Impacts of Rural Drainage on Nature Conservation Values

Proposed Evaluation Guidelines

Project for Department of Conservation and Land Management

RFQ 46510/99

Prepared by

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Disclaimer:

The assessment criteria presented in this report are suggestions made by the consultants for policy consideration. The assessment criteria do not represent the views of CALM or any other organisation.

Introduction

Drainage is used globally for control of groundwater levels and the conveyance of water. Some drainage water is re-used, but most is discharged to a receiving water body (stream, lake, estuary, inlet, ocean).

Drainage is being used for control and reclamation of saline farmlands in parts of Western Australia, and additional drainage schemes have been proposed. However, there is concern about the impact of discharge from drainage schemes on rural wetlands that support indigenous flora and fauna assemblages.

As the rising groundwater in the rural environment moves towards a new equilibrium, the salt burden in natural environments is also increasing. There are concerns that the constructed drains will increase or speed up the burden.

Project Background

Under the State Salinity Action Plan (1996), the 1998 Draft Update and the revised version currently nearing completion, four government agencies are charged with developing mechanisms to achieve improved management of rural drainage. The Inter-agency Steering Committee on Drainage (IASCD) has been established to work through the matters raised in the Salinity Action Plan and its re-draft.

One issue being considered by the Committee is the impacts of rural drainage on downstream land uses and natural diversity values. Work to date on this issue has included:

- Development of criteria for assessment of wetlands receiving saline drainage (Actis Environmental Services and Regeneration Technology Pty Ltd 1998);

- Draft guidelines outlining information required of proponents (Regeneration Technology Pty Ltd 1998); and
- A literature search for use of environmental impact assessment, and use of tradeable quotas or cross compliance in drainage management (Regeneration Technology Pty Ltd 1999).

Given the work completed, the next steps are to:

- Further develop evaluation criteria;
- Apply the evaluation criteria to a specific situation and assess their value as a means of assessing drainage;
- Further develop guidelines for requirements of drainage proponents, and test these on a specific situation; and
- On the basis of the above experience, evaluate the cost-effectiveness of using environmental impact assessment as a mechanism for assessing drainage proposals.

Scope

actis Environmental Services and Regeneration Technology Pty Ltd were contracted by the Department of Conservation and Land Management (CALM) to:

a) Further develop the criteria prepared by *actis* Environmental Services and Regeneration Technology Pty Ltd (1998) including consultation with relevant research personnel from a range of organisations to establish salt and nutrient tolerances for native fauna, particularly invertebrates and waterbirds.

b) In consultation with representatives of Agriculture Western Australia (AGWEST), Department of Conservation and Land Management (CALM), Department of Environmental Protection (DEP), and Water and Rivers Commission (WRC); prepare revised draft guidelines for drainage planners;

c) Provided there is agreement from the landholders and drainage contractors, re-work the current Nyabing Drainage Proposal into the format developed in (b) noting costs of the work, and revisions to the guidelines that should be made. After a satisfactory drainage proposal has been prepared, the guidelines will be re-drafted along with a description of problems encountered and recommendations for future use of the guidelines;

d) Apply the evaluation criteria developed in (a) to the Nyabing Drainage Proposal, including scenarios of increased drainage. This will involve re-working estimates of outputs (salt, water, silt and nutrients) from the proposal. It will also involve calculation of outputs (50 and 100 year timeframes) from the Coyrecup Lake Catchment assuming no action is undertaken to combat salinity and other hydrological related threats;

e) Evaluate the cost-effectiveness of using environmental impact assessment as a mechanism for assessing drainage proposals. This will involve some additional literature search and analysis.

The last three components of this Scope of Works are reported in three separate documents entitled:

1. Coleman, M and Meney, K (2000). Impacts of Rural Drainage on Nature Conservation Values - Nyabing Case Study: 1. Self-Assessment. Report to Department of Conservation and Land Management. *actis* Environmental and Regeneration Technology.
2. Coleman, M and Meney, K (2000). Impacts of Rural Drainage on Nature Conservation Values - Nyabing Case Study: 2. Technical Assessment. Report to Department of Conservation and Land Management. *actis* Environmental and Regeneration Technology.
3. Coleman, M and Meney, K (2000). Impacts of Rural Drainage on Nature Conservation Values – Cost-effectiveness of the EIA Process for Evaluating Drainage Proposals. Report to Department of Conservation and Land Management. *actis* Environmental and Regeneration Technology.

This report addresses proposed criteria and procedures for evaluation of rural drainage schemes that are designed to reduce problems of water logging and soil salinity in rural areas, but discharge saline water to natural wetlands.

Part A is a five-step guide outlining what is required of drainage proponents who are seeking approval for a project. It is proposed that this section replaces the Notice of Intent (Proponents Form A) currently required under the Soil Conservation Act.

Part B details the evaluation process, and is designed to assist drainage proponents and planners in undertaking an assessment of the likely downstream impacts of a given drainage project. This should be completed using the attached electronic disk, and will require a computer with Microsoft Excel to complete.

Rationale

This document addresses the impact of drainage using estimates of hydrologic and chemical change as a surrogate for biological factors. This is considered the only feasible method given the lack of sufficient biological data on wheatbelt wetlands. The method is not a substitute for biological research, but is rather a tool for flagging potential conflicts between drainage disposal and protection of biodiversity values.

The parameters addressed include salt, water, ionic composition, and nutrients. In the self-assessment process, a potentially significant change is considered likely if the drainage discharge results in a shift in any parameter >10% for salt water and nutrients, or >20% for ionic composition. These percentages are arbitrarily based on the natural variation present within wetland systems from year to year, as well as the natural error involved in snapshot sampling. This 'allowable change percentage' should be refined as more information on individual wetlands and species tolerances become available and is by no means considered fixed in the context of this evaluation approach. However, for now they serve as essentially 'no change' limits. This does not imply that any change is unacceptable, but exceedances to the allowable change scenario require either a more detailed technical assessment of the parameters that increase beyond this limit, or require a management authority accepts a change with a better understanding of the extent of that change. For example, an increase in salt concentration of 25% may not be critical in a secondary saline wetland that no longer shows much seasonal change in salinity range. However, to know this depends on knowing the wetland salt status on a monthly basis over time. If this were not known, a technical impact assessment would be required.

Supporting Documents

Part A and B of this report are revised versions of the following documents:

1. *actis* Environmental Services and Regeneration Technology Pty Ltd (1998). Evaluation Criteria for Assessment of Wetlands Receiving (Saline) Drainage. Unpublished report prepared for the Department of Environmental Protection.

2. Regeneration Technology Pty Ltd (1998). Proponents Requirements – Notification of Intent to Drain and/or Pump. Unpublished report prepared for the Department of Conservation and Land Management.

Those planning drainage should also refer to the following document for selection of drain type and best practice guidelines:

Keen, M (1998). Common Conservation Works Used in Western Australia. Resource Management Technical Report 185. Agriculture Western Australia and Natural Heritage Trust.

Or

http://www.smileys.net/agriculture/a1.html

A shallow drain (Tammin)

Part A – Guidelines for Drainage Planners

Disclaimer:

The assessment criteria presented in this report are suggestions made by the consultants for consideration. The assessment criteria do not represent the views of CALM or any other organisation.

Step 1: Defining the Drainage System

The FIRST step in the drainage approval process is to describe the drainage network.

A. Drainage Area

This section seeks descriptive details on location, soil type and the total area of the subcatchment to be drained under the proponents project. Two maps should be provided as follows:

(i). A subcatchment map at a scale of 1:100 000 on one or more A3 pages to include the drainage area and receiving wetlands;

(ii). A project map, preferably aerial photo, no smaller than 1:80 000 to fit one or more A3 pages. This should show the location of proposed drains, landholder boundaries and receiving wetlands.

Soil type information is important to estimate the rate of discharge from the drainage system, which differs according to soil type.

B. Drainage Design

Within the Western Australian context of agricultural drainage, a **drain** can be defined as an *artificial engineered construction that is designed to convey surface and subsurface water.*

Constructed drains within the Western Australian wheatbelt are often associated with earthworks that could be more accurately described as creek desilting. What is clear is that the act of **creek desilting** *must improve some or all of the natural functions of that creek.* Therefore creek desilting must not

increase the water velocity and must maintain or improve the heterogeneity of the watercourse (meanders, ponds) and riparian growth. The drainage criteria should not be applied to excavations that are defined as creek desilting. A separate form will need to be completed if your project includes creek desilting.
Selection of the type of drain required for salinity and waterlogging works should be based on information contained in the following booklet:
Keen, M (1998). Common Conservation Works Used in Western Australia. Resource Management Technical Report 185. Agriculture Western Australia & Natural Heritage Trust.
Additional information can be viewed at the internet address
http://www.smileys.net/agriculture/a1.html

Planning and construction using any drainage design should be undertaken by appropriately qualified persons. Agriculture Western Australia conducts a best management practice course for drainage contractors, and should be contacted to provide a list of accredited contractors.

The type of drain and construction standard is important because it determines the nature and extent of discharge impacts on downstream wetlands. Open drains carry surface water and sediment, which are high in nutrients and agrochemicals such as pesticides and herbicides. This will degrade natural wetland systems unless nutrient-trapping devices, such as simple sediment traps, are incorporated into the design. All engineering design drawings and specifications should be included with your proposal. These should incorporate flood control structures, erosion/sediment control treatments and safety structures.

Erosion (Drain Design)

Step 1: Drainage System Checklist

A. Drainage Area

i. Name of the surface hydrological subcatchment___________________________

ii. Area of the surface subcatchment to be drained (ha)_________________________

iii. Using a soil map or on-site test data, list the main soil types (eg. clay, sand, loam) and area of each soil type in the proposed drainage area:

Soil type : _______________ *Area(ha)*________
Soil type: _______________ *Area(ha)*________
Soil type: _______________ *Area(ha)*________

iv. Project maps attached? _____________

B. Drainage Design

v. Type of drain :_______________________*eg. closed/open drain*

vi. Length of each drain type (km): ________

vii. Total length of drain (km): ________

viii. Attach design drawings and specifications. (gradient, catchment, contours)

ix. Name & contact # of accredited drainage contractor, if known:

Name: _________________ *Accreditation Lic. No.*_____________

x. If the drain is to be constructed on slopes >0.2%, or if drain type is **high risk**, complete the following questions (refer to Keen, Appendix 3):

- Describe erosion, sediment, nutrient & organic pollutant control options *(eg. sediment traps, vegetated swales)*:
  ____
  ____
  ____

- Describe drain safety controls (eg. stock, humans, fire):
  ____
  ____
  ____

- Describe flood performance (eg. where it will overflow & how this will affect downstream infrastructure). Define for 1:5 year & 1:20 year events:
  ____
  ____
  ____
  ____

Step 2:
Defining the Receiving Wetland System

The SECOND step in drainage evaluation is to determine key wetland types in the receiving wetland system. A wetland is defined as..'*any area of marsh or water, whether natural or artificial, permanent or temporary, with water static or flowing, fresh, brackish or saline, including areas of marine water which support mangrove and samphire communities'* (Balla 1994 page 8). The definition of wetland types is based on the Semeniuk (1987) global classification scheme into 1. basins, 2. channels, 3. flats. For the purpose of this report, wetlands receiving drain discharge are defined as follows:

A. RECEIVING WETLAND SYSTEM:

A **receiving wetland system** is defined as:
The chain of wetland types in sequence receiving drainage discharge.

A **receiving wetland** is defined as:
All wetlands receiving drainage water, including channels, basins and flats, either within floodplains or isolated, that receive all or part of the discharge every two years or less. In most cases the receiving wetland will be a watercourse or flat.

The **primary receiving wetland** is defined as:
The first wetland at the end of the drainage network. In some cases there will be multiple discharge points to this wetland.

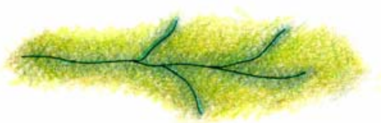
The **final receiving wetland** is defined as:
The first basin or flat downstream of the discharge point which discharges less frequently than every two years.

In addition to the function of the wetland, the wetland can also be classified geomorphically into basins, channels and flats (**wetland type**).

BASINS eg. lakes

Primary Receiving Wetland

CHANNELS eg. creeks, rivers



Secondary Receiving Wetland

FLATS eg. salt marsh

Final Receiving Wetland

B. **IDENTIFYING THE FINAL RECEIVING WETLAND**

To identify the final receiving wetland, you must identify how often it overflows to holding capacity. This is called the turnover (T-factor). If there is an annual outflow from the wetland, estimate the holding capacity of the wetland and the discharge per annum from outflowing creeks. For instance, a wetland with a winter capacity of 1000 ML and an annual discharge of 100 ML per annum would have a turnover of once per 10 years or T-factor of 10. A watercourse which fully drained every year would have a T-factor of less than 1.

If there is no annual overflow, determine the approximate turnover by visual evaluation and local knowledge of the area.

Step 2: Receiving Wetlands Checklist

A. Receiving Wetland System:

i. Name of the final receiving wetland catchment______________________________

ii. Total area of the final receiving wetland catchment (ha) _____________________

iii. Approximate number of receiving wetland types between point of discharge and final receiving wetland: (0-5, 5-10 or >10).

Channels:____ Flats: ________ Basins:________

Primary receiving wetland:

i. Name: ___________________ *eg. Nyabing Creek*

ii. Wetland Type:______________*(ie. flat, basin, channel)*

B. Final receiving wetland:

iii. Name: _______________________*eg. Coyrecup Lake*

iv. Wetland Type:________________(ie. flat, basin, channel)

v. Area (ha): ____________

vi. T-factor (years) __________

Step 3:
Conservation Risk Assessment

Conducting a RISK ASSESSMENT is the THIRD step in the evaluation process shown in Figure 1.

Using available information (eg. CALM), identify if any part of the receiving wetland system is subject to any conservation category of state, national or international listing, or if any part of the system is under consideration for conservation listing. If this is the case, you may be required to undertake a full TECHNICAL ASSESSMENT, which may be subject to formal DEP assessment.

Step 3: Conservation Risk Assessment

A. Receiving Wetland System:

i. Does the primary receiving wetland, or any downstream wetland other than the final receiving wetland, have a conservation listing?

Yes/No _____

If yes, describe ___________________________

ii. Does the final receiving wetland have a conservation listing?

Yes/No _____

If yes, describe ___________________________

Typical primary receiving wetland - Nyabing Creek

Typical final receiving wetland - Lake Coyrecup lake bed

Step 4: Project Details

A. PROJECT GOALS

This section asks about the objectives and expected timelines of your project, and proposals for additional conservation works, such as revegetation and/or changes to farming practices.

B. INFORMING RELEVANT STAKEHOLDERS

This section requires you to show what measures you have undertaken to inform relevant landholders and interested parties of your intention to drain. You will need to inform all affected downstream neighbours as far as the final receiving wetland, the local Shire, the LCDC representative within the subcatchment to be drained, and any relevant regional initiative group (Northern Agricultural, Swan-Avon, South-west, or South Coast). Stakeholders should be sent a letter including project details.

C. MONITORING PLAN

A brief monitoring program is required which incorporates seasonal monitoring of the salt concentration and flow rates from the drain measured at point of discharge to the primary receiving wetland. Monitoring is required to track the success of your project, and will be required if further expansion of drainage is to occur in the catchment.

Results of monitoring should be sent to the Landcare Coordinator annually.

Step4: Project Details

A. PROJECT TITLE & GOALS

i. ______________________________

ii. Briefly outline what you intend to do and what you expect to gain from your drainage project.

____

____

____

____

D. INFORMING OF STAKEHOLDERS

iii. Have relevant stakeholders been informed of the project? _________________

(Attach relevant letters, advertisements etc).

C. MONITORING PLAN

iv. Monitoring plan attached? ___________

Step 5:
Determining the Type of Evaluation

Three evaluation approaches are considered appropriate for assessing the impact of saline drainage:

1. SELF-ASSESSMENT
2. TECHNICAL ASSESSMENT
3. FORMAL ASSESSMENT

Selection of the most appropriate method is determined by the:

1. Conservation status of the receiving wetland
2. Outcome of self-assessment approach
3. Choice

A high conservation category wetland will immediately require a TECHNICAL ASSESSMENT; all others will require a SELF-ASSESSMENT. If the wetland is considered unsuitable after self-assessment, the proponent will then need to complete a TECHNICAL ASSESSMENT, or consider other disposal options. If the technical assessment disallows drainage, and the proponent still wishes to pursue the proposal, he/she will need to submit the proposal for FORMAL ASSESSMENT to the Department of Environmental Protection. A proponent may choose to pursue a technical assessment, without completing a self-assessment first.

Self-Assessment

The self-assessment approach can be undertaken by the drainage proponent, whether this is a catchment group, collective of a few landholders, or an individual landholder.

The assessment is based on examining key physical parameters that may alter the <u>processes</u>, <u>characteristics</u> and/or <u>functions</u> of a natural wetland receiving rural drainage. These parameters are:

Water
Salt
Ionic Composition
Nutrients

Significant changes to these parameters will cause changes to vegetation and fauna.

If all the drainage works in a catchment result in less than 10 - 20% change to any parameter in a downstream wetland, it is considered unlikely to cause significant environmental impact. The percentage allowable change is a rough estimate of the capacity of wetlands to 'buffer' additional inputs, and is loosely based on what they may tolerate due to natural fluctuation.

Each drainage proposal is given a discharge allowance based on the proportion of the catchment their project covers. Therefore, each project is allowed a proportion of the 10% allowable change for each parameter. For instance, if the project incorporates 50% of the catchment then the project is only allowed to change the final wetland parameters by 5%. The proportional allowance may be increased if other landholders in the catchment who don't intend to drain are prepared to 'hand-over' their drainage allowance.

The 'Do Nothing' Approach

The 'do-nothing' approach is taken into account in this self-assessment process for salt loads, using an estimate for salt export from existing salt scalds.

The 'do-nothing' approach for water balance changes is addressed in the self-assessment by including current catchment run-off levels. Groundwater changes can only be considered in the 'do-nothing' context as part of a more comprehensive technical assessment.

The self-assessment approach is shown graphically in Fig. 2.

To conduct a self-assessment of a drainage project, you will need to collect the information outlined below, and complete the evaluation form in PART B of this document.

How to Use the Self-Evaluation Spreadsheet

The self-evaluation process is divided into two parts: the MAIN FORM and explanatory notes contained in this document, and an electronic spreadsheet HELP document included in the attached disk. The spreadsheet asks you to enter the information in the DATA INPUT sheet and automatically calculates the answers in the SELF EVALUATION sheet. The information you are required to enter in the spreadsheet is shown in the Checklist for Assessors below. The answers and relevant data generated in the SELF EVALUATION spreadsheet should then be added to the MAIN FORM for submission, together with a print-out of your DATA INPUT sheet and SELF EVALUATION sheet.

Self-Assessor
Checklist of Information Required

1. Area of subcatchment to be drained (ha)
2. Area of subcatchment under proponents control (ha)
3. Type of drains
4. Length of drains in clay, loam and sand
5. Estimated time of construction (yrs)
6. Estimated drain discharge (L/sec)
7. Primary receiving wetland name & type (basin, channel, flat)
8. Width, depth & slope or fall of primary receiving wetland at discharge point
9. Catchment size above point of discharge
10. Final receiving wetland name & type (basin, channel, flat)
11. Subcatchment name & size (ha)
12. Width, length, depth, area, volume of final receiving wetland when full
13. Turn-over factor
14. Average monthly rainfall for a year
15. Average daily evaporation
16. Expected salt concentration of drain water
17. Pre-drainage salt concentration of receiving wetlands
18. Ionic composition & pH of groundwater in area to be drained
19. Ionic composition & pH of receiving wetland
20. For <u>open</u> drain systems, average concentrations of nitrogen & phosphorus in drain water and receiving wetland.

Technical Assessment

A technical assessment can be undertaken as a first choice option and will need to be undertaken if the self-assessment *disallows* drainage to the proposed receiving wetland, and the proponent still wishes to pursue the proposal.

A technical evaluation will require a water and salt mass balance to be undertaken, to determine the additional effect the drainage will have on total salt and water fluxes on a seasonal basis. This may require a one-year period to gather sufficient data on seasonal groundwater and surface water processes, and will need to be undertaken by a qualified hydrologist approved by the affected land managers.

A technical assessment may also include a detailed biological survey of flora and fauna and assessment of impacts present. There is limited information on most wheatbelt wetlands for this to be undertaken comprehensively.

Technical Assessor
Checklist of Information Required

1. All information listed under SELF-ASSESSOR – CHECKLIST OF INFORMATION REQUIRED'
2. Maximum water depth in all receiving wetlands and the final receiving wetland, at monthly intervals for a year in which the total is within 40 and 60-percentile values for the area, and the rainfall distribution is not abnormal.
3. The relationship between water area and depth for the final receiving wetland (measure area at the same time as monthly measurements of maximum water depth).
4. The water level in piezometers positioned across the final receiving wetland, constructed to indicate the head of water in the shallowest aquifer beneath the (relatively impermeable) bed of the wetland. (This level must be measured relative to the same datum as the depth of water in the lake).
5. Monthly measurements of discharge from each drain and inflow to any receiving wetland, and salinity of the flows.

Part B – Self Evaluation

This section is to be completed by working through each of the questions, tasks and methodologies for each criteria. The criteria are as follows:

SUBCATCHMENT FACTOR
VEGETATION CONDITION
WATER – FATE & FLOOD RISK
WATER – HYDROPERIOD
SALT – CONCENTRATION
SALT – LOAD
IONIC COMPOSITION
NUTRIENTS

In most cases, the same data (eg. wetland area or drain flow) will be used to answer questions in more than one section.

Use the checklist as a record of data, filling each criteria in as you work through the worksheets.

Key Data

1. T-factor (years) ____________
2. P-factor ____________
3. Drain discharge over 6 months (Q_d), m^3
4. Peak flow in primary receiving channel (m^3) __________
5. Ellipsoid wetland area (ha) ____________
6. Wetland depth (m) _________
7. Ellipsoid wetland volume (m^3) ________
8. Median effective evaporation (mm/day) ___________

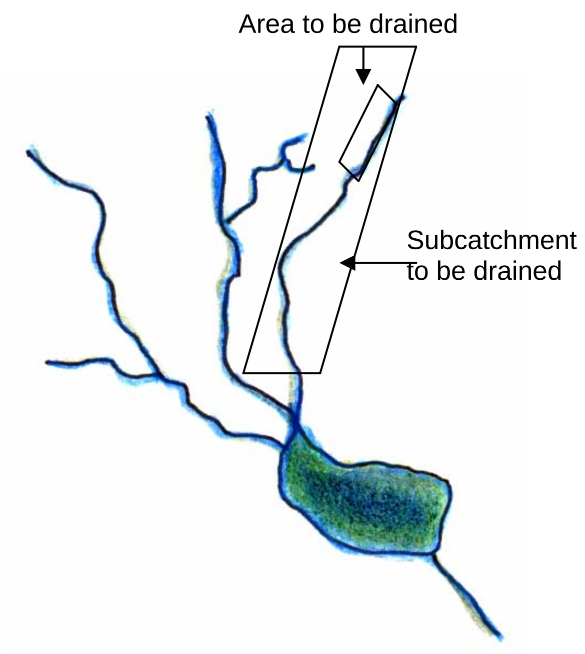
A. Sub-Catchment Factors

P-FACTOR

The impact of a single drainage proposal needs to be viewed in terms of existing and future drainage within the receiving wetland catchment, i.e. cumulative impact. The proponents factor ("P-factor") allocates a drainage proponent an upper limit for allowable salt and water discharge. This is based on the proportion of the subcatchment controlled by the proponents to the subcatchment area above the relevant receiving wetland. For the primary receiving wetland, this will be the area above the point of discharge, and for the terminal receiving wetland, this will be the whole subcatchment draining into the lake.

For a project that comprises 26% of the total subcatchment, the proponents are allocated 26% of the **allowable change** to the receiving wetland in terms of salt load, water load, nutrient load. The **allowable change** is 10 percent of the existing load in the system (in one criterion the **allowable change** is 20 percent). In the above case the drainage project would be considered not to have a change if the estimated change in the natural system was less than 26% times 10% of the existing load.

An alternative and more technical method of calculating the P-Factor is to estimate the area of salt scald to be drained and the total salt scald in the subcatchment. These figures will need to be independently determined. The P-Factor is the proponent's proportion of the total area of salt scalds in the subcatchment.



B. Vegetation Condition

A. RECEIVING WETLAND

1. Is there remnant vegetation fringing the wetland YES/NO ___

Approximate % cover living [ ]

2. Identify habitat types:

(a) Large trees present? YES/NO ___

(Eucalyptus, Casuarina, Melaleuca) % living [ ]

b) Understorey present? YES/NO ___

Shrubs % living [ ]

Rushes/sedges % living [ ]

(c) Samphires/saltmarsh present? YES/NO ___

% living [ ]

Attach photos.

B. FINAL WETLAND

1. Is there remnant vegetation fringing the wetland YES/NO ___

Approximate % cover living [ ]

2. Identify habitat types:

(a) Large trees present? YES/NO ___

(Eucalyptus, Casuarina, Melaleuca) % living [ ]

b) Understorey present? YES/NO ___

Shrubs % living [ ]

Rushes/sedges % living [ ]

(c) Samphires/saltmarsh present? YES/NO ___

% living [ ]

Attach photos.

C. Water – Fate and Flood Risk

QUESTION

Will from the drain increase the maximum wetted area of the wetland by less than 10%? Compare with a year of median rainfall.

Primary Wetland

EVALUATION *(please tick correct box)*

☐ Yes — Go to Final Wetland below

☐ No — Discharge high risk, undertake technical assessment or consider alternatives.

Final Wetland

EVALUATION *(please tick correct box)*

☐ Yes — Go to D. HYDROPERIOD

☐ No — Discharge high risk, undertake technical assessment or consider alternatives.

RATIONALE

Water depth and surface area

The depth of water in a drain or wetland is a factor affecting the rate of any seepage to or from any underlying aquifer. Moreover, the depth of water controls the wetted area of the wetland bed. This usually has a major effect on the rate of leakage from the wetland by seepage through its bed.

Minimising the change of water depth will ensure that there is minimal change of rate of seepage of water through the bed of a wetland. Moreover, since the change of water level in an aquifer beneath land surrounding the wetland must be less than that beneath the stream or wetland, there will be minimal impacts of drainage disposal on regional groundwater levels.

There is a large change of surface area for only small changes of water level in the great majority of streams and wetlands in rural areas of WA. Therefore, it is considered that control of water surface area will provide control of both area and water depth.

C. Water – Fate and Flood Risk continued

TASK

1. Estimate discharge from the drain for a six-month period.

METHODOLOGY

Determine the soil types the drain is passing through using local knowledge or AgWA maps. Overlay soil types on the drainage map and determine the length of the drain in each soil type. Enter in the DATA INPUT spreadsheet.

2. Identify available wetland capacity of the primary receiving wetland

For a channel (ie. river or creek), work out the size of the catchment above the point of discharge in hectares. Enter in the DATA INPUT spreadsheet.

3. Identify available wetland capacity of the terminal wetland.

Work out the size of the subcatchment and the wetland turnover factor. Enter in the DATA INPUT spreadsheet.

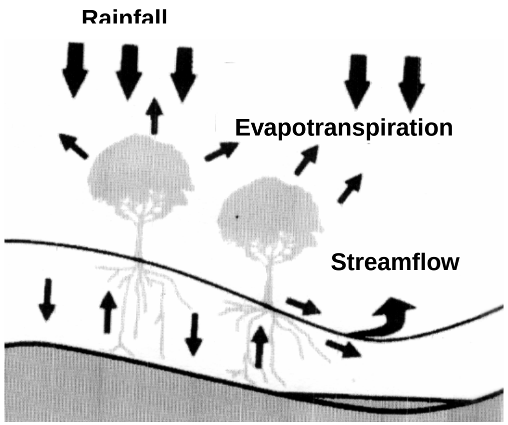
D. Water - Hydroperiod

QUESTION

Is the drainage discharge (during the month of lowest evaporation) less than 45 days (x P-factor) of the median effective evaporation from the wetland?

EVALUATION	*(please tick correct box)*
☐ Yes	Go to E. SALT
☐ No	Discharge high risk, undertake technical assessment or consider alternatives

Movement of water in landscape



RATIONALE

The period that the level of water in a wetland exceeds a specified level affects wetland vegetation, dependent fauna etc, and is referred to as the hydroperiod. The hydroperiod for any specified water level can be derived from the hydrograph of water level in the wetland.

Most wetlands in the wheatbelt have excess evaporation while the wetland is at its lowest, and the drains contribute little while the effective evaporation is high. The danger of detrimental increases of hydroperiod is during the 6 months of the year with the lowest effective evaporation.

Changes in the biomass and species composition of submergent aquatics is strongly modified by the hydroperiod. Biomass declines significantly with longer flooding duration, which reduces the amount of food resources to waterbirds.

Modified flow regimes significantly alter invertebrate diversity and abundance, favouring only resilient taxa. The duration of high water levels is considered a more significant factor than seasonality in changing microfaunal communities.

Some aquatic and fringing plant species need a draw down of water level to germinate and establish.

It is assumed that 45 days of increased saturation / flooding at any point within the wetland profile will have a detrimental effect on the ecosystem. This has been observed for selected rush & sedge species (Meney pers. obs, C. Semeniuk, unpub).

D. Water – Hydroperiod continued

TASK	METHODOLOGY
1. Determine median effective evaporation for an average year.	Collect the average rainfall and evaporation data for the meteorological station closest to your project site. This data is available from the Bureau of Meteorology. Add this data to the relevant section in the DATA INPUT spreadsheet.
2. Calculate the area of final receiving wetland	The ellipsoid shape is the simplest shape & would best approximate the shape of most wetlands in the wheatbelt. Wetland area = 3.141 x (0.5 x width) x (0.5 x length). Add this data to the relevant section in the DATA INPUT
3. Calculate volume of receiving wetland	Wetland volume = 2.0944 x (0.5xwidth)x (0.5xlength)x depth. Add this data to the relevant section in the DATA INPUT spreadsheet.

E. Salt – Concentration

QUESTION

Will there be less than 10 percent change in TDS concentration of the receiving wetland after drain water has been added?

↓

EVALUATION **(please *tick correct box)***

☐	Yes	Go to F. SALT LOAD
☐	No	Discharge high risk, undertake technical assessment or consider alternatives

RATIONALE

The concentration of salt in a stream or drain will generally increase in the direction of flow, due to evaporation. It will reach a very high level in a wetland where the entire flow is lost by evaporation alone. Maximum salinity will be lower in wetlands where water is lost by a combination of evaporation and seepage into the bed of the wetland, or via surface discharge.

A maximum salinity criterion may be almost impossible to meet. As stream salinity will be lower during the higher flows that spread over a larger area of land, it is argued that the criterion should be a flow-related concentration.

An immediate indication of the salinity range characterising a receiving wetland can be gauged from a biological assessment of the wetland. The following table gives indicative species for each salinity category. As a guide, a receiving wetland in the meiomesosaline or hyposaline range will probably be unsuitable as drainage discharge wetlands. (see Table 1, Appendix 1)

E. Salt – Concentration continued

TASK		**METHODOLOGY**
1.	Determine the salinity of the primary receiving wetland.	If salinity information for the wetland is not already available, measure the salinity of the receiving wetland during the winter months. Salinity can be measured with a hand-held TDS salinity meter. Data should be collected monthly for a minimum 3-month period. Refer to Appendix -- for more detailed methodology. Add data to DATA INPUT spreadsheet.
2.	Determine the salinity of the drainage water	Measure the salinity of the groundwater within the proposed drainage area during the winter months. Salinity can be measured with a hand-held TDS salinity meter. Data should be collected monthly for a minimum 3-month period. Refer to Appendix 2 for more detailed methodology. Add data to DATA INPUT spreadsheet.

F. Salt - Load

QUESTION

Will there be less than 10 percent change in SALT Load in the wetland after drain water has been added?

EVALUATION *(please tick correct box)*	
☐ Yes	Go to G. IONIC COMPOSITION
☐ No	Discharge high risk, undertake technical assessment or consider alternatives

RATIONALE

Basins and temporary storage wetlands will accumulate salts over time. It is important that the TDS load (that is, amount) does not increase to a level that is detrimental to the receiving wetlands.

The only types of wetland that would not be affected in the long term by increased loading of salt are those that are already hypersaline for the greater part of a year or those that 'turnover' (discharge its own volume) more frequently than every two years.

Do not complete this section if your final receiving wetland is hypersaline

F. Salt - Load continued

TASK

1. Determine the amount of additional salt that will be carried to the primary and terminal receiving wetlands after drainage

Nyabing Creek – 31 msm salt

METHODOLOGY

Salt load is automatically calculated from data already entered in the DATA INPUT spreadsheet.

Sampling salt concentration of drain water

G. Ionic Composition

QUESTIONS

1. Is the pH of the drain water less than 2 units different from the receiving wetland?

EVALUATION (*please tick correct box)*

☐ Yes — Go to G_2 ION RATIO

☐ No — Discharge high risk, undertake technical assessment or consider alternatives

2. Is the ratio of ions in the drain water within 20% of the receiving water?

EVALUATION (*please tick correct box)*

☐ Yes — Go to H.NUTRIENTS

☐ No — Discharge high risk, undertake technical assessment or consider alternatives

RATIONALE

The pH is a measure of the acidity of the water. A low pH will increase the release of nutrients from the sediment affecting the number and type of algae species. A low pH will also dissolve limestone and increase the bicarbonate concentration. A high pH will precipitate out limestone causing scale and in general reduce the nutrient concentration in the water. Both a high and low pH will have implications for animal and plant life.

Whereas pH is a measure of the hydrogen ion or acidity, the other dissolved chemicals or ions are just as important. The concentration of dissolved chemicals such as calcium will affect the precipitation of gypsum and limestone and is implicated in the fixing of nutrients. Most plants and animals also use it. The ratio of potassium to sodium plays an important role in the osmotic regulation of both plants and animals. Sulphate is an important chemical used by hypersaline bacteria that are part of the biological cycle.

Ionic composition changes with changing total ion concentration, and it is therefore necessary to compare brines from different sources with a standard such as evaporated seawater. The selection criteria should consider whether the drainage water will significantly change this balance.

The chemistry the water may have important ramifications for industries using the water. Salt producers for instance, aim to reduce calcium and magnesium in the final product. Changing the chemistry can change the salt quality. In some cases the water is used commercially as cooling water. Increased scaling can be very costly just as low pH water can corrode concrete culverts.

G. Ionic – Composition continued

TASK	METHODOLOGY
1. Analyse the wetland for pH, Na, Cl, Mg, Ca, SO4	Take at least two 200ml samples from different locations in the wetland. Send to a NATA accredited laboratory for analysis
2. Analyse the groundwater for pH, Na, Cl, Mg, Ca, SO_4	The pH can be determined in the field using a hand-held meter. The drain water can be analysed by sampling from groundwater bores in the area to be drained.
3. Compare the pH of the wetland and the pH of the drain	Enter the average values for each ion into the DATA INPUT spreadsheet. The SELF-EVALUATION spreadsheet will calculate the difference in pH and ionic composition between the wetland and the drain waters.

H. Nutrients - Concentration

QUESTION

NUTRIENTS AND ORGANIC METALIC POLLUTANTS

Will the drain increase the Total Nitrogen and/or Total Phosphorus concentration in the receiving wetland by less than 10%?

↓

EVALUATION *(please tick correct box)*

☐	Yes	EVALUATION COMPLETE
☐	N/A	EVALUATION COMPLETE
☐	No	Discharge high risk, undertake technical assessment or consider alternatives

RATIONALE

Increases in the concentration of nitrogen and phosphorus in soil, soil water and ground water is known to be a significant contributor to the decline of riparian vegetation and spread of weeds in agricultural regions of Australia and overseas.

Altered nutrient regimes significantly affect invertebrate, phytoplankton and macrophyte diversity and abundance.

Excessive nutrients in waterways can lead to algal blooms that are toxic to livestock and native flora. Metal and organic pollutants (i.e. pesticides, herbicide, other agri-chemicals) from human activities can have a detrimental effect on the flora and fauna of a natural wetland.

Increased nutrient loading will increase the depth of organic sediments and anaerobic recycling of nutrients will become a more prominent feature of the wetland. Significant changes to biology may result.

*** Assess only if the drainage system collects surface water**

H. Nutrients – Concentration continued

TASK	METHODOLOGY
1. Analyse the wetland for Total Phosphorus and Total Nitrogen	Take at least two 200ml samples from different locations in the wetland. Send to a NATA accredited laboratory for analysis. Refer to the Ag West Bulletin on Environmental Water Quality for further information on how to sample (Appendix 2).
2. Analyse the groundwater for Total Phosphorus and Total Nitrogen	The drain water can be analysed by sampling from groundwater bores in the area to be drained.
3. Compare the nitrogen & phosphorus of the wetland and the nitrogen & phosphorus of the drain	Enter the average values for Nitrogen & Phosphorus into the DATA INPUT spreadsheet. The SELF-EVALUATION spreadsheet will calculate the difference in pH and ionic composition between the wetland and the drain waters.

Self Evaluation-Spreadsheets

Attach spreadsheet printouts

Attachments

Include copies of letters from relevant stake-holders, aerial mosaic, maps and other documentation.

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Appendixes

Appendix 1: Ecology of Changing Salinity for non tidal saline wetlands

Terms Salinity Range ppm	Meiomesosaline 1,000 – 3,000	Hyposaline 3,000 – 20,000	Mesosaline 20,000 – 50,000	Polysaline 50,000 – 100,000	Hypersaline > 100,000
Diversity Vertebrates	High Frogs numerous, numerous fish species (eg. minnows, *Galaxiella* spp, western pygmy perch, *Edelia vittata)*	High Frogs uncommon	Moderate Estuarine fish species (black bream, *Acanthopagrus butcherii*), numerous bird species (eg. black ducks)	Reduced One or two fish species present of *Chrinodon* and *Atherinosoma* genera. *Galaxias maculatus* Waders very common (eg. stilts, avocets)	Low Waders very common
Invertebrates	Numerous crustaceae (eg. cladocerans, isopods, amphipods, shrimps yabbies, (*Cherax* spp)), damselfly, dragonflys	Few crustaceae, Shield shrimp (*Triops* spp) dominate *Daphnia carinata* *Alona sp.*	Rotifera (*Brachionus, Hexaarthra*) Anostraca (*Parartemia*) *Daphniopsis pusilla* *Daphniopsis australis* *Gladioferens spinosus* *Mytilocypris splendida*	*Artemia/Parartemia* start. Some species of *Diptera,* isopod crustacean *(Haloniscus searlei, Austrochiltonia subtenuis*) at lower range. Species of gastropod *Coxiella*at lower range	Artemia common, Trichoptera (*Symphytoneuria wheeleri*)
Macrophytes	Nardoo *(Marsilea spp)* Duckweed (*Lemna* spp.), Water fern (*Azolla* spp.), Pondweed (*Potamogeton* spp), Water Ribbons (*Triglochin* spp) Sedges & rushes (*Baumea* spp., *Gahnia trifida Juncus* spp, *Typha domingensis*)	Nardoo *(Marsilea spp),* Water Ribbons (*Triglochin* spp), Pondweed (*Potamogeton* spp), *Ruppia* spp Sedges & rushes (*Baumea* spp., *Gahnia trifida, Juncus* spp, *Typha domingensis*)	Estuarine species, *Ruppia* spp.	Rare clumps of *Ruppia, Lepilaena* species	Upper range of *Ruppia, Lepilaena* [1](rarely seen)
			Mainly green algae, *Ulva*, *Chaetomorpha*. Estuarine species, green algae diatoms, dinoflagellates	Filamentous green algae in small numbers. Diatoms and dinoflagellates dominate biota	*Dunaliella salina*, *Carteria* sp

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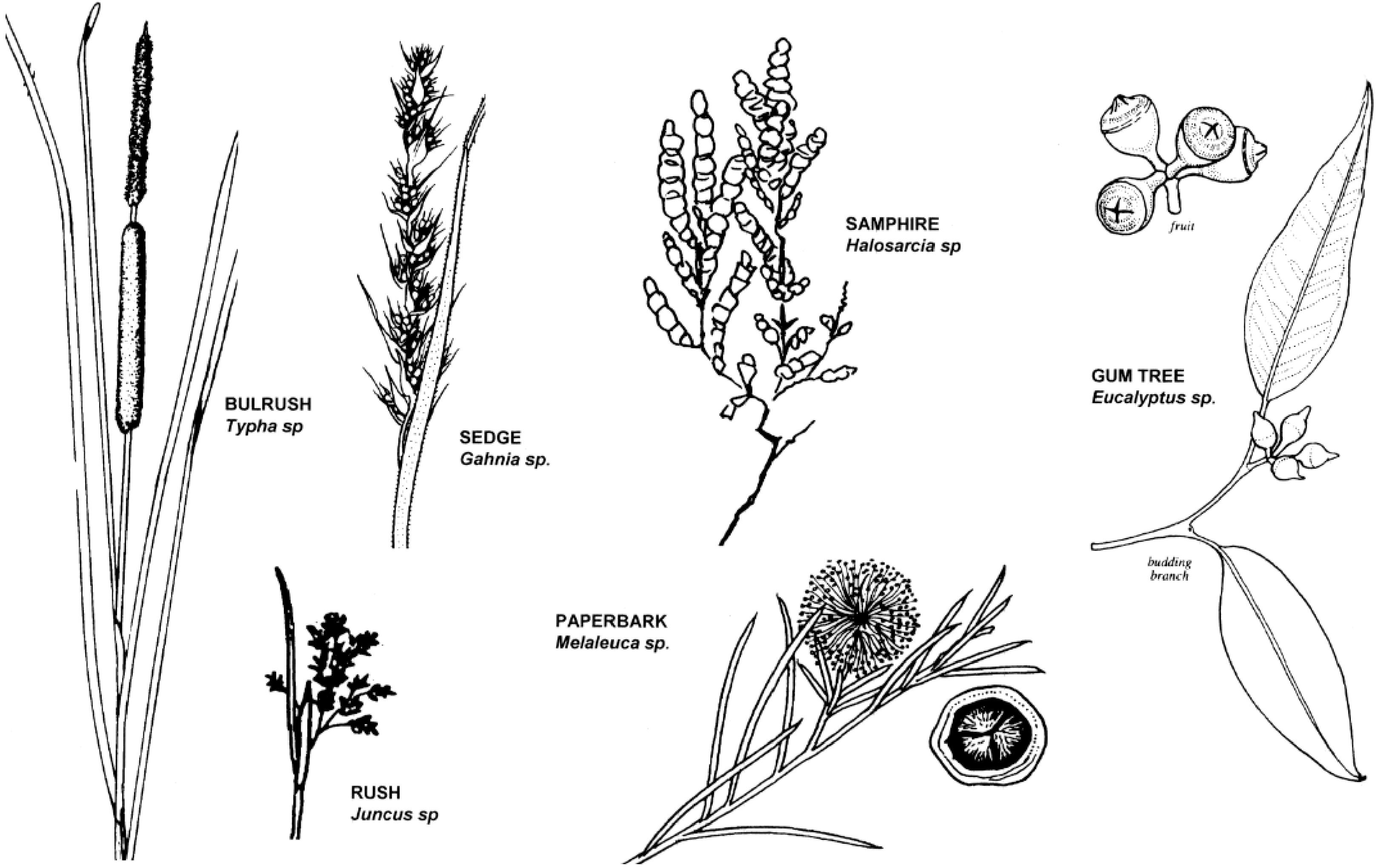
Appendix 2. Common Wetland Plants



Appendix 3 Source of Technical Information

Conductivity

Salinity is the sum of all dissolved salts in water. Ideally it is expressed on a mass per mass basis (Williams and Sherwood, 1994). Historically any water with a significant concentration of sodium chloride salt has been called brine. As the brine evaporates the concentration of salts increase until a set of salts reach 'saturation'. Typically the first salts to reach saturation in natural waters are the metal oxides such as iron and manganese. The low oxygen conditions of groundwater means that the metal oxides rapidly reach saturation once exposed to air. After metals the next salts to reach saturation are the calcium compounds such as calcium carbonate (limestone, calcrete), followed by calcium sulphate (gypsum). Sodium chloride or 'common salt' is the next salt to precipitate out as evaporation concentrates the chemicals. The other chemicals are very soluble and don't normally form salts in the natural environment although commercially they do have significant value. Epsom salts is one of these chemicals.

Groundwater can vary from this sequence for a number of reasons, it could be ancient water that formed at a time when the earth was radically different from today, or the more likely scenario is that the groundwater takes on the chemical characteristics of the soil it is passing through. Arsenic and other chemicals toxic to life can accumulate in large concentrations in groundwater.

Scientifically the best method of determining the salinity is to evaporate the solution to a dry salt or salts, and then weigh the solid. Alternatively the chemical concentration for all chemicals can be determined and the total concentration used as an expression of salinity. These two methods should be completed by a registered analytical laboratory and cannot be completed in the field. There are a number of methods that can be used in the field but in general provide results in units that are not readily converted to salinity. The refractory or the light bending ability of the brine can be used to give a measure of salt in the water but is a relatively coarse method. The most common method is using the electrical properties of a salt solution. Pure water does not conduct electricity well but with small amounts of dissolved salts the conductivity increases rapidly. In other words as the salt concentration increases so does the conductivity of the brine. A common measure is siemens per unit distance or something like millisiemen per centimetre. Nearly all battery operated field 'salinity' meters use this property. Some units convert the reading to salinity (grams per litre) by using a 'common' factor. The danger is that the relationship between conductivity and salinity is not even approximately linear after about 35 g/L. That is, a doubling in conductivity does not mean a doubling in salinity.

All field measurements for salinity should be measured as a conductivity and converted to millisiemen per centimetre. The measurement is not accurate at a conductivity above 100ms.cm^{-1} or 70 g/L.

The formulae for converting conductivity to salinity ($ms.cm^{-1}$ to g/L) is:
$S = 0.466.K^{1.0878}$

With a temperature correction of:
$K_{25} = K_t/(1 + 0.025[t - 25])$

Where S is salinity and K is conductivity.

Brines with a higher salt concentration than $100ms.cm^{-1}$ or 70 g/L should be diluted, the salinity estimated and then the figure multiplied by the dilution factor.

This work has been taken from ;
Williams, WD and Sherwood, JE 1994; *Definition and measurement of salinity in salt lakes*; International Journal of Salt Lake Research 3 (1), 53-64.

Sampling

Before sampling for groundwater it is best to review the existing information held by government departments. Water and Rivers Commission have several databases with relevant information, for instance AQWABASE, Agbores and Combores.

The publication 'Environmental Water Quality' by Agriculture Western Australia provides most if not all the information needed for the collection and preservation of samples.

Samples that are to be sent to a chemical laboratory must be collected in clean sample bottles, either plastic or glass. Most laboratories will provide sample bottles for their analysis when visited in person.

Laboratories can be located by talking with local AgWest and Water and Rivers Commission personnel, or alternatively selecting a chemical laboratory from the 'Yellow Pages'.

Weather Data

Weather data can be bought from the Bureau of Meteorology for a small fee. They will need to know the location and type of data needed. Climatic averages for the nearest station can be accessed from the Internet at http://www.bom.gov.au.

Drains

There is much useful information on drains. The publication by M Keen AgWest 'Common Conservation Works Used in Western Australia' gives a comprehensive background on drain types. Another useful source is the internet address http://www.smileys.net/agriculture.

Appendix 4. Drain Discharge Rates

General

Theory of groundwater discharge to a series of parallel or intersecting drains is presented in several texts (e.g. “Drainage for Agriculture”. van Schilfgaarde, Amer. Soc. Agron., 1974). Flow to a single drain is akin to groundwater discharge to a stream, which has not been subjected to the same degree of analysis, but could be modelled using one of the standard groundwater modelling packages.

We are not aware of any measurements of discharge from rural drains or drainage schemes in inland WA. However, we understand that a drainage contractor (Lyons) estimates flows of 0.2 to 0.5 L/s per kilometre length of drain. We do not know the soil types intersected by these drains.

Drainage Setting/Model

Rural drainage schemes in WA generally incorporate a single drain, or drains that are separated by such distances that there is essentially no interaction between them. Applying the principle of superposition, the effect of a single drain can be investigated for conditions of an initially horizontal water table. In the absence of better information, it is assumed that the hydraulic conductivity and thickness of the strata are spatially uniform within the area of influence of the drain.

The drain is assumed to be straight, and to reach a dynamic equilibrium with the superficial aquifer, with recharge during a wet season moving through the aquifer to the drain during the following dry season. Drain construction is assumed to prevent inflow of surface water runoff.

Region of Influence of a Drain

Dimensional analysis indicates that changes at the boundary of an aquifer of transmissivity T (m^2/d) and storativity S (dimensionless) are propagated a distance of order L (m) within the aquifer in time t (days) where:

$$L = O(T*t/S)^{0.5}$$

In this equation, the ‘O’ indicates ‘order of magnitude of’ the term in brackets.

Rate of Discharge to a Drain

We assume that water in the drain is at a depth of about 2 m below ground level. Then as the influence of the drain on groundwater levels declines to nil at a distance or order L, the average change of water level during the dry season will be about 1 m, and total flow Q (m3 per metre length of the drain) in the dry season will be about:

$$Q = 2*(S*1*L)$$

(The number 2 enters this equation because water is assumed to flow to the drain from each side.) We assume that the superficial aquifer is filled by rainfall in the wet season, and this aquifer discharges to the drain throughout a 300-day dry season. Further, the thickness of the superficial aquifer (the only aquifer making a significant contribution to drain flow) is assumed to be about 3 m.

Two extremes of aquifer type are considered:

- Sand aquifers with hydraulic conductivity of order 1 m/d (transmissivity $T=3\ m^2/d$) and storativity of order 0.1; and
- Clay aquifers with hydraulic conductivity of order 0.01 m/d (transmissivity $T=0.03\ m^2/d$) and storativity of order 0.01.

The basis of these assumed values of hydraulic conductivity is a table relating the nature of the strata to typical values found in practice as reported by Kruseman and de Ridder ("Analysis and Evaluation of Pumping Test Data", Intl. Inst. for Land Reclam. and Improvement, Wageningen, 1983). However, the hydraulic conductivity of the clay aquifer is high relative to values normally reported for this type of material, to allow for the presence of root channels and other structural features that are normally found in shallow soils.

Substituting values in the equation, we find:

$Q_{sand} = 2*0.1*1*(3*300/0.1)^{0.5} = 20\ m^3$ per metre length; and

$Q_{clay} = 2*0.01*1*(0.03*300/0.01)^{0.5} = 0.6\ m^3$ per metre length.

The rate of discharge of an aquifer to a drain will be high at the end of the wet season, and decrease during the dry season due to the decreasing gradient of water level towards the drain. Rates are likely to vary roughly in proportion to $t^{1/2}$ where (as before) t is time since the end of the wet season. Any loss of water by evapotranspiration from the aquifer will also contribute to a decreasing rate of discharge to the drain.

Averaging the drain discharge flows over a 12-month period, and expressing them as L/s per kilometre length of drain, we have:

$Q_{sand} = 0.6$ L/s per kilometre length; and

$Q_{clay} = 0.02$ L/s per metre length.

Note that as T and S enter the equation within the square root term, Q is relatively insensitive to assumed values for these parameters. Therefore, for the 100-fold difference of hydraulic conductivity and 10-fold difference of storativity between the sand and clay aquifers there is only a 30-fold difference in the estimated rate of discharge of groundwater to the drain. Moreover, the above estimates will be relatively insensitive to the thickness of the surface soil, which contributes to the transmissivity.

Soils of intermediate texture will yield water at rates that will be intermediate between those for sand and clay aquifers.

Limitations of Model

The order-of-magnitude approach of the model presented above, should not be expected to provide an accurate estimate of aquifer discharge to a drain, but it should be reliable for indicating the relative rates of discharge from soils of different hydraulic conductivity and storability. It may be possible to 'calibrate' the above model against measurements of drain discharge from areas where soil survey results show the length of drain in each soil type.

This model does not account for variations of the rate of discharge of groundwater to a drain. It may be possible to infer the dynamics of discharge subject to assumptions that should be tested by comparison with observations.

Measured discharge from a drain may be less than the total discharge to the drain, due to losses of water by evaporation, and infiltration through the bed of the drain in areas where the water level in the drain is above the regional groundwater level. Incomplete recharge during the wet season would also reduce discharge from the aquifer to the drain, and therefore result in lower-than estimated discharge from a drain.

In our experience, there are situations in inland WA where groundwater discharges to a stream or seepage area by primarily vertical flow from a partially confined aquifer. The model of drainage applied above is not appropriate in this situation. A drain installed above a confined aquifer will capture the upward movement of groundwater from a strip of land only a few-times greater than the width of the drain. A greater benefit can be obtained if the drain is deep enough to cut right through the confining layer.

Mass Balance Approach

A mass balance calculation provides the total width of a strip of land contributing to steady discharge from a drain for a range of net rates of recharge to a superficial aquifer and rates of discharge to a drain. Some results are shown below. Note that the drain discharge rate is expressed in L/s per kilometre length of the drain, and that the width includes flow from both sides of the drain. Therefore the influence of the drain (term L used in the order-of-magnitude model) is half the width listed in this table.

Table 1 Mass Balance Calculation

Net Recharge to Aquifer (mm/d)	Width (m) Drained for Discharge at 0.2 L/s	Width (m) Drained for Discharge at 0.5 L/s
0.1	173	432
0.5	34.6	86.4
1	17.3	43.2
3	5.8	14.4
5	3.5	8.6
10	1.7	4.3

The mass balance calculations neglect any change of storage water within the superficial formations, which is the prime source of flow to the drain in the order-of-magnitude model. Moreover, they take no account of the hydraulic conductivity of the strata, and therefore of the hydraulic gradient that is necessary to drive water from the aquifer to the drain.

The mass balance calculations are useful in indicating the limited distance from which water may flow to a drain, even in the cases of very high aquifer conductivity. Evidently there will be little interaction between drains that are separated by more than about 500 m in sand.

Conclusions

- The average rate of discharge of groundwater to a drain will vary over a factor range of 30. The discharge rate is primary dependent on the soil type in the area drained, and to a lesser extent the thickness of the superficial aquifer and the depth of the drain.
- Average rates estimated by the order-of-magnitude model presented here are unlikely to be accurate, but they are similar to estimated field values. The method should be 'calibrated' by comparison with flow measurements in an area where soil types have been identified. No such data are known.
- The rate of discharge of groundwater to a drain will vary seasonally being a maximum at the end of the wet season, and may decrease to nil due to decreasing water level gradients, evapotranspiration and evaporation in the dry season. The present model does not predict variations of the rate of groundwater discharge to a drain, but it is likely to decline roughly in proportion to the square root of time since the end of the wet season.
- Steady-state mass balance calculations confirm that a drain will effectively capture net recharge to an aquifer over a limited distance from the drain.

Recommendation

An agency of the WA government (WRC, CALM or AgWest) should ensure that drain flow is measured in selected areas where soil types have been identified, to provide data for assessment of the order-of-magnitude method presented here, or other drainage models that may be developed in the future. These data should be measured accurately and made available for general use.

Williams, W. D. (1998). Guidelines of Lake Management. Kusatsu, Shiga 525-0001, Japan, International Lake Environment Committee Foundation & UN Environment Programme.