/year inflow for a given groundwater salinity and Potential Net Evaporative Loss (via Figure 3) can be determined based on the curves in Figure 4.

To determine the required basin area, A_b, for the design inflow, Q_i:

$$A_b = A_{100} \times Q_i / 100$$

Where A_b = Area of required basin (ha)

A_{100} = Area of basin (ha) for a 100 ML/yr annual inflow (via Figure 4)

Q_i = Annual Design Inflow (ML/yr)

A_b is therefore the required evaporation basin area assuming negligible leakage.

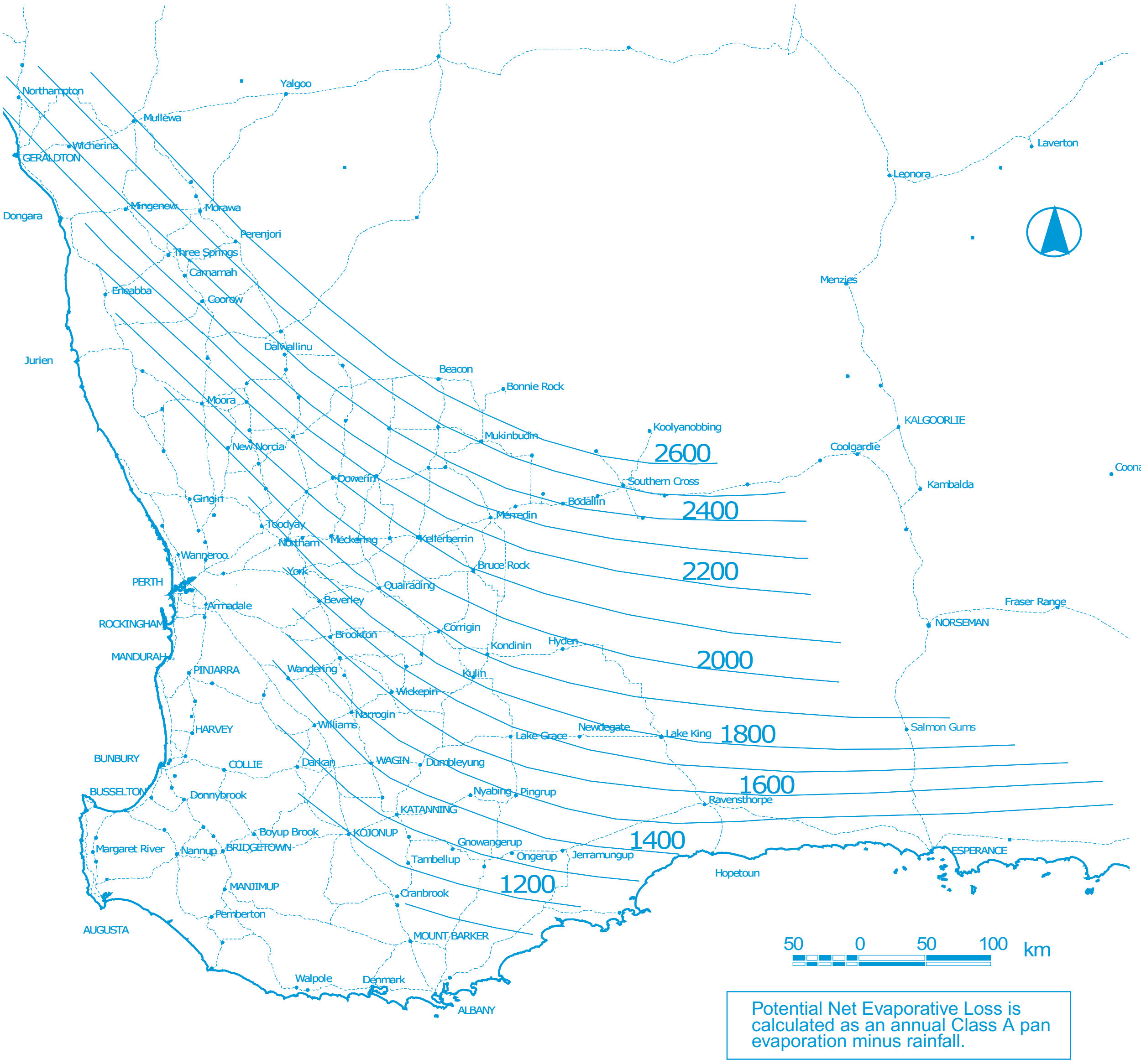


Figure 3. Potential net evaporative loss (mm/yr)

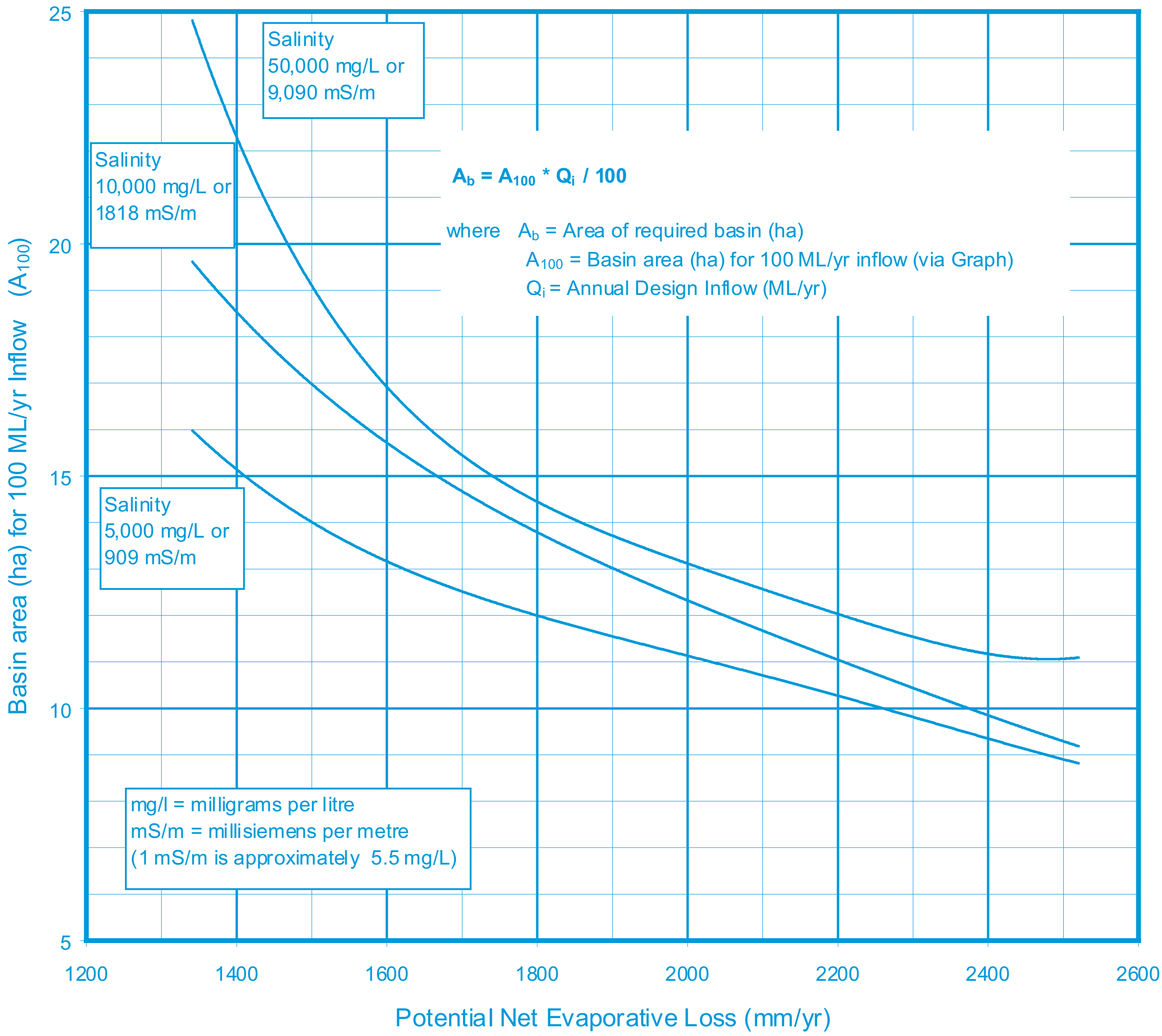


Figure 4. Basin area (ha) per 100 ML/yr of annual inflow (A100)

6.6 Basin Depth

All basins are designed to have a depth, referenced from the top of the embankment, of 2.2m for a 50-year design life.

This depth includes a 0.5m freeboard, to allow for the effect of wind and waves within the basin and extreme rainfall events, and a 0.2m spillway. A maximum water depth of 1.5m is allowed over the life of the basin, which includes any precipitation of salt within the basin. If the basin water level exceeds the 0.5m freeboard all pumping or disposal of water into the basin should cease. The freeboard depth on all basin cells should be maintained for the extended life of the project.

The 2.2m design depth is valid for basins located on flat topography. Where basins are located on sloping land, the 2.2m design depth should be taken as the depth at the deepest point of impoundment.

6.7 Basin Dimensions

Basin length and width will depend on the shape of the basin selected. Dimensions for square and circular basins for the basin area A_b (ha) derived in Section 6.5 are:

$R_c = (A_b \times 3{,}183)0.5$

$L_c = R_c \times 6.28$

$L_s = 4 \times (A_b \times 10{,}000)0.5$

where R_c = Radius of circular basin (m)

L_c = Total length of bank for circular basin (m)

A_b = Area of required basin (ha)

L_s = Total length of bank for square basin (m)

If a rectangular basin is required, dimensions for the basin L_a and L_b can be calculated according to:

$L_a = (A_b \times 10{,}000) / L_b$

where L_a = Length of side A of rectangular basin (m)

L_b = Length of side B of rectangular basin (m)

All areas are based on internal embankment toe to toe, rather than crest to crest, and on a single cell basin. If features such as islands or internal embankments are included within the basin, the basin dimensions need to be increased to maintain the required evaporative area within the basin.

The staged construction of basins is discussed in Section 6.15.

6.8 Embankment Design

Embankment slopes of 1:5 to 1:7 are desirable to encourage the establishment of plant growth on the embankments. Lower slopes will reduce wind and wave erosion, and allow for easier access to the basin when necessary. Slopes steeper than 1:3 are not recommended.

The required crest width of the embankment typically ranges from 1m to 2m if no vehicle access on the crest is required, to 3m to 4m if vehicle or machinery access is required.

The volume of a 2.2m high embankment with 1:3 slope and a crest width of 4m is $23m^3$ per linear metre of embankment (Figure 5).

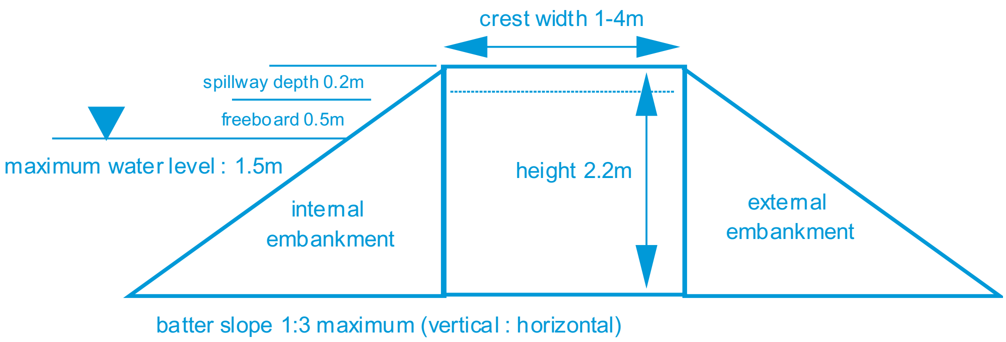


Figure 5. Typical embankment cross section

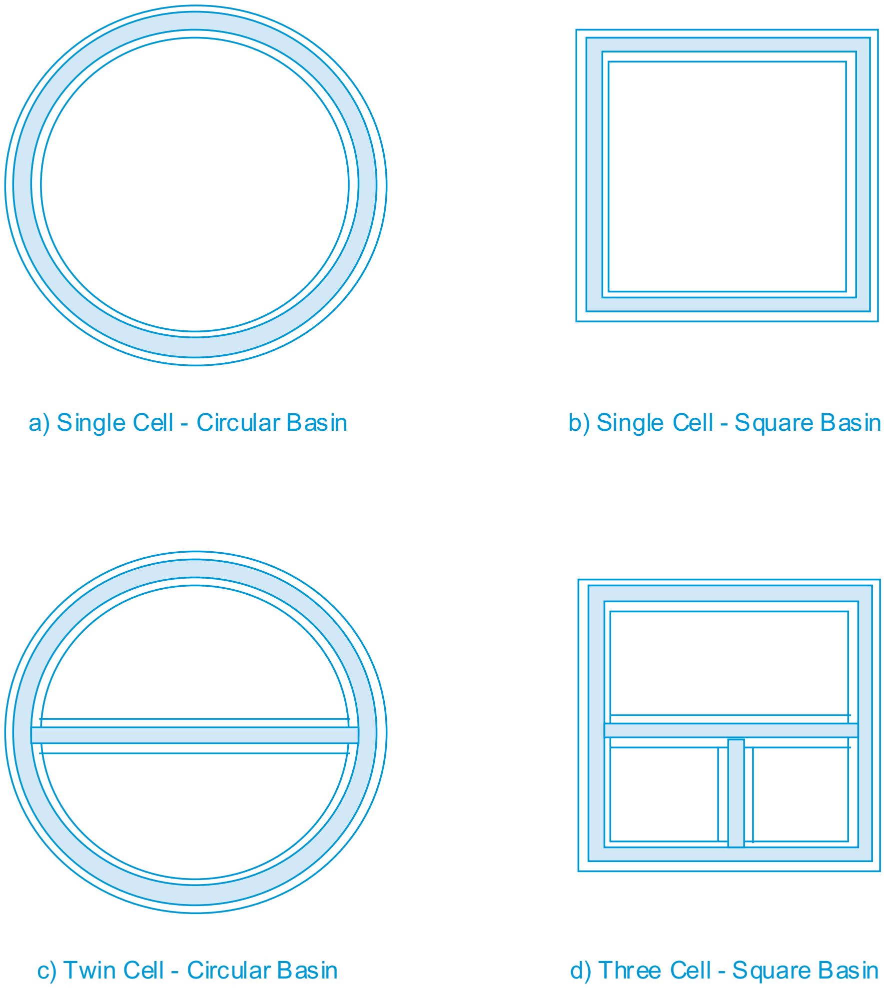
6.9 Basin Configuration

Single cell evaporation basins have comparatively less maintenance and lower construction cost, and are preferable where the main purpose of the basin is for water disposal and not for salt production or other commercial activities.

For salt harvesting and aquaculture, two (or more) evaporative cells may be desirable to manage salinity concentrations and production requirements. Multiple cell configurations entail greater construction and maintenance costs than a single cell configuration, as well as requiring a larger area (Figure 6).

The basin shape with the smallest embankment length for a given area is a circular basin. The embankment length of a square basin for a given area is approximately 10% longer than a circular basin.

Where multiple cells are used, hydraulic connections between cells such as pipes must be designed and constructed for the required purpose.



a) Single Cell - Circular Basin

b) Single Cell - Square Basin

c) Twin Cell - Circular Basin

d) Three Cell - Square Basin

Figure 6. Examples of different basin configurations

6.10 Basin Spillway

A spillway (Figure 7) is required to ensure that under no circumstances will water contained within the basin overtop the embankments, and result in basin failure.

The spillway height should be set to typically 200mm below the 2.2m height of the embankment.

The width of the spillway should be designed to ensure adequate discharge capacity from the basin is possible, and should consider the likely magnitude of extreme rainfall events and the rate of pumping groundwater into the basin.

The spillway will need to be protected from erosion by use of rip rap or rock armouring. The protection will need to extend sufficiently downstream of the spillway to ensure the embankment will not erode during any overflow event from the basin.

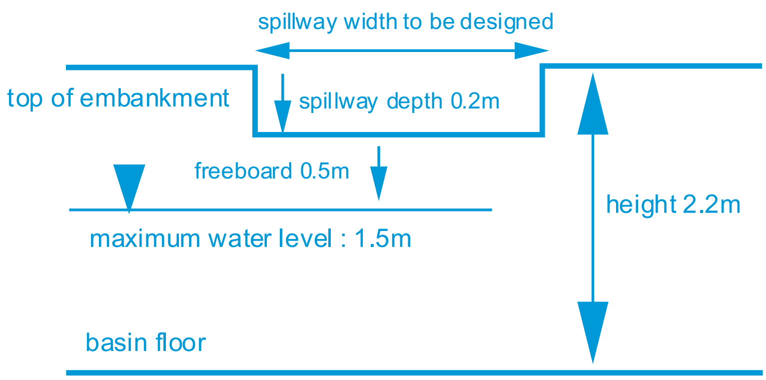


Figure 7. Cross section of spillway

6.11 Basin Aesthetics

Where practicable, improvements to evaporation basins are recommended to make them more aesthetically pleasing for the duration of their extended life. Excess spoil can be used to create islands within the basin, that may be vegetated to provide safe nesting locations for birds.

Tree planting may also be used around the perimeter of the basin, however extensive tree planting is not advised as this will reduce the wind across the basin and hence evaporation. Planting of trees must not occur upon the embankments as roots may cause leakage through the embankments in their search for water.

6.12 Basin Leakage

Basin leakage refers to the loss of water, via infiltration from within the basin, into the underlying groundwater system.

The size of the evaporation basin, as calculated using these guidelines (Section 6.5) is based on the assumption that no basin leakage occurs. This provides a conservative basin sizing.

At basin leakage rates greater than 1mm/day, the loss of water through leakage would start to dominate evaporative losses from the basin. The required area of an evaporation basin is defined in Section 6.5, however, in instances where leakage can be justified through an environmental impact study, the required basin area may be reduced provided that inflows are managed to maintain minimum freeboard requirements as shown in Figure 7.

To maximise the effective performance of the evaporation basin, basin leakage should be maintained at the minimum possible acceptable level through use of appropriate construction techniques (Section 7), and an ongoing monitoring program (Section 8.1).

Where significant rates of leakage are detected and where resulting environmental impacts are unacceptable, recovery bores can be installed (where practical) to recycle leaking water back into the basin. In situations where no practical solution is available the evaporation basin should be decommissioned.

6.13 Flow Control and Special Purpose Structures

Controlled flow will enter the evaporation basin via piped inflow pumped over the basin embankment. Typically inflow will come from deep drains and bores, with flow collected at a central location prior to pumping over the embankment wall. Flow can be collected in either:

- a sump (below ground excavation), or
- a backwater containment area (dam type wall creating above ground storage).

The choice of which collection system is appropriate and the size of the components of the system will need to be individually determined for each basin scheme based on:

- inflow rates from deep drains and bores,
- site and size constraints,
- pumping rate into the evaporation basin, and
- financial considerations.

6.14 Review of Economic Feasibility and Environmental Impacts

Prior to commencing construction, and based on the site investigations and detailed design of the evaporation basin, a review of the economic feasibility and environmental impacts of the basin (undertaken in Section 4) should be conducted.

This review should include a revision of construction and operation cost estimates and a review of likely project benefits and environmental impacts.

6.15 Staged Construction of the Basin

There could be some benefit for construction of the basin in several stages. Staged construction of the basin should be considered in the context of:

- economic benefit of delaying capital expenditure,
- minimisation of capital risk and flexibility in access to new technology as it develops, and
- technical feasibility of later modification to the basin, without increasing the risk of possible degradation to the natural environment or others.

Estimates of the impact of staging construction of the basin's embankment height on the design life of the basin are shown in Table 2. A basin with an embankment height of 1.4m would have a design life of 10 years, after which time the embankment height would need to be raised if basin use is to be continued.

When considering staged construction of a basin, planning should ensure suitable fill material is available outside the basin to allow for future raising of the embankment.

Table 2. Variation of design life with embankment height

Embankment Height	Estimated Design Life
1.4 m	10 years
1.6 m	20 years
1.8 m	30 years
2.0 m	40 years
2.2 m	50 years

6.16 Development of a Project Plan

Based on conceptual planning, site investigations, and design, a project plan for construction should be developed. The project plan should include:

- a revised working map of the project (Section 4.2), indicating key features and the proposed location of the basin and any associated infrastructure,
- documentation of design sizings and key design assumptions,
- a typical cross-section of the basin embankment, detailing key design dimensions, and
- justification of key design decisions and steps taken to reduce risks and maintain public safety.

7. CONSTRUCTION

7.1 Basin Construction

Based on the site investigation, a geotechnical engineer should be engaged to advise the suitability of the following guideline.

Embankments need to be constructed from uniform fill, ideally borrowed from within the basin area. The fill should be excavated from borrow pits to ensure various layers of different materials (silts, sand and gravel) are blended to form a uniform fill.

If construction takes place during the summer, it may be necessary to moisture condition the fill to achieve optimum moisture content. Adding water during the excavation of the fill will ensure that the soil moisture content is uniform, improving the performance of the fill when compacted into the embankment. The ideal way to borrow and place the fill is to use scrapers (either self-loading or push loaded). Scrapers allow natural blending of the fill to occur during excavation and also allow the fill to be spread in thin layers ensuring effective compaction and a dense fill. Use of excavators without additional compaction equipment should be avoided.

Construction of the evaporation basin should include the following steps:

- strip available topsoil from the area of the evaporation basin for future reuse, as required and where subsurface compaction is necessary to reduce basin leakage,
- strip all weak material from beneath the footprint of the embankment (this material would include organic material and saturated silty clay material and/or permeable material such as sand),
- rip beneath the footprint of the embankment,
- excavate a key trench within the footprint area to a low permeability layer if the near surface material is permeable,
- strip unsuitable material from the areas selected for borrow,
- backfill the key trench with selected low permeability fill, placed in 200 mm layers at optimum moisture content, compacted with a roller,
- excavate and place fill into the embankment in horizontal lifts of approximately 200 mm, compacting each layer across the full width of the embankment with at least four passes of a heavy duty tamping foot roller,
- place and compact low permeability material over any permeable strata uncovered during the borrowing of fill,
- trim the embankment crest and the inside and outside batters to the required grades,
- protect the inside and outside batters of the embankment as required,
- construct an emergency spillway with a stabilised outside batter in a selected area of the embankments (generally at the lowest corner of the storage), forming a channel to carry any discharge away from the embankment toe,
- selectively replace stripped top soil on the crest and embankment as required and where feasible, and
- compact the floor of the basin using a heavy duty tamping foot roller (or drum roller) to achieve a near impermeable surface.

7.2 Fencing

In areas where livestock are present, fencing of an evaporation basin is recommended to protect the livestock and prevent possible embankment erosion from livestock movement. Fencing of an evaporation basin may also be required to maintain public safety.

8. OPERATION & MAINTENANCE

8.1 Monitoring and Contingency Plans

Monitoring of vegetation, groundwater levels and salinity of soils and groundwater adjacent to the basin is required to detect leakage. A series of monitoring bores should be located such that the downstream spread of any leakage plume can be detected. Monitoring over depth is required, as the hypersaline water will be denser than groundwater and will sink.

Shallow observation wells and deep piezometers are required on the downstream side of the basin. Groundwater monitoring is recommended on all four sides of the basin with additional monitoring as required. Observation wells and piezometers should be located within 10m of the outside toe of the basin embankment, and installed prior to inflow to the basin.

Records of monitoring data (water level, salinity etc) should be maintained and updated at seasonal or monthly intervals. To protect groundwater quality, the initial background figure plus or minus 10% should be used as a guide to trigger management responses.

Advice on groundwater monitoring strategies should be sought from a qualified hydrogeologist. Monitoring should be linked to contingency plans that define appropriate actions when the level of monitored criteria reach defined thresholds. Where environmental impacts exceed acceptable levels, inflows to the basin should cease and decommissioning of the basin should proceed.

8.2 Embankments

Regular inspections are required for embankment cracks, settlement, slides, seepage, piping and erosion. Cracks should be filled with bentonite slurry, or dug out and refilled with compacted clay.

Settlement of the crest may lead to overtopping of the embankment. Clay fill or sandbags can be used to build up the crest level if required. Slides can occur on both the internal and external batters of the embankment. A reduction in water level will alleviate the stress. Placing additional fill against the slope and flattening the embankment may contain a slide.

Seepage through more pervious pathways of the embankment may occur. Coarse sand or pervious material can be placed against the downstream seepage areas to prevent fine material being washed out of the embankment.

Wave action will cause erosion, especially for steeper slopes. Vegetation cover will help reduce erosion. Artificial structures such as floating PVC pipe booms may be necessary if erosion of batters becomes excessive.

8.3 Salt Disposal

There are three main options for disposing of accumulated salt: on-site storage, off-site disposal, and salt harvesting. Plans for dealing with salt wastes should be included in preliminary project planning for an evaporation basin.

The most inexpensive disposal option is to store the salt on site. The viability of this option depends on the life of the basin and the rate at which salt is accumulated. This is considered the best option for evaporation basins in the wheatbelt of Western Australia. On-site storage at the end of the basins design life must ensure the minimum 0.5m freeboard is maintained and the emergency spillway is operational. Plans for rehabilitating the evaporation basin should be included in the design of the project.

Off-site disposal involves the removal of salt from the evaporation basin and transporting it to an appropriate location. Possible alternatives for disposal sites are to the ocean, to landfill, or to a degraded salt pan. Plans for off-site disposal must receive regulatory approval, under the provisions of the legislation listed in Section 4.5. Off-site disposal is likely to be viewed as environmentally unacceptable due to the likely impacts on biodiversity. Salt harvesting is not usually a financially viable option for salt disposal, unless a local niche market is identified.

9. Additional Information

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Since the release of the first edition of this publication, additional information has been made available through the CRC for Catchment Hydrology and CSIRO Land and Water, based on work in the Murray-Darling Basin. More detailed information on site investigation and construction and the impact of leakage on groundwater systems is now available (Anon 2000).

In planning an evaporation basin, site investigation and leakage components have been more fully described, with the relationship between size and leakage being highlighted. Small basins are considered as covering 2-30 ha and large or community basins 30-200 ha in size (Singh and Christien 1999) that accept drainage waters from a series of landholders. As highlighted in these guidelines, many variations in siting are possible in relation to soil suitability, underlying geology, presence of infrastructure, depth to groundwater method of construction and layout. Singh and Christien (1999) identified four major areas that could be manipulated to reduce costs incurred: geotechnical investigations; leakage control; basin geometry; and lateral leakage interception. Their evaluations suggested that costs could vary for a 2 ha basin between. $19,000 and $22,700 per hectare and large 200 ha basin cost vary between $4,700 and $11,700/ha. Significant savings could be achieved by a thorough geotechnical investigation during site selection, which reduces the need for leakage control measures such as compaction or lining and would prevent environmental damage through excessive leakage.

Dowling et al. (2000) devised and tested a GIS approach to site selection in the Riverene Plain based on soil permeability, depth to groundwater and proximity to infrastructure. This approach can be adapted for WA conditions, based on available data for the different regions within the dryland agricultural areas. Jolly et al. (2000) stressed the importance of implementing appropriate monitoring regimes to ensure basin integrity and that any adverse environmental impacts can be detected and constrained within the design limits. Leany and Christien (2000) have used a number of methods to assess leakage, water balance, salt balance, isotope analysis and seepage meters. The simplest method (as highlighted in these guidelines) is a water balance. However, leakage was assumed to be negligible in the original publication.

Leany and Christien (2000) have shown that leakage can vary from 0.5-5.4 mm/d with acceptable losses set a 0.5-1.0 mm/day. Controlled leakage of concentrated saline water maintains the optimum salt concentration and evaporation rate in the pond. Leakage rates of greater than 3 mm/d are undesirable as evaporation efficiency is reduced and recovery of the leakage at these rates may become unmanageable. In designing a basin, the physical plan must ensure that leakage is forecast, managed and that suitable recovery systems are in place. Leany and Christien (2000) noted leakage tended to be higher from small basins (i.e. <5 ha) than from large basins (i.e. >30 ha). As part of the planning and site investigation process, it is recommended that potential for leakage be evaluated and the acceptable leakage calculated based on likely environmental and infrastructure impact, and the cost of remediation.

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